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Use of dietary vitamin E and selenium (Se) to increase the shelf life of modified atmosphere packaged light lamb meat

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ABSTRACT

The aim of this work was to determine the increase in the shelf life of modified atmosphere packaged fresh lamb meat due to the effect of dietary vitamin E and selenium supplementation on colour and lipid oxidation. 128 lambs were fed on a concentrate with standard levels of vitamin E (C), a concentrate enriched with vitamin E (V), a concentrate with sodium selenite (S) and a concentrate enriched with both vitamin E and sodium selenite (VS). The lambs were slaughtered at 27.3 ± 1.45 kg LW, and chops stored on MAP for 7, 9, 11 and 13 days. CIELab colour and TBARs were studied on these days. Use of dietary vitamin E extended the shelf life a further 4 days from the commercial sell-by date in terms of lightness, hue angle, metmyoglobin formation and lipid oxidation. Selenium could be used to increase the lightness of meat without vitamin E supplementation in lambs' diets.

1. Introduction

Shelf life is one of the problems of packaged meat. Shelf life is conditioned by oxidative processes that are brought about by temperature, oxygen exposure, light, and microbiological growth. In the meat industry the possibility of extending meat shelf life by delaying oxidative deterioration is one of the most important objectives (Luciano et al., 2009). The colour of meat is the most important factor in the decision to purchase it (Mancini & Hunt, 2005). Modified atmosphere packaging is used to keep the colour stable, but high concentrations of oxygen increases lipid oxidation compared to meat stored in air (Jayasingh, Cornforth, Brennand, Carpenter, & Whittier, 2002). Despite this, MAP extends shelf life for 6–10 days (McMillin, 2008). To increase shelf life antioxidants can be added directly to meat, but this may not be acceptable to consumers (Resconi, 2007). Another way of improving colour and fat stability is to include antioxidants in animals' diets. The antioxidants are incorporated in cell membranes, increasing meat stability (Kerry, Buckley, Morrissey, O'Sullivan, & Lynch, 1998).

Vitamin E, especially as α-tocopherol, is widely used as an antioxidant, reducing lipid oxidation, drip losses and providing colour stability (López-Bote, Daza, Soares, & Berges, 2001) as consequence of the close relation between oxidation of lipids and oxymioglobin in muscle tissues (Yin & Faustman, 1993). Muscle cell membranes are composed of polyunsaturated fatty acids, which are particularly susceptible to peroxidation during storage at low temperatures (Kanner, 1994). Vitamin E is an antioxidant that is not degraded in the rumen (Leedle, Leedle, & Butine, 1993) but rather it is deposited in muscle cell membranes (Liu, Lanari, & Schaefer, 1995) and lipid depots, working as an antioxidant.

The major lipid-soluble free radical scavengers are tocopherols, ubiquinone and carotenoids. There are also enzymatic antioxidants: superoxide dismutases, catalases and glutathione peroxidises (GSH-Px). Glutathione peroxidise is a key enzyme in the antioxidant defence system of cells since it reduces a number of peroxides. It would be expected that the glutathione peroxidase system could act as an antioxidant system in post-mortem muscle by destroying both hydrogen peroxide and lipid hydroperoxides without producing radical products. To act in this way GSH-Px needs selenium. Furthermore, an important step in selenium metabolism in the mammalian organism is its incorporation into specific proteins such as myoglobin (Eisler, 1985; McConnell, 1963). In relation to this, Ku, Ely, Groce, and Ullrey (1972) found a strong correlation between dietary selenium and tissue selenium concentration. Tappel and Zalkin (1959) also indicated that vitamin E and selenium have related antioxidant properties. In vitamin E deficiency, peroxidation is widespread and is particularly damaging to the mitochondria and microsomes of the cells where lipid free radical intermediates react at random with structural and functional proteins, lipids, and other compounds (Tappel & Zalkin, 1959). It is conceivable that selenium may act as an antioxidant in serum lipoproteins as it probably does in the tissues (McConnell, 1963).

In many Mediterranean areas lambs are fed indoors on straw and concentrates instead of forages. There is little information on the use of selenium and vitamin E as additives in the feeding diets of lambs, fed on concentrates in indoor conditions, and their subsequent effect

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on meat production. The aim of this work was to determine the increase in the shelf life of fresh lamb meat packaged with a modified atmosphere due to the effect of dietary vitamin E and selenium supplementation on colour and lipid oxidation.

2. Materials and methods

2.1. Animals and diets

The experiment was carried out twice and one hundred twenty eight ($n_1 = 64$ and $n_2 = 64$) male lambs were selected from a collective feedlot with 19.2 ± 0.96 kg of live-weight. Lambs were individually identified and weighed, following which they were randomly distributed to four pens in accordance with four treatments (16 lambs per pen and repetition). Lambs were fed indoors on commercial concentrate for 33 days. The treatments were: lambs fed on a commercial concentrate (Table 1) with standard levels of vitamin E (10 mg α-tocopherol/kg of concentrate) and without selenium (C); the same concentrate with 500 mg α-tocopherol/kg of concentrate (V), the same concentrate with 0.3 mg sodium selenite/kg of concentrate (S) and the same concentrate with 500 mg vitamin E and 0.3 mg sodium selenite/kg of concentrate (VS). Lambs were weighed individually at weekly intervals at 8 a.m., using electronic scales (0.5 kg precision) and concentrate consumption of each pen was controlled. Eight lambs of each treatment and repetition were selected and slaughtered the same day at each repetition when they reached the target weight (27.3 ± 1.45 kg). The experimental and slaughter procedures used in this study met the guidelines of Council Directive 86/609/EEC (European Communities, 1986) on the protection of animals used for experimental and other scientific purposes.

