Recent Patents for Sodium Reduction in Foods

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Abstract: There are many foods containing variable amounts of sodium chloride in their formulation, sometimes its content is relatively large and has strong contribution to the salt dietary intake. Some of these foods belong to usual products like bakery, butchery and dairy foods, ready meals, sauces, snacks, etc. There is a clear increasing trend in the number of patents towards a lower salt content in foods as demanded by consumers and medical associations. Different approaches have been proposed, most of them by replacement with other salts and addition of other substances to keep the sensory quality. The recent patents for sodium reductions and its applications in foods are reviewed in this manuscript.

Keywords: Low sodium, low salt, sodium replacement, sodium free.

INTRODUCTION

A significant sector of the population in Western societies is suffering of cardiovascular diseases being hypertension the most extended. Part of them experience an increase in blood pressure when sodium is present in the diet. One of the strategies to reduce the risk for cardiovascular diseases is by controlling sodium intake. Currently, many foods contain variable amounts of sodium chloride in their formulation. Some of the foods having larger salt content are bakery, butchery and dairy foods, ready meals, sauces, snacks, etc. In recent years, consumers and health authorities have been demanding a lower salt content in foods. Food industry is trying to attend this growing demand but still many foods contain excessive amounts of sodium. In many cases, the reason is due to the difficulties in reducing the salt content in foods due to the important roles (contribution to taste, water activity reduction, partial protein solubilization, etc) played by salt. One of the best parameters to measure the evolution towards reduced salt levels is by evaluating the trend in the number of patents in recent years. So, the number of patents filed in the last 20 years has experienced a progressive increase as a result of the demand by consumers for sodium reduction in foods. So, the patents filed for low sodium in foods were below 20 per year up to the year 2000. However, this number rapidly increased up to 80-100 patents per year in the last 5 years see Fig. (**1**). Year 2008 is only partly scored. Something similar happened when searching for low salt in food where the number of patents rapidly grew since 1998 [1], reaching more than 250 patents per year filed in the last 6 years see Fig. (**2**). However, some variability was observed for low salt since some of them had no relationship with sodium reduction.

The distribution of the patents filed by food fields reveal that patents on low sodium in foods were equally distributed among meat and meat products, fish and seafood, bakery (including bread) and sauces (including mayonaise) with

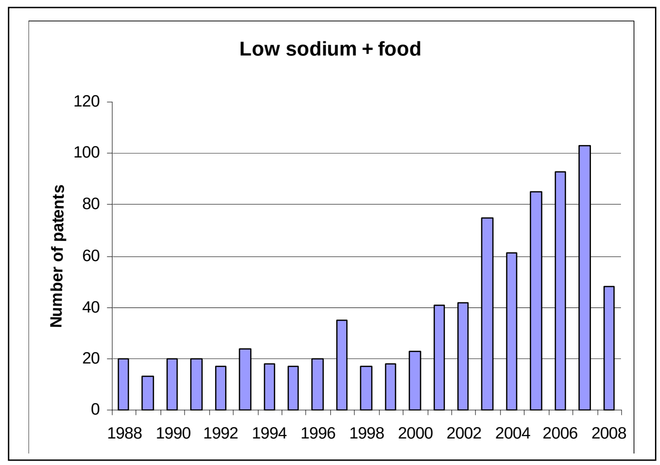

Fig. (1). Evolution of the number of patents on low sodium in foods filed in the past 20 years.

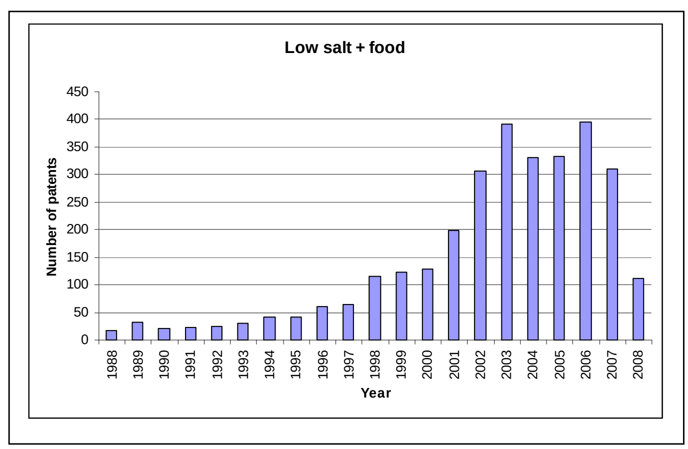

Fig. (2). Evolution of the number of patents on low salt in foods filed in the past 20 years.

