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Strategies for reducing salt in meat and meat products: A review

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Abstract

Salt has become an important component in the daily diet of human lives. It enhances the flavor, juiciness, texture, water holding capacity, emulsifying capacity, etc. But excess consumption of the salt has been a risk to the human lives especially the adult population. With the day-to-day increase in the consumption rate of the salt has been seen to raise a concern among the consumers. So, in order to overcome the situation, several researches have been conducted to reduce the daily salt intake to a minimum level. Several strategies adopted include- lowering the salt content by stealthy approach, use of some salt alternatives, salt mixtures and flavour enhancers. Apart from these, experiments using some advanced alternative technologies such as High Pressure Processing, hot boning, pulsed electric field processing, radiation, power ultrasound are still in progress and also expected to be conducted in the near future.

Keywords: Salt reduction technology, salt, shelf life, water-holding capacity, emulsion stability

1. Introduction

Table salt, also known as sodium chloride, is composed of 40% sodium and 60% chloride. Salt plays a crucial role in well-being of human lives. The importance of salt is accountable based on its sensory role for human taste, functionality role for consumer wellbeing, preservation, and processing technologies (Elias *et al*., 2020) [17]. In addition, salt is essential for maintaining fluid balance in the body, which facilitates in the transit of nutrients through cell membranes, adsorption, and blood pressure regulation.

A survey conducted by Johnson *et al*. in 2017 [32] revealed that the average daily salt intake in India is approximately 11 grams. This is almost double the maximum recommended intake of 5 g per day for adults by the WHO in 2016 [70].

The function of kidney is crucial as it helps in controlling the levels of salt and water in our blood. Increased salt intake possibly leads to high water retention because the kidneys are unable to eliminate sodium through urine. This leads our body to hold onto more water ultimately leading to increase in both the volume of extracellular fluid and blood in our bloodstream. As blood volume increases, the flow pressure on blood vessels also increases and one of the most significant risk factors for cardiovascular diseases is high blood pressure (Elias *et al*., 2020) [17].

According to Grillo *et al*., 2019 [25], there is a large variation in how individuals in the general population respond to dietary salt changes in terms of blood pressure. The term for these phenomena is salt sensitivity of BP. This prolonged stress can cause blood vessels to stiffen, increasing the risk of heart disease and stroke. In India, hypertension is a major cause of mortality. At least one in four persons in India is thought to have hypertension, and only around 12% of them are believed to keep their blood pressure under control. Nearly 63% of all deaths in India are linked to non-communicable diseases, with cardiovascular disease accounting for 27% of these deaths and affecting 45% of those in the 40–69 age group (WHO, 2022) [69].

In terms of food category, meat and meat products stands out as the second most contributor to dietary salt- intake, but raw meat as such is relatively very poor in sodium content, constituting about 50-90 gm of sodium per 100 gm of meat (Romans *et al*., 1994) [53].

The main source of salt is processed meat products (salami, sausages, etc.), salted preserved food items, cheese, and sauces like mayonnaise, ketchup, etc. (Eufic, 2020) [19]. In India meat consumption is estimated to be 10 gm/head/day which is far low than the world's average of 25 gm/head/day (Singh and Karim, 2006) [61]. The culinary practice of Indian people is not hidden from all over the world. As for Indian scenario, meat consumption is mainly in a traditional way like curry, roasted meat products which are estimated to contain 2% more salt then other processed meat.

India being the fastest growing nation in the world to catch up the need of quality life there is an increase in the consumption of animal protein which has been unexpectedly fuelled by urbanization and income growth. There is an exponential increase of meat consumption in India, which has contributed a significant rise in dietary sodium and has given rise to a more alarming situation in the aspect of cardiovascular diseases. It was reported that out of a total 9.4 million deaths in India in 1990, cardiovascular diseases caused 2.3 million deaths (25%). WHO has predicted that by the year 2030, hypertension prevalence will rise to 44% (Gupta *et al*., 2018) [26].

