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Potassium chloride and potassium lactate as salt replacing ingredients in low salt processed meat products: A review

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Abstract
Sodium chloride is the crucial ingredient in processed meats owing to its preservative properties, capacity to improve taste and flavor as well as functional attributes to solubilise myofibrillar proteins. However, apprehensions regarding high sodium intake from the diet has necessitated strategies to be evolved to minimize the salt added to products and also reconsideration of product recipes employing salt substitutes to minimize the proportion of sodium in different food products formulations. Various researchers have recommended that the partial substitution of sodium chloride with potassium chloride is one of the finest alternatives to alleviate the sodium level in meat products. Incorporation of potassium lactate potentiates function of sodium chloride, enhances saltiness, Z line solubilization thus improves the palatability of the developed products. It can be summarized that up to 40% of sodium chloride can be substituted either with potassium chloride or potassium lactate without significantly affecting physicochemical, technological, sensory and microbiological characteristics.

Keywords: low salt, sodium chloride, potassium chloride, potassium chloride, meat products

Introduction
Sodium chloride is the principal ingredient in processed meats due to its preservative properties, capacity to improve taste and flavor as well as functional attributes to solubilise myofibrillar proteins. However, diets high in sodium content have been identified as one of the dietary risk factors for various health concerns (Lim *et al*., 2012) [37]. The recommendation of World Health Organization (WHO, 2003) [63] suggests that daily salt (sodium chloride) consumption should not exceed 2g/day for general public. Presently, sodium ranks second after calories as the ingredient most looked for by about 65% of people who read nutritional label of the product prior buying (Sloan, 2010) [55]. Total dietary salt intake by Americans is 10 to 12 g per day (Anon, 1980) and about 33% of Americans has been diagnosed with high blood pressure, a problem coupled with excessive dietary sodium intake (Sloan, 2010) [55]. This issue must be even higher in Indians being fond of more salty and spicy foods. Meat itself contains sodium but the amount is fewer than 100 mg/100 g. So the main source of sodium in meat products is sodium chloride which is added during processing as it contains 39.3% sodium. The apprehensions regarding high sodium intake from the diet has necessitated to evolve strategies to minimize the salt added to products and also reconsideration of product recipes employing salt substitutes to minimize the proportion of salt in different food products formulations (Doyle and Glass, 2010; Pietrasik and Gaudette, 2015) [18, 44]. Various researchers have recommended that the partial substitution of sodium chloride with potassium chloride is one of the finest alternatives to alleviate the sodium level in meat products (Campagnol *et al.*, 2011; Dos Santos *et al.*, 2015; Lorenzo *et al*., 2015a; Lorenzo *et al.*, 2015b) [11, 17, 38, 39]. The use of potassium chloride in salt mixtures provides an additional benefit as potassium being a counter ion to sodium, diminishes the injurious outcome of sodium on blood pressure and the comparable perceived saltiness can be attained with lower sodium level (Puolanne *et al*., 1988; Wettasinghe and Shahidi, 1997) [47, 62]. Some studies have been conducted to minimize salt content in meat products such as bologna type sausages (Ruusunen *et al.*, 1999) [50]; ground meat patties (Ruusunen *et al.,* 2005) [52] and pork sausages (Khate, 2007) [35]. Since incorporation of potassium chloride is limited because of its bitter taste, potassium lactate could also be a potential alternative for sodium chloride (Astruc *et al.*, 2008) [6]. However, uncontrolled addition of potassium lactate could impart an unusual taste (Gimeno *et al.*, 2001) [27]. Incorporation of potassium lactate potentiates function of sodium chloride, enhances saltiness, Z line solubilization and mitochondria swelling (Astruc *et al.*, 2008) [6] and thus improves the palatability of the developed products (Pipek *et al.*, 2005) [45].

Role of sodium chloride in meat processing

Sodium chloride by lowering water activity controls microbial growth, hence contributing to food safety (Wirth, 1989) [64]. Extracellular sodium and intracellular potassium are crucial for osmotic balance, nerve impulse, muscle functioning and metabolism. Sodium chloride is universal, necessary and inexpensive ingredient incorporated in meat formulations during processing. It plays vital role in solubilization of functional myofibrillar proteins (Choi *et al.*, 2014) [12] and solubilized proteins facilitate water holding capacity, emulsification and retention of fat in the meat blend and stabilizes gel during cooking (Totosaus and Perez-Chabela, 2009) [58] resulting in enhanced cooking yield and juiciness as chloride ions bind strongly to proteins (Desmond, 2006) [16].

