Meat Science 95 (2013) 212–218

Contents lists available at SciVerse ScienceDirect

Meat Science

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

The effect of the change from a herbage- to a concentrate-based diet on the oxidative stability of raw and cooked lamb meat

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ARTICLE INFO

Article history:
Received 13 December 2012
Received in revised form 22 March 2013
Accepted 10 May 2013

Keywords:
Lamb meat
Lipid oxidation
Colour
Finishing diet
Pasture
Fatty acids

ABSTRACT

Over 89 days, 10 lambs (S) were fed concentrates and hay in stall, while 9 lambs (P) grazed at pasture. Two groups of 9 animals grazed at pasture until switching to a concentrate-based diet for 14 or 37 days before slaughter (P-S14 and P-S37). The fat content of *longissimus dorsi* muscle (LM) increased with increasing duration of concentrate feeding ($P = 0.05$). As a consequence, the concentration of polyunsaturated fatty acids (PUFA) and of the highly peroxidisable (HP) PUFA in the polar lipids was similar between treatments. Lipid oxidation in fresh LM over 8 days of storage was affected by the diet ($P < 0.0005$) with the P-S37 and P treatments producing, respectively, the highest and the lowest TBARS values. The P treatment reduced TBARS in cooked minced LM over 2 days of storage and no difference was found between the P-S14, P-S37 and S treatments. Colour stability of fresh LM was not noticeably affected by the dietary treatment.

1. Introduction

One of the main challenges in marketing meat is the retention of quality during storage and retail display by delaying the oxidative deterioration of muscle components, such as lipids and myoglobin, which compromises the sensory and nutritional quality (Faustman, Sun, Mancini, & Suman, 2010). The exogenous addition of antioxidants to the meat or the adoption of opportune packaging systems are used to delay the oxidative processes in meat (Balasundram, Sundram, & Samman, 2006; McMillin, 2008). On the other hand, the inherent oxidative stability of meat may vary depending on the dietary background of the animals because the balance between pro-oxidant and antioxidant components in muscle can be strongly affected by the diet (Descalzo & Sancho, 2008). Polyunsaturated fatty acids (PUFA) in the phospholipid fraction of cell membranes are highly oxidizable substrates and may act as pro-oxidants, while antioxidant molecules of dietary origin may contribute to meat oxidative stability (Morrissey, Sheehy, Galvin, Kerry, & Buckley, 1998).

For ruminants, extensive feeding systems based on pasture generally promote the deposition of highly unsaturated PUFA in muscle, but provide higher levels of dietary antioxidants compared to diets based on concentrate feeds (Wood & Enser, 1997). For this reason, pasture-based diets confer on the meat a superior oxidative stability compared to diets based on concentrates only (Luciano et al., 2012). While most of the muscle antioxidant defences can remain active in fresh meat, cooking represents a significant deteriorative stress which impairs meat oxidative stability (Alfaia et al., 2010). Although little information has been provided on the effect of the animal diet on the oxidative stability of cooked meat, it has been demonstrated that diets based exclusively on pasture decrease lipid oxidation in cooked meat and the occurrence of oxidation-derived off-flavours compared to grain-based diets (Luciano et al., 2009; Tansawat, Maughan, Ward, Martini, & Cornforth, 2013). However, in the Mediterranean environment, the availability of herbage is uneven and limited to rather short seasons (Vasta et al., 2012). Therefore, a number of intermediate solutions between exclusively pasture-based or concentrate-based feeding systems are adopted for ruminants. For example, animals raised on pasture often receive supplemental concentrates or, in other instances, animals initially grown at pasture are subsequently finished on concentrates in stall. However, such modifications in the composition of the diet can alter the balance between pro-oxidants and antioxidants in muscle, with a possible impact on meat oxidative stability (Luciano et al., 2011; O'Sullivan et al., 2003).

In lambs, it has been clearly demonstrated that a finishing period on concentrates in stall after a growing period on a diet based on herbage at pasture can modify the fatty acid composition of intramuscular fat. Particularly, long finishing periods on concentrate-based diets are able to mask the effects of the preceding growing phase at pasture,

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0309-1740/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.meatsci.2013.05.015

resulting in a fatty acid composition of intramuscular lipids similar to that obtained by feeding animals exclusively with concentrates (Aurousseau, Bauchart, Faure, et al., 2007; Aurousseau, Bauchart, Galot, et al., 2007). However, very limited information with the effects of the change from a pasture- to a concentrate-based diet on meat oxidative stability has been provided. For example, Franco, Bispo, González, Vázquez, and Moreno (2009) studied the effect of finishing cattle on concentrates after a period spent at pasture on the oxidative stability of vacuum-packaged beef over time. Nevertheless, removal of the atmosphere by vacuum packaging effectively limits the oxidation of lipids, while maintaining myoglobin in its deoxygenated form (McMillin, 2008). Moreover, no studies have investigated the effect of a finishing diet on concentrates after a pasture-based diet on the oxidative stability of cooked meat. Therefore, it would be of interest to study the effect of such feeding systems on the oxidative stability of fresh or cooked meat stored aerobically or in modified atmosphere, conditions in which lipid and myoglobin oxidation are promoted.

Recently the fatty acid composition of intramuscular fat from lambs fed exclusively concentrates in stall or grass at pasture, or finished on concentrates in stall for a short or a long period after a previous phase on a pasture-based diet were studied (Scerra et al., 2011). Using the same lambs of that study, the objective of the present experiment was to assess, for the first time, the effect of the change from a pasture to a concentrate-based diet on the oxidative stability of raw and cooked lamb under aerobic storage.

