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Reducing salt: A challenge for the meat industry

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Abstract

Intake of dietary sodium has been linked to hypertension and consequently increased risk of cardiovascular disease (CVD). The estimated cost of CVD to both the EU and US economies is €169B and $403B, respectively. Currently the daily sodium adult intake is approximately three times the recommended daily allowance (Ireland and UK) and therefore public health and regulatory authorities are recommending reducing dietary intake of sodium to 2.4 g (6 g salt) per day. Processed meat products comprise one of the major sources of sodium in the form of sodium chloride (salt). Salt has an essential function in meat products in terms of flavour, texture and shelf-life. Apart from lowering the level of salt added to products there are a number of approaches to reduce the sodium content in processed foods including the use of salt substitutes, in particular, potassium chloride (KCl) in combination with masking agents, the use of flavour enhancers which enhance the saltiness of products when used with salt and finally optimising the physical form of salt so that it becomes more functional and taste bioavailable. The ultimate goal of ingredient suppliers and meat processors is to produce reduced sodium meat products that consumers can enjoy as part of an ongoing healthier diet and lifestyle. This article reviews some of the technological aspects of reduced salt meat products and how the meat and food ingredient industries are responding to this current health issue.

Keywords: Salt; Salt reduction; Sodium; Sodium reduction; Meat products; Reduced salt meat products; Health; Sensory and technological aspects

1. Introduction

The addition of salt to foodstuffs has become a major issue for the processed food sector, in particular the meat industry, as a result of campaigns by public health bodies, in particular, the Food Standards Agency (FSA) in the UK. Recent reports from the Food Safety Authority of Ireland (FSAI, 2005a) and the Food Standards Agency in the UK (SACN, 2003) have shown that the average daily sodium (salt) intake from foods in Irish and UK adults has been estimated as 3.3–3.9 g (8.3–10 g salt). The FSA and The Institute of Medicine, The National Academy of Science in the USA recommend an upper level of no higher than 6 g of salt per day by 2010. Similar recommendations have been made in the 2005 Dietary Guidelines for Americans (US Dept of Health and Human Services, 2005). The association between excessive sodium intake and the development of hypertension (Dahl, 1972; Fries, 1976; MacGregor & Sever, 1996; MacGregor & de wardener, 2002) has prompted public health and regulatory authorities to recommend reducing dietary intake of salt (NaCl). Hypertension is a major risk factor in the development of cardiovascular disease. The results of the DASH sodium study (Dietary Approaches to Stop Hypertension) showed a graded linear relation between salt intake and blood pressure (Appel et al., 1997). The cost of CVD to the EU economy is estimated at €169B per annum (Petersen et al., 2005) while in the US the estimated direct and indirect cost of CVD for 2006 is $403.1B (Thom et al., 2006). However, it must be stated that sodium intake is one of many factors that contribute to the possible development of CVD.

In Ireland, cured and processed meats contribute 20.5% to the sodium intake (Table 1). Similarly, in the UK, meat and meat products contribute 20.8% to the sodium intake. In the USA, meat and meat products contribute 21.0% to

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Table 1
Sources of sodium in the diet

Food sector	Na contribution (%)		
	Ireland[a]	UK[b]	USA[c]
Cereals and cereal products (inc. bread, breakfast cereals, biscuits, cakes, pastries)	34.6	37.7	26.8
Meat and meat products	20.5	20.8	21.0
Soups and sauces	7.0	12.7	8.2
Processed vegetables (inc. crisps and snacks)	4.0	8.5	6.6
Milk and cream	8.5	5.4	6.5

[a] FSAI (2005a).
[b] SACN (2003).
[c] Engstrom et al. (1997).

the sodium intake (Engstrom, Tobelmann, & Albertson, 1997). In October 2003, the FSA produced a salt model in order for the UK food industry to reduce the amount of salt in food products. The FSA model targeted a 50% reduction in bacon and ham, 40% reduction in burgers or patties and a 43% reduction in sausages. However, these reductions where seen by the industry as unachievable. In August 2005, the FSA sought views on new proposed targets for a number of products including meat products. The new proposed targets (g/100 g) to be achieved by 2010 (Table 2) are a maximum of 3.0 g salt/1.4 g sodium for bacon; 2.5 g salt/1 g sodium for ham/other cured meats; 1.4 g salt/550 mg sodium for sausages; 1.8 g salt/700 mg for cooked uncured meats; 1.0 g salt/400 mg sodium for burgers/patties/grill steaks and 1 g salt/400 mg for coated poultry products (FSA, 2006).

