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Effect of packaging conditions on shelf-life of fresh foal meat

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ABSTRACT

The objective was to determine the shelf life of foal meat (*Longissimus dorsi*) stored in four different packages: (i) vacuum, (ii) overwrap and (iii) two modified atmospheres (MAP): high O_2 MAP (80% O_2 + 20% CO_2) and low O_2 MAP (30% O_2 + 70% CO_2) stored at 2 °C during 14 days. Shelf life evaluation was based on pH, colour, lipid and protein oxidation, microbial counts and sensory assessment of odour, colour and appearance. Based on aerobic bacterial counts, the shelf life of foal meat samples in overwrap and high O_2 MAP packages would be 10 days at most, almost 14 days in low O_2 MAP and more than 14 days in vacuum packaging. Scores for sensorial evaluation were unacceptable after 10 days of storage in samples in overwrap and MAP packs, but they were still acceptable in vacuum ones. Moreover, for all packaging conditions except vacuum, which remained constant, a decrease in redness (a*) and an increase in carbonyl content and TBAR'S values was observed with storage time. High O_2 levels negatively affected foal meat quality, while anaerobic conditions extended shelf life to 14 days.

1. Introduction

Horse meat production in Spain has increased in the recent years, being the fourth major producer of horse meat in the U.E. in 2009 with 6400 tonnes (FAOSTAT, 2009). However consumption in Spain is limited, a high percentage is exported to other countries, mainly to Italy (MERCASA, 2011). In 2009, worldwide horse meat production was over 750 thousand tonnes. The major producers were Asia, with 45% of worldwide production, followed by Europe (19%), South America (12%), Central America (11%), and North America (6%). The greatest importers of horse meat were Italy, Belgium, Russia and France, and the most important exporters were Argentina, Belgium, Canada and Poland (FAOSTAT, 2009).

Previous studies revealed that foal meat is highly nutritious due to low fat and cholesterol levels, high protein, bioavailable iron and vitamin B quantities, and a suitable fatty acid profile (Badiani, Nanni, Gatta, Tolomelli, & Manfredini, 1997; Franco et al., 2011; Lanza, Landi, Scerra, Galofaro, & Pennisi, 2009; Sarriés & Beriain, 2005; Sarriés, Murray, Troy, & Beriain, 2006; Tateo, De Palo, Ceci, & Centoducati, 2008) with a high proportion of omega-3 unsaturated fatty acids (Lorenzo, Fuciños, Purriños, & Franco, 2010).

The role of food packaging is being increasingly recognised as it has multiple functions and is very important in terms of increasing product shelf life by retarding quality degradation and ensuring safety. Packaging of fresh red meat is carried out to avoid contamination, delay spoilage, permit some enzymatic activity to improve tenderness, reduce weight loss, and where applicable, to ensure a cherry-red colour in red meats at retail or consumer level (Kerry, O'Grady, & Hogan, 2006). Vacuum and modified atmosphere packaging (MAP) techniques are used in to extend the product shelf-life.

Shelf life and quality of fresh meat are influenced by initial quality, package parameters, and storage conditions (Zhao, Wells, & McMillin, 1994). Colour, microbial growth, lipid oxidation (Esmer, Irkin, Degirmencioglu, & Degirmencioglu, 2011), appearance, flavour and texture (Lawrie, 1998) are important factors for the shelf life and consumer acceptance of fresh meat. MAP systems with 20–30% CO_2 + 70–80% O_2 are widely used for fresh red meat (Esmer et al., 2011; Kim, Huff-Lonergan, Sebranek, & Lonergan, 2010) because the O_2 preserves the bright red colour and CO_2 aids in preventing microbial growth (Seyfert et al., 2005; Stubbs, Morgan, Ray, & Dolezal, 2002). Nevertheless, high oxygen atmospheres promote oxidative changes in meat (Cayuela, Gil, Bañón, & Garrido, 2004; Leygonie, Britz, & Hoffman, 2011; O'Grady, Monahan, Burke, & Allen, 2000; Zhao et al., 1994) which negatively affects quality including colour and flavour stability and tenderness (Grobbel, Dikeman, Hunt, & Milliken, 2008; Zakrys, Hogan, O'Sullivan, Allen, & Kerry, 2008). Oxidation could be a major problem in foal meat as it is rich in iron, protein and polyunsaturated fatty acids, factors that increase the meat's susceptibility to oxidation (Chaijan, 2008).

