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Effects of Pre-Slaughter Lairage Period on Carcass and Meat Quality Characteristics in Lambs Subjected to Road Transportation

REKAN Salaye, Azad SABW*

College of Agriculture Engineering Sciences, Salahaddin University, Erbil, 44001 Zanko Street, Kurdistan Region, Iraq
* Corresponding authore-mail: azad1979sabow@yahoo.com; azad.sabow@su.edu.krd

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Abstract

The aim of the present study was to evaluate the carcass and meat quality of *Longissimus lumborum muscle* in lambs subjected to different pre-slaughter lairage times. A total of 20 lambs of 1 year belonging to Awasi Syrian sheep breed were subjected to two pre-slaughter groups. In the first group, the lambs were transported by road for 2h in an open truck covered with straw and used without lairage while the animals in other group were loaded and transported by road for 2 h and then with lairage for 12 h. Data obtained showed that the lambs with a lairage period before slaughter had significantly higher live weight loss than those slaughtered on arrival at the abattoir. At day 1 postmortem, the transported animals without lairage presented similar values of muscle pH than those from lambs with lairage. However, lambs from lairage group had lower pH values ($p<0.05$) compared to those without lairage at day 7. In both groups, the water-holding capacity and sensory meat quality was not affected. The meat samples from slaughtered lambs from the group without lairage had significantly higher bacteria counts compared to those from lairage group at day 7 postmortem. Thus, the results obtained in the current study suggest that animals will be less stressed at the time of slaughter with an overnight lairage compared with slaughter on arrival at the abattoir.

Keywords: eating quality, lamb, pre-slaughter lairage, shelf-life.

1. Introduction

It is well known that sheep are frequently transported for a variety of reasons including the sale, breeding and slaughter. During pre-slaughter transportation, animals can be exposed to several potential stressors including human contact, physical exercise, confinement, unfamiliar environments, food and water deprivation, changes in social structure and extreme climatic conditions [12]. In addition to breeding, rearing, and fattening of domestic animals, meat production systems include transport, lairage and slaughter at the abattoir [12]. Therefore, transportation is considered an important pre-slaughter stressor that adversely affects carcass quality through increasing weight and shrinking loss and thus profitability of the meat production enterprise [6].

Pre-slaughter transportation as a stressor could also influence meat quality characteristics in lambs, particularly due to an increase in ultimate pH which is affected water holding capacity of meat.

Meat pH is a result of the amount of glycogen present in the muscles before slaughter, which depends greatly on the factors responsible for physical and psychological stress [21]. Exposure to stressors pre-slaughter transport results in ATP reduction, leading to depletion of muscle glycogen concentrations which inversely increase plasma glucose production [22].

Significant depletion of muscle glycogen reserves pre-slaughter has a profound effect on meat pH, and tenderness [7]. A value of pH ≥ 6 at 12 to 24 h postmortem results in dark meat cuts, make them more susceptible to microbial contamination and have a shorter shelf life and become less acceptable to the consumer [1].

A study has been showing that lairage allowed lambs to recover from the transportation stress [21] which is a common commercial practice that can be defined as a period, where animals are given access to water but not feeds, for hygienic reasons, before slaughter at the slaughterhouse [3].

Other studies confirmed that lairage potentially allows animals to replenish muscle glycogen concentrations, reducing dehydration and carcass weight loss [10, 14], however, how pre-slaughter handling regulates lamb eating quality and shelf life during postmortem aging are not well understood.

Additionally, the hot dry climate, such as Kurdistan Region-Iraq during summer, may further increase transport stress and aggravate its effects on carcass and meat quality.

Because there is limited information available on the impact of pre-slaughter transportation on carcass and meat quality produced in this productive region, the aim of this study is to determine the stress during road transportation and carcass characteristics and meat quality in lambs slaughtered at an Erbil slaughterhouse in Kurdistan Region of Iraq, to recommend appropriate changes in handling routines that could minimize the stress of the animals during the pre-slaughter transportation in order to improve quality of carcass and meat.

2. Material and Method

Study Description. The experiment was conducted on two consecutive days (25 and 26 July 2021) with an average ambient temperature of 38.14 °C and relative humidity of 14.9%. The total number of twenty lambs of one-year-old Syrian Awassi breed with an average live weight of 63.894 kg ± 0.48 kg was used.

