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The application of response surface methodology for the development of sensory accepted low-salt cooked ham using high pressure processing and a mix of organic acids

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ABSTRACT

The objective of this study was to develop sensory accepted low-salt cooked ham by the application of response surface methodology (RSM). A Box-Behnken experimental design was used to assess the effects of the independent factors salt replacer (Artisalt™) (0–100%), high pressure treatment (0.1–600 MPa) and a mix of organic acids (Inbac™) (0.2–0.4%) on hardness, flavour, saltiness and overall sensory acceptability (OSA) of the cooked ham. The main factor that affected all response variables was salt replacement. The optimum parameters to maximise salt reduction and produce hams with similar OSA associated with this type of products were Artisalt™ (53%), HPP (535 MPa) and Inbac™ (0.3%) and the cooked ham manufactured using the optimum parameters contained 1.4% total salt which is a 46% reduction compared to control samples which contained 2.6% total salt. Overall, a combination of salt replacer, HPP and organic acids showed great potential for the development of cooked ham with significantly reduced salt content.

Industrial relevance: Consumer studies have shown that meat consumption is being more and more influenced by health, nutritional and environmental considerations; therefore, companies are constantly searching for new and emerging technologies to reduce salt in meat products and enhance shelf life to reduce food waste. In this study we used a novel approach which showed great potential in salt reduction of ham as the quality and sensory acceptability of the ham were similar and/or better after salt was replaced by 53%. The hurdle approach used in this study is expected to improve the safety and shelf life of the low-salt optimised ham and this confirmatory study is underway.

1. Introduction

Sodium chloride (NaCl), commonly known as salt plays a significant technological role in processed meat due to its preservation and antimicrobial properties provided by its ability to reduce water activity. Moreover, salt activates proteins to increase hydration and water-binding capacity; it increases the binding properties of proteins to improve texture and it is essential for flavour (Mariutti & Bragagnolo, 2017; Terrell, 1983). Thus salt reduction in processed meat products is challenging as quality of the final product can be compromised. High salt consumption has been associated with cardiovascular disease (CVD) which is the most common cause of death in Ireland which accounts for 10,000 deaths per year (IHF, 2016). Salt intake of < 5 g/day for adults has been recommended by the World Health Organisation (WHO) to reduce blood pressure and risk of cardiovascular disease, stroke and coronary heart attack; however, in most European countries this recommended dietary intake is greatly exceeded with an estimated salt consumption as high as 9–12 g/day. It was reported that an estimated 2.5million deaths can be prevented each year if global salt consumption is reduced to the WHO recommended levels (WHO, 2016).

Due to the preservation properties of salt, when salt is reduced in meat products, the safety and shelf-life can be compromised. Hurdle technology combines intelligently different mild preservation techniques (hurdles) such as high pressure processing (HPP) to control or eliminate pathogens (Rodríguez-Calleja, Cruz-Romero, O'sullivan, García-López, & Kerry, 2012). HPP can fulfil consumer requirements for minimally processed additive-free products, maintain sensory and nutritional properties and can contribute to the development of meat products with lower salt content (Watson, 2012). Furthermore, Karłowski et al. (2002) reported that HPP did not have an effect on the sensory quality of cooked ham; indicating that HPP affect minimally the physicochemical characteristics of cooked meat products as the protein

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had been denatured by cooking. Some studies have also pointed out that HPP enhances the saltiness perception in meat products (Ken, Atsushi, Tadayuki, Yoshihide, & Hiroyuki, 2006; Clariana, Guerreor, Sarraga, & Garcia-Regueiro, 2011) due to differential binding forces of NaCl within the product network and its release in the mouth (Tamm, Bolumar, Bajovic, & Toepfl, 2016).

The main strategies used for salt reduction in processed meat products include product reformulation, compensation by the use of substitutes, use of saltiness enhancers and the use of salt replacers (Kilcast & Angus, 2007). Dimitrakopoulou, Ambrosiadis, Zetou, and Bloukas (2005) successfully reduced salt in reformulated pork shoulder from 2% to 1% based on acceptability of sensory attributes. Aaslyng, Vestergaard, and Koch (2014) found that through product reformulation the salt in cooked ham can be reduced from 2.3% to 1.8% without altering the sensory properties, sliceabilty, production yield, shelf life and safety; however, further reductions affected significantly product quality and would therefore require other measures such as the substitution of salt with other functional ingredients such as salt replacers.

Potassium Chloride (KCl) is probably the most common salt substitute/replacer used in reduced-salt meat products and has been extensively examined for salt reduction in cooked ham (Aliño et al., 2009; Hand, Terrell, & Smith, 1982; Lorenzo, Cittadini, Bermúdez, Munekata, & Domínguez, 2015; Ruusunen & Puolanne, 2005; Tamm et al., 2016); however, one of the major problems when replacing NaCl with KCl is the bitterness and the use of higher concentrations of KCl can leave a metallic aftertaste (Albarracín, Sánchez, Grau, & Barat, 2011). Lorenzo et al. (2015) found that partial replacement (50%) of NaCl with KCl in the manufacture of hams resulted in an increased bitterness.

