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Effect of space allowance during transport and fasting or non-fasting during lairage on carcass contamination and meat traits in Merino lamb

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Abstract

A total of 72 Merino breed male lambs were used in this work, to study the effect of the space allowance during transport [(SA): low (SAL: 0.16 m²/animal; n=24); medium (SAM: 20 m²/animal; n=24); high (SAH: 0.30 m²/animal; n=24)], and the management during 18 h lairage [(TL): fasting (TL-FAST; n=36) vs feeding (TL-FEED; n=36)] on carcass microbial contamination (total viable count, Enterobacteriaceae and *Pseudomonas*) and meat quality. Carcasses contamination determination was carried out by swabbing (neck, flank and rump). Meat quality was assessed by pH, colour coordinates, drip loss (DL), shear force (SF) and lipid oxidation. SA did not have effect on carcass microbiological quality. TL caused a significant effect on total viable count and *Pseudomonas* spp values. Flank was the most contaminated site. SAL-FEED group showed the highest values of drip loss and lipid oxidation. At 24 h post-mortem, pH values were the highest in fasted lambs. At 7 d post-mortem the lowest pH was found in SAM-FAST group while the highest in SAM-FEED. TL had no effect on SF, DL neither on lipid oxidation values. These results could help to meat industry to decide the best management as in the transportation as during lairage before lambs slaughter.

Additional key words: sheep; transportation; pre-slaughter conditions; carcass-contamination; meat quality

Abbreviations used: DL (drip loss); FAST (fasting); FEED (feeding); GLM (General Lineal Model); MDA (malondialdehyde); SA (space allowance treatment during transport); SAH (space allowance high); SAL (space allowance low); SAM (space allowance medium); SAH-FAST (fasting space allowance high); SAL-FAST (fasting space allowance low); SAM-FAST (fasting space allowance medium); SAH-FEED (feeding space allowance high); SAL-FEED (feeding space allowance low); SAM-FEED (feeding space allowance medium); SF (shear force); SW (south-west); TL (lairage treatment); TBARS (thiobarbituric acid reactive substances) TVC (total vial count); LD: (*Longissimus dorsi*); VRBG (violet red bile glucose agar);

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Topic: Animal health and welfare

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Introduction

Merino sheep is very popular in many countries around the world. In Spain, is one of the main breeds (raised mainly in the South West), producing a lamb highly valued by consumers (Tejeda *et al.*, 2008). Under normal production system conditions, lambs are reared on farms far from slaughter plants. For this reason, transportation conditions to the abattoir, such as the used space allowed, are critical point (Miranda-de Lama *et al.*, 2010). Afterwards animals are usually kept in lairage previous to slaughter.

Pre-slaughter handling implies an important additional stress (Duncan, 2004). Some authors have also pointed out that pre-slaughter handling conditions contribute to carcass and meat quality (Ferguson & Warner, 2008). The effect of space allowance during transport on carcass and/or meat quality has been studied on suckling lambs of several sheep breeds [De la Fuente *et al.* (2010, 2012) on Assaf breed; Sánchez-Sánchez *et al.* (2013) in Lacaune breed].

Lairage at the slaughterhouse is important issue for the meat processing industry and helps animals to at least partially recover from transport stress before

slaughter (Kannan *et al.*, 2000). In lambs, there are some references relating lairage with meat quality such as Liste *et al.* (2011), Ekiz *et al.* (2012), Díaz *et al.* (2014) in Rasa Aragonesa, Kivircik and Lacaune breed, respectively. The law states that water must be 'available' to all animals at all times and feed if necessary when animals are lairaged for more than 12 h. Pre-slaughter feed deprivation helps reducing carcass contamination (Gregory & Grandin, 1998). However, prolonged feed deprivation may increase stress responses, metabolic changes and body weight loss (Kannan *et al.*, 2002). Sheep lose 5-8% of their live weight during a 24 h journey without access to food (Knowless, 1998). Feeding during lairage could allow recovery (Cozar *et al.*, 2016) and according to Grandin (2007) have a positive effect on carcass and meat quality. In our previous paper (Cózar *et al.*, 2016) we showed the effect of space allowance during transport, the management (fasting or feeding) during lairage, and their interactions on welfare indicators of Merina breed lambs.

