PS9.02 Sodium reduction in meat products: an opportunity for industry. 431.00

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1. INTRODUCTION

Research carried out since 1970s has shown that the sodium content of meat products can be lowered. In contrast with the research results, the sodium content used by the meat industry has increased over the years, due to a desired higher consumer safety level, less additives added, and an extended shelf life of the meat products. This happened not only with meat products, but with the total diet up to a level at which the intake of sodium has become a major health concern.

Sodium reduction is an issue for all processed foods. The meat industry has a responsibility to focus on lowering the salt content of meat and meat products. If the amount of sodium in meat products is lowered, a list of possible problems concerning product structure, shelf life, yield and taste can occur. The problems that may occur are dependent on the type of meat product.

Most of the research is performed by substituting sodium partly with potassium, which does not always result in a product with an acceptable structure, yield or taste. Although the last years a lot of work has been done by ingredient suppliers on sodium replacement, there is still no satisfactory solution for a substantial reduction of sodium.

2. Improving health through sodium reduction

Already for several decades, scientists debate the health benefits of a reduction of sodium intake. It took time before consensus was achieved. Initially the effects of salt on blood pressure seemed small, but, as scientific evidence continued to accrue, they turn out to be immense. Today, a vast body of evidence underpins the benefits of a reduced sodium intake on blood pressure and cardiovascular disease and stroke.

2.1. Health effects of sodium

2.1.1. Blood pressure

The main health effect of a surplus of sodium intake is an increase in blood pressure, one of the major risk factors for cardiovascular disease and stroke. Above a sodium intake minimally required to maintain normal physiological functions (about 1.5 g/day for adults) and health, the relationship between sodium intake and blood pressure seems to be more or less linear.

Scientific evidence for the blood pressure enhancing effect of a high sodium intake comes from numerous animal studies, epidemiological studies and clinical trials and controlled intervention studies [He and MacGregor, 2007;Penner et al., 2007]. It has been shown that addition of sodium to the diet of chimpanzees increases their blood pressure substantially. Fortunately, this effect is reversible after the withdrawal of salt supplements [Denton et al., 1995]. It appears that a moderate reduction of the salt content in human diets decreases blood pressure not only in subjects with hypertension, but also in normotensive subjects, as has been demonstrated in a large number of clinical trials [Geleijnse et al., 2003]. The effect in the latter group seems very small (i.e. 1-2 mgHg), however, the impact of this decrease on incidence of cardiovascular disease and stroke in the population is large. For example, projections have been made that 150,000 deaths in the US per year can be avoided by a moderate decrease of sodium intake [Dickinson and Havas, 2007] or decrease the prevalence of hypertension in Canada with 30% [Penner et al., 2007]. Such projections are based on the evidence that a permanently lower salt intake results in a smaller increase of blood pressure with age.

2.1.2. Cardiovascular events and strokes

The few epidemiological cohort studies that directly investigated 24-h salt excretion and risk of cardiovascular and stroke mortality after long follow-up support the evidence that salt contributes to the risk of these diseases [Tuomilehto et al., 2001]. As 24-h urine excretion is a short-time indicator of long-term salt intake, such studies tend to underestimate the true risk, however. In the control groups of two salt reduction intervention studies in prehypertensive people (Trials of Hypertension Prevention follow-up study) 3 to 7 24-h urine samples per participant were collected over time. After a follow-up time of 10 to 15 years, sodium excretion was positively associated with cardiovascular events, which in turn were inversely associated with potassium excretion. The strongest positive association with cardiovascular disease risk–stronger than the associations for sodium and potassium alone - was found for the sodium/potassium ratio [Cook et al., 2009]. In the intervention group, in which sodium intake was reduced with 40 mmol/day compared to the control group during 1.5-4 years, the risk of cardiovascular events decreased with 25% [Cook et al., 2007].