As a result of the ongoing campaign by public health authorities, the following paper examines how both the meat and food ingredient industries are responding to this public health issue.

2. Functionality of salt

Salt has been used since ancient times for the preservation of meat products and is one of the most commonly used ingredients in processed meat products. In the modern meat industry salt is used as a flavouring or flavour enhancer and is also responsible for the desired textural properties of processed meats. Salt imparts a number of functional properties in meat products: it activates proteins to increase hydration and water-binding capacity; it increases the binding properties of proteins to improve texture; it increases the viscosity of meat batters, facilitating the incorporation of fat to form stable batters; it is essential for flavour and is a bacteriostatic (Terrell, 1983). Product development and studies concerning the reduction of salt should address the scientific effects that it may have on such technological functions as water-holding capacity, fat-binding, texture, sensory, stability and shelf life.

3. Role of salt in meat products

Salt has a flavour enhancing effect in meat products, with the perceived saltiness mainly due to the Na^{+} with the Cl^{-} anion modifying the perception (Ruusunen & Puolanne, 2005; Miller & Barthoshuk, 1991). Fat and salt jointly contribute to many of the sensory properties in processed meats. Matulis, McKeith, Sutherland, and Brewer (1995) have shown that as the salt levels rise, the increase in saltiness is more noticeable in more fatty products that lean ones. Ruusunen, Simolin, and Puolanne (2001a, 2001b) have shown that the fat content of cooked sausages affects the perceived saltiness, depending on the formulation. Their research has shown that an increase in meat protein content reduced perceived saltiness. More recently, Ruusunen et al. (2005) found that the effect of meat content on perceived saltiness was stronger than the effect of fat content. This study showed that more salt was needed in ground beef patties of high meat content to achieve the same perceived saltiness as in products of low meat content. According to (Bertino, Beauchamp, & Engelman, 1982), the reduction of salt must happen slowly over several months in order not to affect taste and consumer acceptability of food products. In a study on cooked hams,

Table 2
FSA (UK) proposed targets of sodium and equivalent salt levels in meat products

Product	Original FSA salt model		FSA proposed targets to be achieved by 2010
	mg Na per 100 g	g salt per 100 g	g per 100 g
Bacon	750 mg	1.9 g	3.5 g salt/1.4 g Na
Ham/cured meats	750 mg	1.9 g	2.5 g salt/1 g Na
Sausages	550 mg	1.4 g	1.4 g salt/550 mg Na
Meat pies	300 mg	0.8	
Sausage rolls, pork pies, etc.			1.5 g salt/500 mg Na
Cornish pasties, etc.			1.3 g salt/450 mg Na
Cooked uncured meats	450 mg	1.1 g	1.5 g salt/700 mg Na
Burgers/grillsteaks (beef, pork & chicken)	300 mg	0.8 g	1.0 g salt/400 mg Na
Coated poultry products	450 mg	1.1 g	1.0 g salt/400 mg Na
Canned frankfurters, hotdogs and burgers	550 mg (sausages) 300 mg (burgers)	1.4 g (sausages) 0.8 g (burgers)	1.4 g salt/550 mg Na

Source. Food Standards Agency UK. Available: http://www.food.gov.uk/multimedia/pdfs/salttargetsapril06.pdf.

hams with 1.7% NaCl were rated as salty as hams with 2.0% and 2.3% salt, but saltier than those with 1.1% and 1.4% (Ruusunen et al., 2001a, 2001b). These authors concluded that it would be possible to reduce the salt content of cooked ham to 1.7% NaCl, while still maintaining the normal sensory saltiness of cooked ham.

One of salt's main functions in processed meats is the solubilisation of the functional myofibrillar proteins in meat. This activates the proteins to increase hydration and water-binding capacity, ultimately increasing the binding properties of proteins to improve texture. Increasing the water holding capacity of the meat reduces cook loss thereby increasing tenderness and juiciness of the meat product. In a comprehensive review on reducing sodium intake from meat products, Ruusunen and Puolanne (2005) put forward two hypotheses to explain the role of NaCl in water binding in meat. This includes Hamm (1986) that proposes that the Cl^- ions tend to penetrate into the myofilaments causing them to swell, while Offer and Knight (1988) and Offer and Trinick (1983) claim that the Na^+ ions form an ion "cloud" around the filaments. Offer and Knight (1988) base their hypothesis on the selective binding of the Cl-ion to the myofibrillar proteins. According to these authors, this does not cause a marked repulsion between the filaments but between the molecules of myosin filaments breaking down the shaft of the filament. This causes loosening of the myofibrillar lattice. They propose that the swelling induced by NaCl is entropically rather than electrostatically driven.