The effect combined of stressful factors previous to slaughter could reduce muscle glycogen concentration, affecting pH 24 h post-mortem and reduce meat quality (Chulayo & Muchenje, 2013). There is little information about the effect of space allowance during transport or management (fasting or feeding) during lairage, nor the interaction between these factors on carcass microbial quality and meat quality variables in Merino lambs (28 kg weight). Therefore, in order to give information to meat industry on optimum management prior to slaughter, the aims of this study were to analyse the effect of (1) the space allowance (SA: low, medium or high) during transport and (2) the management (TL: fasting vs feeding) during 18 h lairage on carcass microbial contamination and meat quality variables for Merina breed lambs.

Material and methods

Study description

This study was carried out in spring (n=72 Merino breed male lambs; 28.03 ± 0.05 kg, 90 days old; two journeys performed in April and May; 36 animals per journey). The details related to the animals feed, transportation, lorry characteristics, values of the temperature and relative humidity registered during loading and lairage, experimental design and others were reported in our previous paper (Cózar *et al.*, 2016). Lambs were randomly distributed in three groups according to the spaces allowances during

transportation to slaughterhouse: SAL (0.16 m²/animal; n=24, 12 per journey); SAM (0.20 m²/animal; n=24, 12 per journey); SAH (0.30 m²/animal; n=24, 12 per journey). After unloading at the abattoir, and in each group of density during transportation lambs were grouped, randomly, according to the treatment during 18 h lairage until the slaughter in two groups: FAST (animals remained fasted; n=36; 18 per journey) vs FEED (lambs were feed *ad libitum* n=36; 18 per journey). Lambs were slaughtered using standard commercial procedures after electrical stunning. Microbial contamination of carcass and meat quality were analysed in order to get the aims of the present paper.

Determination of microbial contamination on the carcass

In all carcasses (n=72), the microbiological sampling was carried out by swabbing areas of 100 cm² in three different sites of each carcass (rump, flank and neck). The wet-dry double swab technique (according to EC Decision 471/2001 (EC, 2001)] with head-cotton swabs was used, 30 min after the end of slaughter. For each area a swab was moistened in peptone water and then rubbed across the carcass surface in each of the vertical, horizontal and diagonal directions. Immediately afterwards, this procedure was also made with a dry swab. Samples were stored at 4°C in sterile tubes containing 10 mL of peptone water until examination, which was carried out after no more than 3 h from sampling. Each sample was homogenised for 60 s. Additional serial 10-fold dilutions of homogenates were made in peptone water and were spread on Petri dishes using a spiral system (Eddy-Jet, IUL-Instruments, Barcelona, Spain), for enumerations of: total viable counts (TVC) on Plate Count Agar (PCA, Scharlau Chemie S.L., Barcelona, Spain), Enterobacteriaceae on Violet Red Bile Glucose Agar (VRBG, Scharlau Chemie S.L., Barcelona, Spain) and *Pseudomonas* spp. on Pseudomonas Agar Base with a cetrimid, fucidin and cephaloridin supplement (Pseudomonas CFC, Oxoid LTD; Basingstoke, Hampshire, England). For all bacterial counts, plates were incubated at 32°C for 48 h (TVC) or 24 h (Enterobacteriaceae), except for *Pseudomonas* spp., which were incubated at 25°C for 48 h. An automatic colony counter (CounterMat-Flash, IUL-Instrument, Barcelona, Spain) was used for counting. All microbial counts were expressed as base -10 logarithms of colony forming units/cm² of surface area (log CFU/cm²).

Meat quality

The *Longissimus Dorsi* (LD) muscles were used to measure instrumental meat quality variables. The pH was assessed after dressing (pH₀) and at 24 h post-mortem (pH₂₄) using a Crison 507 equipment with a penetrating electrode. At 24 h post-mortem the LD muscle was removed from the carcass and divided into two pieces. One of them was used to evaluate (in the laboratory) the initial meat quality and the other was packed in a clear tray (LINPAC Plastic) with a film (having an oxygen permeability of 500 cm³/m²/day at 1 atm and 25°C). Samples were stored at 2°C in a conventional chiller until their analysis in the laboratory.

