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Slaughter performance and carcass and meat quality of Bergamasca light lambs according to slaughter age

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ABSTRACT

This study was designed to evaluate the effects of slaughter age (40 vs. 60 days) on slaughter performance, carcass and meat quality, and fatty acid composition of intramuscular and subcutaneous fat of Bergamasca lambs reared according to the traditional transhumant system in central Italy. Lambs slaughtered at 60 days of age had higher carcass weight (12.44 vs. 10.36 kg), lower dressing percentage (47.68% vs. 52.16%), and higher proportion of non-carcass components and leg commercial cut (37.82% vs. 35.49%). Furthermore, after 3 and 6 days of storage, the meat of older lambs showed lower drip loss (3.69% vs. 6.16%; 5.73% vs. 9.36%, respectively). Slaughter age did not influence meat pH, cooking loss, or chemical composition while older lambs had meat with higher a* (19.43 vs. 18.91). The fatty acid composition of intramuscular fat was not affected by slaughter age, except for C:13 and C:14 fatty acids, which were higher in older lambs. Subcutaneous fat of lambs slaughtered at 40 days of age showed a better fatty acid profile, as lower saturated fatty acids (52.46% vs. 55.68%) and higher mono- and polyunsaturated fatty acids (34.06% vs. 30.16%, 6.46% vs. 5.79%, respectively), and n-6 and n-3 polyunsaturated fatty acids. Furthermore, subcutaneous fat of lambs slaughtered at 40 days of age had better polyunsaturated/saturated fatty acid ratio (0.12 vs. 0.11) and hypocholesterolemic/hypercholesterolemic ratio (1.42 vs. 1.03), and lower atherogenic index (1.32 vs. 1.82) and thrombogenic index (1.98 vs. 2.35). For light lamb production using the traditional rearing systems, slightly heavier lambs can be produced without worsening chemical composition and cooking loss and fatty acid composition of the *longissimus lomborum* muscle. However, lambs slaughtered at 60 days of age had lower dressing percentages and higher SFA amount of the subcutaneous fat than lambs slaughtered at 40 days.

1. Introduction

Traditional lamb production in Mediterranean countries is based on light lambs that are slaughtered at early ages (i.e., at 30–60 days of age), so just after weaning or after a short fattening period (Juárez et al., 2009; Santos-Silva et al., 2002a). These carcasses weigh up to 13 kg and are characterised by their pale pink colour, lower amounts of fat, and good flavour (Beriain et al., 2000), compared to heavier carcasses produced in other production systems and countries (Ekiz et al., 2013; Hajji et al., 2016; Jacques et al., 2011; Lind et al., 2009; Piasentier, 2003; Priolo et al., 2002).

In recent years, the demand for lean carcasses has grown due to increased awareness of consumers for healthy meat, with a focus on the quantity and quality of fat (Font i Fournols and Guerrero, 2014). Scientific studies and nutritional guidelines recommend not only a reduction in total fat intake in the human diet, but also a focus on saturated fatty acids (SFAs) and increased consumption of polyunsaturated fatty acids (PUFAs), and especially n-3 PUFAs (Calder and Yaqoob, 2009; World Health Organisation, 2003).

The age and weight of lambs at slaughter are among the main factors that affect the meat quality at both levels, in terms of the carcass and the meat. A greater weight usually implies an older lamb, except when the feed is manipulated or the lamb has periods of specific alimentary restrictions (Guerrero et al., 2013). Although greater slaughter age of lambs results in heavier carcasses, increased adiposity and better carcass conformation (D'Alessandro et al., 2013; Juárez et al., 2009), this can also result in increased intramuscular fat (Abdullah and Qudsieh, 2009; della Malva et al., 2016; Pérez et al., 2002). Furthermore, lambs slaughtered at a greater age can have more SFAs, less PUFAs and n-3 PUFAs, and increased atherogenic and thrombogenic indices (Cifuni et al., 2000; Marino et al., 2008; Santos-Silva et al., 2002b).

These aspects are of the utmost importance for the definition of strategies to enhance the production of lamb meat while also taking into consideration the market demand. In this sense, there are significant gaps of knowledge for lamb produced under quality labels, such

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as the Protected Geographical Indication of '*Agnello del Centro Italia*' (Lamb from Central Italy; European Union, Commission Regulation No. 475/2013). This can be produced using Bergamasca sheep, as well as some other sheep breeds.

Bergamasca sheep are an autochthonous Italian breed that originated from the Lombardy region (northern Italy) and that are traditionally raised according to the transhumant system (Piasentier, 2003). Nowadays, Bergamasca sheep are raised principally for meat in most parts of continental Italy (Bigi and Zanon, 2008), and they are often used for cross-breeding with other to improve meat yield. Male and female Bergamasca sheep can reach adult weights of 105 kg and 82 kg, respectively. In the Lombardy region, Bergamasca sheep are still the most important breed used to produce castrated, heavy and light lambs, as the traditional products of transhumant management (Piasentier, 2003).

In the Marche region (central Italy), lamb production is mainly based on extensive grazing and the transhumance is still of major importance. In summer, most of the flocks graze on upland pastures. Starting from autumn, the sheep are progressively transferred to lowlands, where until spring the main forage resources are lucerne meadows, although green cereals, crop residues, marginal lands, and riverbanks are sometimes also used (Caballero et al., 2009; D'Ottavio and Santilocchi, 2014). Lamb production mainly occurs in the lowlands for the Easter and Christmas markets, which is when lamb meat is traditionally consumed in Italy (Cifuni et al., 2000). Lambs are reared on pastures with their dams until they reach the optimal slaughter weight, which according to local practices starts from 40 days of age. The lambs are not weaned so their diet is mostly based on milk (i.e., to 20 days of age), while later they are supplemented with concentrate and/or hay, as needed.

