Salt reduction in vegetable fermentation, reality or desire?

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Salt reduction in vegetable fermentation: reality or desire?

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Abstract

NaCl is a widely used chemical in food processing which affects sensory characteristics and safety; in fact, its presence is frequently essential for the proper preservation of the products. Because the intake of high contents of sodium is linked to adverse effects on human health, consumers demand foods with low sodium content. A first step to reduce the use of salt would imply the proper application of this compound, reducing its levels to those technologically necessary. In addition, different chloride salts have been evaluated as replacers for NaCl, but KCl, $CaCl_2$ and $ZnCl_2$ show the most promising perspectives of use. However, prior to any food reformulation, there is a need for exhaustive research before its application at industrial level. Salt reduction may lead to an increased risk in the survival/ growth of pathogens and may also alter food flavor and cause economic losses. This review deals with the technological, microbiological, sensorial and health aspects of the potential low-salt and salt-substituted vegetable products and how this important segment of the food industry is responding to consumer demand.

Keywords: sodium chloride, vegetable fermentation, healthier product, salt reduction.

Reduction of sodium in foods: an international demand

The use of salt is reported in the Old Testament as a food ingredient with a religious connotation. Lueck (1980) showed that its usefulness for preserving foods was well-known in Ancient Egypt, the Middle East, and in Ancient Rome. Common salt (NaCl) has been employed in many foods and it is used for flavoring and stabilizing many different types of products, such as fish, eggs, bread, meat and vegetables, among others.

Nowadays, there are numerous worldwide initiatives to decrease sodium consumption through foods. According to the Dietary Guidelines for Americans (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010) all Americans consume more sodium than they need because the average intake of sodium for American population (2 years and older) was approximately 3,400 mg/day. This amount is substantially higher than the recommendation included in the same Guide, which suggests reducing the daily sodium intake (SI) to less than 2,300 mg/day and further reduces this intake to 1,500 mg/day in the case of special population groups (51 years and older or those who suffer from hypertension, diabetes, or chronic kidney diseases). A similar situation has also been reported for Finland (Reinivuo and others 2006).

Consumer concern has raised low Na to a status similar to that of low fat, low sugar and low carbohydrates and, currently, there are favorable perspectives for new, low Na food commercialization (Market Research 2004). The link between high sodium intake and cardiovascular diseases is clearly demonstrated (Ortega and others 2011). A diet high in potassium (K) and calcium (Ca) and low in Na is suggested to improve high blood pressure problems (Leiba and others 2005) and prevent against osteoporosis and/or colon cancer development (Berner and others 1990). A current study (Bibbins-

Domingo and others 2010) has estimated that reducing salt intake to 3,000 mg/day (1,200 mg of Na) could bring down the annual number of new cardiovascular diseases in the USA by between 60,000 and 120,000 cases, myocardial infarction by between 54,000 and 99,000 and avoid annual deaths from these causes by between 44,000 and 92,000. Such benefits could affect virtually the entire population. The decrease may be similar to that assigned to tobacco consumption, high cholesterol levels or obesity. Cost savings for medical care could be 24,000 million dollars. In recent years, several studies have discussed these effects. The predicted benefits from a decrease in salt intake are consistent with the estimated effects on clinical events attributable to the small blood pressure reduction achieved (Taylor and others 2011). Against these studies and others, He and others (2011) defend that a reduction in salt intake of the present 9,000 – 12,000 mg/day to the recommended proportion of less than 5,000 – 6,000 mg/day will have great beneficial effects on health along with large cost savings throughout the world (Appel and others 2011; He and others 2010). The World Health Organization has recommended salt reduction as one of the main priority actions to challenge the worldwide non-communicable- disease crisis (Beaglehole and others 2011; Whelton and others 2012). Clearly, because the objective must be saving lives, the priority in the near future should be focused more on reducing salt intake by consumers than in a deeper clarification of the contribution of salt intake to cardiovascular diseases.

The use of Ca and K for the fortification of foods with mineral elements is authorized in the European Union (Directive 2002/46/CE). Thus, an eventual Na substitution with K and Ca in foods is possible and would have a beneficial effect on consumer health. Recently, the European Union (EU) has developed a National Salt Initiative (June 2009), whose conclusions on measurements to decrease salt intake in the EU (June 2010) were passed to the Commission (European Council 2010). Later on, the

Commission asked the EU Member States to implement national nutritional policies with the aim of achieving such a goal. Following this initiative, the “Agencia Española de Seguridad Alimentaria y Nutrición” (AESAN) has developed the NAOS strategy to fight against obesity and promote wholesome habits in Spain; the project includes diverse initiatives to diminish the use of salt in foods. The first objective has been a reduction of 16% sodium in bread (AESAN 2010).

The substitution of sodium chloride, at least partially, with other chloride salts in foods currently prepared with high concentrations, could improve the consumers’ opinion of them. Research has been mainly focused on the use of different chloride salts because of their similarities with common salt with respect to chemical structures, effects on microorganisms, and organoleptic characteristics. However, other salts could also been considered. Among chloride salt replacers, potassium chloride (KCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$) (Alemany Lamana 1999) or $ZnCl_2$ (Bautista-Gallego and others 2011c) can be mentioned. Furthermore, all of them have favorable effects on health. K, Ca, and Mg are macro elements while Zn is considered a microelement, but all of them are mentioned in the list of nutrients that can be included in the nutritional labeling in the USA and the EU (Code of Federal Regulations 2007; European Commission 1990). These elements have also permitted health claims within the current EU legislation (Commission Regulation EU 432/2012).

