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Review

Salt reduction strategies in processed meat products – A review

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ABSTRACT

Background: Sodium chloride is one of the most widely used additives in the food processing sector. Currently, the daily sodium intake is approximately three times the recommended daily allowance for an adult (in Ireland and UK) and **processed meat** products contribute to about 20% of the total sodium dietary intake. The dietary concern about salt consumption has encouraged food industries to consider methods for lowering salt use. However, due to the essential functions (flavour, texture and **shelf-life**) provided by salt in meat products, the effects of using reduced amounts of salt must be carefully considered.

Scope and approach: In this review the numerous approaches for **sodium reduction** in processed foods are presented, highlighting: the reduction of salt level over time, the use of salt substitutes such as other metallic salts and the use of flavour enhancers such as monosodium glutamate or yeast extract. Novel technologies to assist the development of low sodium products, such as high pressure processing and power ultrasound are also introduced. Limitations for each method are discussed, with emphasis on the microbiological implications for the shelf-life stability of low-sodium products.

Key findings and conclusions: Multiple challenges need to be addressed in order to improve the flavour perception and safety of sodium-reduced products. A combination of multiple tools could give the desired effect; in particular, novel technological treatments such as high hydrostatic pressure and **ultrasound technology**, seem to be promising to ensure **microbiological safety** in low-sodium meat products.

1. Introduction

Salt has been used as a food preservative for thousands of years. Although the development of refrigeration systems allowed for the reduction of salt as a preservative, the large increase in the consumption of highly salted processed foods has resulted in a general salt intake that has exceeded recommended dietary values worldwide. This is true in most countries including the US, UK and Ireland (Desmond, 2006). Daily salt intakes in Ireland are estimated to be 11.1 g for men and 8.5 g for women, and a reduction in salt intakes to 6 g/day was recommended by the Irish Food Safety Authority of Ireland (FSAI) in 2011 (Trieu et al., 2015). In 2012, the World Health Organization (WHO) recommended a further reduction to <2 g/day sodium (5 g/day salt) in adults. The risks associated with a diet high in sodium have been identified as one of the top two dietary risk factors for disease by the Global Burden of Disease (GBD) (Lim et al., 2012). The effects of high sodium intakes on blood pressure, and consequently on the risk of cardiovascular disease and various other diseases, have been well documented (Aburto et al., 2013; Morgan, Aubert, & Brunner, 2001). The general concern pertaining to sodium intake from the diet has led to the development of methods to reduce the amount of salt added to products, as well as intensive reformulation of product recipes employing salt replacers to help reduce the quantities of salt used in a range of prepared foods (Doyle & Glass, 2010; Pietrasik & Gaudette, 2014). In Europe, North America and Australia, around 70% of consumed salt comes from processed foods, among which 20% is derived from meat products (Ruusunen & Puolanne, 2005). More specifically, 77% of sodium intake is obtained from packaged and restaurant food, 12% occurs naturally in foods and 11% comes from adding salt to food while cooking or while eating at the table. In fresh foods like meat,

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vegetables, and fruit, salt is naturally present in small quantities, but when processed, salt levels tend to increase exponentially as shown in Table 1. For example, fresh pork typically contains 70 mg of sodium/100 g, but bacon contains about 1480 mg sodium/100 g (Henney, 2010). In the last decade, an increasing number of countries have implemented various initiatives to reduce the use of sodium salt in the food industry. A successful example is the UK, where salt reduction strategies followed a double approach via i) food reformulation, by working with all sectors of the food industry and ii) increasing awareness through public campaigns. According to the Ministry of Health, in 2012 salt intake in the UK has decreased from 9.5 g to 8.1 g per day since 2005. In Ireland, between the years 2003 and 2011, salt was reduced by up to 18% in white bread, 20% in wholemeal bread, 25% in canned and dried soups, 19% in potato crisps and to 45% in breakfast cereals.

