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CARCASS TRAITS, PHYSICOCHEMICAL CHARACTERISTICS AND SENSORY PROPERTIES OF *LONGISSIMUS LUMBORUM* MUSCLE OF LAMBS AS AFFECTED BY PRE-SLAUGHTER LAIRAGE AFTER ROAD TRANSPORT

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ABSTRACT

In this study, the effect of lairage on carcass traits, physicochemical parameters, and sensory properties of *Longissimus lumborum* muscle in lambs transported by road was investigated. Thirty (30) one-year-old Awasi Syrian lambs were randomly allotted into three slaughtering groups. The first group of lambs was not moved and served as a control (NT), while the animals in the other two groups were loaded into an open vehicle covered with straw and transported by road for two hours, followed by 0hours of lairage (T2L0) and 12hours for (T2L12). The collected data demonstrated that lambs that ware given a lairage period before slaughter lost significantly more live weight ($p \leq 0.05$) than those slaughtered immediately upon arrival at the slaughterhouse. The carcass shrinkage of T2L0 lambs was less ($p \leq 0.05$) than that of T2L12 and control lambs. On postmortem days 1 and 7, the muscles of T2L0 treated lambs had significantly ($p \leq 0.05$) less drip loss but more shear force than T2L12- and control-treated lambs. At day 7 postmortem, bacterial counts in the meat of T2L0 lambs were higher ($p \leq 0.05$) than those of NT and T2L12 lambs, most likely due to a numerical increase in ultimate pH at day 7. In conclusion, the lairage after transit had no effect on meat quality indicators compared to the control group. The meat from lambs in both groups (non-transported and transported with lairage) had a longer shelf life after postmortem aging than when slaughtered immediately upon arrival at the abattoir.

Keywords: Lamb, Lairage, Road transport, Shelf-life, Sensory properties

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INTRODUCTION

It is well known that the sheep are frequently transported for various reasons, including sales, breeding, and slaughter. During pre-slaughter transportation, animals may be exposed to various stressors, including physical exercise, human contact, confinement, food and water deprivation, novel habitat, and extreme temperatures (Miranda-De La Lama *et al*., 2018). Transportation is a significant pre-slaughter stressor that negatively affects carcass quality by increasing weight and shrinkage loss and, consequently, the meat-producing industry (Faucitano, 2018). According to Xin *et al.* (2018), as a stressor, pre-slaughter transportation may also affect the meat quality features of lambs due to an increase in final pH, which influences the water-holding capacity, softness, and meat color. The amount of glycogen present in the muscles prior to slaughter regulates the meat's pH, significantly influenced by the factors that produce physical and psychological stress. During pre-slaughter transit, animals exposed to stresses experience a decrease in ATP, depleting muscle glycogen levels and increasing plasma glucose synthesis (Xing *et al*., 2019). According to Gallo *et al*. (2018), a considerable glycogen depletion before slaughter significantly impacts meat pH and tenderness. Dark meat cuts with a pH of ≥ 6 at 12 to 24 hours postmortem are more susceptible to microbial contamination, have a shorter shelf life, and are less appealing to customers (Álvarez *et al*., 2022).

Xin *et al*. (2018) found that lambs are allowed 8-12h in lairage to recover from transportation stress, which is a standard commercial procedure where animals are provided access to water but not fed for hygienic reasons before slaughter at the slaughterhouse (Costa *et al*., 2019). Additionally, other findings affirmed that lairage might allow animals to replenish muscle glycogen levels, reducing dehydration and carcass weight loss (Nikbin *et al*., 2016; Liste *et al*., 2011); however, how pre-slaughter handling affects lamb eating quality and shelf life during postmortem aging in Kurdistan Region-Iraq remain without a piece of valid scientific information. According to our knowledge, this is the first study to document the effects of pre-slaughter handling and road transportation of lambs in Erbil, Kurdistan Region of Iraq.

We hypothesize that the hot, dry climate of Erbil Kurdistan Region-Iraq during summer may further increase transport stress and aggravate its effects on carcass and meat quality which necessitates the conduct of this trial. This study aims to determine the stress during road transportation and carcass characteristics and meat quality in lambs slaughtered at an Erbil slaughterhouse in Iraq's Kurdistan Region and recommend changes in handling routines that could reduce animal stress during transportation prior to slaughter.

