Monitoring the effects of high pressure processing, salt levels and refrigeration on the sensory and technological properties of pork sausages

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Abstract—**The objective was to assess the use of high pressure processing (HPP) for enhancing the functionality of NaCl and to assess the effects of different salt levels, pressure treatments and refrigerated storage on technological and sensory properties of pork sausages. The combined effect of HPP and salt level on the sensory and technological properties of pork breakfast sausages was examined. Two salt levels (1.4 and 2.5%) and four pressure treatments (0.1 (non-pressurised control), 200, 300 and 400 MPa) were examined. Sausages were manufactured to contain a salt level of 2.5% or 1.4%. Results indicated that the salt level can be reduced to 1.4% without a noticeable change in sensory attributes, composition, emulsion stability, lipid oxidation and total viable count (TVC). However, salt reduction in non-pressurised control samples reduced the pH value, increased the cook loss and slightly altered the colour and texture attributes. HPP in the range 200 to 400 MPa did not promote lipid oxidation and reduced TVC levels. Moderate pressure levels of 200 MPa resulted in sausages with similar cook loss, colour, water holding capacity (WHC), texture and sensory attributes compared to the non-pressurised sausages at both salt levels, suggesting that HPP improved salt-induced protein extraction. However, HPP at 300-400 MPa would not be recommended as these higher pressure levels altered the binding properties and therefore the texture and sensory attributes of the pork breakfast sausages.**

Keywords— **high pressure processing, salt reduction, pork sausages.**

I. INTRODUCTION

There is a strong need to find alternative ways to manufacture low-NaCl products with high functionality and acceptable organoleptic properties. The possible role of sodium in the development of hypertension in certain sensitive individuals has prompted public health and regulatory authorities to recommend reducing dietary intake of sodium chloride. Salt reduction in meat products can have an effect on microbial quality, colour stability, water and fat binding, texture, cooking loss and sensory quality. A variety of approaches to reduce the sodium content of meat products include substitution of NaCl with other chloride salts or alteration of processing techniques. Another approach to reduce the sodium content is through the use of HPP which may improve the solubility of certain myofibrillar proteins, increase binding between meat particles following heat denaturation [1], reduce cook loss, enhance textural properties [2] and permits microbial inactivation at low or moderate temperature [3]. No research to date has been carried out using a combination of HPP and salt reduction on pork breakfast sausages. The objective of this research was to assess the use of high pressure processing (HPP) at enhancing the functionality of NaCl and to assess the effects of different NaCl levels, pressure treatments and refrigerated storage on technological and sensory properties of pork sausages.

II. MATERIALS AND METHODS

A. Materials and chemicals

All reagents and solvents used in this work were ‘AnalaR’ grade and were obtained from Sigma–Aldrich, Ireland.

B. Sample preparation

Prior to sausage manufacture raw minced pork and fat were placed into vacuum bags and vacuum packed twice. The vacuum packed bags of meat were individually placed in the high pressure vessel (Quintus type QFP 600, Avure Technologies,

Vasteras, Sweden). Meat and fat were packed and loaded into a cylindrical load basket which was placed in a water-filled pressure vessel [4]. The samples were pressure treated in batches at 100, 200 and 300 MPa, each for 10 min. After pressure treatment the samples were immediately removed from the vessel, stored at 2°C for 24 h prior to sausage manufacture. A separate batch not subjected to high pressure (0.1 MPa) acted as a control for each NaCl level. Pork breakfast sausages were prepared [4].

All sausages were formulated to contain 20% pork fat, 43% pork shoulder, 1.96% white sausage seasoning (Salt, Pepper Compound, Wheat flour, E503, E450, E451, Coriander, Mace, Preservative, Ginger, Nutmeg, Antioxidant E301, Cayenne) and 11% rusk, 1.4 or 2.5% NaCl and 23.6 or 22.5% water (Table 1). All analyses were carried out following 7 days refrigerated storage at 4^{o}C.

Table 1 Sausage formulations

Salt (%) /(MPa)	Pork (%)	Fat (%)	Water (%)	Rusk (%)	Seas (%)	Salt (%)
1.4/0.1	43	20	23.64	11	1.96	0.4
1.4/200	43	20	23.64	11	1.96	0.4
1.4/300	43	20	23.64	11	1.96	0.4
1.4/400	43	20	23.64	11	1.96	0.4
2.5/0.1	43	20	22.54	11	1.96	1.5
2.5/200	43	20	22.54	11	1.96	1.5
2.5/300	43	20	22.54	11	1.96	1.5
2.5/400	43	20	22.54	11	1.96	1.5

C. Compositional analysis and pH

The moisture, fat, protein content and pH of the pork sausages was determined [5].