Harmful effect of excessive sodium in diet

The excessive intake of sodium in addition to fat, is a risk element for the development of cardiovascular diseases (Ozvural and Vural, 2008; He and MacGregor, 2010) [43, 32] which have surged dramatically in recent times and are presently the leading causes of mortality in industrialized countries (WHO/FAO, 2003; Food Standards Agency, 2009) [63, 22].

The consumption of sodium beyond certain limit has been proved to be accompanied with hypertension, elevated risk of coronary heart disease, both forms of stroke and renal failure (Sebranek *et al*., 1983; Truswell, 1984; WHO/FAO, 2003) [53, 59, 63]. It has viable consequences on colorectal cancer (Demeyer *et al*., 2008) [15] and is also coupled with other harmful influences such as stomach cancer and osteoporosis (Gilbert and Heiser, 2005) [25]. Thus, it is highly advocated by health authorities in most of the countries to reduce salt proportion in food and minimize the consumption of salted foods (WCRF, 2007) [60].

Issues associated with reduced sodium chloride content in meat processing

Reduction of salt level raises many concerns for meat processing which include textural problems, flavor changes, decreased yield and also appearance of products (Collins, 1997) [14]. Sodium reduction is not as simple as it inevitably involves removing or partially substituting sodium chloride, which is the chief source of sodium in meat products (Weiss *et al.*, 2010) [61]. However, reduction of sodium chloride to 1.4% in cooked sausages and to 1.75% in lean meat products has been found to be acceptable while maintaining perceived saltiness, firmness, water binding and fat retention (Tobin *et al.*, 2013) [56]. Therefore, a holistic approach is needed to curtail the salt content in meat products, contemplating the inherent impact that sodium chloride exerts on meat processing, especially on attributes like flavor, water activity, microbial quality, enzyme activity, water holding capacity, protein solubility and texture (Toldra, 2006) [57].

Potassium chloride and potassium lactate as salt substitutes

Initially attempts were made for the complete substitution of sodium chloride with other chloride salts such as calcium, lithium, magnesium and potassium. However, the results demonstrated considerable negative impact on different aspects of texture, flavor, appearance and storage life of the products (Seman *et al.*, 1980) [54]. Since then, more priority has been given to incorporation of salt replacers, flavor enhancers and natural salty products like yeast extract and sea weeds in the formulation of meat products.

One of the recent strategies to reduce the sodium content in processed foods and meat products is based on sensory evaluation of products by complete or partial replacement of sodium chloride (Liem *et al.*, 2011; Fellendorf *et al.*, 2016) [36, 21]. Dietary intake of potassium is associated with a decreased risk of hypertension and cardiovascular diseases, opposite role to sodium (Geleijnse *et al.*, 2007; Aburto *et al*., 2013; Binia *et al*., 2015) [24, 1, 9]. The average global intake of potassium is below the WHO guidelines of at least 3510 mg/day (WHO, 2012) [63]. Moreover, long term intake of potassium supplements at level of 3000 mg/day is also considered as low risk for the healthy adult population (EFSA, 2005). This makes potassium as an interesting alternative of sodium from a consumer, production and health point of view.

Effect of substitution of sodium chloride with potassium chloride and potassium lactate on quality attributes of meat products, proximate composition

Horita *et al.* (2011) [33] formulated low fat bologna sausages with partial replacement of sodium chloride with other chloride salts and did not observe any statistical difference in proximate composition. The replacement of sodium chloride with potassium chloride along with incorporation of lysine and liquid smoke did not result in any significant alteration on moisture, protein, ether extract and ash content of low fat bologna type sausages (Alves *et al.*, 2017) [3].

Emulsion stability and cooking yield

Ruusunen *et al.* (2001) [51] reported that bologna type sausages added with sodium chloride below 1.4% had lower cooking yield as compared to 1.7% or above. Tobin *et al.* (2013) [56] studied that the reduction of sodium chloride from 1.75% to 1.3% (25% reduction) resulted in 18% decline of sodium from 916 mg/100 g to 750 mg/100 g but did not affect the yield and purge loss of frankfurters during storage. Similarly, Choi *et al.* (2014) [12] indicated no significant impact on cooking loss or moisture content of the low sodium frankfurter sausages when 40% sodium chloride was replaced by potassium chloride or combination of potassium lactate and calcium ascorbate.

