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# Shelf life extension of vacuum-packed salt reduced frankfurters and cooked ham through the combined application of high pressure processing and organic acids

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ABSTRACT

The objective of this study was to assess the efficacy of a combination of high pressure processing (HPP) and a mix of organic acids Inbac™ as hurdles to extend the shelf life of previously optimised sensory accepted frankfurters and cooked ham with significantly ($P < 0.05$) lower salt content. The optimum parameters for the manufacture of low-salt frankfurters were; Salt replacer Artisalt™ (48%), HPP (580 MPa) and Inbac™ (0.3%) and for manufacture of low-salt cooked ham the optimum parameters were; Salt replacer Artisalt™, HPP (535 MPa) and Inbac™ (0.3%). Physicochemical changes ($P < 0.05$) occurred over storage time; however, the sensory acceptability did not change significantly. From the microbiological point of view, the results indicated that the hurdles (HPP and Inbac™) applied in the manufacture of low-salt processed meat products extended ($P < 0.05$) the shelf-life of low-salt frankfurters by 51% and low-salt cooked ham by 97%, compared to control samples which contained full salt content. These results highlight the potential use of the hurdle strategy for extending the shelf-life and safety of low-salt processed meat products.

## 1. Introduction

The functions of salt in meat processing fall into three broad categories; enhancing sensory properties, providing specific physical processing effects and affecting preservation (Matthews & Strong, 2005), therefore salt reduction in processed meats can be problematic (Pietrasik, Gaudette, & Johnston, 2017) as the sensory acceptability and the safety and shelf life can be compromised. The antimicrobial effects of salt is based on its ability to reduce water activity ($a_w$) (Inguglia, Zhang, Tiwari, Kerry, & Burgess, 2017; Sofos, 1984). The effect of salt on microorganisms depends on the concentration of salt present in the aqueous phase of the food (Inguglia et al., 2017). The concentration of salt in the water phase has to be high enough to inhibit the growth of pathogenic micro-organisms such as *Clostridium botulinum* and *Listeria monocytogenes* in vacuum packed and chilled food products (Matthews & Strong, 2005). However, salt reduction increases $a_w$ reducing the preservative effects of salt which in turn increases water availability for microbial growth.

There is strong evidence that our current salt consumption is the major factor increasing blood pressure and thereby cardiovascular disease (He & Macgregor, 2009). Regardless of this, in most European countries the recommended dietary salt intake of < 5 g/day is greatly exceeded with an estimated salt consumption as high as 9–12 g/day (World Health Organisation, 2016) with 75% of dietary salt coming from processed foods (Appel & Anderson, 2010). As a result, the food industry is currently under pressure from food standards agencies to deliver reductions in the salt intake of the population through the introduction of lower salt levels in processed foods (Phillips, 2003) without compromising consumer acceptability or food safety & shelf life. Salt replacers such as Potassium Chloride (KCl) are commonly used to reduce salt in meat products; however, health concerns regarding the replacement of Sodium chloride (NaCl) with KCl have been highlighted by Steffensen et al. (2018) and include renal malfunctioning, hypoaldosteronism and Addison disease.

Shelf life is the period of time during which a food retains acceptable characteristics of flavour, colour, aroma, texture, nutritional value, and safety under defined environmental conditions (Lee, Yam, & Piergiovanni, 2008). During storage, the main factors of deterioration leading to unacceptable food quality or safety issues of cooked food products are physical, chemical and microbiological, such as; discoloration, oxidative rancidity, increase in the numbers of spoilage microorganisms or the presence of food pathogens (Lee et al., 2008;

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Robertson, 2009).

