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Reduktion av natrium i emulsionskorv

Lisa Skogsberg

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Abstract

Sodium chloride (salt) is consumed in varying amounts between individuals and populations worldwide, but the consumption is generally higher than the recommended intake in many parts of the world. Research has shown that high sodium consumption is associated with increased blood pressure and we are therefore recommended to consume less sodium. Meat and meat products are a group of products that contribute to a large amount of sodium in the diet. Therefore it is relevant to develop low sodium alternatives in this product segments.

Two batches of three emulsion-type sausages with different level of substitution from sodium chloride to potassium chloride were manufactured in cooperation with a local company specialized in meat products (Andersson & Tillman, Uppsala, Sweden). The sausages produced had 0%, 15% and 30% degree of substitution with KCl on molar basis from the total of 2 g NaCl / 100g sausage.

No difference could be observed between product types for moisture content, water activity, yield, color, pH and texture after Benjamini-Hochberg adjustment for false discovery rate. Consumer acceptance was lower for the 30% substitution sausage compared to the other sausage types. These results are however confounded by the fact that the 30% substitution batch used for sensory evaluation had softer texture, most likely due to production variability. It is likely that parameters other than the sodium content, such as variation in ingredients, temperature of production or pH have bigger impact on the sausage properties than the substitution of sodium chloride to potassium chloride. Consumers also showed great interest in buying low-sodium sausages if available on the market.

There is market potential for the product segment of low-sodium sausages and there is technological potential of producing a sausage with low sodium content by replacing 30% of sodium chloride with potassium chloride, however, the sensory aspects need further studies.

Keywords: salt, sodium reduction, potassium chloride, substitution, sausage

Sammanfattning

Natriumklorid (salt) konsumeras i varierande mängder mellan olika individer och populationer och konsumtionen är generellt högre än det rekommenderade intaget i många delar av världen. Forskning har visat att hög natriumkonsumtion kan förknippas med förhöjt blodtryck och därför rekommenderas vi konsumera mindre natrium. Kött och charkprodukter är en grupp produkter som bidrar med en stor mängd natrium i kosten och det är därför relevant att utveckla alternativ med låg natriumhalt för detta produktsegment.

Tillsammans med det lokala charkuteriet Andersson & Tillman (Uppsala, Sverige) tillverkades två batcher av tre emulsionskorvar med reducerad natriumhalt där 0%, 15% och 30% av natriumkloriden (totalt 2g natriumklorid/100g korv) ersattes med kaliumklorid. Substitutionen gjordes på molar basis för att erhålla samma tekniska egenskaper av saltet.

Ingen skillnad kunde observeras mellan produkternas vattenhalt, vattenaktivitet, utbyte, färg, pH eller textur efter 'Benjamini-Hochberg false discovery rate' justering. Konsumenternas acceptans var lägre för korven med 30% substitution jämfört med de andra. Detta är troligen relaterat till att proverna för denna korv (från den andra tillverkningsomgången som användes vid den sensoriska bedömningen) hade en mjukare konsistens. Det är emellertid troligt att andra parametrar än natriumhalten, såsom variation i ingredienser, temperatur vid produktion eller pH har större inverkan på korvens egenskaper än substitution av natriumklorid till kaliumklorid. Konsumenterna visade också stort intresse av att köpa korv med reducerad natriumhalt om det skulle finnas på marknaden.

Det finns därmed marknadspotential för detta produktsegment och det finns potential att producera en korv med låg natriumhalt genom att ersätta 30% av natriumklorid med kaliumklorid dock behöver de sensoriska aspekterna studeras ytterligare.

Nyckelord: salt, natrium reduktion, kaliumklorid, substitution, korv

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1 Introduction

1.1 Salt consumption and its health effects

Salt has been used as a seasoning and preservative since early civilizations. The addition of salt has a preservative effect in the product by lowering the water activity, but salt can also be added to improve texture and mouthfeel. Today salt is mainly used for flavoring and texture enhancements (Desmond, 2006) while other methods such as processing and chilling have taken over as the main methods for preservation (Coultate, 2009). Salt is not only discussed concerning its effects on the food product but also concerning its effects on the humans consuming it. In this text salt will refer to sodium chloride if nothing else is specified.

1.1.1 Salt and health

Sodium is naturally occurring in food but today most of the sodium consumed is from sodium added to the food product e.g. as sodium chloride (salt), sodium phosphate, sodium nitrite or sodium glutamate. The salt added to processed food for flavor, texture or preservation is the main source of sodium making up for about 75% of the total sodium intake. Products as bread, cheese and processed meat products are generally high in salt (EFSA, 2005). Meat and bread followed by sausages and the group of pizza, pasties and pies are the main sources of sodium in the Swedish diet (National Food Agency in Sweden, 2012).

The daily consumption of sodium is generally higher than the physiological requirements both in Sweden (National Food Agency in Sweden, 2012) and worldwide (Brown, Tzoulaki, Candeias, & Elliott, 2009). This high consumption is generally believed to be associated with increased blood pressure and thereby also increased risk for cardiovascular diseases (CVD) (He & MacGregor, 2009). Renal diseases and increased risk for stroke are other disorders associated with the high sodium consumption. The Nordic Nutrition Recommendations (NNR) review of the subject concluded that there is a “progressive dose-response relationship between sodium intake and blood pressure” and the consumption should thereby be limited (Nordic Council of Ministers, 2014).

EFSA (2005) concluded that current consumption levels of sodium contribute to increased blood pressure in the European population and is a risk factor for cardiovascular and renal diseases. Increased sodium intake results in elevated blood pressure, but there is a variation between individuals (EFSA, 2005).

High blood pressure is the biggest risk factor for mortality worldwide and high sodium consumption is one of the main factors contributing to a higher blood pressure together with alcohol consumption, obesity and lack of exercise (WHO, 2009). In this context, it should be mentioned that the development of cardiovascular diseases (CVD) is dependent on many factors and salt is only one of those (Desmond, 2006).

However, there is scientific disagreement regarding if salt reduction is the best way to reduce the health issues mentioned. Graudal, Jürgens, Baslund, & Alderman (2014) showed in a meta-analysis that both low and high sodium intake was linked to a higher risk for all-cause mortality and CVD compared to the usual sodium intake by most of the world’s population. Based on these results they are far from certain that lowering the salt consumption is the best way to reduce the population risk for CVD.

Sodium and salt have also been discussed regarding cancer. World Cancer Research Fund and the American Institute for Cancer Research (2007) concluded that it is likely that increased salt intake is associated with higher risk for stomach cancer. However, EFSA (2005) state that sodium is non carcinogenic.

Even though there are different opinions regarding sodium, is it generally accepted that high salt consumption is related to higher blood pressure (Coultate, 2009) and the recommendation from many government agencies and other organizations is to reduce the salt consumption (Nordic Council of Ministers, 2014; WHO, 2009; World Cancer Research Fund / American Institute for Cancer Research, 2007).

The Nordic Nutrition Recommendations (NNR) acts as the basis for food recommendations for the general population in Denmark, Finland, Norway, and Sweden (Nordic Council of Ministers, 2014). Regarding salt, the recommendation is to “Limit the use of salt in food products and food preparation” and consume less salt by “choosing low-salt varieties”. NNR point out that the diet as whole, not single food products needs to be considered for the overall health.

