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Effect of Diatary supplementation of L-carnitine on male Sangsari lambs meat quality

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ABSTRACT

L-carnitine is used as a nutritional supplement in animal nutrition to improve meat quality and reduce fat oxidation. This study was conducted on male Sangsari lambs with the aim of investigating the effect of L-carnitine on color characteristics, fat oxidation, tenderness, and meat cooking loss. The lambs were divided into three groups of control, 150, and 300 mg L-carnitine per kilogram of diet. The results showed that the addition of L-carnitine to the diet, especially at the 300 mg level, caused significant changes in meat color parameters; such that the intensity of yellowness increased and the amount of redness decreased. These changes are probably due to increased fat oxidation and changes in muscle protein composition. The group receiving 300 mg showed the highest level of brightness, which may be related to a decrease in red pigments and an increase in yellow pigments. Measurement of malondialdehyde, an indicator of fat oxidation, showed that L-carnitine significantly reduced fat oxidation, resulting in improved meat quality and shelf life. L-carnitine supplementation also temporarily tenderized the meat, but this effect decreased over time. No significant differences were observed between groups in terms of cooking loss. Overall, L-carnitine may improve meat quality, but further studies are needed to confirm the results.

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1.introductin

The compound carnitine, whose name is derived from the Latin word "carnis", is chemically known as beta-hydroxy-gamma-trimethylaminobutyrate [1]. In terms of chemical classification, carnitine is in the group of amines. Amines are generally considered ammonia derivatives in which alkyl groups have replaced ammonia hydrogens [2]. This compound is structurally similar to amino acids and has two active isomers of L-carnitine and inactive D-carnitine, whose L-isomer is a water-soluble vitamin and plays various roles, including protecting and regulating cell membranes, increasing fat metabolism, increasing the power of the immune system, and improving the performance of human and animal nutrition [3]. In addition to playing an important metabolic role in the transfer of long-chain fatty acids into the mitochondria to carry out beta-oxidation reactions, L-carnitine also has positive effects on the immune system [4]. Also, L-carnitine supplementation helps prevent fat deposition in conditions of excessive energy consumption by increasing the oxidation of fatty acids and improving the efficiency of energy use [5]. L-carnitine biosynthesis in livestock through two essential amino acids lysine and methionine and with the help of several vitamins including vitamin C (ascorbic acid), vitamin B_3)، B_6) and iron that act as cofactors. The endogenous production of L-carnitine in livestock varies depending on factors such as age, health status, diet and metabolic needs [6].

Mehdishahr, which is also known as Sangsar, is one of the cities of Semnan province, which is located in the northwest of Semnan city and at a distance of about 20 kilometers from it [7]. In the past, the residents of this region lived as nomads and their migration range included the provinces of Tehran, Mazandaran, Golestan and Khorasan, but nowadays most people have turned to urban life. Animal husbandry is one of the main pillars of Sangsar people's life, and based on historical evidence and contemporary research, this activity has a history of several thousand years. Sangsari nomads are specialized in producing dairy products from sheep's milk and produce more than 30 types of unique dairy products, including yogurt, buttermilk, Arshe, cheese, laurel, chiko, curd, and waroon, etc. [8].

Sangsari sheep, which is one of the indigenous and resistant breeds of Iran, is raised in Sangsar region as nomadic, semi-nomadic and rural. This breed of small to medium sized sheep is found in black, white, blond and light to dark brown colors. Sangsari sheep have a small body, delicate hands and feet, a short tail and a small, bow-shaped tail, and they do not have horns. This breed is famous for its unique meat quality, and almost 60% of the sheep's body weight is dedicated to meat before slaughter [9].

In adult vertebrates, endogenous production of L-carnitine is usually sufficient; However, in certain conditions such as some diseases and heavy physical activities, the synthesis of L-carnitine may not be sufficient [10]. Research shows that younger animals and those in good health usually produce sufficient amounts of this compound to meet their physiological needs. However, under conditions of stress, disease or periods of rapid growth, the demand for L-carnitine may exceed endogenous production, which can lead to a deficiency of this compound in livestock [11]. According to Sarika et al. 2007, the need for L-carnitine in animals increases in some conditions, including the limitation of its synthesis in young animals, the consumption of diets containing high amounts of fat and low intestinal absorption; Therefore, adding this compound as a supplement to feed can be effective [12]. On the other hand, studies show that adding L-carnitine to the diet improves the use of dietary protein [10].

