Available online at www.sciencedirect.com
ScienceDirect
Meat Science 76 (2007) 715–720
MEAT SCIENCE
www.elsevier.com/locate/meatsci

Lipid oxidation in lamb meat: Effect of the weight, handling previous slaughter and modified atmospheres

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Received 19 June 2006; received in revised form 9 February 2007; accepted 16 February 2007

Abstract

This study examined the effect of pre-slaughter handling (electrical, gas (CO_2) or non-stunning) on lipid oxidation (as thiobarbituric acid reactive substances, TBARS; in the unit of mg malondialdehyde/kg^{-1} of meat) of Spanish Manchega breed lamb meat, at 24 h and at 7 days post-mortem. Lambs were slaughtered at two different weights (light (L), 25 kg, *vs.* suckling (S), 12.8 kg). In general gas-stunned lambs had lower lipid oxidation ($P < 0.001$), and it was higher ($P < 0.001$) in light lambs compared to suckling lambs. In both groups (S and L), malondialdehyde level increased with time ($P < 0.001$), although this increase was lower ($P < 0.05$) in gas-stunned suckling lambs.

In addition, we evaluated the effect of stunning methods (TS: electrical *vs.* gas) and the weight (L *vs.* S) on lipid oxidation values in samples packed in different types of modified atmosphere (MA: A: $70\%O_2 + 30\%CO_2$; B: $69.3\%N_2 + 30\%CO_2 + 0.7\%CO$; C: $60\%N_2 + 40\%CO_2$) at 7, 14 and 21 days post-packing. Values were higher in samples with MA-type A and lower in B and C types ($P < 0.05$). A significant interaction ($P < 0.001$) weight × TS was observed and the lowest rates of TBARS were found in the samples of light lambs stunned with gas and packed under anaerobic conditions (MA-B and C).

Keywords: Lipid oxidation; Lamb; Stunning; Modified atmosphere; Weight

1. Introduction

Some researchers (Biesalski, 2005; Willett et al., 1995) indicate that a moderate consumption of red meat is necessary to guarantee a healthy diet due to its nutritional properties. Moreover, lamb meat has a higher level of polyunsaturated fatty acid (PUFA) ω-3 (linolenic acid, 1.37 mg/100 mg) than beef or pork meat (0.70 and 0.95 mg/100 mg ω-3 fatty acid, respectively), which is beneficial to health since it helps control blood cholesterol levels (Wood et al., 1999). However, PUFA acts as a substrate which favours the beginning of the oxidative process in meat (Abuja & Albertini, 2001). Final products of lipid oxidation are considered to be responsible for developing rancidity in stored meats (Bostoglou et al., 1994) and are directly related to carcinogenic and mutagenic processes (Liu, Lanari, & Schaefer, 1995).

Development of the lipid oxidation mechanism starts immediately after death, when blood circulation stops and metabolic processes are blocked. Some authors (Buckley, Morrissey, & Gray, 1995) consider this process as the major cause of deterioration in the quality of meat. According to these authors, the ratio and the proportions of oxidation in meat are also influenced by pre-slaughter (e.g. stress) and post-slaughter events (cold shortening, pH, electrical stimulation etc...).

Stress is directly related to lipid oxidation in muscle (McClelland, 2004) and therefore an inadequate handling of animals during slaughter may affect rancidity levels in meat and meat products (Juncher et al., 2003).

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doi:10.1016/j.meatsci.2007.02.012

On the other hand, the modified atmospheres most used to pack meat contain high oxygen concentrations in order to preserve colour stability (Jeremiah, 2001), although this molecule can accelerate the development of oxidative processes (Abuja & Albertini, 2001). Other types of gas mixtures (without oxygen) can also preserve the stability of colour, such as CO, (Krause, Sebranek, Rust, & Honeyman, 2003). Although the effect of some pre-slaughter factors, such as animal feeding, on lipid oxidation is well known (Carreras et al., 2004; Guidera, Kerry, Buckley, Lynch, & Morrissey, 1997) more studies are necessary to determine the influence of others extrinsic factors, such weight/age of animal, type of stunning on the lipid oxidation.

Thus, the aim of the current study is (1) to evaluate the effect of pre-slaughter handling on lipid oxidation level and (2) to determine which atmosphere is the most suitable for the preservation of fresh meat with a minimal TBARS level in two groups of Manchega breed lambs of different slaughter weight.