MATERIALS AND METHODS

Animals and transportation trial: The experiment was conducted over two days (25th and 26th of July 2021) at an average temperature of 38.14 °C and relative humidity of 14.9%. One year old, thirty (n=30) Awasi Syrian lambs weighing an average of 63.894± 0.48 kg were used in the investigation. All lambs in Erbil originated from the same farm and were raised under uniform conditions. A day before travelling, the animals were divided into three groups, each having ten lambs. The first group was a control and did not travel (NT). The animals in the control group were slaughtered in at the farm of rearing, which includes slaughterhouse and about 2 h far from the abattoir. The other two groups were loaded onto an open truck covered with straw and transported by road for two hours at a density of 0.25 m^2 per animal (Xin *et al*., 2018), followed by lairage for either zero hours (T2L0) or twelve hours (T2L12). The path was level, and the speed was maintained at 60 km/h. With the aid of a diving board, the animals were carefully loaded and unloaded. During lairage, the animals had unlimited access to water but were denied food.

Determination of live weight loss: The percentage of live weight loss was determined by calculating the weight change (kg) after transportation. To achieve this, each lamb was weighed prior to transportation (before loading onto the truck) (W1) and immediately after transportation (W2). The percentage loss in live weight was calculated as:

Live weight loss (%) = [(W1- W2) ÷ W1] × 100

Where:
W1= initial lamb weight before transportation
W2= lamb weight after transportation.

Slaughtering and sample collection: According to Muslim or halal slaughter methods, the animals were humanely slaughtered at a commercial abattoir (Erbil's slaughterhouse for ruminants - Kurdistan Region, Iraq). The procedure involves severing the carotid arteries and jugular veins and cutting the neck. All lambs were slaughtered in a lateral position (animal upon its left side). After bleeding and evisceration, the carcasses were immediately brought to the laboratory for measurements and evaluation of the meat quality. Within 45 minutes of slaughter, dressed carcasses were weighed (hot carcass weight; HCW), chilled at 4°C, and reweighed one day later to determine cold carcass weight (CCW). The difference in carcass weight between hot and cold was utilised to quantify the chilling loss. The dressing out proportion was determined by dividing the HCW and CCW by the slaughter weight. Samples of meat were taken from the *Longissimus lumborum* (LL) muscle (located between the 6th and 12th vertebrae). The LL muscle was separate from fat and connective tissue and subjected to two independent postmortem periods, 24 hours (1D) and seven days (7D). After each ageing period, 2.5 cm thick muscle cuts was collected, labelled, vacuum packed, and frozen at -20°C for further meat quality analyses.

Meat quality assessment*:* One gram of *Longissimus lumborum* muscle was homogenised in 10 millilitres of ice-cold distilled water to determine the meat's pH. A portable pH meter was used to measure the pH. China (PHS-3C) Using a portable pH meter calibrated at pH 4.0 and 7.0, the indirect pH of the resulting homogenates was measured.

Meat colour values were determined using a Color Flex spectrophotometer (Shenzhen 3nh Technology Co., Ltd, China) following the International Commission on Illumination (CIE) Lab-values (also known as L^*, a^*, b^*, C^* and H^*) with D65 illuminant and 10º standard observer and reflectance at a specific wavelength (400-700 nm) to express the meat colour data. Before using the instrument, it was calibrated against a standard black and white plate. The frozen *Longissimus lumborum* muscle samples from days 1 and 7 were placed in a 4 °C chiller overnight. Thawed samples with a thickness of around 12 mm (Coombs *et al*., 2017) were bloomed for 30 minutes and put with the bloomed surface facing the base of the colour flex cup. Each sample had two measurements for L^* (lightness), a^* (redness), b^* (yellowness), c^* (chroma), and h^* (hue angle) values, which were then averaged.

Water holding capacity was calculated using drip loss and cooking loss. Approximately 20 g of fresh meat samples were collected from the *Longissimus lumborum* muscle, weighed separately, and recorded as the initial weight for drip loss computation (W1). The weighed samples were placed in vacuum-sealed, labelled polyethene plastic bags and refrigerated at 4°C for seven days. During each postmortem period, samples were instantly taken from polyethene bags, blotted gently to dry, and reweighed before being recorded as W2. The following calculation was used to get the drip loss percentage:

Drip loss (%) = [(W1 − W2) ÷ W1] × 100

Where:
W1= initial sample weight before ageing

W2= final weight of sample designated for each ageing time.