The consumption in the Nordic countries is unclear but studies generally show a consumption of about 7-12 g salt/ day. This is considerably higher than the population target of 6g salt /day for adults (Nordic Council of Ministers, 2014).

WCRF and WHO give similar recommendations of less than 5 g salt/day for a population average consumption (World Cancer Research Fund / American Institute for Cancer Research, 2007; World Health Organization, 2012).

1.1.2 Sodium reduction initiatives

Because of the high consumption compared to the recommendation, sodium reduction initiatives have started in many countries around the world. Sodium reduction initiatives in Finland, United Kingdom and USA have received much attention and will be further discussed.

In Finland, labeling of salt content has been a successful initiative. Products containing salt levels above threshold values (e.g. as >1,8% for sausages) are labeled as “high-salt content” whereas products containing a lower amount of salt (e.g. as <1,2% for sausages) the product can be labeled “low salt”. This labelling, together with governmental recommendations and media attention has resulted in a lower salt consumption in the population. Concurrently, the blood pressure in the general population has decreased together with a decrease of heart attacks and strokes (World Action on Salt & Healt, n.d.).

In the UK, the food industry has voluntarily adhered to a goal for reducing the salt content in processed foods. Mainly by this action, named the Public Health Responsibility Deal, and a public awareness campaign the consumption of salt has been reduced by 15% during the last ten years and the current consumption of salt is 8,1g daily. This action will be continued until the public target of 6g/day is reached (CASH, n.d.). In 2003 Ireland introduced a similar program together with the food industry (FSAI, 2015).

The Dietary Approaches to Stop Hypertension (DASH) Eating plan is a heart-healthy diet based on trials initiated by the National Heart, Lung and Blood Institute in the U.S. Department of Health & Human Services. One of the DASH-studies showed that a reduction of sodium reduces blood pressure and a higher reduction of blood pressure occurs when sodium reduction was combined with DASH-diet compared to a typical American diet. Central parts of the DASH-diet includes consuming products low in *trans*-fat, low in saturated fat, low in sodium and products rich in magnesium, calcium, potassium, protein and fiber. The DASH-diet was shown to have positive effects on health outcomes, such as lower LDL cholesterol and blood pressure (National Heart Lung and Blood Institute NIH, 2015a, 2015b).

In the European Union, a voluntary action for sodium reduction with 29 participating countries has been established. This action, named European Union framework for national salt initiatives was created in 2008 with the goal of a 16% sodium reduction of all foods during a 4 year period. Sweden is working with this within the framework of the “keyhole” brand (European Commission, 2012). The keyhole is a label marked on products low in salt and sugar, high in fiber and wholegrains and products with a higher degree of unsaturated fat or with less fat compared to other (National Food Agency in Sweden, 2015). This European framework is a voluntary action but address the importance and the political position on this issue in the European Union.

1.2 Health effect of processed meat products

Meat is an important source of high-quality protein, vitamins as B_6 and B_{12} and minerals as iron, zinc and selenium in our diet (Nordic Council of Ministers, 2014). However, processed meat and red meat have also been associated with negative health outcomes, such as colorectal cancer, type II diabetes and coronary heart diseases. According to the definition by World Cancer Research Fund / American Institute for Cancer Research (2007) processed meats refer to products "preserved by smoking, curing or salting, or by the addition of preservatives", which includes products such as sausage, salami and ham but excludes products only cooked. Because of these health concerns the recommendation for the general population is to limit the consumption of red and processed meats (Nordic Council of Ministers, 2014; World Cancer Research Fund / American Institute for Cancer Research, 2007).

1.3 Emulsion-type sausage

1.3.1 Emulsion-type sausage formulation

Bologna, frankfurters and hotdogs are all examples of emulsion-type sausages. These sausages are characterized by a stable, finely chopped mixture of meat, fat, water, salt and other ingredients such as fillers, stabilizers, antioxidants or spices depending on the desired product. The meat protein is responsible for the stable matrix formed during cooking (*Encyclopedia of meat sciences*, 2004).

Lean meat and fat not used for fresh meat cuts can be used in various amounts in sausages. Water or ice is added to keep the low temperature during comminution and is often needed as a part of the formulation to avoid having a dry product in the end. Water and moisture improves juiciness and tenderness in the final meat product (Hedrick, 1994).

Salt, usually sodium chloride, has important properties in processed meat products. A sufficiently high salt content is needed to solubilize the myofibrillar proteins for coating fat globules creating a stable gel (Hedrick, 1994). The salt also improves the water-holding capacity, stability of the batter, taste, aroma and yield. It influence taste, texture and juiciness in a desirable way but has the negative aspect of contribution to increased fat rancidity and increased sodium content (SIK, 2001). Nitrite is usually added as sodium nitrite or potassium nitrite and the main purpose of nitrites is to limit the growth of *clostridium botulinum* but it also contributes to the flavor stability and color formation. Moreover, the addition of salt lowers the water activity which leads to retarded growth of microorganisms and a longer shelf life (Hedrick, 1994).

By tradition, potato flour is a common ingredient in Swedish meat products. Potato flour can bind a lot of water and has traditionally been used as a filler to reduce the amount of meat which was and still is a much more expensive ingredient (SIK, 2001).

Spices are added to obtain the desired flavor and may also contribute to preservation (Hedrick, 1994). Ascorbic acid is usually added to reduce the formation of carcinogenic nitrosamines from the nitrite salt but it also contributes to stable color formation (SIK, 2001).

Emulsion-type sausages have some characteristics of fat-in-water emulsion. The aqueous phase contains muscle fibers, connective tissue and soluble proteins such as sarcoplasmatic proteins but also myofibrillar proteins are solubilized in the presence of salt. Soluble proteins act as emulsifying agents by coating the fat globules, enabling the fat to be dispersed in the aqueous phase. The salt soluble myofibrillar proteins actin, myosin and actomyosin are of big importance for this action. A stable matrix is important for the structure of the final product since it prevents coalescence of fat droplets and also retains water in the product during heat processing (Hedrick, 1994).

Batter formation and stability are affected by factors such as pH, temperature during formation, fat particle size and amount of soluble protein. A higher pH is favorable for water holding capacity and protein extraction resulting in a juicier and more stable product. Unfavorable effects such as denaturing of proteins, lower batter viscosity and fat melting may occur if the temperature is too high during processing. If the fat particle size becomes too small e.g. from overchopping, the fat surface area will increase and the soluble protein may not be able to cover the entire surface. This may then end up in a non-stable emulsion with coalescence between fat globules which can cause fat separating from the meat generating so called fat pockets or fat caps in the product (Hedrick, 1994).

1.3.2 Production of emulsion-type sausage

Cold meat and salt are added to a cold bowl chopper or meat grinder. A low temperature (about 0°C) is important during comminution, when reducing particle size, to improve protein solvation and to limit growth of bacteria. Ingredients are therefore chilled from the beginning of the process. Water and ice are added during chopping to continually control the temperature. Pre-salting of meat can be used to activate the salt-soluble proteins actin and myosin to improve its dissolution. Sarcoplasmatic proteins on the other hand are water-soluble and do not need salt for activation (SIK, 2001).

