# SALT REDUCTION IN COOKED HAM BY USING HIGH PRESSURE PROCESSING

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**Abstract –The effect of salt content (0, 0.95, 1.33 and 1.90 %) and the application of high pressure processing (HPP) at three pressure levels (100, 300 and 600 MPa) and at different processing stages (raw material, after injection, after tumbling and after cooking) on the technological quality parameters (cooking loss, texture, water holding capacity (WHC), color and saltiness perception) of cooked ham was investigated as a strategy to reduce the salt content based on the HPP-induced structure formation.**

**The application of HPP to the raw material or after injection was detrimental to the quality of the cooked ham leading to unacceptable structure and water retention whereas the application after tumbling and after cooking showed slight improvements. The WHC of the salt-reduced cooked ham was improved 5 % by HPP treatment at 100 MPa after tumbling. The color changes could be minimized if the HPP treatment was after cooking. A correlation between HPP and an increased saltiness perception was not appreciated.**

**Key Words – HPP, Meat products, Food functionality, Salt perception.**

## I. INTRODUCTION

High salt consumption in industrialized countries is linked to high blood pressure and other cardiovascular diseases [1]. A reduction of salt consumption to 5 g/day could reduce the risk of cardiovascular diseases by 24 % according to the WHO [2]. Nearly 80 % of the daily salt intake comes from processed food and meat products represent nearly 20 % out of the total [3]. Therefore, the development of strategies to reduce the salt content in meat products would lead to a reduction of the sodium daily intake.

Traditionally, salt (NaCl) has been used for preservation and to ensure a longer shelf life. Salt lowers the water activity and limits the microbial growth. In addition salt has an effect on the structure formation and acts as flavor enhancer [3]. The sodium chloride interacts with major components, like proteins. In meat products, myosin and actin swell in the presence of salt. Salt also promotes the binding of proteins to each other. Ruusunen et al. [1] and Crobcraft et al. [4] suggested that a reduction below 10 % has no essential effects on taste and a reduction of 10 to 30 % is possible by using ingredients with salt enhancements properties [4]. A reduction above 30 % is difficult to achieve without changes in flavor and technological properties.

HPP is mostly used for pasteurization, however, the pressurization can also be used for structuring and improving the functionality of meat products [5, 6]. It has been hypothesized that HPP could have similar effects as salt on the solubilization of myofibrillar proteins by changing the spatial structure of the proteins [7]. Since HPP has value in the formation of gels from myofibrillar protein at low (1.2 %) salt concentration may have potential for the development of low sodium-containing meat products [8]. Furthermore, some studies have pointed out that HPP treatments enhance the saltiness perception of meat products [9, 10].

The aim of the present paper was to investigate the applicability of HPP as a functionalization processing method to produce salt reduced cooked hams and to ascertain the saltiness enhancement by HPP.

## II. MATERIALS AND METHODS

*Processing*

The cooked ham consisted of pork topsides injected with 12 % brine. The product contained 0.25 % di-/triphosphate (1:1) (E451 / E450, Frutarom Savory Solutions GmbH, Germany), 0.05 % sodium ascorbate (E300, Frutarom Savory Solutions GmbH, Germany) and 0.0095 % sodium nitrite (E250, Sigma-Aldrich Chemie GmbH). The salt varied from 1.9 % (control), 1.33 % (30 % reduction), 0.95 % (50 % reduction) to 0 % (100 % reduction). All batches were manufactured by the same standard procedure which consisted of injection, tumbling, cooking and cooling. The brine was injected at 0.5 bar with an injector equipment (IR 56, Rühle GmbH, Germany). After injection, the meat was tumbled for 14 h with alternant tumbling and resting time of 10 min and 20 min respectively, at 0 - 2 °C and vacuum of 90 %, at the tumbler (MKR 150, Rühle GmbH, Germany). Then, the meat was filled into molds and cooked in the cooking chamber (ASR 1297 EL/WA, Maurer-Atmos Middleby GmbH, Germany) up to a core temperature of 72 °C. After cooking, the ham was cooled below a temperature of 3 °C. HPP treatment for 5 minutes was applied at the pressure levels and processing stages indicated in Table 1.