Mayer et al. 2020 studied the effects of L-carnitine supplementation on the performance and postpartum recovery of dairy cows. According to the opinion of these researchers, dairy cows suffer from metabolic diseases due to the high energy requirements for the birthing process, the start of milk production, and the limitation of feed consumption capacity. Not having enough L-carnitine available during times of increased energy needs, such as shortly after delivery, may exacerbate energy deficits. Insufficient supply of L-carnitine is a limiting factor for fatty acid metabolism [13].

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On the other hand, Kidd et al. (2004) reported that the addition of 255 ppm L-carnitine supplement to the diet of broiler chickens led to a decrease in visceral fat, improved carcass characteristics of broilers, and increased breast muscle volume. This combination also helps to increase body weight, reduce carcass fat and improve food conversion ratio [14]. In addition, the lack of carnitine precursors, including the amino acids lysine and methionine, in broilers can lead to an increase in carcass fat [15]. Also, Ixo et al. (2015) found that adding L-carnitine supplement to the diet of broiler chickens significantly reduces abdominal fat, improves live weight, meat color and crude fat content in muscle [15]. Berhani et al. (2015) in a study on Farahani lambs, showed that the use of sources of oilseeds and L-carnitine supplement in feeding these lambs during the fattening period does not affect their response to diets containing soybean and canola seeds. The results of this research indicated that these diets have the least effect on lipid-related metabolites, including triglycerides, total cholesterol, HDL, LDL, total protein, glucose, and ammonia concentration in the serum of growing lambs [16]. In addition, in another study, L-carnitine supplementation along with soybean oil and protected fat calcium in Afshari lambs has led to a decrease in blood cholesterol concentration [17].

Considering that the effect of adding L-carnitine supplement on meat quality, especially in Sangseri lambs breed, has not been comprehensively investigated so far, this study is designed and implemented with the aim of evaluating the effects of this supplement on the meat quality characteristics of Sangseri male lambs. Investigating this issue can help improve meat quality and develop knowledge related to the use of nutritional supplements in animal husbandry.

2 - Materials and methods

1-2- Materials

L-carnitine with high purity was obtained from Arin Rushdafza, the official representative of the German company Salamat Dom Lohmann. Also, all the chemical compounds used in this research were obtained from the products of Merck, Germany.

2-2- Research method

In this research, 32 Sangsari male lambs aged four to five months and average weight 16.5 kg were used in the animal breeding station of Semnan University Veterinary Faculty. The lambs were randomly kept in individual stalls and had free access to water and feed. After a 14-day habituation period, the animals were randomly assigned to one of the experimental diets according to Table 1 and in compliance with the principles of animal welfare and ethical code number 140311022644 and were fed for 84 days. The feeds were completely mixed and provided in two daily meals (at 7:00 and 17:00) based on the needs of the animals. Diets were adjusted equally for metabolizable energy and crude protein. At the end of the fattening period, the animals were slaughtered and the carcasses were separated and examined on the day of the start of the experiment, the third day and the seventh day, and they were kept in the refrigerator until the end of the experiment. [18].

Table 1. Feed ingredients and chemical composition of experimental diets (percentage of dry matter).

Rations			
Ingredients (by dry matter)	Control	L-carnitine 150 (mg/kg)	L-carnitine 300 (mg/kg)
Alfalfa	14.60	14.60	14.60
Corn silage	15.40	15.40	15.40
Barley	41.26	41.26	41.26
Corn	11.04	11.04	11.04
Rapeseed meal	3.06	3.06	3.06
Soybean meal	3.72	3.72	3.72
Wheat bran	7.64	7.64	7.64

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L-carnitine (mg/kg)	0	150	300
Calcium carbonate	1.10	1.10	1.10
Vitamin-mineral supplement*	0.85	0.85	0.85
Sodium bicarbonate	0.85	0.85	0.85
Salt	0.51	0.51	0.51
Metabolizable energy (Mcal/kg)	2.61	2.61	2.61
Dry matter (percent)	69.92	69.92	69.92
Crude protein	14.00	14.00	14.00
Cell wall (percent dry matter)	28.90	31.70	31.70
Non-fibrous carbohydrate (percent dry matter)	48.40	44.20	44.20
Calcium (percent dry matter)	0.73	0.90	0.90
Phosphorus (percent dry matter)	0.42	0.41	0.41

* A kilogram of vitamin supplement contained 600,000 international units of vitamin A, 200,000 international units of vitamin D, 200 mg of vitamin E, 2,500 mg of antioxidants, 195 g of calcium, 80 g of phosphorus, 21,000 mg of magnesium, 2,200 mg of manganese, 3,000 mg of iron, 300 mg of copper, 300 mg of zinc, 100 mg of cobalt, 120 mg of iodine, and 1.1 mg of selenium.

