Impact of high pressure processing on the quality and safety of ready-to-eat Iberian chorizo and dry-cured loin

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Abstract— **The aim of the work was to assess the impact of high pressure processing (HPP) on physico-chemical and sensory properties and microbial safety of ready-to-eat (RTE) Iberian chorizo and dry-cured loin. Four independent batches of each product were sliced, vacuum-packaged and the half were pressurised at 600 MPa (5min/15 ºC). Storage consisted of 2 months at 4ºC plus 4 months at 8ºC. For quality assessment, physico-chemical determinations (pH, a_w, proximal analysis, lipid oxidation, proteolysis), instrumental colour and texture and sensory analysis were performed along the storage. For safety assessment, a set of samples were inoculated with *L. monocytogenes* (*ca.* 100 cfu/g) and its behaviour was monitored periodically. Physico-chemical results were not significantly affected by the HPP, irrespectively of the product. HPP had no significant effect on instrumental colour in any sampling time, increased hardness for dry-cured loin, increased saltiness of both products, but did not modify their overall liking. The loads of *L. monocytogenes* were significantly reduced by HPP and absence of the pathogen was higher in the pressurised (48%) than in untreated (7%) products. As a conclusion, high pressure processing renders safer products with insignificant or minor impact on the physico-chemical and sensory characteristics.**

Keywords— **High pressure processing, Iberian cured meat products, quality and safety.**

I. INTRODUCTION

The high quality and unique sensory properties of Iberian cured meat products, such as chorizo and dry-cured loin, make them very appreciated by consumers. When they are commercialised as sliced ready-to-eat (RTE), the risk of contamination by *Listeria monocytogenes* constitute the main safety concern, specially in countries applying a "zero tolerance" policy such as USA [1]. To ensure microbiological criteria compliance, the industry tends to implement listericidal treatments. High pressure processing (HPP) is recognised by the FDA and Codex Alimentarius as a useful post-packaging treatment to hyginise RTE products [2; 3]. However, for a commercial implementation of HPP technology to Iberian cured meat products, the overall impact on the quality characteristics should also be assessed.

In this frame, the aim of the work was to globally evaluate the impact of HPP on sensory and physico-chemical properties and microbial safety of RTE Iberian chorizo and Iberian dry-cured loin.

II. MATERIALS AND METHODS

A. Sample preparation, high pressure processing and storage

Four independent batches of Iberian chorizo and Iberian dry-cured loin were manufactured following the traditional process by an Andalusian producer (COVAP, Pozoblanco, Córdoba). Both types of products were sliced and vacuum skin packaged in Darfresh® plastic materials (top TC201 and bottom web RSCO3X60; OTR<2 cc/m2, 24h, bar) from Cryovac (Sealed Air Packaging S.L.U., Viladecans, Barcelona Spain) using a semi-automatic thermoforming packaging machine Cryovac® VS-26. For each type of product, half of the samples were pressurized at 600 MPa for 5 minutes at an initial fluid temperature of 15ºC (Wave 6000/120 model, NC Hyperbaric, Burgos, Spain). All samples, pressurized and not pressurized, were stored for 2 months at 4°C plus 4 month at 8ºC.

B. Physico-chemical determinations

pH was measured after mincing the samples with a penetration probe (52-32; Crison Instruments SA,

Alella, Spain) connected to a portable pH-meter (PH 25; Crison Instruments SA, Alella, Spain). a_w was measured with the AquaLab™ (Series 3; Decagon, Devices Inc., Pullman, WA, USA) equipment. *Proximal analysis:* fat, protein, moisture and NaCl content were determined according to the AOAC official method 2007.04 [4] with a FoodScan™ device (FOSS Analytic, Hillerod, Denmark). *Lipid oxidation:* Peroxid Index (PI) and ThioBarbituric Reactive Substances (TBARs) following the methods described by [5] and NORMEX [6], respectively. *Proteolysis:* Non protein nitrogen (NNP) and α-amino nitrogen (AAN) were determined according to Astiassaran et al. [7] and the Sorensen method [8], respectively, from a 0.6N perchloric acid extract of the samples.

C. Instrumental colour and instrumental texture

Instrumental colour measurements were performed using a Minolta Chromameter CR200 (Minolta, Japan) in the CIELAB space using illuminant C and 2° standard observer. The mean of six measurements was recorded for each product.