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lower amount for pickled foods see Fig. (**3**). In the case of low salt in foods, a little bit more than 50% were filed for fish and seafoods, less than 30% for meat and meat products and the rest for the other food fields see Fig. (**4**). These results demonstrate that muscle foods and its derived products constitute the group of foods where more efforts have been done for the reduction of sodium.

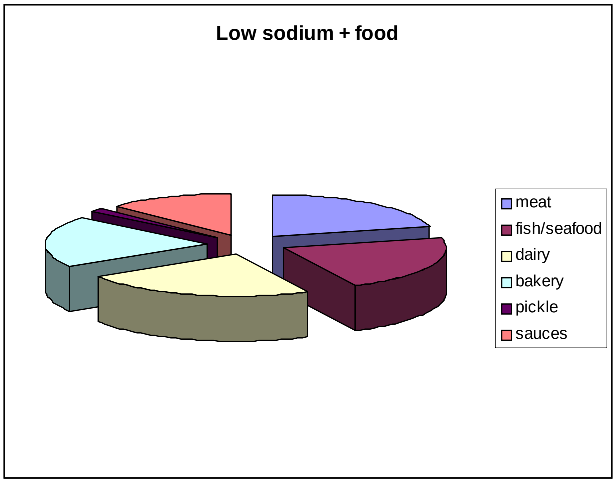

Fig. (3). Distribution of the patents filed in the last 20 years on low sodium within the main food fields. Bakery includes bread and sauces includes mayonnaise.

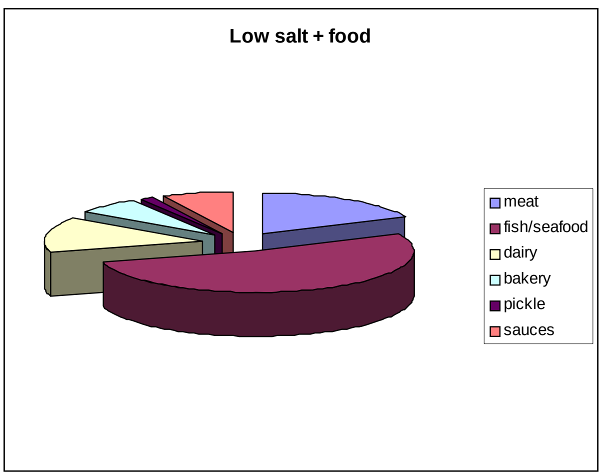

Fig. (4). Distribution of the patents filed in the last 20 years on low salt within the main food fields. Bakery includes bread and sauces includes mayonnaise.

STRATEGIES FOR SODIUM REDUCTION

Salt mixtures with low sodium content are prepared for its application to human consumption. These salts are characterized by having sodium chloride mixed with other salts based on chloride, carbonate or sulphate. In addition, one or more flavoring additives may be added to mask bitter or metal aftertastes. Some of the potential flavorings are pepper, onion, garlic, tomato, sweet pepper, basil, parsley, thyme, celery, lime, chilli, nettle, rosemary, smoke flavouring, curry, coriander and lemon [1]. Some examples of recent patents based on such mixtures are given below.

Most usual is the use of a salt mixture containing sodium chloride, potassium chloride, minor amounts of magnesium sulphate and calcium carbonate, and trace amounts of folic acid and zinc oxide [2]. In other cases, the salt substitutes preferably include NaCl and KCl at similar amounts, a modifier consisting of a cereal flour such as rice flour and a food grade acidulant like citric acid [3]. A salt with low sodium chloride and high organic potassium salt content was based on the use of potassium bicarbonate, with addition of magnessium, potassium or calcium carbonate, lactate, citrate, tartrate, succinate, glutamate or orthophosphate to mask the taste [4].

Recently, a carrier modified salt chloride was reported to contain a chloride salt (a chloride of potassium, magnesium, calcium, lithium, ammonium, or a mixture thereof), a modifier (selected among citric acid, malic acid, tartaric acid, fumaric acid, lactic acid, acetic acid, and benzoic acid), and a carrier (selected from a maltodextrin and a monosaccharide). An antioxidant like rosemary extract, a phosphate and a colorant may be added [5]. Other authors have also proposed similar formulations. So, the composition comprises an organic acid, a potassium salt, a calcium salt, a magnesium salt, and rice flour [6, 7]. The acid can be citric acid, tartaric acid, fumaric acid or lactic acid, the magnesium salt is magnesium sulphate, the calcium salt is calcium chloride or calcium phosphate. Finally, the seasoning may contain flavoring agents (garlic powder, pepper powder, onion powder, celery powder, sweet basil, thyme powder, dehydrated parsley, sweet red pepper powder, and spicy red pepper). Calcium phosphate and calcium silicate may be added as stabilizing agents. It can contain up to 20% by weight sodium chloride and natural or artificial essences, colorants, and aromatizers are added [6,7].