To evaluate the cooking loss, samples of *Longissimus lumborum* muscle were weighed (W1), placed in polyethene bags, and vacuum packed and transported into a water bath (HAAKE C10, UK). The samples were cooked in a pre-heated water bath set at 80 °C for 20 min. Once the internal temperature of the samples had reached 78 °C as monitored using a stabbing temperature probe, the cooking was continued for another 10 min. After removing the cooked samples from the water bath and subsequent cooling to room temperature, the samples were blotted gently dry and reweighed (W2). The percentage of cooking loss was estimated using the following formula:

Cooking loss (%) = [(W1- W2) ÷ W1] × 100

Where:
W1= initial sample weight before cooking
W2= sample weight after cooking.

Meat samples used to determine cooking loss were prepared for shear force measurements using a texture analyser (CT3TM, USA) with a Volodkevitch bite jaw. The device was calibrated with a 10 mm return distance for height and a 10 mm/s blade speed. Parallel to the direction of the muscle fibres, two 1 cm (height) × 1 cm (width) × 2 cm (length) blocks were cut from each sample. Each block was sheared on the texture analyser with the Volodkevitch biting jaw positioned in the centre and perpendicular to the fibres' longitudinal direction. The shear force measurements were the average positive peak force (in kilograms) of all sample blocks.

Tenfold serial dilutions of each *Longissimus lumborum* muscle sample in deionised water were made to determine the total aerobic count, ranging from 10^{-1} to 10^{-9}. 100 µl of each dilution was then deposited and disseminated in triplicate on selective agar plates (Neogen®, Lansing, Michigan, United States). After spreading, the plates were incubated for 72 hours at 32°C (Ahmad *et al*., 2019). The average number of microbial colonies from two replicated plates was calculated. After the incubation period, the total population was expressed as log10 colony-forming units (CFU) per gram of meat prior to statistical analysis.

Sensory analysis was performed with ten panelists using the approach described by Xin *et al*. (2018). The frozen *Longissimus lumborum* muscle samples were thawed overnight at 4°C before being sliced into 5 cm (length) × 5 cm (width) × 2 cm (height) steaks. The steaks were cooked for 20 minutes at 180°C to obtain an internal temperature of 70°C. The cooked steaks were cut into pieces of 1 cm × 1 cm × 1 cm in size, placed on white plastic trays covered with aluminum foil, and stored in an oven for about 10 min at 70 °C until tasting. According to the method described by Teixeira *et al*. (2020) scores for the tenderness, juiciness, flavor, and general acceptability of lamb were recorded on a five-point scale ranging from 5 = denoted strong appreciation to 1 = implied extreme dislike.

Data analysis: The generalised linear model technique of the SAS programme was used for the data analysis (Version 9.2, SAS Inc., Cary, NC). Except for the physicochemical quality of the meat, a one-way ANOVA was used, with pre-slaughter handling treatment as the fixed factor and individual animals as the experimental unit. The model for sensory assessment data included the assessor as a random variable, with sensory triplicate data being averaged. Using repeated measures, the physicochemical meat quality parameters were analysed. Multiple comparisons were made using Duncan's multiple range test, where significant effects were found. P-values less than 0.05 were regarded as statistically significant for all tests.

RESULTS AND DISCUSSION

Effect of pre-slaughter lairage on live weight loss: Due to economic concerns, it is desirable for minimal live weight loss during transport and lairage (Yalcintan *et al*., 2018). Figure 1 illustrates the difference in live weight loss results. The lambs that were transported for 2 hours and then lairage for 12 hours lost significantly ($p \leq 0.05$) more live weight (2.180 percent) than lambs that were transported for 2 hours and then lairage for 0 hours (1.674 percent). This difference may be due to gastrointestinal tract contents and urine output during the lairage phase (Najafi *et al*., 2020). Similar findings have been made in goats (Nikbin *et al*., 2016) and lambs (Miranda-de la Lama *et al*., 2011).

Effect of pre-slaughter lairage on carcass traits: Table 1 presents the carcass trait results. Except for carcass shrinkage, the pre-slaughter handling treatments did not significantly ($p > 0.05$) affect the carcass characteristics variables. Animals transported for two hours followed by zero hours of lairage (T2L0) experienced less ($p \leq 0.05$) carcass shrinkage than non-transported animals (NT) and animals transported for two hours followed by 12 hours of lairage (T2L12). This may be due to a change in the hormonal profile of animals subjected to transportation stress, which promotes excessive water loss by urination and respiration, resulting in increased tissue dryness (Nikbin *et al*., 2016; Minka *et al*., 2009). As a result, stressed animal carcasses had significantly less evaporation during the cooling time. Pre-slaughter handling conditions are vital for farm animals because they may be exposed to stressful situations that result in fear, dehydration, hunger, increased physical activity, fatigue, and physical damage, negatively impacting meat quality. According to some research, a lairage time may assist farm animals in recovering from the stress of pre-slaughter transit (Costa *et al*., 2019).