Potential NaCl reduction depends on characteristics linked with the kind of product, its composition, other ingredients, processing and elaboration conditions. These variables define the type of product that can be subjected to salt reduction, the safety risk involved, and the technological restriction that can be found. It should be noted that osmotic effects of the different salts will depend on their molar concentration and not their molecular weight. Therefore, any modification (NaCl total/partial replacement of it with other chloride salts or reduction) in the current processing must be preceded by deep scientific investigations that assure its feasibility and safe implementation at industrial scale.

Studies on non-vegetable foods

Some studies have focused their attention on the reduction of salt in meat products (Desmond 2006; Ruusunen and Puolanne, 2005) because of the fact that NaCl is one of the most commonly used ingredients during processing. In the same way as vegetables, NaCl has a marked effect on organoleptic characteristics, hardness and shelf life of the corresponding meat products. The NaCl levels of meat products must be lowered because of the wide variability among producers; for example, the Na content in 30 liver sausages may vary between 500 and 1,000 mg/100 g (Greubel and others 1997). Potential NaCl reduction or replacement by other chloride salts depends on many aspects. Samapundo and others (2010a) concluded that $CaCl_2$ has antimicrobial activity on the presence and growth of *Lactobacillus sakei* in ham and white sauce. On the contrary, $MgSO_4$ has the lowest antimicrobial properties. A reduced-fat 'mortadella' using different chloride salt mixtures was studied by Horita and others (2011), who showed that it was viable to lower the NaCl concentration by 50% with 25% $MgCl_2$-25% KCl (sensory properties) or 25% $CaCl_2$-25% KCl (emulsion stability).

The partial substitution of NaCl with KCl resulted in a similar hardness profile and microstructure of Halloumi cheese compared with the control (only NaCl) (Ayyash and others 2011). Furthermore, the hardness, cohesiveness, adhesiveness, and gumminess of Halloumi cheeses submerged in NaCl/KCl brine solutions were comparable to those stored in NaCl only. Cruz and others (2011) described that different types of cheese were produced with a progressively lower NaCl content or partial/total replacement of this salt with KCl, $CaCl_2$ and $MgCl_2$. The results were in general positive, leading to acceptable cheeses, but in some treatments there was a sour residual taste caused by the substitution.

Bread is the main contributor to SI in most countries, therefore reducing the salt content in this product would be an efficient way to decrease overall SI. Samapundo and others (2010b) found that NaCl and $MgCl_2$ had the largest antimicrobial activities in *Aspergillus niger* and *Penicillium roqueforti* in bread, while $MgSO_4$ had the least antifungal activity. Lynch and others (2009) determined that lowering the salt content from 1.2% to 0.6% or 0.3% had no effect on the rheological characteristics and bread-making behavior of wheat dough, although the organoleptic properties of the bread needed to be enhanced. Bolhuis and others (2011) concluded that a salt decrease of up to 52% in bread (or even up to 67% in flavor-compensated bread) did not have any effect on bread consumption or choice of sandwich fillings.

Reduction of salt in vegetable products

The impact of fermented vegetable consumption on the overall consumer SI is limited because these products are usually consumed only in a limited proportion with respect to the overall diet. Because of this circumstance, the pressure to reduce salt in their elaboration has not yet been determinant for a general change in their processing. However, their contribution to SI should not be underestimated.

Traditionally, fermented vegetables are processed using common salt solutions. As a result, Na is one of their major ingredients in the final products (Garrido-Fernández and others 1997; Guillou and others 1992) (Table 1). To reduce the sodium content in these products a first step would consist of using the minimum level compatible with the proper preservation and habitual organoleptic characteristics. With only this action, it would be possible to make a considerable contribution to salt intake reduction from fermented vegetables. A study on the concentrations of salt in packed table olives showed that their contents oscillated between 4,740 - 7,570 mg/100mL in green (Spanish style) presentation while the range was narrower in directly brined olives (4,250 - 5,710 mg/100mL). In ripe olives, the levels were always fairly similar with an average of 2,550 mg/100mL and only a standard error of 0.100 mg/100mL (López López et al., 2004). Therefore, it is obvious that the concentrations used in some green (Spanish-style olives) packages could be markedly reduced.

However, the use of other chloride salts such us KCl, $CaCl_2$ or $ZnCl_2$ could have promising perspectives in some circumstances. In the specific case of Spanish-style table olive elaboration, the fruits are treated with an NaOH solution (lye) and the excess of alkali is removed with several washings with tap water. Then, olives are brined in an NaCl solution. These processes cause a progressive increase in the flesh of the Na levels and, on the other hand, reduce the contents of other mineral elements or nutrients such as sugars and vitamins used as fermentation substrates, due to the subsequent dilutions (Garrido Fernández and others 1997). It is clear that a reduction in Na and an increase in other salts may lead to a more equilibrated mineral composition in table olives and can contribute to enhancing the consumers' diet and the perception by society of their nutritional value.

Below, the real capabilities to reduce the Na level in fermented vegetable products which possess the microbial, physicochemical and sensory aspects of this reformulation are presented.