The effect of NaCl on meat proteins is most likely caused by the fact that the Cl^- ion is more strongly bound to the proteins that the Na^+ ion. This causes an increase in negative charges of proteins. Hamm (1972) concludes that this causes repulsion between the myofibrillar proteins, which results in a swelling of myofibrils due to the repulsions of individual molecules. The adsorption of Cl^- ions with positively charged groups of myosin results in a shift of the isoelectric point to lower pH, causing a weakening of the interaction between oppositely charged groups at a pH greater than the isoelectric point and therefore an increase in swelling and water-holding capacity (Hamm, 1986).

The extraction of myosin from myofibrils when they swell is of great importance to meat processors. In processed meats the salt-solubilised myofibrillar proteins form a sticky exudate on the surface of the meat pieces which binds the meat pieces together after cooking. This layer forms a matrix of heat-coagulated protein which entraps free water. In finely chopped or emulsified products such as frankfurters, bologna, etc. the solubilised protein in the continuous phase forms a protein film around fat globules, thereby retaining the fat during cooking (Monahan & Troy, 1997). Salt is a critical component in contributing to the texture of processed meat products. Ruusunen et al. (2001b) reported that cooked ham with added salt levels below 1.4% had higher cook losses compared to hams with salt levels greater than 1.7%. The authors point out than in products with low salt content with a high amount of added water it is necessary to add extra protein or other functional ingredients to increase yield.

4. Effect of salt on microbial stability

The preservation and shelf life of processed meats is of vital importance when reducing the salt levels. Reducing NaCl levels below those typically used without any other preservative measure has been shown to reduce product shelf life (Madril & Sofos, 1985; Sofos, 1983, 1985). Whiting, Benedict, Kunsch, and Woychik (1984) found that reducing the level of salt by 60% to 1.5% resulted in a more rapid growth in natural flora of frankfurters. Reducing the salt level by 50% to 1.25% in ground pork resulted in slight increases in the growth of *Lactobacillus* spp. (Terrell, 1983). There are also significant interactions between NaCl and nitrite in cured meats (Collins, 1997). In terms of nonmicrobial aspects of shelf life, studies have shown that when NaCl was reduced by 50% to 1.25% or replaced by KCl or $MgCl_2$ in ground pork, no significant differences was found for TBA values. In fact data suggests that NaCl may accelerate the development of rancidity in comparison to KCl or $MgCl_2$ (Rhee, Terrell, Quintanilla, & Vanderzant, 1983). In summary, research has shown that it is important to examine the microbial shelf life and safety of processed meat products before NaCl levels are reduced or replaced by other ingredients.

5. Salt content in meat products

For the most part, the Food Standards Agency in the UK has been leading the way in trying to get both consumers and the food industry to reduce their sodium intake and usage in foods. Table 3 shows the nutritional composition of typical meat products in both Ireland/UK and the USA. Sodium occurs naturally in beef, pork and poultry meats ranging from 50 to 70 mg per 100 g (Table 3). Most processed meat products contain variable amounts of salt and are associated with high salt contents. In addition to the usual source of sodium in processed meats that everyone readily identifies (salt), other ingredients also effect the sodium content; sodium tripolyphosphate (31.2% Na), sodium nitrate (27.1% Na), sodium Ascorbate or erythorbate (11.6% Na), sodium nitrite (33.2% Na), MSG (13.6% Na) and HVP (18.0% Na) (Maurer, 1983). However, according to Breidenstein (1982) a typical meat product containing 2% salt, the salt contributes approximately 79% of the sodium in the final meat product. The sodium content of processed meats in Ireland and the UK is quite variable with cured meats having higher sodium/salt contents (Table 3). In a study carried out by Desmond (1992) the composition of a number of processed pork products in Ireland was determined. The sample number ranged from 150–250 depending on the product. Salt levels ranged from 2.8% for cooked ham; 3.2% for back rashers; 3.5% for back bacon; 4.1% for streaky bacon; 3.2% for a

Table 3
Sodium and salt equivalent content (per 100 g) of typical meats and meat products