The salt substitute usually contains potassium chloride even though it imparts a bitter taste to the food. This may be overcome by adding a sweetener or a flavouring as mentioned before. For instance, Iwayama and Fujieda [8] used as sweetener either licorice extract and/or steviside or monoglycosyl stevioside or a corresponding amount of stevia extract They also used an edible polyfunctional organic acid such as malic acid or citric acid as essential components on the surface. This substitute was claimed to be used by less than 30% to make a food product of low sodium content [8]. The same authors [9] proposed to add aspartame as sweetener and include a seasoning such as monosodium glutamate and, if necessary, an iodine compound, vitamin, or mineral. A low-sodium salt substitute, based on replacement by potassium chloride and either magnesium sulfate or magnesium chloride, results in a 50% reduction of sodium intake with respect to table salt for an equivalent level of saltiness taste [10]. This formulation is claimed to provide potassium without the associated bitterness because of the presence of magnesium salt that masks such bitterness. A low sodium edible salt composition with less than 50% NaCl, which is replaced by KCl and some additives which are at least one edible nucleotide monophosphate salt and, at least, another one (low organic acid, low organic acid salt, phosphoric acid, phosphate salt, a magnesium salt, sugar and burnt sugar) that allow to mask the bitterness of potassium [11].

Other alternatives consist of the use of botanic origin products like Salicornia plants and Eucheuma plants/ sea weeds from sea which once dried forms a white salt containing an adequate sodium chloride: potassium chloride ratio as well as traces of micronutrients (calcium, magnesium, iron, copper, zinc and iodine). This salt is claimed to contain 20-30% by weight of sodium chloride [12]. The addition of up to 1.5% by weight of trehalose has been claimed to favor the sodium reduction in comparison to the food controls. The ratio of sodium chloride to potassium chloride in the finished product is reported to be 1:1 [13,14]. The food product contains from about 20% to about 50% less sodium than the control food product [15].

Another strategy may consist in the use of a salt taste enhancer. In this way, a minimum amount of sodium chloride is required in the food, about 0.20% by weight, allowing a reduced sodium content. This enhance consists of a mixture of one or more inorganic salts (not sodium chloride but either anhydrous calcium chloride, calcium chloride dihydrate, calcium chloride hexahydrate, anhydrous magnesium chloride, magnesium chloride dihydrate, magnesium chloride hexahydrate, potassium dihydrogen phosphate or dipotassium hydrogen phosphate) , one or more mono or polyvalent salts of polybasic food acids (either potassium succinate, dipotassium succinate, potassium malate, dipotassium malate or mixtures), and one or more amino acids or salts [16]. The salt taste enhancer may also consist of dehydrated proteolyzed protein, either proteolyzed egg white or proteolyzed gelatin, low amounts (below 3%) of free glutamic acid, free lysine and free arginine; and ammonium phosphate [17].

APPROACHES FOR SODIUM REDUCTION IN FOOD PROCESSING

The results of the patent search in the SCIRUS database by using the key words "low salt", were filtered for the main food types susceptible to the low salt approach; meat, fish, seafood, dairy, bakery (including an additional search with the work "bread"), pickle and sauce (including an additional search with the work "mayonnaise").

The first 20 results sorted by relevance in the "Patent Offices" section of the SCIRUS database were carefully analyzed and classified according to four different approaches listed below to obtain a product with low salt content. It must be noted that some of the results provided after the search in the database did not correspond to patents focused on protection of results aiming to reduce the salt content in the foods, and were excluded of the mentioned analysis. So, four types of approaches as regards the processing of foods with reduced salt content were identified after the analysis of the patents. The obtained results, sorted by each of the 4 approaches, are summarized in Tables **1**, **2**, **3** and **4**, respectively. The approaches are:

Approach 1: Use of mixtures with low sodium content, affecting the taste perception: the reduction of sodium content in food can be done, as previously mentioned, basically by replacing total or partially the sodium cation by others, such as potassium, or by reducing the total amount of salt. Some modifications in the perceived taste can occur, mainly associated to the bitterness of the usual substitutes of sodium, when the first approach is used. In this case there are some of the reviewed patents that pretend to reduce such bitterness perception (e.g. 27 and 29).

When the total amount of salt in food is diminished, enhancers of the salt perception or tastes that hide the low amount of added salt can be used (e.g. 18 and 24).

