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Effect of vacuum ageing on quality changes of lamb steaks from early fattening lambs during aerobic display

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ABSTRACT

The effects of vacuum ageing on the quality changes of lamb steaks during retail display were assessed. *Biceps femoris* and *Quadriceps femoris* muscles from thirty early fattening lambs fed barley straw and concentrate or alfalfa and concentrate were used. Half of the muscles were vacuum aged for three weeks (VA), and the other half were not aged (control). Control and VA muscles were sliced and aerobically displayed. Weight loss, pH, aldehyde contents, instrumental color characteristics and color acceptance were measured at display days 1, 3, 7 and 14. At day 1 redness was higher in VA lamb. However, redness of VA lamb decreases more rapidly during further storage. Redness and color acceptance decreased in VA lamb from day 3, whereas in not-aged lamb the decrease was observed from day 7 onwards. From days 7 to 14 a drop of color acceptance accompanied by an increase in pH and a decrease in lightness was observed in control and VA lamb.

1. Introduction

Lamb is widely consumed in the European Mediterranean countries (Karabigas, Badeka, & Kontominas, 2011; Sañudo, Sánchez, & Alfonso, 1998). However, both its relatively high price and the consumer habit of buying lamb mainly for special events have led this product to be considered as a luxury food (Linares, Bórnez, & Vergara, 2007). In general, red-meat quality and shelf life are determined by different characteristics including color, microbial quality, lipid oxidative status, water holding capacity, nutritive value and palatability (McMillin, 2008). Among those, meat-purchasing decisions are influenced by color more than by any other of those quality factors (Mancini & Hunt, 2005).

Quality and shelf life of refrigerated meat at retail stores are strongly affected by packaging and storage conditions (McMillin, 2008). In this context, vacuum packaging of primal and subprimal cuts is being normally used by the meat industry as a mean to extend meat shelf life (Walsh & Kerry, 2002). Vacuum-packaged meat is normally stored (aged) for several days or few weeks at retail stores or butcheries. Afterwards, meat is removed from the packaging, cut as chops or steaks, or grinded, and displayed under aerobic atmosphere (McMillin, 2008). Following vacuum packaging, the surface color of fresh meat changes from bright red to purplish red due to deoxymyoglobin formation (Kim, Stuart, Black, & Rosenvold, 2012). Then, upon exposure to oxygen, bright-red oxymioglobin is rapidly formed on surface, allowing meat to bloom to the characteristic color of fresh meat. Then, during aerobic display, color gradually deteriorates, as meat desiccation, microbial population and lipid autoxidation increase (Jacob, D'Antuono, Gilmour, & Warner, 2014; Kennedy, Buckley, & Kerry, 2004). This changes in color must thus be related to moisture losses, microbial slime appearing, and/or metmyoglobin formation.

Several studies have determined the effect of vacuum ageing on the changes in quality (mainly in color) of lamb during further aerobic retail display. Kim, Frandsen, and Rosenvold (2011) studied the effect of vacuum-ageing prior to freezing on color and texture characteristics of thawed lamb during display, and found that vacuum ageing could improve lamb tenderness and color stability. Furthermore, Kim et al. (2012) and Rosenvold and Wiklund (2011) studied the changes in quality of vacuum-aged lamb during further display as affected by several processing conditions, i.e., electrical stimulation, vacuum storage temperatures, atmosphere composition; however, in those studies the quality changes were not compared with non-aged lamb. Moreover,

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Moore and Gill (1987) compared the display life (based on color acceptability) between lamb aged under vacuum and not aged-lamb. They found that vacuum ageing resulted in a reduction of color stability during aerobic display, with the magnitude of this effect depending on both storage time and temperature. Two recent studies (Ponnampalam, Trout, Sinclair, Egan, & Leury, 2001; Ponnampalam et al., 2013) reported that vacuum-aged lamb showed greater redness compared with fresh non-aged lamb during up to three days of display; however, aged-lamb redness decreased more rapidly over the display time.

The studies above appeared to have been conducted with meat from heavier and older lambs (e.g. six–seven months of age) than those normally produced in the Mediterranean region. In this region, lamb meat is mainly derived from younger lambs and tends to have lower fat content, paler color and a more delicate flavor (Sañudo et al., 2007). Therefore, the aim of the current study was to evaluate the effect of vacuum ageing of meat from early fattening lambs (intensively reared, slaughtered at three months of age, yielding a carcass weight of 13–15 kg; Sañudo et al., 1998) on the changes on selected quality traits, with focus on color, during further aerobic retail display. In order to provide more robust data, meat from early fattening lambs reared under three different feeding systems was included in the study.

2. Materials and methods

2.1. Animals

Thirty male Merino lambs (6–8 week old and 14.1 ± 0.20 kg mean body weight at the beginning of the experiment) were used in this study. Lambs were housed in individual pens, each lamb being individually fed for the entire experimental period. After randomization on the basis of body weight, lambs were randomly assigned to one of the following feeding types (n = 10): straw + concentrate (conventional system; barley straw and concentrate feed in separated feeding troughs), mixed ration (total mixed ration pellets including 250 g barley straw per kg), and alfalfa + concentrate (alfalfa and concentrate feed in separated feeding troughs). These feeding types were considered as three different options for finishing early fattening lambs. The procedures used in the two first feeding types were described in a previous study (Blanco et al., 2014). In the third, lambs received 17 g of concentrate per kg of body weight daily, plus alfalfa hay ad libitum. Fresh drinking water was always available, and animals were able to see and hear the other lambs. All handling practices followed the recommendations of the Directive 2010/63/EU of the European Parliament and of the Council on the protection of animals used for scientific purposes.

