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REVIEW

Emerging Innovations to Reduce the Salt Content in Cheese; Effects of Salt on Flavor, Texture, and Shelf Life of Cheese; and Current Salt Usage: A Review

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Abstract

Salt is an essential ingredient for cheese production, and it influences various aspects of cheese, including the shelf life, enzyme activity, flavor, casein hydration, and microbial proliferation during ripening. Several consumers avoid cheese with high salt content, mainly due to health problems such as hypertension, cardiovascular disease (CVD), stroke, and heart attacks. Salt has been commonly used for several purposes in cheese production, including for obtaining the required flavor and texture, for its preservative properties, and as a taste enhancer. However, salt usage has been opposed by the public and governmental bodies, who have been advised by health authorities that salt should be reduced or avoided in cheese for healthier life. However, salt replacement or reduction in cheese manufacturing requires formulation of intensive strategies. This review provides information about several strategies and innovations for reduction and replacement of salt in cheese manufacturing without seriously affecting the quality, microbial safety, and sensory properties of cheeses.

Keywords cheese, sodium reduction, health aspects, emerging technologies

Introduction

Cheese is a fermented food product for human consumption. Fermentation has an array of beneficial effects on the characteristics of foods, such as extending the shelf life, diversifying the nutritional content and taste, and breaking down food components to simpler compounds for aiding digestion. Cheese is considered as a very special food product as it not only has all the features of a fermented food, but can also extend the short shelf life of milk, thereby providing a solution for one of the biggest disadvantages of raw milk. Additives are typically required for prolonging the best before date (BBD) of cheese, and salt is considered the most effective among the available additives. Extension of the shelf life of cheese without salt is unfathomable. Therefore, the role of salt in cheese production is the basis for supporting the possibility of cheese itself. Salt is an indispensable ingredient because it is essential for improving the quality and safety of cheese. Consumer preferences for individual cheeses, and the role and effect of salt in various types of cheese are varied and unique. The main functions of salt in cheese making is moisture control through easier elimination of whey and enabling the formation of a firm cheese rind by removing water from the surface. Furthermore, the inhibition of lactose fermentation by lactic acid bacteria prevents the pH from becoming too low during pressurization and at the beginning of ripening. Salt improves cheese texture by modifying it to a sticky texture in the hydrated state. In addition, salt regulates the proliferation of microorganisms as well as enzyme activity. Salt contributes to flavor development of cheese, as well as acts as a flavor enhancer (Bishop and Smukowski, 2006; Guinee, 2004; Johnson *et al*., 2009; Kindstedt, 2005). However, recent advances in medicine and basic science have revealed the adverse effects of prolonged, excessive cheese consumption and excessive salt consumption on human health, it is being strongly suggested that salt usage be reduced in all food products. As the use of salt in cheese has become a problem, there has been a widespread awareness of the negative effects of salt on human health. The minimum amount of salt required for living organisms is very small, i.e., 0.5-1.0 g/d; hence, although salt deficiency is not associated with health concerns, excessive consumption is linked to many problems (Chang *et al*., 2010).

The USDA (2011) noted that the daily sodium consumption of Americans reached an average of 3,400 mg in 2011 and announced the Dietary Guide for Americans (DGA) on February 1, 2011. It has been recommended that the maximum daily sodium intake be reduced from 2,300 mg to 1,500 mg (www.usda.gov). The WHO (2012) has published a detailed document on sodium intake in adults and children. Although cheese is a highly nutritious fermented milk product, its high fat and salt contents are consumption limiting factors that prompts consumers to exclude cheese from their daily diet. This is because common health problems such as hypertension, stroke, and arterial disease (Culter, 1999) have been consistently reported in people with a high salt intake. Hence, the cheese industry has tried to replace or reduce the amount of sodium chloride (NaCl) used. One option is to limit the amount of salt used in cheese making, and the other is to replace NaCl with potassium chloride (KCl). Although KCl or calcium salt were promising NaCl replacements, they produced an undesirable metallic or bitter flavor. It is reported that the amino acid arginine most commonly contributes to the salty taste in cheese. (Angus *et al*., 2005).

The use of salt substitutes or artificial salt can increase the cost of cheese and create a negative perception about cheese in consumers seeking natural foods, thus limiting their sale. To date, there have been three studies regarding the reduction of NaCl in cheese manufacturing. The first suggests the use of lower sodium levels, while maintaining the salty taste of cheese. The second suggests the replacement of NaCl with KCl. It was found that KCl lowers blood pressure and reduces CVDs. The third study attempted to lower the sodium concentration while maintaining a salty taste by adding various degradation products generated during cheese fermentation to manufactured cheese (El-Bakny, 2011). This review examines the function and importance of salt in cheese, side effects of excessive salt intake on human health, strategies to substitute salt without reducing the benefits of salt usage in cheese manufacturing, and recent technological advances in this area.