The fat is then added to the batter and the addition of ice is stopped since the fat needs a higher temperature to be divided into small particles and give a stable emulsion. Dry ingredients such as flour and spices are added last and just needs to be evenly distributed in the batter. A good emulsion-like batter should be achieved at a temperature of about +14°C if fat from pork is used and about +20°C for fat from beef. The batter is put into casings and usually heat treated by smoking and/or cooking. When producing raw sausage the heating step is omitted, this however also leads to decreased shelf-life. A batter-type sausage is generally produced as described but many different types of bowl choppers, grinders, mixers and emulsion mills are available on the market and can be used in different combinations for sausage manufacture (SIK, 2001).

Smoking was originally used as a method for preservation but today the color and flavor development during smoking are the most important aspects (Hedrick, 1994; SIK, 2001). The type of wood, smoke density, time of smoking, temperature and moisture during smoking affect the result and the smoking process varies between different products. After smoking most products are cooked to an internal temperature of 65-77°C depending on the product produced. The heat treatment allows the product to be quickly prepared in the home and the reduction of microorganisms contributes to a longer shelf-life. Gelatinization of meat proteins during heating also stabilizes the matrix in the sausage and enables the product to keep its shape (Hedrick, 1994).

1.4 Main functions of salt in sausage production

1.4.1 Salt impact on sausage characteristics

Even though meat itself contains sodium, the sodium chloride added during processing is the main source of sodium in sausage (Ruusunen & Puolanne, 2005). The average salt content in sausages in Sweden is generally around 2%, as assessed by inspection of labels in products normally found in Swedish supermarkets. It has been observed that when reducing salt content below 2.0% frankfurters became less firm and had a softer texture. Flavor and overall acceptability scores were also lower and flavor deterioration faster (Sofos, 1983a). Sofos (1983a, 1983b) thus concluded that reducing salt <2.0% in frankfurters resulted in unacceptable flavor and texture together with lower emulsion stability.

Salt is needed to dissolve actin, myosin and the actomyosin complex which are needed for the coating of fat globules in the batter to create a stable emulsion. In the presence of salt, proteins also take up water forming a viscous matrix (Hedrick, 1994). The stability of the protein matrix formed is of big importance for the water-holding of the product (Tornberg, 2005) and the water and moisture improves juiciness and tenderness in the final meat product (Hedrick, 1994).

1.4.2 Salt reduction

In the European Union, a reduction of sodium is allowed to be labeled on the product. The product can be labeled with the statement "reduced salt content" when making a >25% reduction of sodium compared to a similar product (European Commission, 2006). Terrell (1983) suggests four ways to reduce sodium:

1. Reduce sodium chloride
2. Replace parts or all of it with other chloride salts
3. Replace parts of it with nonchloride-salt compounds
4. Alter processing

A reduction of the sodium chloride content is possible but can cause some undesirable effects. The perceived saltiness and overall flavor intensity is decreased by reducing the salt content (Crehan, Troy, & Buckley, 2000). Lower salt content decreases water binding and gel strength of the batter (Whiting, 1984) and already at salt content <2% sausage characteristics are affected (Sofos, 1983a, 1983b). There are different opinions of how much the salt content can be reduced. Below 1.5% sodium chloride smokehouse losses increases and emulsion stability is reduced (Sofos, 1983b) but already at <2% the overall consumer acceptance was negatively affected (Sofos, 1983a). Ruusunen & Puolanne (2005) suggest even further reduction possible. They suggest that without addition of other components the sodium chloride content can be reduced to 1.5-1.7%. Products with lower salt content are harder to reduce than the ones with higher amounts without undesirable effects.

To replace parts of the salt with other chloride salts such as KCl, $MgCl_2$ or $CaCl_2$ have been tested in several studies (Corral, Salvador, & Flores, 2013; Gimeno, Astiasaran, & Bello, 1999, 2001; Gou, Guerrero, Gelabert, & Arnau, 1996; Guàrdia, Guerrero, Gelabert, Gou, & Arnau, 2008). The substitution to other chloride salts can give results as less desirable texture and flavor but when reducing sodium, potassium chloride is the best alternative (Terrell, 1983) and also the most common salt used for this substitution (Desmond, 2006). A bitter taste has been detected at 30% level of substitution when sodium chloride is substituted with potassium chloride, but below 40% substitution the bitterness was not considered important (Gou et al., 1996). Corral et al. (2013) found that a reduced acceptance of aroma, juiciness, taste and overall quality caused by a 16% reduction of sodium chloride could be removed if the sodium chloride was substituted to potassium chloride instead of being reduced. Addition of potassium also reduces the harmful health effects of sodium by acting as a counter-ion to sodium (Ruusunen & Puolanne, 2005). The approach of substitution to other chloride salts does not in itself address the question of lowering the taste threshold for saltiness which is desired for lowering the sodium consumption but still having consumers liking the taste (Desmond, 2006).

Nonchloride-salt compounds such as phosphates, glutamates and yeast extracts can be used in reduced sodium products to improve sausage attributes. Phosphates acts synergistic with salt by increasing pH which in turn increases protein extraction and water-holding capacity. Phosphates also have the ability of converting actomyosin into the pre-rigor state as actin and myosin which facilitates their extraction (*Encyclopedia of meat sciences*, 2004). These properties can be used to improve firmness and perceived saltiness, to reduce off-flavors and to increase juiciness in sausages (Terrell, 1983). Ruusunen et al. (2003) showed that frankfurters made without phosphates need addition of other non-meat ingredients for salt levels below 1.5% and studies on cooked bologna-type sausage (Ruusunen, Sarkka-Tirkkonen, & Puolanne, 1998) showed that a reduction down to 1.35% added salt was accepted when phosphate was included in the recipe. In turkey frankfurters a reduction from 2.5% to 2% added salt was acceptable without phosphate, but when including phosphate an even greater reduction could be achieved (Barbut, Maurer, & Lindsay, 1988). Yeast autolysates can be added to reduce the perceived metallic flavor of potassium chloride (Desmond, 2006) and the addition of monosodium glutamate (MSG) can improve the sensory properties for cooked sausages (Ruusunen, Simolin, & Puolanne, 2001). Herbs and other spices can also be used to produce a pleasant flavor of the salt reduced products (Desmond, 2006).

There have also been studies investigating alternative process techniques e.g. high pressure techniques to achieve salt reduction without compromising product attributes. A reduction of salt from 2.5% to 1.5% can be achieved without affecting cooking loss or emulsion stability when using pressure technique (Crehan et al., 2000). Pre-rigor meat can also be used owing to the higher pH and a higher ability to extract soluble proteins which is of importance to stabilize the gel (Hedrick, 1994). The perceived saltiness can furthermore be increased by changing the formulation. Substitution of meat protein with fat can increase perceived saltiness without adding more salt (Ruusunen et al., 2001).

1.4.3 Taste of salt

Flavor is an attribute clearly affected by the salt content. Naturally occurring sodium is important for the natural flavor of many foods and salt is often added to foods not only to generate the salty taste but as a flavor enhancer. Only a few inorganic salts taste salty as many instead have a bitter taste. This phenomenon is depending of the matter of size. When the sum of the ionic diameters is below 0.658 nm the taste is salty. Sodium chloride has a salty taste with a diameter of 0.556 nm whereas e.g. magnesium salts such as magnesium chloride ($MgCl2$ 0.850 nm) taste bitter (Coultate, 2009).

