Meat Science 93 (2013) 906–913

Contents lists available at SciVerse ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Effects of finishing period length with vitamin E supplementation and alfalfa grazing on carcass color and the evolution of meat color and the lipid oxidation of light lambs

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ARTICLE INFO

Article history:
Received 28 May 2012
Received in revised form 20 September 2012
Accepted 22 September 2012

Keywords:
Alpha-tocopherol
Shelf life
TBARS
Supplementation
Heminic pigment

ABSTRACT

Indoor-kept concentrate-fed light lambs (n = 54) were supplemented with 500 mg of dl-α-tocopheryl acetate/kg concentrate for 0, 10, 20 and 30 d before slaughtering at 22–24 kg BW. Simultaneously, 8 lambs with their dams were alfalfa-grazed and the lambs were slaughtered at the same weight. The age at slaughter and carcass characteristics were more affected by grazing than by supplementation with α-tocopherol. The grazing lambs had similar α-tocopherol levels to the lambs fed concentrate with dl-α-tocopheryl acetate for 10 days before slaughter. The length of the feeding period affected the evolution of the color, delaying the blooming and discoloration of the meat. Feeding lambs α-tocopherol enriched concentrate during the last 10 days of life or grazing them on alfalfa drastically diminished the lipid oxidation of the meat. Alfalfa grazing is a feasible alternative to increase light lamb meat shelf life without using additives.

1. Introduction

One of the most important qualities influencing consumers' decisions to purchase meat is the cherry red color (Mancini & Hunt, 2005). Brown meat often cannot be sold at the full retail price, resulting in an economic loss. This browning of meat is caused by the oxidation of the muscle heme pigment, from the red oxymyoglobin to the brown metmyoglobin form (Jose, Pethick, Gardner, & Jacob, 2008b). To avoid this process, an antioxidant should be incorporated into cell membranes, increasing the meat's stability (Kerry, Buckley, Morrissey, O'Sullivan, & Lynch, 1998). Therefore, the addition of antioxidants has emerged as a strategy for increasing the commercial value of meat. To increase meat's shelf life, antioxidants can be added directly to the meat, although doing so might not be acceptable to consumers (Resconi, 2007), or antioxidants can be added to the animals' diets. The composition of the diet is one of the most effective routes by which to inhibit lipid oxidation in animal fat (Wulf et al., 1995).

One of the most widely used antioxidants in animal diets is vitamin E, which retards lipid oxidation and drip losses and provides color stability (López-Bote, Daza, Soares, & Berges, 2001). Muscle cell membranes are composed of polyunsaturated fatty acids, which are particularly susceptible to peroxidation during storage (Kanner, 1994). Vitamin E is an antioxidant that is not degraded in the rumen (Leedle, Leedle, & Butine, 1993) but rather is deposited in muscle cell membranes and lipid depots (Liu, Lanari, & Schaefer, 1995). Thus, dietary supplementation with vitamin E in lambs increases the amount of α-tocopherol deposited in the muscle and fat tissues (Jensen, Lauridsen, & Bertelsen, 1998).

There have been several experiments that evaluated the effects of increasing dietary α-tocopherol concentrations during the whole finishing period of lambs (Lauzurica et al., 2005; Wulf et al., 1995). López-Bote et al. (2001) reported that the optimum level to delay meat deterioration would be in the range from 5.3 to 5.6 mg α-tocopherol/kg muscle, which corresponds to a dietary inclusion of 550 to 625 mg α-tocopheryl acetate/kg diet. Turner, McClure, Weiss, Borton, and Foster (2002) predicted that the maximum *longissimus dorsi* α-tocopherol concentrations resulted at an intake of approximately 584 IU of total vitamin E/d suggesting that supplementation greater than that amount did not affect α-tocopherol concentrations in the muscle.