2.1.3. Sodium intake

Mean daily sodium intakes of populations in Europe range from about 3-5 g (about 8-11g

salt) and are well in excess of dietary need, which is about 1.5 g sodium/day in adults. The main

source of sodium in the diet is from processed foods (about 70-75% of the total intake), with

about 10-15% from naturally occurring sodium in unprocessed foods and about 10-15% from

discretionary sodium added during cooking and at the table [Scientific Panel on Dietetic Products, 2005b], although discretionary use may be higher (e.g, one third) in some populations [Leclercq and Ferro-Luzzi, 1991]. From several national surveys, the contribution of bread and cereals is about 25%, the contribution of meat and meat products 18%, milk products and cheese products 17%, soups and sauces 10%.

Many European countries established the recommended intake of sodium at 6 g salt/day (~2400 mg sodium) for adults [Scientific Panel on Dietetic Products, 2005b]. The US Dietary Guidelines (2005) set a value of 2300 mg sodium/day, i.e. equivalent to 5.7 g/day salt/day (http://www.health.gov/dietaryguidelines/dga2005/recommendations.htm). These values are chosen because they encompass a substantial and worthwhile reduction of salt intake, but, at the other hand, are also considered achievable for consumers provided the reduction is gradually implemented.

2.2. The health effects of potassium and other cations

In contrast to sodium, potassium appears to have a favorable effect on blood pressure [Geleijnse et al., 2003] and cardiovascular events [Cook et al., 2009] and probably stroke. The effects of both cations on blood pressure are independent. However, as potassium (as well as magnesium and calcium) enhances sodium excretion, potassium may reinforce the effect sodium reduction. Other cations such as magnesium and calcium may also have a favorable, but weaker effect on blood pressure [Karppanen and Mervaala, 2006]. In the DASH (Dietary Approaches to Stop Hypertension) intervention study, a healthy diet with fruits and vegetables, whole grain, nuts, fish, and low-fat dairy products was compared to a regular American diet [Appel et al., 1997]. The DASH diet, which is high in potassium, magnesium, calcium and fiber, reduced the blood pressure. Additional salt reduction resulted in an extra decrease of blood pressure [Sacks et al., 2001].

2.2.1. Potassium intake

In many processed foods, the sodium content is much higher while the potassium content is much lower than in the natural ingredients they are produced from [Karppanen and Mervaala, 2006]. In diets consisting of predominantly processed foods the same imbalance is apparent.

Potassium is mainly provided by vegetables, fruits, potatoes, dairy products, coffee, processed meat, and bread. The recommended intake of potassium in the US is 120 mmol or 4.7 g/day (based on the blood pressure lowering effect), which most people do not meet. In Europe, recommended intakes range between 3.1 and 3.5 g/day [Scientific Panel on Dietetic Products, 2005a]. Intake in Europe amounts to about 3 g/day with a 97.5th percentile of about 5 g/day.

2.2.2. Safety of potassium (supplementation)

Homeostasis of potassium is tightly regulated in healthy people. Excess is excreted by the kidneys. However, several groups at risk for adverse effects of a high intake of potassium have been identified. People with reduced renal function, including elderly people, and people with diabetes are at risk to experience cardiac side effects, sometimes fatal. Also people taking drugs that interfere with potassium balance constitute a risk group. The Scientific Panel on Dietetic Products, Nutrition and Allergies of EFSA has not been able, however, to establish a Tolerable Upper Intake Level, due to lack of quantitative data [Scientific Panel on Dietetic Products, 2005a].

In Ireland, the FSAI scientific committee [FSAI, 2005] 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 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.

One of the solutions to protect susceptible risk groups from adverse effects of potassium, is to state expressly the amount of potassium (and sodium) on the food label.

2.3. Impact for the food industry

The scientific evidence for substantial health benefits of a reduction of sodium intake is very convincing. For this reason, international organizations, such as the World Health Organization, have called for action. Several national authorities, such as those in Finland (already since the 1970's!) and the UK (since 2003) have developed policies and/or regulation to reduce the sodium intake of their population. Many other countries are trailing behind [Ness, 2009], leaving the initiative to the food industry and private organizations. The tide is turning, however. Large food companies such as Unilever (www.unilever.com) have developed a strategy to decrease the sodium content of their products gradually over time, so that consumers keep used to it. This implies that in the long run all food companies and caterers have to adjust their products as the consumers' taste changes.