Pietrasik and Gaudette (2015) [44] concluded that not the type of ion but the ionic strength of the sample played more vital role in preserving protein extraction ability and moisture retention potential. Alves *et al.* (2017) [3] observed no significant difference in percent water and fat release among the treatments when sodium chloride was replaced by potassium chloride in low fat bologna type sausages. They also found that 50% substitution of sodium chloride with potassium chloride did not reveal significant difference in cooking loss in comparison to control sample.

pH and Water Holding Capacity (WHC)

The pH and WHC of meat are extremely correlated. Gou *et al.* (1996) [28] reported that pH of control fermented sausages reached to less than 5.0 within 22 h while replacement of sodium chloride with higher level of potassium lactate (more than 40%) did not result in drop in pH below 5 even after 36 h. Horita *et al.* (2011) [33] noticed significantly higher pH readings in mortadella sausages with 50% substitution of sodium chloride with potassium chloride.

Gimeno *et al.* (1998) [26] observed no significant change in WHC after substitution of sodium chloride with a mixture of sodium chloride, potassium chloride, magnesium chloride and calcium chloride at equivalent ionic strength to that of control. Choi *et al*. (2014) [12] observed lowest pH value (6.46) for control and highest (7.80) for the treatment having combination of 10% potassium lactate and 30% calcium ascorbate. They also reported no significant difference in WHC on sodium chloride substitution with combinations of potassium lactate and calcium ascorbate when equivalent ionic strength was maintained as of the control sample. The substitution of sodium chloride with potassium chloride revealed significantly higher pH as compared to the control formulation (Alves *et al.*, 2017) [3].

Salt soluble proteins and thiobarbituric acid (TBA) value

Salt soluble proteins are extracted by sodium chloride in meat emulsion resulting in increased emulsifying capacity and reduced cooking losses. Desmond (2006) [16] reported that extracted and solubilized myofibrillar proteins were increased on addition of sodium chloride but decreased on reduction of sodium chloride concentration, impacting the functionality of the meat batter. When the sodium chloride content is reduced to a certain level, it not only exerts negative impact on sensory and microbiological properties of the products but also decrease extractability of myofibrillar proteins, resulting in poor functionality (Totosaus and Perez-Chabela, 2009) [58]. Rhee *et al.* (1983) [49] observed no significant difference in TBA value during storage when sodium chloride was reduced to 50% (2.5% to 1.25%) or substituted by potassium chloride or magnesium chloride in ground pork.

Instrumental colour and texture profile analysis (TPA)

Colour is one of the most vital quality attributes which refers perceived quality and freshness of the food products. Hand *et al*. (1987) [29] revealed increase in lightness (L*), decrease in yellowness (b*) but no effect on redness (a*) value of low fat frankfurters when the sodium chloride level was reduced from 2.5% to 1.5%. The springiness and chewiness of samples did not change when the sodium chloride level was limited to 50% but the readings were significantly higher when combination of monovalent salts (potassium chloride and sodium chloride in equal proportion) was used. Gou *et al.* (1996) [28] did not observe change in colour values by the substitution of sodium chloride with potassium chloride in meat product. The springiness of the bologna type sausages did not show any significant change between the control and salt substituted samples (Yang *et al.,* 2007) [66].

Horita *et al.* (2011) [33] observed no significant difference in instrumental colour and hardness values of emulsified mortadella when 50% of sodium chloride was substituted with potassium chloride. Choi *et al.* (2014) [13] reported that the hardness, springiness, cohesiveness and chewiness values did not vary when comparing sample with 2 g/100 g (100%) of sodium chloride and sample having only 60% sodium chloride. Luckose *et al.* (2015) [40] observed significant increase in the hunter colour values especially lightness values on replacing sodium chloride with potassium chloride and potassium lactate in restructured chicken jerky. The texture of the product relies on the structure and integrity of the protein matrix developed during cooking and lowering or substituting sodium chloride content with other salt in the sausages resulted in softer texture as compared to control (Pietrasik and Gaudette, 2015) [44]. The 50% substitution of sodium chloride with potassium chloride did not alter the readings of L*, a*, b*, instrumental chewiness and other texture attributes significantly (Alves *et al.,* 2017) [3].

Shear press value (Firmness and toughness)

Maesso *et al.* (1970) [42] observed that binding and tensile strength were enhanced when sodium chloride level was increased from 0% to 2% and 2% sodium chloride incorporation resulted in a tightly bound loaf as compared to loaf without sodium chloride. Substitution of 100% sodium chloride with potassium chloride or magnesium chloride significantly decreased the firmness of turkey frankfurters, but substitution up to 35% did not alter firmness significantly (Hand *et al*., 1982a) [30]. Hand *et al.* (1987) [29] found that shear force values were increased with increasing sodium chloride level in both low and high fat frankfurters. Barbut and Mittal (1989) [7] revealed decreased shear stress value with decreasing salt ingredient in beef, pork and poultry meat batters. As compared to control, the fermented sausages with potassium chloride had less hardness value (Gou *et al.,* 1996) [28].