— Initial meat quality. At 24 h post-mortem the following variables were measured: Colour coordinates (L*, lightness, a*, redness, b*, yellowness) values, using a chromameter Minolta CR400 according to the proposal by Vergara *et al.* (1999). Lipid oxidation: TBARS content (as thiobarbituric acid reactive substances) was determined in duplicate from 5 g of LD muscle as described by Tarladgis *et al.* (1964). Absorbance at 532 nm was read with a Helios alfa spectrophotometer (THERMO, Electron Corporation, England). Results were expressed as mg MDA/kg of meat. At 72 h post-mortem, shear force (SF) was analysed using a TA.XT2 texture analyser equipped with a Warner-Bratzler device. For this analysis, each meat sample was individually placed in a polyethylene bag in a water bath at 70°C for 15 min. After drying the cooked samples with filter paper, they were cut into three replicates with a 1 cm² cross-section and 2-3 cm in length. SF was then assessed and the results were expressed as N/cm².

— After 7 days post-mortem (6 days post-storage), all the above-mentioned variables (pH, colour, SF and lipid oxidation) were analysed again and also Drip loss (DL) according to Vergara *et al.* (2003) and expressed as a percentage of the initial portion weight.

Statistical analysis

Data were analysed using the GLM procedure with the Statistical Package SPSS 19.0 version (IBM

Corp. Armonk, NY). The two-way model included the effects of the studied factors (space allowance treatment during transport, treatment during lairage and sampling site) and their interaction for carcass microbiological quality. For meat quality variables the model included the effects of space allowance treatment during transport, treatment during lairage and their interactions. In addition, an ANOVA test was used to check the effect of time on meat quality variables in each SA-TL group.

Previously, the normality and the variance homogeneity of all variables were tested by a Shapiro-Wilk test. The study was realized twice (two journeys) and no effect of the journey factor was found. The differences between pairs of groups were analysed by a Tukey's test (significance level of $p < 0.05$). Because lambs were targeted for slaughter at fixed weight, the cold carcass weight was included as a covariate for meat quality variables studied.

Results

Carcass quality

Carcass microbial values and the effect of space allowance during transport (SA), management during lairage (TL) and sampling site (SS) and their interactions are presented in Tables 1 and 2, respectively. There was no significant effect of SA on the microbiological contamination of the carcass. However, TL caused a strong effect ($p < 0.05$) on the number of TVC and on the *Pseudomonas* spp. In general TVC values were higher in fasted lambs while *Pseudomonas* spp. counts was lower in this group. In general, the flank site was the most contaminated site for all groups of lambs. Depending on the carcass region, the total viable counts, Enterobacteriaceae and *Pseudomonas* spp. varied between 3.96-2.86 log CFU/cm², 1.70-0.67 log CFU/cm² and 1.76-0.41 log CFU/cm² respectively.

Table 1. Microbial contamination on Merino breed lambs carcasses (means \pm SE). Effect of space allowance during transport (SA) and management during lairage (TL) and sampling site (SS)

Microorganism (log CFU/cm ²)	SA			TL		SS			SE
	SAL	SAM	SAH	TL-FAST	TL-FEED	Rump	Flank	Neck	
Total viable count	3.21	3.27	3.27	3.35 ^y	3.14 ^x	2.96 ^a	3.96 ^b	2.86 ^a	0.06
Enterobacteriaceae	1.19	1.22	1.24	1.22	1.21	1.28 ^b	1.70 ^c	0.67 ^a	0.06
<i>Pseudomonas</i> spp.	0.91	0.90	1.08	0.64 ^x	1.31 ^y	0.41 ^a	1.76 ^b	0.72 ^a	0.07

SA: Space allowance treatment during transport (SAL, SAM and SAH: low, medium and high, respectively). TL: Treatment during lairage [fasting (TL-FAST) vs feeding (TL-FEED)]. SE: standard error. ^{x,y}: Different superscript indicate significant differences ($p < 0.05$) due to the treatment during lairage. ^{a,b,c}: Different superscript indicate significant differences ($p < 0.05$) due to the sampling site.

Table 2. Effect of space allowance (SA: SAL, SAM and SAH), management during lairage (TL: TL-FAST and TL-FEED) and sampling site (SS: rump, flank, neck) on carcass microbial quality (log CFU/cm²) from Merina breed lambs

	Microorganism (log CFU/cm ²)		
	Total viable count	Enterobacteriaceae	<i>Pseudomonas</i> spp.
SA	NS	NS	NS
TL	*	NS	***
SS	***	***	***
SA*TL	NS	NS	NS
SA*SS	NS	NS	NS
TL*SS	***	***	**
SA*TL*SS	NS	NS	NS