D. WHC and Emulsion Stability

WHC was carried out on raw pork sausages [5] and the percentage WHC was calculated using Equation 1 [6]. The emulsion stability of the sausage was determined [7].

E. Colour evaluation

Lightness (L^*), redness (a^*) and yellowness (b^*) values of raw sausages was measured by the CIE LAB system using a dual beam xenon flash spectrophotometer (Ultra Scan XE, Hunter lab, Virginia, USA).

F. Lipid oxidation measurement

Thiobarbituric acid reactive substances (TBARS) were determined by the filtration method [8]. The malondialdehyde content of the sample was calculated using an extinction coefficient of 1.56×10^5 $M^{-1}cm^{-1}$. Results were expressed as TBARS in mg malondialdehyde (MDA)/kg product.

G. Microbiological analysis

The TVC of raw pork sausages (10 g) were determined (ISO, 2003) using plate count agar (tryptone glucose yeast agar) (Oxoid Ltd. CM0325, Basingstoke, Hampshire, United Kingdom). Plates were incubated at 30^{o}C ± 1 ^{o}C for 72 hr. Results were expressed as $\log_{10}$CFU (colony forming units)/g muscle.

H. Texture profile analysis(TPA)

TPA was applied to the cooked pork sausages [9].

I. Sensory evaluation of cooked pork sausages

Eight different pork sausage formulations were evaluated by a 60 member untrained panel. Pork sausages were cooked by grilling on a conventional oven at 180^{o}C, turning every 3 min until cooked to an internal temperature of 71°C and held for a further 10 minutes to assist browning. Sausages were divided into 25 mm pieces, wrapped in aluminium foil and placed in a bain-marie (50^{o}C) until serving (< 15 min). Sample were labelled with 3 digit random numbers and served in William Latin square order to panellists. Panellists were asked to evaluate overall liking, flavour liking, tenderness liking and juiciness liking on an eight point hedonic scale from extremely like to extremely dislike.

J. Statistical analysis

The data was analysed using SPSS® Base 18.0 (SPSS Inc., Chicago, IL, USA). Statistical analysis was performed using a two way analysis of variance

(ANOVA) with pressure and salt level as factors and a Duncan test. Where significant differences were present, individual treatments were compared using the least significance different (LSD) test. The effect of the panellists in the sensorial responses was corrected by rescaling all the scores given by each panellist.

III. RESULTS AND DISCUSSION

HPP and salt reduction from 2.5 to 1.4% had no effect ($p>0.05$) on the composition of raw pork sausages.

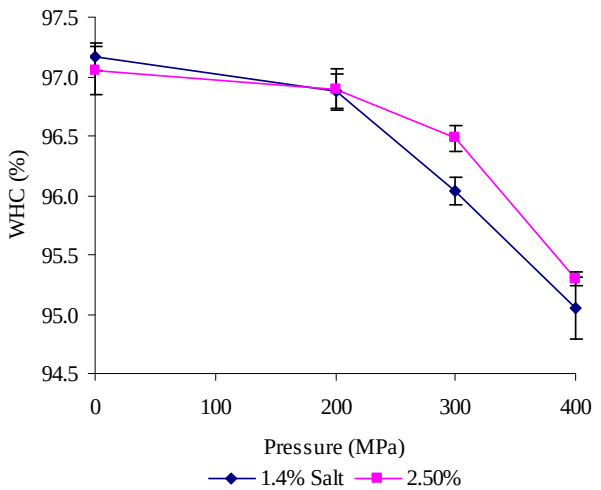

Fig 1. Effect of salt and HPP on WHC of pork sausages

Pressure treatment at 200 MPa resulted in a sausage with similar cook loss and WHC relative to the control. HPP at 300 and 400 MPa had a negative effect on the binding properties of the pork sausages with HPP above 300 MPa increasing ($p<0.001$) cook loss compared to the control. HPP at 400 MPa reduced WHC.

HPP induced a small increase ($p<0.05$) in pH values between pressure levels of 200 and 400 MPa. NaCl reduction resulted in lower pH values and higher cook loss ($p<0.05$) in pork sausages formulated with 1.4% NaCl compared with sausages formulated with 2.5% NaCl. A significant difference in cook loss and pH values was observed at both NaCl levels at 200 MPa, relative to the control.

HPP at 200MPa and salt reduction had no effect on emulsion stability while HPP ≥300MPa reduced emulsion stability.

Salt reduction had no major effect on colour parameters however a slight increase ($p<0.05$) in L* values was observed at 400 MPa.

HPP and salt reduction had no effect ($p>0.05$) on lipid oxidation.

