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Investigating the effect of edible coating based on *Citrus paradisi* essential oil nanoemulsion and *Lallemantia iberica* seed mucilage on the microbial and chemical characteristics of lamb slices during storage period

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ABSTRACT

In this study, the effect of edible coating based on *Lallemantia iberica* seed mucilage (LISM) with different contents (0, 0.5, 1, 1.5 and 2% vol/vol) of *Citrus paradisi* essential oil nanoemulsion (CPN) was investigated on the microbial, chemical, and sensory qualities of lamb slices during cold storage. The antimicrobial results showed that at the end of the storage period, the lowest number of total viable bacteria (6.26 log CFU/g), psychrotrophic count (3.28 log CFU/g), *Escherichia coli* (0.95 log CFU/g), *Staphylococcus aureus* (0.87 log CFU/g) and fungi (1.12 log CFU/g) were observed in LISM+2% CPN sample. The highest and lowest pH at the end of the storage period were related to uncoated samples (6.42) and LISM+2%CPN (5.65). The amount of peroxide number and thiobarbituric acid in the control and LISM+2%CPN samples were 11.60 meq O2/kg and 1.20 mg MDA/kg and 5.40 meq O2/kg and 0.59 mg MDA/kg, respectively, after 9 days of cold storage. The meat color (L*, a*, b*) was also preserved by edible coating containing *C. paradisi* essential oil nanoemulsion (LISM+CPN). The addition of nanoemulsion in edible coating increased sensory scores such as aroma, color, texture, and overall acceptance of lamb slices, especially on the last day of cold storage. The obtained results suggest the LISM+CPN edible coating as a solution for retarding the chemical and microbial spoilage of lamb slices.

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1- Introduction

Due to its low oxidative stability and its special composition, meat is sensitive to microbial spoilage as well as color and fat oxidation [1 and 2]. Therefore, different storage methods should be used to prevent microbial and chemical spoilage of meat. There are many antimicrobial and synthetic antioxidants that are commonly used in the meat industry to extend the shelf life of raw and cooked products. However, the high price of these additives and their carcinogenicity create a negative view of consumers [3].

Food packaging is one of the determining and influencing factors on food quality and consumer acceptance. Due to its good mechanical and physical properties, conventional packaging methods are widely used compared to fossil fuel-based materials for the production of synthetic polymers, including polyvinyl chloride, polystyrene, polyamide, polypropylene, ethylene vinyl alcohol and other synthetic polymers. Attention has been paid [4]. Today, the use of biological coatings is considered as barriers to the exit of moisture and the penetration of oxygen, which effectively increases the useful life of products. Among the common biopolymers used for edible coatings, we can mention all kinds of polysaccharides, including cellulose derivatives, chitosan, alginate, starch, dextrin, vegetable gums and mucilages [5 and 6]. Mucilages are heteropolysaccharides that are obtained from some medicinal plants, they are easily available and are highly regarded due to their reasonable price [7].

Balangoi, a city with a scientific name*The Iberian allemancy* It is a herbaceous, annual and drought-resistant plant that grows autonomically in many regions of Iran, including Kermanshah, Hamadan, Lorestan, Chaharmahal, Bakhtiari, etc. [8]. The mucilage of this plant is used to relieve throat congestion and coughs caused by colds and to treat kidney diseases, nervous and liver disorders, and it has been reported that its oil has antioxidant properties [9, 10]. However, polysaccharide coatings have few antimicrobial and antioxidant properties and are usually improved in combination with natural antimicrobial and antioxidant agents [11]. Among natural additives, plant extracts and essential oils have shown significant potential in a wide range of applications due to their antioxidant and antimicrobial properties [12]. Grapefruit (*Citrus paradise*) is one of the most important natural citrus fruits in the world, which has high phenolic compounds and significant antimicrobial and antioxidant properties [13]. Antimicrobial and antioxidant effects of different parts of grapefruit have been investigated in various studies [14 and 15]. However, the low solubility of essential oils in water, high vapor pressure, and physical and chemical instabilities have limited the use of these compounds. Also, the unpleasant smell and taste of essential oil in food products has brought dissatisfaction to consumers. Therefore, nowadays the use of methods to minimize the adverse effects of essential oils is considered [16]. The use of nanotechnology to disperse plant essential oils in water has helped to increase the solubility and stability of these compounds [17]. Among nanoemulsions, oil-in-water emulsions with small particle sizes in the range of 100 to 500 nm. ToThe reason for the safety and compatibility with water compared to water-in-oil nanoemulsions have received more attention. Compared to conventional emulsions, nanoemulsions have some unique properties, including high optical clarity and better physical stability,

which are useful for food applications [18, 19].]. Therefore, the purpose of this study was to use grapefruit essential oil nanoemulsion in coatings produced from balangou urban mucilage and use it to increase the shelf life of mutton.

2- Materials and method

2-1- Preparation of grapefruit essential oil

Cloninger machine was used to extract grapefruit essential oil. In this way, 500 grams of ground grapefruit was mixed with water at 100 degrees Celsius and its essential oil was extracted through distillation with the help of a Cloninger machine. At the end, after removing excess water, the extracted essential oil was dried using sodium sulfate and stored at 4°C [20].

2-2- Preparation of grapefruit essential oil nanoemulsion

Grapefruit essential oil nanoemulsion was prepared by preparing a mixture of grapefruit essential oil, Tween 80 and water with a ratio of 89:1:10 weight/weight using an ultrasonic homogenizer with a power of 500 watts, a frequency of 20 kHz and an amplitude of 72 micrometers for 15 minutes. [21].

2-3- Preparation of urban balgo and extraction of its mucilage

The genus and species of the urban sycamore purchased from Mazandaran province were confirmed in the herbarium of the Research Institute of Plant Sciences. After removing the dust and dirt from the seeds using ethanol, the urban sycamore was dried in an oven at 30°C for 12 hours. Dried plant with water at a ratio of 1:20 in 7=pH And the temperature of 50 degrees Celsius and the extraction time of 3 hours was subjected to mucilage extraction. After straining and centrifuging the mixture for 15 minutes at a speed of 3000 rpm, the mucilage was separated. The obtained mucilage was dried for 3 hours at a temperature of 50 °C and after packaging it was kept at room temperature [22].