When an animal reached the intended body weight (27 kg; at approximately 3 months of age), lambs were slaughtered (Blanco et al., 2014). At 24 h post mortem legs from both sides of the carcasses were separated and, finally, at 48 h postmortem the *Biceps femoris* and *Quadriceps femoris* muscles were removed from each leg.

2.2. Meat packaging, storage, and sampling procedure

B. femoris and *Q. femoris* muscles from right and left sides were weighed and then randomly assigned to two groups of ten muscles (for each feeding treatment) on the basis of parity (5 right-sided and 5 left-sided muscles per group). The muscles of one group (control) were not aged. The muscles of the other group (vacuum aged; VA) were individually vacuum aged under simulated retail conditions: using a 150-μm plastic film with oxygen permeability of 30 $cm^3/(m^2 \times bar \times 24\ h)$, at 23 °C and 0% relative humidity, and then stored refrigerated in darkness at 4 ºC for 21 days. Both control muscles (just after dissection) and VA muscles (just after storage) were sliced and displayed as further described below. Analysis of pH, weight loss, color and sensory analysis (visual score) were carried out on the slices obtained at different displaying times.

Each *B. femoris* muscle was cut into three sections perpendicular to the long axis: proximal (1.5 cm), central (the largest, 12 cm approximately) and distal (1.5 cm) sections. Afterwards, four steaks (2.5-cm thick) were cut from the central section and weighed. The steaks were randomly placed in polypropylene trays, covered by an 8.5-μm polyvinylchloride film (oxygen and water permeability of 4000 cm^3 and 140 g per m^2, bar and 24 h). The trays were then stored under simulated retail display conditions: at 4 °C for 14 days, while exposed to a light source (12 h per day) provided with twin linear fluorescent tubes (34 W) placed at a distance of 1 m from the trays. At days 1, 3, 7 and 14 of display one of the steaks was sampled, weighed and kept frozen (−50 ºC) until further analysis (aldehyde content). Moreover, visible subcutaneous and intermuscular fat was removed from the proximal section of the *B. femoris* muscle, which was then frozen for further analysis of moisture and fat content.

Each *Q. femoris* muscle was cut following the same procedure as described for *B. femoris* muscles, and proximal and distal sections were discarded. The four steaks obtained from the central section were packaged in trays and stored refrigerated under the same conditions as those described for *B. femoris* muscles. At days 1, 3, 7 and 14 of display one of the steaks was sampled, and then used for immediate analysis (pH, color and sensory analysis).

2.3. Meat analysis

Moisture and intramuscular fat content was determined in meat samples (distal portion of control *B. femoris* muscles) following the methods recommended by the AOAC (AOAC, 1999) — Official methods nos. 950.46 and 991.36, respectively. The pH value was determined in duplicate directly on the meat steaks (*Q. femoris*) using a pH meter (Model GLP 22, Crison, Barcelona, Spain) equipped with a puncture electrode (Model 52-32; Crison). Weight loss during display was calculated as follows: $[(W_1 - W_2)/W_1] \times 100$, where W_1 are the weight of the steak (*B. femoris*) at day 1 and W_2 is the weight at the sampling day (day 3, 7 or 14). Before analyzing the aldehyde content, the steaks of meat (*B. femoris*) were cooked in a double-sided griddle (preheated at 220 °C) until a core temperature of 75 °C following the guidelines for cooking procedures of AMSA (1995). The cooked steaks were minced in a food processor. Five grams of sample, 4.7 ml of water and 0.07 g of NaCl were then placed in 20-ml vials, sealed with magnetic screw caps with silicone/PTFE septa (Agilent Technologies), and the vials were placed in a tray for analysis. Volatile aldehydes content (hexanal, heptanal, octanal and nonanal) was determined by static headspace-gas chromatography in a 7890A gas chromatograph (Agilent Technologies, Santa Clara, CA, USA) coupled to a MSD 5975 C5975 mass spectrometry (Agilent Technologies, Santa Clara, CA, USA). The chromatographic and mass detection operation conditions were those described by Vieira et al. (2012). The identification and quantification of the aldehydes were carried out using standard solutions (aldehyde standards from Sigma-Aldrich, Madrid, Spain, diluted in hexane) which were injected in the chromatograph and analyzed under the same conditions as the samples.

Instrumental color determinations were carried out in triplicate at three selected locations directly on the cut surface of steaks (*Q. femoris)*, using a portable spectrophotometer CM-700d (Konica Minolta Sensing Inc., Osaka, Japan) operating with a D65 illuminant, SCI mode, 11 mm aperture for illumination and 8 mm for measurement, and 10° visual angle. Previously to the measurement the day-1 steak, meat was allowed to bloom for 60 min at room temperature after cutting. Results were expressed as lightness (L^*), redness (a^*) to yellowness (b^*) ratio (a^*/b^*), chroma (C^*) $[(a^{*2} + b^{*2})^{1/2}]$, hue angle ($H^*$) $[\tan^{-1}(b^*/a^*) \times (180/\pi)]$ and total color change of 3-, 7- and 14-day displayed meat with respect to day 1 of display (ΔE^*) $[(L^*_{day\ n} - L^*_{day\ 1})^2 + (a^*_{day\ n} - a^*_{day\ 1})^2 + (b^*_{day\ n} - b^*_{day\ 1})^2)]^{1/2}$ (with n = 3, 7 or 14), in order to study change of color due to treatments (AMSA, 2012). Afterwards, a visual sensory evaluation was carried out