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Effect of post mortem temperatures and modified atmospheres packaging on shelf life of suckling lamb meat

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ABSTRACT

The effect of different post-mortem temperature treatments (conventional: 3 ± 1 °C for 24 h post-mortem *versus* slow: 12 ± 2 °C for the first 7 h and 3 ± 1 °C until 24 h post-mortem) and different modified atmospheres of packaging (20/70/10% $CO_2/O_2/N_2$ *versus* vacuum) was evaluated on forelegs of suckling lamb during 18 days of display at 4 °C. The results of the present study showed that slow post-mortem temperature treatment applied to suckling lamb carcasses had no adverse effect on the quality of forelegs packaged in comparison to the conventional post-mortem treatment. The packaging method had an effect ($P < 0.05$) and the samples packaged with the gas mixture presented higher lipid and myoglobin oxidation. However, this fact did not involve a disadvantage compared to vacuum packaging. The deterioration of the quality of packaged lamb forelegs was due to microbiological deterioration during the storage period. From day 13, the total viable counts reached values beyond the limit of microbiological acceptability which resulted in the presence of off-odour and rejection by the judges.

1. Introduction

The production of suckling lambs is traditional in Europe's Mediterranean sheep dairy farms. Suckling lambs are fed exclusively on maternal milk and are slaughtered before 35 days of age. For this reason suckling lamb carcasses are of low weight (4.5–7.0 kg) and have a thin subcutaneous fat cover. These characteristics mean that the chilling rate may affect the quality of the meat.

In Spain, the most common chilling treatment used in commercial abattoirs is to transfer lamb carcasses to a chamber at 0–2 °C air temperature immediately after carcass processing operations. The above mentioned particular characteristics of suckling lamb carcasses enable faster decreases in temperature which increases the risk of cold shortening. Slow chilling has been proposed as an alternative in order to prevent cold shortening and improve meat tenderness (Fernández & Vieira, 2012). These authors indicated that maintaining suckling lamb carcasses at approximately 12 °C air temperature (until 8 h post-mortem) results in longer sarcomere length and better organoleptic characteristics. Besides Rubio, Martínez, Vieira, and Fernández (2013) indicated that slow chilling could be chosen as post-mortem treatment of suckling lamb carcasses since conventional and slow chilled carcasses presented similar total viable and *Enterobacteriaceae* counts. So far the evaluation of the effect of chilling slow has not been evaluated on the shelf life of fresh suckling lamb meat. Due to changing consumer purchase habits that involve weekly shopping trips to supermarkets and smaller family sizes, fresh suckling lamb meat currently needs to be commercialized in smaller pieces (hind legs or forelegs) that require a longer shelf life (Osés et al., 2013). Among the different strategies that can be used to prolong the shelf life of fresh meat is the use of modified atmosphere packaging (MAP).

The simplest form of MAP is vacuum packaging (VP). The VP maintains an oxygen deficient environment within the pack and extends the storage life of chilled meats by preventing the growth of obligate aerobic spoilage bacteria and leading to a slow growth of CO_2 tolerant bacteria (Reis, Reis, Mills, Ross, & Brightwell, 2016). However, following VP the surface colour of fresh meat changes from bright red to purplish red due to deoxymyoglobin formation (Kim, Stuart, Black, & Rosenvold, 2012). Colour is the major determinant of consumer acceptability of fresh meat at the retail counter (Mancini & Hunt, 2005), therefore a method of packaging that maintains desirable colour while inhibiting bacteria growth is needed. In this sense, retail packaging of meat in a modified

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atmosphere with 70–80% $O_2$is used to provide a stable, bloomed red meat colour which is attractive to the consumer (Lorenzo & Gómez, 2012). Moreover, the inclusion in the MAP of 20–30% CO_2 prolongs shelf life by inhibiting bacterial growth (McMillin, 2008). However, a high concentration of O_2 may cause quality deterioration through lipid and protein oxidation (Zakrys, Hogan, O'Sullivan, Allenand, & Kerry, 2008).

The aim of the present work was to study the effect of different post-mortem temperature treatments (conventional chilling rate *vs* slow chilling rate) and different common MAP (vacuum and 20/70/10% $CO_2/O_2/N_2$) on microbiological, physico-chemical and sensory quality of forelegs of suckling lamb during display at 4 °C.

2. Materials & methods

2.1. Preparation of samples

The study was conducted with sixteen suckling lambs of the Churra breed, protected by the Protected Geographical Indication "Lechazo de Castilla y León", with a month of age and an average live weight of 9.86 ± 0.81 kg. Suckling lambs, fed only ewe milk, were slaughtered after weaning according to standard commercial procedures. Immediately after carcass processing, the lamb carcasses were randomly assigned to two post-mortem temperature treatments: conventional (CT) and slow (ST) to give a total of 8 carcasses for each treatment. CT carcasses were stored in a chilling room (3 ± 1 °C) for 24 h post-mortem, while ST carcasses were stored at 12 ± 2 °C for the first 7 h and then transferred to the chilling room (3 ± 1 °C) until 24 h post mortem. The air movement velocity of chilling room was 2 m/s and the relative humidity of 80–90%.