Table 1: Experimental design

| | Salt reduction | Pressure level | Processing stage where HPP is applied |
|---|---|---|---|
| | [%] | [MPa] | |
| Reference – No HPP-treated | 0 | - | - |
| | 30 | - | - |
| | 50 | - | - |
| | 100 | - | - |
| HPP-treated | 0 | - 100<br>- 300<br>- 600 | - raw meat<br>- after injection<br>- after tumbling<br>- after cooling |
| | 30 | Idem | Idem |

*Analytical methods*

The cooking loss was calculated by weight difference before and after the cooking steps. The water holding capacity (WHC) was determined by calculating the drip loss of the cooked ham according to the method by Tintchev *et al.* [11]. The texture was determined by using a texture analyzer (TA-TX2, Stable Micro Systems Ltd., UK). Samples of size (2 X 2 cm) were cut at a speed of 2 mm/sec-1 and the required force (N) registered. The color change (ΔE) was determined with a Minolta spectrophotometer CM 700d (Koniac Minolta GmbH, Germany) and using the formula: $(\Delta E) = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. The sensory evaluation for saltiness perception was assessed by a ten-member trained panel (α-error > 0.05 mean significant difference). The statistical significances were determined by one-way-analysis of variance (ANOVA) with software Past by Hammer & Harper (version 2.17b).

## III. RESULTS AND DISCUSSION

*Reference cooked ham with different content of salt*

The dramatic effect on the structure of the cooked ham due to a salt reduction higher than 30 % can be observed in the Figure 1.

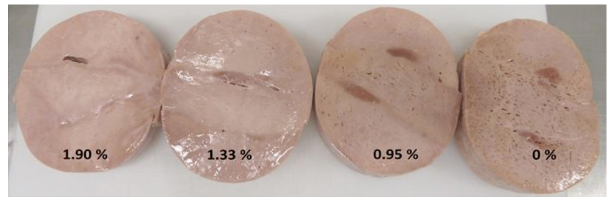


Figure 1. Effect of different NaCl content (%) on the structure and the amount of holes of cooked ham

A clear correlation between the cooking loss and the salt content was observed. The higher the salt content the lower the cooking loss was (Table 2). The measurements of the drip loss and the cutting force for the cooked ham with a salt content of 0.95 % and 0 % were not taken into account as the cooking losses were extremely high, 23.4 and 44.7 % respectively, and resulted in an unacceptable unstructured and dry product. Concomitant, the WHC got lower with a decreasing salt content (Table 2).

Table 2. Effect of different salt content on the cooking loss, drip loss and cutting force of cooked ham.

| Salt content | Salt reduction | Cooking loss | Drip loss * | Cutting force |
|---|---|---|---|---|
| [%] | [%] | [%] | [%] | [mN/ mm²] |
| 1.90 | 0 | 11.6 ± $2.0^{a}$ | 27.6 ± $1.9^{c}$ | 30.6 ± $2.9^{a}$ |
| 1.33 | 30 | 14.4 ± $4.3^{b}$ | 35.0 ± $0.6^{d}$ | 29.1 ± $3.4^{a\ b}$ |
| 0.95 | 50 | 23.4 ± $0.9^{c}$ | 24.7 ± $0.7^{a\ b}$ | 32.8 ± $3.0^{ab}$ |
| 0 | 100 | 44.7 ± $4.4^{d}$ | 23.1 ± $0.1^{a}$ | 43.7 ± $3.7^{c}$ |

Different superscripts with the same column mean significant difference at p-value < 0.05.
*: The drip loss is a measurement of the water holding capacity (WHC).

*Cooked ham treated by HPP at different pressure levels and processing stages*

The cooked ham was treated by HPP with the goal of improving the structure and the WHC of the salt-reduced formulation. Three pressure levels (i.e. 100, 300 and 600 MPa) at different stages of processing (i.e. raw meat, after injection, after tumbling and after cooking) were assayed. The HPP treatments of the raw material and after injection showed negative effects on the cooking loss, WHC and texture (data not shown).

Table 3. Effect of the application of HPP treatment at (100, 300 and 600 MPa) at different stages of processing (after tumbling and after cooking) on cooking loss and drip loss of cooked ham of two salt content (1.9 % and 1.33 %).

| | Pressure level | Cooking loss | | Drip loss* | |
|---|---|---|---|---|---|
| | [MPa] | [%] | | [%] | |
| | | 1.9 % NaCl | 1.33 % NaCl | 1.9 % NaCl | 1.33 % NaCl |
| Control | 0 | $10.5 \pm 0.1^{a}$ | $9.8 \pm 1.5^{a}$ | $27{,}6 \pm 1.9^{a}$ | $35{,}0 \pm 0.6^{b}$ |
| HPP after tumbling | 100 | $10.1 \pm 2.6^{a}$ | $13.0 \pm 1.6^{a}$ | $29{,}4 \pm 0.4^{a}$ | $29{,}8 \pm 1.0^{a}$ |
| | 300 | $14.1 \pm 7.1^{a}$ | $21.7 \pm 3.5^{b}$ | $30{,}3 \pm 2.7^{ab}$ | $31{,}5 \pm 0.8^{ab}$ |
| | 600 | $23.9 \pm 4.1^{b}$ | $22.9 \pm 2.8^{b}$ | $21{,}9 \pm 0.6^{c}$ | $28{,}4 \pm 1.2^{a}$ |
| HPP after cooking | 100 | $10.5 \pm 0.1^{a}$ | $9.8 \pm 1.5^{a}$ | $29{,}3 \pm 1.1^{a}$ | $32{,}3 \pm 1.5^{ab}$ |
| | 300 | $10.5 \pm 0.1^{a}$ | $9.8 \pm 1.5^{a}$ | $33{,}0 \pm 1.1^{b}$ | $30{,}8 \pm 1.3^{ab}$ |
| | 600 | $10.5 \pm 0.1^{a}$ | $9.8 \pm 1.5^{a}$ | $33{,}2 \pm 1.2^{b}$ | $30{,}9 \pm 1.2^{ab}$ |