2-4- Preparation of edible coating and coating of sheep meat

First, a mixture of 5 grams of Balangoo Shahri gum, 1.75 grams of Tween 80 and 100 milliliters of distilled water was prepared and heated and stirred until the ingredients were completely dissolved. Then 0-2% essential oil (in the form of nanoemulsion[1]) was added to the mixture. After preparing identical pieces of sheep meat, the samples were immersed in the prepared coating for 1 minute. The coated meat pieces were dried at room temperature for 10 minutes and kept at 4 degrees Celsius for 9 days to perform various tests. The samples include the sample without mucilage and essential oil (control sample), the sample coated with mucilage without essential oil nanoemulsion (LISM) and the samples coated with mucilage containing different percentages of grapefruit essential oil nanoemulsion were divided as follows [23]:

Control, LISM, LISM+0.5%CPN, LISM+1%CPN, LISM+1.5%CPN, LISM+2%CPN.

5-2- Microbial tests of coated meat

5 grams of meat sample was homogenized with 45 ml of 0.1% peptone water for one minute. Then successive dilutions of the sample were prepared in tubes containing 0.1% peptone water and inoculated in plates containing culture medium. Microbial tests include counting total bacteria (TVC)[2] in Kant agar plate medium[3] For 24 hours at 37°C, cryophilic bacteria[4] (PTC) In the environment

[1]- CPN
[2]- Total viable count
[3]- Plate Count Agar
[4]- Psychrotrophic count

Kant agar plate for 10 days at 7 degrees Celsius,*Escherichia* in eosin methylene blue culture medium[5] for 24 hours in a greenhouse at a temperature of 37 degrees Celsius,*Staphylococcus aureus* In mannitol salt agar culture medium for 24 hours at 37°C temperature and mold and yeast (fungi) in Sabrose dextrose agar culture medium for 72 hours at 27°C temperature [24].

6-2- Physicochemical tests of coated meat samples

2-6-1- Humidity

Moisture content of meat samples using oven drying method at 102 degrees Celsius according to standardAOAC was measured [25].

2-6-2- MeasurementpH

to determinepH10 grams of each sample was mixed with 90 ml of distilled water and homogenized in a homogenizer at a speed of 10,000 rpm for 30 seconds.pH They with helppHm was measured at a temperature of 25 degrees Celsius [11].

2-6-3- histometry

After preparing 2 x 2 x 2 cm pieces of coated meat samples, their hardness was measured using a texture tester (FACING ،XT2i, England) was measured. A cylindrical probe with a diameter of 36 mm and a compression force with a weight equal to 10 kg up to a height of 30% of the initial height with a constant speed of 5 mm/s was used. stiffness parameter (N) was calculated with the help of force-time curve [26].

2-6-4- Measurement of peroxide number[6]

In order to measure the peroxide value, first, the lipid part of the meat pieces was extracted using chloroform-acetic acid solution. Then distilled water, 1% starch solution and saturated potassium iodide were added to release iodine. Iodine released with 0.01 thiosulfate normal titer and peroxide number (PV(in milliequivalent grams of oxygen per kilogram of lipid)meqO_2/kg) was reported [27].

2-6-5- Amount of thiobarbituric acid

To measure the amount of thiobarbituric acid[7] (TBA), 2 grams of each of the meat samples were mixed with 5 ml of 20% trichloroacetic acid solution and passed through filter paper. Then 5 ml of the filtered sample was mixed with 5 ml of 0.01 M thiobarbituric acid solution and heated at 100 degrees Celsius. The absorbance of the samples was checked at a wavelength of 532 nm [27].

7-2- Color of the samples

Amounts*L (brightness index),a* (redness index) andb* (yellowness index) samples using a colorimeter (CR-400 Konica Minolta, Japan) was measured at three different points of each sample [23].

8-2- Sensory evaluation

Covered meat samples were evaluated in terms of aroma, color, texture and overall acceptance based on the 9-point hedonic method (1 lowest score and 9 highest score) by 25 trained evaluators. Samples with more than 4 points were considered as acceptable samples [24].

9-2- Statistical analysis

All tests of this research were done in three repetitions. Data analysis with the help of softwareSPSS (Version 26) and using one-way analysis of variance at a confidence level of 95% (0.05p<) and Duncan mean comparison was done.

3. Results and Discussion

1-3- Microbial growth changes

Although the amountTVC All samples increased significantly during the storage time (0.05).p<), but the use of essential oil nanoemulsion in edible coating increasesTVC It was prevented in the samples. At the end of the storage period, the control sample and the sample covered with mucilage of urban

[5]- Eosin methylene blue

[6]-Peroxide value

[7] -Thio Barbituric Acid

balangoi containing 2% essential oil nanoemulsion (LISM+2%CPN(in order of greatest)log CFU/g 12/64) and the lowest (log CFU/g 6/26) amountTVC assigned to themselves. It should be noted that the effect of grapefruit essential oil nanoemulsion in preventing the increaseTVC The meat samples were significantly higher compared to the sample coated with mucilage without essential oil nanoemulsion, which could be because the reduction of essential oil droplet size with the formation of nanoemulsion allows the antimicrobial compounds to penetrate into the bacterial cell faster, therefore, the antimicrobial behavior Microbial is observed higher and faster. [28]. It should also be noted that the maximum amount allowedTVC in fresh meat equal tolog CFU/g It is 7. LevelTVC control meat samples andLISM After six days of storage and samplesLISM+0.5%CPN ،LISM+1%CPN AndLISM+1.5%CPN After 9 days of storage at a temperature of 4 degrees Celsius than the allowed amountTVC violated while the amountTVC in meat samples coated with 2% essential oil nanoemulsion (LISM+2%CPN) during the storage period was less than the allowed amount of the standard, which indicates the role of food coating rich in essential oil nanoemulsion in increasing the shelf life of mutton during the storage period in cold conditions. The results of this research were consistent with the results of Moghimi et al. (2016) who reported that the use of essential oil in the form of nanoemulsion significantly increased its antibacterial activity compared to its free form [29]. Similar results in other studies about the antibacterial effect of coatings with essential oil nanoemulsion onTVC sheep meat during 20 days of storage at 4°C has been reported [12, 30].