Microbiological aspects

NaCl lowers the water activity (a_w) and has a marked effect on the ionic strength of a system (Ross 1975). These changes lead to less favorable conditions for microbial growth in general. Salt preserves food free of microbes in the following ways: i) salt draws water out of food and dehydrates it (because water is essential for all living cells, they cannot grow), and ii) osmolarity changes alter diverse internal processes of cells producing microbial death. This presence of NaCl also reduces the solubility of oxygen in water. As a result, the lower availability of oxygen restricts the growth of aerobic microorganisms in products with high NaCl proportions (Lueck 1980). The mechanisms used by the microorganisms to respond to changes in the osmolarity are not completely known, although great advances in its understanding have been recently made (O'Byrne and Booth 2002). The response of microorganisms to salt is highly variable. The effect to which salt concentration causes changes in bacterial growth depends on the osmotic balance required for such growth. Some microorganisms require an astonishingly high level of salt to begin growth (halophilic), whereas others would be immediately killed at such high levels.

Diverse groups of microorganisms are involved in the fermentation of vegetables determining their organoleptic characteristics, quality and safety of the final product. In general, lactic acid bacteria (LAB) and yeasts are always relevant microorganisms in these processes (Garrido-Fernández and others 1997; Pérez-Pulido and others 2005; Franco and Pérez-Díaz 2013).

The effects of different NaCl levels (4-8%) and temperature (18-25ºC) on the microbiological evolution of naturally black olives of the Conservolea cultivar showed that LAB presence was increased to 4 and 6% NaCl instead of higher NaCl levels (Tassou and others 2002). Similar results were obtained in the presence of $CaCl_2$; however, in this case, this salt enlarged the depth of the peripheral region where the cell wall breakage preferably occurred (Tassou and others 2007). Kanavouras and others (2005) assayed treatments using 16% NaCl, 0.025M $CaCl_2$ buffered with acetic/acetate and 0.025M $CaCl_2$ with 12.8% NaCl with acetic acid added. In this case, the third treatment led to olives with reduced salt content (healthier products), no spoilage microbiota and higher acceptance, according to consumer tests. Bautista-Gallego and others (2010) reported that the overall growth of *Enterobacteriaceae* was lower in the presence of $CaCl_2$ but was higher as the proportions of NaCl and KCl in Aloreña cracked table olive increased. Tassou and others (2007) showed that the growth of Gram-negative bacteria did not follow a clear pattern but, in any case, their presence was observed only for a limited period of time since they were rapidly inactivated during Greek olive fermentations. Bautista-Gallego and others (2010) noticed that decline rates and the time to reach half the maximum yeast populations were significantly related to salt levels in the brine mixtures. In these experiments, a delayed LAB onset with respect to yeasts was always observed but their growths were never related with the initial salt mixture composition. $CaCl_2$ also delayed *Enterobacteriaceae* and yeast sprang in Gordal table olive fermentation, decreasing their overall growth (Bautista-Gallego and others 2011b). Calcium chloride also showed a trend towards reducing overall LAB presence. KCl had a similar pattern with respect to NaCl but, overall, favored microbial growth. Therefore, a partial substitution of NaCl with KCl and $CaCl_2$ in Spanish style green olives did not substantially modify the fermentation pattern, but caused modifications, which, when properly managed, can help to control the process and improve the final product. Mulè and others (2000) used cover brines composed of only 8% NaCl, 50% mixtures of this salt with $CaCl_2$ and 33.3% mixtures of NaCl+KCl+$CaCl_2$ in developing natural black olives. There were no significant differences during the fermentation process.

The maximum specific growth rate of *Lactobacillus plantarum* in black olive juice was studied in a combination of NaCl (377 mM) and Ca-acetate and lactate mixture (67 mM, together). In general, high concentrations of the last salt led to marked inhibitory effects. The maximum specific growth rate of mixed cultures of *L. plantarum* and *Debaryomyces hansenii* in olive juice fermentations was observed when the medium contained an NaCl-KCl mixture in a 50% proportion (Tsapatsaris and Kotzekidou 2004). On the other hand, Tassou and others (2007) reported no effect of $CaCl_2$ on LAB when the initial salt concentration in the cover brine was at a concentration of 0.5%. However, in absence of $CaCl_2$, yeast growth had a two fold increase in 4% NaCl. In other experiments, natural black table olives were also processed in 12% NaCl brine buffered with acetic acid (0.05M) and 0.025M $Ca(OH)_2$; results showed that such conditions were very convenient for significantly improving hardness, color, and consumer acceptability with respect to those using NaCl or acetic acid (0.05M) and 0.025M $Ca(OH)_2$ in the cover brine (Kanavouras and others 2005). Conservolea table olives brined in NaCl, KCl and $CaCl_2$ mixtures led to a very active lactic acid fermentation of natural black table olives (Panagou and others 2011). Bautista-Gallego and others (2011c) observed a reduction in *Enterobacteriaceae* and yeast populations in Aloreña fruits packed in brines containing $ZnCl_2$. No changes were observed in LAB levels. Furthermore, an exhaustive study performed with the objective of investigating the effect of $ZnCl_2$ on 22 table olive related yeasts (Bautista-Gallego and others 2012), showed that low levels of this chloride salt inhibited yeast growth, so it could be used as a potential preservative chemical in fermented vegetables (olives, cucumber, capers, etc.) reducing the levels of NaCl necessary in packaging.

Some studies have reported the effects of several chloride salts on microbial growth in cucumber extracts (Naewbanij and others 1990; Chavasti and others 1991). Guillou and others (1992) produced good quality pickles when moderate amounts of NaCl (5%) and $CaCl_2$ (0.2%) were present together with potassium sorbate (0.2%). In cucumber fermentation, a vigorous lactic fermentation decreased the population of yeasts and other microorganisms, thus improving the product stabilization. Yeasts were almost absent from cucumber fermentations in the presence of NaCl and $CaCl_2$ mixtures added with potassium sorbate as preservative (Guillou and Floros 1993). Yamani and others (1999) fermented cucumbers and turnips in various NaCl concentrations and found that 4% NaCl was the lowest concentration to produce acceptable products, but 3% NaCl in combination with 0.5% KCl and 0.5% $CaCl_2$ was also acceptable. The use of a starter of *Lactobacillus plantarum* in the brine gave a pH similar to that of natural fermentation (about 3.0).