More detailed information about the specific strategy approach and the product developed under such strategy are shown in table 1 [13, 18-29].

Approach 2: Use of treatments to solve some technological problems that affect food quality and shelf-life and are related with the low salt content: It is very well known that NaCl not only imparts its own taste to the product but also plays a key role in many other sensory and technological aspects. That's why in some of the patents the authors pretend to develop alternative strategies to prevent the changes in those parameters.

The product shelf-life can suffer important changes if the salt is reduced in food, basically because the addition of NaCl implies the water activity reduction. This aspect not only can affect the shelf-life itself but also the safety of the product. The alternative to lower amounts of electrolytes in the product is the reduction of the a_w by further water removal (e.g. 35) or the use of other water activity depressors different from NaCl (e.g. 42). As an alternative to that, the safety of a product with higher a_w values could be assured by using other preservation approaches, such as pH reduction (e.g. 36 and 37) or use of high hydrostatic pressures (e.g. 44).

Other alternatives are proposed in the patents aimed to solve the possible modifications in texture, gelation capability, color, typical flavor and taste of food [30-53] see Table **2**.

Approach 3: Reduction of the amount of salt of the product by using desalting or filtering techniques [54-61] see Table **3**. There is a number of patents with the main objective of adding a new step to the process for obtaining a product that resembles the original one, but removing the salt from the final food. The basis of the approach deals with the salt transport between the food and the surroundings.

Approach 4: Reduction of the salt uptake by using low salt solutions, controlling the added salt or using of a salt transport barrier [62-69] see Table **4**. This approach is similar to the previous one, but in this case instead of removing the salt form the food, it is prevented the salt gain by using the before mentioned strategies.

CURRENT & FUTURE DEVELOPMENTS

The general strategy consists of partial replacement of sodium chloride by potassium chloride. The bitterness associated to the presence of potassium is then masked with some other agents like sugars, flavorings, etc. An acid modifier is usually present in the formulations. Other alternative cations are magnessium and calcium even though at lower replacement rates. Some recent developments

Table 1. Summary of Patents Aimed to Develop Mixtures with Low Sodium Content, Affecting the taste Perception; Reducing the Bitterness Perception, Enhancing the Salt Perception, or Using other Tastes that Keep Hidden the Low Amount of Salt (Approach 1)

Product	Brief Description	Reference
Use of mixtures with low sodium content		
Cheese	Protein concentrate and serum obtained by treating a dairy stream	[18]
Cheese	Use potassium salt as molten salt	[19]
Fish	Ultrafiltrated, concentrated and crystallized whey, rich in mineral components, as a substitute for salt	[20]
Fish	Addition of ethyl alcohol in a saline solution	[21]
Fish	Use of a transglutaminase, an alkaline salt (e.g., trisodium phosphate) and sodium caseinate and/or potassium caseinate	[22]
Flour	Use of calcium and vitamin D or calcium and magnesium	[23]
Food	The ingredient systems comprise trehalose and can include sodium, potassium, or combinations thereof	[13]
Sauce	Partial or total substitution by using potassium chloride and aminobutyric acid	[24]
Sauce	Addition of capsaicin	[25]
Development of taste improving agents		
Food	Reacting basic amino acids particularly arginine, lysine or ornithine with citric acid	[26]
Flavoring seasons		
Food	Salt substitute containing potassium chloride and bitterness inhibitors taurine and 5'-adenosinic acid, 5'-inosinic acid and/or 5'-guanylic acid	[27]
Food	Various compounds suitable for use as flavoring agents	[28]
Increasing or imparting a flavor enhancement effect or modifying the perception of one or more of the five basic tastes		
Food	At least one N-substituted unsaturated alkyl amide	[29]

Table 2. Summary of Patents Aimed to Develop Treatments that Enable to Avoid some Technological Problems Related with the Low Salt Content, such as Texture, Gelation Capability, Shelf-Life, Color, Flavor and Taste

Product	Brief Description	Reference
Texture and water-binding properties		
Bread	Specific formulation with saccharides + decomposed starch material + wheat flour + oil and fat + few content of table salt	[30]
Bread	Starch + wheat flour + etherified starch + thickening polysaccharides and dietary fibers	[30]
Livestock and Fish meat	Addittion and reaction of a transglutaminase with a partial hydrolyzate of a protein such as wheat protein in the presence of a common salt at a low concentration	[31]
Meat	Use of tyrosinase to improve the texture and water-binding properties	[32]
Pickle	salt + sugar + phosphate used to improve the water-retainability and bindability of a processed cattle meat by the heat-treatment of the pickle	[33]
Mayonnaise	Oil phase + water phase + lysed yolk + low salt	[34]
Shelf life		
Food	Freeze-drying of the pickle obtained with low salt content	[35]
Food	Reduction of pH by acidifying a foodstuff with a membrane acidic electrodialyzed composition, and/or addition of edible inorganic acids and/or their metal acid salts	[36,37]

(Table 2) Contd….