Despite the benefits of vitamin E, enriched concentrate is expensive and can result in an increase of more than 2.5% in costs (Albertí, 2012). Therefore the use of enriched concentrates over the whole lamb-finishing period, can incur unnecessary costs in achieving the α-tocopherol muscle concentrations needed to delay muscle discoloration and lipid oxidation. As yet, there have been no studies regarding the different finishing periods using the same vitamin E-supplemented concentrate. In addition, most studies on vitamin E have involved lambs heavier than 30 kg live weight (LW) and feeding periods longer than 6 weeks (Ponnampalam, Butler, McDonagh, Jacobs, & Hopkins, 2012; Wulf et al., 1995). Heavy and old lambs have more intramuscular fat than light lambs of the same breed fed in the same way (Okeudo & Moss, 2007). Because α-tocopherol is a liposoluble vitamin, more vitamin E is expected to be in the muscle of marbled lambs than in the muscle of leaner lambs.

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0309-1740/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.meatsci.2012.09.017

In many Mediterranean areas, lambs are kept indoors and fed concentrate and straw, avoiding the use of forage. However, grazing is a good option for increasing α-tocopherol muscle content, as green forages are rich in this compound. Numerous studies have shown that animals finished on pastures have higher levels of α-tocopherol in their meat than those fed high-concentrate diets (Jose et al., 2008b; Turner et al., 2002; Yang, Brewster, Lanari, & Tume, 2002)

The first objective of this study was to study the influence of finishing period length with concentrates enriched with α-tocopherol on the shelf life of light lamb meat. In addition, the effectiveness of the grazing of ewes on alfalfa pastures, on the meat stability of their lambs, compared to that of indoor-kept lambs fed enriched concentrates was determined.

2. Material and methods

2.1. Animals and diets

Fifty-four single reared male lambs of the Rasa Aragonesa breed were weaned at 49 d ± 1.61 days of age and then fed a basal concentrate (Control (C); 185 g crude protein (CP)/kg dry matter (DM), 190 g of neutral detergent fiber (NDF)/kg DM and 13.22 megajoules (MJ)/kg DM and 30 mg dl-α-tocopheryl acetate/kg of concentrate). According to the treatment, this concentrate was replaced with another concentrate with the same characteristics but enriched with 500 mg of dl-α-tocopheryl acetate/kg concentrate (VE) several days before the lambs reached their target slaughter weight (22–24 kg). The experimental treatments (Fig. 1) were as follows:

- Treatment C: the lambs received basal concentrate from weaning to slaughter (n = 12);
- Treatment VE10d: the lambs received basal concentrate from weaning to 10 d before slaughter; then, concentrate supplemented with 500 mg dl-α-tocopheryl acetate/kg was used until slaughter (n = 14);
- Treatment VE20d: the lambs received basal concentrate from weaning to 20 d before slaughter; then, concentrate supplemented with 500 mg dl-α-tocopheryl acetate/kg was used until slaughter (n = 14); and
- Treatment VE30d: the lambs received basal concentrate from weaning to 30 d before slaughter; then, concentrate supplemented with 500 mg dl-α-tocopheryl acetate/kg was used until slaughter (n = 14);

Additionally, another group of animals (8 ewes and 8 lambs) was continuously grazed on alfalfa pasture (Treatment A). The vitamin E content of the alfalfa was 11.5 mg ± 1.6 mg/kg alfalfa DM. No concentrate was available to the dams. Lambs suckled their mothers, grazed and received the same basal concentrate (C) *ad libitum* as their indoor counterparts in lamb creep feeders until slaughter at their target slaughter weight (22–24 kg). The grazing and indoor ewes came from the same experimental flock of CITA. The ewes were mated during the same period and had similar ages, body condition scores and parities.