Product	Sodium (mg)	Salt equivalent (g)
Irish/UK products		
Beef	63	0.16
Pork	63	0.16
Lamb	70	0.18
Chicken	77	0.20
Turkey	68	0.17
Beef burgers	290–590	0.7–1.5
Sausages	433–1080	1.1–2.7
Frankfurters	720–920	1.8–2.3
Cooked ham	900–1200	2.3–3.0
Bacon/rashers	1000–1540	2.5–3.9
Salami	1800	4.6
Reduced fat sausages	800–1180	2.0–3.0
Breaded chicken	200–420	0.5–1.1
Chicken nuggets	510–600	1.3–1.5
Crispy chicken	300	0.8
US products		
Beef patties	68	0.17
Pork sausage	636	1.6
Frankfurters	1120	2.8
Oscar Myer Weiners	1025	2.6
Cured ham	1500	3.8
Corned beef	1217	3.1
Hormel Canadian bacon	1016	2.6
Beef bologna	1080	2.7
Salami	1890	4.8

Sources. Food Standards Agency (2002) and USDA (2005). Data also sourced from products retailing in Irish/UK Supermarkets.

Table 4
Sodium and salt equivalent content (per 100 g) of typical "reduced-salt or sodium" meat products

Product	Sodium (mg)	Salt equivalent (g)
Irish/UK products		
Reduced salt sausages	520–750	1.3–1.9
Reduced fat/salt sausages	520–720	1.3–1.8
Low fat/salt rashers	900	2.3
Cooked ham	670–790	1.7–2.0
US products		
Low sodium frankfurter	311	0.8
Low sodium ham	969	2.5
Salami 50% less sodium	936	2.4
Reduced sodium beef bologna	682	1.7
Reduced sodium luncheon meat	946	2.4
Reduced sodium bacon (cooked)	1030	2.6

Sources. Data sourced from products retailing in Irish/UK Supermarkets and from USDA (2005).

gammon joint. Cured meat products and sausages have the highest levels of salt/sodium above the FSA proposed targets while burgers and some coated poultry products are quite close to the proposed targets. Therefore meat processors will have to reduce their salt levels and offer alternative products to their current ranges in order to meet the FSA proposals. Currently there are only a limited number of salt reduced products available to the consumer at retail level (Table 4), however these are increasing. In particular a number of the major multiples have introduced healthier product ranges with lower fat and salt levels. Similarly some major meat processors have introduced products with reduced fat and salt giving the consumer more choice. The US has a larger range, but for a market of this size, the number of products is quite small. In some cases the products that are currently available do meet the FSA target, however for some sausage and cured meat product further reductions are needed in order to meet the FSA proposals. These reductions will have processing implications in terms of texture and flavour of products and shelf-life of these products. The Food Safety Authority of Ireland (FSAI, 2005b) has published a list of salt reduction undertakings by the food industry in Ireland. The Irish Food and Drink Industry have given an undertaking for a number of products to have the following sodium levels: bacon at or below 1.3 g sodium/100 g; sausages at or below 0.88 g/100 g; cooked ham at or below 0.99 g sodium/100 g and burgers at or below 0.5 g sodium/100 g. In some cases companies point out that some of their product within their product portfolio have 20–50% less salt than their standard products and that further reductions in products is underway. As well as agreeing salt reductions in standard products many lower salt "healthy alternatives" have been launched by Irish/UK companies and retailers.

All the major retail multiples have committed themselves to reducing salt levels in their products and are working with the FSA (UK) and through the British Retail Consortium (BRC). One retailer in Ireland, Superquinn has had a salt reduction policy since March 2004 and has targeted a reduction in salt in bacon and ham from 5% to 2% in 2007; sausages 5% to 3% in 2007. In the UK, the British Meat Processors Association (BMPA) and the Food and Drink Federation Meat Group have made a commitment to have 1.1 g salt/100 g in burgers; 2 g salt/100 g in uncured cooked meats; 1.1 g salt/100 g in coated poultry, however, no target has been set for bacon or cured meats. As a consequence of these reductions processors will have to develop strategies to reduce the sodium levels in their products. In 2003 the FSA found that the average salt content of meat sausages had reduced by 11% in comparison to 1991 (FSA, 2003). However, this was mainly due to the reduction in the amounts of salt in the low/reduced fat range. In fact, standard pork sausages had increased their salt content by approximately 9%. According to the UK Food and Drink Federation ('FDF Press Release, 2006), in 2005 the UK food and drink manufacturing industry delivered £7.4 bn worth of products (36% of products) with lower levels of salt than 2004. In addition £2.4 bn worth of products were lower salt variants.