2.2. Packaging and storage of samples

After 24 h of chilling treatment, forelegs from the right side of the carcasses of CT and of ST treatments were removed and packed in the atmosphere 20/70/10% $CO_2/O_2/N_2$. For that, forelegs of each treatment were randomly placed in polystyrene trays (one foreleg per tray), were flushed with the gas mixture supplied by Carburos Metálicos S.A. (Barcelona, Spain) and were closed by heat-sealing with a packer (Linvac 400 TECNOVAC, Barcelona, Spain) with a high barrier film (with an oxygen transmission rate of 1.8 cm^3/m^2/24 h/bar at 20 °C and 65%RH, supplied by Fibosa Packaging S.L., Tordera, Spain).

In the same way, forelegs from the left side of the carcasses of both treatments CT and ST were removed and vacuum packed. For that, forelegs of each treatment were individually packaged in commercial plastic bags (polyamide/polyethylene with an oxygen transmission rate of 30/40 cm^3/m^2/24 h/bar at 23 °C and 50% RH and a water vapour transmission rate of 2.5 g/m^2/24 h at 23 °C and 50% RH, supplied by W. K. Thomas España S.L., Rubí, Spain) which were subjected to vacuum and sealed using a packer (mod. EVT-7-TD, Tecnotrip, Barcelona, Spain).

The samples were stored in chilling at 4 ± 1 °C for 0, 4, 7, 13 and 18 days in a display cabinet (Odessa 2, Arneg Portuguesa, Portugal) simulating retail display conditions. The trays were illuminated with white light fluorescent (about 800 lx) for 12 h to the day, 6 days for week. Every 24 h the trays were rotated to minimize the effects due to the differences of intensity of light and to the variation of temperature inside the cabinet.

2.3. Analyses

2.3.1. Gas composition

In the samples packed with the gas mixture, oxygen and carbon dioxide concentrations were measured in the headspace of the trays using a digital O_2 and CO_2 analyzer OXYBABY (WITT-GasetechnikGmbH & Co. KG., Witten, Germany). On each sampling day, readings were taken after moving the packages from refrigeration and the gas composition was measured in two different packages per treatment. A syringe needle was used to draw off 10 ml gas samples into the analyzer through a septum glued onto the surface of the packaged product.

2.3.2. Microbial analyses

Ten grams of each sample were taken aseptically and homogenized with 90 ml of tryptone water (Scharlau, Spain) for 2 min in a sterile plastic bag in a PK 400 Masticator (IUL, S.A., Barcelona, Spain). Serial decimal dilutions were made in sterile tryptone water and in duplicate 1 ml or 0.1 ml samples of appropriate dilutions were poured or spread onto total count and selective agar plates.

Total viable counts (TVC) were determined on 3M Petrifilm Aerobic Count Plates (3M, Spain) incubated at 30 °C for 72 h, **Enterobacteria** on 3M Petrifilm Enterobacteriaceae Count Plates (3M, Spain) incubated at 37 °C for 24 h, ***Escherichia coli*** on 3M Petrifilm Selective *E. coli* Count Plates (3M, Spain) incubated at 42 °C for 24 h, **Lactic acid bacteria** (LAB) on MRS Agar (Scharlau, Spain) incubated at 30 °C for 72 h, **Pseudomonads** on Pseudomonads Agar (Oxoid, Spain) supplemented with Cetrimide, Fucidine and Cephaloridine (CFC, Oxoid, Spain) incubated at 30 °C for 48 h and ***Brochothrix thermosphacta*** on STAA Agar (Oxoid, Spain) supplemented with STAA selective supplement (Oxoid, Spain) incubated at 25 °C for 48 h. For Pseudomonads and *B. thermosphacta,* from each set of countable plates, five colonies were randomly selected and examined for oxidase reaction using Oxidase Test Sterile Swabs (Scharlau, Spain).

The detection limit of the above techniques was 1 log cfu/g except for Pseudomonads and *B. thermosphacta* whose limit was 2 log cfu/g.

2.3.3. Physical–chemical analysis

Changes of pH, light reflection and lipid oxidation were determined to monitor meat spoilage during display life. The **pH** values were determined by puncture with a pH meter model 507 (Crison Instruments, Barcelona, Spain) equipped with a glass electrode and a temperature control.

Lipid oxidation was assessed by the TBARS (thiobarbituric acid reactive substances) assay which is based on the reaction between malondialdehyde and thiobarbituric acid and the production of a coloured pigment, as determined by Maraschiello, Sárraga, and García-Regueiro (1999), using a UV-1700 spectrophotometer (Shimadzu, Kyoto, Japan). The TBARS values were expressed as milligrams of malonaldehyde per Kg of sample.

Metmyoglobin percentage (%MMb) was estimated spectrophotometrically by measuring the reflectance at 525 and 572 nm according to Krzywicki (1978). The metmyoglobin relative percentage was calculated as follows:

$$\%\ \mathrm{MMb} = [1,395 - ((A_{572} - A_{730})/(A_{525} - A_{730}))] \times 100$$

Colour measurements were performed directly on the meat surface after blooming for 1 h. Visible reflectance spectra (from 360 to 760 nm) were determined with a Minolta CM-2600d spectrophotometer (Minolta, Tokyo, Japan). Reflectance measurements were collected under D65 illuminant, 10° observer visual angle, 11 mm aperture for illumination and SCI mode conditions. Colour coordinates were calculated in the CIE-L*a*b* system where L* is lightness, a* redness and b* yellowness (Chen, Zhu, Zhang, Niu, & Du, 2010).