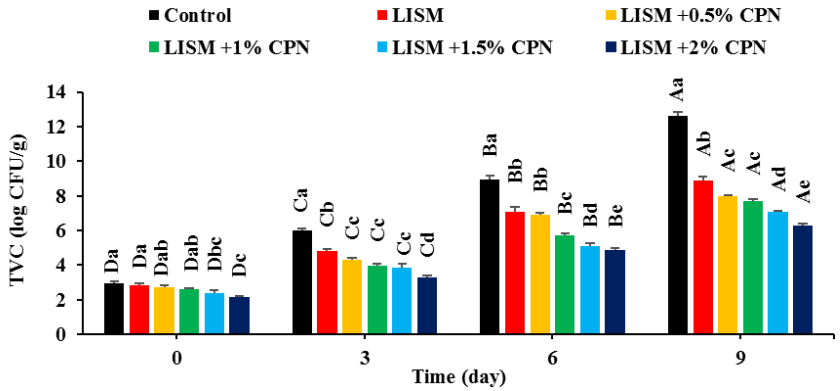

Fig. 1 Changes in total viable bacteria count (TVC) in meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

amount of cold-loving bacteria (PTC) samples also increased significantly during the storage period (Figure 2). At the end of the storage time at 4 °C, control samples andLISM+2%CPN respectively the highest (log CFU/g 8/3) and the lowest (log CFU/g 3/28) amountPTC showed It should be noted that edible coating containing essential oil nanoemulsion (LISM+CPN) compared to the coating produced from mucilage of better efficiency in preventing the increasePTC in sheep meat samples during the storage period. Aerobic cold-loving bacteria such as species*Pseudomonas* They are known as the main cause of meat spoilage under cold aerobic storage conditions [31]. Therefore,

low valuesPTC In the meat samples coated with the mucilage of the urban falcon containing nanoemulsion of grapefruit essential oil, it is mainly due to the antimicrobial effect of the essential oil, the faster and easier penetration of the small droplets of the nanoemulsion into the bacteria and the ability of edible coating to prevent oxygen from entering the surface of the meat [32-34]. . Essential oils in the form of nanoemulsions are more dispersed in the aqueous phase than in the normal form, which leads to more access of nanoemulsions to microbial cells. In addition, small nanoemulsion droplets can disrupt the cell membrane by changing the integrity of phospholipid bilayers or by interfering with transport proteins. On the other hand, the electrostatic interaction of positively charged nanoemulsion droplets with the negatively charged microbial cell wall increases the concentration of essential oils at the site of effect and leads to their interference and complete destruction of the bacterial membrane. Also, the surface energy of nanoparticles increases compared to the normal form, and due to increased passive cellular absorption mechanisms and their smaller size, they will have more antibacterial properties [30].

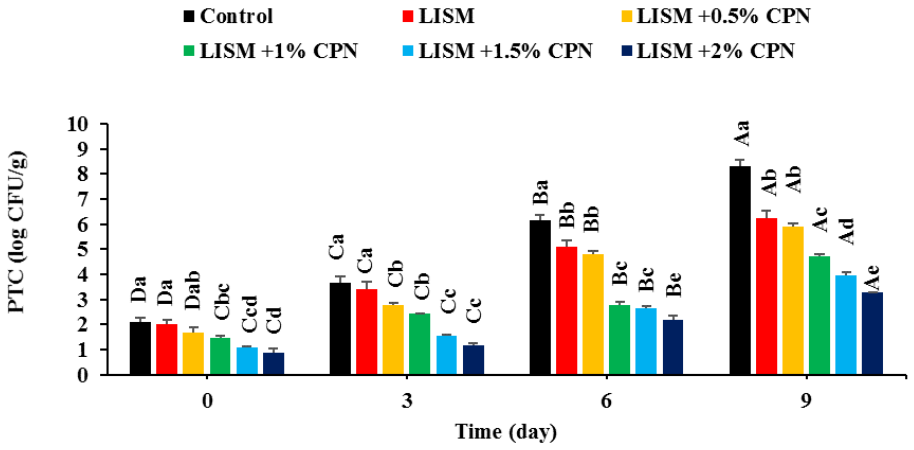

Fig. 2 Changes in Psychrotrophic count (PTC) in meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

Results of bacterial count changes*E. coli* It is shown in the meat samples during the storage period in Figure 3. Over time, the number of bacteria*E. coli* AtAll the samples increased significantly, but this increase was lower in the samples coated with the mucilage of the urban balango enriched with grapefruit essential oil nanoemulsion than the control sample. In general, at the end of the maintenance period, the control sample has the highest (log CFU/g 84/1) and exampleLISM+2%CPN has the lowest (log CFU/g 0.95) number of bacteria*E. coli* They were. As mentioned, nanoemulsions can penetrate and contact bacteria more easily, and the smaller the particle size, the better antibacterial effect they have [35 and 36].

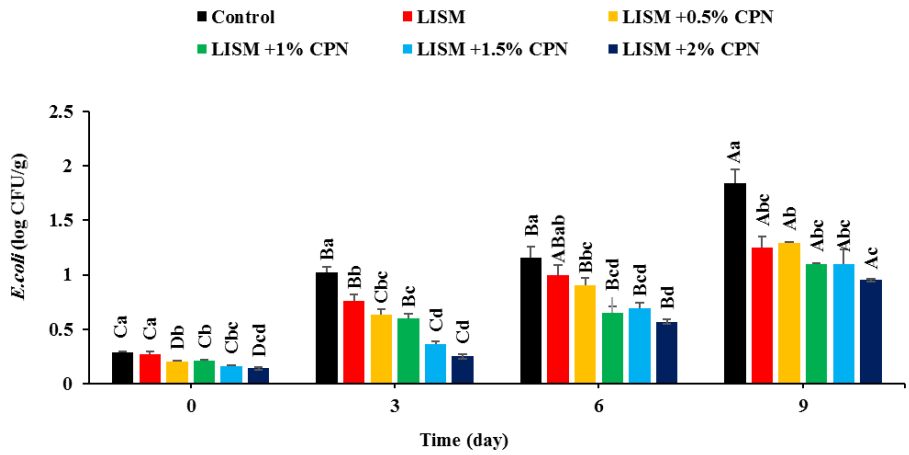

Fig. 3 Changes in *E. coli* count in meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

The process of bacterial growth changes*S. aureus* In control and coated sheep meat samples during storage time at 4°C, it is presented in Figure 4. As can be seen from the figure, all samples underwent a significant increase in bacterial growth*S. aureus* have been maintained during the period. The highest rate of bacterial growth*S. aureus* In the control sample (log CFU/g 1/68) and the lowest amount in the meat sample covered withLISM+2%CPN (log CFU/g 0.87) was observed.