Taste is perceived by receptors in the mouth and for saltiness an ion channel receptor is responsible for the salty taste perceived. Upon long-term high salt consumption some adaptation occurs and the response to salt exposure is decreased (Lawless & Heymann, 2010). The perceived saltiness is thereby dependent on the regular consumption of salt. As the consumption of salt varies, the amount of salt needed to produce an acceptable product may vary between individuals and populations. Since salt not only affects saltiness but also affects the overall characteristic flavor of meat products and the fact that the general population is used to a high amount of salt in the products, a reduction of salt would reduce the overall flavors and thereby also the consumer acceptance of the product (Ruusunen & Puolanne, 2005). It is thus a challenge to reduce the salt content.

1.5 Sensory analysis

The consumer is the person deciding which products will survive on the market and many studies have shown the importance of flavor when choosing the product. Compared to market surveys when the products are shown together with the label and other information, the sensory study is performed with samples marked with 3-digit codes without labels and with as little amount of information as possible. This is made in order to make the characteristics of the product to be in focus for the assessment. To get reliable results, the samples served during sensory assessment should be treated in the same way and be as similar as possible when served according e.g. to size and serving temperature (Gustafsson, 2014).

Sensory methods are divided into two groups, analytic methods and affective methods. For analytical tests an analytical panel of trained assessors is used as an objective measuring instrument to describe the product or to evaluate if products differ for a given attribute. For affective tests, untrained consumers are the assessors and these tests are used to investigate the subjective experience of the product. Affective tests, or consumer tests, are used to see if a product is preferred over another product or to evaluate the acceptability of the product (Lawless & Heymann, 2010). Consumer tests can be performed for different reasons e.g. for product category review, development of new products, product maintenance, product improvement, assessment of market potential or to support advertising claims (Meilgaard, Civille, & Carr, 2007).

Having the right participants, representative for the population of interest, is of big importance to have a successful consumer test. A sample size of 75-150 persons (Lawless & Heymann, 2010) or 50-150 persons (Gustafsson, 2014) is usually enough for consumer testing. When performing a consumer test on a public place it can be hard to find an undisturbed environment and it can also be hard to inform all the consumers about how to perform the test. It is therefore very important to have a simple and easy performance of the assessment (Gustafsson, 2014). Pretesting is usually needed and is a good way to evaluate the questionnaires (Lawless & Heymann, 2010).

1.6 Aim and objectives

The aim of this work was to produce a sodium-reduced emulsion-type sausage by replacing sodium with potassium and to investigate how the replacement affected the sausage quality characteristics. The sausage was manufactured in collaboration with a local meat-company (Andersson & Tillman, Uppsala, Sweden) and aimed to be a new variant of an already existing product on the market.

Two different sausages with 15% and 30% sodium substitution on a molar basis were chosen to be examined against a control with 2 g salt per 100g sausage (i.e. 0% substitution). The higher substitution was chosen to pass the EU criterion to label the product with lower salt content by a safe margin (sodium reduction by > 25%; European Commission, 2006). The intermediate level of 15% substitution was chosen to examine if any trend could be seen between the non-substituted sample and the 30% level of substitution. The substitution was based on molar amount to have the same technical action of the salt.

The objectives of this study was to investigate how the yield, water activity, moisture content, texture, color and consumer acceptance of the sausage were affected by the replacement of sodium with potassium.

1.7 Limitations

Product formulation and production was performed within the company Andersson & Tillman (Uppsala, Sweden) and was therefore limited by their production framework. By having the production in a commercial plant and the sausages being made by the in house personnel, batch-differences may occur even though they are instructed to produce all the products in the same way. This cannot be equally controlled as in laboratory setting. For practical reasons, the in-house personnel also assisted with some sample collection.

The specific sausage formulation is confidential and recipe formulations reported herein are a close approximation of the actual formulation, albeit with exact spice addition and procedural aspects removed. These discrepancies, however, are not believed to affect the results in any measurable degree.

The sensory consumer evaluation could only be performed during one specific day using only sausages from the second production round and is therefore not including production differences between production rounds.

There are several health concerns regarding meat and processed meat but this work will only focus on salt, more specifically on sodium replacement by potassium. It will not include other measures of reducing sodium as reducing the total amount of salt, usage of non-salt additives or to alter processing. Microbial safety is of big importance regarding food products but because of time constraints this is not further studied in this paper.

2 Material and method

2.1 Production

Emulsion-type sausage was prepared as follows. To make the result representative for the industrial production and to exclude errors from using non-industrial equipment, the sausages were produced in 50 kilogram batches in a commercial plant at Andersson & Tillman (Uppsala, Sweden).

Meat, fat, ice, salt and spices were mixed together in a bowl chopper. When the batter was properly mixed, at a temperature of about 6°C, potato flour was added and mixed to a good emulsion. At a temperature of 14°C the batter was transferred for stuffing into hog casings followed by smoking and heat processing until an internal temperature of 72°C was reached. The sausages were vacuum-packed and stored at 4°C before further analysis was performed. The final sausages had a diameter of about 3 cm and a length of about 15 cm.

Table 1. *Sausage ingredients and amounts (percent by weight).Ingredients used in different amounts marked with (*).*

Ingredients	**A 0% sodium reduction**	**B 15% sodium reduction**	**C 30% sodium reduction**
Meat from pork	37.6%	37.6%	37.6%
Meat from beef	24.7%	24.7%	24.7%
Pork fat	5.6%	5.6%	5.6%
Water (added as ice)	22.4%	22.4%	22.4%
Potato flour	6.2%	6.2%	6.2%
Sodium chloride including 0,6% sodium nitrite *	2%	1.7%	1.4%
Potassium chloride *	0%	0.3%	0.6%
Spice mix	1.2 %	1.2 %	1.2 %
Ascorbic acid	0.3%	0.3%	0.3%

The total amount of ingredients can be seen in Table 1 and was designed to have a final content of 62.3% meat and 23.1% fat. The salt content was varied in three products equivalent to the molar amount of 2g NaCl/100g product. The three products were produced with three levels of sodium reduction. The levels were 0% (A), 15% (B) and 30% (C) of molar substitution by KCl. Two batches of each sausage were prepared with approximately three weeks in-between.

2.2 Chemical and physical analysis

All chemical and physical analyzes were performed on three samples per sausage and three sausages per batch if nothing else is stated. The sampling scheme is graphically represented in Figure 1.

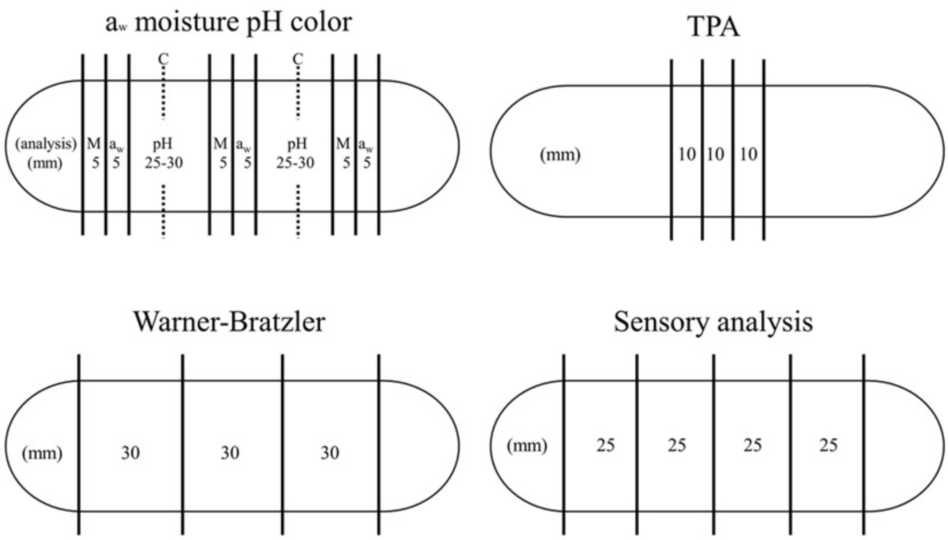

Figure 1. *Sampling procedure of the sausages. M=moisture analysis, a_w=water activity, C = color, pH, TPA = texture profile analysis, Warner-Bratzler and sensory consumer analysis. End pieces were not used.*

2.2.1 Moisture content and water activity

Moisture content was determined gravimetrically. Samples (Fig. 1) were weighed before and after drying at 105°C for 24 hours. Water activity was measured at ambient temperature using the dew point technique in the AquaLab CX-2 (Decagon devices Inc., Pullman, WA, USA).

