THE USE OF HIGH PRESSURE PROCESSING AS AN ALTERNATIVE TO PHOSPHATES IN THE MANUFACTURE OF COOKED HAM

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***Abstract*—Increasing consumers demand of meat product manufactured with a reduction or without additives, has focused the researches in looking for new alternatives to the use of additives The high pressure processing (HPP) could be an option to the use of phosphates since increases the solubility of certain myofibrillar proteins which could improve the binding between meat particles. The aim of this study was to evaluate the effect of the application different high pressures (200 and 300 MPa) at different steps (before injection, after injection and after tumbling) during the manufacture process of cooked ham on the yield and the sensory properties of cooked ham. HPP improved the yield and the connection of muscle of cooked ham, being the best results those obtained when HP was applied after tumbling. Nevertheless, the application of HPP caused some faults in the sensory properties.**

***Index Terms*—cooked ham, HPP, phosphates.**

I. INTRODUCTION

In recent years, consumers demand meat product manufactured with a reduction or without the use of additives, being the organic products an alternative to satisfy the consumers' demand. Besides the increasing demand for organic products, nowadays, cooked meat market has grown steadily. Therefore, the manufacturing of organic cooked ham would be a good alternative for satisfying the consumers' demand.

In the manufacturing of cooked hams, phosphates (E-450, E-451 and E-452), that improve cohesion of meat pieces and binding of water (Keenan, Desmond, Hayes, Kenny and Kerry, 2010), are commonly added. However, for manufacturing organic products the use of phosphates are not allowed (DOUE, 2008). In our knowledge for manufacturing cooked ham with high quality (low levels of brine and with the whole muscles of the pork's hams) have not been possible the total elimination, without obtaining faults in the texture in final product.

The high pressure processing (HPP) has been used as a possible means of improving the functional properties of muscle proteins since increases the solubility of certain myofibrillar proteins and improve the binding between meat particles in emulsion-type meat products (Sikes, Tobin and Tume, 2009). In base to the effect that high pressure exerts in the binding of meat muscle, one alternative to the use of phosphates could be the HPP application. In this way, the aim of this study was to evaluate the effect of the application of different high pressures (200 and 300 Mpa) at different steps during the manufacture of cooked ham in order to achieve the manufacture of organic cooked ham without phosphates added.

II. MATERIALS AND METHODS

Pork legs deboned without skin, tendons and fatty tissues were obtained from a local abattoir. One group of pork legs remained untreated and the rest were treated with two different pressures (200 and 300 MPa) during 10 min.

The HPP were applied on pork legs at different points of the manufacture process of cooked ham: *1*-before injection, *2*-after injection and *3*-after tumbling. HPP was performed at an industrial hydrostatic pressure unit (Wave 6000/135, NC. Hyperbaric, Burgos, Spain) equipped with a 135 l volume high-pressure vessel.

All cooked hams were obtained according to a conventional procedure. Pork legs were pumped to 120% of their green weight with a brine solution (mix of water, salt, dextrose, sodium nitrite and sodium ascorbate), using a multi-needle brine injector (Ogalsa CH-14). The injected hams were massaged in a meat tumbler (SM-Pulmax) at slow speed with cycles of time on and time off, at 2 ºC. Then, each ham were placed in pear-shaped ham moulds and were steam cooked in an oven (Industrial Junior 1100, Verinox) using different stages of cooking cycles until to get a core temperature of 68 °C. Finally, cooked hams were cooling with water and put them into a chamber at 2 ºC.

On all cooked hams manufactured, different analysis were carried out. **Yield** was calculated as the differential weight of hams between the green and the final cooling weight. **Surface color** of the cooked hams was measured using a spectrophotometer (CM-2600d/2500d, Konica Minolta). Colour results were determined in the CIE-LAB system and the lightness (L*), redness (a*, red↔green) and yellowness (b*, yellow↔blue) were calculated. **Instrumental Texture**

Profile Analysis (TPA) was performed with a texture analyzer TA-XT2 (Stable Micro Systems, Haslemere, UK.) Ten cooked ham cores (diam. 2.5 cm × ht. 2 cm) were taken from two 2 cm thick slices. Each core was compressed to 50% of its original height with a crosshead speed of 1 mm s^{-1}. The parameters calculated from the force and time curves were hardness, cohesiveness, springiness, gumminess and chewiness. Finally, **sensory evaluation** was carried out on cooked ham by a trained sensory panel (UNE 87-024-1, 1995; UNE EN ISO 8586-2, 2009). The colour (homogeneity and intensity), odour (intensity and quality), hardness, chewiness, juiciness, taste (intensity and quality) and the overall acceptability were evaluated on slices (1.5 mm thick) of cooked ham. These attributes were scored on a 5-point scale (1: minimum intensity, 5: maximum intensity).