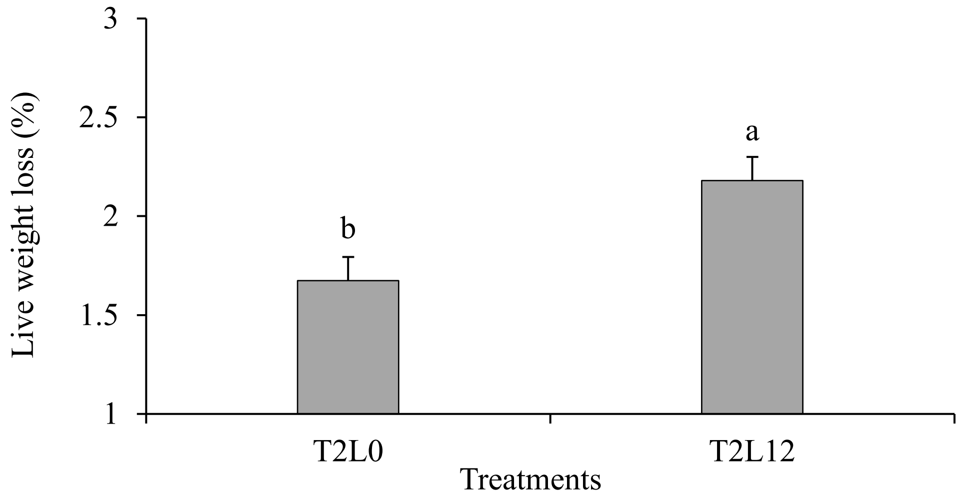

Figure 1 Live weight loss in lambs as effects of pre-slaughter lairage after road transport

T2L0 - lambs were transported by road for 2 h then lairage for 0 h.

T2L12 - lambs were transported by road for 2 h then lairage for 12 h.

[a, b]Means with different letters differ significantly at ($p \leq 0.05$).

Table 1 Carcass traits in lambs as effects of pre-slaughter lairage after road transport

Parameter	Treatments			P value
	NT	T2L0	T2L12	
Slaughter weight (Kg)	63.433 ± 0.80	62.830 ± 0.67	61.770 ± 0.88	0.9945
Hot carcass weight (kg)	33.900 ± 0.39	33.855 ± 0.41	33.079 ± 0.36	0.4698
Cold carcass weight (kg)	33.154 ± 0.38	33.175 ± 0.42	32.350 ± 0.36	0.4131
Carcass shrinkage (kg)	0.746 ± 0.11[a]	0.680 ± 0.15[b]	0.729 ± 0.13[a]	0.0040
Dressing out (%)[1]	52.613 ± 0.45	53.883 ± 0.34	53.552 ± 0.68	0.3428
Dressing out (%)[2]	51.455 ± 0.45	52.801 ±0.34	52.371 ± 0.65	0.6299

NT - lambs were not transported and used as a control.

T2L0 - lambs were transported by road for 2 h then lairage for 0 h.

T2L12 - lambs were transported by road for 2 h then lairage for 12 h.

[1]Dressing out (%) = [Hot carcass weight/ Slaughter weight]*100

[2]Dressing out (%) = [Cold carcass weight/ Slaughter weight]*100

[a, b]Means with different letters differ significantly at ($p \leq 0.05$).

Effect of pre-slaughter lairage on meat quality characteristics: The pH of the *Longissimus lumborum* (LL) muscle of lambs subjected to varying lairage durations after road transport is presented in Table 2. When discussing the current findings, it should be noted that, because of technical constraints, pH readings were not taken for 6h and 12h.

On day 1 postmortem, the animals transported for 2 hours and lairage for zero hours (T2L0) presented higher values of muscle pH than those not transported (NT) and transported animals for two hours and followed by 12-hour lairage (T2L12). However, the results were not statistically significant because they fell within the normal range (≤5.8) for meat quality. On day 7 postmortem, lambs subjected to NT (5.486) and T2L12 (5.432) had lower ($p \leq 0.05$) pH levels than those subjected to T2L0 (5.798). The pH in muscle is regulated by the amount and breakdown of the glycogen and lactate released before and after slaughter.