The use of low salt levels for the natural spontaneous fermentation of sauerkraut led to products with highly variable quality, noticeable losses in firmness and the development of a marked off-flavor; however, using a starter culture of *Leuconostoc mesenteroides* resulted in a hard texture and reduced off-flavor regardless of the salt concentrations (Johanningsmeier and others 2007). In this way, the use of selected LAB starter cultures can also improve processing in salt mixtures. Sauerkraut fermentation with NaCl and KCl showed a faster growth of LAB in high levels of NaCl and, at the end of the process, the same counts for all trials were found (Viander and others 2003). In chile pepper mash, Flores and others (2007) found that the presence of $CaCl_2$ controlled microbial growth and maintained diverse quality characteristics. In addition, the treatments with different Ca compounds improved viscosity compared to the control.

Izumi and Watada (1994) used $CaCl_2$ in carrot shreds, sticks and slices and observed that 0.5 and 1% $CaCl_2$ treatments reduced microbial growth in carrot shreds at all temperatures.

Physicochemical aspects

A critical issue in the fermentation of vegetables is the formation of lactic acid by LAB, which provokes the rapid and safe acidification of brines and fruits. Combined acidity, acid production and pH in olive fermentations are also affected by the use of different salt mixtures and, in general, their productions could be modeled as a function of the initial salt concentrations (Bautista-Gallego and others 2010). Cracked Aloreña table olives may be stored prior to their packaging. During this period, olives can also be fermented in diverse chloride salt mixtures (Bautista-Gallego and others 2011a) and no relevant changes were found in color, but the triple mixtures (NaCl, KCl and $CaCl_2$) showed the highest firmness. Rodríguez-Gómez and others (2012) investigated the effects of different salts on the fermentation profile (individual sugar solubilization into brines and lactic acid and acetic acid formations) in Spanish style green table olives. Na, K and Ca chloride salts markedly influenced the diffusion of reducing sugars (glucose, sucrose, fructose and mannitol) into the cover brines which, in turn, affected the formation of lactic acid. The main effect was noticed in the presence of Ca which decreased the difussion rate of all sugars and produced a delay in lactic acid formation. Bautista-Gallego and others (2011b) showed that the addition of Ca to Gordal table olive fermentation can drop the pH after brining and the final pH values, limit sugar difussion into the brine and decrease the rate of acid production. In this way, the presence of $CaCl_2$ in Gordal table olives fermentation caused marked modifications in the fermentation pattern such as lower initial pH, slower rate of sugar diffusion into the brine, lower maximum concentration of sugars and titratable acidity formation as well as lower pH at the end of the fermentation (Bautista-Gallego and others 2011a). In addition, the use of $ZnCl_2$ in olive packaging led to a slow consumption of sugars but did not modify the pH and titratable acidity of the cover brines (Bautista-Gallego and others 2011c).

Guillou and Floros (1993) used a mixture of 3.0% NaCl and 0.28% $CaCl_2$ in cucumber fermentation. The product showed a vigorous fermentation which prevented the presence of mould/yeast and maintained proper hardness for up to 6 months after brining. Similar results were also obtained using 4.0% NaCl concentrations, from 0.20 to 0.25% $CaCl_2$, acetic acid and sodium metabisulfite (Sahin and Akbas 2001). McFeeters and Pérez-Díaz (2010) have demonstrated the possibility of carrying out the fermentation of cucumbers in the exclusive presence of $CaCl_2$. The product resulted in a sufficient acidification to lower the pH below 3.5 units and was stable during storage. As a result, no formation of propionic or butyric acid, which may indicate the growth of spoiling microorganisms, was detected.

The addition of $CaCl_2$ to carrots shreds, sticks and slices maintained firmness and also resulted in lower tissue pH than in the water-dipped controls (Izumi and Watada 1994). Ca content was slightly increased in sticks and slices and to a large extent in shreds but did not affect the storage quality of these products. Kimchi prepared using KCl and NaCl showed acceptable ranges of pH and titratable acidity after 13 and 21 days of fermentation, respectively (Choi and others 1994).

Viander and others (2003) observed that the pH decreased slightly faster when 1.2% NaCl was used, but the final pH was approximately the same in all cabbage treatments. Accordingly, no significant differences among them were found. Furthermore, lactic acid formation was clearly lower after 2 weeks of processing in the presence of KCl, but no notable differences could be observed between the levels of acetic acid concentrations in the diverse experiments.

In *Colocynthis citrullus* L. seed flour, Arogundade and others (2004) found no significant differences using a partial substitution of NaCl with KCl. But a complete replacement of NaCl with KCl, at an appropriate level, showed similar or even better foaming capacity/stability and water absorption.

Sensorial aspects

Before new products are marketed, they have to be assessed by trained expert panels and tested for consumer acceptance. There are various sources which explain panel training step by step and how to proceed (Stone and Sidel 2003; Mailgaard and others 1991).