Sensory characteristics

Hand *et al.* (1982b) [31] observed that 100% substitution of sodium chloride with potassium chloride or magnesium chloride produced off flavor. The firmness and overall acceptability were also reduced significantly but substitution at 35% level did not affect firmness and off flavor was also negligibly affected. Gou *et al.* (1996) [28] observed no significant variation in the textural and flavor scores of fermented sausages up to 40% sodium chloride substitution with either potassium chloride or potassium lactate, although, slight bitter taste with potassium chloride and little potassium lactate flavor could be noticed at 30% replacement.

Gimeno *et al*. (1999) [26] observed that substitution of sodium chloride with just one salt had significantly negative influence which could be minimized by incorporating different salts in combination. Gelabert *et al.* (2003) [23] noticed flavor and texture defects in fermented sausage when sodium chloride was partially replaced (above 40%) with mixtures of potassium chloride and glycine or potassium lactate and glycine but at 25% – 40% substitution, flavor impact was undetected. Even partial replacement of sodium chloride with potassium chloride generally had adverse effect on flavor and texture of the product (and Lambert, 2008) [8].

Horita *et al.* (2011) [33] did not notice any significant alteration between the treatment with lowered sodium chloride and those containing different mixtures of salt replacers and the control sample in terms of appearance, aroma and texture.

Potassium chloride is the most usual alternative in the formulation of low sodium meat products. But it leads to sensory denial beyond a certain limit of replacement due to perception of bitter and metallic taste (Dos Santos *et al*., 2015; Lorenzo *et al.,* 2015b) [17, 39]. Campagnol *et al.* (2011) [11] found that consumers were unable to detect colour difference in fermented cooked sausages when 50% sodium chloride was substituted by potassium chloride. However, instrumental colour values were reported to be significantly variable among treatments.

Choi *et al*. (2014) [12] observed no significant variation in colour scores of low sodium frankfurter sausages when sodium chloride was partially replaced by potassium chloride or combination of potassium lactate and calcium ascorbate. Alves *et al*. (2017) [3] observed that replacement of 50% sodium chloride with potassium chloride resulted in slightly diminished salty taste and a little bitter, astringent and metallic flavor in reduced fat low salt bologna type sausages.

Microbiological quality
Madril and Sofos (1985) [41] recommended that the preservation of shelf life of processed meats was of prime importance while reducing the salt level. Gou *et al*. (1996) [28] advocated potassium lactate as suitable alternative for sodium chloride substitution owing to similar structural characteristics and bacteriostatic properties. Gelabert *et al*. (2003) [23] reported that 40% substitution of sodium chloride with potassium chloride, potassium lactate and glycine in fermented meats at low initial counts of pathogenic microorganisms, resulted in safe product in terms of microbiological characteristics.

Potassium lactate was reported to be effective in inhibiting most spoilage and pathogenic bacteria in meat products (Pipek *et al.*, 2005; Quilo *et al*., 2009) [45, 48] and due to preservative attribute of the lactate ion, it was possible to incorporate potassium lactate as an alternative for sodium chloride, although, the abnormal taste perceived could limit its incorporation (Annemiche *et al.*, 1990) [4].

The partial replacement of sodium chloride with potassium chloride did not reveal significant impact on the microbiological quality of spanish cured ham (Blesa *et al*., 2008) [10] and dry fermented sausages (Ibanez *et al*., 1996) [34]. Similarly, Alino *et al*. (2010) [2] observed that 45% of sodium chloride could be partially replaced with mixtures of potassium chloride, calcium chloride and magnesium chloride without any variation on microbial growth. Potassium lactate and calcium ascorbate are usually incorporated in different food products to improve shelf life because of their antimicrobial activity and also has been approved as food additives (FDA, 2013). Tobin *et al.* (2013) [56] reported that the 25% reduction of sodium chloride resulted in 18% reduction of sodium content but did not alter microbiological quality of frankfurters during storage. Alves *et al.* (2017) [3] reported no detrimental effect on microbiological attributes of low fat bologna type sausages after 50% substitution of sodium chloride with potassium chloride.

Conclusion
Sodium chloride is universal, necessary and inexpensive ingredient incorporated in meat formulations during processing. But consumption of sodium beyond certain limit has been proved to be accompanied with hypertension, elevated risk of coronary heart disease, stroke and renal failure. It can be concluded that while processing of meat products 40% of sodium chloride can be replaced either with potassium chloride or potassium chloride without any significant deteriorating impact on physicochemical, technological, sensory and microbiological characteristics.

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