The high pH value in T2L0 could be associated with a higher level of physical activity (stress-related) in the animal's prior slaughter. The ultimate pH of skeletal muscle is one of the most significant meat quality indicators (Poleti *et al*., 2018). These results support the conclusions reached by Xin *et al*. (2018) in lambs. They discovered that meat animals transported for 3 hours and then lairage for 0 hours had higher pH values than those transported for 3 hours and lairage for 12 hours, as well as a control treatment of 0 hours of transit and 0 hours of lairage. After postmortem storage, the pH values of animals exposed to pre-slaughter animal treatments decreased significantly ($p \leq 0.05$). This fall in pH may be due to the conversion of muscle glycogen to lactic acid after death (Scheffler *et al*., 2013).

When an animal is exsanguinated and suffers hypoxia, as a result, the muscle fibres ultimately succumb to anaerobic glycolysis, which serves as the only energy source for postmortem muscles. Consequently, glycogen reserves are exhausted as they are converted to lactic acid, lowering the pH.

Water holding capacity (WHC) is the ability of meat to maintain endogenous water, which is a crucial characteristic that influences meat yield and quality (Apata, 2014). Table 2 displays the impact of lairage on water holding capacity, drip and cooking losses following road transport. Transport treatments had no influence ($p>0.05$) on drip loss on 1 and 7 days postmortem for animals subjected to lairage. The drip loss was less in the T2L0 treatment than in the T2L12 treatment and the non-transport group (NT) control treatment ($p\leq0.05$).

This is most likely due to a significant water loss during transportation stress (Kadim *et al*., 2006). The amount of residual muscle water that could be passively released from samples was lower in animals with low-stress levels. According to previous studies, meat from animals transported prior to slaughter without lairage showed lower drip loss values than meat from non-transported or transported animals with 12 hours of lairage (Xin *et al*., 2018; Liste *et al*., 2011). Regardless of treatment, drip loss increased ($p\leq0.05$) as postmortem ageing progressed. This may be attributable to collagen and myofibrillar protein instability associated with ageing, which causes myofibrillar proteins to lose their capacity to hold water (Rant *et al*., 2019).

The lairage after transport treatments did not affect ($p>0.05$) cooking loss throughout the postmortem storage (Table 1). This could be due to similarity in ultimate pH pre-slaughter transportation treatments. Daszkiewicz *et al*. (2018) reported that water holding capacity is influenced by the ultimate pH of muscle. This observation concurs with those of Xin *et al*. (2018), in lambs and Nikbin *et al*. (2016), in goats, who found that pre-slaughter transportation treatments did not influence the cooking loss values. Irrespective of the treatment, cooking loss decreased with increasing postmortem ageing. The increase in meat water holding capacity with age in terms of cooking loss may be due to structural muscle breakdown caused by disruption of the channels via which water is lost, resulting in the formation of a "sponge effect" that holds the water and inhibits its loss (Sabow *et al*., 2015). Shear force is inversely related to tenderness, one of the meat's most important eating qualities (Sacca *et al*., 2019).

Table 2 presents the obtained values for shear force. The treatment had a significant influence on the shear force value. On days 1 and 7, meat samples from the control (NT) and those transported with 12 h lairage (T2L12) were more tender than those from the T2L0 group. This result agrees with that of (Xin *et al*. 2018). Meat from the not-transported or pre-slaughter transported with lairage groups exhibited lower shear force values than pre-slaughter transported without lairage.

On the other hand, Liste *et al*. (2011) discovered no significant difference in shear force values between pre-slaughter lambs transported without lairage and lambs lairage for 12 hours. Shear force values decreased ($p\leq0.05$) with age. The decrease in shear force may be attributable to rigour development, caused by the enzymatic breakdown of collagen that keeps muscle fibres together as individuals age (Sazili *et al*., 2013). According to Bhat *et al*. (2018), changes in meat tenderness are mediated directly by the activation of calpains, which are primarily responsible for the postmortem proteolysis of muscle myofibrillar proteins. Consequently, it is responsible for the increasing tenderness of meat with postmortem storage.

