Innovative Food Science and Emerging Technologies 23 (2014) 25–32

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Effect of high pressure processing and modified atmosphere packaging on the safety and quality of sliced ready-to-eat "lacón", a cured–cooked pork meat product

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ARTICLE INFO

Article history:
Received 20 January 2014
Accepted 12 March 2014
Available online 22 March 2014

Editor proof received date 10 April 2014

Keywords:
Pressurization
Modified atmosphere packaging
"Lacón"
Cured–cooked pork meat
Shelf-life
Food safety

ABSTRACT

Microbiological and sensory characteristics of sliced "lacón", a cured–cooked meat product, vacuum-packaged (VP), pressurized at 500 or 600 MPa, and modified atmosphere packaged (MAP), were investigated during storage at 4 °C for 120 days. Viable bacterial counts exceeded 10^8 cfu/g in VP and MAP "lacón" from day 30 while this level was not reached in pressurized "lacón" until day 90. Pressurization at 500 MPa was the best procedure to control Gram-negative bacteria. During storage the pH value declined by 0.13 units in VP, 0.23 units in MAP, and 0.49 units in pressurized "lacón". Primary and secondary lipid oxidation indexes declined during storage, with small differences between treatments. Flavour quality scores for 90-day and 120-day samples averaged 5.63 for VP "lacón", 6.51 for MAP "lacón", 6.48 for 500 MPa "lacón" and 5.81 for 600 MPa "lacón". Flavour quality correlated negatively with viable bacterial counts, lactic acid bacteria and Gram-negative bacteria.
Industrial relevance: Shelf-life of sliced "lacón" can be prolonged by applying HPP or using MAP. Both procedures showed to be valid in retarding the growth of most microbial groups during the first month of refrigerated storage of sliced "lacón". Pressurization was more effective than MAP in preventing the growth of Gram-negative bacteria throughout the 120-day storage period, in particular HPP at 500 MPa.

1. Introduction

Dry-cured "lacón", also known as "lacón gallego", is a traditional meat product made in the North-West of Spain from pig forelegs, following manufacturing procedures similar to those of dry-cured ham. Its microbiological, chemical and sensory characteristics have been investigated (Lorenzo, García Fontán, Franco, & Carballo, 2008; Lorenzo, Prieto, Carballo, & Franco, 2003; Vilar, García Fontán, Prieto, Tornadijo, & Carballo, 2000). Because of its high salt content, dry-cured "lacón" requires desalting and cooking in boiling water before consumption. After these treatments the NaCl concentration may still attain 6.3% (Cobos, Veiga, & Díaz, 2004).

Changes in consumer preferences and initiatives to reduce salt in meat products (Duranton, Guillou, Simonin, Chéret, & de Lamballerie, 2012) have led to the production of a milder type of "lacón", with 2.0–2.8% NaCl, by a process resembling that of cooked ham. Commercial presentation of "lacón" has also evolved. Dry-cured "lacón" was marketed as whole forelegs, which were cut into blocks or thick slices at retailers. The increasing consumer demand for ready-to-eat (RTE) foods has given rise to new presentations, basically consisting in trays of mechanically- or manually-sliced "lacón" with shelf-life periods not exceeding 60 days.

Post-manufacture processing steps such as cutting, slicing and packaging may cause microbial recontamination of cooked meat products. Long shelf-life periods and consumption without further preparation or cooking increase the microbiological risk of some RTE meat products. The characteristics of cured–cooked "lacón", in particular its lower salt concentration, are more favourable for microbial growth than those of dry-cured "lacón".

High pressure processing (HPP), a non-thermal technology used for "cold pasteurization" of foods, is also valid for controlling post-cooking recontamination in packaged RTE products (Hereu, Dalgaard, Garriga, Aymerich, & Bover-Cid, 2012; Vercammen et al., 2011). HPP kills microorganisms by inactivating key enzymes and altering cell membrane and morphology (Hoover, Metrick, Papineau, Farkas, & Knorr, 1989). The lethal effect of HPP depends on pressurization conditions (pressure level, temperature and time), microorganisms (type and phase of growth) and medium characteristics (composition, pH and water activity). Pressurization also affects the characteristics of meat and meat products such as tenderness, colour, drip loss, lipid oxidation and microbial population (Cheftel & Culioli, 1997; Vercammen et al., 2011). HPP is currently used in many countries for a wide range of RTE meat products, including cooked (ham, sausages, turkey, chicken), dry-cured (ham, loin), fermented (salami, sausages), marinated (beef, pork) and raw (carpaccio) meat products (Campus, 2010).