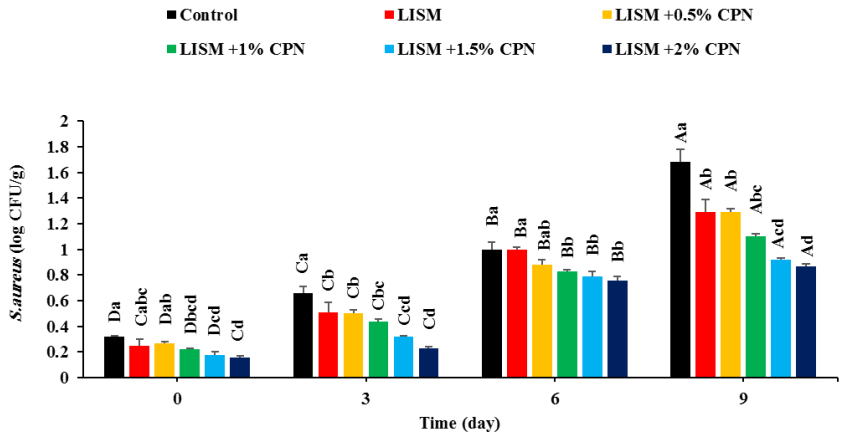

Fig. 4 Changes in *S. aureus* count in meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

The total number of fungi in mutton samples (control and coated) stored at 4°C is shown in Figure 5. The growth pattern of fungi in meat samples is similar to the trend of increasing the total number of live, cold-loving bacteria.*E. coli*And*S. aureus* Was. Although the samples underwent a significant increase in the growth of fungi during the storage period, the use of edible coating containing essential

oil nanoemulsion significantly prevented the increase in the number of fungal strains on the surface of the meat samples. In fact, adding grapefruit essential oil in the form of nanoemulsion to the edible coating based on the mucilage of urban balangoo caused a decrease in the growth of fungi in the samples. so that at the end of the maintenance period, control samples andLISM+2%CPN respectively having the most (log CFU/g 2/22) and the lowest (log CFU/g 1.12) growth rate of fungal strains. The decrease in the growth of fungal strains in meat samples can be caused by the barrier property of the food coating in preventing oxygen from entering the product surface; Because fungi are aerobic microorganisms and therefore cannot grow under anaerobic conditions of coated meat samples [24].**In general, edible coatings containing plant essential oils are very effective against mold and yeast, because edible coatings act as a barrier to oxygen transfer [37]. In addition, nanoemulsions can achieve the slow release effect of essential oils, so that they are able to be slowly released on the product surface for a longer period of time [32]. According to the results of this research, the number of yeast and mold in the pork control samples and the samples coated with fennel essential oil nanoemulsion continued with increasing storage time, but the increase in the treated group was significantly lower than the control group [32].**

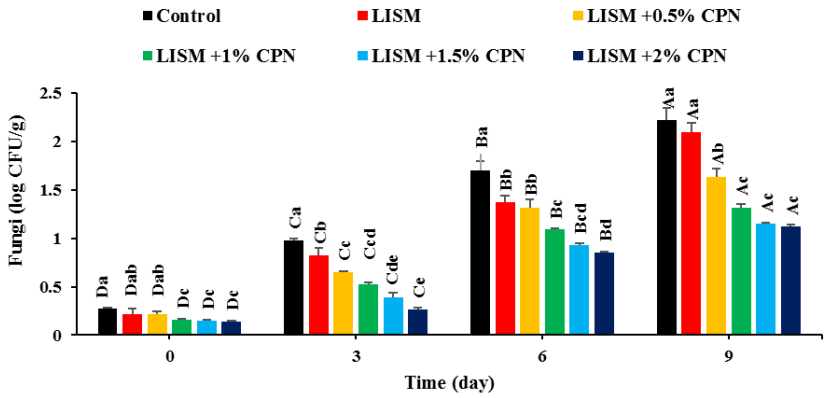

Fig. 5 Changes in fungi count in meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

2-3- Physicochemical changes

LevelpH The samples showed a significant increase during the storage time, but this increase was partial in the sheep meat samples coated with essential oil nanoemulsion (Figure 6). Increase the amountpH Different groups can be related to the activity of microorganisms and the accumulation of volatile bases [38]. In this regard, the meat samples with the highest microbial load, the highest rate of increasepH had the In general, at the end of the maintenance period, the maximum amountpH in the control sample (6.42) and the lowest amount (5.65) in the sampleLISM+2%CPN It was observed that this state is caused by the antimicrobial activity of grapefruit essential oil nanoemulsion. Similar results have been reported in different studies. For example, valuespH The control sample and meat containing thyme essential oil nanoemulsion stored after 30 days increased from 1.6 to 11.8 and from 5.75 to 7.05, respectively [39].

