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Modified atmosphere packaging and vacuum packaging for long period chilled storage of dry-cured Iberian ham

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ABSTRACT

Dry-cured Iberian ham slices were stored under vacuum and under four different modified atmospheres (60/40 = 60%N_2 + 40%CO_2; 70/30 = 70%N_2 + 30%CO_2; 80/20 = 80%N_2 + 20%CO_2; argon = 70%argon + 30% CO_2) at 4 ± 1 °C during 120 days. Gas composition, moisture content, pH, colour, pigment content, and lipid stability were measured, as well as sensory and microbial analysis were carried out throughout storage. A loss of intensity of red colour (a^*-values) was observed during storage in ham slices ($P < 0.05$). Consistently, MbFe(II)NO content also decreased throughout storage ($P > 0.05$). Slices of ham packed in 40%CO_2 (60/40) and 30%CO_2 (70/30) showed lower a^*-values than the rest of the batches after 60 days ($P < 0.05$), though differences were not evident after 120 days ($P > 0.05$). TBARs values showed an upward trend during the storage of packaged slices ($P < 0.05$). Vacuum-packed slices showed the lowest TBARs values and those packed with 40%CO_2, the highest. Sensory attributes did not vary significantly ($P > 0.05$) throughout storage under refrigeration and packed either in vacuum or in modified atmospheres. No safety problems were detected in relation to the microbial quality in any case.

1. Introduction

Dry-cured Iberian ham is a typical meat product from the southwest of Spain, highly appreciated by consumers and with a considerable economical importance as a result of its unique and high sensory quality (Cava, Ventanas, Ruiz, Andrés, & Antequera, 2000). Over years, Iberian hams have been commercialized in a traditional way, which consists of presenting the whole leg with the hoof included. However, new ham retail presentations, such as packaged ham slices are being developed in recent years, as a result of new consumer demands and in order to increase competitiveness.

On the other hand, industry demands the use of preservation methods which increases the shelf life of manufactured foods ensuring food safety. In this sense, the food industry has developed different packaging technologies in order to extend the shelf life of products such as meat and meat products. Among these technologies, vacuum packaging and modified atmosphere packaging (MAP) prevent products from contamination and evaporative losses and also extend storage life (Stiles, 1990). In MAP, food products are packed in an atmosphere which has been modified so that its composition is something other than air (Hintlian & Hotchkiss, 1986). The optimisation of the gas mixture composition is critical to ensure both product quality and safety (Møller, Jensen, Olsen, Skibsted, & Bertelsen, 2000). The gases normally used for MAP include carbon dioxide, oxygen and nitrogen. The most important gas, from a microbiological standpoint is CO_2, which effectively inhibits the growth of many microorganisms, including spoilage bacteria (Hotchkiss, Werner, & Lee, 2006). Among the new gases, argon must be emphasized, this gas being very similar to nitrogen but being denser and more soluble in water than nitrogen and oxygen (Spencer & Humphreys, 2003), which could have relevant consequences on its effect on shelf life. Nevertheless, no scientific works have been carried out, as far as we are concerned, in order to evaluate the potential consequences of argon characteristics on its effect on shelf life of meat products.

Microbial growth, decolouration and lipid oxidation are important factors determining shelf life and consumer acceptance of packed dry-cured products. Colour and flavour characteristics are the main quality factors in dry-cured Iberian meat products (Cava et al., 2000), making necessary to achieve a better knowledge of the effect of different packaging conditions on parameters related to quality of these products during storage. Colour of dry-cured meat is mainly attributed to nitrosylmyoglobin content and discolouration is mainly ascribed to its oxidation (Møller et al., 2000). Recent studies by Adamsen, Moller, Parolari, Gabba, and Skibsted (2006) and Moller, Adamsen, Catharino, Skibsted, and Eberlin (2007)

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reveal that a Zn–protoporphyrin pigment constitutes a major chromophore in Iberian ham cured without nitrates and nitrites, though a complete absence of nitrosylmyoglobin was not demonstrated in this product. Salt was used in the curing process of the dry-cured hams for the present experiment, and though analysis for nitrate/nitrite content was not carried out, it is expected these chemical compounds are present as impurities (Andrés & Ruiz, 2001). On the other hand, as far as we are concerned, there is no published or accepted protocol for extracting specifically the Zn–protoporphyrin pigment. Colour stability of dry-cured meat packaged with modified atmospheres depends on a complex interaction between headspace oxygen level, product to headspace volume ratio and level of illuminance (Andrés, Adamsen, Møller, Ruiz, & Skibsted, 2005; García-Esteban, Ansorena, & Astiasarán, 2004). Lipid oxidation promotes rancidity problems which are considered unpleasant for consumers (Jeremiah, 2001). On the other hand, a close relationship between pigment and lipid oxidation has been pointed out by several authors (Faustman & Cassens, 1990; Skibsted, Mikkelsen, and Bertelsen, 1998).

A number of studies have been carried out in order to evaluate the effectiveness of vacuum, gas composition and packaging material on the preservation of fresh meat (Economou, Pournis, Ntzimani, & Savvaidis, 2009; Houben, van Dijk, Eikelenboom, & Hoving-Bolink, 2000), cooked meat products (Møller et al., 2003) dry fermented sausages (Fernández-Fernández, Vázquez-Odériz, & Romero-Rodriguez, 2002), cooked ham (Møller et al., 2000) and dry-cured ham (García-Esteban et al., 2004). Reports on Iberian dry-cured ham are much more scarce to the best of our knowledge (Andrés et al., 2005).