Roles of salt in cheese

Potential roles of salt in cheese

Cheeses have been perceived as products with high sodium levels. Recently, many consumers consider cheese as a diet, and most of them will be selecting products with less salt. Indeed, salt is an important ingredient influencing the flavor, texture, safety, and overall suitability of cheese. Johnson *et al*. (2009) reviewed desirable low sodium cheese and elaborated on regulatory and labelling requirements, consumer preferences, and future challenges. The demands for the reduction in salt content in processed foods made by health advisers and wholesalers has led to an increase in research on salt substitutes and innovative production techniques to lower the quantities of salt included in food. It is particularly challenging to reduce the sodium content in certain cheeses, such as artisanal, specialty, and raw milk cheeses. A sound understanding of the influence of salt on the properties of such cheeses is essential for developing strategies for producing low-sodium cheeses that satisfy consumer demands. Regardless of the stage at which it is added, salt has at least six roles in the making and ripening of specific and artisan cheese. These include enhancement of whey separation and controlling the final moisture content, controlling the metabolism and viability of cheese starter culture, influencing the secondary microorganisms that might proliferate and produce volatile compounds during the aging process, controlling enzyme activity and the body of the final cheese products when NaCl replaces with Ca in the cheese matrix, and improving the flavor and taste of the cheese (El-Bakny, 2011).

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Flavor functions of sodium compounds in cheeses

Hence, a significant reduction of salt content in foods would render them unpalatable. McMahon (2010) reported role of salt in cheese flavor. Sodium and lithium are unique cations having a primarily salty taste. Although saltiness can be imparted by other minerals such as calcium and potassium, these minerals also impart other flavors, which are sometimes described as metallic or bitter. NaCl is the saltiest sodium compound. If the size of the anion coupled to sodium increases, the salty flavor might decrease. Salt is an important provider to cheese flavor, and it has been shown to increase the flavor intensity of ripened cheese, while reducing bitterness (Albrecht-Sieidel and Mertz, 2006). This might be because salt affects the perceived cheese flavor or starter culture activity during storage. Food preference felt by each person depends on the flavor of salt that improves diverse flavors of products, which is one of the abilities of salt. Food flavor is an essential cue in daily diet management, as it is the important reason of food gratitude. In many foods, NaCl is an essential constituent for flavor and flavor-enhancement (Keast *et al*., 2004; Liem *et al*., 2011).

Texture

Salt reportedly affects final product characteristics such as body, constituents', outlooks, and mouth-feel. NaCl interrelates with the major ingredients of foods, therefore influent the body of foods and affects occurring throughout processing. Salt especially enhances the hydration of proteins and combining of proteins to fats (Bishop and Smukowski, 2006; Guinee, 2004; Johnson *et al*., 2009). Salt also affects the solubility of proteins and the moisture content of cheese, which in turn determine the rheology, texture, and changes that occur during cooking. Low contents of NaCl (5-6%, w/w) upraised the solubility of casein or para-casein in natural cheeses (El-Bakny, 2011). NaCl exerts several important effects on the textural aspects of cheese. For example, it affects casein hydration, and thus affects the water binding capacity of the casein gel. Adding NaCl to cheese initially results in enhanced protein hydration. However, at higher concentrations, it is associated with a decrease in casein hydration; therefore, increased NaCl concentrations cause the cheese matrix to become firmer and stiffer (Tomas and Pearce, 1985).

Preservation and safety aspects

The salt content during the moisture phase of cheese production, and not the total amount of salt in the final product, controls the growth of microorganisms. Salt has been used to preserve various foods for thousands of years. Its primary effect is to reduce the water level in foods so that it is unavailable to pathogenic or spoilage organisms (Guinee and Fox, 2004). If the pH, oxygen levels, or temperature is not optimized, microbes cannot grow at low water levels due to unsuitable micro-environmental conditions. Some microbes such as *Listeria monocytogenes* synthesize particular stress proteins in reaction to high sodium contents. Furthermore, some toxin-producing bacteria may be able to grow at relatively lower water levels, but can only synthesize toxins in the presence of a greater content of water amounts (Esse and Saari, 2004). A previous study reported that salt is one of the major hurdles to microbial proliferation and helped maintained general cheeses safe for consumption (Bishop and Smukowski, 2006). Out of various cheeses, in case of cheese with low fat, the water content is high, so that the salt-in-moisture (S/M) gets lowered in the same content of salt. Lowering the S/M ratio lowers the safety and shelf-life of cheese, thereby adversely affecting the distribution and marketing (Bishop and Smukowski, 2006). Growth of microorganisms is partially controlled by the S/M ratio rather than the absolute amount of salt in the food, and all factors controlling microbial growth should be considered while standardizing safe storage conditions for cheese (Johnson *et al*., 2009). Salt level controls microbial growth, affects the growth and activity of cheese starter culture, and the growth of putrefactive and pathogenic microorganisms (Ayyash *et al*., 2013). Starter bacteria exhibit variable salt sensitivity. High NaCl concentrations generally inhibit the growth of starter bacteria, and lower concentrations stimulate their growth. Salt also suppress the growth of many potential undesirable microbes that could inhibit with the growth of cheese starter cultures (Ardö *et al*., 2014).