Colour is an essential organoleptic attribute that impacts meat acceptance and plays a significant role in purchasing decisions, as customers use it as an indicator of quality and freshness (Font-i-Furnols and Guerrero, 2014). In the present study, colour values were determined as L^* (lightness), a^* (redness), b^* (yellow), c^* (chroma), and h^* (Hue). Table 2 shows the effect of pre-slaughter transportation treatment on the colour coordinates of lamb LL muscle. Although the values of colour coordinates were not significantly different among pre-slaughter treatments, the L^* and b^* values were higher. The a^* (redness) value was lower in meat from lambs that were not transported (NT) and those transported with lairage (T2L12) compared to lambs that were not transported (NT) (T2L0). The hue-angle values of the NT and T2L12 lambs were considerably less than those of the T2L0 lambs, although the chroma values did not significantly differ among the NT, T2L0, and T2L12 lambs.

These results correspond to the ultimate pH value. The concentration of muscle pigment, the chemical structure of the pigments, and the pH of the meat are influenced meat colour. According to De la Fuente *et al*. (2010), redness and pH levels negatively correlate. As a result of the production of adrenaline and noradrenaline hormones, it has been hypothesised that stress might lead to black meat. In addition, transportation stress induces skeletal muscle glycogen depletion and the production of black meat in animals (Gonzalez-Rivas *et al*., 2020). There is evidence that stress causes the darkening of flesh (Miranda-de la Lama *et al*., 2011; Nikbin *et al*., 2016).

Other studies, however, have shown no correlation between pre-slaughter handling and meat colour (Saribey and Karaca, 2018; Xin *et al*., 2018). Regardless of the pre-slaughter handling method, postmortem brightness and hue values increased (p0.05). However, redness levels declined ($p\leq0.05$). According to Gao *et al*. (2016), Myoglobin oxidation with ageing causes a considerable decrease in colour characteristics, particularly a* values. Myoglobin is the most important heme protein responsible for the red colour of meat (Calnan *et al*., 2016).

Table 2 Meat quality characteristics of LL muscle in lambs as effects of pre-slaughter lairage after road transport.

Parameter	Storage (day)	Treatment			P value
		NT	T2L0	T2L12	
pH	**1**	5.662 ± 0.02^{x}	5.730 ± 0.02^{y}	5.652 ± 0.02^{x}	0.1007
	7	5.486 ± 0.03^{by}	5.798 ± 0.02^{ax}	5.432 ± 0.03^{by}	≤.0001
Drip loss (%)	**1**	2.366 ± 0.12^{ay}	2.081 ± 0.15^{by}	2.391 ± 0.13^{ay}	0.0267
	7	3.635 ± 0.33^{ax}	3.177 ± 0.35^{bx}	3.704 ± 0.26^{bx}	0.0198
Cooking loss (%)	**1**	19.785±0.86^{y}	21.153±0.53^{y}	19.137± 0.33^{y}	0.0801
	7	24.337±1.40^{x}	23.473±0.83^{x}	23.696±1.37^{x}	0.8765
Shear force (kg)	**1**	1.676±0.01^{bx}	1.730±0.02^{ax}	1.663± 0.00^{bx}	0.0312
	7	1.541±0.01^{by}	1.582±0.00^{ay}	1.526±0.01^{by}	0.0052
Lightness (L*)	**1**	34.470±0.90^{y}	35.123± 1.54^{y}	34.411±1.14^{y}	0.3171
	7	37.558±1.39^{x}	39.768± 0.66^{x}	38.021±1.33^{x}	0.8252
Redness (a*)	**1**	22.628±0.75^{x}	23.148± 0.70^{x}	22.515±0.72^{x}	0.5095
	7	20.321±0.70^{y}	20.209± 0.85^{y}	20.650±0.63^{y}	0.3161
Yellowness (b*)	**1**	12.650±0.43	11.807±0.31	12.417±0.32	0.5720
	7	11.422±0.30	11.004±0.23	11.505±0.33	0.0667
Chroma (c*)	**1**	24.433 ± 0.74	25.253 ± 0.67	24.134 ± 0.65	0.5489
	7	24.831 ± 0.68	25.324 ± 0.73	24.911 ± 0.51	0.1358
Hue (h*)	**1**	27.788 ± 1.06^{by}	29.780 ± 0.91^{ay}	27.455 ± 0.94^{by}	0.0102
	7	28.002 ± 0.92^{bx}	31.406 ± 0.80^{ax}	28.928 ± 1.23^{bx}	0.0491

NT - lambs were not transported and used as a control.
T2L0 - lambs were transported by road for 2 h then lairage for 0 h.
T2L12 - lambs were transported by road for 2 h then lairage for 12 h.
^{a,b} means within the same row with different superscripts are significantly different (p≤0.05).
^{x,y} means within the same column with different superscripts are significantly different (p≤0.05).