2. Strategies for salt reduction

Concerning the rising statistic count due to the ill health effect of table salt consumption, researchers have stepped forward and reported many approaches in an attempt to reduce the content of sodium in meat products and other processed foods. Main strategies are- gradual dietary reduction of salt intake either by a complete or partial replacement of NaCl (Liem *et al*., 2011 [41]; Fellendorf *et al*., 2016 [20]), replacement of NaCl with alternative low sodium salt or salt mixture (Paulsen *et al*., 2014) [49], the addition of flavour enhancers such as monosodium glutamate(MSG) or yeast extract (Santos *et al*., 2014) [57] and improved techniques like high-pressure treatment, ultrasound technology, etc. (Ojha *et al*., 2016) [47].

2.1 A stealthy approach towards salt reduction

The human taste bud can recognise 5 tastes: sweet, salty, sour, bitter, and umami. In correspondence to salty taste, it is believed that Na^+ concentration should be high enough to activate amiloride-sensitive epithelial sodium channels (ENaCs). When we consume food that contains salt, it breaks down into two ions - Na^+ and Cl^-. The Na^+ ions then stimulate the ENaCs, which send sensory signals to the brain, resulting in the perception of a salty taste. This process has been studied by Roper in 2015 [54] and Dotsch *et al*. in 2009 [16].

Out of the numerous strategies adopted, one aims to reduce the detection and recognition threshold. The detection threshold is the lowest NaCl concentration that leads to receptor activation and electrical stimulation in the brain. In contrast, the recognition threshold relates to the sensitivity of saltiness (lowest concentration of NaCl to which stimulus cannot only be detected, but also be recognized). The recognition threshold for cooking salt is approximately 9 g of salt per 1,000 g of water or other solutes; however, it can vary based on gender, age, and eating habits (Petit *et al*., 2019) [50]. So, this can be concluded that repeated and gradual exposure to salt-reduced foods results in increased sensitivity to salty taste, which may in turn, lower the threshold for the detection of saltiness without any changes in acceptability.

This strategy was shown to be successful in the UK, where the sodium content of many processed foods was reduced by 20-30% over three years (He and MacGregor, 2009) [28]. For the effective study of this strategy, an experiment was designed with a group of 110 volunteers to test the efficacy of the method, where they were subjected to a single-blind test. The test aimed in 5% reduction of sodium per week for six weeks in sliced bread, where they found the test sample passed undetected when compared to control which was normal white bread (Girgis *et al*., 2003) [23]. A study conducted by Delgado-Pando *et al*., 2018 [14], where they reported the salt reduction in bacon upto 34% and in ham upto 19% was feasible without the need for salt replacement.

This method aims in step wise gradual reduction of salt in processed food or food products over a long period of time, which suggest to mark acceptability of the product without any visible organoleptic differences determined by consumers. How so ever, this strategy fails when it comes to the implementation worldwide because for that it should be applied at industry level to reach the consumers where there is risk of product unacceptability based on taste by consumers. Moreover, salt has been used since back days as preservatives, so reduction in salt might result in decrease in shelf life of the product.

2.2 Substitution of common salt with salt alternatives, salt mixtures and flavour enhancers

The widely acceptable strategy is the partial replacement of table salt (NaCl) with other salt alternatives or mixture of salts. Good choice of salt substitution relies on the improvement of palatability of reduced salt food products to the consumers. Therefore, it is also important to replace the missing strong taste while maintaining an acceptable texture and shelf life of the product (Rysová and Šmídová, 2021) [56]. The impact of replacement ingredients on the taste of meat products depends on the type of replacement ingredient and the product's formulation and type (Fellendorf *et al*., 2016) [20].

There are many different types of alternative salts used for substitution in the commercial field, where their main role is to replicate the role of salt without affecting the palatability and texture of the food products. Some of them are listed below (Rysová and Šmídová, 2021) [56].