2.2. Preparation of samples and packaging

After slaughter, the 16 carcasses per treatment were chilled for 48 h at 4 °C and whole loin (lumbar and caudal) were extracted from the carcass and sliced. Lamb chops from each carcass were randomly assigned to three white semi-rigid trays (Cryovac 1825-50) and were packaged with a 40% O_2, 30% CO_2 y 30% Ar air mixture with a 2:1 gas to meat headspace. Cover film (Cryovac Lid2050) had an oxygen permeability rate of 15 $cm^3\ m^{-2}\ day^{-1}$ at 1bar and 23 °C). Trays from each loin were assigned to three of four storage times (7, 9, 11 and 13 days post-packing) in an equilibrated incomplete design and kept in darkness at 4 °C. Hence, there were 12 trays per treatment and storage time. Ten hours before instrumental colour and TBARS measurements, the trays were placed under illumination (242 ± 22.5 lx). Trays kept closed until the moment of colour measurements and TBARS determination. 7 days post-packaging was considered as the sell-by date and the reference of the acceptability of the meat.

Table 1
Composition of concentrate.

Ingredients (g/kg)	
Maize	320.0
Barley	300.0
Soybean meal	250.0
Wheat	50.0
Sugarcane molasses	23.0
Fatty acid salts	20.0
Calcium carbonate	20.0
Sweet wheypowder	10.0
Sodium chloride	5.0
Vitamin–mineral premix	2.0
Composition	
Crude protein	180.0
Starch	37.0
Ether extract	39.0
Ash	57.0

2.3. Meat colour

Muscle colour was measured using a Minolta CM-2006 d 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 (colour temperature 6504 K), observer angle 10° and zero and white calibration. Each sample was measured twice and then averaged. The lightness (L*), redness (a*) and yellowness (b*) were recorded, and hue angle (H*) and chroma (C*) indices were calculated as $H^* = \tan^{-1}(b^*/a^*) * 57.29$, expressed in degrees and $C^* = \sqrt{a^{*2} + b^{*2}}$. Chroma is related to the quantity of pigments and high values represent a more vivid colour and denote lack of greyness (Miltenburg, Wensing, Smulders, & Breukink, 1992). Hue is the attribute of a colour perception denoted by blue, green, yellow, red, purple, etc. (Wyszecki & Styles, 1982), and it is related to the state of pigments (Renerre, 1982).

Myoglobin oxidation was predicted from the ratio of light reflectance at 630 and 580 nm (Strange, Benedict, Gugger, Metzger, & Swift, 1974; AMSA, 1991), and the relative proportion of metmyoglobin (MetMb) was calculated according to Krzywicki (1979), taking the achromatic absorption of lamb meat at 690 nm instead 730 nm.

2.4. Lipid oxidation analysis (TBARS)

Lipid oxidation was determined by the procedure reported by Maraschiello, Sárraga, and García-Regueiro (1999). 20 mL of pure water were added to 1.5 g of minced meat. Sample homogenization was carried out using an Ultra-Turrax T25 (IKA-Labortechnik, Staufen, Germany) at 13 500 rpm for 10 s. Cold 25% trichloroacetic acid (5 mL) was added followed by gentle stirring at 4 °C for 15 min. A supernatant was obtained by centrifugation at 13 000 g for 15 min at 4 °C. The supernatant (3.5 mL) was transferred to a test tube, and 1.5 mL of 0.6% aqueous thiobarbituric acid was added. Test tubes were incubated for 30 min in a water bath at 70 °C. The test tubes were cooled and the TBARS were recorded at 532 nm in a Shimadzu spectrophotometer against a blank consisting of 2.5 mL of ultrapure H_2O, 1 mL 25% aqueous trichloroacetic acid, and 1.5 mL 0.6% of thiobarbituric acid. Calibration curves were prepared using MDA standard working solutions. A stock MDA solution was obtained after hydrolysis of 690 mg of TEP in 10 mL of 0.1 N HCl. The reaction was carried out in a 100 mL screw-capped bottle. The bottle was immersed in a bath of boiling water for 5 min and quickly cooled under tap water. The hydrolyzed TEP solution was then accurately diluted to 100 mL with ultrapure water. Appropriate working solutions were prepared from the stock MDA solution. The tubes used for the calibrations including the blank and samples to be analysed were taken through the TBA procedure the same time. Reaction and the detection proceeded as previously described. The TBARS values are expressed as micrograms of malonaldehyde per kilogram of meat.

2.5. Statistical analysis

Variables were analysed using the MIXED procedure for repeated measures based on Kenward–Roger's adjusted degrees of freedom solution. The factors included were dietary selenium or vitamin E as between-subject fixed effects, time as within-subject effect and animal as subject (experimental unit) and repetition as blocking factor. The lowest Akaike Information Criterion (AIC) was used to choose the matrix of the error structure. Least square means were estimated and differences were tested with a t-test. Pearson's correlation coefficients among TBARS and the other variables were calculated. Live-weight, average weight gain and feed intake were analysed using ANOVA with dietary selenium or vitamin E as fixed effects. For all of the tests the level of significance was 0.05.