3-2- Loss due to cooking [1] (CL)

To measure the loss caused by cooking, the coded samples were first weighed and then placed on a greased grid in the oven at a temperature of 163 degrees Celsius. The central temperature of the samples was recorded during the baking process using a digital thermometer equipped with a probe. For this purpose, the probe was placed in the center of each sample and the baking process continued until the temperature of the center of the sample reached 77°C. After baking, the samples were removed from the oven and exposed to cold air flow until they reached the ambient temperature. Finally, the samples were weighed again and the percentage of loss due to baking was calculated using formula (1).

$$Cl = \frac{w1 - w2}{w1}$$

(CL: loss due to baking, IN_1: sample weight before cooking, IN_2: sample weight after baking)

4-2- Colorimetry

After slaughtering the animals, the rectus muscle (located between the 6th and 10th ribs) was selected and dissected due to the proper accumulation of fatty acids and the favorable quality of the muscle fibers, which makes it an ideal option for meat color evaluation. Color indicators including brightness (L*) From black (0) to white (100), red (a*) From green (negative values) to red (positive values), and yellow (b*) From blue (negative values) to yellow (positive values) were examined. The color evaluation was done using Hunterlab colorimeter device, in three repetitions for each sample, 24 hours after slaughter. Before starting the measurement, the device using the standard white screen and according to the guidelines of the International Group of Color Indexes L*، a* and b* was calibrated [18].

2-5- Determining the amount of lipid oxidation [2] (TBARS)

At the specified times, the fat of the extracted meat samples and their resistance to oxidation were measured by measuring the number TBARS, was determined based on the method of Nam and Ahan (2003). In order to measure thiobarbituric acid (TBA)5 grams of the meat sample was

1 . Cooking losses

2 . Thiobarbituric acid reactive substances

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homogenized with 31 ml of extraction solution containing 4% perchloric acid and 1 ml of butylhydroxyanisole (with a concentration of 1 g/l), which was kept at a temperature of 4 degrees Celsius, for 1 minute at a speed of 13,500 rpm. The resulting solution was passed through Whatman filter paper and its final volume was increased to 50 ml by adding 4% perchloric acid. Then, 5 ml of the filtered solution with 5 ml of solution TBA (with a concentration of 0.02 mol/liter) was mixed, vortexed and placed in a water bath at a temperature of 100 degrees Celsius for 60 minutes to form the malonaldehyde complex. Optical absorption of the final solution (As) at a wavelength of 530 nm using a spectrophotometer against a distilled water reference (Ab) It was measured. number TBARS It was calculated and reported as milligrams of malonaldehyde per kilogram of sample [19].

$$TBA=\frac{As-Ab\times 50}{500}$$

2-6- Examination of tissue profile [3] TPA

To check the texture profile of meat samples, straight muscle pieces with dimensions (1.9 x 1.8 x 0.8 cm) Cut and placed in the center of the tissue profile analyzer screen (TPA) They were subjected to two cycle compression tests. This analysis was performed using a histometer equipped with a 500 N load cell, at ambient temperature and under double compression conditions. The speed of pre-test and post-test was 5 mm/s, the return speed was 1 mm/s, and the percentage of changes was 50%. The initial loading force was equal to 10 grams. In this test, the samples were subjected to 50% axial stress in order to prevent the damage and destruction of the tissue of the meat samples during the test [18].