2. Materials and methods

2.1. Animals and dietary treatments

The detailed description of the experimental design was provided by Scerra et al. (2011). Briefly, 37 single male Italian Merino lambs were divided into 4 groups at 60 days of age. For 18 days lambs were adapted to the experimental diets by gradually replacing the weaning concentrate with oat hay and the experimental diet. Over 89 days of the experimental period, 10 lambs (group S) were individually penned indoors and were fed a barley/chickpea-based concentrate and oat hay in a ratio of 80:20 on an as fed basis. Nine lambs (group P) were allowed to graze at pasture for 7 h during the day and, at night, were kept in stall in multiple boxes without any feed supplementation. The remaining 18 lambs were divided into two groups of 9 animals each and were initially raised at pasture as the P group until their switching to the same treatment as the S group for 14 or 37 days before slaughtering (groups P-S14 and P-S37, respectively). The duration of the pasture and concentrate feeding for each group during the experimental period is depicted in Fig. 1.

All the animals were weekly weighed and feed allowances for the concentrate-fed lambs were adjusted to obtain similar growth rates as the pasture-fed animals. Water was freely available in the stall.

2.2. Slaughter procedures and muscle sampling

After slaughtering, the carcasses were stored at 4 °C. Following 24 h of refrigerated storage, carcasses were halved and the pH of the *longissimus dorsi* muscle (LM) of the left side was measured using an Orion 9106 pH-meter in the region of the 13th rib. Subsequently, the LM was excised between the 6th thoracic and the 4th lumbar vertebrae and divided into three portions of approximately 80g each. Two portions were immediately vacuum-packaged and stored at −30 °C for analyses of the intramuscular fatty acid composition and of lipid oxidation in cooked minced meat (performed two weeks later). The remaining portion was vacuum packaged, delivered to the laboratory and stored at 4 °C for 24 h for the determination of lipid oxidation and colour stability in fresh raw muscle slices. The detailed description of sample preparation and analytical procedures is provided below.

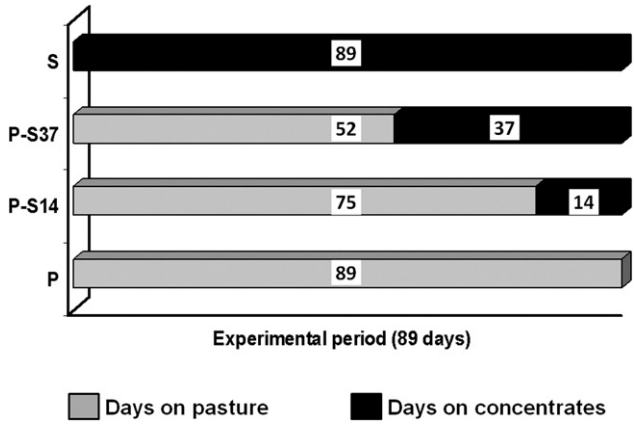

Fig. 1. Time (number of days) on concentrates and/or pasture feeding for lambs in the 4 dietary treatments over the 89 days experimental period. Treatments were: concentrates and hay for the entire duration of the trial (S); pasture for the entire duration of the trial (P); initial pasture-based diet followed by a concentrate-based diet in stall for 37 or 14 days (P-S37 and P-S14, respectively).

2.3. Extraction of intramuscular lipids and separation into polar end neutral lipids

Total intramuscular lipids (TL) were extracted using a chloroform/methanol solution (2:1, v/v), according to Folch, Lees, and Sloane Stanley (1957) as modified by Rodriguez-Estrada, Penazzi, Caboni, Bertacco, and Lercker (1997). An aliquot of the extracted TL was used for separation of the neutral (NL) and polar (PL) lipids according to Juaneda and Roquelin (1985) using Sep-Pak® silica cartridges (Waters, Milford-Massachusetts, USA). Briefly, 30 mg of lipid sample were applied to solid-phase extraction cartridges (360 mg sorbent per cartridge, 55–105 μm particle size) previously conditioned with chloroform. The NL fraction was eluted with 20 mL of chloroform and collected. Then the cartridges were washed with 5 mL of chloroform/methanol solution (49:1, v/v), the PL fraction was eluted with 30 mL of methanol and collected. The NL and PL fractions were dried to constant weight and then dissolved in toluene for preparation of fatty acid methyl esters (FAMEs).

2.4. Fatty acid analysis of intramuscular lipid fractions

For each lipid fraction (i.e. TL, NL and PL), FAMEs were prepared according to Christie (1982) and, before methylation, C9:0 and C23:0 FAMEs were added as internal standards. The FAMEs were analysed according to Serra et al. (2009) using a gas-chromatograph (GC) equipped with a flame ionization detector (FID; ThermoQuest, Milan, Italy) and a high polar fused silica capillary column (WCOT fused silica CP-Select CB for FAME Varian, Middelburg, Netherland; 100m × 0.25 mm i.d.; film thickness 0.25 μm). Helium was used as the carrier gas at a flow of 1 mL/min. The split ratio was 1:80. The GC conditions were as follows: the oven temperature was programed at 150 °C and held for 1 min, then increased to 175 °C at 0.8 °C/min, held for 14 min, then increased up to 188 °C at 2 °C/min, held for 18 min, and then increased up to 230 °C at 2 °C/min, held for 13 min. The injector and detector temperatures were 270 °C and 300 °C, respectively. A mixture of 52 component FAME Mix (Nu-Chek Prep. Inc., Elysian, MN, USA) and 77 individual FAME standards (Larodan Fine Chemicals, Malmo, Sweden) were used for the identification of individual FAMEs. For each fatty acid, the response factors to flame ionization detector and inter- and intra-assay coefficients of variation were calculated using a reference standard, butter (CRM 164, Community Bureau of Reference, Brussels, Belgium).

Individual fatty acids (FA) were expressed as mg/g of fresh muscle and polyunsaturated fatty acids (PUFA), as well as highly peroxidisable