6. Approaches to salt reduction in meat products

One of the biggest barriers to salt replacement is cost as salt is one of the cheapest food ingredients available. Also, consumers have grown accustomed to salt through processed foods so in some cases it has being difficult to remove as previously discussed. Another issue is that although there are alternatives to salt in term of functionality some consumers and retailers may not be comfortable with these new ingredients on the label (Searby, 2006). However, apart from lowering the level of salt added to products there are currently three major approaches to reduce the salt content in processed foods. Firstly, and probably the most widely used, is the use of salt substitutes, in particular, potassium chloride (KCl). Masking agents are commonly used in these products. Secondly, the use of flavour enhancers which do not have a salty taste, but enhance the saltiness of products when used in combination with salt. This allows less salt to be added to the products. Thirdly, optimising the physical form of salt so that it becomes more taste bioavailable and therefore less salt is needed (Angus, Phelps, Clegg, Narain, & Kilcast, 2005).

7. Use of salt substitutes

Potassium chloride is probably the most common salt substitute used in low- or reduced salt/sodium foods. However at blends over 50:50 sodium chloride/potassium chloride in solution, a significant increase in bitterness and loss of saltiness is observed. In Ireland, the FSAI scientific committee (FSAI, 2005a) was of the opinion that the use of low sodium salts incorporating potassium salts could not be endorsed at this time. Concerns were raised about the possible vulnerability of certain population sub-groups (including those with Type I diabetes, chronic renal insufficiency, end stage renal disease, severe heart failure and adrenal insufficiency) to high potassium load from these salt substitutes. It was also noted that the use of salt substitutes does not address the need to reduce salt taste thresholds in the population. The US Dietary Guidelines (2005) also commented on the effect some salt substitutes would have on certain individuals, however the guidelines also state that a potassium-rich diet blunts the effects of salt on blood pressure and recommend an intake of 4.7 g potassium /day.

Notwithstanding the FSAI's concerns most research has focused on reducing the sodium intake with the partial replacement of salt with KCl. According to Ruusunen et al. (2005) the use of mineral salt mixtures is a good way to reduce the sodium content in meat products. The same perceived saltiness can be achieved with salt mixtures at lower sodium content. Some of these mixtures have been commercialised such as Pansalt®. Pansalt® is a patented salt replacer where almost half of the sodium is removed and replaced with potassium chloride, magnesium sulphate and the essential amino acid L-lysine hydrochloride. According to the manufacturer, the patented usage of the amino acid enhances the saltiness of the salt replacer and masks the taste of potassium and magnesium, while increasing the excretion of sodium from the human body. Other commercially available mixtures of NaCl and KCl include Lo® salt, Saxa So-low salt and Morton Lite Salt® amongst others. Studies by Morton salt found that ham, bacon and turkey ham products manufactured with Morton Lite Salt® with a 60:40 mixture of NaCl:KCl had similar flavour scores to the control salt products. Further studies have found that the Lite Salt® maintained protein hydration in meat products (Morton Salt, 1994).

Research indicates that 25–40% replacement appears to be the range at which the flavour impact is not as noticeable. As the flavour intensity of some flavour increases such as salty, acidic or spice, a higher proportion of KCl may be acceptable (Price, 1997). In cooked hams it was found that a 50% replacement with KCl gave superior bind and acceptable sensory scores (Frye, Hand, Calkins, & Mandigo, 1986). In sectioned and formed hams, Collins (1997) stated that using a 70% NaCl/30% KCl or 70% NaCl/30% $MgCl_2$ mixtures were not different in terms of flavour, tenderness and overall acceptability compared to hams made with 100% salt.

In fermented sausages, Gou, Guerrero, Gelabert, and Arnau (1996) found no significant alteration in texture of the products using KCL to replace NaCl; a bitter taste was detected at 30% level of substitution although panellists did not consider its intensity important until the 40% level was reached. These authors also found that in dry-cured loins, KCl and potassium lactate could substitute 40% of NaCl without any significant detrimental effect to flavour. According to Ruusunen and Puolanne (2005), simple salt reduction in fermented products cannot be made due to the low A_w that has to be reached in order to control the microbial flora. As a result the technological and microbial safety as well as the sensory properties of the substitutes compared to NaCl will determine the extent NaCl can be reduced. This will limit the lowering of NaCl to >2.0%. A process has been developed to produced a low sodium cured meat product by injecting the meat with a brine containing KCl in combination with calcium citrate, calcium lactate, lactose, dextrose, potassium phosphate, ascorbic acid and sodium nitrite (Riera, Martinez, Salcedo, Juncosa, & Sellart, 1996). The patent claims that the process produces a low sodium cooked ham with zero weight-loss and a flavour identical to cooked ham with a "normal" sodium content.

