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Effect of different gas stunning methods on Manchega suckling lamb meat packed under different modified atmospheres

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ABSTRACT

Forty-nine Manchega breed male suckling lambs were used in this experiment. The effect of CO_2 concentration and exposure time at stunning [80% CO_2 for 90 s (G1); 90% CO_2 for 90 s (G2); 90% CO_2 for 60 s (G3); 80% CO_2 for 60 s (G4)] plus an electrically stunned control group (G5) was assessed for pH, colour (L^*, a^*, b^*, C^* and h^*), water holding capacity (WHC), drip loss (DL), cooking loss (CL) and shear force (SF) in samples packed under two different types of modified atmospheres (MA: MA A: 70%O_2 + 30%CO_2; MA B: 69.3%N_2 + 30%CO_2 + 0.7%CO) at 7, 14 and 21 d post-packaging. The lowest pH was found in G4 and in G5. The highest WHC and the lowest CL were found in G2 and G3 groups ($P < 0.05$). Modified atmospheres did not affect on pH, WHC, CL and DL, although a significant effect ($P < 0.001$) on colour was found at all the analysis times. Both the type of stunning and the modified atmosphere affected SF values.

1. Introduction

An important extrinsic factor which affects lamb meat quality is the type of stunning (Sañudo et al., 1998). Many studies have been carried out in order to compare gas stunning systems with electrical stunning in lambs (Linares, Bórnez, & Vergara, 2007a, 2008; Vergara, Linares, Berruga, & Gallego, 2005) and also in other species such as pigs (Channon, Payne, & Warner, 2000; Nowak, Muefling, & Hartung, 2007; Velarde, Gispert, Faucitano, Manteca, & Diestre, 2000). In addition, the disadvantages of electrical stunning have been widely discussed in a previous paper by Bórnez, Linares, and Vergara (2009a).

The gas mixture used to preserve meat is another important extrinsic factor in lamb meat quality (Vergara & Gallego, 2001). The packaging technologies under modified atmospheres maintain the sensory quality of foodstuffs and extend their shelf-life (García, Gago, & Fernández, 2006). Packaging of fresh meat in modified atmospheres uses a mixture of oxygen (O_2), carbon dioxide (CO_2) and nitrogen (N_2) in different concentrations (Luño, Roncalés, Djenane, & Beltrán, 2000; Veberg et al., 2006). However, a high oxygen concentration reduces meat shelf-life due to the development of lipid oxidation and colour loss. These effects have been reported in different animal species and meat products by various authors, such as John et al. (2005) in fresh beef meat; Martínez, Djenane, Cilla, Beltrán, and Roncalés (2005) in pork sausages; Seydim, Acton, Hall, and Dawson (2006) in ground ostrich meat; Veberg et al. (2006) in ground turkey meat and by Linares, Berruga, Bórnez, and Vergara (2007b) in fresh lamb meat. Carbon dioxide is used in modified atmosphere packaging due to its bacteriostatic effect, since only 20–30% of CO_2 concentration is enough to prevent aerobic spoilage bacteria (Sørheim, Ofstad, & Lea, 2004). On the other hand, other studies have reported that the packaging with low carbon monoxide (CO) concentrations together with high CO_2 concentrations improve colour and shelf-life of pig meat (Krause, Sebranek, Rust, & Honeyman, 2003; Sørheim, Nissen, & Nesbakken, 1999), increase shelf-life and inhibit growth of spoilage bacteria in beef meat (Luño et al., 2000) and restrain the development of lipid oxidation in lamb (Bórnez, Linares, & Vergara 2009c; Linares et al., 2007b).

A recent paper (Bórnez, Linares, & Vergara, 2009b) showed the effects of the carbon dioxide concentration (80% or 90% CO_2) and exposure time (60 or 90 s) at stunning on suckling lamb meat quality at initial time with differences in tenderness and drip loss. Subsequently Bórnez et al. (2009c) showed the effects of time of exposure/gas concentration and modified atmosphere on microbial quality and on lipid oxidation in suckling lamb meat. However the effect of these factors (time of exposure/gas concentration) on meat quality is not well known when meat is packed in modified atmospheres. Moreover, a significant interaction between these factors (stunning method and modified atmosphere) was observed by Linares et al. (2008) especially with reference to colour.

Therefore, the aim of the present study was to evaluate the effects of different gas stunning methods (two different CO_2

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concentrations and two exposure times) on the quality (assessed by pH, colour, WHC, DL, CL and SF) of suckling lamb meat packed under two different modified atmospheres.

2. Materials and methods

The experimental protocol was approved by the University of Castilla-La Mancha Animal Ethics Committee, according to the Executive Committee Directive 86/609/CEE of 2nd November 1986 regarding the protection of animals used in research and for scientific purposes.