7-2- Measurement of water storage capacity WHC [4]

The water holding capacity of the samples was evaluated using the method proposed by Hamonides et al. (1999). In this method, 5 grams of the sample was weighed with high precision and then wrapped in two layers of filter paper and placed in a Falcon tube. Falcon was centrifuged in a refrigerated centrifuge at a speed of 3600 g and a temperature of 8 °C for 30 minutes. After the centrifugation process was completed, the sample was separated from the filter paper and the weight of the paper and the sample was recorded separately. The water holding capacity of the samples was calculated using the relevant formula [20].

$$WHC\ g/kg = [\ (\ 1 - Mw\ /Ms\ )1000\ ]$$

Ms = initial weight of the sample in grams

Mw = weight of water removed from the sample in grams after centrifugation

8-2- Statistical analysis

All experiments were performed at least in three replications using a completely randomized factorial design. Data using one-way analysis of variance (ANOVA) And Tukey mean comparison test with 95% confidence level was analyzed for significant variables. All data with SPSS Version 29 (SPSS Inc., Chicago, IL, USA) were analyzed and the results were presented as mean ± standard deviation. Charts with Excel 2016 was drawn

3- Results and discussion

3-1- Color evaluation

The results showed that adding L-carnitine to the diet of the treatment groups significantly increased the jaundice index. (b*) compared to the control group. The highest amount of jaundice was related to the group receiving 300 mg of L-carnitine, while the lowest amount was

3 . Texture Profile Analyzer

4 . Water holding capacity

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observed in the control group. By increasing the concentration of L-carnitine from 150 to 300 mg, the yellowness of the meat increased, although these changes were not statistically significant. ($P<0.05$). This increase may be related to the oxidation of fats, the accumulation of yellow pigments, or changes in the composition of muscle proteins. In addition, increasing the duration of storage also increased the yellowness of the meat in all samples compared to day zero. According to the researchers' findings, there is a positive relationship between intramuscular fat content and jaundice index (b*) reported [21].

On the other hand, adding L-carnitine to the diet of the treatment groups significantly reduced the redness index (*a) Meat was compared to the control group. This reduction may be due to a decrease in the concentration of myoglobin, the main protein responsible for the red color in meat. However, in all groups, meat redness increased over time. Contrary to this finding, Khoo et al. (2003) reported that supplementing the diet of male chickens with L-carnitine significantly increased the index. *a It is in meat [15].

Adding L-carnitine to the diet of livestock leads to an increase in brightness index (*L) compared to the control group. The highest amount of brightness was observed in the treatment group with 300 mg of L-carnitine and the lowest amount was observed in the control group. This increase may decrease the index *a and the increase of yellow pigments (*b) be related [22]. The brightness index, similar to other indices, increased over time in all groups. According to the researches, the increase in intramuscular fat content in the meat of cattle fed with L-carnitine may be associated with a decrease in moisture (which is inversely correlated with fat) and more importantly, with higher values of the index. *L to be related in the meat of these animals. In fact, the brightness index (*L) It has shown a positive correlation with intramuscular fat content [23].

2013 reported a direct correlation between L-carnitine levels and meat pigmentation in fat-tailed gazelle lambs [21]. In addition, these researchers in 2014 found that supplementing the diet of goat lambs with L-carnitine could improve the texture and color of the meat in lambs and make the meat more attractive, although it had no significant effect on growth performance [21]. Also, Owen et al. 2001 reported in their research that supplementing pig diet with L-carnitine by increasing protein accumulation leads to better muscle development, meat quality and improved meat color [2]. According to Liu et al. 2020, supplementation with L-carnitine affects blood metabolites and the expression of genes related to fat metabolism. These supplements not only reduce serum glucose concentration, but also neutralize the negative effects of energy-rich diets by changing the expression of genes involved in fat metabolism [17, 24].

Table 2. Results of evaluation of optical parameters of meat during the study.

		Sample		
Day	Indicators	Control	Lc 150 mg	Lc 300 mg
0	b^*	11.45 ± 0.35^{and}	12.13 ± 0.21^{of}	12.83 ± 0.40^{bcd}
	a^*	13.37 ± 0.31^{cd}	12.34 ± 0.22^{and}	12.40 ± 0.20^{of}
	L^*	31.50 ± 0.25^{cd}	32.30 ± 0.21^{cd}	32.20 ± 0.51^{b}
3	b^*	12.53 ± 0.46^{cd}	13.13 ± 0.40^{bc}	13.73 ± 0.21^{ab}
	a^*	14.27 ± 0.45^{bc}	14.17 ± 0.36^{bc}	12.33 ± 0.50^{and}
	L^*	32.30 ± 0.50^{cd}	34.20 ± 0.50^{ab}	34.50 ± 0.56^{ab}
7	b^*	12.70 ± 0.57^{cd}	14.17 ± 0.55^{a}	14.53 ± 0.40^{a}
	a^*	15.83 ± 0.26^{a}	14.77 ± 0.57^{b}	14.17 ± 0.45^{bc}
	L^*	33.20 ± 0.56^{bc}	34.80 ± 0.58^{a}	35.00 ± 0.72^{a}

A-E: Different letters in each column indicate statistical differences between doses on different days ($p<0.05$).