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http://dx.doi.org/10.1016/j.ifset.2014.03.003
1466-8564/

Although the characteristics of dry-cured "lacón" during curing have been investigated, there are no studies to our knowledge on the characteristics of sliced "lacón" during refrigerated storage and on the influence of HPP or modified atmosphere packaging (MAP) on those traits. The objective of the present work was to investigate the effect of HPP at 500 or 600 MPa and MAP on the microbiological and sensory characteristics of sliced RTE cured–cooked "lacón" throughout a 120-day refrigerated storage period, on the aim of prolonging its shelf-life.

2. Materials and methods

2.1. Manufacture and processing of "lacón"

Two batches of cured–cooked "lacón" were manufactured on consecutive days at a meat industry in Central Spain. Hind legs (11–13 kg in weight) from Duroc × Landrace pigs were intrafemorally injected with brine consisting of a mixture of sodium chloride, sodium nitrite, sodium ascorbate, disodium diphosphate, sodium triphosphate and sodium polyphosphate. They were cold cured for 5 days at 8 °C and then submerged in spiced brine for 6 h. Afterwards, they were cooked in steam oven at 80 °C and 80% RH for approximately 12 h to an inner temperature of 67 °C, smoked for 1 h with natural smoke produced in situ from slivers of beech wood and rapidly cooled to 4 °C. "Lacón" was hand-sliced to 6–10 g pieces and dispensed in expanded polystyrene trays (250 g per tray).

Treatments applied to "lacón" were vacuum packaging (VP), MAP in 80% N_2 and 20% CO_2, pressurization at 500 MPa for 5 min (P500) and pressurization at 600 MPa for 5 min (P600). HPP was carried out in a 50-litre capacity apparatus (model 55, Hiperbaric, Burgos, Spain), with 20 trays per batch and a filling factor of 1/10. The temperature of "lacón" before HPP was 4 °C. The initial temperature of water was 9 °C and it did not exceed 16 °C during HPP. Compression and decompression rates were 3.57 and 71 MPa/s. Afterwards, "lacón" trays were held at 4 °C for 120 days. One tray per batch and treatment was used for microbiological analysis, pH determination, lipid oxidation analysis and colour measurements and a second tray for the evaluation of sensory characteristics.

2.2. Microbiological analysis and pH determination

Representative 10 g samples from different slices of "lacón" were homogenized with 90 ml of sterile 0.1% peptone water containing 0.85% NaCl in a stomacher (Masticator; IUL Instruments, Barcelona, Spain) for 2 min at room temperature. Decimal dilutions were prepared in 0.1% peptone water and surface plated on different culture media, in duplicate plates. For samples and culture media with expected low counts four plates were used.

