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The application of high-pressure treatment in the reduction of salt levels in reduced-phosphate breakfast sausages

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ABSTRACT

This study investigated the effects of high pressure (HP) treatment of pork meat before manufacturing sausages with reduced salt levels and compared them to sausages manufactured with untreated meat (control sausages). A 2 × 5 factorial design was set up incorporating two pressure levels (0 or 150 MPa) and five salt levels (0.5, 1.0, 1.5, 2.0 and 2.5%). Most quality attributes were affected when salt levels were reduced below 1.5%. Fat loss (FL) was ($P < 0.05$) affected by salt level; samples with <1.5% salt had the highest FL. HP treatment increased emulsion stability and reduced cook loss (CL) compared to control sausages. Increased CL was observed when salt was reduced below 2.0%. Salt reduction below 1.5% adversely affected colour, sensory and texture attributes. Independent of salt, HP treatment affected adversely juiciness and cohesiveness while adhesiveness was improved. Overall, there is potential to manufacture sausages maintaining organoleptic and functional properties traditionally associated with sausages using HP treated meat.

1. Introduction

Meat based products are often criticised for their high fat and sodium content. Despite being immensely popular there is not a large range of low fat and/or low salt meat products available in the market. Based on U.S. and U.K. figures, the global low salt market was estimated as $50 bn in 2010 (Morley, 2012). The sodium content in salt is commonly related to high blood pressure (hypertension) and increases the risk of heart disease and strokes (Strazzullo, D'Elia, Kandala, & Cappuccio, 2009). To meet consumer's and worldwide regulatory demands for healthy and more nutritious meat products, the meat industry has been given the task of producing reduced salt meat products. Daily salt intakes are thought to be too high in Ireland (11.1 g for men or 8.5 g for women) and a reduction in intakes to 6 g/day is being sought (FSAI, 2011). Around 70% of the salt consumed comes from foods and about 20% of this comes from meat products (Safefood, 2012). Despite widely acknowledged links to a diet high in salt to adverse health outcomes, products such as comminuted meat products remain popular.

One of the main approaches to salt reduction is the reduction of overall salt content in a food product formulation (Kilcast & den Ridder, 2007); as meat products are usually high in salt content, they have been specifically targeted as products, in which the salt level could be considerably reduced. Beef, poultry and pork meats naturally contain sodium ranging from 50 to 70 mg per 100 g. Most processed meat products contain variable amounts of salt; sodium content in sausages in the U.K. and Ireland are variable ranging from 600 to 1180 mg of sodium or 1.5 to 3.0 g salt per 100 g (Desmond, 2007). Salt contributes to the flavour of processed meats but also adds functional benefits such as preservation, emulsification, tenderness and juiciness to meat systems (Pszczola, 2010). In comminuted meat products salt is involved in three important interactions with the myofibrillar proteins: protein–water (water holding), protein–protein (meat-binding) and protein–fat (fat binding) (Man, 2007). The reduction of sodium in meat products presents significant challenges to developed meat products maintaining quality attributes in an acceptable and affordable manner (Clemens, 2012). E.g. too little sodium in meat products can result in unstable emulsions with poor texture. Salt reduction has been also reported to change palatability attributes such as saltiness, flavour intensity and juiciness (Matulis, McKeith, Sutherland, & Brewer, 1995).

High pressure (HP) processing is an alternative method for food preservation (Barbosa-Cánovas & Bermúdez-Aguirre, 2011), fulfilling consumer requirements for minimally processed and additive-free products and inactivates pathogenic and spoilage micro-organisms at room temperatures, maintains sensory and nutritional properties and can contribute to the development of meat products with lower salt content (Watson, 2012). Of all foods and food constituents, muscle and muscle proteins are probably the most responsive to pressure. This is because of the relatively high sensitivities to pressure of the glycolytic processes and of the associations between proteins and the myofibrill (Macfarlane, 1985). Efforts are being made in the food industry to introduce HP treatment to improve tenderness and gel-forming properties in processed meat products (Ikeuchi, Tanji, Kim, & Suzuki, 1992; Jimenez-Colmenero, 2002; Macfarlane, 1985). Pressure greatly influences the binding properties of meat products even at low ionic

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strengths (Macfarlane, 1985) which would be the case in low-salt, low-phosphate products. Suzuki and Macfarlane (1984) found that in meat model systems HP considerably enhanced the thermal gelation of proteins. The effects of HP are instantaneously and uniformly transmitted throughout foods regardless of their geometry or size, and has been shown to have particular applications for meat products, being commercialised by large meat companies, e.g., in the USA (Hormel, Purdue), Germany (traditional German dry cured ham) and Spain (Espuna and Campo Frio) (Tonello, 2011). It has been reported that HP treatment can be used to compensate for the reduction of sodium ion content in processed meats (Cheftel & Culioli, 1997; Crehan, Troy, & Buckley, 2000; Grossi, Knudsen, Christensen, & Orlien, 2012; Sikes, Tobin, & Tume, 2009).

In a previous study it was found that the application of HP at 150 MPa for 5 min at ambient temperature has great potential for reducing phosphate levels in low fat breakfast sausages to 0.25% without significant changes in their functionality (O'Flynn, Cruz-Romero, Troy, Mullen, & Kerry, 2014).

The objectives of this study was to reduce the salt content of breakfast sausages containing low-phosphate levels (0.25%), using high pressure treatment at 150 MPa.