Hurdle technology combines intelligently different mild preservation techniques (hurdles) to control or eliminate pathogens (Rodriguez-Calleja, Cruz-Romero, O'sullivan, Garcia-Lopez, & Kerry, 2012). One of the potential hurdles to assure the safety of reduced sodium ready-to-eat (RTE) meat products is HPP (Han et al., 2011; Myers et al., 2013; Oliveira et al., 2015; Rendueles et al., 2011). Application of HPP at 600 MPa has demonstrated the inactivation of most pathogens and spoilage bacteria resulting in substantial extension of shelf-life of RTE meat products such as low-fat pastrami, strassburg beef, export sausage, cajun beef, cooked ham, dry cured ham and marinated beef loin (Hayman, Baxter, O'Riordan, & Stewart, 2004; Jofré, Aymerich, Grebol, & Garriga, 2009). Marcos, Aymerich, Guardia, and Garriga, 2007 improved the microbial quality of fermented sausages without affecting the quality applying HPP at 400 MPa for 10 min. at 17 °C. Pietrasik et al. (2017) reported that HPP does not impact the sensory acceptability of reduced sodium naturally cured wieners and can also successfully extend the shelf-life up to 12 weeks without compromising eating quality. Garriga, Grebol, Aymerich, Monfort, and Hugas, 2004 examined microbial inactivation on cooked ham after HPP at 600 MPa and found that after 60 days storage lactic acid bacteria (LAB) count was 6 log (CFU/g) lower in HPP cooked ham than in untreated samples. A study carried out by Diez, Santos, Jaime, and Rovira, 2008 examined independently the application of organic acids (L-potassium lactate, L-potassium lactate/sodium lactate or L-potassium lactate/sodium acetate) and high-pressure treatments (300, 500 or 600 MPa for 10 min.) to improve the shelf life of blood sausage. The longest shelf life of 15 days was achieved using L-potassium/sodium lactate or HPP at 600 MPa for 10 min. The authors suggested that the synergetic effects of the organic acids and HPP might further improve the effectiveness of these treatments.

In our previous studies (O' Neill, Cruz-Romero, Duffy, & Kerry, 2018; O' Neill, Cruz-Romero, Duffy, & Kerry, 2015) sensory accepted low-salt frankfurters and cooked ham were developed through the application of response surface methodology (RSM). The optimum parameters to maximize the overall sensory acceptability (OSA) of frankfurters were salt replacer Artisalt™ (48%), HPP (580 MPa) and Inbac™(0.3%) and for cooked ham the optimised parameters were Artisalt™ (53%), HPP (535 MPa) and Inbac™(0.3%). As processed meat manufacturers are constantly looking for new ways to reduce salt levels without compromising food safety, shelf-life or consumer acceptability; in our previous work a novel approach which showed great potential for reducing salt in frankfurters and ham was used; however, the shelf life of these low-salt products was not investigated. The use of HPP as additional post packaging processing and a mix of organic acids Inbac™ as hurdles was expected to not only increase the shelf life of the significantly reduced salt processed meat products but also increase the safety of these products which is necessary to compensate for the loss of safety and shelf life due to significant salt reduction. Extending the shelf life of these low-salt processed meat products can also reduce food waste of these products which will enhance sustainable food production

Moreover, most of the studies reported in the literature were carried out using lab scale HPP to treat processed samples (Rodriguez-Calleja et al., 2012; Vercammen et al., 2011; O' Flynn, Cruz-Romero, Troy, Mullen, & Kerry, 2014; O' Neill et al., 2018; Crehan, Troy, & Buckley, 2000; Andres, Moller, Adamsen, & Skibsted, 2004; Han et al., 2011; Cava, Ladero, González, Carrasco, & Ramírez, 2009) with a few studies using industrial HPP units for treating processed meat products. (Garriga et al., 2004; Jofré et al., 2009; Marcos et al., 2007). In the present study an industrial scale HPP unit and commercially available mix of organic acids Inbac™ were used in the manufacture of frankfurters and cooked ham which have the advantage of scaling the manufacture of these products up easily.