Pietrasik and Gaudette (2014) examined the effects on the physicochemical characteristics and sensory acceptability of cooked ham when NaCl was fully replaced (100%) with two commercial salt replacers: Oceans flavour sea salt™ OF45 or 0F60, which are natural sea salts that contain 45% and 60% less sodium than table salt, respectively. The authors reported that the texture and cook loss of the cooked ham were not significantly affected; however, the hams containing the sea salt replacers were liked significantly less compared to control for flavour and aftertaste. The authors concluded that further flavour optimisation through the application of bitter masking agents or flavour enhancers was required to suppress undesirable levels of bitterness elicited by the ingredients used. Tamm et al. (2016) achieved a 45% salt reduction in ham through the use of KCl combined with a pressurisation step at 100 MPa after tumbling, these salt-reduced hams were acceptable in terms of texture, consistency and appearance but a lower saltiness taste was detectable by the sensory panel, which can potentially reduce product acceptability.

To the best of our knowledge no previous studies have been carried out on the application of product optimisation using a combination of salt replacers, HPP and antimicrobials in the development of low-salt cooked ham; therefore, the objective of this study was to use response surface methodology (RSM) to develop a sensory accepted low-salt cooked ham using salt replacers (Artisalt™) and hurdles including high pressure processing (HPP) and a mix of antimicrobial organic acids (Inbac™).

2. Materials & methods

2.1. Materials

Pork Silverside was obtained from Ballyburden meats, Ballincollig, Cork. NaCl, Sodium Nitrite, Sodium Nitrate, Sodium Ascorbate and Sodium tripolyphosphate hydrated food grade, Carfosel 990 (Prayon, Belgium) were obtained from All in All ingredients Ltd., Dublin. Artisalt™ (a mix of Potassium chloride 41%, Ammonium chloride 40% and flavour enhancers - yeast extract, onion and celery 19%) is a commercially available salt replacer used in processed meat products which was obtained from Chemital Ltd., (Chemital Ltd., Barcelona, Spain). According to the manufacturer specification sheet Artisalt™ can replace all (100%) or part (50%) of common salt in meat products without giving any off-taste and allowing meat proteins solubilisation which is an essential factor in producing products with good texture and palatability. A commercial antimicrobial 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%,) was obtained from Chemital Ltd. and used as recommended by the manufacturer (2–4 g/kg of product).

Table 1
Experimental design of uncoded and coded parameters.

Independent variables	Symbols		Levels	
	Uncoded	Coded	Uncoded	Coded
Salt replacement (%)	A	× 1	0	− 1
			50	0
			100	+ 1
High pressure treatment (MPa)	B	× 2	0	-1
			300	0
			600	+ 1
Concentration of Inbac (%)	C	× 3	0.2	-1
			0.3	0
			0.4	+ 1

2.2. Methods

2.2.1. Experimental design

A three-factor experimental design (Box-Behnken) was used to optimise salt reduction and consisted on the manufacture of 15 different formulations (Table 1). The centre point of the experimental design was repeated 3 times. The independent factors were Salt replacer Artisalt™ (0–100%), HPP (0.1-600 MPa) and organic acid Inbac™ (0.2–0.4%). The full polynomial model involving the main effects (linear terms), interaction terms (cross products) and quadratic or squared terms were defined to fit the responses as is shown in Eq. (1).

$$Y = b_0 + b_1A + b_2B + b_3C + b_4AB + b_5AC + b_6BC + b_7A^2 + b_8B^2 + b_9C^2 \quad (1)$$

where: Y represents the dependent or response variable (overall sensory acceptability (OSA), flavour, saltiness or hardness), b_0 is a constant coefficient of the models and A, B & C represents the independent coded variables; A = Salt replacement (%), B = HPP (MPa) and C = Inbac (%) ranging from − 1 to + 1and b_0–b_9 are the regression coefficients to be determined.; b_1–b_3 are the linear coefficient terms; b_4–b_6 are the interaction coefficient effects; and b_7–b_9 are the quadratic coefficient effects of the model estimated by multiple regression analysis, respectively. The effect of variables at the linear, quadratic, and interactive levels on individual responses was described using a significance level of confidence set at 5%.

2.2.2. Characterisation of salt replacer and antimicrobial

Ammonium Chloride was determined using the methods outlined in 23rd Joint FAO/WHO Expert Committee on Food Additives (1979). KCl, Nitrites and Nitrates concentration of the salt replacer Artisalt™ and concentration of sodium acetate and malic acid of the antimicrobial Inbac™ was determined by a commercial external analytical testing facility (ALS laboratories, Little Island, Cork). Analytical methodologies used by the commercial testing facility are industrially confidential therefore specific details were not obtainable. For the determination of KCl, Artisalt™ was homogenized and mineralized by acids and hydrogen peroxide prior to analysis by atomic emission spectrometry with inductively coupled plasma and stoichiometric calculations of compounds concentration carried out from measured values. Nitrites and Nitrates