Thus, this work was focused on studying the evolution of instrumental colour, biochemical and sensory characteristics and microbiological quality in slices of dry-cured Iberian ham packed under vacuum and in four different modified atmospheres during chilled storage.

2. Material and methods

2.1. Samples

A total of 24 dry-cured hams obtained from Iberian pigs fed on acorn, weighing 11.7 ± 0.7 Kg were used in this study. Approximately 1.5 mm thick slices were obtained from hams. Homogeneous slices were selected in order to assign them to instrumental, sensorial or microbial analysis. Approximately 100 g of dry-cured Iberian ham slices were packed under vacuum or in the mixture of gases produced by a gas mixer (Witt-Gasetechnik GmbH and Co., Witton, Germany). The mixture of gases consisted in (i) 70%argon + 30%CO_2 = argon batch; (ii) =60%N_2 + 40% CO_2 = 60/40 batch; (iii) 70%N_2 + 30%CO_2 = 70/30 batch; (iv) 80%N_2 + 20%CO_2 = 80/20 batch. The laminated film used for packaging consisted of a mixture of PA (Polyamide) and PE (Polyethylene) (Viduca, S.L.), with an oxygen transmission rate (OTR) of 38 cm^3/m^2/24 h/atm. Packages had a headspace volume ratio of 1:1. All samples were stored in darkness at 4 ± 1 °C. The samples were opened for subsequent analysis after 1, 60 and 120 days of storage.

2.2. Gas composition

Gas composition of the headspace was analysed before opening packages in order to perform the determinations using a headspace analyser (Abiss, LS212, Germany). A septum was placed in the package and a 6 ml gas aliquot was withdrawn for analysis of relative oxygen (±1%) and carbon dioxide (±2%) content.

The oxygen level (%) was measured before opening the package and used to detect leaking packages (packages containing more than 10.3% and 20.6% oxygen after 60 and 120 days, respectively). These threshold values for leakage was chosen based on a theoretical calculation of the amount of oxygen permeating through the laminated packaging material during the days of storage using the upper limit for residual oxygen after packaging and upper limit for OTR ("worst case" conditions). The amount of oxygen inside the package was found from the following equation:

$$Q = P' \times A \times t \times \Delta P$$

where Q is the oxygen quantity, P' is oxygen transmission rate (corrected for decreased temperature, by reducing the OTR value twice for every 10 °C decrease on temperature). A is the total area of pouch, t is the time in days and ΔP is the pressure difference between the atmosphere and the headspace of the pouch.

Q = 10 cm^3/m^2/atm/24 h × 2 × 0.18 m × 0.35 m × 60 days × (0.21–0.005) = 15.5 ml O2, relative O_2 content after 60 days: (15.5 ml/150 ml) × 100 = 10.3%.

On the other hand, Q = 10 cm^3/m^2/atm/24 h × 2 x 0.18 m × 0.35 m × 120 days × (0.21–0.005) = 31.0 ml O2, relative O_2 content after 120 days: (31.0 ml/150 ml) x 100 = 20.6%.

Based on these assumptions 14 leaking packages were found.

CO_2 percent reduction was calculated considering the initial amount or concentration of the gas in the packaging (e.g. 40% CO_2 in the 60/40 batch: 60%N_2 + 40%CO_2,) and its concentration after 1 day.

2.3. Moisture content and pH measurement

Moisture content was determined following the ISO recommended method (ISO, 1973). The pH of dry-cured Iberian ham samples was measured using a micropHmeter model 2001 (Crison Instruments, Barcelona, Spain) after homogenizing 2 g of sample in 18 ml distilled water for 10 s at 1300 rpm with an Sorvall Omnimixer (Mod.17106).

2.4. Colour measurement

Colour measurements were taken in muscle BF (*Biceps femoris*) immediately after opening the package (to prevent colour degradation because of light and oxygen) in accordance with the recommendation on colour determination of the American Meat Science Association (AMSA, 1991).

The following colour coordinates were determined: lightness (L^*), redness (a^*, red ± green) and yellowness (b^*, yellow ± blue). The colour parameters were determined using a Minolta CR-300 colorimeter reflectance spectrophotometer (Minolta Camera Co., Osaka, Japan) (Illuminant D65/0° standard observer and 0.8 cm port/viewing area). a^* and b^* values were used to calculate spectral colour (hue = arctan $[b^*/a^*]$) and colour saturation (chroma = $[a^{*2} + b^{*2}]^{0.5}$). Before use, the colorimeter was standardized using a white tile (mod CR-A43). The measurements were repeated on five randomly selected locations on each slice BF and averaged for statistical analysis.

2.5. Determination of pigment content

Nitrosylmyoglobin (MbFe(II)NO) concentration was assessed following the method described by Hornsey (1956) for isolation of MbFe(II)NO in nitrite-cured meat products with slight modifications described by Andrés et al. (2005).

2.6. Lipid oxidation analysis

The extent of lipid oxidation was estimated as TBARs (thiobarbituric acid-reactive substances) by the extraction method