Research has also demonstrated that phosphates can be very useful in lowering the NaCl content in meat products (Barbut, Maurer, & Lindsay, 1988; Puolanne & Terrell, 1983; Sofos, 1983; Trout & Schmidt, 1984). More recently, Ruusunen, Niemistö, and Puolanne (2002) and Ruusunen et al. (2005), have investigated the use of phosphates in reduced sodium cooked meat products. Phosphates are generally used in meat products to enhance water-holding capacity and improve cook yield. They increase water-holding capacity in fresh and cured meat products by increasing the ionic strength, which frees negatively charged sites on meat proteins so the proteins can bind more water. The functionality of phosphates is greatly affected by the addition of salt and both of these ingredients act synergistically. In terms of sodium reduction, some phosphates are sodium salts; however the usage rate is substantially lower than NaCl. Sodium polyphosphate contains 31.24% Na compared to 39.34% in NaCl and is typically used at 0.5% compared to 2–4% usage rate for salt. The potassium salts of phosphate are also commercially available and are equally effective in terms of water binding, gelation or ionic strength as the sodium salts.

Ruusunen et al. (2002) found it is possible to produce reduced-salt (1.0–1.4%) bolognas and cooked hams provided that phosphates are added. Further reduction of sodium content in reduced-salt meat products is possible by replacing sodium phosphate with potassium phosphate. The extent of sodium reduction depends on the phosphates used and their sodium content, being equivalent to a sodium content of 0.2% NaCl or more. In addition to phosphate, other ingredients have been investigated in low-salt meat products. These are mainly binding agents that, in the absence or at reduced salt levels, replace salt soluble proteins. These ingredients enhance the binding of meat pieces in restructured or reformed meat products and/or increase the water binding capacity of the finished product. There is a wide variety of ingredients that can be used for this purpose and include functional proteins, fibres, hydrocolloids and starches. The gel matrix formed with these alternative ingredients provide bind through a combination of protein coagulation and gel formation rather that direct interaction with muscle proteins (Collins, 1997).

8. Use of flavour enhancers and masking agents

There are a number of flavour enhancing and masking agents commercially available and the number of products coming to the market is increasing. These include yeast extracts, lactates, monosodium glutamate and nucleotides amongst others. Taste enhancers work by activating receptors in the mouth and throat, which helps compensate for the salt reduction (Brandsma, 2006). Pasin et al. (1989) found that it was possible to reduce the NaCl by 75% in pork sausage patties using a modified KCl salt, co-crystallised with Ribotide (a commercially available blend of 5′-ribonucleotides IMP and GMP). The addition of any level of MSG in these products decreased the acceptable level of modified KCl to 50% (w/w). Ruusunen et al. (2001a) found that flavour intensity of 'bologna-type' sausages was stronger when MSG or Ribotide was added to the formulations. However, after 17 days storage no significant difference was found, even though MSG and Ribotide had a higher panel score than the control. The perceived saltiness was greater when sausages contained MSG than Ribotide or without flavour enhancers. Consumers also rated the MSG sausages more palatable. Linguagen, a US company, received patent protection and regulatory approval for a bitter blocker, adenosine 5′-monophosphate (AMP). AMP works by blocking the activation of the gustducin in taste receptor cells and thereby preventing taste nerve simulation (McGregor, 2004). This bitter blocker, marketed under the name Betra™, can be used to improve the taste of NaCl/KCl mixtures. According to McGregor (2004) this bitter blocker is only the first of what will become a stream of products that are produced due to the convergence of food technology and biotechnology.

Prime Favourites, a US company, has launched NeutralFres®, which removes the metallic, bitter taste of KCl while maintaining a similar taste to sodium salt. The company claims that NeutralFres® naturally neutralises the characteristic taste or off-flavour of KCl. The product significantly eliminates the alkaline, bitter off-flavour (Primefavourites, 2005). Quest are also looking at technologies to cut salt levels and claim that processors using its new ImpaQ taste technology could cut salt levels by 50%. This has lead to Quest submitting patents for completely new flavour molecules (FoodNavigator.com, 2005). Givaudan's new, customized Natural Flavour System modifies off notes exhibited by KCl and enhances the saltiness overall. Other products such as Magifique Salt-Away or Mimic, produced by Wixon Fontrome, claim to mask the bitterness and metallic character of KCl. This product is a water-soluble, natural flavouring and can be used in processed meats at a level of 0.1–0.3% to reduce the metallic character of potassium based salt substitutes. Wild Flavours Inc. has introduced SaltTrim™. The company claims that this product simultaneously blocks the negative tastes of KCl while keeping the true taste and mouthfeel of salt. SaltTrim™ creates a complete eating experience by adding much of the taste and texture unique to salt and allows for a 50% substitution of salt with KCl without impacting taste.