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3-2- Oxidation resistance

The addition of L-carnitine to the diet of animals on day zero, as shown in Table 3, led to a decrease in the concentration of malondialdehyde. This reduction was significantly observed at the 150 mg level, but the changes on this day were not statistically significant. The highest and lowest levels of malondialdehyde were observed in the control group and the group receiving 150 mg of L-carnitine, respectively. On the seventh day, a significant difference was observed between the three groups and both treated groups showed a significant decrease in malondialdehyde concentration compared to the control group. The reduction of this index indicates the reduction of lipid oxidation in meat, which leads to increased shelf life and improvement of meat quality during the storage period.

On the other hand, the results showed that with increasing storage time, the concentration of malondialdehyde increases. However, the effect of L-carnitine in reducing lipid oxidation was more evident in longer periods of storage, and this indicates the effective role of this compound in reducing lipid oxidation over time. In addition, previous studies confirm that L-carnitine is an organic compound that plays a key role in transporting long-chain fatty acids to mitochondria for oxidation and energy production. [2]. Supplementation with L-carnitine in lambs can affect lipid oxidation and fat metabolism, and evidence shows that this compound has a positive effect on improving fat metabolism. which plays a key role in the transfer of long-chain fatty acids to mitochondria for oxidation and energy production and reduces oxidation [25].

Table 3. Results of assessment of malondialdehyde concentration during the study.

	Day 0	Day 3	Day 7
Control	0.400± 0.020^{and}	0.630± 0.020^{c}	0.840± 0.030^{a}
Lc 150 mg	0.380± 0.015^{and}	0.580± 0.010^{c}	0.770± 0.015^{b}
Lc 300 mg	0.386± 0.010^{and}	0.530± 0.015^{d}	0.720± 0.021^{c}

A-E: Different letters in each column indicate statistical differences between doses on different days ($p<0.05$).

3-3- Water storage capacity

As shown in Table 4, the results indicate that the addition of L-carnitine to the diet of sheep increases the water holding capacity. (WHC) It is in the flesh. With the increase of L-carnitine dose, this parameter showed an increasing trend, but these changes were not statistically significant. Possible cause of increase WHC can be attributed to the effect of L-carnitine on the structure of muscle proteins. It seems that by changing the structure of proteins, this combination improves their ability to absorb and retain water. In addition, L-carnitine can affect pH Meat provides more favorable conditions for water retention. decrease pH After slaughter, it leads to a change in the volume of myofibrils and a transformation of the protein structure, which ultimately increases the water holding capacity [26].

Previous studies have shown that WHC It has a direct effect on the texture, softness and overall quality of the meat and is influenced by factors such as the type of muscle, pH, temperature and composition of muscle proteins [27]. Specifically, changes pH Before stasis and binding of myosin to actin at this stage, a key role in WHC they perform Perillo et al. (2001) reported that changes pH، WHC, the crispiness and color of the meat is usually related to the amount of fat, the degree of fatness of the carcass and so on pH The final is relevant [28].

Also, WHC increased during storage time. These changes are probably caused by post-

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slaughter processes and changes in the protein structure of meat [29].

Table 4. Results of water holding capacity assessment during the study.

	Day 0	Day 3	Day 7
Control	0.130± 0.010^{d}	0.150± 0.030^{cd}	0.190± 0.013^{ab}
Lc 150 mg	0.131± 0.020^{d}	0.170± 0.033^{bc}	0.170± 0.025^{bc}
Lc 300 mg	0.150± 0.010^{cd}	0.180± 0.022^{bc}	0.210± 0.020^{ab}

A-E: Different letters in each column indicate statistical differences between doses on different days ($p<0.05$)

3-4- Evaluation of meat texture

The hardness of the meat as one of the physical characteristics, in the control group and the groups fed with the diet containing L-carnitine with different doses, is shown in graph 1. According to this graph, on days 0 and 3 of storage, respectively, the highest and lowest hardness of the meat was related to the control group and the group fed with a diet containing 300 mg of L-carnitine, which difference is statistically significant in these days. In other words, in the initial days of storage (0 and 3), the group receiving the dose of 300 mg of L-carnitine had softer meat, indicating the short-term effect of this supplement on reducing the hardness of the meat. However, as the storage time increased to day 7, the difference between L-carnitine receiving groups and the control group decreased and was not statistically significant. This finding indicates the instability of the softening effect of L-carnitine with increasing storage time.