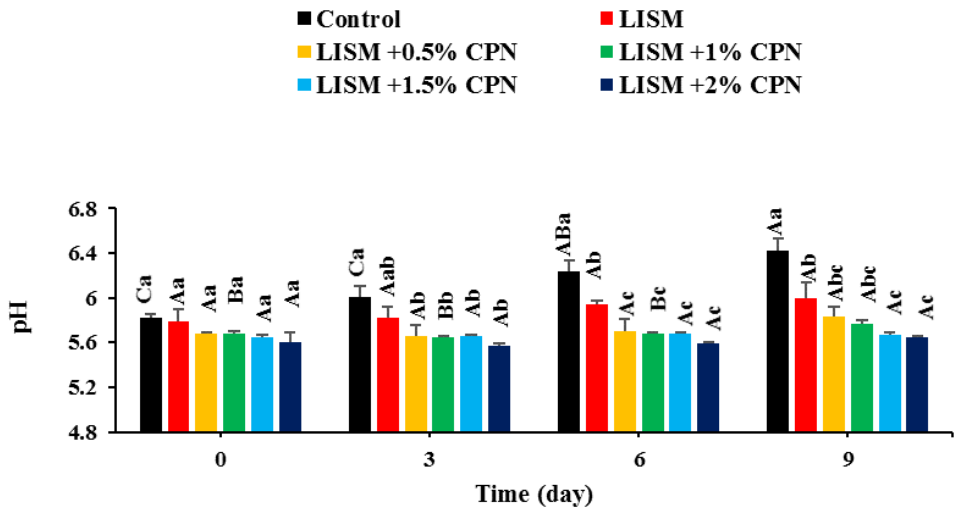

Fig. 6 pH changes in meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

Figure 7 shows the change in moisture content of meat samples during the storage period. The control sample underwent the highest moisture loss during storage time, while the moisture loss in coated meat samples was significantly lower. In general, the moisture content of samples coated with high concentrations of essential oil nanoemulsion was higher than the control sample. This behavior is due to the increase of hydrophobic compounds (essential oils as lipid compounds), which usually leads to the improvement of the barrier properties of water exit in polymer coatings [40]. Similar to the results of this research, Wu et al. (2016) attributed the higher moisture content of the samples coated with essential oil nanoemulsion to more crosslinking between polymers in the matrix. The formed nanoparticles reduce the intermolecular distance in the coating and prevent the diffusion of water molecules through the coating [40].

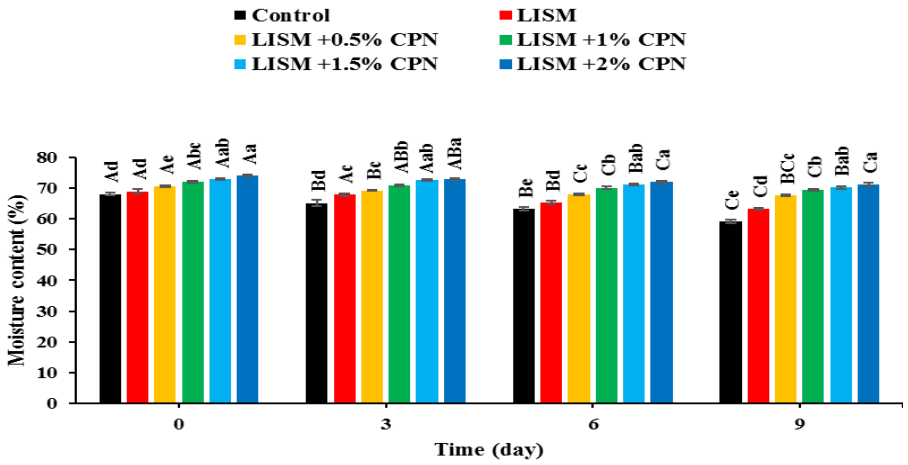

Fig. 7 Changes in moisture content of meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

The results of the effect of food coating on the hardness of meat samples during storage at refrigerator temperature are shown in Figure 8. The effect of storage time and food coating on the hardness of mutton samples was significant (0.05).*p*<). Although the stiffness of the control and coated samples decreased significantly with increasing storage time, this decrease was less in the samples coated with grapefruit essential oil nanoemulsion.It should be noted that the stiffness of the samples was dependent on the concentration of grapefruit essential oil nanoemulsion in the edible coating, and higher concentrations of the essential oil nanoemulsion resulted in a higher stiffness of the samples. Also, the stiffness of coated samples on the first day of storage It was more than the control sample, which may be attributed to the mucilage gelling property [11]. Although the increase in the storage time caused a significant decrease in the hardness of the samples, the hardness of the mutton samples coated with the mucilage of urban balangou and urban balangou containing different concentrations of nanoemulsion of grapefruit essence (0.5, 1, 1.5 and 2%) At the end of the maintenance period, it was significantly higher than the uncoated sample. In this regard, control samples,LISM ،LISM+0.5%CPN ،LISM+1%CPN ، LISM+1.5%CPN AndLISM+2%CPN They underwent a 1.22, 1.16, 1.14, 1.13, 1.18 and 1.07 fold decrease in hardness on the last day of storage at 4°C, respectively. The higher degree of hardness of sheep meat samples covered with mucilage of urban balango containing different concentrations of nanoemulsion of grapefruit essential oil is mainly due to the antimicrobial effect of grapefruit essential oil and its inhibitory effect on the activity of intrinsic enzymes that decompose meat tissue such as collagenase [6]. also,**The addition of nanoemulsions containing essential oil can reduce and prevent protein oxidation and thus maintain the tenderness of meat products [**41**].**

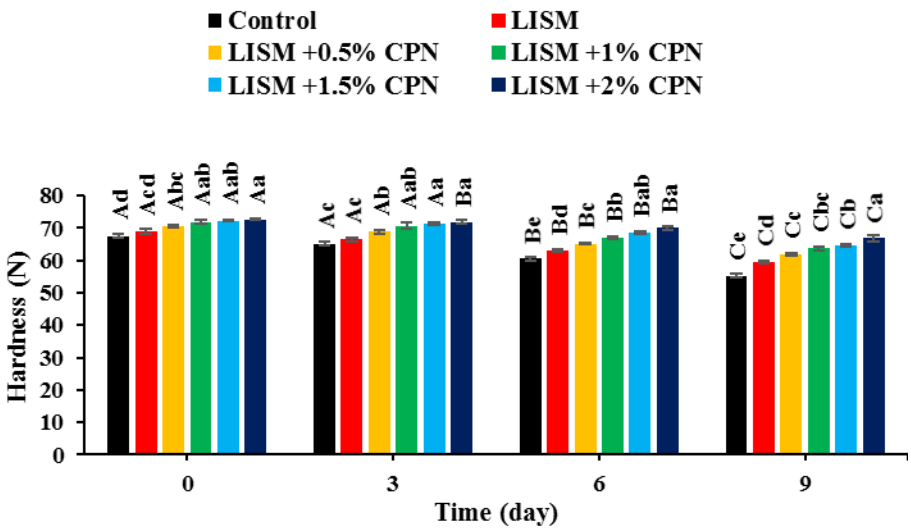

Fig. 8 Changes in the hardness of meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