Whether sodium should be simply reduced or substituted with other cations, depends on many factors. Gradual sodium reduction seems indicated for foods in which sodium has no other function than taste. In foods, such as meat products, where sodium choride is being added for other purposes as well, substitution with other cations, in particular potassium, may be the best solution. To be able to control the total amount of potassium added to the diet as substitute of sodium, it is advisable for Food Authorities to conduct or commission simulation studies to assess the range of potassium (and sodium) intake by the population for several Na/K substitution scenarios.

3. SUBSTANTIAL REDUCTION OF SODIUM IN MEAT PRODUCTS

3.1. Function of sodium in meat products

The role of salt (normally NaCl) in meat products is related to taste, microbiological safety and texture. In order to reduce especially the sodium content in meat products, it is of great importance to understand the role of salt. The role of salt strongly depends on the type of meat product. In products were water or fat binding is essential (minced meat products, cooked sausages or hams), the major role of salt is the solubilisation of myofibrillar proteins. This solubilisation is required because the myofibrillar proteins are responsible for the largest part of gelling and emulsifying capacity in meat products. It seems that especially the chloride is responsible for the expansion of the myofibrils by penetrating into the myofibril and causing a repulsion between the negative charges [Hamm, 1972][Offer and Trinick, 1983]. Sodium seems to be located more on the outside of the fibrils [Offer and Knight, 1988]. Simply minimization of the salt concentration will lower the protein solubility and therefore reduce the gel strength and water holding capacity of the meat product. Phosphates are used to lower the amount of sodium chloride. These salts seem to work synergistically which enables a reduction of the amount of sodium chloride.

In dry fermented meat products (e.g. Coburger, Salami), the role of the salt is not related to the solubilisation of the myofibrillar protein, but instead is required to prevent microbial spoilage. The addition of salt to such a meat product minimizes the amount of free water in the product which prevents or slows down the growth of micro-organisms.

Apart from the role of salt in solubilisation of the myofibrillar proteins and in preventing microbial spoilage, taste is another essential factor. Besides the direct effect of salt perception on the tongue, salt also has an additional effect in enhancing other flavors. The salty taste we experience when we add sodium chloride to a food product comes from the sodium ion and not the chloride ion. This effect is caused receptors on the tongue that can detect sodium ions and not chloride ions. The reason that salt enhances other flavors is more difficult to understand, but seems to be mostly related to a reduction of the taste of bitter substances and enhancement of the taste of sweetened substances [Breslin and Beauchamp, 1997].

3.2. Substitution of sodium in meat products

Substantial sodium reduction in meat products is challenging. Potassium is still the most common substitute for sodium, however blends with more potassium chloride over sodium chloride (on weight basis) have a significant bitterness [FSAI, 2005], loss of saltiness, increase on microbiological risks [Verkleij et al., 2009] and loss of yield. To cover all those aspects like structure, yield, microbiological stability and taste, a multidisciplinary approach must be considered. The functionality of sodium (and its replacements) should be distinguished for four different meat product groups (Table 1). The function of sodium in cooked whole-muscle meat products (e.g. cooked ham) and cooked comminuted meat products (e.g. cooked sausages) is different compared to the functionality of sodium in raw whole-muscle meat products (e.g. Coburger ham) and raw comminuted meat products like salami.

Substitution of sodium with potassium can be carried out for a certain amount, up to 30% or more, dependent on the type of product. It should be kept in mind, however, that exchange of cations in meat products should be based on ions, not grams, to achieve comparable properties in terms of structure and shelf life. Substitution of NaCl for KCl on gram level would imply that 1.28 % less ions is available for replacement of the functionalities. Substitution on ion level means addition of more KCl (in grams) and therefore more risk for off taste.

Table 1: Classification of meat products into categories with respect to sodium functionality.

Meat Products	Whole muscle	Comminuted meat products
Non heat treated	Dried products like Coburger or Parmaham	Fermented sausages like Salami and Chorizo
Heat treated	Cooked products like ham, shoulders or cooked Rib eye	Cooked sausages like luncheon meat, Frankfurters or Bologna

3.3. Challenge to maintain satisfactory structure

3.3.1. Non-heat treated meat products

The structure of non heated meat products is developed by elimination of a certain amount of water from the raw product. Most of the current products are produced by adding salt in the form of NaCl to the meat, in a dry form (salting) or in a combination of salt and lowering the pH (through fermentation or addition of glucono-delta-lacton). The interaction between salt, pH and temperature is crucial to control the fermentation and thereby the safety and the quality of dry fermented meat products [Leistner et al., 1971]. If for instance the salt concentration is changed, it should be compensated with other factors to control safety and quality.