All lambs were from one farm in Erbil city and maintained under similar routine management conditions.

Animals were randomly divided into two groups before the slaughter of 10 animals by group, 1 day before transfer (without lairage and with overnight lairage). The two groups were loaded into an open truck covered with straw and transported by road for 2 h at a density of 0.25 m^2 per animal [24].

The road surface was flat, and the speed was constant at 60 km/h.

Animals were gently loaded and unloaded using a dashboard. Animals were given access to water and to satiety but not food during aspiration.

Determination of Live Weight Loss. The percentage of live weight loss was determined by calculating the percentage change in weight (kg) after transportation.

To achieve this, each lamb was weighed prior to transportation (before loading onto the truck) (BW1) and immediately before slaughter (BW2). The percentage loss in live weight was calculated using the formula [14]:

Live weight loss (%)
$$[(BW1 - BW2) \div BW1] \times 100.$$

Where:

BW1 = live weight before loading onto the truck
BW2 = weight immediately before slaughter.

Carcass and Meat Quality Variables. The animals were humanely slaughtered in a commercial abattoir (Erbil's slaughterhouse for ruminants - Kurdistan Region, Iraq) according to the Muslim or halal slaughter procedure.

After evisceration, the hot carcass was weighed (HCW) within 15 min of slaughter and then the weighted carcasses were stored in the chiller and were weighed again after one day, to record cold carcass weight (CCW).

The HCW was used to estimate the dressing out (%) using the formula [14]:

Dressing out (%)
$$HCW/BW2 \times 100$$

Where:

HCW = hot carcass was weighed
BW2 = weight immediately before slaughter.

The difference between hot and cold carcass weights (HCW - CCW) was used to calculate carcass shrinkage. Meat samples were taken from the *Longissimus lumborum* muscle (LL) between the 6th and 12th vertebrae, after the completion of each aging time (day 1 and 7 postmortem), labeled, vacuum packaged and stored at -20 °C for subsequent meat quality analyses.

Muscle pH. Approximately 1 g of muscle samples was homogenized in 10 mL of ice-cold distilled water and the pH was measured using portable pH-meter model (PHS-3C, China). The indirect pH of the resultant homogenates was read using a pre calibrated portable pH meter at pH 4.0 and 7.0.

Water holding capacity. Water holding capacity was measured following the procedure of Yuet al. [23]. About 1 g of breast meat samples were wrapped in absorbent cotton and placed in a centrifugal tube and then the tubes with samples were centrifuged (Hettich™ ROTINA 380R, Germany) at 3000 g for 10 min at 4 °C. The percentage of water holding capacity was calculated and expressed as the ratio of the sample weight after centrifugation to the initial sample weight.

Microbiological analysis. For enumerations of total aerobic count, ten-fold serial dilutions of each muscle sample were prepared in deionized water from 10^{-1} to 10^{-9}. Then, 100 µL of the different dilutions were separately dropped and spread in duplicate on selective agar plates (Neogen®, Lansing, Michigan, United States).

After the spreading, the plates were incubated at 32 °C for 72 h [18]. The microbial colonies were counted in two replicated plates and the average was taken. Following the incubation period, total population was expressed as log10 colony-forming units (CFU) per gram of meat prior to statistical analysis.

Meat sensory evaluation. Sensory analysis was carried out according to the method reported by Xin et al. [21] using ten panelists. The meat samples were thawed overnight at 4 °C and cut into 5 cm (length) × 5 cm (width) × 2 cm (height) steaks.

The steaks were roasted in an oven setting at 180 °C and for 20 minutes to reach the 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. Scores for lamb tenderness, juiciness, flavor, and overall acceptability were recorded based on a five-point scale ranging from 5 = meant strong appreciation to 1 = an extreme dislike according to the method reported by Teixeira et al. [20].

Data Analysis. The statistical analysis was carried out using the generalized linear model procedure of SAS software (Version 9.2, SAS Inc., Cary, NC). Where significant effects were found, multiple comparisons were made using the Duncan's multiple rang test. P-values less than 0.05 were regarded as statistically significant for all tests.

3. Results and Discussions

Effects of Lairage after Road Transportation on Weight Loss. Low live weight loss during the transport and lairage period is preferred considering the economic concerns [24]. The results of the change in live weight loss are presented in Figure 1.