***, **, * Indicate significance levels at 0.001, 0.01 and 0.05 respectively; NS: not significant.

Meat quality

The effects of space allowance during transport (SA) and treatment at lairage (TL) on meat quality are shown in Table 3. SA only affected drip loss ($p < 0.001$) and lipid oxidation ($p < 0.01$ and $p < 0.05$, at 24 h and 7 d post-mortem respectively) but not the rest of evaluated meat quality variables. A significant effect ($p < 0.001$) of TL was found on pH₂₄, pH₇, and at 24 post-mortem on b* coordinate ($p < 0.05$). In general, the highest pH₂₄ values were found in FAST lambs group. No effect of TL was observed on SF, DL and lipid oxidation values.

Discussion

Space allowance during transport is one of the most important factors influencing animals welfare (Hall & Bradshaw, 1998), and meat quality (Sañudo *et al.*, 1998). In agreement with Liste *et al.* (2011) lairage period conditions must be consider in order to rise the best results for all meat industry (producer, processor, consumer) and for animals. Fasting before slaughter is potentially beneficial to food safety, since reduces incidence of intestinal tract rupture during evisceration and the contamination of carcass (Terlouw, 2005). However this practise could be associated to others negative effects such as weight loss (Warris, 1985), depletion of muscle glycogen (Adzitey, 2011) and consequently difficult to keep meat (Terlouw, 2005). In our previous paper (Cózar *et al.*, 2016) we reported information about the effect of factors previous to slaughter (SA and TL) on lamb welfare blood indicators. Now, we show the effect of these factors on carcass microbiological contamination, meat instrumental quality, and lipid oxidation.

Carcass quality

The prevention of microbial contamination of the carcass is crucial in order to ensure both meat quality and carcass safety and quality (Zweifel & Stephan, 2003). However, there is a scarcity of references regarding the effect of space allowance and lairage conditions on carcass microbial contamination, and inconsistent results have been observed in relation to this subject. We have not found any previous reports on the effect of space allowance during transportation on carcass contamination in lamb. Now, our study showed that SA did not influence microorganism count, suggesting that this factor did not contribute to the carcass hygienic. However the effect of TL varied with the sampled site (SS: rump, neck or flank) and a significant interaction was found between both factors. Some authors, such as Vanguru *et al.* (2009), in goats, have reported the effect of the duration of feed deprivation prior to slaughter on carcass microbial quality, concluding that the duration of feed deprivation tended to reduce aerobic counts and *Escherichia coli* on carcass. Pointon *et al.* (2012) indicated that adverse food borne microbial growth could be minimised by not exceeding 48 h of feed withdrawal before slaughter. Other reports (Grau & Smith, 1974) suggested that carcass contamination increased with time off feed and with the contamination on the flooring material, highlighting the effect of ground flooring.

Values of TVC have been used as an indicator of both general carcass hygiene and the presence of faecal indicators (Biss & Hathaway, 1996). In addition, TVC $\geq \log 4.0$ CFU/cm² have been attributed to direct faecal contact (Bell, 1997). According to our results, it could be concluded that the slaughtering practices in the abattoir were acceptable and that the space allowance

during transport and/or the treatment applied during lairage (fasting or feeding) had no significant impact on the level of microbial carcass contamination.

Independent from treatment during lairage (fasting vs feeding), our findings showed a particular distribution of the contamination on the carcass, with the flank as the most contaminated site, suggesting that faecal contamination is more frequent at this sampling site. Our findings contrast with the results of Zweifel & Stephan (2003) in sheep carcass as regard TVC (being the highest values in the brisket and the neck) and Enterobacteriaceae values (the highest in brisket and perineal area). The different processes and manipulation carried at different meat packing plants can be regarded as the most plausible cause.