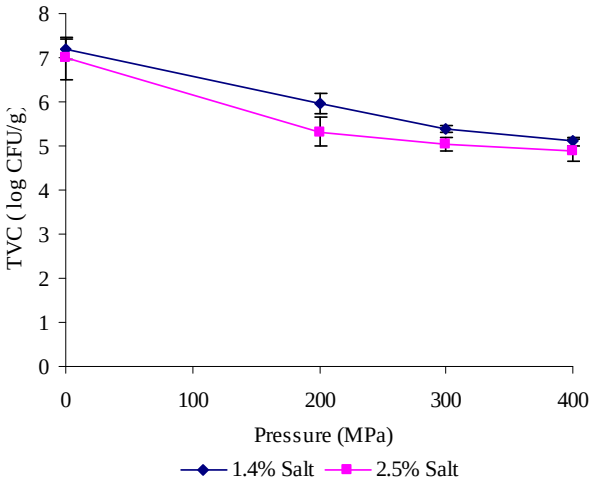

Fig 2. Effect of salt and HPP on TVC of pork sausages

HPP reduced ($p<0.001$) TVC levels therefore suggesting a way to improve meat hygiene and extend the shelf-life of the raw product. No significant difference was observed between sausages pressurised at 200 MPa, 300 MPa and 400 MPa, suggesting even the lowest pressure level (200 MPa) improved the microbiological quality of the sausage. NaCl reduction had no effect ($p>0.05$) on the level of TVCs.

HPP > 300 MPa resulted in an increase ($p<0.001$) in cohesion force and a decrease ($p<0.001$) in chewiness, hardness, springiness and gumminess. No significant difference was observed between the control (0.1MPa) and samples treated at 200 MPa for chewiness, cohesion force, hardness and springiness. These results suggest that the optimal pressure condition to improve hardness and conserve texture attributes in cooked pork sausage would be 200 MPa. Salt reduction had no effect on the texture profile of the cooked pork sausages.

The untrained sensory panel detected no detrimental effects in sausage samples pressure treated at ≤ 300 MPa for all sensory parameters (Table 2). The

application of 400 MPa pressure resulted in a decrease ($p<0.001$) in flavour, juiciness, tenderness and overall liking and acceptability scores.

It would seem possible to reduce the NaCl content from 2.5 to 1.4% in pork breakfast sausages, obtaining a healthier product with only 1.4 g NaCl/kg that is acceptable to the consumers as no difference ($P>0.05$) was detected between NaCl levels for all sensory parameters analysed. Small reductions of NaCl in sausage products over time may be one solution to lowering salt in products without losing consumer loyalty. Improved labelling and marketing of reduced-sodium meat products and health benefits will also enhance consumer acceptance.

Table 2 Sensory attributes of pressurised-cooked pork sausage at different pressure treatment and salt concentrations

Treatment (%/MPa)	App[1]	Liking[2]	Ten[3]	Flav[4]	JL[5]	PI[6]
1.4/0.1	5.2[a]	5.4[a]	5.5[a]	5.4[a]	5.5[a]	4.7[a]
1.4/200	5.1[a]	5.1[a]	5.1[a]	5.1[a]	5.2[a]	4.2[a]
1.4/300	5.4[a]	5.1[a]	5.1[a]	5.3[a]	5.0[a]	4.1[a]
1.4/400	4.5[a]	3.4[b]	3.5[b]	3.7[b]	3.3[b]	2.3[b]
2.5/0.1	5.3[a]	5.4[a]	5.5[a]	5.2[a]	5.5[a]	4.3[a]
2.5/200	5.4[a]	5.3[a]	5.4[a]	5.1[a]	5.4[a]	4.4[a]
2.5/300	5.5[a]	5.0[a]	5.3[a]	4.9[a]	5.0[a]	4.3[a]
2.5/400	4.4[a]	3.7[b]	4.0[b]	3.9[b]	3.7[b]	2.8[b]

[abc]Different letters within a column indicate differences among values. [1]Overall appearance, [2]Overall liking, [3]Tenderness liking, [4]Flavour liking, [5]Juiciness liking, [6]Purchase intent.

IV. CONCLUSIONS

It is possible to reduce the NaCl content from 2.5 to 1.4% in pork sausages obtaining a product with only 1.4 g NaCl/kg that is acceptable to the consumers and without a noticeable change in composition, emulsion stability, lipid oxidation and total viable count (TVC). HPP in the range 200 to 400 MPa did not promote lipid oxidation and improved total viable counts (TVC) levels. Moderate pressure levels of 200 MPa resulted in a sausage product with similar cook loss, colour, water holding capacity, texture and sensory attributes compared to the non-pressurised (0.1 MPa) sausage at both NaCl levels suggesting HPP improved protein extraction. The results indicated that HPP at 200 MPa can be used to produce a low salt sausage with good sensory and technological quality.

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