Other combinations such as lysine and succinic acid have been used as salt substitutes (Turk, 1993). This compound has a salty flavour and also some antimicrobial and antioxidative properties and may be used to replace up to 75% of the NaCl from a flavour perspective. However, other water binders such as phosphates, starches or gum may have to be used to maintain the water binding function lost due to the salt reduction. The use of sodium or potassium lactate with a corresponding reduction in NaCl tends to maintain certain saltiness while reducing the sodium content in products to some degree (Price, 1997). Gou et al. (1996) studied the effects of glycine and potassium lactate as potential salt substitutes. In fermented sausages it was possible to substitute 40% of NaCl with either potassium lactate or glycine, above this level a slight potassium lactate or an unacceptable sweet taste was detected. In dry cured loins results showed that KCl and potassium lactate could substitute 40% of NaCl without any significant detrimental effect to flavour. While 30% was the maximum substitution level for glycine.

Products derived from mycoprotein, such as Mycoscent, claim to have the ability to impart a salty taste without the addition of salt. According to the manufacturer, it has a synergistic effect with dairy and savoury notes. It is possible to have a 50% sodium reduction in biscuits and snack foods and 25% sodium reduction in savoury dishes. Mycoscent 400 has a darker, richer brothy taste and can be used to deliver a succulent, cooked taste in meat applications (Mycoscent, 2005). Mycoscent provides a natural source of ribonucleotides and glutamic acid, both of which deliver flavour enhancing properties without adding salt.

Yeast autolysates are also commonly used in low salt preparations. In particular they mask the metallic flavour of KCl. Synergy, Carbery Food Products flavour and savoury ingredients business manufacture specific yeast extracts for low-salt applications under the SaltMate brand. They claim to have shown that a 20%+ salt reduction is possible using their products. In some cases, companies blend the yeast extracts with KCl to offer a complete solution. Provesta® Flavour Ingredients have a number of low sodium yeast autolysates. The patented co-processed combination with potassium or aluminium chloride and the yeast autolysates is significantly less bitter than KCl alone. Typical application rates are 0.2–0.6% of the final product. Another yeast extract that is available is Aromild produced by Kohjin Co. Ltd in Japan. According to the company, Aromild contains an abundance of natural 5′-inosinic acid (5′-IMP) and 5′-guanylic acid (5′-GMP) and is capable of enhancing flavour of foods with the effect of reducing the salt content. It can be used as an alternative to MSG and HVP and as it is in such a concentrated form, only around a tenth of the amount is needed. Recommended usage rates in meat are 0.01–0.1%. Research from Kohjin has shown that Aromild is ten times stronger that MSG has a longer lasting taste. According to Searby (2006) yeast extracts are capable of producing products with low salt content palatable; they do have limitations and can impart a meaty bouillon taste which is undesirable in some products. Other speciality ingredient manufacturers such as DSM have developed high nucleotide yeast extracts which have a completely neutral taste. Marketed under the name Maxarome Select, DSM launched this product at the FIE Paris in November 2005. The company claims that this product lends a genuine umami taste sensation to foods, giving mouthfeel, delivering taste enhancement and masking off-tastes. Similarly Sensient Flavours also launched a range of yeast extracts in 2005 which are taste neutral, and designed to optimise the umami effect in processed foods (Searby, 2006).

9. Optimising the physical form of salt

The perception of salt in the solid form is affected by crystal size and shape. Research has been carried out using various forms (flaked versus granular) as a method of reducing salt content in meat products. Flake type salt has been shown to be more functional, in terms of binding, increasing pH, increasing protein solubilisation and improve cooking yield, in model emulsion systems (Campbell, 1979). Flake salt has better and more rapid solubility than granular salt, and this may be critical where no water is added to formulations and therefore flake salt may be beneficial in products where no water is added such as dry-cured products.