Product	Composition	Commercial claims
Metallic salt		
Potassium chloride	KCl	50% sodium reduction when mixed with NaCl
Potassium lactate	$C_3H_5KO_3$	More than 25% sodium reduction
Calcium chloride, magnesium chloride, and magnesium sulphate	$CaCl_2$, $MgCl_2$, and $MgSO_4$	30% sodium reduction when mixed with NaCl
Salt reducer		
Lite Salt™	Salt and potassium chloride blend, iodide, and a free-flowing agent	Contains 50% less sodium
Sub4salt®	Sodium gluconate, sodium chloride, potassium chloride	100% substitution, leads to a 35% reduction in sodium. Degree of substitution depends on product
Pansalt®	Sodium chloride, Potassium chloride,magnesium sulphate and Lysine hydrochloride	100% substitution leading to a 77% reduction in sodium

The common salt used as salt substitute is potassium chloride (KCl) which is a mineral salt, has been successfully substituted NaCl in meat products without loss of functionality. KCl is the only salt which is having GRAS status (Collins, 1997) [12]. However, problems like off flavours have limited its use up to 1% (Collins, 1997) [12]. Gelabert *et al*. (2003) conducted a study to investigate the impact of replacing NaCl with KCl, potassium lactate, and glycine on the physicochemical, microbiological, and sensory properties of fermented sausages [22]. He found textural and flavour defects on sensory analysis when substitution level was up to 40% potassium chloride, 30% potassium lactate, and 20% glycine. So, it was concluded that substitution of NaCl by KCl, potassium lactate and glycine mixture should be restricted up to 40%.

Bidlas and Lambert (2008) [7] conducted a study to test the preservative effect of KCl on laboratory media using a different range of pathogenic bacterial species such as *Aeromonas hydrophila*, *Enterobacter sakazakii*, *Shigella flexneri*, *Yersinia enterocolitica* and three strains of *Staphylococcus aureus* where it was confirmed that KCl has same effective antimicrobial effect on these microbes when compared with NaCl which was calculated on the basis of molar weight. Study of Ibanez *et al*. (1997) [31] reported that there was no difference in the hygienic quality in dry fermented sausages which was treated with partial replacement of NaCl with KCl (3% NaCl by 1.5% NaCl+ 1% KCl).

Besides having such highly advantageous property, it is never advised to completely replace NaCl with KCl as it gives the food product a bitter taste, reducing its palatability. The blends over 50:50 NaCl/KCl in solution resulted in a significant increase in bitterness and loss of saltiness (Collins, 1997[12]). Usually, partial replacement of salt with KCl is used and the taste is adjusted with some flavour enhancer. This undesirable flavour can be partially masked. The salt substitute can be further composed of calcium and magnesium salts, potassium citrate or lactate, glucose, nitrite, and adenosine monophosphate to mask the bitter taste. Similarly, the combination of Potassium Lactate and glycine could replace 60% of NaCl without affecting sensory items, except for saltiness (Fellendorf *et al*., 2016) [20]. A successful attempt was made for reduction of salt content upto 0.25-1.0% and partial replacement with salt mixture (KCl 50% + $MgCl_2$ 25% + $CaCl_2$ 25%) in chicken sausage (Schmidt *et al*., 2017) [58].

McMahon *et al*. (2014) [45] reported a partial replacement of NaCl by potassium chloride with a total % salt content of 1.7% in cheddar cheese. After salting, rapid depletion of pH changed the environment for microflora. It was found that the concentration of *Lactococci* decreased while the count of non-starter lactic acid bacteria (NSLAB) increased. As the content of salt decreased, the zone of NSLAB vegetation widened. So, potassium salts, flavouring agents, and bitter taste masking agents were successfully used to reduce the salt content in cheddar cheese. 25-75% of NaCl was decreased in a restructured chicken nugget from the original content of salt i.e., 1.5% with the help of salt substitution method where $CaCl_2$ was used to maintain the original ionic strength of the food product. Sensory acceptance also did not show much difference from the original product (Barros *et al*., 2016) [4].

Now-a-days many commercial brands have come front with different successful products like Pansalt®, Sub4salt® as low sodium salt mixture. Many studies were conducted for the successful substitution of NaCl with this salt. Ketenoglu and Candogan (2011) [36] reported no negative effects of ground beef patties formulated with the Pansalt® mixture when compared with ground beef patties formulated with the NaCl. Another study conducted by Jungbunzlauer, 2013 [33] reported that Sub4salt®, a salt mixture formulated with NaCl, KCl and sodium gluconate claims upto 30% salt reduction without any significant taste difference in hams and emulsified sausages.