In all storage days, increasing the dose of L-carnitine from 150 to 300 mg in the diet of animals led to a decrease in meat hardness. This reduction can be related to changes in the composition of muscle fatty acids. Different studies have shown that supplementation with L-carnitine can improve the texture of lamb meat and increase its tenderness, which changes are probably due to the modification of muscle fatty acid composition [30]. Similarly, Ing et al. (2013) also reported the positive effect of L-carnitine on reducing pork hardness [31].

L-carnitine, as a natural compound in the body, plays an important role in fat metabolism. Some studies have reported reductions in body fat and muscle fat content with L-carnitine supplementation, which may indirectly affect meat tenderness. However, in some other researches, no significant effect on feed consumption, digestibility and animal growth has been observed. Based on the available evidence, the dose and duration of L-carnitine consumption, along with factors such as the breed and age of the animal, are among the factors affecting the hardness of the meat. In addition, the composition of the diet and the amount of energy received can affect the metabolism of L-carnitine and ultimately lead to the improvement of meat quality [17, 21, 24].

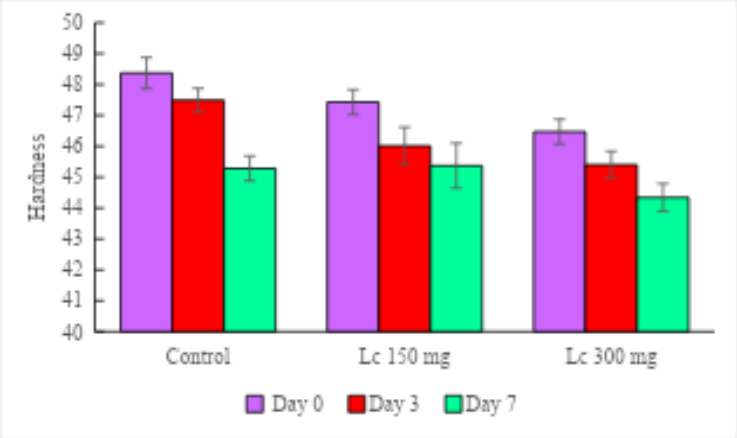

Fig 1. Results of meat hardness assessment during the study.

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3-5- Loss due to cooking

Table 5 shows the amount of loss caused by cooking meat in different days of storage (days 0, 3 and 7). The results indicate that there were differences in the cooking loss in different samples during the storage period, but these differences were not statistically significant. Also, the addition of L-carnitine to the food diet of animals did not show an effect on the reduction of the amount of water lost due to cooking, but this reduction was affected by the duration of storage. According to a study by Leo et al. (2020), the addition of L-carnitine may increase cooking-induced weight loss in lamb, although this study did not directly measure total cooking-induced weight loss [24]. Previous studies have shown that weight loss due to cooking occurs mainly due to reasons such as water evaporation, reduction of interstitial water, and loss of soluble substances. These results also indicate that factors such as storage time, temperature, and humidity of the storage environment play an effective role in the amount of loss caused by cooking [28].

On the other hand, with the increase in the storage time, the destruction of the cellular skeleton and the decrease in the ability of the meat to retain water can be expected, which leads to an increase in the loss caused by cooking. This assumption is based on the effect of destruction of the cell structure on reducing the tissue's ability to retain water [25]. However, the results of the present study contradicted this prediction. This contradiction can be attributed to the influence of several factors such as temperature, humidity, pH Meat and the composition of amino acids may have influenced the amount of loss caused by cooking and may have affected the effect of supplementation with L-carnitine. The mechanisms affecting the loss due to curing are complex and are influenced by a variety of factors. It is possible that supplementation with L-carnitine affected some of these factors, but this effect was not enough to create a statistically significant difference.