Total viable counts were determined on plate count agar (PCA; Biolife, Milano, Italy) incubated at 30 °C for 72 h under aerobic and anaerobic conditions (Anaerogen system packs; Oxoid, Basingstoke, UK), lactic acid bacteria (LAB) on Man–Rogosa–Sharpe (MRS) agar with Tween 80 (Biolife) acidified at pH 5.7 with acetic acid after incubation at 30 °C for 72 h, and Gram-negative bacteria on McConkey agar (Scharlab, Barcelona, Spain) after incubation at 30 °C for 24 h. Spore-forming bacteria were determined by heating homogenate dilutions for 30 min at 80 °C and plating on PCA, after incubation at 30 °C for 72 h. Yeasts and moulds were determined on chloramphenicol glucose agar (CGA; Scharlab) plates incubated at 25 °C for 3 to 7 days. Lactobacilli were determined on Rogosa-SL agar (Difco, Madrid, Spain) plates incubated anaerobically at 37 °C for 72 h, enterococci on Kenner-faecal (KF) agar (Scharlab) plates incubated at 37 °C for 48 h, and *Brochothrix thermosphacta* on streptomycin thallous acetate agar (STAA; Oxoid) plates incubated at 25 °C for 48 h. Micrococcaceae were determined on mannitol salt agar (MSA; Oxoid) plates incubated at 30 °C for 72 h, staphylococci on Baird–Parker (BP) agar (Oxoid) with RPF supplement II (Biolife) incubated at 37 °C for 48 h, and *Listeria monocytogenes* on Palcam agar (Merck) plates incubated at 37 °C for 48 h. Pseudomonadaceae were determined on cetrimide–fucidin–cephalotin (CFC) agar (Merck) incubated at 30 °C for 48 h, Enterobacteriaceae on violet red bile agar (VRBA; Merck, Darmstadt, Germany) with 1% glucose added incubated at 37 °C for 24 h, coliforms on VRBA plates incubated at 37 °C for 24 h and *Escherichia coli* on VRBA plates incubated at 44.5 °C for 24 h. Microbial counts were expressed as log cfu per gram of sample.

The pH was directly measured on six different slices randomly selected from each tray, using a portable pH-meter (model GPL22, Crison Instruments, Barcelona, Spain) with a penetration electrode (model 52-3.2, Crison Instruments), at room temperature.

2.3. Lipid oxidation analysis

Representative 2.5 g samples from different "lacón" slices were taken in duplicate. The extent of lipid oxidation was determined in quadruplicate using two colorimetric indexes (TBAR1 and TBAR2) by means of the thiobarbituric acid (TBA) method as described by del Olmo, Calzada, and Nuñez (2013). The index TBAR1, measured at 532 nm and expressed as mg of malondialdehyde (MDA) per kg, estimated the early or primary stage of lipid oxidation. The index TBAR2, measured at 450 nm and expressed as mg of hexanal per kg, estimated the advanced or secondary stage of lipid oxidation.

2.4. Instrumental colour analysis

Colour measurements were performed on six randomly selected "lacón" slices, at room temperature. A chromameter CM-700 (Minolta, Osaka, Japan), with a D65 illuminator at 10° standard observer angle and 8 mm port/viewing area, was used after standardization with a white calibration cap (model CM-A177, Minolta). Colour coordinates obtained in the CIELAB space with the specular component included (SCI) were lightness (L^*), redness (a^*) and yellowness (b^*). Spectral colour or hue (h^*) was calculated as arctg (b^*/a^*) and chroma or colour saturation (C^*) as $(a^{*2} + b^{*2})^{1/2}$.

2.5. Sensory analysis

Nineteen panellists, with previous training for the sensory analysis of meat products (del Olmo et al., 2013), evaluated sliced "lacón" submitted to the four treatments on days 0, 30, 60, 90 and 120 of storage. Slices from each tray, which were opened and held for 30 min at room temperature before analysis, were presented to panellists on white ceramic plates under artificial light, coded with random 3-digit numbers. Bread and water were used as rinsing agents between samples. Flavour quality and intensity were evaluated on a 0 to 10 point scale using a horizontal line anchored in the middle and at both ends, where 0 indicates "dislike extremely" for quality and "extremely mild flavour" for intensity, and 10 indicates "like extremely" for quality and "extremely strong flavour" for intensity. In addition, acid, rancid, putrid and salty taste attributes were evaluated on a 0 to 10 point scale using a horizontal line anchored in the middle and at both ends, where 0 indicates "absence" and 10 "maximum intensity" of the descriptor. For texture descriptor "hardness", as perceived in the mouth, 0 indicates "extremely soft texture", 5 the "correct texture" expected for "lacón", and 10 "extremely hard texture".

2.6. Statistical analysis

Analysis of variance (ANOVA), which included treatment (VP, MAP, P500 and P600) and time of storage as main effects, and their interaction, was carried out using Statview version 5.0 (SAS Inst., Cary, N.C., USA). Pearson's correlation analysis and mean comparison by Tukey's test, with the significance assigned at $P < 0.05$, were performed using the same programme.