The lambs were transported for 2 hours and then slaughtered after lairage for 12 hours showed significantly higher live weight loss (2.180%) than those transported for 2 hours and then slaughtered without lairage (1.674%).

The reasons for this difference may be due to the excretion of gastrointestinal tract contents and urine during the lairage period [13]. Similar observations were obtained else where in lambs [12] and goats [14].

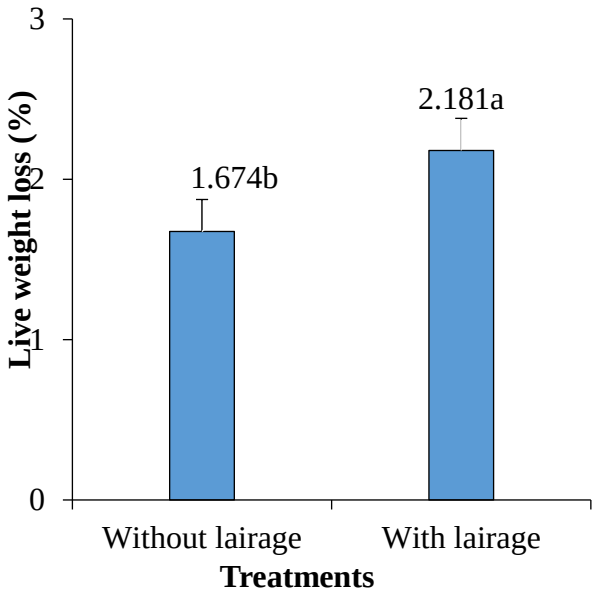

Figure 1. Live weight loss in lambs subjected to different pre-slaughter lairage times
[a,b] Means with different letters differ significantly at ($p<0.05$).

Effect of Pre-Slaughter Lairage on Carcass Traits. The results of carcass traits are shown in Table 1. The carcass traits variables were not significantly ($p>0.05$) influenced by different pre-slaughter handling treatments except carcass shrinkage.Transported animals for 2 hours and lairage for zero hour had significantly ($p<0.05$) lower carcass shrinkage than transported animals for two hours, followed by 12-hour lairage.

The reason for this could be due to a change in hormonal profile of animals under transportation stress which causes high amounts of water loss via urination and breathing and consequently higher tissue dehydration [14].

Therefore, carcasses from animals under stress show significantly lower evaporation during cooling period.

Pre-slaughter handling conditions are very essential factors for farm animals because the animals may be exposed to stressful situations in which fear, dehydration, hunger, increased physical activity, fatigue, and physical injury may occur and may negatively affect meat quality characteristics; therefore, it should not be overlooked.

Some studies have shown that a period of lairage may allow farm animals to recover from the stress of pre-slaughter transportation [4].

Table 1. Carcass traits in lambs subjected to different pre-slaughter lairage times

Parameter	Treatments	
	Without lairage	With lairage
Live body weight (kg)	62.830 ± 0.67[a]	61.770 ± 0.88[a]
Hot carcass weight (kg)	33.855 ± 0.41[a]	33.079 ± 0.36[a]
Cold carcass weight (kg)	33.175 ± 0.42[a]	32.350 ± 0.36[a]
Carcass shrinkage (kg)	0.680 ± 0.15[b]	0.729 ± 0.13[a]
Dressing out (%)	53.883 ± 0.34[a]	53.552 ± 0.68[a]

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

Effects of Lairage after Road Transportation on Meat Quality and bacterial count. Pre-slaughter handling conditions are very essential factors for farm animals because the animals may be exposed to stressful situations in which fear, dehydration, hunger, increased physical activity, fatigue, and physical injury may occur and may negatively affect meat quality characteristics; therefore it should not be overlooked. Some studies have shown that a period of lairage may allow farm animals to recover from the stress of pre-slaughter transportation [4].

Results for pH and water holding capacity values of lambs subjected to different lairage periods after road transportation are shown in Table 2. On day postmortem, the transported animals without lairage presented higher values of muscle pH than those from with lairage although the differences between these values were not significant. However, lambs subjected to lairage had lower ($p<0.05$) mean pH values (pH = 5.432) compared to those subjected without lairage (pH = 5.798) at day 7 postmortem.