A study by Smith et al. (1978) on bulls showed that there was no statistically significant difference in cooking losses between animals fed normal diets and those fed treated layer droppings (presumably containing L-carnitine). Although some evidence, including reports of increased cooking-induced weight loss in lamb following L-carnitine administration, points to this issue, the results of different studies remain inconsistent [32]. This discrepancy is probably due to the effect of the type of cooking method, as the cooking method plays a more prominent role in cooking-induced weight loss than L-carnitine supplementation. More research is needed to directly evaluate the effect of L-carnitine supplementation on cooking-induced weight loss in both lamb and bull species to achieve definitive results. In addition, the findings of the study by Leal et al. (2023) showed that cooking in a water bath, compared to cooking in an oven, leads to a lower weight loss in lamb cuts. These results emphasize that the cooking method is a more important factor in weight loss caused by cooking, and the effect of supplementing with L-carnitine alone may not be significant [33].

Table 5. Results of the evaluation of cooking loss during the study period.

	Day 0	Day 3	Day 7
Control	22.27± 0.47^{of}	23.63± 0.45^{bc}	25.13± 0.25^{a}
Lc 150 mg	21.67± 0.55^{and}	23.20± 0.36^{cd}	24.57± 0.45^{ab}
Lc 300 mg	22.77± 0.35^{cde}	23.47± 0.31^{bc}	25.70± 0.56^{a}

A-E: Different letters in each column indicate statistical differences between doses on different days ($p<0.05$).

4- Conclusion

The present study evaluated the effect of different levels of L-carnitine on the meat quality of Sangseri male lambs, and the results show the positive effects of this supplement on the color characteristics and overall quality of the meat. The addition of L-carnitine, especially at the level of 300 mg per kg of diet, significantly increased the yellowness index. (b*) and reducing the redness index (a*) became

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meat These changes are probably related to increased oxidation of fats and changes in muscle protein composition. Also, this level of ration supplementation is the brightest (L*) showed that it can be related to the reduction of red pigments and the increase of yellow pigments. The results indicated a decrease in the amount of malondialdehyde and, as a result, a decrease in the oxidation of fats in the groups receiving L-carnitine, which improved the quality and increased the shelf life of the meat. However, increasing the dose from 150 to 300 mg may result in a slight increase in malondialdehyde in some cases. Although supplementation temporarily made the meat more tender, this effect decreased in the long term and no significant difference was observed with the control group. In addition, other factors such as storage time, temperature and humidity of the environment also had an effect on the loss caused by cooking. In general, L-carnitine can help to improve meat quality characteristics, especially in reducing fat oxidation and improving color characteristics.

5-Resources

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چکیده

ال-کارنیتین به عنوان یک مکمل غذایی در تغذیه دام‌ها برای بهبود کیفیت گوشت و کاهش اکسیداسیون چربی‌ها استفاده می‌شود. این تحقیق بر روی بره‌های نر سنگسری با هدف بررسی تأثیر خوراکی ال-کارنیتین بر ویژگی‌های رنگی، اکسیداسیون چربی، نرمی و افت ناشی از پخت گوشت انجام شد. بره‌ها به سه گروه کنترل، ۱۵۰ و ۳۰۰ میلی‌گرم ال-کارنیتین به ازای هر کیلوگرم جیره تقسیم شدند. نتایج نشان داد که افزودن ال-کارنیتین به جیره، به ویژه در سطح ۳۰۰ میلی‌گرم، تغییرات قابل توجهی در پارامترهای رنگی گوشت ایجاد کرده است؛ به‌طوری که شدت زردی افزایش و میزان قرمزی کاهش یافت. گروه دریافت‌کننده ۳۰۰ میلی‌گرم بالاترین سطح روشنایی را نشان دادند. اندازه‌گیری مالون‌دی‌آلدهید، به‌عنوان شاخص اکسیداسیون چربی، نشان داد که ال-کارنیتین به طور معنی‌داری اکسیداسیون چربی‌ها را کاهش داده و در نتیجه بهبود کیفیت و ماندگاری گوشت را به همراه داشت. همچنین، مکمل‌سازی با ال-کارنیتین باعث نرم‌تر شدن موقت گوشت شد، اما این اثر با گذشت زمان کاهش یافت. در مورد افت ناشی از پخت، هیچ تفاوت معنی‌داری بین گروه‌ها مشاهده نشد. به‌طور کلی، افزودن ال-کارنیتین به جیره دام می‌تواند کیفیت گوشت را بهبود بخشد، اما مطالعات بیشتری برای تأیید نتایج مورد نیاز است.

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