Different superscripts within the same column mean significant difference at p value < 0.05.

*: The drip loss is a measurement of the water holding capacity (WHC).

The cooking loss increased significantly with the pressure level applied and the reduced content of salt (Table 3). The HPP treatments after tumbling at 300 and 600 MPa resulted in unacceptable cooking losses and color changes becoming a hard, dry and pale cooked ham (Table 3 and 4). The treatment at 100 MPa after tumbling proved to be the best combination to produce a cooked ham with reduced salt content as it had less cooking loss and drip loss and acceptable texture and color change (Table 3 and 4).

The positive effect of HPP treatment on the WHC was observed for a cooked ham with a salt content of 1.33 %. The WHC of the cooked ham was significantly increased ($p < 0.05$) at a pressure level of 100 MPa after tumbling. The HP-treatment likely improves the WHC by favoring protein solubilisation and swelling through partial protein unfolding [6, 11, 12].

Table 4. Effect of the application of HPP treatment at (100, 300 and 600 MPa) at different stages of processing (after tumbling and after cooking) on cutting force and color change of cooked ham of two salt content (1.9 % and 1.33 %).

| | Pressure level | Cutting force | | Color change | |
|---|---|---|---|---|---|
| | [MPa] | [mN·mm⁻²] | | [ΔE] | |
| | | 1.9 % NaCl | 1.33 % NaCl | 1.9 % NaCl | 1.33 % NaCl |
| Control | 0 | $30.6 \pm 2.9^{b}$ | $29.1 \pm 3.4^{a}$ | 0 | $0.4 \pm 0.66^{a}$ |
| HPP after tumbling | 100 | $22.7 \pm 2.1^{a}$ | $27.8 \pm 2.1^{ab}$ | $2.6 \pm 0.5^{c}$ | $0.8 \pm 0.5^{a}$ |
| | 300 | $20.6 \pm 4.3^{ab}$ | $34.1 \pm 4.2^{ab}$ | $5.2 \pm 0.8^{d}$ | $3.0 \pm 0.6^{d}$ |
| | 600 | $27.9 \pm 3.8^{b}$ | $34.1 \pm 4.2^{a}$ | $3.6 \pm 1.2^{d}$ | $4.5 \pm 1.3^{d}$ |
| HPP after cooking | 100 | $23.6 \pm 2.3^{ab}$ | $33.2 \pm 1.0^{a}$ | $1.1 \pm 0.6^{b}$ | $0.8 \pm 0.4^{a}$ |
| | 300 | $31.7 \pm 1.6^{b}$ | $34.5 \pm 2.1^{a}$ | $1.1 \pm 0.5^{a}$ | $0.7 \pm 0.6^{a}$ |
| | 600 | $23.9 \pm 1.1^{ab}$ | $30.7 \pm 2.3^{a}$ | $1.0 \pm 0.7^{a}$ | $0.7 \pm 0.5^{a}$ |

Different superscripts within the same column mean significant difference at p value < 0.05.

For the salt-reduced formulation, if the HPP-treatment was after cooking, the cutting force of the cooked ham trended to be harder than the control.

The intensity of the color changes clearly depended on the pressure level and the processing stage. Higher pressure level and application of HPP immediately after tumbling resulted in higher color change what is in agreement with Campus [13]. The treatments after tumbling (100 MPa) and after cooking of cooked hams with salt content of 1.33 % are auspicious since the color changes were minimal.

The saltiness perception of the cooked hams treated by HPP after tumbling and after cooking was compared to its counterpart untreated with same salt content for both salt levels (1.9 and 1.33 %). No significant differences in saltiness perception between HPP-treated and control were detected. Contrary to what reported in the studies [9, 10]. Therefore, it is concluded that HPP-treatment did not enhanced the saltiness perception under the conditions assayed.

## IV. CONCLUSION

It was possible to obtain a slight improvement in the structure formation of salt-reduced cooked ham (30 % reduction) by applying HPP at 100 MPa after tumbling. This opens the possibility of using HPP equipments, which operates at low working pressures, in order to confer protein functionality to processed meats. In the present study, the salty taste of cooked ham was not enhanced after HPP treatment.

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