More recently, Leatherhead Food International have been investigating optimising the physical form of salt and looking at changing the physical form of salt so that it becomes more taste bioavailable and therefore less can be added to the products. This involves increasing the efficiency of the salt, changing the structure and modifying the perception of the salt (Angus et al., 2005). A number of companies, such as Morton Salt and Cargill Salt, manufacture various forms of salt and claim that they can be used at reduced levels and therefore there is potential to reduce the sodium content in meat products. According to Cargill, its Alberger brand salt gives you more salt flavour (Cargill Salt, 2001). The Alberger® Fine Flake Salt has a cube agglomerate structure and is recommended for use in meat products. Lutz (2005) has shown that flake salt (such as the Alberger Fine Flake Improved Salt) can produce red meat batters with superior fat and water binding properties compared to Dendritic or regular vacuum evaporated salts. This study found that using this salt type resulted in a product with improved yield, increased protein functionality and had less detrimental effects in sensory quality of bologna-type meat products. The pH of the batters made with the Alberger® salt was significantly higher than the pHs of batters made with other salts which, in theory, should lead to a greater degree of solubilisation of the myofibrillar proteins. The results also showed that the moisture of the batters with the Alberger® salt was more tightly bound and exhibited superior binding properties than the other salts examined. Cook losses where also reduced in comparison to the other salts. This increase in functionality using the Alberger® Salt may lead to the possibility of using less salt and producing products of similar quality but with less sodium content. Morton Salt describes its Star Flake® dendritic salt as a "hybrid" combing the most useful features of vacuum granulated salt and grainer flake salt. The dendritic crystals are branched or star-like in shape and exhibit the low-density, high specific surface area and rapid dissolution properties of fine grainer salt. A unique feature is the cavitation or macroporosity of the crystal (Morton Salt, 1997). With an extremely high exposed surface area per unit weight, dendritic salt exhibits a rapid dissolution rate and theoretically should dissolve twice as fast as granulated salt, but it depends on the dissolving parameters.

10. Alternative processing techniques

Monahan and Troy (1997) conclude that research should also be directed towards the meat system itself and methods of enhancing the functionality of the meat system to low salt formulations, such as use of pre-rigor meat and high pressure technologies. Pre-rigor meat is known for its superior functionality in terms of extractability of myofibrillar proteins, bind and water-holding capacity (Claus & Sørheim, 2006). The sodium content of can be reduced when using pre-rigor meat without detrimentally affecting the physical, chemical or sensory properties of emulsion-type sausages (Puolanne & Terrell, 1983). Pressure treatment could be of interest to improve protein functionality where it is desired to reduce the sodium content of meat products (Cheftel & Culioli, 1997). Sensory analyses on reduced salt high pressure treated frankfurter batters have shown that panellists preferred these products to controls. Results also indicate that the texture of these products was improved after pressure application (Crehan, Troy, & Buckley, 2000). These authors conclude that that high pressure technology is a viable process that partially compensates for the reduction of salt levels in frankfurters.

11. Conclusions

The ultimate goal of ingredient suppliers and meat processors is to produce reduced sodium meat products that consumers can enjoy as part of an ongoing healthier diet and lifestyle. The strategies for and consequences of salt reduction are discussed in this article. This was by no means an all-encompassing discussion, but an attempt to review some of the technological aspects of reduced salt meat products and how the meat and food ingredient industries are responding to this current health issue.

Because there is no panacea in terms of a single ingredient that can be used to replace salt in meat products, a range of functional ingredient combinations must be developed and/or optimised. Products need to be recreated that will continue to appeal to consumers. With the food industry working together with the regularity authorities and consumer groups, the ultimate aim of reduced salt in the diet can be achieved if a cooperative approach is established and a full understanding of the technological problems associated with salt reduction is realised. The food industry needs to produce reduced salt products that are similar, in terms of texture and flavour, to regular products the consumer is familiar with. Government agencies need to continue educating consumers in terms of salt and health, as 15–20% of salt intake is coming from discretionary sources (SACN, 2003). A reduced salt product which is left on the shelf or to which customers add salt at the table will not benefit anyone.

Any alteration in salt content of meat products requires ingredient reformulation or manipulation. Some companies have produced products that are successful in replacing or substituting sodium in processed products others have been less so. Research is continuing to look at various flavours, in particular more savoury/umani taste to enhance the flavour of reduced salt products. Both the use of these flavours and by adding more aromatics such as herbs and spices a reduction in salt can be achieved, however, salt cannot be totally eliminated due to its functionality regarding binding and texture of products unless other ingredients such as phosphates, hydrocolloids, etc. are added. It should also be recognised that a number of companies and retailers have produced successful reduced-salt meat products and that provide variety, taste and nutritional value to consumers.

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