2.1. Animals and experimental design

Forty-nine Spanish Manchega male suckling lambs were used in this trial. All animals were raised exclusively on milk and slaughtered at 12.80 ± 0.20 kg live weight (30 d old). Lambs were transported from the farm to the slaughterhouse (20 km taking approximately 30 min) in a adequately conditioned vehicle. Animals were then placed in pens (3 m wide × 5 m long; 6–10 lambs per pen) and remained there for approximately 15 h, without access to food, although they received water *ad libitum*. After lairage, lambs were slaughtered and dressed using standard commercial procedures.

Lambs were distributed into five groups according to the type of stunning prior to slaughter:

- Four groups were stunned with gas using different CO_2 concentrations and exposure times [G1: 80% CO_2 for 90 s (n = 9); G2: 90% CO_2 for 90 s (n = 10); G3: 90% CO_2 for 60 s (n = 10); G4: 80% CO_2 for 60 s (n = 10)] using a gondola dip-lift system (G van Wijnsberghe and Co. N.V.[1] Veurne, Belgium) normally used for stunning pigs (3 m long × 1.5 m wide × 1 m high) that indicates the concentration of CO_2 in the pit, which was tested by the authorized personnel. Animals were placed in the gondola in groups of three or four. The motor on the gondola transporter was set to reach the bottom of the pit in 10 s and to the ejection level 16 s after the conclusion of the exposure period. The lambs were shackled by the leg and hoisted onto the overhead rail where they were bled by cutting the blood vessels of the neck between 25 and 35 s after removal from the gondola.
- A control group [G5 (n = 10)] was electrically stunned at 110 V, 50 Hz for 5 s (plate electrodes applied on both sides of the head, behind the ears; Electronarcosis Panel, MAC-01, Bernard, S.L.).

Immediately after stunning, lambs were slaughtered and dressed using standard commercial procedures. Finally, carcasses were chilled at 4 °C for 24 h in a conventional chiller.

2.2. Analysis of samples

The *Longissimus dorsi* from both sides of the carcasses was removed and cut into similar size portions (eight per lamb). Two samples were used to determine initial (at 24 h and 7 d) meat quality and the results were reported by Bórnez et al. (2009b). The remaining samples were packed under modified atmosphere and remained in a conventional chiller at 2 °C. A packaging machine (Efabind L-650, Efabind, Spain), was used for packaging the meat portions. Samples were placed in clear trays (Linpac, Plastic, West Yorkshire, UK), with an oxygen permeability rate of 3.2 $cm^3\ m^{-2}\ d^{-1}$ at 1 atm and 23 °C, and covered by a film with transmission rates of 1 $cm^3\ m^{-2}\ d^{-1}$ for oxygen (23 °C; 50% RH);

[1] N.V.: Naamloze Vennootschap or Society Anonym S.A.

Table 1
Effect of the type of stunning and modified atmosphere in meat pH (mean ± e.e.) from Manchega suckling lamb breed.

pH (d)	Type of stunning										GLM		
	G1 (80% 90 s)		G2 (90% 90 s)		G3 (90% 60 s)		G4 (80% 60 s)		G5 (electrical)				
	MA A	MA B	MA A	MA B	MA A	MA B	MA A	MA B	MA A	MA B	MA	S	MA × S
7	5.65 ± 0.01^{xybc}	5.66 ± 0.01^{e}	5.66 ± 0.02^{yc}	5.65 ± 0.01^{e}	5.64 ± 0.01^{bc}	5.64 ± 0.01^{e}	5.57 ± 0.01^{a}	5.59 ± 0.02^{d}	5.60 ± 0.01^{ab}	5.62 ± 0.01^{de}	NS	***	NS
14	5.62 ± 0.01^{xabc}	5.64 ± 0.02	5.62 ± 0.01^{xabc}	5.63 ± 0.03	5.63 ± 0.01^{c}	5.63 ± 0.01	5.57 ± 0.01^{a}	5.59 ± 0.01	5.58 ± 0.01^{ab}	5.61 ± 0.01	NS	***	NS
21	5.67 ± 0.01^{yc}	5.64 ± 0.01^{e}	5.63 ± 0.01^{xybc}	5.62 ± 0.01^{de}	5.63 ± 0.01^{bc}	5.63 ± 0.01^{e}	5.55 ± 0.01^{a}	5.56 ± 0.01^{d}	5.57 ± 0.01^{a}	5.59 ± 0.02^{de}	NS	***	NS
	*	NS	*	NS	NS	NS	NS	NS	NS	NS			

MA: modified atmosphere; MA A (70% O_2 + 30% CO_2), MA B (69.3% N_2 + 30% CO_2 + 0.7% CO). S: type of stunning. *,***: Indicates significance levels at 0.05 and 0.001, respectively. NS: not significant. ^{a,b,c} Values in the same row with different superscripts are significantly different ($P < 0.05$) for the different stunning method and modified atmosphere type A. ^{d,e} Values in the same row with different superscripts are significantly different ($P < 0.05$) for the different stunning method and modified atmosphere type B. ^{x,y} Values in the same column with different superscripts are significantly different ($P < 0.05$) for the different post-packaging time (7, 14 and 21 d) at the same stunning method and modified atmosphere.