<u>Dried products like Coburger</u>

Chloride-ions are able to act as swelling promoters. As for the production of dried products swelling is unwanted, water has to be eliminated. For this purpose, higher salt concentrations are required. When the salt-concentration is above 6%, the thick myosin filaments structure will be broken, followed by shrinkage of the muscle and reduced water holding capacity.

For the production of dried meat products, other additives besides sodium chloride are also used, e.g. sodium nitrite, sodium ascorbate and/or sodium citrate. Replacement of sodium nitrite with potassium nitrite or nitrate can be considered. Replacement of sodium ascorbate with calcium and/or magnesium ascorbate is also possible. The introduction of calcium or magnesium in a dried product will give a more solid texture but less decrease of the a_w , which is the most important factor for bacterial growth. In addition, diffusion of ions like calcium and magnesium is lower compared to sodium, resulting in a necessary increase of the salting period.

<u>Fermented sausages</u>

Fermented sausages show a decrease in pH value during ripening which is more pronounced than dried meat products. This decrease in pH increases the loss of bound water, which is necessary to reach a certain shelf life. Studies carried out by Puolanne and Peltonen [Ruusunen and Puolanne, 2005] on the combined effects of sodium chloride and pH on the water-binding capacity of meat showed that two steps can be distinguished in the process: an initial phase where water binding is still high (pH 5.6), which enhances cohesion and a second phase in which the pH is lowering, resulting in reduced water binding.

The ionic strength obtained through the addition of sodium chloride can be reached by several other salts, like potassium, but also magnesium and calcium salts.

Another additive which can attribute to a stable shelf life of fermented sausages is potassium-lactate. Besides the potassium, which contributes to a low a_w, the lactate ion is also directly able to contribute to microbiological stability. Although the growth of *Lactobacillus* and *Micrococcus spp,* necessary for fermentation, is affected by the lactate ion, there is still room to use a certain amount of lactate [Guardia et al., 2008].

3.3.2. Heat treated meat products

During heating the structure of the product is formed by denaturation of the meat proteins [Tornberg, 2005]. The whole meat muscle has a well defined structure and heating of those proteins gives a more or less predictive structural change of the meat proteins. Depending on the availability of myofibrillar protein and sodium concentrations, the amount and type of protein which is extracted into the aqueous phase differs and this will influence the structure of the product after heating. Other factors are able to influence this process, like the pH of the meat, and the presence of additives like phosphates.

Besides the swelling capacity of the myofibrils in meat, the water holding capacity and the structure after cooking are critical factors for determining product quality. For industrial processors, the yield of their process is also an area for special attention.

<u>Cooked products like ham</u>

Most of the cooked whole muscle meat products is injected with a brine solution. This solution contains a mixture of polyphosphates, salt (sodium chloride with added sodium nitrite), flavor enhancers such as sodium glutamate, ascorbic acid and/or citric acid, sodium or potassium lactate and in some cases also proteins.

During the last decades, a huge amount of literature has been reported on the decrease of the amount of salt especially sodium. Salt content of over 2% can be markedly lowered without substantial sensory deterioration or technical problems causing economical losses [Ruusunen and Puolanne, 2005], however, shelf life issues can occur.

There is a wide range of possible substitutes for sodium chloride in injected cooked meat products, like potassium chloride, magnesium chloride, and calcium lactate. Other sodium salts like for instance phosphates and nitrites can be replaced by their potassium salts and sodium citrates by calcium citrate. It is important to recalculate the substitution of sodium by the same ionic strength as is necessary to achieve the same structure.

Besides the sodium substitutes mentioned, there is also a wide variety of ingredients that can be used to enhance the binding and forming structure. Among them are functional proteins, fibers, hydrocolloids and starches. The gel matrix formed with these alternative ingredients provide binding through a combination of protein coagulation and gel formation rather that direct interaction with muscle proteins.