The aim of this work was to study the shelf-life of foal steaks stored under four different packaging conditions: 80:20, O_2/CO_2, 30:70, O_2/CO_2, vacuum and overwrap (overwrap).

2. Materials and methods

2.1. Sample preparation

Twelve foals were obtained from "Monte Cabalar" (agricultural cooperative of "Galician Mountain" breed) (A Estrada, Pontevedra,

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Spain). The majority of the foals were born in April and May of 2010. Animals were reared with their mothers on pasture and were kept suckling and grazing until 6–7 months old. After weaning, foals were fed mainly ryegrass (*Lolium perenne*), *Ulex europaeus* L. and *Pteridium aquilinum* (L.) Kuhn., receiving complementary grass silage *ad libitum* when the grass available was limited, especially in the summer and winter time, but they were never given concentrates. All foals were reared with their mothers in an extensive production system based on wood pasture. The animals were slaughtered at fifteen months old. They were transported to the abattoir the day before slaughter, without mixing foals from different groups at any time, and trying to minimize stress to the animals. The animals were stunned with a captive bolt and slaughtered and dressed according to current European Union regulations (Council Directive of the European Union 95/221EC) in an accredited abattoir.

Carcasses were chilled for 24 h at 2 °C (relative humidity: 98%). At this point, the *longissimus dorsi* (LD) muscle was extracted from the right side of each carcass, between the fifth and the tenth rib.

2.2. Storage conditions

Foal steaks were aseptically sliced (eight steaks about 100 g weight were cut from each muscle) using sterile cutting boards and knives. Each pack (a total of 60 packs) was prepared by placing two steaks (randomly distributed) in polystyrene trays (300 mm of thickness) sealed with PE film for gas mixtures 74 mm thick (VIDUCA, Alicante, Spain) and with an oxygen permeability of less than 2 ml per m^2 per 24 h per bar and bags with an oxygen transmission rate of 50 cm^3 per m^2 per 24 h per bar at 23 °C and 75% RH and water vapour transmission rate of 2.6 g per m^2 per 24 h at 23 °C and 85% RH., for vacuum packed (TECNOPACK, Barcelona, Spain).

These packs were grouped in 4 batches of 15 packs. Each batch was packed in different atmospheres using a LARI/3 pn-VG packaging machine (CAVECO, Milano, Italy). One batch was packaged directly by sealing the film upon the tray (OVERWRAP). A second batch was vacuum packed in a FRIMAQ V-900 packaging machine (Lorca, Spain). The third batch was packed in modified atmosphere using a gas mixture of 80:20 O_2/CO_2 (high O_2 MAP). The fourth batch was also packed in modified atmosphere, but using a different gas mixture: 30:70 O_2/CO_2 (low O_2 MAP). Both gas mixtures were supplied by PRAXAIR (Madrid, Spain).

All packs were stored at 2 ± 1 °C (simulating retail conditions in a refrigerated chamber). This chamber was illuminated by a standard supermarket fluorescent lamp. The position of the samples in the chamber were rotated every 24 h to minimize light intensity differences and possible temperature variations at the surface of the meat. Twelve samples (three for each batch) were removed from the chamber at 0, 4, 7, 10 and 14 days of storage for microbial, sensorial and physico-chemical analysis.

2.3. Microbial analysis

Ten grams of meat were aseptically placed into a stomacher bag and then homogenised with 90 mL of sterile 0.1% peptone water in a masticator blender (IUL Instruments, Barcelona, Spain) for 2 min at room temperature. For each sample, appropriate serial decimal dilutions were prepared in Peptone Water solution (0.1%) and duplicate 1 mL or 0.1 mL samples of appropriate dilutions were poured or spread onto total count and selective agar plates.