While there are studies that use a combination of HPP and organic acids to extend the shelf life of meat products such as chicken and sausages (Diez et al., 2008; Rodriguez-Calleja et al., 2012; Vercammen et al., 2011); to the best of our knowledge, a combination of HPP and organic acids as hurdles has not been used as a methodology to enhance the safety and shelf life of low salt processed meat products. Therefore, the objective of this study was to assess the efficacy of a combination of HPP and a mix organic acids Inbac™ as hurdles to extend the shelf life of previously sensory optimised salt replaced frankfurters and cooked ham from a microbiological and physicochemical point of view".

## 2. Materials & methods

### 2.1. Materials

Pork oyster meat (90–95% VL), pork silverside and pork fat were obtained from Ballyburden meats, Ballincollig, Cork, Ireland. NaCl, starch, farina (milled wheat), paprika, sodium caseinate, tomato powder, sodium tripolyphosphate hydrated food grade (Carfosel 990, Prayon, Belgium), carmine, sodium nitrite, sodium nitrate and sodium ascorbate were sourced from All in All ingredients (All in All ingredients, Ltd, Ireland). Frankfurter spice and artificial cellulose casings (26 mm) were obtained from Fispak (Fispak Ltd, Ireland) and Viscofan (Viscofan, Spain), respectively. Combivac vacuum pouches (20 polyamide/70 polyethylene bags were obtained from Alcom, Campogalliano, Italy. The barrier characteristics of the vacuum pouches were: oxygen permeability 50 $cm^3/m^3$/ 24 h at STP) and water vapour transmission rate 2.2 $g/m^2$/ 24 h at STP.

A commercially available salt replacer Artisalt™ (a mix of potassium chloride 41%, ammonium chloride 40% and flavour enhancers - yeast extract, onion and celery 19%) and a commercial antimicrobial mix of organic acids Inbac™ (a mix of sodium acetate 43%, malic acid 7%, emulsifier-mono and diglycerides of fatty acids and technological coadjuvants; anticaking agents, calcium phosphate, magnesium carbonate and silicon dioxide ~50%,) used in processed meat products were obtained from Chemital (Chemital Ltd, Barcelona, Spain).

### 2.2. Methods

#### 2.2.1. Frankfurters manufacture

The formulation of control frankfurters were as follows: pork oyster (65%), pork fat (19%), ice/water (10.15%). Additional ingredients were as follows: NaCl (2%), starch (0.92%), farina (milled wheat) (0.92%), frankfurter spice (0.5%), paprika (0.5%), sodium caesinate (0.35%), tomato powder (0.25%), phosphate (0.25%), sodium ascorbate (0.05%), sodium nitrite (0.0075%) and carmine (0.005%). For the manufacture of optimised frankfurters 48% of the NaCl was replaced with Artisalt™and included 0.3% Inbac™.

Pork meat and pork fat were minced separately through a 3 mm plate using a Talsa mincer (Talsabell, Valencia, Spain).The minced pork meat was placed in a bowl chopper (Seydelmann, Germany) and chopped at low speed for 3 min and then added the curing ingredients, seasonings and half of the ice. The mixture was then chopped for 2 min at high speed and the minced pork fat and remaining ice was added and then chopped for a further 2 min. The batter was then stuffed into a 26 mm diameter cellulose casings using a Mainca vacuum filler (Mainca, Barcelona, Spain). The frankfurters were hand-linked (~12 cm in length) and heat-treated at full steam (100 °C) in an electric steam-convection oven (Zanussi Professional, Italy) until an internal temperature of 74 °C was achieved. Final internal end-point temperatures were re-checked using a hand-held food thermometer (Testo, Germany). The frankfurters were rapidly cooled down by immersion in icy cold water (1–2 °C) for 5 min and then stored at 4 °C overnight. Before packaging, the casing of the frankfurters were aseptically removed and 7 frankfurters were placed into a combivac vacuum pouch, vacuum packed using a Webomatic vacuum packaging system (Werner Bonk, type D463, Bochum, German) and then stored at 4 °C in a chill room. The treatments used for the shelf life analysis are presented in Table 1.