All the samples undergo an increase in meaningDar in the indexPV During the storage period, they were kept at 4°C (Figure 9). At the end of the maintenance period, the highest and lowest amountPV In the control sample ($meqO_2/kg$ 60/11) AndLISM+2%CPN ($meqO_2/kg$ 40/5) was observed. This state is mainly attributed to the antioxidant activity of the essential oil and the ability of the edible coating to prevent oxygen from entering the surface of the meat samples [42]. It should be noted that the limitPV in meat equal to$meqO_2/kg$ is 7 [6]. LevelPV The control sample was higher than the permissible limit on the sixth day of storage ($meqO_2/kg$ 10/8) and therefore its storage life is estimated to be 3 days. Except for the sampleLISM, LevelPV Meat samples coated with mucilage containing grapefruit essential oil nanoemulsion were lower than the standard during the storage period, which indicates an increase in the shelf life of sheep meat to more than 9 days. Similar to the results of this research, Ansarian et al. (2020) increased peroxide value in camel meat samples (control and coated with nanoemulsion of clove essential oil and resveratrol[8]) due to the faster formation of hydroperoxides than their decomposition and the production of free fatty acids with short chains by microbial enzymes and their oxidation. In addition, these researchers reported that nanoparticles improve the barrier properties of biopolymers against oxygen penetration due to their filling properties and subsequently form a complex pathway for molecular diffusion. Therefore, in the samples coated with essential oil nanoemulsion compared to the control samples, the peroxide number increased to a lesser amount [43]. Similar results were obtained for minced camel meat coated with chitosan and carboxymethyl cellulose nanocomposite containing fig extract and kakuti essential oil, in which the nanocomposite coating showed a lower peroxide number than the control group during storage [44].

[8] Resveratrol

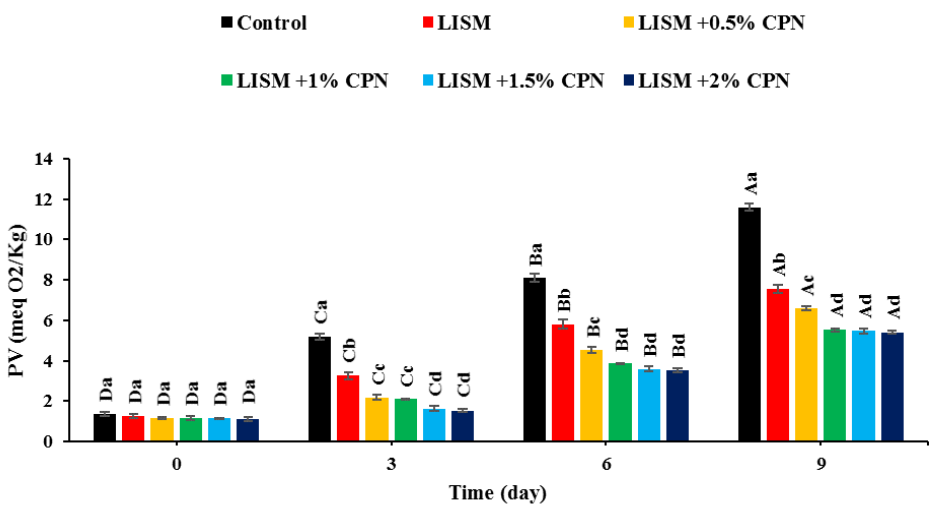

Fig. 9 Changes in the Peroxide value (PV) of meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

The amount of thiobarbituric acid of sheep meat samples was also affected by food coating and storage time (Figure 10). Indicator changesTBA The samples followed the same trend and the highest and lowest amountTBA (mg MDA/kg 1.20 and 0.59) at the end of the storage period were observed in the control and coated samples with mucilage containing 2% nanoemulsion, respectively. Considering that microbial lipases are capable of inducing lipid oxidation in meat and meat products [45], the lower level of indicatorsPV AndTBA In the coated samples compared to the control sample, it may be due to the antimicrobial activity of grapefruit essential oil in reducing microbial growth and lipase formation. These results are consistent with the results of Hong et al. (2020) who showed that the addition of emulsion in meat decreased the valuesTBA The meat becomes red. In addition, these authors have confirmed that the reduction of oxidation is due to the formation of an oxygen barrier on the surface of the meat and the presence of antioxidant activity, both of which participate in the control of lipid oxidation [46]. In control meat samples covered with films containing Shirazi thyme essential oil nanoemulsion, the amountTBA increased, but this increase was less in the treated samples because the size of small drops of essential oil nanoemulsion has a major effect on their stability against lipid oxidation [47].

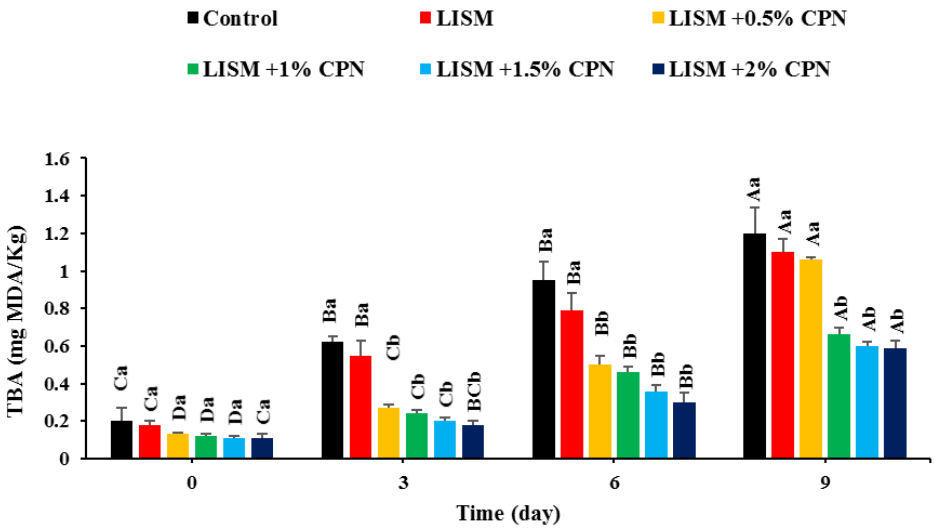

Fig. 10 Changes in the thiobarbituric acid of meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