Total viable counts, were enumerated in Plate Count Agar (PCA; Oxoid, Unipath Ltd., Basingstoke, UK) incubated at 30 °C for 48 h; psychrotrophic aerobic bacteria were enumerated on Plate Count Agar (PCA; Oxoid, Unipath Ltd., Basingstoke, UK) after incubation at 7 °C for 10 days; lactic acid bacteria were determined on Man Rogosa Sharpe medium Agar (Oxoid, Unipath Ltd., Basingstoke, UK) (pH 5.6), after incubation at 30 °C for 5 days; *Enterobacteriaceae* was determined on Violet Red Bile Glucose Agar (Merck, Darmstadt, Germany) after incubation at 37 °C for 24 h; moulds and yeasts were enumerated using Oxytetracicline Glucose Yeast Extract Agar (OGYE) (Merck, Darmstadt, Germany) with OGYE Selective Supplement (Merck, Darmstadt, Germany), previously incubated at 25 °C for 4–5 days and *Pseudomonads* spp. were counted on *Pseudomonads* Selective Agar (Merck, Darmstadt, Germany) with *Pseudomonads* CFC Selective Supplement (Merck, Darmstadt, Germany), previously incubated at 25 °C for 48 h. After incubation, plates with 30–300 colonies were counted. Microbiological data were transformed into logarithms of the number of colony forming units (cfu/g).

2.4. Sensory evaluation

Meat samples were evaluated by ten semi-trained panellist selected among the staff of "Centro Tecnológico de la Carne". The attributes studied were the red colour, off-odour and general appearance acceptability using nine point hedonic rating scales. The scales included 1 = extremely unacceptable, 2 = very much unacceptable, 3 = moderately unacceptable, 4 = slightly unacceptable, 5 = between acceptable and unacceptable, 6 = slightly acceptable, 7 = moderately acceptable, 8 = very much acceptable and 9 = extremely acceptable (Ranganna, 1994).

2.5. Physico-chemical analysis

2.5.1. pH and Colour parameters

The pH was measured using a pH-meter (Hanna Instrument HI-9024, Portugal) equipped with a glass probe for penetration. A portable colorimeter (Minolta CR-400 Osaka, Japan) with the settings: pulsed xenon arc lamp, 0° viewing angle geometry and aperture size 8 mm) was used to measure meat colour in the CIELAB space (Lightness, L*; redness, a*; yellowness, b* (CIE, 1978). Hue (Ho) and chroma (C*) were calculated from the a* and b* values according to the formula:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad \text{and} \quad h_{ab} = acr\tan\frac{b^*}{a^*}$$

2.5.2. Lipid oxidation

Lipid stability was evaluated using the method proposed by Vyncke (1975). Briefly, a sample (2 g) was dispersed in 5% trichloroacetic acid (10 mL) and homogenized in an Ultra-Turrax (Ika T25 basic, Staufen, Germany) for 2 min. The homogenate was maintained at −10 °C for 10 min and centrifuged at 2050 g for 10 min. The supernatant was filtered through a Whatman No. 1 filter paper. The filtrate (5 mL) was reacted with 0.02 M TBA solution (5 mL) and incubated in a water bath at 96 °C for 40 min. The absorbance was measured at 532 nm. Thiobarbituric acid reactive substances (TBARS) values were calculated from a standard curve of malonaldehyde with 1,1-3,3 tetraetoxipropane (TEP) and expressed as mg MDA/kg sample.

2.5.3. Protein oxidation

Protein carbonyls, as measured by the total carbonyl content, were quantified following the method described by Oliver, Ahn, Moerman, Goldstein, and Stadtman (1987). Meat samples were homogenized in 20 ml of 0.15 M KCl buffer for 60 s using an Ultra-Turrax (Ika T25 basic, Staufen, Germany). Two aliquots of homogenate (0.1 mL) were transferred to Eppendorf vials. Then, proteins were precipitated in both aliquots by 10% trichloroacetic acid (TCA) (1 mL) and centrifuged for 5 min at 5000 g. One pellet was treated with 1 mL of 2 N HCl (protein quantification) and the other with 1 mL of 2 M HCl containing 0.2% 2,4-dinitrophenyl hydrazine (DNPH) (carbonyl content). Both samples were incubated for 1 h at room temperature (shaken every 20 min). After incubation, 10% TCA was added (0.8 mL). The samples were vortexed for 30 s, centrifuged for 5 min at 5000 g and