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# Salt (NaCl) reduction in cooked ham by a combined approach of high pressure treatment and the salt replacer KCl

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ABSTRACT

The food industry must develop effective methods to address the reduction of salt in meat products and contribute to the reduction of salt consumption associated with cardiovascular diseases. This paper investigated the effect of NaCl content (0, 0.95, 1.33 and 1.90%), phosphate content (0 and 0.25%) and the use of high pressure processing (HPP) (100, 300, 600 MPa) at different processing stages (raw material, after injection, tumbling and cooking) on the quality parameters (cooking loss, texture, water holding capacity, color and saltiness perception) in cooked ham. The application of HPP to the raw meat or after its injection was detrimental to the structure and water retention of the salt-reduced cooked ham. Whereas the application of HPP at 100 MPa after tumbling was beneficial. A further salt reduction up to 1.1% NaCl was possible by the salt replacement with KCl (0.2%) in combination with the HP treatment.

*Industrial relevance:* High-pressure treatment can help in the production of salt-reduced meat products but efforts are needed to understand the feasible levels of NaCl, phosphates and specific HP treatments to apply in commercial scenarios. The present paper describes a strategy to produce a salt-reduced cooked ham (45% reduction) using a HP treatment at 100 MPa after tumbling stage in combination with KCl (0.2%).



## 1. Introduction

The high salt consumption in industrialized countries is linked to high blood pressure and other cardiovascular diseases (CVD). The World Health Organization (WHO) recommends a salt consumption of 5 g/day. However, the current daily salt intake worldwide is usually higher, for instance in Europe is 8–10 g/day (WHO, 2011; European Commission, 2012). A reduction of salt consumption to 5 g/day could reduce the risk of CVD by 24% according to the WHO (2011). Nearly 80% of the daily salt intake comes from processed food and meat products represent nearly 20% out of this total (Desmond, 2006). Therefore, the development of strategies to reduce the salt content in meat products would lead to a reduction of the daily sodium intake and the production of healthier foods (Toldrá & Barat, 2009; Tamm, Bolumar, Bajovic, Toepfl, & Heinz, 2013).

In most cases "salt" is used synonymously for "sodium" as around 90% of the sodium intake is consumed in the form of salt (Matthews & Strong, 2005). Sodium (Na) is a cause for CVD and hence sodium is the target for reduction (European Commission, 2012; Toldrá & Barat, 2009; Tamm et al., 2013). Cooking salt, chemically mainly sodium chloride (NaCl) contains 39.5% sodium. In addition to the sodium content from NaCl, the real sodium content in meat is 10–20% higher. This is because there are additional sources of sodium such as sodium phosphates, sodium nitrite and the naturally present in meat (Honikel, 2008). Traditionally, salt (NaCl) has been used for preservation and to ensure a longer shelf life. Salt lowers the water activity ($a_w$) and limits microbial growth. Salt has also an effect on structure formation (Desmond, 2006). The sodium chloride interacts with major components, like proteins, and solubilizes the myofibrillar proteins. In meat products, myosin and actin swell in the presence of salt. Salt also promotes the binding of proteins to each other. Therefore the addition of salt plays a decisive role in the structure and yields after processing by lowering the purge or fluid exudates (Doyle & Glass, 2010). Salt also acts as flavor enhancer. The multi-functionality of salt points out the technological challenge of salt reduction while maintaining product quality (Tamm et al., 2013).

Cooked ham is a typical meat product with wide-spread acceptability in many countries and therefore a good target for salt reduction. It is well known that cooked ham with lower salt content has issues with the water holding capacity (WHC) (Hamm, 1972). Indeed, a

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reduction of the salt content from 1.7% to 1.4% has an impact on cooking loss (Desmond, 2006). Ruusunen and Puolanne (2005) and Crobcraft, Tikellis, and Busch (2008) suggested a distinction in the level of salt reduction. A reduction below 10% has no essential effects on taste. A step-wise reduction of the salt content by 5–10% per year could educate the consumer's taste to less salty products (Crobcraft et al., 2008). A salt reduction of 10 to 30% is possible by using ingredients such as salt substitutes and flavor enhancers (Ruusunen & Puolanne, 2005; Crobcraft et al., 2008). The solubilisation of muscle proteins with salt can be substituted using salt replacers such as KCl, $MgCl_2$ and $CaCl_2$. According to the "Hofmeister Series" the addition of KCl would have the highest effectiveness on protein stabilization (Puolanne & Halonen, 2010). The content of $Cl^-$ anions is also important for the swelling of meat proteins (Puolanne & Halonen, 2010). Consequently, KCl was selected for this study. However a total replacement of NaCl with KCl is not possible due to the bitter taste of KCl (Desmond, 2006; Morris et al., 2010). A NaCl reduction above 30–40% is difficult to achieve without severe changes in the technological properties and flavor.