In natural green table olives, the use of $CaCl_2$ and KCl in directly brined fruits led to a product with a reduced salt concentration and acceptable sensory characteristics (Di Silva 2000). Table olives with a high level of $CaCl_2$ showed a more attractive firmness (Bautista-Gallego and others 2011a). In addition, KCl and NaCl played significant roles in saltiness, which was mainly associated with the NaCl level but the presence of KCl did not make a noticeable contribution to it either. The $CaCl_2$ concentration negatively affected the overall acceptability which was inversely related to initial level; the highest scores were estimated for olives preserved in the presence of 3.67% NaCl and 7.33% KCl, approximately. Gordal table olives fermented with different brines showed that all sensory descriptors considered in this study were linked to the initial proportions of the different salts used to prepare the brining solutions (Moreno-Baquero and others 2012). Thus, the nitial concentrations of NaCl and KCl were significantly associated with saltiness, while the $CaCl_2$ level was related to hardness, fibrousness, crunchiness, and bitterness. Marsilio and others (2002) reported similar scores for saltiness in the absence of $CaCl_2$ for green olives fermented in brines containing 6% NaCl, 6 % KCl or in a solution prepared with a mixture of 3% of each salt. In addition, they reported the highest overall score and lower bitter scores for olives prepared in a mixture with 3% NaCl and KCl salts. Kanavouras and others (2005) showed that processing naturally black table olives in a buffer solution (brine) with 0.05 mol/L CH_3COOH, 0.025 mol/L $Ca(OH)_2$ and 12% NaCl (pH adjusted to 4.3) produced olives with an overall acceptability significantly improved with respect to the traditional one. The sensory analysis of natural black olives showed that the scores using NaCl alone were practically the same as those found for olives processed in a mixture of NaCl, KCl and $CaCl_2$ but the use of NaCl and $CaCl_2$ gave a slightly higher score (Mulè and others 2000). Panagou and others (2011) found that the effectiveness of the replacement of NaCl was constrained by the organoleptic acceptability of the respective final products. Only one mixture of chloride salts, with initial concentrations of 4% NaCl and 4% KCl, was able to produce olives with reduced Na content and acceptable sensory characteristics. In the case of $ZnCl_2$, Bautista-Gallego and others (2013) obtained better scores for firmness and the lowest scores for the kinesthetic sensations in treatments with $ZnCl_2$ (mainly 0.075%) than in those containing potassium sorbate.

The fermentation of cabbage with low salt brines led to products with variable final quality; on the contrary, the application of a starter culture of *Leuconostoc mesenteroides* ensured that the typical texture and flavor qualities were maintained, while allowing, at the same time, for a 50% NaCl reduction in the product (Johanningsmeier and others 2007).

Sensory tests carried out with the objective of evaluating the quality of kimchi fermented for 13 days showed that the use of KCl in brine had no effect at all on hotness, firmness, bitterness, sourness, saltiness, or overall acceptability of the products (Choi and others 1994).

A trained taste panel evaluated different sauerkraut trials prepared with NaCl, KCl and their mixtures; the best taste was observed for the sauerkraut juice fermented with mineral salt (28% KCl- 57% NaCl mixture) (Viander and others 2003).

Yoo and others (2006) fermented cucumbers with diverse salt types. The best sensory results were obtained when the fruits were brined in a mixture which contained the same concentrations of Ca and Mg as bay salt. A low level of NaCl (0-5.8%) with 0.2% $CaCl_2$ in cucumber fermentation led to an improvement in the firmness of the fruits' mesocarp with respect to the product prepared with just NaCl in the brine (Fleming and others 1987).

As a summary of the most commonly employed replacers, KCl, $CaCl_2$ and $ZnCl_2$ show promising perspectives because their addition does not significantly alter the microbiological, physicochemical and sensorial characteristics of the final products (Table 2). However, $MgCl_2$ and, possibly, other salts may have a weaker or a more specific role in the replacement of NaCl in vegetables.

Conclusion

In most countries and in most cases, Na content in vegetable products can be markedly lowered. A first and very convenient step would simply consist of using the recommended concentration in each product, compatible with its proper stabilization and organoleptic characteristics. However, the substitution or replacement of NaCl with other salt mixtures is progressively gaining support because, in this way, the use of NaCl in brines can be reduced and the contribution to SI decrease. $ZnCl_2$ is expected to have a marked function in lowering the level of NaCl in vegetable packaging due to its apparent yeast control. Nowadays, as was shown through this review, the possibility of reducing salt in fermented vegetables is becoming a reality. However, this reformulation must always be checked product by product. As far as it is known at the moment, it is very unlikely that a single ingredient could replace NaCl in vegetable products. Thus, a detailed research related to the effects of any potential modification of food composition on consumer acceptability, shelf life, and safety evaluation of new products is essential before marketing any reformulated food. KCl, $CaCl_2$ and $ZnCl_2$ show promising perspectives of application because their additions do not significantly alter the microbiological, physicochemical and sensorial characteristics of the final products.

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References

AESAN (Agencia Española de Seguridad Alimentaria y Nutrición). 2010. Plan to Reduce the Salt Intake, within the Estrategia NAOS. http://www.naos.aesan.msps.es/naos/observatorio/observatorio00102.html (accessed January 2011).

Alemany Lamana M. 1999. Enciclopedia de las Dietas y la Nutrición. Editorial Planeta, Barcelona, Spain. p. 1239–40,

Appel LJ, Frohlich ED, Hall JE, Pearson TA, Sacco RL, Seals DR, Sacks FM, Smith SCJr, Vafiadis DK, Van Horn LV. 2011. The importance of population-wide sodium reduction as a means to prevent cardiovascular disease and stroke: a call to action from the American Heart Association. Circulation. 123:1138–43.