2.2.2 Yield determination

Yield was measured gravimetrically by weighing six sausages with three replicates before and after smoking process.

Smoking yield (%) = (smoked sausage/batter sausage) x 100

2.2.3 Color analysis and pH

Color was measured using a CM-600d Spectrophotometer (Konica Minolta, Japan) according to CIE L* a* b* scale. L* indicates lightness from dark (0) to light (100), a* indicates color from green (-a*) to red (+a*) and b* indicates color from blue (-b*) to yellow (+b*). A white tile (L:97.5, a:-0,16 b:0.02) was used for calibration. Sausages were cut on two places (Fig. 1) and measurement was made on both surfaces made by the cut, four measurements per sausage. Color measurement was performed in the center of the sausage.

pH was measured in the batter and in the sausage (Fig. 1) at room temperature (Portamess 913 with pH Electrode SE 104, Knick, Germany). Before usage the electrode was calibrated with pH 7,0 and pH 4,0. During the first batch production, pH was measured in three samples per batter produced but only two samples during the second production. pH in smoked sausage was measured in four pieces per sausage generated by color analysis.

2.2.4 Texture analysis

Warner-Bratzler shear force measurement was performed on a Texture Analyzer TA-HDi (Stable Micro System, Surrey, UK) equipped with a 3 mm thick steel blade with a V cut into the lower part of the blade. The samples (Fig. 1) were punched into 15mm wide and 30 mm long rods for measurement at ambient temperature. Pre-test speed of 2mm/s, test speed of 1mm/s, post-test speed of 4mm/s and 50 kilogram load-cell was used. The maximum force (N) was measured which represents the tenderness and indicates the force needed to cut the meat.

Texture profile analysis, a two cycle compression test, was performed according to (Bourne, 1978). The test was performed on the same machine, albeit equipped with a 25 mm diameter probe (P25). Pre-test speed of 2mm/s, test speed of 1mm/s, post-test speed of 2mm/s, 50 kilogram load-cell and 50% degree of compression were used. The samples (Fig. 1) were punched into 15mm in diameter and approximately 10 mm high rods for measurement at ambient temperature. This compression test was used to measure hardness, springiness, cohesiveness and chewiness. The maximum force for deformation during the first compression cycle represented hardness (N), height recovered between compressions represented springiness, the ratio between the area under the curve during second and first penetration represented cohesiveness and hardness x springiness x cohesiveness represented chewiness of the sample (Bourne, 1978).

2.2.5 Sodium content

This analysis was performed by an external accredited laboratory (SS-EN ISO/IEC 17025, ISO 9001, ILAC). Sodium content was analyzed by NMKL 139, 1991. This analysis was only performed on sausages in the first batch of A, B and C produced.

2.3 Sensory consumer evaluation

After chemical and physical analysis a sensory consumer evaluation was performed. Pre-test and sensory consumer evaluation was performed only using sausages from the second production round.

The samples were served in 2.5 cm pieces (Fig. 1) in plastic cups marked with 3-digit codes in randomized order. End pieces were not served. Information about the ingredients according to the ingredients-list was shown but no further information about the study was given. The evaluation was performed at a local shopping mall during weekend to ensure representativity among the participants of consumers usually working during weekdays. Consumers (n=109) stated the degree of appreciation on a 10 cm visual analog scale and they did also have the opportunity to comment their statement. After performing the sensory test the consumers were asked questions about their age, gender, degree of consumption, their relation to salt and consumption of salt. The form given to consumers is shown in Appendix 1 (Swedish). A pre-test was performed at the production plant by employees (n=7) to evaluate the form and the performance of the test.

2.4 Statistical analysis

All statistical analysis was performed in the open source statistical environment R 3.2.2 (R Core Team, 2015). For chemical and physical measurements, linear model ANOVA of response variables (dependent) was performed using batch as categorical variable (independent). P-values are reported both in unadjusted and Benjamini-Hochberg false discovery rate-adjusted (fdr) forms. Tukey-adjusted pairwise comparisons were performed for those response variables with unadjusted $p<0.05$ using the ‘lsmeans’ R package v 2.23.

For the sensory consumer evaluation, repeated measures mixed modelling was performed using the ‘geepack’ R package v 1.2-0.1. Sensory evaluations consisted of visual analogue scale (VAS) responses (0-100 mm) for taste, texture and overall liking per sausage type in similar scales, i.e. with ‘strong dislike’ on the extreme left and ‘strong like’ on the extreme right. The questions were therefore analyzed jointly in the same model. In the first (raw) model, VAS response was therefore analyzed using ‘sausage’ (A, B or C) and ‘question’ (taste, texture and overall liking) as fixed factor, repeated by responding individual. A second model was made to account for contribution from confounding factors, by adding the effects of ‘age’ (numeric), ‘gender’ (factor), ‘habitual consumption’ (numeric) and their two-way interactions to the raw model.

Factorial logistic regression was performed to investigate possible systematic effects of the categorical independent variables age, gender, age x gender and habitual sausage consumption on the categorical dependent variables “Do you think about your salt consumption?” (think), “Do you want to reduce your salt consumption?” (reduce), “Are you actively looking for low-salt products?” (look) and “Would you be interested in buying low-salt sausage?” (interest). The significance of the correlations between age and the four dependent variables were subsequently tested using $\chi 2$-tests.

3 Results

3.1 Chemical and physical analysis

No visible differences between the samples could be observed during production and handling by the production staff and all sausages generated a stable emulsion without visual fat caps. The further analyzes made provided further insight into similarities and differences in product characteristics. Notation of samples and batches are mentioned as shown in Table 2.

Table 2. *Explanation of abbreviations used in the following text.*

Abbreviation	**Sample**
A	0% sodium reduction
B	15% sodium reduction
C	30% sodium reduction
Batch 1	First batch of A, B and C
Batch 2	Second batch of A, B and C
A1 and A2	Sample A batch 1 and sample A batch 2
B1 and B2	Sample B batch 1 and sample B batch 2
C1 and C2	Sample C batch 1 and sample C batch 2

The results of moisture content, water activity, yield, pH and color are shown in Table 3. Some differences between batches could be observed, when examining unadjusted p-values: Batch B had slightly higher batter pH, a* (redness) and b* (yellowness). However, these differences were no longer observed after false discovery rate-adjustment. In batch 1, there was a higher batter pH in B1 resulting in the significant difference compared to A and C.

Moisture content, water activity, yield and pH of the smoked sausages did not show any significant difference between the samples with different levels of substitution.