Currently, the available alternatives to reduce the salt content in meat products are limited and hence more methods need to be developed particularly coming from the processing side (Table 1). Based on the structuration effects of high pressure (HP) the use of HPP could contribute to this purpose (Crehan, Troya, & Buckley, 2000; Sun & Holley, 2010; Bajovic, Bolumar, & Heinz, 2012; Buckow, Sikes, & Tume, 2013). HPP is mostly used for cold-pasteurization, however, the pressurization can also be used for structuring and improving the functionality of meat products. It has been hypothesized that HPP could have similar effects on the solubilisation of myofibrillar proteins as salt and phosphates as a result of the modification of protein spatial structure (Macfarlane, 1985; Cheftel & Culioli, 1997). This solubilizing effect depends on the system characteristics such as ionic strength, pH, type of salt and processing conditions such as pressure level, temperature and processing time, which make the finding of the right settings quite challenging (Fernandez-Martın, Cofrades, Carballo, & Jimenez-Colmenero, 2002). HPP improved the solubilisation of myofibril at 150 MPa (Macfarlane, 1974) and opposite effects were observed with pressure above 300 MPa (Cheftel & Culioli, 1997). A severe denaturation of the proteins lowers the solubilisation of proteins and the WHC. Furthermore, some studies have pointed out that HP treatment enhances the saltiness perception in meat products (Atsushi, Ken, Hiroyuki, & Tadayuki, 2006; Clariana et al., 2011). This might be due to differential binding forces of NaCl within the product network and its release in the mouth. In addition to the salt reduction, the phosphate content should be reduced. Phosphates are also an important sodium source in meat products although they also play an important role in the solubilisation of meat proteins (Honikel, 2003). The study of O'Flynn, Cruz-Romero, Troy, Mullen, and Kerry (2014) showed that it is possible to produce breakfast sausages with a phosphate content of 0.25%, instead of 0.5% when a HPP treatment (150 MPa, 5 min) is applied. Finally, the salt (NaCl) content can be further reduced by partial replacement with KCl.

The aim of the present paper was to investigate and develop an industrial process to produce a salt reduced cooked ham combining HPP applied at different stages of the process with the salt replacer KCl. First, the content of NaCl (0, 0.95, 1.33 and 1.90%) and phosphate (0 and 0.25%) in the cooked ham were varied to assess the technological feasibility in the level of reduction, and subsequently, HP treatments at different levels (100, 300 and 600 MPa at room temperature for 5 min) were applied at different processing steps (raw material, after injection, after tumbling and after cooking). These effects on quality parameters (cooking loss, texture, WHC, color and saltiness perception) were monitored to find the positive HP treatments. Finally, the salt (NaCl) content was further reduced by a partial replacement with KCl (0.2% KCl) in combination with the optimal HPP treatment developed in the previous step.

## 2. Materials and methods

### 2.1. Cooked ham processing

Fresh pork topsides (*m. semimembranosus*) were obtained from a local slaughterhouse (Landschlachterei G.H. Diekmann, Essen, Oldenburg, Germany) after 24 h post-slaughter. The quality of each piece of meat was analyzed by measuring the pH (Testo 205, Testo AG, Essen, Germany), only meat with a pH-value within the range 5.5–5.9 and a temperature of 3–5 °C was used. The cooked ham consisted of pork topsides injected with 12% brine. The brine formula based on finished product was composed of 0.25% di—/triphosphate (1:1) (E-450/E-451, Frutarom Savory Solutions GmbH, Holdorf, Germany), 0.05% sodium ascorbate (E-300, Frutarom Savory Solutions GmbH, Holdorf, Germany) and 0.0095% sodium nitrite (E-250, Sigma-Aldrich Chemie GmbH, Schnelldorf, Germany). The cooked hams were produced following the above formulation with varying content of salt (0–1.9%) (Suprasel Salt Akso Nobel Salt A/S, Denmark), phosphate (0 and 0.25%) and KCl (0.2%) (E-508, Frutarom Savory Solutions GmbH, Holdorf, Germany) and applying different pressure levels (Table 2). All treatments followed the same manufacture procedure which comprised injection, tumbling, cooking and cooling. Ten to twelve cooked hams were produced per treatment. During the production process the room was chilled at 5 °C.

The brine was injected at 0.5 bar with an injector equipment (IR 56, Rühle GmbH, Grafenhausen, 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, Grafenhausen, Germany). Afterwards, the meat was packed into plastic film (HDPE, Barg Packaging, Lauterbach, Germany) and filled into molds (Rund-Form 690, Adelmann, Kelh-Goldscheuer, Gemany). The ham was steam-cooked up to a core temperature of 72 °C at the cooking chamber (ASR 1297 EL/WA, Maurer-Atmos Middleby GmbH, Reichenau, Germany). The temperature increased step-by-step to 45 °C, 58 °C and 79 °C. After cooking, the cooked ham was cooled to

**Table 1**
Technical approaches and tools for salt reduction in meat products.

| Approach | Tool | Main mechanism | Reference |
|---|---|---|---|
| Salt substitutes | KCl, $MgCl_2$, $CaCl_2$ | Ionic strength | Puolanne and Halonen (2010) |
| | Phosphates | Ionic strength and disassociation of actomyosin | Fernandez-Martın et al. (2002); Ruusunen and Puolanne (2005) |
| | Protein, fibers, starches | Protein coagulation and gel formation | Desmond (2006) |
| Flavor enhancers | Yeast extracts, ribonucleotides, sugars, organic acids, creamers, spices, herbs, amino acids, aroma compounds | Compensate for the reduction in salt, improve the overall taste profile and boost overall mouthfeel. | Dermiki, Phanphensophon, Mottram, and Methven (2013) |
| Optimizing the physical form of the salt | Crystal size and shape and distribution of the salt | Bioavailability of salt in the product confers enhanced functionality. Gradients can increase salt perception. | Quilaqueo and Aguilera (2015) |
| Processing technologies | High pressure processing (HPP) | Enhancement of saltiness perception HPP-induced structure modification | Bajovic et al. (2012) |