Meat quality

pH

According to Lawrie (1998) the endocrine response system react to physiological stress thereby influencing meat quality indirectly. The stress increase release of catecholamine and post-mortem speed of pH decline (Terlouw, 2005). Meat pH has been used as an indicator of meat quality and pre-slaughter stress (Grandin, 1980). In the present study, space allowance did not affect pH. Our results are consistent with the reports by De la Fuente *et al.* (2010) and Teke *et al.* (2014) in lambs transported at different stocking densities. On the other hand, lairage allows animals to recover from the stress of transport and unloading, and consequently to improve meat quality (Rabaste *et al.*, 2007). According to the results on lamb welfare blood indicators of our previous paper (Cózar *et al.*, 2016) and of other authors (Zimerman *et al.*, 2013), fasting during lairage could result stressful. In addition, feed deprivation during lairage would generate lower reserves of muscle glycogen and an increase of pH values of meat (Fisher *et al.*, 2011). In our study, the lowest pH₂₄ values were found when animals had feed during lairage, which is consistent with that report. In contrast, Liste *et al.* (2011) found no significant differences in pH comparing the effects of lairage in Rasa Aragonesa breed lambs. In agreement with Miranda-de la Lama (2013) the pre-slaughter logistic conditions are the key factor for deciding the waiting time. In our study, conditions (feed or fast) in resting time (18 h) affected meat pH.

Colour

An increase in pH has been related to darker meat (Abril *et al.*, 2001). Despite the differences found in pH₂₄ among groups (Table 3), this was not associated

with different values in L* or a* coordinates, in contrast with the previously cited paper. Supporting our results, Ekiz *et al.* (2012) did not find any significant influence of lairage time in redness value in Kivircik lambs.

At 1 day post-mortem b* variable was significantly higher in SAM-fasted lambs (7.34) than in SAM-feed lambs (5.91). Interestingly fasting induced a rise in catecholamine levels, particularly of noradrenaline (Cózar *et al.*, 2016). Highest b* values could therefore be associated to higher catecholamine levels found in this group. Liste *et al.* (2011) reported a significantly higher yellow index in lambs slaughtered with not previous lairage. Other authors (Chulayo & Muchenje, 2013) also reported that adverse pre-slaughter stressors negatively affected meat quality attributes such as colour. The remaining groups showed similar colour coordinates values at 1 day and at 6 d post-mortem.

Shear force (SF) and drip loss (DL)

Space allowance during transport and treatment during lairage did not affect shear force. Ultimate pH has been associated to the activity of endogenous enzyme systems, proteolysis of existing structures, water holding capacity and meat tenderness (French *et al.*, 2000; Huff-Lonergam & Lonergam, 2005; Ekiz *et al.*, 2012). In spite of the differences observed on ultimate pH values in the current study, meat samples showed similar SF values. Similar findings were found by De la Fuente *et al.* (2010) or Teke *et al.* (2014), in suckling and light lambs respectively, who found no significant effect of stocking density on SF values. Liste *et al.* (2011) did not find any effect of treatment before slaughter (with or without lairage) on textural variables.

Many factors previous to slaughter can cause variation in DL. Our results showed a tendency for lambs transported at high density (SAL-FEED or SAL-FAST) to have highest DL values (2.39% and 1.57% respectively). In goats, Nikbin *et al.* (2016) associated high amount of loss water to the stress conditions, and, in agreement with our results, animals transported at high stocking density (0.2 m² per animal, *i.e.* low space allowance) has higher DL values than samples from animals transported at 0.4 m² per goat (high space allowance). Both, the significant effect of space allowance during transportation and the absence of management during lairage effect on this variable (Table 3) could be interesting for meat industry. In addition these result suggest that the level of stress associated to SA during transportation. According to Cózar *et al.* (2016), a recuperation overnight when lambs were fed during lairage, (since some physiological variables associated with stress returned to basal levels, on farm), could explain the lower values in DL in SAM-FEED and SAH-FEED groups.

Table 3. Effect of space allowance (means \pm SEM) during transport (SA) and treatment (fasting vs feeding) during lairage on pH, color coordinates (L*, a*, b*), shear force and drip loss, and lipid oxidation in Merina breed lambs