Strategies and emerging technologies in formulation of salt-reduced cheeses

Current techniques in lower salt level: Reduction over a period of time

Current techniques include the reduction of salt by stealth, which involves lowering the steady stepwise salt level in processed foods over a prolonged period, such that the reduction cannot be perceived by the customer (Liem, 2011). It is thought that this process prevents the consumer from detecting changes in the ergonomics and sensory qualities of products, while diminishing the amount of salt and consumer sensitivity to the saltiness of a product. The duration needed to effectively lessen down the salt content requires at least one year. However, the food industry is trying to maintain the strong salty flavor in food, while lowering the sodium content (Dotsch *et al*., 2009).

Salt substitutes and salt replacing ingredients

Initiatives directed at developing salt substitutes have primarily focused on the addition of other mineral bases such as KCl, flavor enhancers, and microbial extracts with strong umami features. However, some of the substitutes for salt are known to have undesirable sensory characteristics. Research conducted to improve the reduction of salt in foods (Dotsch *et al*., 2009) led to the development of various salt replacing components and combinations. Dotsch *et al*. (2009) claimed that they either enhanced the saltiness or replicated the role of salt without influencing the salt flavors; however, they did not have the preserving effects of salt. Therefore, producers need to be careful while using salt substituting ingredients in low-salt products, and should ensure that other preservatives are included to assure the safety and long shelf life of the final products. Salt replacers, which consist of other mineral bases, can impart a salty flavor to food; however, the aroma profile is different from that of salt. KCl or modified KCl is most commonly used. Other mineral bases such as ammonium chloride, calcium chloride, and magnesium sulphate have undesirable flavors that limit their use. KCl can generally only be used to replace up to 30% of sodium salt in food products, because it has a noticeable metallic flavor at higher levels (Brandsma, 2006); accordingly, it is usually mixed with NaCl or other mineral bases to minimize the metallic flavor and aftertastes. Taste relishes, including monosodium glutamate(MSG) and hydrolyzed vegetable protein (HVP) are also used to improve the quality of reduced salt products. The Umami effect of these compo increases the perceived salty flavor, without the food having a high sodium level. Enhancers upturn the flavor of products by encouraging taste buds linked to the Umami taste sensors (Brandsma, 2006). Nevertheless, there is still a negative sensory impact associated with the ingredients. However, food industry and scientists still need to develop new techniques to aid the lowering of salt level in a wide range of food products. There are salt replacers that contain little bit or no sodium and yet confer a taste similar to that of NaCl. KCl is the compound that is most chemically similar to NaCl and the most recognizable choice for NaCl substitution. However, large amounts of magnesium chloride, KCl, or calcium chloride provide a largely unfavourable bitter taste, metallic flavor, and crumbly body to the cheese. Conversely, a mixture containing a 1:1 ratio of NaCl and KCl resulted in a cheese comparable to the control. Salt replacers are low-sodium alternatives that prevent the risk of hypertension and CVD associated with a higher intake of NaCl, while maintaining a similar taste. Salt substitutes usually contain mostly KCl, which has a toxicity level that is approximately equal to that of table salt in healthy individuals. However, a great variety of illnesses and medicines may reduce the excretion of potassium, thereafter growing the risk of potentially fatal hyperkalemia. People with heart-related diseases or diabetes should not use substitutes for salt without accurate diagnosis of disease. To improve the taste and scent of substitutes for salt, in case of Kwak *et al*. (2002), the hydrolyzed protein or 5'-nucleotide could be added to KCl.

Modification of the structure of NaCl

It is thought that a smaller particle size is associated with a faster rate of dissolution and therefore with increased salt perception. Improvement of NaCl by modifying its structure has also been explored; modified NaCl would have the same ability and activities as salt, but with a physical structure that has been re-engineered to hollow nanoparticles. One product, Soda Lo®, statements to have the ability to lower NaCl by up to 50%, while delivering a stronger, saltier flavor, than table salt, and can still be affirmed as salt on the packaging labels (University of Nottingham, 2012). The lowering of salt content using Soda Lo® in a variety of foods has been examined and the results statement that it produces low-salt foods with the same taste the original products.