Microbial contamination degrades fresh meat quality, shortens its shelf life, and poses economic and health problems (Liang *et al*., 2021). The microbiological quality of meat is affected by the physiological state of the animal at slaughter as well as the spread of contamination during slaughter and processing (Rani *et al*., 2017). Figure 2 displays the microbiological levels of transportation-stressed meat lambs. On day 1, microbial counts did not differ significantly among pre-slaughter animal treatments. At 7 days postmortem, however, meat samples from the T2L0 group (p≤0.05) showed a greater increase in total aerobic counts than those from the NT and T2L12 groups. In general, meat samples from all pre-slaughter treatment groups exhibited increasing bacterial growth with storage time; the highest number of studied bacteria found in meat samples from pre-slaughter transported animals without lairage. Increased bacterial growth in the T2L0 group may be attributable to the final pH value, which may produce favourable conditions for microbial development and hence a shorter shelf life. In contrast, the levels of pathogens in meat samples from the three pre-slaughter treatment groups were within acceptable limits. According to Karabagias *et al*. (2011), beef spoils when the total aerobic counts surpass 7 to 8 log10 CFU/g.

Meat palatability characteristics are usually recognized as crucial elements for customer acceptance, and they are influenced by a range of factors, such as pre-slaughter management. Typically, panelists' tenderness, juiciness, and flavour are crucial concerns (López-Pedrouso *et al*., 2020). The sensory quality values of meat samples from the control group or pre-slaughter transportation with 12h lairage were marginally higher than those of meat samples from pre-slaughter transportation without lairage. However, the disparity was not statistically significant (p>0.05) (Figure 3). Due to the homogeneity in ultimate pH, the lairage time did not affect the sensory properties of meat, as determined by this investigation (Díaz *et al*., 2014). One possible explanation for this result is that the level of stress required to degrade the sensory quality of beef during transit appears to be higher than the level used in this study. These results align with those of Miranda-de la Lama *et al*. (2018). There were no differences in sensory quality between lambs moved with or without lairage prior to slaughter.

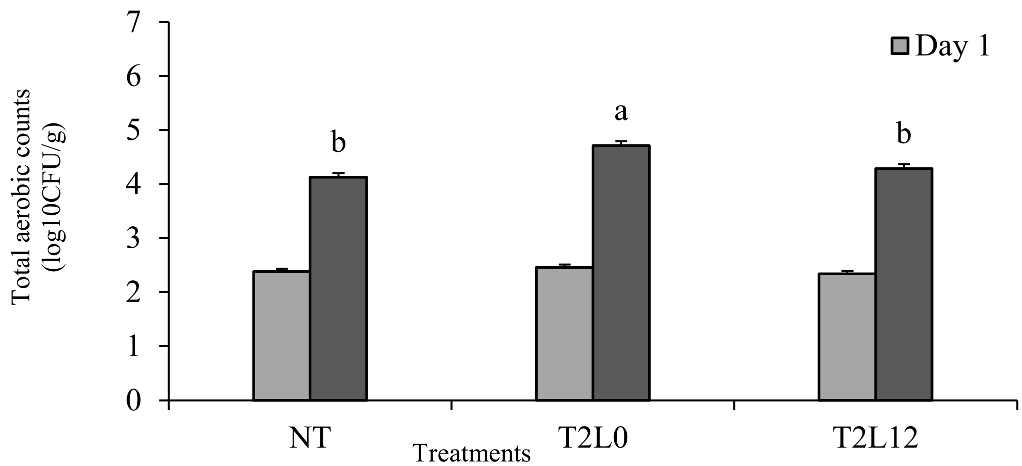

Figure 2 Microbiological quality of LL muscle in lambs as effects of pre-slaughter lairage after road transport

NT - lambs were not transported and used as a control.

T2L0 - lambs were transported by road for 2 h then lairage for 0 h.

T2L12 - lambs were transported by road for 2 h then lairage for 12 h.

[a,b]Values with different superscripts differ significantly at $p \leq 0.05$.