Table 3. *Results from measurements of moisture content, water activity (aw), yield, pH and color (L* a* b*) measurement. Means, p-values and p-values false discovery rate-adjusted (fdr) shown. Different letters within a row denote significant differences (P<0.05) for p-values (not for p-values (fdr)).*

Sausage	A 0% sodium reduction	B 15% sodium reduction	C 30% sodium reduction	p-value	p-value (fdr)
Moisture content	58.41%	57.07%	58.24%	0.084	0.182
a_w	0.963	0.962	0.966	0.135	0.195
Yield	89.56%	89.87%	90.11%	0.786	0.851
pH batter	5.68^{a}	5.71^{b}	5.69^{ab}	0.011	0.102
pH sausage	5.93	5.96	5.93	0.260	0.307
L*	61.07	61.35	62.11	0.219	0.285
a*	9.52^{ab}	9.61^{b}	9.21^{a}	0.035	0.102
b*	12.42^{a}	12.75^{b}	12.59^{ab}	0.039	0.102

The result of the sodium content analyzed by the external accredited laboratory is shown in Table 4. It was observed, from reported sodium concentration and corroborated by moisture content data (data not used for this study), that the external laboratory had mislabeled samples from batch B and C. This mislabeling was manually corrected. Table 4 thus has the corrected batch attributes.

The mixed samples are only a concern for this external analysis, since the sample collection for the other analyzes were not performed in the same way. In the table the mix-up have been corrected (B and C exchanged).

Table 4. *Results from external analysis of sodium content. Salt content calculated from sodium as sodium x 2,5.*

Sausage	A 0% sodium reduction	B 15% sodium reduction	C 30% sodium reduction
Sodium content (g/100g)	0.91	0.76	0.63
Salt content (g/100g)	2.3	1.9	1.6
Sodium reduction	0%	16.5%	30.8%

The sodium content analyzed includes both the naturally occurring sodium content in the ingredients, mainly in meat, and the added sodium as sodium chloride. According to National Food Agency in Sweden (n.d.) a content of about 0.2 g sodium/100g is normally present in meat. Since the product includes over 60% meat the higher result is consistent with the expected result. The sodium reduction in total is somewhat higher than target values for both B and C, but still very close to the expected values of 15% and 30% reduction, respectively.

Instrumental texture analysis showed that sample C had lower hardness and chewiness than the other samples, although these differences were not significant after false discovery rate-adjustment (Table 5). C2 was the sample mainly responsible for the significant difference.

Table 5. *Results from texture analysis. The maximum peak force (WB Peak) from Warner-Bratzler shear force and hardness, springiness, cohesiveness and chewiness from Texture Profile Analysis. Means, p-values and p-values false discovery rate-adjusted (fdr) shown. Different letters within a row denote significant differences (P<0.05) for p-values (not for p-values (fdr)).*

Sausage	A 0% sodium reduction	B 15% sodium reduction	C 30% sodium reduction	p-value	p-value (fdr)
WB Peak	6.13	6.40	5.27	0.127	0.195
Hardness (N)	29.46[ab]	30.16[b]	25.89[a]	0.018	0.102
Springiness	0.812	0.832	0.821	0.122	0.195
Cohesiveness	0.604	0.603	0.601	0.970	0.970
Chewiness	14.46[ab]	15.12[b]	12.74[a]	0.033	0.102

3.2 Sensory consumer evaluation

For 24 of the 109 participants answering the questionnaire, the answers were not complete. This was mainly because some parts of the questionnaire had not been filled in correctly by the participants. The data from these consumers were included in the analysis as far as possible but left out when the data for the specific analysis was not complete, thus resulting in some of the analyzes having different amount of respondents in the analysis.

Table 6. *Results from sensory consumer evaluation.. Means of mm from "dislike very much" to "like very much" on the visual analog scale (min-max, 0-100) and p-values. Model 1 using 'sausage' (A, B or C) and 'question' (taste, texture and overall liking) as fixed factor, repeated by responding individual. Model 2 was made to account for contribution from confounding factors, by adding the effects of 'age' (numeric), 'gender' (factor), 'habitual consumption' (numeric) and their two-way interactions to model 1.*

Sausage	**A** **0% sodium reduction**	**B** **15% sodium reduction**	**C** **30% sodium reduction**	**p-value**
Model 1				
Sausage (factor)				<0.001
Question (factor)				0.172
Taste	63^{b}	64^{b}	58^{a}	
Texture	63^{b}	64^{b}	57^{a}	
Overall	66^{b}	67^{b}	60^{a}	
Model 2				
Sausage (factor)				<0.001
Question (factor)				0.218
Age (numeric)				0.012
Gender (factor)				0.068
Habitual (numeric)				0.888
Age x Gender				0.017
Age x Habitual				0.026
Gender x Habitual				0.013
Taste	63^{b}	64^{b}	55^{a}	
Texture	63^{b}	64^{b}	55^{a}	
Overall	66^{b}	67^{b}	58^{a}	

Results as least-square mean values from the sensory consumer evaluation of the acceptability are shown in Table 6. There was no systematic difference between the questions of taste, texture and overall acceptability. However, there were differences between the sausages for both models. These results show that C had significantly lower acceptability scores for taste, texture and overall acceptability than the others but no linear trend with increasing sodium reduction could be observed.

Age had an impact on the given answers while gender and habitual consumption alone did not.

Table 7. *Results as factorial logistic regression and χ2-tests of consumer sensory evaluation. "Do you think about your salt consumption?" (think), "Do you want to reduce your salt consumption?" (reduce), "Are you actively looking for low-salt products?" (look) and "Are you interested in low-salt products?" (interested).*

Age	**0-19**	**20-34**	**35-49**	**50-64**	**65-**	**Sum**	**P (regr)**	**P (χ2)**
Think							0.032	0.087
Yes	0	10	7	14	13	44		
No	5	12	17	12	11	57		
Reduce							0.032	0.003
Yes	0	17	20	17	19	73		
No	5	5	4	8	5	27		
Look							0.032	0.298
Yes	1	3	6	4	9	23		
No	4	19	18	22	15	78		
Interest							0.032	0.124
Yes	1	14	18	12	18	63		
No	1	1	1	1	2	6		
Don't know	3	7	5	13	4	32		

Further questions asked to the consumers were "Do you think about your salt consumption?" (think), "Do you want to reduce your salt consumption?" (reduce), "Are you actively looking for low-salt products?" (look) and "Would you be interested in buying low-salt sausage?" (interest). Factorial logistic regression showed that the only systematic effect stemmed from the age factor (Table 7), not dependent on gender or degree of habitual consumption (data not shown). Although this effect was only significant for "reduce" using the more robust χ2-test, it was apparent that the driver for this age effect stemmed from individuals belonging to the youngest age category.

4 Discussion

When producing a salt reduced product it is important that the quality parameters such as product yield, texture, flavor, consumer acceptance, shelf life and food safety are acceptable (Aaslyng, Vestergaard, & Koch, 2014). Sausage characteristics are dependent on many factors such as ingredients, pH, temperature at production etc. which are all important factors to control during production to get the desired result.