<u>Cooked comminuted meat products like luncheon meat.</u>

The structure of comminuted products like cooked sausages is obtained through a complete other process than whole meat products. During comminuting the salt and phosphates are added to extract the myofibrillar protein, which in turn creates a dense protein network which forms the structure of the product during heating. The higher the amount of extracted myofibrillar protein, the denser the protein network will become after heating. When substituting sodium ions with other ions, their solubilisation capacity will differ, partly because the ionic strength is altered, but also because they solubilize the myofibrillar proteins differently. Several experiments report the synergistic effect of phosphates.

3.4. Challenge to achieve satisfactory shelf life

Microbiological shelf life is achieved by preventing the growth of certain types and kinds of microorganisms, which is dependent on the intrinsic and extrinsic properties of the meat product for a given time and temperature line. One of the intrinsic properties of meat products is the a_w value. For each meat product, replacement of sodium chloride by other additives requires a recalculation based on the a_w value necessary to maintain the shelf life of the meat product. For an overview see table 2.

Table 2: Overview of possible additives to replace NaCl while maintaining a_w

Additive	Formula	Amount needed (in %) to replace 1% NaCl to maintain a_w
Sodium chloride	$NaCl$	1.0
Potassium chloride	KCl	1.3
Calcium chloride	$CaCl_2$	1.3
Ammonium chloride	NH_4Cl	0.9
Magnesium chloride	$MgCl_2$	1.1
Potassium sulfate	K_2SO_4	2.0
Magnesium sulfate	$MgSO_4$	2.0
Potassium lactate	$C_3H_5O_3K$	2.2
Potassium acetate	CH_3COOK	1.7
Glucose	$C_6H_{12}O_6$	6.2

With replacement of sodium chloride by one other additive it is almost impossible to reach the same a_w without affecting other aspects like taste or structure. Some additives have a proven additional effect on reaching shelf life, e.g. lactate [Stekelenburg, 2003]. Therefore the combination of several additives must be considered, tailored to the products they will be used for.

3.5. Get used to the taste

Salt gives a flavor enhancing effect in meat products, with a perceived saltiness mainly due to the Na+ with the Cl− anion modifying the perception. As the salt levels rise, the increase in saltiness is more noticeable in fatty products than in lean meat products. Fat and salt jointly contribute to many of the sensory properties in processed meats.

There are several routes to lower the amount of sodium without affecting the taste of the products substantially. Firstly, the added amount of sodium can be lowered with small steps of 0.1 %. According to [Bertino et al., 1982] a reduction of salt must occur slowly over several months in order not to affect taste and consumer acceptability of food products. Secondly, a salt substitute can be used, in particular potassium chloride. The amount of substitution by potassium must be checked for the possible off-taste which occurs when adding a higher amount, so other ions must be considered. Thirdly, flavor enhancers that are able to enhance the saltiness perception of the meat can be used. Possibilities are glutamate or yeast extracts. The fourth option is to optimize the local availability of the salt, which decreases the amount of salt needed for taste, but not for the other functionalities of salt.

There is an increasing market for ingredients that are able to replace sodium or enhance the flavor in meat products; each product needs special attention for application.

4. CONCLUSION

To produce meat products which are enjoyable to consumers and contribute to a healthy diet must be the ultimate goal for meat processors. The need for improving health through sodium reduction in meat products is essential to reach this goal. Products need to be redesigned if they will have to continue their appeal to consumers, a reduced sodium product which is not bought, will benefit no industry. There is no single solution in terms of one ingredient that can be used to replace the sodium substantial in meat products; a range of substitutes has been discussed. It is important to realize that replacement has to be worked out on ionic base in stead of grams. The meat industry needs to produce reduced sodium meat products that are equivalent, in terms of texture, yield and shelf life to regular products.

With the knowledge available in research institutes and universities, a reduced sodium diet can be achieved if, in a collaborative approach, full understanding of the technological problems of sodium reduction is achieved.

Consumers need to be educated by Government agencies in terms of salt intake corresponding to health, as well from sodium as from its replacements. Government needs to coordinate and monitor also the total intake of sodium and the substitutes like potassium.

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