Variable	Time post-mortem	Treatment during lairage (TL)						SEM	GLM		
		Fasting (TL-FAST)			Feeding (TL-FEED)				SA	TL	SA \times TL
		SAL	SAM	SAH	SAL	SAM	SAH				
pH	After dressing (pH ₀)	6.82 ^z	6.82 ^z	6.83 ^z	6.99 ^y	7.02 ^y	6.90 ^y	0.03	NS	NS	NS
	24 h (pH ₂₄)	5.84 ^{b,y}	5.82 ^{b,y}	5.91 ^{b,y}	5.50 ^{a,x}	5.51 ^{a,x}	5.52 ^{a,x}	0.02	NS	***	NS
	7 days (pH ₆)	5.41 ^{ab,x}	5.39 ^{a,x}	5.42 ^{abc,x}	5.47 ^{bc,x}	5.49 ^{c,x}	5.43 ^{abc,x}	0.01	NS	***	NS
	Effect of time	***	***	***	***	***	***				
L*	24 h	39.95	40.72	40.38	39.41	40.05	40.00	0.24	NS	**	NS
	7 days	42.46	43.15	43.25	42.75	43.15	43.14	0.20	NS	NS	NS
	Effect of time	**	**	**	***	***	***				
a*	24 h	16.39	16.88	15.90	15.77	15.97	15.31	0.15	NS	NS	NS
	7 days	13.01	12.90	13.28	13.00	13.06	12.23	0.12	NS	NS	NS
	Effect of time	***	***	***	***	***	***				
b*	24 h	6.46 ^{ab}	7.34 ^c	6.20 ^{ab}	6.04 ^a	5.91 ^a	5.92 ^a	0.14	NS	*	NS
	7 days	8.98	9.29	9.26	8.94	8.83	8.78	0.09	NS	NS	NS
	Effect of time	***	***	***	***	***	***				
Shear force (N/cm ²)	24 h	90.26	92.70	110.10	109.48	100.80	107.66	2.58	NS	NS	NS
	7 days	77.70	62.41	67.50	71.86	61.98	71.52	1.70	NS	NS	NS
	Effect of time	NS	***	***	***	***	***				
Drip loss (%)	7 days	1.57 ^b	1.10 ^{ab}	1.24 ^{ab}	2.39 ^c	0.56 ^a	0.60 ^a	0.09	***	NS	NS
Lipid oxidation (mg MDA/kg meat)	24 h	0.15 ^{ab}	0.11 ^a	0.14 ^{ab}	0.19 ^b	0.12 ^a	0.13 ^a	0.01	**	NS	NS
	7 days	0.28 ^{ab}	0.25 ^a	0.22 ^a	0.36 ^b	0.22 ^a	0.24 ^a	0.02	*	NS	NS
	Effect of time	**	***	NS	***	**	***				

SA: Space allowance treatment during transport (SAL, SAM and SAH: Low, medium and high space allowance, respectively). TL: Lairage treatment (Fasting or Feeding). SE: standard error. GLM: General Lineal Model. *, **, ***: Indicates significance levels at 0.05, 0.01 and 0.001, respectively. NS: not significant. ^{a,b,c}: Values in the same row with different superscripts are significantly different ($p < 0.05$). ^{x,y,z}: Values in the same column with different superscripts are significantly different ($p < 0.05$).

Lipid oxidation

Little research has focused on the relationships between density during transport or lairage conditions and lipid oxidation of lamb meat. Zhong *et al.* (2011) reported an increase of lipid oxidation of sheep meat after 8 h of road transportation. De la Fuente *et al.* (2010) found a higher lipid oxidation after 5 days of ageing in suckling lambs transported for longer journeys (5 h) than those transported for 30 min. However, these same authors did not find an effect of stocking density on LO. In contrast, our findings showed a significant effect ($p < 0.05$) of space allowance during transport on lipid oxidation (Table 3). A lower lipid stability was found in meat of lambs transported at high density (SAL). This could indicate

that more stressful conditions result in higher lipid oxidation. However, Sanchez-Sanchez *et al.* (2013), in suckling lambs observed that LO was unaffected by the SA during transport. The lambs weight could explain the differences on the SA effect on LO.

Liste *et al.* (2011) indicated that the fasting period during lairage should not be too long (*i.e.* >12 h), since it might increase lipid metabolism. Although lairage could be associated with the mobilisation of fat depots increasing meat lipid oxidation (Sävendahl & Underwood, 1999), especially in fasted lambs, our findings show that LO values were not affected by treatment during lairage.

After comparing the effect of SA and TL on microbiological contamination of carcass and meat

quality variables on lamb, the results showed: (1) SA had no effect on carcass contamination, but TL had a different effect depending on carcass location sampled; (2) a significant effect of SA on drip loss and lipid oxidation was found, with a lack of effect for the rest of variables; (3) despite the differences on pH values caused by treatment imposed during lairage, TL had not effect on instrumental variables. On the basis of these conclusions and those found in our previous paper (Cozar *et al.*, 2016), pre-slaughter conditions (such as SA or TL), should be considered for meat industry in order to decide the best practises. The industry's point of view (animal welfare, meat quality, carcass contamination, economic implications) will be decisive for choosing the management previous to slaughter.

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