brightness index (L*) The samples decreased significantly with the increase of storage time from 0 to 9 days, which shows the darkening of the color of the meat samples during the storage period (Figure 11). However, edible coating showed a significant effect on this parameter and indexL* Sheep meat samples covered with mucilage of urban balangoi containing nanoemulsion of grapefruit essential oil were significantly higher than the control sample at the end of the storage period.

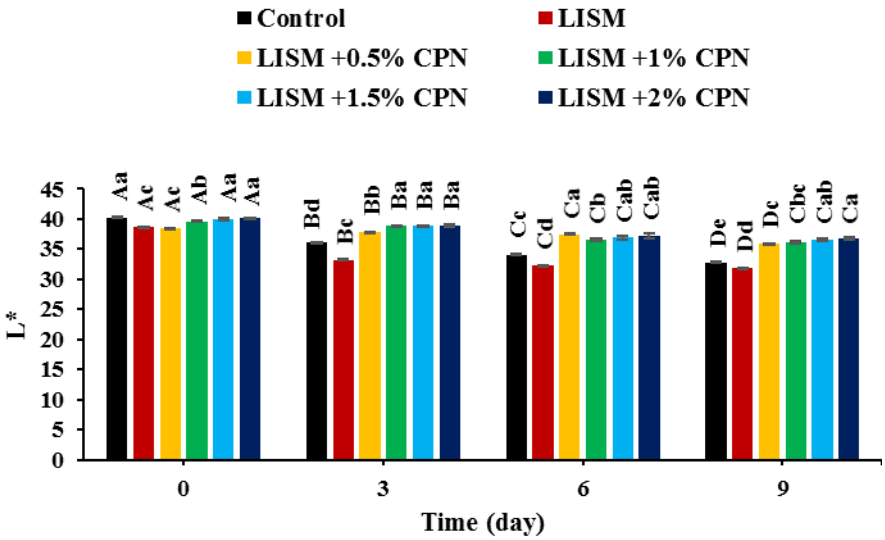

Fig. 11 Changes in the brightness index (L*) of meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

Redness index (a*) The control and treated samples with edible coating loaded with grapefruit essential oil also experienced a significant decrease during the storage period (Figure 12). The decrease in the redness index of meat samples may be due to the conversion of myoglobin to metmyoglobin during the storage period [34]. Examining the effect of food coating on this parameter showed that at the end of storage time, meat samples covered with mucilage and mucilage containing nanoemulsion have higher values.a* They are compared to the control sample, which is in accordance with the research of Zhang et al. (2020), which stated the reason for the protective system of emulsions and nanoemulsions on the antioxidant compounds of essential oils, which leads to the improvement of the antioxidant properties of meat [41].

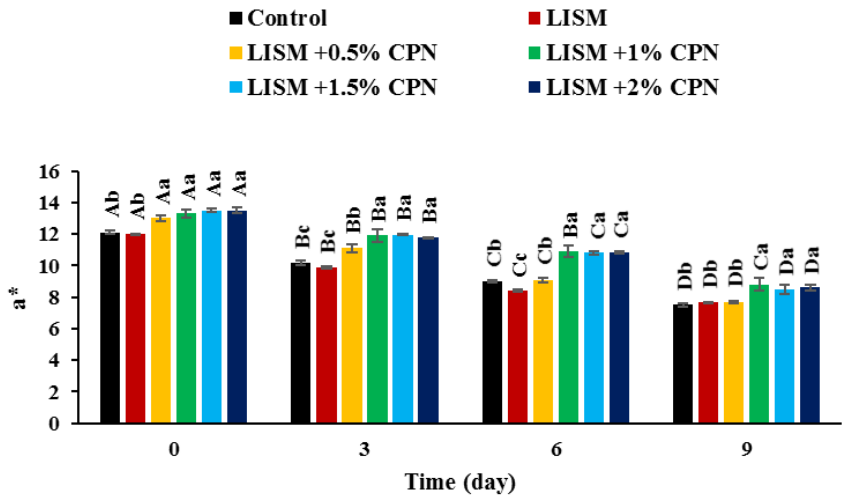

Fig. 12 Changes in the redness index (a*) of meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time).

Jaundice index (b*) Sheep meat samples showed a significant decrease during the storage period (Figure 13). But samples coated with higher percentages of nanoemulsion have valuesb* They were higher than the control sample without cover. Decrease indexL* Andb* In the samples, it may be due to the transformation of myoglobin pigment with purple-red color to brown met-myoglobin pigment [48].