Instrumental texture was determined with the Stress Relaxation test by using a Universal Texture Analyser TA.TX2 (Stable Micro Systems Ltd., Surrey, England), with a 25 kg load cell and a 50 mm diameter compression plate. Six specimens from each product were accurately carved with a scalpel into parallelepipeds of 10 × 10 × 10 mm (length × width × height) and wrapped in plastic film to avoid drying and stored at 4 ± 1 °C for 24 h. The specimens were compressed 75% of their original height, perpendicular to the fibre bundle direction and at a crosshead speed of 1 mm/s. The force *vs*. time after compression was recorded at speed of 50 points per second during 90 s (relaxation time).

D. Sensory analysis

Six trained assessors [9] undertook the sensory analysis on 1.5 mm thick slices of the products. The generation and selection of the descriptors was previously carried out by 2 open discussion sessions. Both products were evaluated for appearance, odour, tactile texture, flavour/taste, texture and overall liking. A non-structured 10-point scoring scale [10] was used, where 0 means absence or very low intensity of the descriptor and 10 means very high intensity of the descriptor. Means of scores given by the assessors for each product and session were recorded. Evaluation was undertaken in four independent sessions for each sampling time (0, 2, 4 and 6 month of storage). A randomized complete block design [11] was used in the sensory sessions, testing four samples per session. Samples were coded with three random numbers and were presented to the assessors balancing the first-order and carry-over effects.

E. Listeria monocytogenes *challenge test*

A set of samples were inoculated with *L. monocytogenes* (three strain cocktail: CTC1011, CTC1043, CECT4031^T at *ca.* 100 cfu/g) just before vacuum packaging. Periodically along the storage, the pathogen was enumerated on Chromogenic Listeria Agar (CLA, Oxoid) incubated at 37ºC/48h after homogenising samples (1/10) on 0.1% Bacto Peptone (Difco) with 0.85% NaCl (Merck). In samples with expected counts below the quantification limit (<4cfu/g), the presence/absence of *L. monocytogenes* of the pathogen was investigated in TSBYE enriched homogenate samples at 37ºC for 48 h. Then streaks were performed on CLA and grown colonies were confirmed by PCR [12].

F. Statistical analysis

Statistical analysis was carried out with the SAS statistical package [13]. The ANOVA test of the General Linear Model (GLM) was used to analyse the effect of HPP treatment on the instrumental colour and texture and sensory parameters. Differences among means were tested with the Tukey test ($P < 0.05$).

Physico-chemical and microbiological results were evaluated by U-Man Witney test.

III. RESULTS AND DISCUSSION

The results in relation to the *physico-chemical characterization* (pH, a_w, proximal analysis) of the products before and after pressurisation were not significantly different ($P > 0.05$). The impact of HPP was neither statistically significant ($P < 0.05$) in relation to lipid oxidation (PI below 1 mgEgO_2/kg in all the analysed samples; and TBARs values between

21-32) or proteolysis indexes (NPN tending to decrease and AAN to increase along the storage, data not shown).

In relation to the *sensory analysis*, the interaction between the factors HPP and storage time was not significant. Thus, data was analysed globally, both at time zero (before and just after the HPP) as well as considering the overall storage (all sampling times).

Very little effect was observed just after the HPP in Iberian chorizo (Table 1), only significant (P <0.05) for the paprika odour. The global evaluation along the storage detected a slight but significant (P <0.05) higher salty and lower garlic taste as well as harder texture in pressurised samples. However, no significant differences could be detected for the overall liking due to the HPP.

Table 1 Sensory characterization of sliced Iberian Chorizo, without and with high pressure processing (HPP).

	Time zero		Overall storage	
	No HPP	HPP	No HPP	HPP
APPEARANCE				
Cooked	6.8	6.6	7.5	7.4
ODOUR				
Intensity	6.4	6.4	6.5	6.6
Acid	2.4	2.4	2.7	2.6
Garlic	2.4	2.2	2.8	2.8
Paprika	3.6^{a}	3.3^{b}	4.0	3.9
TACTILE TEXTURE				
Elasticity	1.3	1.2	0.7	0.8
TASTE / FLAVOUR				
Intensity	6.0	6.2	6.5	6.6
Acid	2.9	3.1	3.2	3.2
Salty	3.0	3.2	3.1^{b}	3.3^{a}
Garlic	2.6	2.1	3.0^{a}	2.8^{b}
Paprika	3.6	3.6	4.4	4.2
TEXTURE				
Hardness	4.0	4.2	4.0^{b}	4.3^{a}
Stringiness	3.9	4.0	3.8	4.0
Crumbliness	4.7	4.6	5.3	5.1
OVERALL LIKING	5.7	5.6	6.2	6.1

^{a,b}: Mean values within a raw with different superscript letters are statistically different (p<0.05).