Strategies to reduce salt in processed meat products commenced in the 1980s. Initial attempts focussed on the complete replacement of sodium chloride (NaCl) with other chloride salts, such as calcium, lithium, magnesium and potassium. However, the resulting data from these studies showed significant and negative effects on certain aspects of texture, flavour, appearance, moisture and shelf-life of the products (Seman, Olson, & Mandigo, 1980). Since then, more attention has been directed to the formulation of salt replacers, flavour enhancers and addition of natural salty tasting products like yeast extract and seaweed, employed especially in the manufacture of restructured meat products. Despite the significant progress that has been already made, new challenging targets have been set for 2017 aiming to encourage further reductions as outlined in Table 2. The necessity to reduce sodium in the processed meat industry is particularly important. NaCl is the principal ingredient in processed meat due to: its preservative properties, its capacity to affect taste and improve product flavour, and its functional capacity to solubilise myofibrillar proteins which is necessary in order to enhance adhesion and cohesiveness in processed meat products. This review discusses the available technologies aimed at reducing sodium content in processed meat products, the possible applications of novel salt replacers and the consequences of salt reduction on the shelf-life and quality of manufactured meat products. Limitations and challenges of the available methods are also outlined.

Table 1
Sodium and salt contents in un-processed and processed meat products. Source: USDA Food National Database.

Product (100 g)	Sodium (mg)	Salt (g)
Unprocessed		
Beef	63	0.16
Pork	70	0.18
Chicken	60	0.15
Turkey	50	0.13
Processed		
Beef burgers	290–400	0.7–1
Sausages	600–1080	1.5–2.7
Frankfurters	720–920	1.8–2.3
Cooked ham	900–1220	2.3–3.0
Bacon	1000–1540	2.5–3.9
Breaded chicken	200–420	0.5–1.1
Chicken nuggets	600	1.5

1.1. Safety aspects of salt in meat

The antimicrobial effects of salt is based on its ability to reduce water activity (a_w), which is defined as the amount of free water available for the growth of microorganisms. The effect of salt on microorganisms depends on the amount of salt present in the aqueous phase of the food. Adding sodium ions to the media causes water efflux through the semipermeable membrane of bacteria; the loss of water from the cell leads to osmotic shock which may result in the death of bacterial cells or in the infliction of serious injury, thereby resulting in a significant reduction in bacterial growth. It has been suggested that for some microorganisms, salt may also: limit oxygen solubility, interfere with cellular enzymes, or force cells to expend energy to exclude sodium ions from the cell, all of which can reduce the rate of growth (Shelef & Seiter, 2005). However, microbes have different strategies to adapt to elevated salt levels in foods, for example, by accumulating potassium, amino acids, or sugars in the cell (to prevent influx of sodium and consequent outflow of water), by increasing the activity of sodium efflux systems, by changing cell morphology and fatty acids profile in the membrane or by producing specific stress response proteins. Reducing salt concentration in a product would not change the bacterial load present initially, but could affect the survival and growth of microorganisms over time. The ability of microorganisms to tolerate salt stress is dependent on various factors, including: target microorganism, environmental conditions (such as pH, temperature, redox potential, nutrient availability), presence of other antimicrobial agents and/or processing variables (McDonald & Sun, 1999; Shelef & Seiter, 2005). A study presented by Stringer and Pin (2005), by modelling the growth of food pathogens assessed the implications of salt reduction on different foods based on pH, moisture contents and salt concentrations of bacon, ham, chicken roll, smoked salmon, cottage cheese and beef burger. They reported that, in all cases, the rate of growth of foodborne pathogens was much greater in reduced salt products. The greatest changes were noticed for salt-sensitive organisms such as *Clostridum botulinum.* According to the model, this organism would not grow in products containing 5.5% aqueous salt, but possessed the potential to grow within 4 weeks at 8 °C if the aqueous salt concentration decreased to 2.85%. The major issue when using lower

Table 2
New targets for salt reduction. Source: Food Standard UK Agency (2013).

Food category	Target (g salt/100 g)	
	2012	2017
Meat products		
Bacon	2.88 g	2.88 g
Ham/other cured meats	1.63 g	1.63 g
Sausages	1.13 g	1.13 g
Meat pies	1.13 g	1.13 g
Cooked uncured meat (includes all roast meat, sliced meat etc.)	0.75 g	0.68 g
Burgers and grill steaks	0.75 g	0.75 g
Frankfurters, hotdogs, and burgers	1.38 g	1.38 g
Bread	1.0 g	0.9 g
Breakfast cereals	0.61 g	0.59 g
Soups	0.58 g	0.53 g