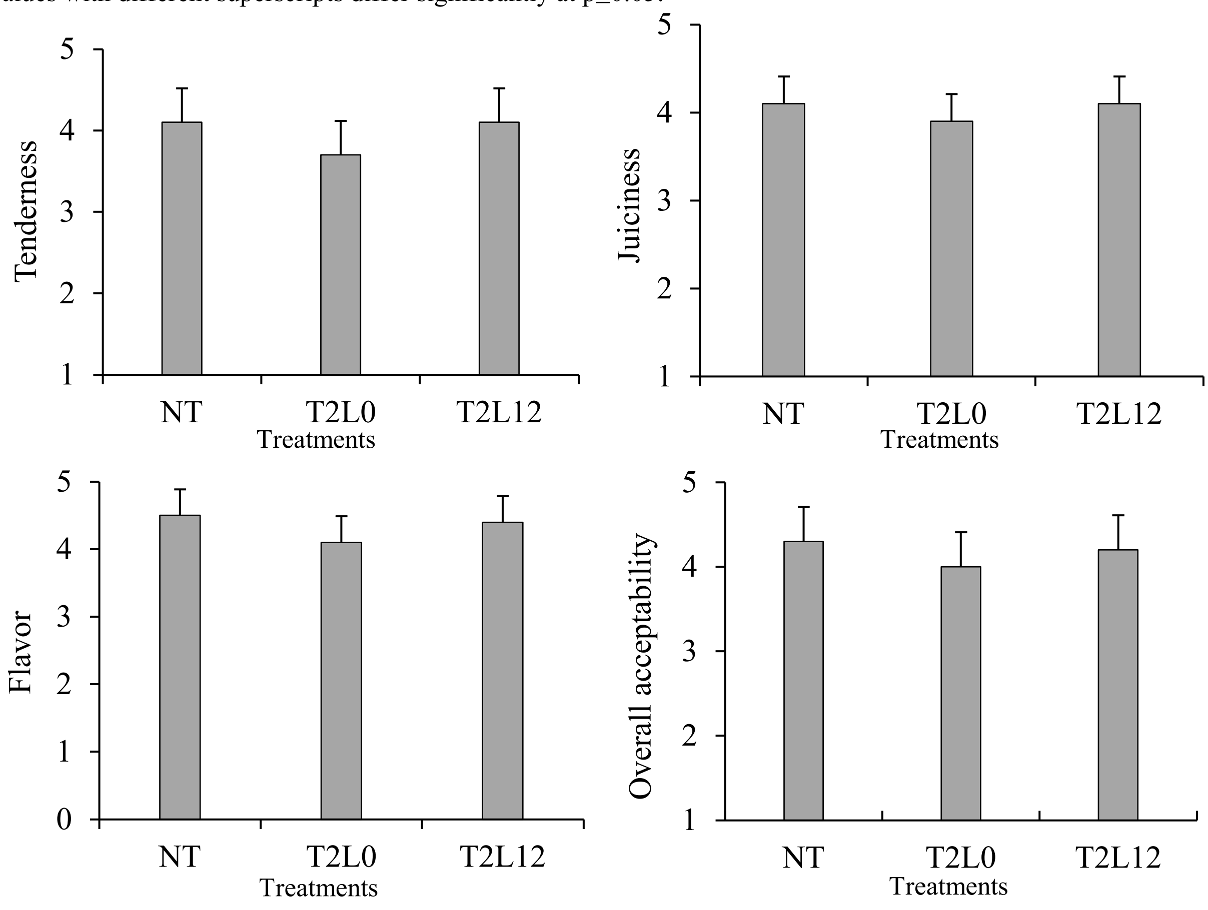

Figure 3 Sensory meat quality parameters of LL muscle in lambs as effects of pre-slaughter lairage after road transport

NT - lambs were not transported and used as a control.

T2L0 - lambs were transported by road for 2 h then lairage for 0 h.

T2L12 - lambs were transported by road for 2 h then lairage for 12 h.

Scoring system based on a five-point scale ranging from 5 = meant strong appreciation to 1 = an extreme dislike following method described by Sañudo *et al*. (1998).

Conclusions: In conclusion, except for carcass shrinkage, this study revealed that the carcass characteristics of non-transported lambs were similar to those of lambs transported before slaughter without or with overnight lairage. Although most physicochemical characteristics and sensory acceptability of meat are comparable across three pre-slaughter treatments, bacteria counts in meat from lambs slaughtered with lairage or control groups on day 7 postmortem were significantly lower than those from lambs slaughtered without lairage. Consequently, it should be considered to implement a proper rest interval after transport.

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