Texture/melting and other quality characteristics

Typical Gouda/Cheddar-type cheeses with considerably reduced NaCl levels may develop undesired softness, leading to problems in maintaining their shape. A more hydrated protein matrix will be more susceptible to enzymatic hydrolysis. Moreover, adjunct starter, non-starter lactic culture and their enzymatic activities may be activated by lower salt levels. This double effect probably contributed to the softening of cheeses with reduced salt. The softening that occurs upon salt reduction enhances the mobility of caseins in the cheese matrix. This makes

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the cheese less viscous, and more extensible, and contributes to desirable cooking properties. While desired salt reduction levels in cheese lead to markedly changed textural properties, cheese makers may apply a combination of measures, processing, and formulations to counterbalance this. Adjusting processing conditions and raw materials (e.g., to reduce the residual lactose content in Cheddar-type cheeses or enhance mineral retention in curds) and adjusting cheese composition (reducing fat content and moisture content, and tailoring the proteolytic capacity in a cheese affected by rennet dosage, type of rennet, starter/adjunct cultures) are potentially effective measures. The skilled fine-tuning of such measures is essential for achieving qualitatively and economically acceptable results. Reduction of NaCl content might require variations in other factors to certify that foods show a suitable perception of flavors and body. It might be possible to significantly let down the salt content of cheeses by improving production techniques, for example, by mixing of salt with cheese curd better or producing a more uniform-sized cheese curd. Moreover, the partial substitution of NaCl with KCl does not adversely affect starter culture activity or texture. However, MgCl and $CaCl_2$ are not good substitutes for NaCl in cheeses, owing to the resulting soft, or greasy cheese texture. Protein enrichment, by the addition of ultrafiltrated retentate to cheese milk, provides better quality low-sodium cheeses with a good texture. It might be attributable to the higher calcium and phosphate content in cheeses. If higher than normal amounts of salt are added to cheese during the manufacturing process, whey separation (syneresis) increases and the cheese will have lower moisture content, which has been shown to be associated with decreased meltability. Moreover, acid production by the lactic acid bacteria can be inhibited so that the cheese has a higher pH, resulting in a higher calcium content (Pastorino *et al*., 2003a; Pastorino *et al*., 2003b) that restricts the ability of cheese to flow and melt.

Preservation

Salt lowers the water content in foods, and this reduced water content thereafter acts as a critical hurdle to the growth of putrefactive microorganisms. It is essential to test any changes in ingredients or processing stages to ensure that the food retains the property of sensory acceptability. If salt content is reduced, it should be necessary to substitute this lowered salt level with other compounds for enabling the safety of foods. Substitution of NaCl by KCl is acceptable for many foods, as long as the substitution is limited to 30%. KCl appears to influence microbes in foods in a fashion similar to that of NaCl. Recent trials with *L. monocytogenes* (Boziaris *et al*., 2007) and *Staphylococcus aureus* (Bidlas and Lambert, 2008) revealed that KCl could straight act as a replacer for NaCl at the same molar ratio, with similar antimicrobial effects on foodborne pathogenic bacteria. This issue has been put forth by advocates of governmental directives or regulations for lower-salt foods. Others point out that prevalent salt reduction in processed foods will have an optimistic economic advantage on the society by dropping health care costs (Beaglehole *et al*., 2007).

Consumer acceptance

When the content of salt gets lowered in a product, its flavor could be negatively influenced, which could work as disadvantage for its sale to customers. This is also applied to cheese. In order to solve this, according to a research by Phan *et al*. (2008), one of the methods lowering salt and increasing the taste of cheese is to increase water and to decrease the content of fat. As cheese is a high-protein food, the composition and balance of cheese should be maintained in accordance with nutrition or customer satisfaction. Lowering the content of NaCl of cheese or food while increasing consumers' expectation of taste has become the main task to every food industry. Especially, cheese is a highly-evaluated fermented food owing to its content of beneficial microorganism like lactobacillus, flavor, and texture, so that it would be necessary to carefully resolve how to reduce the content of NaCl.

Conclusions

Various approaches have been used to produce high-quality cheeses with reduced salt content. Salt replacers, enhan- cers, and combinations thereof can be effectively applied to improve the flavor quality of low-sodium cheese. Espe- cially, as salt plays an essential role in the process of ripening cheese, its reduction is one of the important issues. The cheese with low NaCl and fat could have bad flavor. Salt is one of the most valued ingredients that play a significant function in the human body and in food manufacture. Nonetheless, it is known that the over-use or misuse of salt has led to opposing effects on health. Effective salt reduction can only be achieved with the cooperation and commitment of the food industry for the development of low-salt processed foods. A potential substitute for food-grade NaCl could be crystalline particles containing both KCl and lysine mono-hydrochloride, where the two components are not susceptible to separation. While some products have used the strategy of mixing NaCl with KCl to reduce sodium consumption, few products on the market are sodium-free. As KCl itself has bitter and metal-like taste, in order to complement this, it would be necessary to carefully approach how to reduce the content of NaCl of cheese and other foods.

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