The muscle pH relates to the amount and rate of glycogen breakdown and liberation of lactate pre- and post-slaughter, which is affected by the events that take place prior to slaughter. The high value of pH in lambs without lairage could be associated with a higher level of physical activity (stress-related) in the animals prior slaughter. The ultimate pH of skeletal muscle is one of the most important criteria for meat quality [15].

These observations were compared with the findings of Xin et al. [21] in lambs who found higher pH values in meat obtained from animals transported for 3 h and slaughter without lairage than those transported for 3 h and then slaughtered following lairage. Throughout the postmortem storage, the pH values decreased significantly ($p<0.05$) in animals subjected to pre-slaughter animal treatments. This reduction in pH may be due to the conversion of muscle glycogen to lactic acid postmortem [19].

Water holding capacity (WHC) is the ability of meat to retain inherent water which is an important factor as it affects the yield and the quality of the meat [2]. In general, instrumental meat quality was not affected by the treatment.

The effects of lairage after road transportation on water holding capacity are shown in Table 2.

The water holding capacity was significantly higher for meat obtained from lamb slaughtered following lairage than those slaughtered without lairage. Our results agree with those reported by Listeet al. [10] who found lower water holding capacity in lambs slaughtered immediately after transport without lairage than those slaughtered after 12 h of lairage.

Regardless of the treatment, water holding capacity decreased ($p<0.05$) as postmortem aging progressed.

This could be due to the disruption of collagen and myofibrillar proteins during the process of aging which makes the myofibrillar proteins lose their ability to hold water [17].

Microbial contamination can reduce the quality of fresh meat, shorten its shelf life and result in economic loss and probably health hazards [9].

The microbiological quality of meat is influenced by the animal's physiological status at slaughter and the spread of contamination during slaughter and processing [16]. Table 2 shows microbial levels of meat lambs subjected to stress by road transportation.

After on one day after slaughter, microbial counts were not significantly different for the pre-slaughter animal treatments.

However, at 7 days postmortem, greater growth of total aerobic counts was indicated by meat samples obtained from the group of animals slaughtered without lairage ($p<0.05$) than in the group of lambs slaughtered with lairage.

Generally, for both groups, meat samples exhibited increased bacterial growth with storage time and meat samples from the pre-slaughter transported animals without lairage had the highest counts of studied bacteria.

The higher bacterial growth exhibited by the without lairage group could be attributable to the final value of pH which may provide favorable conditions for microbial growth and then shorter shelf life.

However, the level of microorganisms in meat samples of the three pre-slaughter treatment groups was within acceptable limits. Karabagiaset al. [8] reported that spoilage occurs when the levels of total aerobic counts reach 7 - 8 log10 CFU/g meat.

Table 2. Meat quality characteristics in lambs subjected to different pre-slaughter lairage times

Parameter	Storage (day)	Treatments	
		Without lairage	With lairage
pH	1	5.730 ± 0.02^{ay}	5.652 ± 0.02^{ax}
	7	5.798 ± 0.02^{ax}	5.432 ± 0.03^{by}
Water holding capacity (%)	1	17.949 ± 1.02^{by}	18.103 ± 2.38^{ay}
	7	19.153 ± 0.53^{bx}	21.137 ± 0.33^{ax}
Total bacteria count (log10 cfu/g)	1	2.457 ± 0.07^{ay}	2.341 ± 0.05^{ax}
	7	4.710 ± 0.13^{ax}	3.341 ± 0.05^{by}

^{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 ($p<0.05$).

Meat Sensory Evaluation. Meat palatability characteristics are usually considered key factors for consumer acceptability which are influenced by several factors including pre-slaughter handling. Normally, the most important parameters for panelists are tenderness, juiciness, and flavor [11]. The values of sensory quality were slightly higher in the group of lambs slaughtered flowing pre-slaughter lairage than those slaughtered without lairage meat samples, but the difference was not statistically significant ($p>0.05$) (Fig. 2).

In the present study, lairage time had no effect on the sensory appreciation of the meat, which could be related to the similarity in ultimate pH [5].

These findings are in agreement with the findings of Listeet al. [10] and Miranda-de la Lama et al. [12] who stated that no significant differences in sensory quality between pre-slaughter transported with or without lairage lambs.