2.3 Flavour Enhancers

Product acceptability by consumers mainly depends upon the flavour and texture of the product. Salt is the primary and most important contributor of flavour enhancer in food products. Many attempts have been successfully made to replace NaCl with other suitable salt or mixture of salts but there is rise in the issue of bitter taste due to replace of NaCl with KCl, so to combat with such disadvantages other flavour enhancers are used where NaCl is reduced into the food formulation. These flavour enhancers mainly include-inosine monophosphate, monosodium glutamate, guanosine monophosphate, hydrolysed vegetable proteins, 50 nucleotides, autolyzed yeast extract, and other potential ingredients (Desmond, 2006 [15]; Brandsma, 2006 [8]). According to Hegenbart (1994) [29], mechanism behind the action of flavour enhancement is not fully understood but researchers has theorized that these ingredients either increase the ability of protein receptors to interact with flavour compounds in organoleptic sensory receptors, interact with the protein receptor sites to improve the environment for taste receptor stimulation, or may even strengthen the synaptic signal from the receptor site to the brain.

Santos *et al*. (2014) [57] reported that addition of MSG, disodium guanylate, disodium inosinate, lysine, and taurine, could successfully mask the unpalatable taste caused by the reduction of 50% and 75% NaCl with KCl. Autolyzed yeast and hydrolyzed vegetable proteins consist of by-products from either yeast autolysis or vegetable protein hydrolysis that include amino acids (including glutamic acid), autolyzed yeast also naturally forms inosine monophosphate and guanosine monophosphate, which masks bitterness by blocking gustuducin activity in taste receptor cells (McGregor, 2004) [44].

Researchers also tried to exploit the potential of halophytes or salt loving plants as a substitution to salt replacer either due to serious health issues like hypertension or consumer acceptability of product (Rysová, and Šmídová, 2021) [56]. Since budding of knowledge about spices, hot spices like black and chili pepper, ginger, and wasabi, were used extensively to enhance the salty taste perception. Many researchers like Elsebaie *et al.* (2013) [18] and Taladrid *et al.* (2020) [67] reported the use of garlic as a salt replacer because of its strong taste and health beneficiary effect to consumer. Grape-derived seasonings is also growing importance to enhance salty flavour along with that it helps in enriching the food with fibres, protects from oxidation and increase the shelf life of products.

Plants belonging to Lamiaceae family like rosemary, basil, thyme, mint etc. are used since centuries to aid perception of cooked food. Beside these lemon grass (*Cymbopogon citratus*), parsley (*Petroselinum crispum*), curry plant (*Helichrysum italicum*), onion species (*Allium cepa*), chive (*Allium schoenoprasum*), summer savory (*Satureja hortensis*), coriander leaves (*Coriandrum sativum*), garlic (*Allium sativum* and *Allium ursinum*) etc. are used and have been successfully incorporated to replace the intensity of the salty taste with their aroma and flavour. Barnett *et al.* (2019) [2]

reports addition of halophytes can successfully substitute 50% of salt without affecting the intensity of saltiness perception.

Now-a-days, oleoresin is growing attention replacing spice and herbs powder. Study conducted by Serrano *et al.* (2020) [60] suggests oleoresins obtained from the mixtures of *Allium schoenoprasum*, *Anethum graveolens*, *Capsicum frutescens*, *Mentha pulegium* or a mixture of *Allium schoenoprasum*, *Satureja montana*, *Capsicum annuum*, and *Origanum vulgare* served as a salt substitute in foods.

Hydrostatic pressure can be used in processed meat products, especially emulsion-type products, to improve protein functionality (MacFarlane *et al*., 1984) [42]. Hydrostatic pressure is also very effective at extending shelf-life by destroying spoilage microorganisms and some pathogenic bacteria (Kalchayanand *et al*., 1998) [34]. Researchers have reported that it allows for reduced sodium chloride at a threshold level of 1.5% in breakfast sausages and frankfurters (Crehan *et al*., 2000 [13]; Troy *et al*., 2001 [68]). In these studies, it was revealed that KCl could be used in hydrostatic pressure-treated samples and that salt could be reduced to 1.5% without negatively affecting sensory properties, including saltiness. Hydrostatic pressure seems to be a viable alternative for reducing sodium content in emulsion type products due to increased protein functionality. The mechanism for maintaining flavour quality has not been reported in literature but is probably related to the increased protein functionality.