Arogundade LA, Akinfenwa MO, Salawu AA. 2004. Effect of NaCl and its partial or complete replacement with KCl on some functional properties of defatted Colocynthis citrullus L. seed flour. Food Chem 84:187–93.

Ayyash MM, Sherkat F, Francis P, Williams RPW, Shah NP. 2011. The effect of sodium chloride substitution with potassium chloride on texture profile and microstructure of Halloumi cheese. J Dairy Sci 94:37–42.

Bautista-Gallego J, Arroyo-López FN, Durán-Quintana MC, Garrido-Fernández A. 2010. Fermentation profiles of Manzanilla-Aloreña cracked green table olives in different chloride salt mixtures. Food Microbiol 27:403-12.

Bautista-Gallego J, Arroyo-López FN, López-López A, Garrido-Fernández A. 2011a. Effect of chloride salt mixtures on selected attributes and mineral content of fermented cracked Aloreña olives. LWT-Food Sci Technol 44:120-29.

Bautista-Gallego J, Arroyo-López FN, Romero-Gil V, Rodríguez-Gómez F, García-García P, Garrido-Fernández A. 2011b. Chloride salt mixtures affect Gordal cv. green Spanish-style table olive fermentation. Food Microbiol 28:1316-25.

Bautista-Gallego J, Arroyo-López FN, Romero-Gil V, Rodríguez-Gómez F, Garrido-Fernández A. 2011c. Evaluating the effects of zinc chloride as a preservative in cracked table olive packing. J Food Protect 74:2169-76.

Bautista-Gallego J, Romero-Gil V, Garrido-Fernández A, Arroyo-López FN. 2012. Modeling the inhibitory effects of zinc chloride on table olive related yeasts. Food Control 23:499-505.

Bautista-Gallego J, Moreno-Baquero JM, Garrido-Fernández A, López-López A. 2013. Development of a novel Zn fortified table olive product. LWT-Food Sci Technol 50: 264-71.

Beaglehole R, Bonita R, Horton R, Adams C, Alleyne G, Asaria P, Bekedam H, Billo N, Casswell S, Cecchini M, Colagiuri R, Colagiuri S, Collins T, Ebrahim S, Engelgau M, Galea G, Gaziano T, Geneau R, Haines A, Hospedales J, Jha P, Keeling A, Leeder S, Lincon P, McKee M, Mackay J, Magnusson R, Moodie R, Mwatsama M, Nishtar S, Norrving B, Patterson D, Piot P, Ralston J, Rani M, Reddy KS, Sassi F, Sheron N, Stuckler D, Suh Il, Torode J, Varghese C, Watt J. 2011. Priority actions for the non-communicable disease crisis. Lancet 377:1438–47.

Berner LA, McBean LD, Lofgren PA. 1990. Calcium and chronic disease prevention: challenges to the food industry. Food Technol 44:50-9.

Bibbins-Domingo K, Chertow GM, Coxson PG, Moran A, Lightwood JM, Pletcher MJ, Goldman L. 2010. Projected effect of dietary salt reductions on future cardiovascular disease. New Engl J Med 362:590-9.

Bolhuis DP, Temme EHM, Koeman FT, Noort MWJ, Kremer S, Janssen AM. 2011. A salt Reduction of 50% in Bread Does Not Decrease Bread Consumption or Increase Sodium Intake by the Choice of Sandwich Fillings. J Nutr 141:2249-55.

Chavasti V, Hudson JM, Torres JA, Daeschel MA. 1991. Evaluation of fermentative bacteria in a model low salt cucumber juice brine. J Food Sci 56:462–5.

Choi SY, Beuchat LR, Perkins LM, Nakayama T. 1994. Fermentation and sensory characteristics of kimchi containing potassium chloride as a partial replacement for sodium chloride. Int J Food Microbiol 21:335-40.

Code of Federal Regulations. 2007. 21 CFR 101, Food labeling. Available at: http://frwebgate3.access.gpo.gov/cgibin/waisgate.cgi?WAISdocID=69469928114+1+0+0&WAISaction=retrieve. Accessed 25 October 2007.

Cruz AG, Faria JAF, Pollonio MAR, Bolini HMA, Celeghini RMS, Granato D, Shah NP. 2011. Cheeses with reduced sodium content: Effects on functionality, public health benefits and sensory properties. Trends Food Sci Technol 22:276-91.

Desmond E. 2006. Reducing salt: A challenge for the meat industry. Meat Sci 74:188-96.

Directive 2002/46/CE of the European Parliament and of the Council of June 2002 on the approximations of the laws of the Member States relating to food supplements. Official Journal of the European Communities 12.07.2002, L183/51

Di Silva A. 2000. Preliminary results of a new processing in order to obtain green table olives with low sodium content. Ind. Alimentari. XXXIX: 844-847.

European Commission. 1990. Council Directive 90/496/EEC of 24 September on nutrition labelling for foodstuffs. Off. J. Eur. Communities 276:40-4.

European Council. 2010. Council conclusions of 8 June on "Action to reduce population salt intake for better health" Adoption of the conclusion. Off. J. Eur. Union 11.11.2010 C305/3-C305-5.

European Commission. 2012. Commission Regulation (EU) 432/2012 of 16 May 2012 establishing a list of permitted health claims made of foods, other than those referring to the reduction of disease risks and to children's development and health. . Off. J. Eur. Union 25.05.2012 L136/1-L136/40.

Fleming HP, McFeeters RF, Thompson RL. 1987. Effects of sodium chloride concentration on the firmness retention of cucumbers fermented and stored with calcium chloride. J Food Sci 52:653-7.