Instrumental chemical and physical analyses showed no significant differences between sausage types after false discovery rate-adjustment. This indicates that sodium reduced emulsion-type sausages can be readily manufactured at least up to 30% substitution from sodium chloride to potassium chloride, which agrees with the results from Gou et al. (1996) study on fermented sausages. Substitution from sodium chloride to potassium chloride seems to have lower effect on the product characteristics than these other factors. Salt is important for water activity and texture (Desmond, 2006) and it seems that both sodium chloride and potassium chloride have the same effect on these factors.

However, unadjusted p-values show that some differences may yet occur. A higher batter pH in sample B1 generated a higher yield and lower moisture content compared to A1 and C1 (data not shown). This can be explained by the higher pH giving higher water binding ability of the batter (Hedrick, 1994), keeping the water in the batter leading to the higher yield. Having water more tightly bound to the matrix may also generate a lower analyzed moisture content if not all of the water was released from the matrix during drying. B1 is the one mainly responsible for the significantly different results for batter pH, but this effect was not big enough to cause a significant difference for the yield and moisture when including all samples. The moisture content seems to be more related to pH than potassium chloride substitution. A final pH of about 6 generates maximum hardness in the sausage (Matulis, McKeith, Sutherland, & Brewer, 1995) and this was also the pH reached after smoking process in all three samples (A, B and C).

The water activity was not affected by the substitution. Water activity is dependent on the solutes in the water (Adams & Moss, 2008) and the substitution was made by molar amount and the amount of salt solutes in the product was thus not changed. The observed results are thus in complete agreement with expected water activity results.

The color does not change considerably by salt reduction which confirms earlier findings (Sofos, 1983a). The variation in redness on the other hand could have been explained by the variation of nitrite present in the sodium reduced samples. Nitrite, mainly responsible for red color formation, was added as a part of the sodium chloride (sodium chloride pre-mixed with 0.6% sodium nitrite) which leads to the nitrite content also being reduced in sodium reduced samples. However, no linear relationship between the samples was observed and B was the sample that stood out also in this result, thus strongly indicating that the observed (unadjusted) differences occur from normally occurring biological or production variability and not from systematic deviation.

Regarding texture no great difference could be observed for A1, B1 and C1. However, during the second batch the C2 sample stood out by having a softer texture. The texture is dependent on many factors during production, such as ingredients, pH, mixing, temperature, protein dissolution etc. which may have affected the final result. There was also not a continuous relationship between sodium reduction and texture. The non-linearity and the observed difference between batches (C1 vs C2) indicates that other factors than sodium reduction, stemming from biological and/or processing variability, were the reason for this softer texture. In fact, the observed softer texture in the high-potassium sausage is contradictory to previous findings where higher hardness has been observed when increasing the amount of potassium chloride in the product (Guàrdia et al., 2008). This gives further evidence that the observed differences are related to variability in ingredient or process related factors.

Many studies present a lower consumer acceptance for salt-reduced sausages (Sofos, 1983a, 1983b; Tobin, O'Sullivan, Hamill, & Kerry, 2012). The salt perception is central for consumer acceptability and the use of salt replacers is one way to reduce sodium without alter the salt perception (Tobin et al., 2012). Regarding sensory parameters, the limiting factor for sodium reduction by potassium chloride replacement is the bitterness (Gou et al., 1996). Sausage C with the highest degree of substitution was the sausage with significantly lower scores for acceptability of taste. As the consumers were able to comment on the sausages, a lot of comments about the samples were collected. Bitterness was not mentioned by those. The conclusion from this is that bitterness was not the main parameter affecting the result. However, the results shows that the potassium may affect the taste as the C sausage with highest degree of substitution stood out but as no linear relationship between the different degree of substitution could be seen, there may be other factors affecting taste than potassium chloride. Guàrdia, Guerrero, Gelabert, Gou, & Arnau (2006) observed no difference regarding consumer preference for fermented sausages including only sodium chloride or sausages including sodium chloride and <40% potassium chloride. This supports the hypothesis that the differences of taste preferences in this study for up to 30% substitution may be because of other reasons than substitution.

The sensory consumer evaluation, where C had a lower degree of acceptability for texture, reflects the differences from texture analysis. The softer texture may also have a carryover effect affecting the acceptance of the taste discussed above. Furthermore the overall acceptability for the product was lower which indicates that both taste and texture are important for the overall acceptability of sausages and that consumers prefer a harder texture of the product. Doing the sensory analysis on products with different texture was not ideal but this was not known when performing the test since the texture analysis was performed afterwards. To perform a sensory consumer evaluation on the first batch produced, without textural differences, would have given results more related to degree of substitution rather than variation between batches but due to unfortunate circumstances, this was not possible.

The question factor was not significant showing that the questions were related and that taste, texture and overall acceptability are parameters that are not significantly different from each other (Table 6, model 1). The answers given by consumers were related to age but not gender or habitual alone. Consequently, gender or degree of consumption does not affect the preferences for the sausage. However, in combinations as age x gender, age x habitual and gender x habitual they have an effect leading to an even more significant pronounced reduction in sensory acceptance scores for sausage C when correcting for these parameters (Table 6, model 2).

During sensory consumer analysis many of the participants orally commented that “they taste very similar” or “are you sure those are not the same sausage?”. Some of the respondents also wrote this as comments on the form. At the same time the results from the analysis showed a clear difference between the samples. This demonstrates that even though people expresses a statement qualitatively, a quantitative analysis such as the 10 cm VAS-scale used in this study may reveal small differences not able to be expressed in a qualitative way. This indicates that in qualitative tests, such as interviews, should be supplemented with quantitative measures when possible.

For the questions “Do you think about your salt consumption?” (think), “Do you want to reduce your salt consumption?” (reduce), “Are you actively looking for low-salt products?” (look) and “Would you be interested in buying low-salt sausage?” (interest), age was the only factor affecting the answers given. It was apparent that the driver for this age effect stemmed from individuals belonging to the youngest age category, not at all interested in salt reduction (Table 7). However, the main part of the participants was looking for low-salt alternatives and was also interested in buying a low-salt sausage. This indicates a market potential for this product segment.

To produce new batches for the sausages and to repeat the sensory consumer analysis would be highly desirable, to make sure to have representative results, excluding the error from the texture differences. New batches produced would also generate more data for texture analysis to examine if the texture differences are depending on the salt substitution or other factors. Regarding this issue it should not be forgotten that the production of sausage is produced by ingredients with large biological variation of great importance for the final product. This variation would also be a source of error in laboratory settings and is not restricted to the commercial plant production.

High hedonic scores is not the only factor affecting the product success in the market. Niche, packaging, image, market and price are also factors affecting the success and must be taken into account before launching the product (Lawless & Heymann, 2010). Regarding interest, the majority of the consumers asked wanted to reduce their salt consumption and would also be interested in purchasing a low-salt sausage (Table 7) if it would be available on the market. The same result was found by Guàrdia et al. (2006) where both women and men, with some higher scores for women, generally were positive to sodium reduced products. Consequently, there is a market demand for this type of product.

A reduction of sodium in sausage could be part of a strategy to reduce overall sodium intake, which could have health benefits especially from the part of the population with elevated blood pressure. From a health point of view the sodium chloride substitution to potassium chloride has dual benefits. Firstly, the direct effects from decrease in sodium consumption. Secondly, the health benefits from the substitution to potassium. An increased potassium intake has been associated with increased sodium excretion, decreased blood pressure, decreased risk for stroke and cardiovascular diseases (Nordic Council of Ministers, 2014). When using other methods to reduce the sodium content, these effects are not achieved. However, by replacing sodium chloride with potassium chloride the perceived saltiness is not reduced. On a short term, this is desirable to maintain consumer acceptability but, on a longer term, a general salt reduction in all foods is needed to get a general consumption reduction but with adaption to the lower perceived saltiness to still maintain the consumer acceptability.