Data collected were statistically analyzed by a two-factor factorial arrangement by analysis of variance (ANOVA), using the statistical package Statgraphics Plus 5.0. The factors were the pressure (0, 200 and 300 MPa) and the different steps in which the HPP was applied during the manufacture process of cooked ham (before injection, after injection and after tumbling). When main effects were significant, the means were separated by Fisher's least significant difference test at 5% level.

III. RESULTS AND DISCUSSION

The pressure and the step of application of HPP affected the yield of cooked ham (Table 1). Cooked hams treated with 300 MPa and those treated after tumbling showed the highest yield ($p<0.001$). Cheftel & Culioli (1997) pointed out that conformational changes in proteins take place after HPP affecting the interatomic distances in weak intra and intermolecular interactions, including protein bound water, which could explain these results. On the other hand, the application of pressure after tumbling could have intensified the solubility of myofibrillar protein, which increased the yield.

Regarding colour parameters (Table 1), there was a significant pressure level effect ($p<0.001$) on L*, a* and b*, whereas the step of application only affected to b* value ($p<0.05$). The cooked hams treated with 300 MPa presented the highest L* ($p<0.001$) and those treated with 200 MPa the highest a* ($p<0.001$). The lighter color found in cooked hams treated with 300 MPa could be due to its highest yield, which involves a higher water content and consequently a higher dilution of meat pigments (Desmond, Kenny and Ward, 2002). In the same way, the higher a* found in cooked ham treated with 200 MPa compared to untreated samples could be attributed to the yield, which entails a higher amount of nitrites responsible of the development of colour. On other hand, the differences found for a* might be due to HPP affects the myoglobin content of meat (Carlez, Veciana-Nogues and Cheftel, 1995). Thus, the reduction of a* value at higher pressure (300 MPa) has been related to the oxidation of ferrous myoglobin to ferric metmyoglobin (Cava, Ladero, González, Carrasco and Ramírez, 2009). For b* value, cooked ham untreated and cooked ham treated with HPP before the injection had the highest value ($p<0.05$). The yield also, could explains these differences since these samples had the lowest yield ($p<0.05$), that involves fewer amounts of additives such as nitrites and sodium ascorbate, which exert an antioxidant action (Honikel, 2008).

The results of the TPA applied to cooked ham are shown in Table 2. In general, an increase in all texture parameters was observed in pressurized ham compared to untreated samples. The application of 200 MPa entailed that cooked ham treated with HP showed a higher cohesiveness ($p<0.01$) than cooked ham untreated. HPP exerts a positive effect on the connection of muscles since improves the functional properties of meat by enhancing moisture-protein or protein-protein interactions (Hong, Ko, Choi and Min, 2008). Samples treated at 200 MPa showed a lower hardness and gumminess ($p<0.05$) and a higher elasticity ($p<0.05$) than samples treated at 300 MPa. Texture modifications could be attributed to the aggregation of myosin molecules, which begin to denature at pressures above 100 MPa (Yamamoto, Yoshida, Morita, & Yasui, 1994). Finally, the step of application affected the hardness ($p<0.01$), gumminess ($p<0.05$) and chewiness ($p<0.05$) values, being these parameters the highest in samples treated with HP after injection.

Considering sensory analyses (Table 3), the results obtained for the colour were in agreement with the instrumental evaluation of these parameters. Contrary, the evaluation of texture was in disagreement with the results obtained in the instrumental texture measurement since the tasters did not detect any effect ($p>0.05$) of the application of HP for the hardness and chewiness. The highest cohesiveness obtained in cooked ham treated with HP (Table 2) might be supported by the highest ($p<0.001$) connection of meat muscles detected by panelists. It is important to indicate that the cooked hams treated with HP showed a higher ($p<0.001$) scores for pastiness and fibrousness than cooked hams untreated. As regard the odour and taste, cooked ham treated at 300 MPa had the lowest ($p<0.001$) values for these parameters, probably due to HPP induce the lipid oxidation (Cheftel & Culioli, 1997). The scores of these parameters were the highest ($p<0.001$) in cooked ham treated with HP after tumbling. The highest yield observed in cooked ham treated after tumbling might explain these results, since a higher amount of additives involve in the development of odour and taste, could have been retained inside these cooked hams.

IV. CONCLUSION

On basis of to these results, it could be concluded that HPP improved the yield and the connection of muscle of cooked ham, being the best results those obtained when HP was applied after tumbling. Nevertheless, the application of HPP caused some faults in texture and sensory properties. For this reason, further investigations are needed in order to use HPP as an alternative to the use of phosphates.

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Table 1.
Effect of HPP on the yield and the colour of cooked hams.