Flores NC, VanLeeuwen D, Pennock RD. 2007. The effect of calcium on microbial quality and consistency of chile pepper (Capsicum annuum cv. Mesilla cayenne) mash during fermentation. LWT-Food Sci Technol 408:1482-7.

Franco W, Pérez-Díaz IM. 2013. Microbial interactions associated with secondary cucumber fermentation. J Appl Microbiol 144:161-72.

Garrido Fernández A, Fernández Díaz MJ, Adams RM. 1997. Table Olives. Production and Processing; Chapman & Hall: London, UK.

Greubel S, Kluthe R, Zuercher G. 1997. Reduction of the sodium content of common foods. What is required – what is possible? Z Ernahrungswiss 36:76–7.

Guillou AA, Floros JD, Cousin MA. 1992. Calcium chloride and potassium sorbate reduce sodium chloride used during natural cucumber fermentation and storage. J Food Sci 57:1364-8.

Guillou AA, Floros JD. 1993. Multiresponse optimization minimizes salt in natural cucumber fermentation and storage. J Food Sci 58:1381-9.

He FJ, MacGregor GA. 2010. Reducing population salt intake worldwide: from evidence to implementation. Prog Cardiovasc Dis 52:363–82.

He FJ, Appel LJ, Cappuccio FP, de Wardener HE, MacGregor GA. 2011. Does reducing salt intake increase cardiovascular mortality? Kidney Int 80:696-8.

Horita CN, Morgano MA, Celeghini RMS, Pollonio MAR. 2011. Physico-chemical and sensory properties of reduced-fat mortadella prepared with blends of calcium, magnesium and potassium chloride as partial substitutes for sodium chloride. Meat Sci 89:426–33.

Izumi H, Watada AE. 1994. Calcium treatments affect storage quality of shredded carrots. J Food Sci 59:106-9.

Johanningsmeier S, McFeeters RF, Fleming HP, Thompson RL. 2007. Effects of Leuconostoc mesenteroides starter culture on fermentation of cabbage with reduced salt concentrations. J Food Sci 72:M166-72.

Kanavouras A, Gazouli M, Leonidas LT, Petrakis C. 2005. Evaluation of black olives in different brines. Grasas Aceites 56:106-15.

Leiba A, Vald A, Peleg E, Shamiss A, Grossman E. 2005. Does dietary recall adequately assess sodium, potassium and calcium intake in hypertensive patients? Nutrition 21:462-6.

López López, A., García García, P., Durán Quintana, M.C., Garrido Fernández, A. 2004. Physicochemical and microbiological profile of packed table olives. J. Food Prot. 67: 2320-2325.

Lueck E. 1980. Antimicrobial Food Additives. Springer-Verlag, Berlin.

Lynch EJ, Dal Bello F, Sheehan EM, Cashman KD, Arendt EK. 2009. Fundamental studies on the reduction of salt on dough and bread characteristics. Food Res Int 42:885–91.

Mailgaard M, Civille GV, Carr BT. 1991. Sensory analysis techniques. Boca Ratón, FL: CRC Press.

Market Research. 2004. Market trends: low sodium foods. http://www.marketresearch.com/map/prod/1018657.html.

Marsilio V, Campestre C, Lanza B, De Angelis M, Russi F. 2002. Sensory analysis of green table olives fermented in different saline solutions. Acta Hortic 586:617-20.

McFeeters RE, Pérez Díaz I. 2010. Fermentation of cucumbers brined with calcium chloride instead of sodium chloride. J Food Sci 75:C291-6.

Moreno-Baquero JM, Bautista-Gallego J, Garrido-Fernández A, López-López A. 2012. Mineral content and sensory characteristics of Gordal green table olives fermented in chloride salt mixtures. J Food Sci 77:S107-14.

Mulé R, Fodale AS, Bati CB, Tucci A, di Pisa A. 2000. Preliminary results of a new processing in order to obtain green table olives with a low sodium content. Ind Alimentarie XXXIX:844–7.

Naewbanij JO, Stone MB, Chambers IV. 1990. Lactobacillus plantarum and Enterobacter cloacae growth in cucumber extracts containing various salts. J Food Sci 55:1634-7.

O'Byrne CP, Booth IR. 2002. Osmoregulation and its importance to food-borne microorganisms. Int J Food Microbiol 74:203-16.

Ortega RM, López Sobaler AM, Ballesteros JM, Pérez Farinós N, Rodríguez Rodríguez E, Aparicio A. 2011. Estimation of salt intake by 24 h urinary sodium excretion in a representative sample of Spanish adults. Brit J Nutr 105:787-94.

Panagou EZ, Hondrodimou O, Mallouchos A, Nychas GJE. 2011. A study on the implications of NaCl reduction in the fermentation profile of Conservolea natural black olives. Food Microbiol 28:1301-7.

Park HP, Jeong GO, Lee SL, Kim JY, Kang SA, Park KY, Ryou HJ. 2009. Workers intake too much salt from dishes of eating out and food service cafeterias; direct chemical analysis of sodium content. Nutr Res Pract 3:328-33.

Pérez Pulido R, Ben Omar N, Abriouel H, Lucas López R, Martínez Cañamero M, Gálvez A. 2005. Microbiological study of lactic acid fermentation of Caper berries by molecular and culture-dependent methods. Appl Environ Microbiol 71:7872-9.