If there is a societal objective to reduce overall salt consumption, a reduction is needed in other products than just sausages. To get the general consumption reduction it is important to deal with the diet as a whole and not only single food items. Sodium reduction initiatives such as in Finland and UK have focused on the bigger picture. In both Finland and UK the general salt consumption has been reduced by identifying several food product groups with high contribution to the salt intake and by making actions to reduce the salt content in these product groups (CASH, n.d.; World Action on Salt & Healt, n.d.)

In this study only substitution was used to reduce the amount of sodium in the product. Further sodium reduction may be possible if salt reduction was combined with other sodium reduction alternatives as described by Terrell (1983). These alternatives can be a reduction of the total salt content together with potassium chloride substitution, further substitution with potassium chloride or other chloride salts such as magnesium chloride or calcium chloride to lower the sodium content further and addition of non-chloride salt compounds as phosphates have successfully been used in several products and studies. Alternate processing is also one alternative. Recipe change by raising the amount of fat and reducing the amount of meat can also increase saltiness (Ruusunen et al., 2001).

Sofos (1983b) concluded that above 2% salt content is needed for manufacturing of emulsion sausages and below 2% other ingredients is needed to get desired texture, flavor and overall acceptability. Our results show that within a commercial production setting, potassium chloride is one ingredient that can be used for this purpose. The sodium content can be reduced by 30% by equimolar substitution by potassium chloride in emulsion sausages and still have the same technical characteristics. This result agrees with Gou et al. (1996). However, further studies are needed to examine consumer preferences for products without errors from texture differences.

Even though safety and microbial issues were excluded in this study, this is of course of big importance and has thoroughly been studied by others. When replacing sodium chloride by potassium chloride the microbial safety of the product might change and needs to be considered (Taormina, 2010). Aaslyng et al. (2014) found that a moderate reduction from 2.2% to 1.7% sodium chloride did not markedly affect the safety or shelf life of sausages but for further reduction the sausage characteristics and safety may change. Salt mixtures have successfully been used in products as fermented sausages without altering the safety of the product (Gimeno et al., 2001). The safety issues needs further investigation before making this product available on the market.

This study does not include analysis of the product over time and it is possible that the salt substitution may affect the product characteristics during storage. In fact, Sofos (1983a) found that quality parameters were reduced during storage in sodium chloride reduced sausages. The sausages in their study were only sodium reduced, and not substituted, so their results cannot be extended to the production in this study. Nevertheless, it highlights an important area that needs to be further studied before product launching.

5 Conclusion

There is market potential for the product segment of low-sodium sausages. Those can be produced with up to 30% degree of substitution (molar basis) with potassium chloride without altering moisture content, water activity, yield, color and texture. However, a lower consumer acceptance was observed for the 30% substitution sausage compared to the other sausage types. The sensory aspects need further studies to examine if the lower preference is depending on salt substitution or other factors.

No linear results from 0% to 15% to 30% degree of substitution was observed in any of the analyzes which indicates that the differences may be depending on other factors such as variation in ingredients, temperature of production or pH during production rather than level of substitution.

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Appendix 1

Sensory consumer evaluation questionnaire

SLU Konsumenttest av korv

Läs instruktionen innan du börjar smaka på proverna.

Skölj munnen med vatten och ta en bit smörgåsrån för att neutralisera smaken. Skölj igen mellan alla prov. Bedömningen ska göras enskilt, utan att diskutera med någon annan.

Smaka på en korv i taget i presenterad ordning, från vänster till höger. Ange provets kod och vad du tycker om korven genom att sätta ett kryss på skalan nedan från "tycker mycket illa om" till "tycker mycket bra om". Gå sedan vidare till nästa prov. Fråga personal om du har frågor.

Ange provets kod (korven till vänster):……………………………………

	Tycker mycket illa om	Tycker mycket bra om
Smak		
Konsistens		
Provet som helhet		

Kommentarer:

Ange provets kod (korven i mitten):……………………………………………

	Tycker mycket illa om	Tycker mycket bra om
Smak		
Konsistens		
Provet som helhet		

Kommentarer:

Ange provets kod (korven till höger):…………………………………………

	Tycker mycket illa om	Tycker mycket bra om
Smak		
Konsistens		
Provet som helhet		

Kommentarer:

Efter att du genomfört provsmakning och fyllt i denna sida – vänd på bladet.

Institutionen för livsmedelsvetenskap vid Sveriges Lantbruksuniversitet
Kontakt: Lisa Skogsberg, lisk0002@stud.slu.se

Ringa in ditt svar på frågorna nedan;

Ålder: (19 eller yngre) (20-34) (35-49) (50-64) (65 eller äldre)

Kön: Kvinna Man Annat

Hur ofta konsumerar du denna typ av produkt? Ringa in ditt svar.

Flera gånger i veckan varje vecka varje månad mer sällan aldrig

Tänker du på hur mycket salt (NaCl) du konsumerar?

Ja Nej

Skulle du vilja minska din saltkonsumtion (NaCl-konsumtion)?

Ja Nej

Letar du aktivt efter produkter med låg salthalt (NaCl-halt)?

Ja Nej

Skulle du vara intresserad av att köpa en korv med lägre salthalt (NaCl-halt)?

Ja Nej Vet ej

Kommentarer:

____

____

____

Tack för din medverkan!
Vänligen lämna in denna blankett på angiven plats.

Institutionen för livsmedelsvetenskap vid Sveriges Lantbruksuniversitet
Kontakt: Lisa Skogsberg, lisk0002@stud.slu.se

Appendix 2
Popular scientific text

Sodium chloride (salt) is consumed in varying amounts between individuals and populations worldwide, but the consumption is generally higher than the recommended intake in many parts of the world. Research has shown that high sodium consumption is associated with increased blood pressure and therefore also increased risk for other related heart disorders. We are therefore recommended to consume less sodium. Meat and meat products are a group of products that contribute to a large amount of sodium in the diet. Therefore it is relevant to develop low sodium alternatives in this product segment.

Sodium reduced products can be produced e.g. by reducing the total amount of sodium, by replacing sodium chloride with other salts, by replacing sodium chloride with other ingredients or by altering the production process. In this study, sausages with sodium chloride replaced by potassium chloride (another salt) were studied. Three sausages with 0%, 15% and 30% degree of substitution were produced in cooperation with a local company specialized in meat products (Andersson & Tillman, Uppsala, Sweden).

There were no observed difference between the three sausages for moisture content, water activity, yield, color, pH and texture. A consumer taste test was also made in a local supermarket. Consumer acceptance was lower for the 30% substitution sausage compared to the other sausage types. However, this sausage also had a somewhat softer texture. Based on the observed variability in texture between batches with similar composition, the difference in texture is most likely related to other production factors than the sodium content, such as variation in ingredients, temperature of production or pH which also have impact on the sausage texture. Consumers also showed great interest in buying low-sodium sausages if available on the market.

As a conclusion, there is market potential for the product segment of low-sodium sausages and there is technological potential of producing a sausage with low sodium content by replacing 30% of sodium chloride with potassium chloride, however, the sensory aspects need further studies.