2. Materials and methods

2.1. Breakfast sausage manufacture

Fresh pork belly (skinless and boneless) was obtained from a local meat processing plant. Excess fat was trimmed from the meat, cut into strips and minced through a 5-mm plate using a Mainca mincer PM-82. The minced pork was then mixed in a Mainca mixer RM.90 to obtain a homogeneous mass. A total of 10 treatments were prepared in which phosphate levels were kept constant at 0.25%. The meat was pre-weighed into vacuum pack bags according to the formulations (Table 1). For samples to be HP-treated the meat was divided in 10 smaller vacuum pouches each weighing 280 g, vacuum-packed (VP) and stored at −20 °C until use. All meat preparation was performed at 10–12 °C. Each increase in salt concentration was compensated for by a decrease in water content.

For the manufacture of HP-treated sausages, raw minced meat samples were HP-treated at 150 MPa for 5 min in an isostatic press (Engineered Pressure Systems International N.V. Belgium) as described by O'Flynn et al., 2014. After HP treatment, the meat samples were immediately removed and placed in a bowl chopper with all other ingredients for sausage manufacture. A separate batch not subjected to high-pressure treatment acted as a control for each salt level.

Each 2.8 kg of meat was placed separately in a bowl cutter (Mainca CR.22) with two thirds of the required water (distilled and chilled overnight at 4 °C) and chopped for 2.5 min at blade setting 1, bowl speed 2. After this time the seasoning, and phosphate, (combination of sodium polyphosphates, E450 (i) disodium diphosphate and (ii) trisodium diphosphate, All in All Ingredients Ltd., Dublin) were added. After 3 min the remaining water was added and the batter mixed for a total 5.25 min (Institute for Industrial Research and Standards, 1975). The final temperature of the batter after chopping was 10–14 °C. The batter was stuffed into 28 mm diameter collagen casings (Devro, McDonnells, Dublin) using a Mainca piston filler. The sausages were hand linked and frozen until required for analysis.

Table 1
Formulation for breakfast sausages (4.0 kg) manufactured using untreated or HP-treated pork belly meat with varying salt levels and 0.25% phosphate.

Pressure (MPa)/salt (%)	Pork belly (kg)	Water (kg)	Seasoning (kg)	Phosphate (kg)	Salt (kg)
0/0.5%	2.8	0.67	0.5	0.01	0.02
0/1.0%	2.8	0.65	0.5	0.01	0.04
0/1.5%	2.8	0.63	0.5	0.01	0.06
0/2.0%	2.8	0.61	0.5	0.01	0.08
0/2.5%	2.8	0.59	0.5	0.01	0.1
150/0.5%	2.8	0.67	0.5	0.01	0.02
150/1.0%	2.8	0.65	0.5	0.01	0.04
150/1.5%	2.8	0.63	0.5	0.01	0.06
150/2.0%	2.8	0.61	0.5	0.01	0.08
150/2.5%	2.8	0.59	0.5	0.01	0.1

2.2. Cooking procedure

Samples were cooked prior to sensory analysis, texture analysis, colour measurements and cooked compositional analysis as described by O'Flynn et al. (2014). Briefly, sausages were cooked, using an electric grill preheated at 200 °C for 5 min before use, until an internal temperature of 77 °C was reached. Final end-point temperature of the sausages was determined using a hand-held food thermometer.

2.3. Compositional analysis and emulsion stability

Moisture, fat, and protein were determined on both the raw sausage batter and the cooked sausages and emulsion stability was measured as described by O'Flynn et al. (2014). The volumes of total expressible fluid (TEF) and the percentage fat were calculated as follows:

$$\text{TEF} = (\text{Weight of centrifuge tube and sample}) - (\text{Weight of centrifuge tube and pellet})$$

$$\%\ \text{TEF} = \frac{\text{TEF}}{\text{Sample weight}} * 100$$

$$\%\ \text{Fat} = \frac{(\text{Weight of crucible} + \text{dried supernatant}) - (\text{Weight of empty crucible})}{\text{TEF}} * 100.$$

2.4. Water holding capacity

Five sausages per treatment were thawed overnight at 4 °C and each of the five samples was analysed. Approximately 10 g of each sausage was weighed into individual glass jars. The jars were covered with lids and placed into a water bath (Model No Y-38, Grant Instruments Ltd., Cambridge, U.K.) for 10 min at 90 °C. After heating, samples were carefully removed from the jar using forceps and allowed to cool for 30 min at room temperature. After cooling each sample was wrapped in cheesecloth and placed into a centrifuge tube (Nalgene Brand Products, NY, USA) with cotton wool on the bottom. The samples were centrifuged for 10 min at 16,770 ×*g* (Mistral 300i Sanyo Gallenkamp, U.K.). The samples were removed from the centrifuge and reweighed. The percentage WHC was calculated using the following equation (Lianji and Chen, 1989).

$$\%\ \text{WHC} = 1 - \frac{B - A}{M_1} \times 100 = 1 - \frac{B - A}{M_2 \times B}$$

B weight of sample before heating.
A weight of sample after heating and centrifuging.
M_1 total water content in the meat sample.
M_2 % moisture of the sample.

2.5. Cook loss

Cook loss (%) was determined by calculating the weight difference before and after cooking (Berry, 1994) of 5 sausages per batch. Each sausage was blotted with a paper towel to remove excess fluid before weighing.