Reinivuo H, Valsta LM, Laatikainen T, Tuomilehto J, Pietinen P. 2006. Sodium in the Finish diet. II trends in dietary sodium intake and comparison between intake and 24h excretion of sodium. Eur J Clin Nutr 60:1160-7.

Rodríguez-Gómez F, Bautista-Gallego J, Romero-Gil V, Arroyo-López FN, Garrido-Fernández A. García-García P. 2012. Effects of salt mixtures on Spanish green table olive fermentation performance. LWT-Food Sci Technol 46:56-63.

Ross KD. 1975. Estimation of water activity in intermediate moisture foods. Food Technol 29:26–30.

Ruusunen M, Puolanne E. 2005. Reducing sodium intake from meat products. Meat Sci 70:531–41.

Sahin I, Akbas H. 2001. Prevention of Softening in Cucumber Pickle and Determination of Applicable Amount of Calcium chloride ($CaCl_2$). Gida 26:333-8.

Samapundo S, Ampofo-Asiama J, Anthierens T, Xhaferi R, Van Bree I, Szczepaniak S, Goemaere O, Steen L, Dhooge M, Paelinck H, Dewettinck K, Devlieghere F. 2010a. Influence of NaCl reduction and replacement on the growth of Lactobacillus sakei in broth, cooked ham and white sauce. Int J Food Microbiol 143:9–16.

Samapundo S, Deschuyffeleer N, Van Laere D, De Leync I, Devlieghere F. 2010b. Effect of NaCl reduction and replacement on the growth of fungi important to the spoilage of bread. Food Microbiol 27:749-56.

Sleator RD, Hill C. 2007. Food reformulations for improved health: A potential risk for microbial safety? Med. Hypothesis 69:1323-4.

Stone H, Sidel JL. 2003. Descriptive analysis. In: Sensory Analysis. Caballero B, Trugo LC, Finglas P, editors. Encyclopedia of food sciences and nutrition. London: Academic Press.

Tassou CC, Panagou EZ, Katsaboxakis KZ. 2002. Microbiological and physicochemical changes of naturally black olives fermented at different temperatures and NaCl. Food Microbiol 19:605–15.

Tassou CC, Katsabouxakis CZ, Georget DMR, Parker ML, Waldrom KW, Smith AC, Panagou EZ. 2007. Effect of calcium chloride on mechanical properties and microbiological characteristics of cv. Conservolea naturally black olives fermented at different sodium chloride levels. J Sci Food Agr 87:1323-31.

Taylor RS, Ashton KE, Moxham T, Hooper L, Ebrahim S. 2011. Reduced dietary salt for the prevention of cardiovascular disease: a meta-analysis of randomized controlled trials (Cochrane review). Am J Hypertens 24:843-53.

Tsapatsaris S, Kotzekidou P. 2004. Application of central composite design and response surface methodology to the fermentation of olive juice by Lactobacillus plantarum and Debaryomyces hansenii. Int J Food Microbiol 95:157-68.

U.S. Department of Agriculture and U.S. Department of Health and Human Services. 2010. Dietary Guidelines for Americans, 7th Edition, Washington, DC: U.S. Government Printing Office, December 2010.

USDA. 2012. National Nutrient Database for Standard Reference. Release 25. Software v 1.2 11-11-2012.

Viander B, Mäki M, Palva A. 2003. Impact of low salt concentration, salt quality on natural large-scale sauerkraut fermentation. Food Microbiol 20:391-5.

Whelton PK, Appel LJ, Sacco RL, Anderson CA, Antman EM, Campbell N, Dunbar SB, Frohlich ED, Hall JE, Jessup M, Labarthe DR, Macgregor GA, Sacks FM, Stamler J, Vafiadis DK, Van Horn LV. 2012. Sodium, blood pressure, and cardiovascular disease: further evidence supporting the American heart association sodium reduction recommendations. Circulation 126:2880-9.

Yamani MI, Hammouth FGA, Humeid MA, Robinson RK. 1999. Production of fermented cucumbers and turnips with reduced levels of sodium chloride. Trop Sci 39:233-7.

Yoo KM, Hwang IK, Ji GE, Moon B. 2006. Effects of salts and preheating temperature on the texture of pickled cucumbers. J Food Sci 71:C97-C101.

Table 1. Average salt contents in different fermented vegetables on the market.

Product	Salt content (mg/100g)	Source
Table Olives	1,156	López et al., 2008
Sauerkraut	661	USDA, 2012
Pickled, cucumber sour	1,208	USDA, 2012
Carrot, cooked, boiled drained with salt	302	USDA, 2012
Pepper, hot chili, red, canned	1,173	USDA, 2012
Kimchi	641	Park et al., 2009
Capers	2,769	USDA, 2012

Table 2. Main effects of the application of diverse chloride salt on the elaboration of fermented vegetables.

	Microbiological	**Physic-chemical**	**Sensorial**
$CaCl_2$	Decreased microbial growth, mainly *Enterobacteriaceae*	Delayed sugar diffusion, delay in the production of lactic acid, drop in the pH, and improved firmness	More attractive firmness and improved bitterness, hardness, fibrousness and crunchiness
KCl	Slight increase in microbial growth	Slight reduction in lactic acid production	Provided similar saltiness scores to NaCl and their mixtures improved taste
$MgCl_2$	Slight increase in microbial growth	Helped to reduce the pH and increase the titratable acidity	Good taste in fermented cucumbers
$ZnCl_2$	Decreased the growth of yeasts and *Enterobacteriaceae*	Delayed sugar consumption and improved firmness	Improved overall sensory profile, mainly by decreasing bitterness