For Iberian dry-cured loin (Table 2), the texture attributes were significantly affected by the HPP (P<0.05), both immediately and along the storage. Pressurised samples showed higher hardness and stringiness and lower crumbliness and fat feeling. The overall evaluation along the storage could also revealed a higher (P <0.05) intensity for the cooked colour and salty taste. Despite of these specific differences, the HPP did not modify the overall liking of the dry-cured Iberian loin.

The *instrumental colour analysis* did not show statistically significant (P >0.05) differences for any of the measured parameters (L*, a* and b*) due to the HPP, irrespectively of the product or sampling time (data not shown). Though the overall evaluation along the storage could detect a slightly higher intensity of the luminosity (L*) in HPP dry-cured Iberian loin (37.13) in comparison with the non treated samples (34.71). HPP did not influence the *Stress Relaxation* test parameters (F_0, Y2, Y90) of chorizo samples, but significantly (P <0.05) affected the F_0 value (higher initial force) in dry-cured Iberian loin, being 26.29 kg for non treated and 45.99 kg for HPP samples.

Table 2 Sensory characterization of sliced Iberian dry-cured loin, without and with high pressure processing (HPP).

	Time zero		Overall storage	
	No HPP	HPP	No HPP	HPP
APPEARANCE				
Cooked	1.8	1.9	0.8^{b}	1.2^{a}
Brightness	3.8	3.6	4.0	3.7
ODOUR				
Intensity	5.7	5.8	6.3	6.0
Acid	1.9	1.9	2.4	2.1
Smoked	2.4	2.2	2.3	2.1
Garlic	2.1	2.0	2.6	2.6
Paprika	3.1	3.0	3.4	3.2
TACTILE TEXTURE				
Elasticity	4.6	4.1	4.4	4.1
TASTE/FLAVOUR				
Intensity	6.3	6.1	6.4	6.4
Acid	1.8	1.9	2.4	2.4
Salty	3.0	3.1	3.1^{b}	3.4^{a}
Smoked	2.1	2.0	2.5	2.4
Garlic	2.1	2.1	2.6	2.7
Paprika	3.3	3.4	3.6	3.6
TEXTURE				
Hardness	3.6^{b}	4.5^{a}	4.0^{b}	4.8^{a}
Stringiness	2.6^{b}	4.1^{a}	3.1^{b}	4.1^{a}
Crumbliness	5.3^{a}	4.6^{b}	5.6^{a}	5.1^{b}
Fat feeling	1.8^{a}	1.5^{b}	2.6^{a}	2.2^{b}
OVERALL LIKING	6.4	6.4	6.7	6.7

^{a,b}: Mean values within a raw with different superscript letters are statistically different (p<0.05).

The challenge test with *L. monocytogenes* revealed a bactericidal capacity of both products, as the inoculum was immediately reduced by 0.6 and 1.0 Log units in Iberian chorizo and dry-cured loin, respectively and the survival of the pathogen decreased along the storage (Fig. 2). Moreover, the HPP resulted in a lethal effect (P <0.001) of 1.07 and 1.73 Log reduction in Iberian Chorizo and dry-cured loin, respectively. As a result, *L. monocytogenes* on pressurised samples was generally below the limit of quantification (LoQ, 4 cfu/g). Noteworthy, along the storage, the absence of the pathogen (in 25g) was mainly confirmed in HPP products (41% of Iberian chorizo and 56% of Iberian dry-cured loin samples). By contrast, *L. monocytogenes* was detected (presence in 25g) in practically all non pressurised samples, except for 5 chorizo samples after 5 month of storage.

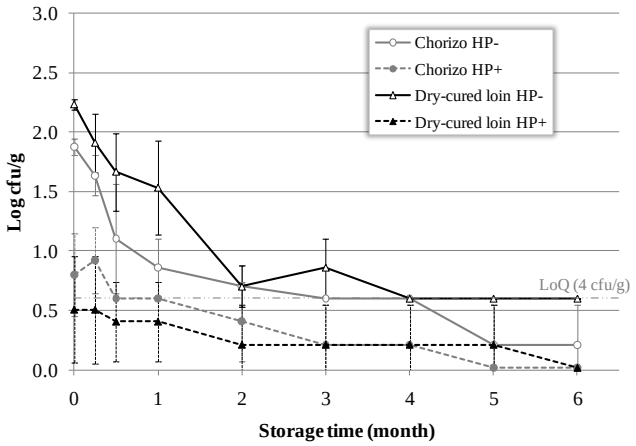

Fig. 1 Fate of *Listeria monocytogenes* during the storage of Iberian chorizo and Iberian dry-cured loin without (HP-) and with high pressure processing (HP+).

IV. CONCLUSIONS

High pressure processing renders safer products with insignificant or minor impact on the physico-chemical and sensory characteristics.

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