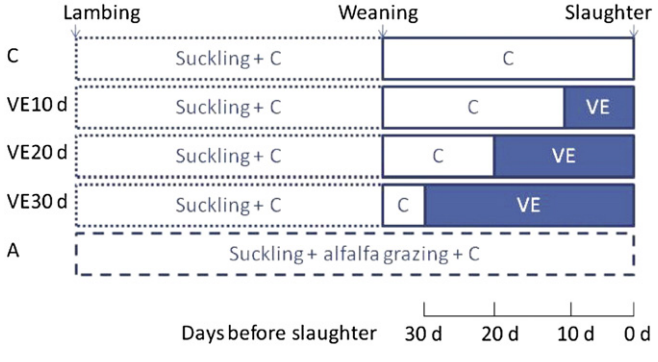

Fig. 1. Schematic representation of experimental treatments. C, *ad libitum* standard concentrate with a basal dose of dl-α-tocopheryl acetate (30 mg dl-α-tocopheryl acetate/kg of concentrate) and *ad libitum* barley straw. VE, *ad libitum* supplemented concentrate (530 mg dl-α-tocopheryl acetate/kg of concentrate) and *ad libitum* barley straw. Weaning at 49 d ± 1.61 days of age. Slaughter at fixed weight of 22–24 kg of live weight.

At weekly intervals all of the lambs were weighted at 8:00 a.m. and when they reached 22–24 kg LW, were slaughtered in the experimental slaughterhouse of the CITA (Centro de Investigación y Tecnología Agroalimentaria de Aragón) in Saragossa. The slaughter was conducted weekly between 08:00 and 09:00 a.m. without a fasting period and according to the specifications of Ternasco de Aragón Protected Geographical Indication (Regulation (EC) No. 1107/96), which stipulate that lambs weigh 22 to 24 kg LW and are younger than 90 days old. The experimental and slaughter procedures used met the guidelines of Council Directive 86/609/EEC (European Communities, 1986) on the protection of animals used for experimental and other scientific purposes. The carcasses were hung by the Achilles tendon and were chilled for 24 h at 4 °C in total darkness to preserve the carotenoid pigments.

2.2. Preparation of samples and packaging

After chilling, the M. *longissimus thoracis et lumborum* was extracted from the carcass and sliced. A piece from the 4th to the 6th lumbar *vertebrae* was used for α-tocopherol analysis. The portion of loin from 7th to 13th thoracic vertebrae was sliced into 4 samples 2.5 cm thick. These samples were randomly assigned to 4 trays (0, 2, 5 or 7 d of storage), wrapped with oxygen-permeable PVC film and kept in darkness at 4 °C until color measurement. The 0 d samples were bloomed for 1 h before being measured. Immediately after the color measurement, the samples were frozen (−20 °C) until TBARS analysis.

2.3. Instrumental meat and fat color

The instrumental color of the *Longissimus thoracis*, the *Rectus abdominis* and the fat was measured using a Minolta CM-2006d spectrophotometer (Konica Minolta Holdings, Inc., Osaka, Japan) in the CIELAB space (CIE, 1986) with a measured area diameter of 8 mm, including specular component and a 0% UV, standard illuminant D65, which simulates daylight (color temperature 6504 K), observer angle 10° and zero and white calibration. The lightness (L*), redness (a*) and yellowness (b*) were recorded, and the hue angle (H*) and chroma (C*) indices were calculated as $H^* = \tan^{-1}(b^*/a^*) * 57.29$, expressed in degrees, and $C_* = \sqrt{a*^2 + b*^2}$. In addition to these parameters, the fat reflectance *spectra* of the *Longissimus thoracis* and caudal subcutaneous were collected from 400 nm to 700 nm at every 10 nm.

Longissimus thoracis samples were placed above a white tile and were measured twice, and then, the measurements were averaged.

Caudal subcutaneous fat from the tail root was measured from three locations that were randomly selected but avoiding blood blots, discolorations and less covered areas. In addition to trichromatic coordinates, the absolute value of the integral of the translated spectrum (SUM) was calculated according to Prache and Theriez (1999). The reflectance spectra were translated to make reflectance value at 510 nm equal to zero (TR). With the translated *spectra*, the integral values were calculated as follows:

$$SUM = (TR_{450}/2 + TR_{460} + TR_{470} + TR_{480} + TR_{490} + TR_{500} + TR_{510}/2) \times 10$$

where TRi was the reflectance value at i nm.

The *Rectus abdominis* muscle color was measured at two locations on the internal face of each piece; these locations were randomly selected to obtain a mean value with a representative reading of the surface color, after having removed the covering fascia (Carrasco, Panea, Ripoll, Sanz, & Joy, 2009). A white tile placed behind the muscle was used to standardize the measurements.