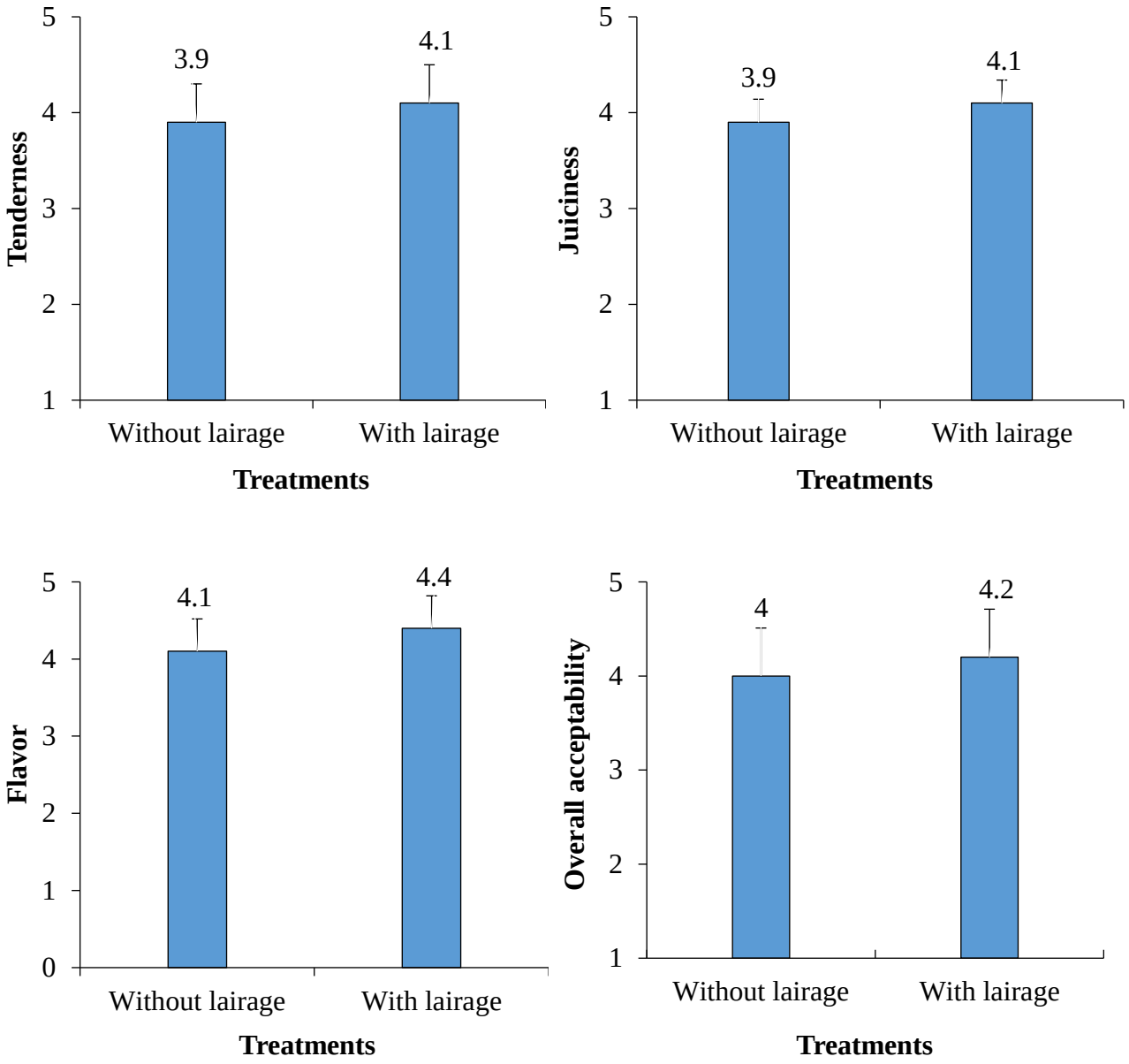

Figure 2. The sensory meat quality parameters in lambs subjected to different pre-slaughter lairage treatments

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).

4. Conclusion

The current results of this study indicated that the absence of lairage had a significant effect on water holding capacity. Although sensory acceptability of meat is comparable for two pre-slaughter treatments, bacteria counts of meat from lambs slaughtered with overnight lairage were significantly lower than those slaughtered upon arrival to the abattoir at day 7 postmortem.

Therefore, using an appropriate resting time following transportation should be considered.

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