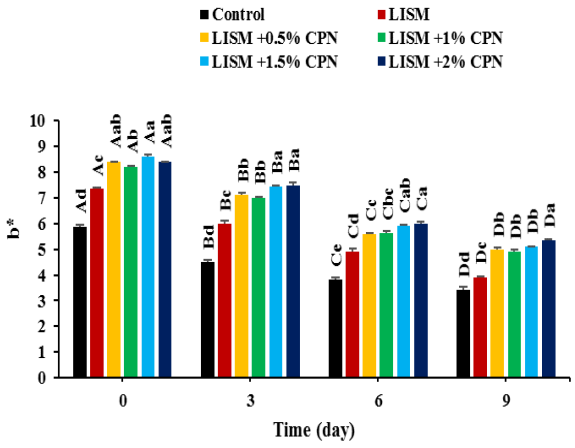

Fig. 13 Changes in the yellowness index (b*) of meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time)

3-3- sensory characteristics

Sensory characteristics of samples were significantly affected by food coating and storage time (Figure 14). The aroma score of the meat samples decreased significantly during the storage time, and this was the case in the control samples andLISM was more obvious (Figure 14-a); So, at the end of the storage period, they were unacceptable in terms of aroma. However, the edible coating based on mucilage of urban balangoui loaded with grapefruit essential oil nanoemulsion prevented the changes in the aroma of meat samples.**(05/0p<).**

It should be noted that the meat samples covered withLISM+CPN which had low microbial load and less lipid oxidation, had less development of unpleasant aromas compared to the control sample. This state indicates the effect of microbial growth and lipid oxidation in the development of unpleasant aroma in meat. Color scores (Figure 14-b) and tissue (Figure 14-c) also showed a similar trend and the results of sensory evaluation of color and texture were in line with the findings of colorimetry (Figures 11-13) and histometry (Figure 8). Samples of mutton coated withLISM+CPN They were acceptable in terms of overall acceptance throughout the storage period, but the control sample was unacceptable on the ninth day of storage (Figure 14-d). The antioxidant antimicrobial activity of grapefruit essential oil and the protective effect of the edible coating and nanoemulsion particles of grapefruit essential oil against microbial growth (Figures 1-5) and lipid oxidation (Figures 9-10), may be the reason for the higher overall acceptance of samples coated with mucilage containing Grapefruit essential oil nanoemulsion. In line with the results of this research, Liu et al. (2020) reported that the use of edible coating based on nanoemulsion of star anise essential oil, polylysine and nisin resulted in better preservation of color, aroma and overall acceptance [49].

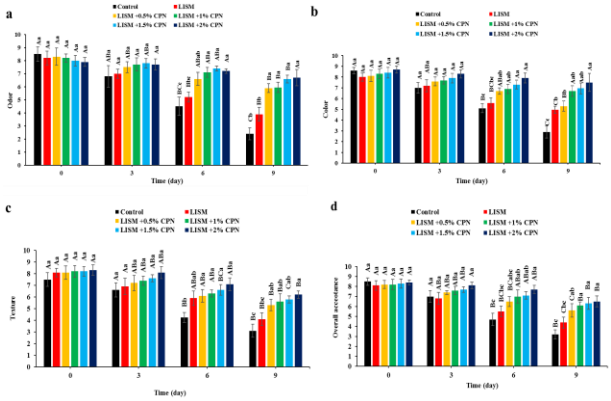

Fig. 14 Sensory evaluation of meat samples during the storage period at 4°C. (Capital letters indicate a significant difference between the days of storage in the fixed treatment of the coating type and small letters indicate a significant difference between the edible coatings in the fixed storage time)

4- General conclusion

The preparation and use of edible coating based on mucilage of Balangoui city containing nanoemulsion of grapefruit essence on sheep meat was investigated. The antimicrobial and antioxidant efficiency of grapefruit essential oil nanoemulsion in the coating structure was affected by its concentration. the leastpH, the amount ofTBA And the total microbial count was obtained in the sheep meat sample covered with urban balangou mucilage containing the highest concentration of grapefruit essential oil nanoemulsion at the end of the storage time. In addition, the coated meat samples obtained a higher sensory score than the uncoated sample. A strong correlation between chemical and microbial parameters of sheep meat samples during storage time was confirmed. This research showed the ability of grapefruit essential oil nanoemulsions to prolong the shelf life of lamb meat during cold storage.

5- Thanks and appreciation

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6- Resources

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بررسی اثر پوشش خوراکی مبتنی بر نانوامولسیون اسانس گریپ فروت و موسیلاژ دانه بالنگوی شهری بر ویژگی‌های میکروبی و شیمیایی گوشت گوسفند طی دوره نگهداری

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چکیده

در این مطالعه، اثر پوشش خوراکی بر پایه موسیلاژ دانه بالنگوی شهری (*Lallemantia iberica* seed mucilage, LISM) حاوی غلظت‌های مختلف (صفر، ۰/۵، ۱، ۱/۵ و ۲ درصد حجمی/حجمی) نانوامولسیون (CPN) اسانس گریپ‌فروت (*Citrus paradisi* essential oil) بر کیفیت‌های میکروبی، شیمیایی و حسی گوشت گوسفندی در طی نگهداری سرد مورد بررسی قرار گرفت. نتایج ضدمیکروبی نشان داد که در انتهای دوره نگهداری، کمترین تعداد باکتری‌های زنده کل (۶/۲۶ log CFU/g)، باکتری‌های سرمادوست (۳/۲۸ log CFU/g)، *Escherichia coli* (۰/۹۵ log CFU/g)، *Staphylococcus aureus* (۰/۸۷ log CFU/g) و قارچ (۱/۱۲ log CFU/g) در نمونه LISM+2%CPN مشاهده شد. بیشترین و کمترین pH در پایان دوره نگهداری به ترتیب مربوط به نمونه‌های بدون پوشش (۶/۴۲) و LISM+2%CPN (۵/۶۵) بود. مقدار عدد پراکسید و تیوباربیتوریک اسید در نمونه شاهد و نمونه LISM+2%CPN به ترتیب ۱۱/۶۰ meq O2/kg و ۱/۲۰ mg MDA/kg و ۵/۴۰ meq O2/kg و ۰/۵۹ mg MDA/kg پس از ۹ روز نگهداری در شرایط سرد بود. رنگ گوشت (L*، a*، b*) نیز توسط پوشش خوراکی حاوی نانوامولسیون اسانس گریپ فروت (LISM+CPN) حفظ گردید. افزایش محتوای نانو امولسیون در پوشش خوراکی، امتیاز پارامترهای حسی مانند بو، رنگ، بافت و پذیرش کلی گوشت گوسفند را به خصوص در آخرین روز نگهداری تحت شرایط سرد افزایش داد. نتایج به‌دست‌آمده، پوشش خوراکی LISM+CPN را به‌عنوان یک راهکار مؤثر برای به تاخیر انداختن زوال شیمیایی و میکروبی گوشت گوسفند پیشنهاد می‌کند.