2.4 Modern Techniques applied for reduction of Table salt

2.4.1 High Pressure Processing (HPP)

It is modern technique considered to be useful in mitigating the aim of table salt reduction in food matrix (Ros-Polski *et al*., 2015) [55]. HPP is a non-thermal preservation technique that applies pressure about 300 to 600 MPa in mild temperatures (<45° C) to food products allowing foods to be preserved with minimal effects on taste, texture, appearance, and nutritional value (Cheftel & Culioli, 1997) [9]. HPP has potential to naturally increase level of saltiness which can be supported by the study conducted by Clariana *et al.* (2011) [11] on dry-cured pork loin and ham which were given HPP treatment of 600 MPa, showed an increased saltiness level in meat, without an increase in salt content. So, the natural rise in salty taste perception may be caused by the interaction between sodium ions and protein structure as an effect of the treatment, which possibly cause a higher release of sodium to the taste receptors on the tongue, thereby producing a saltier taste. Hydrostatic pressure seems to be a viable alternative for reducing sodium content in emulsion type products due to increased protein functionality. Troy *et al*., 2001 [68], reports reduction of sodium chloride at a threshold level of 1.5% in breakfast sausages and frankfurters on application of HPP and proved in successfully replacing NaCl without negatively affecting sensory properties, including saltiness. Similarly, Yang *et al.* (2015) reports decreased cooking loss values and increased emulsion stability in pork sausage emulsions (1% salt) and frankfurters (2.5% salt), when treated with pressures between 100 and 400 MPa. Application of HPP technique has shown successful result in inactivation of harmful pathogens like *Escherichia coli* O157:H7, *Salmonella*, and *L. monocytogenes*, as well as vegetative spoilage microorganisms such as yeasts, *Pseudomonas* and lactic acid bacteria, in a variety of meat products (Hugas *et al*., 2002 [30]; Kamenik *et al*., 2015 [35]).The success rate of HPP technology depends upon interaction between HPP parameters *viz*., pressure, temperature and time, type of product prepared, initial NaCl level and concentration of additives(when added).

2.4.2 Hot Boning Technology

Hot boning technology refers to the removal of the muscles or cuts from a warm carcass prior to the onset of rigor mortis. In this regard, while the pH of the meat is still high leading to the increased WHC of the muscle proteins, there occurs a reduced weight loss during chilling and drip loss during storage. Advantage of this technique is the improvement in the quality attributes as well as reduction in the economic losses during storage and distribution of the final products (Pisula and Tyburcy, 1996) [52]. Disadvantage of this technique is the requirement of appropriate facilities along with the expensive equipments and also, when compared to the conventional methods, this process needs to be regulated properly due to the high temperature, microbial contamination, and higher microbe growth rate (Seideman and Cross, 1982) [59]. As mentioned by Sukumaran *et al*., 2018 [66], pre-rigor salting is an important process while utilizing hot-boning technology. Using the hot boning technology for production of low salt meat products enhanced the characteristics of the product (Desmond, 2006) [15], also improvement of the WHC, cooking loss, protein solubility and hardness was observed with at least 2% NaCl (Kim *et al*., 2015) [37].

Choi *et al*., 2015 [10] prepared chicken breast mixed to see the combined effects of pre-salted pre-rigor and post-rigor batter mixtures. A reduction in the cooking loss and improved emulsion stability was observed with 1% NaCl (Pisula and Tyburcy, 1996) [52]. In another study, pre-rigor salting of chicken breast with KCl (2%) showed an increase in the redness and decrease in the hardness, gumminess, and chewiness, hence, showing an overall lower sensory characteristic. Also, a better WHC, pH value and protein solubility were noticed in the pre-rigor salting with KCl rather than the post-rigor salting with NaCl (Song *et al*., 2020) [62].