Product	Brief Description	Reference
Foods and Drinks	Use of glycine and/or a glycine derivative as antibacterial agent	[38]
Pickle	Preservation under vacuum or modified atmosphere	[39,40]
Pickle	Atmosphere of a vacuum, under reduced pressure and then hermetically sealed nitrogen gas + high pressure	[41]
Pickle	Product blended with ethyl alcohol	[42]
Pickle	After pickling with low salt, steaming and boiling the papaya, kneading in millet brandy, mixing with a seasoning, and preserving in a closed vessel	[43]
Sausage	Treatment with a high hydrostatic pressure and cooking	[44]
Color, Flavor and taste		
Bakery	Yeast extract with 5'- ribonucleotides (5'-GMP plus 5'-IMP)	[45]
Pickle	Immersing vegetables in an aqueous solution containing salt and arginine	[46]
Pickle	Addition of thiamine dilaurylsulfate	[47]
Pickle	Adding saponin to a pickling bed with curd bean refuse as the main stock	[1]
Sauce	Soy sauce treated with a NF (nanofiltration) membrane	[48]
Sauce	Addition of an extract from Labiate plants	[49]
Sauce	Addition of potassium chloride and adding calcium chloride and/or magnessium chloride to neutralize the bitterness	[50]
Sauce	Low salt extract + yeast for soy sauce to promote alcohol fermentation quickly	[51]
Sauce	Liquid seasoning with polyphenols and potassium chloride	[52]
Vinegar	Low-salt saline solution + UME vinegar + honey	[53]

Table 3. Summary of Patents Aimed to Reduce of the Amount of Salt of the Product by Using Desalting, Filtering or Dilution Techniques

Product	Brief Description	Reference
Desalting		
Fish	The fish gel is washed with water to remove the salt inside	[54]
Fish	Extract from fish and shellfish is subjected to desalting treatment	[55]
Fish	Use of oolong tea and desalting in a second pickling step with the addition of seasoning	[56]
Pickles	Second immersion in a dilute seasoning liquid of low osmotic pressure (desalting effect)	[57]
Pickle	Reduce the salt content through steps of desalting, cutting, pressing, dehydrating, etc.	[58]
Filtration		
Meat	Forming an aqueous acidic protein solution which is filtered to remove salt and acid. The solution is pasteurized and dried. The gelation is done by adding a physiologically acceptable salt	[59]
Sauce	Addition of potassium chloride and aminobutyric acid. Removing the Na by electrodialysis or any other membrane treatment	[24]
Dilution		
Sauce	Mixing raw soy sauce with ocean deep water which is nutritious and clean and adding sake	[60]
Sauce	Blending unrefined soy sauce obtained from soybean and wheat with mayonnaise	[61]

Table 4. Summary of Patents Aimed to Reduce the Salt Uptake by Using Low Salt Solutions, Controlling the Added Salt or Using of a Salt Transport Barrier

Product	Brief Description	Reference
Use of a salt-transport barrier between the medium with salt and the food		
Fish	Lightly salting and contacting the salted meat with a polymeric water-absorbent through a water-permeable sheet	[62]
Fish, shellfish and meat	Use of semipermeable membrane for osmotic dehydration for dehydration + flavoring + smoking	[63]
Meat	Processing + following osmotic dehydration after sealing with semipermeable membranes	[64]
Addition of lower amount of salt		
Bakery	Flour + sodium chloride + potassium chloride + ascorbic acid	[65]
Fish	Addition of low salt content to the processed product	[66]
Pickle	Seasoning + fermented liquid with low salt content obtained from useful microorganisms	[57]
Pickle	Dipping in a pickle solution of low salt concentration	[67]
Sauce	Using compounds which are extracted from sea algae and/or a bittern from sea water, contains potassium chloride (as a main component), calcium compounds, Mg compounds, and fine amounts of other minerals	[68]
Sauce	Molluscus blanching + enzymatically hydrolyzed in the presence of a protease + deactivation of protease by heating + cooling and filtering	[69]

include the use of other salts like carbonate or sulphate instead of chloride or other technologies like filtering or desalting for the reduction of salt content.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

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