2. Material and methods

2.1. Animals

Sixty-three Spanish Manchega breed lambs of different slaughter weight suckling (S, $n = 30$) and light (L, $n = 33$) from the flock of the Experimental Farm of Castilla-La Mancha University (Albacete, Spain) were used in this study. Suckling lambs were milk-fed until slaughter at 12.8 ± 0.2 kg live weight (30 days old). Light lambs were slaughtered at 25.1 ± 0.14 kg (70 days old), having been fed with milk until weaning at 12 kg of weight and then with a commercial concentrate and cereal straw *ad libitum* until slaughter. Lambs of both groups were distributed into the following three groups according to pre-slaughter handling, which was approved by the Animal Ethics Committee of the University of Castilla-La Mancha:

- ESL, electrically stunned lambs (S, $n = 15$; L, $n = 10$): at 110 V, 50 Hz for 5 s with the electrodes applied on both sides of the head, behind the ears.
- GSL, gas stunned lambs (S, $n = 10$; L, $n = 10$): by CO_2 gas in groups of five lambs per box, 90% CO_2 for 90 s.Immediately after stunning, lambs were slaughtered using standard commercial procedures.
- Another group of animals was slaughtered without previous stunning, USL (S, $n = 8$; L, $n = 10$).

Carcasses from the three groups (ESL, GSL, USL) were chilled at 4 °C for 24 h in a conventional chiller.

2.2. Sample preparation and packaging conditions

Twenty-four hours post-mortem, the *Longissimus dorsi* muscle was removed from both sides of each carcass and cut into portions of similar size for each lamb (11 samples per lamb).

One portion was used to determine initial values of lipid oxidation (at 1 day post-slaughter), and another sample was packed in a clear tray (LINPAC, Plastic) with a film having an oxygen permeability of 500 cm^3 m^{-2} day^{-1} at 1 atm and 25 °C and was then analysed after 7 days of storage at 2 °C.

Only meat samples from stunned lambs (ESL and GSL) of both slaughter weights (L, light lambs and S, suckling lambs) were packed in MA, using an ULMA Packaging machine, model Smart 500 (Guipúzcoa, Spain).

Samples were placed individually into clear rigid trays (PSEVOH-PE, LINPAC, Plastic) with an oxygen permeability rate of 3.2 cm^3 m^{-2} day^{-1} at 1 atm and 23 °C, and a cover film (OPP-PE-EVOH PE) with transmission rates of 1 cm^3 m^{-2} day^{-1} for oxygen 23 °C (50% RH) and were randomly assigned to one of the three types of packaging analysed (A, B and C treatments). The following gas mixtures were compared:

Treatment A: $30\%CO_2 + 70\%O_2$
Treatment B: $30\%CO_2 + 69.3\%N_2 + 0.7\%CO$
Treatment C: $40\%CO_2 + 60\%N_2$

Samples packed in MA types remained chilled at 2 °C and lipid oxidation was evaluated at 7, 14 and 21 days post-packaging. Samples from each lamb were used in all treatments and in all times of analysis.

2.3. Lipid oxidation analysis

TBARS level was determined in duplicate from 2 g of *L. dorsi* muscle by measuring 2-thiobarbituric acid-reactive substances (TBARS) as described by Bostoglou et al. (1994). Absorbencies were measured with a Helios alfa spectrophotometer (THERMO, Electron Corporation, England) at 532 nm. Results were expressed as mg malondialdehyde (MDA) kg^{-1} meat.

2.4. Data analysis

Data were analysed using the SPSS 11.0 version statistical package. A General Linear Model was used to determine the effects of pre-slaughter handling (ESL, GSL, USL) and slaughter weight of lamb (L *vs.* S) on initial lipid oxidation in meat (24 h) and at 7 days post-mortem. For each group of weight/pre-slaughter handling the differences in lipid oxidation between 0 and 7 days post-packing were calculated using an analysis of variance.

In samples packed in MA, we examined the effect of the type of stunning (TS) (ESL, GSL), slaughter weight (light, suckling) and type of MA (A, B, C) on lipid oxidation at 7, 14 and 21 days post-packaging using the General Linear Model procedure. To check the effect of time (7, 14, 21d) on lipid oxidation, a Tukey's test at a significance level of $P < 0.05$ was carried out to analyse the differences in each MA-weight-TS group with time.