2.4.3 Power Ultrasound

It is a non-thermal food processing technology that utilizes sound waves with frequencies higher than those detected by the human ear (>20 kHz). Generally, two frequencies are available-low -intensity ultrasound (LIU with frequencies 20–100 kHz and intensities <1 W/cm^2) and high-intensity ultrasound (HIU with frequencies >100 kHz and intensities >1 W/cm^2).

Regarding the inactivation of microorganisms through ultrasound, many studies have been conducted (Gao, *et al*., 2014 [21]; Kordowska-Wiater and Stasiak, 2011 [38]; Marchesini *et al*., 2015 [43]; Zhou *et al*., 2012 [72]). For even and better salt distribution in the product, the ultrasound technology should be mainly used during brining (Alarcon-Rojo *et al*., 2015) [1]. Many previous studies have been conducted using this technology and found to be advantageous – enhances mass transfer of salt in processes like meat brining (Ozuna *et al*., 2013) [48]; enhances tenderization (Stadnik and Dolatowski, 2011) [64], water holding capacity (Stadnik *et al*., 2008) [65], retards microbial growth (Kordowska-Wiater and Stasiak, 2011) [38]. It also aids in the texture modification of the final product. However, negative impact may arise due to its application- lipids' accelerated oxidation and thus the reduction of the shelf life of meat products.

Li *et al*., 2015 [40] found an improvement in the gel properties while applying this technology in preparation of Chicken breast meat batter. Barretto *et al*., 2018 [3] observed reduction in the total fluid released and increased hardness of the restructured cooked ham prepared with 0.75% salt and high-intensity ultrasound (600 W) treatment. Also, the sensory attributes of the ham sample with 0.75% salt was found to be acceptable.

2.4.4 Radiation

Radiation, a non-thermal salt reduction technology known for ripening and the retardation of microbial growth, thereby enhancing the shelf life of the fresh and processed meat products, uses primarily three ionizing sources (gamma rays, electron beams, and X-rays) (O'bryan *et al*., 2008) [46].

Song *et al*., 2017 [63] on low-salt emulsion sausage (0.75% NaCl) observed an inhibition of the growth of aerobic microbes, coliforms, *Enterobacteriaceae*, and *Pseudomonas* spp. during chilled storage upon application of radiation technology (gamma rays, electron beams, and X-rays) at 5 kGy. Negative effects such as accelerated deterioration in physicochemical properties- discoloration and the oxidation of biological molecules formation of irradiation off-flavors and odors may result due to application of such technology (Ham *et al*., 2017 [27]; Li *et al*., 2017 [39]). Also, a negative impact on mostly the consumers regarding the technology which needs to be considered is it's higher operational and maintenance cost.

2.4.5 Pulsed Electric Field Processing

Pulsed electric field processing, a non-thermal process, mainly contributes to the microbiological safety of processed food without considerably affecting its nutritional and sensory characteristics (Gomez *et al*., 2019) [24], thus leading to the improvement of the meat quality and enhances the shelf life of the product (Pinton *et al*., 2021) [51].

Bhat *et al*., 2019 [5] conducted a study to see the current and future prospects for the use of pulsed electric field in the meat industry. This study revealed that the use of pulsed electric field processing in low-salt beef jerky (1.2% NaCl) improved the salt diffusion and distribution in the meat matrix and improved the saltiness naturally. No effect was seen in the colour, yield, oxidative and microbial stability. Another study was conducted by Bhat *et al*., 2020 [6] in Loin Deer *Longissimus dorsi* muscle and found higher soluble protein and digestibility of muscle.

3. Conclusion

This review was to give a brief outline of the different methods adopted so far to reduce the salt intake to a minimum level. As seen the raising concern among the consumers regarding the higher or excess intake of the salt (NaCl), many traditional as well as modern technologies have been adopted so far. Although not many researches using the modern advanced technologies are yet conducted, but with the few conducted research, it can be concluded that combining the traditional methods with the advanced ones can somehow help to reduce the salt level. Use of single traditional methods cannot reduce the salt intake to the minimum expected level.

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