The effects of slaughter age on the quality of light lamb meat has been studied for some Italian breeds, such as the Altamurana (della Malva et al., 2016; Marino et al., 2008), Apulian (Cifuni et al., 2000), Leccese (D'Alessandro et al., 2013), Trimeticcio (Marino et al., 2008) and Italian Merino (Oriani et al., 2005) sheep. However, there is little or no such information available for the lamb meat quality of the Bergamasca breed of sheep.

The aim of the present study was to evaluate the effects of slaughter age on slaughter performance, carcass traits and meat quality, including FA composition of intramuscular and subcutaneous fat, of Bergamasca light lambs reared under the traditional transhumant system of the Marche region of Italy.

2. Materials and methods

All animal handling followed the recommendations of European Union Directive 2010/63/EU, which are implemented in Italian law according to Legislative Decree No. 26/2014.

2.1. Experimental design, diet and animal management

This study was carried out from September to November 2015 in the Marche region (central Italy) under the standard conditions for rearing and management of the transhumant sheep system that is characteristic for this region. Twenty-two male, single-born, Bergamasca lambs were included in the study. At birth, the lambs were randomly distributed into two groups that were balanced for body weight. All of these lambs stayed with their dams on grasslands dominated by alfalfa (10.3 MJ metabolisable energy kg^{-1} dry matter [DM], 15.7% crude protein DM, 28.5% crude fibre DM), and suckled their dams throughout the whole study period. The dams grazed and had free access to alfalfa hay (11.8 MJ metabolisable energy kg^{-1} DM, 15.2% crude protein DM, 22.3% crude fibre DM) and their diet was supplemented with corn grain (0.5 kg $head^{-1}$ day^{-1}; 16.5 MJ metabolisable energy kg^{-1} DM, 7.9% crude protein DM, 5.0% crude fibre DM). The lambs had access to alfalfa hay and from 20 days of age were given corn grain ad libitum in creep feeders. The chemical compositions of collected feed samples were determined according to Martillotti et al. (1987). To calculate the average daily gain (ADG), the individual lamb weights were recorded at birth and after each 20 days, until slaughter. The lambs were slaughtered at two different ages: 11 lambs at an average of 40 days, and the other 11 lambs at an average of 60 days.

2.2. Slaughter procedure and assessment of carcass traits

To obtain the pre-slaughter weight, the lambs were weighed on the farm and soon after being transferred to a commercial slaughterhouse, where they were stunned and slaughtered by cutting the jugular vein. After the slaughter, the non-carcass components were removed and weighed (i.e., skin, head, feet, pluck [heart, lungs, liver, spleen], digestive tract). After chilling at 4 °C for 24 h, the cold carcass weights were recorded, and the dressing percentages were calculated. The right side of each carcass was jointed into three main commercial cuts: shoulder, whole loin with flank, and leg. The weights of each commercial cut were recorded and are expressed as proportions of the half carcass weight. For further analyses, the *longissimus lomborum* muscles between the first and sixth lumbar vertebrae were obtained.

2.3. Meat quality parameters

The pH of the *longissimus thoracis* muscle (between the tenth and thirteenth thoracic vertebrae) was measured 45 min and 24 h (final pH) *post-mortem* using a portable pH meter (XS pH 110; Eutech Instruments, Singapore) equipped with a penetrating glass electrode.

The drip loss and cooking loss were determined on approximately 80 g of 3-cm-thick *longissimus lumborum* muscle. To measure the drip loss (ASPA, 1996), the meat samples were weighed and wrapped in polyethylene bags. After 24 h storage at 4 °C, the samples were gently dried with paper towels, and reweighed. This procedure was carried out as two replications, and was repeated for the third and the sixth days of storage. For cooking loss determination (ASPA, 1996), the meat samples were initially weighed, and then placed in polyethylene bags and cooked in a water bath until they reached an internal temperature of 75 °C. The bags with the cooked meat samples where than cooled under cold running water for 30 min, and then they were removed from the bags, dried with paper towels, and reweighed.

The meat colour was assessed according to the CIELAB system (CIE, 1986), as the lightness (L*), redness (a*) and yellowness (b*) of the *longissimus lumborum* muscle were recorded for the fresh meat (~24 h *post-mortem*) using Minolta CR 200. A D65 illuminant was used at an observation angle of 10° and with an aperture of 30 mm. The instrument was calibrated using white standard coordinates. Chroma (C*) value and hue angle (H°) were calculated as $(a^{*2} + b^{*2})^{1/2}$, and $\tan^{-1}(b^*/a^*) \times 180/\pi$ (Luciano et al., 2009), respectively. For each meat sample, three colour measurements and calculations were performed for each parameter, and the means are reported. After the colour measurements were performed, the meat samples were frozen (–20 °C), freeze-dried, ground and analysed for their chemical composition. The procedures outlined by the AOAC (1999) were used to determine the DM (method ID 950.46), Kjeldahl N (crude protein; method ID 981.10), fat (method ID 991.36) and ash (method ID 920.153). Analyses were performed in duplicate for each sample, and the parameters and data are corrected for moisture content.

2.4. Fatty acid analysis

The FA composition analysis was performed on freeze-dried samples of *longissimus lomborum* muscle (i.e., intramuscular) fat and subcutaneous fat. The fat was extracted using a Soxtec system with petroleum ether (boiling point range, 40–60 °C). The oven temperature for both the pre- and post-extraction drying was within the temperature range suggested by Foss for use with the Soxtec system, as 102 ± 3 °C