	Yield (%)	L*	a*	b*
Pressure				
0	90.9^{a}	65.28^{a}	7.25^{b}	8.37^{b}
200	97.8^{b}	63.98^{a}	8.49^{c}	6.48^{a}
300	100.5^{c}	70.94^{b}	6.39^{a}	6.61^{a}
Step of application				
Before injection	95.1^{a}	66.91	7.61	7.85^{b}
After injection	96.7^{b}	67.17	7.20	6.68^{a}
After tumbling	97.3^{c}	66.13	7.33	6.93^{a}
SEM	4.19	0.59	0.27	0.31
ANOVA				
p level (Pressure)	***	***	***	***
p level (Step of application)	***	ns	ns	*
p level (Pressure * Step of application)	***	***	**	ns

SEM: standard errors of the mean.
p level: ***= p<0.001; **= p<0.01; * = p<0.05; ns= p>0.05.
[a,b,c] Means within the same column with different letters differ significantly.

Table 2.
Effect of HPP on the texture (TPA) of cooked hams.

	Hardness (N)	Elasticity (mm)	Cohesiviness	Gumminess	Chewiness (N×mm)
Pressure					
0	63.16^{a}	0.60^{a}	0.45^{a}	29.16^{a}	17.37^{a}
200	82.54^{b}	0.73^{b}	0.56^{b}	46.04^{b}	33.28^{b}
300	104.25^{c}	0.63^{a}	0.57^{b}	59.54^{c}	37.91^{b}
Step of application					
Before injection	75.77^{a}	0.64	0.52	40.28^{a}	25.85^{a}
After injection	98.57^{b}	0.66	0.53	53.80^{b}	36.03^{b}
After tumbling	75.60^{a}	0.67	0.53	40.65^{a}	26.68^{a}
SEM	4.51	0.01			
ANOVA					
p level (Pressure)	***	***	**	***	***
p level (Step of application)	**	n.s	n.s	*	*
p level (Pressure * Step of application)	***	n.s	n.s	*	*

SEM: standard errors of the mean. p level: ***= p<0.001; **= p<0.01; * = p<0.05; ns= p>0.05.
[a,b,c] Means within the same column with different letters differ significantly.

Table 3.
Effect of HPP on the sensory properties of cooked ham evaluated by a trained sensory panel.

	Homogeneity colour	Intensity colour	Connection meat	Intensity odour	Quality odour	Hardness
Pressure						
0	1.50^{a}	3.00^{b}	1.16^{a}	4.33^{c}	4.67^{b}	2.00
200	2.89^{b}	3.72^{c}	2.72^{b}	3.33^{b}	3.22^{a}	1.72
300	4.50^{c}	2.22^{a}	3.83^{c}	2.56^{a}	3.00^{a}	2.00
Step of application						
Before injection	2.83	2.78^{a}	2.72^{b}	3.11^{a}	3.50^{a}	2.00
After injection	2.94	2.67^{a}	1.39^{a}	3.17^{a}	3.39^{a}	1.72
After tumbling	3.11	3.50^{b}	3.61^{c}	3.94^{b}	4.00^{b}	2.00
SEM	0.14	0.15	0.29	0.12	0.12	0.16
ANOVA						
p level (Pressure)	***	***	***	***	***	n.s
p level (Step of application)	n.s.	**	***	***	**	n.s
p level (Pressure * Step of application)	**	***	***	**	**	n.s

	Chewiness	Juiciness	Pastiness	Fibrousness	Intensity taste	Quality taste
Pressure						
0	2.00	3.50^{b}	1.17^{a}	2.50^{a}	4.67^{c}	4.83^{c}
200	2.17	3.61^{b}	2.33^{b}	2.28^{a}	4.17^{b}	2.89^{b}
300	2.33	2.11^{a}	2.11^{b}	4.00^{b}	3.00^{a}	2.39^{a}
Step of application						
Before injection	2.00	2.83	2.33^{c}	2.94^{ab}	3.50^{a}	2.39^{a}
After injection	2.17	3.28	1.89^{b}	3.17^{b}	3.94^{b}	3.28^{b}
After tumbling	2.33	3.11	1.39^{a}	2.67^{a}	4.39^{c}	4.44^{c}
SEM	0.17	0.15	0.14	0.15	0.12	0.12
ANOVA						
p level (Pressure)	n.s	***	***	***	***	***
p level (Step of application)	n.s	n.s	***	n.s	***	***
p level (Pressure * Step of application)	n.s	n.s	*	**	***	***

SEM: standard errors of the mean. p level: ***= p<0.001; **= p<0.01; * = p<0.05; ns= p>0.05.
[a,b,c] Means within the same column with different letters differ significantly.