8 Salt Reduction in Food

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8.1 INTRODUCTION

This chapter will deal with approaches to salt reduction in food products. Salt has a wide range of roles in foods, such as microbiological stability, texture development, taste and flavour enhancement. The emphasis of this chapter will be on flavour, and maintaining consumer acceptance of foods with salt reductions. Some of the different approaches to salt reduction will be introduced, with advantages and limitations to using the different methods, and suggestions for future approaches.

8.2 FLAVOUR PERCEPTION AND SALT

The perception of flavour within a food product is the result of a combination of factors, including the experience of gustatory (detected by the tongue) and olfactory (detected by the nose) sensations (Verhagen and Engelen, 2006). The experience of odour occurs when volatile substances are carried from the mouth up into the nasal cavity, where they bind and interact with a series of specialised receptor cells (primary olfactory neurons) triggering a response which is sent and interpreted by the brain, in conjunction with all of the other odours and tastes (detailed below) which are experienced simultaneously (Coren *et al.*, 2004).

Epithial cells are responsible for taste perception, and are within the taste buds located in the fusiform papillae, which can be found on the tongue and oral cavity (Lindemann, 2001). Five distinct tastes are detected by the tongue: sour, sweet, bitter, salt and umami. More recently, fat (i.e. fatty acids) is thought to be detected, and thus may

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make up a sixth taste sensation. The taste of salt itself relies mainly on the sodium ion component of sodium chloride. Within the body, salt is responsible for controlling blood pressure, cell water content and facilitating nerve impulse transition. The scarcity of salt in natural products, combined with the vital role played by salt in the human body, is thought to be the explanation for the selective, dedicated ability to taste it. However, salt is not just desirable because of its own taste, but also because of its ability to mask other, often unpleasant, tastes such as bitter, and for enhancing desirable flavours. This effect is seen even at levels that are subthreshold i.e. in foods that do not taste salty to the consumer. This has been observed in bread products, for example by Beauchamp and Stein (2008).

The condition in which salt is released affects how it is perceived. For example, the viscosity of the food product may affect how salty the product is thought to be. An example of this is seen where high-viscosity fluids that contain the same amount of salt as low-viscosity versions are perceived as less salty. This is due to differences in mixing: a higher-viscosity fluid takes longer to mix with saliva and as a result less material comes into contact with the oral surfaces that contain the taste buds (Ferry *et al.*, 2006). Similarly, a comparison made between liquid and gelled model cheese structures showed that liquid products were perceived as saltier than gelled versions, despite containing the same levels of salt. This was as a result of increased product mixing and contact with the tongue in the liquid version (Panouillé *et al.*, 2011).

Salt perception is also affected by how homogenous salt is within a product. Noort *et al.* (2010) investigated the effect of an inhomogeneous distribution of salt within bread on perceived salt intensity. Findings show that having alternating layers of high and low salt within the food sample allows a reduction in overall salt level to be achieved, without reducing perceived intensity. A similar approach has been investigated using gelatin as a model food product when considering sugar distribution. Layered gel samples with differences in concentration were used, maintaining the sample structure, whilst reducing overall content. Samples with the same concentration, but a different distribution, were deemed to have more sugar than the homogeneous samples by a sensory panel (Holm *et al.*, 2009).

Not only does the distribution of tastant within the product affect perception, but the release profile can also have an effect. Altering the release of tastant whilst keeping the overall salt content the same has been explored using continuous liquid flow equipment, where the concentration over time can be programmed. One such study on salt shows that release profiles affect overall perception: an initial high burst of flavour results in an overall higher perception of salt than a sustained delivery of the same concentration (Busch *et al*., 2009). For sugar, Burseg *et al*. (2010) showed that up to a 14% enhancement of perceived flavour can be achieved by introducing an early pulse of higher concentration followed by a lower level, maintaining the same overall concentration.

It is agreed then that flavour perception is a complex phenomenom and is different for each person and each product (Boland *et al*., 2004; Etiévant and Andrée, 2006). Our perception of flavour relies not only on the individual taste and odour chemicals in a product, but also their interaction with one another, and their temporal behaviour during eating. For the perception of salt (and other tastes), pure quantity in a product does not necessarily dictate experienced intensity. This is promising for efforts to reformulate food products to contain reduced quantities of salt without affecting product flavour.

8.3 SALT REDUCTION TECHNIQUES

While salt is essential in the diet, excessive consumption has been linked to hypertension and stroke, especially in those with a genetic predisposition (Law *et al*., 1991; Cook *et al*., 2007). The value given to actual amount of salt required for health can vary vastly, based on individual weights, age and lifestyle, with values from as little as 0.5 g per day of salt for adults (National Research Council, 1999) being proposed. Modern food production has changed dramatically in recent years, with processed foods becoming more common and affordable. Foods such as soups, sauces, cereals and processed meats can account for around three quarters of a consumer's daily salt intake. Thus, the salt in these foods leads to many people exceeding their recommended daily allowance (RDA), often without their own knowledge (Bull and Buss, 1980). Salt in food products has multiple roles. For processed foods, shelf life is a major consideration, and as in historic use, salt is used to reduce water activity within the food, thus preventing bacterial growth and extending shelf life. Other major roles of salt are for flavour (as discussed previously) and structuring of products. An example of this is for processed meat products, where salt is needed to increase water retention maintaining an acceptable, juicy structure during cooking (Desmond, 2006). Achieving the consumption target set by the Food Standards Agency (6 g/day) is not possible without the food industry making significant efforts to reduce salt in foods. The value set is considered to be an achievable target, but still in excess of the actual daily requirements. Processed foods, while requiring less effort to digest and often containing higher levels of fat/salt and sugar, are structurally complex, the implication being that reformulation can have effects on other product attributes. In many cases, the removal of salt in excess of around 30% is not possible without adversely affecting the sensory characteristics of the product (Desmond, 2006). As such, a drive towards better understanding, to allow salt reductions without affecting product quality, is underway.

In the next sections a number of possible methods for reducing salt within food products will be proposed, along with the advantages and limitations of each.

8.3.1 Gradual reduction

The desirable salt level in foods from a flavour perspective varies between individuals, and has been shown to be a function of an individual's regular intake of salt (Bertino *et al*., 1982). The authors controlled salt intake at a lower than normal amount in a group of participants for a five-month period. Participants initially rejected the samples as tasteless and bland, but eventually became acclimatised to the lower sodium intake. This would suggest that a radical reduction in salt levels for current processed foods would cause rejection by the regular consumer, who would then move to alternative brands. Despite this, the first stage in efforts to reduce salt in the diet is often a simplistic reduction or reformulation approach, which has been used in a variety of products, such as breads and processed meats. A gradual change is often used to prevent rejection, but the levels of salt are still higher than ideal from a health perspective (Desmond, 2006). This approach can often achieve a reasonable reduction in ingredients such as salt (~30%) and fat without adverse effects on flavour and consumer acceptance (Dubow and Childs, 1998; Girgis *et al*., 2003). The main barrier for greater levels of reduction using this method comes from the potential for rejection. Manufacturers are reluctant to reduce salt within food products below the consumer's ideal level, as it would result in rejection and loss of revenue.

8.3.2 Substitution

Salt substitution is possible by replacing salt with a non-sodium salt or salty compound. In theory, this approach maintains flavour whilst lowering sodium levels. Potassium chloride (KCl) is commonly used as a salt replacement, although complete replacement results in excessive bitterness and the actual achievable level depends on product type (Morris *et al*., 2010), but in some products, such as feta, can be up to a 50% replacement (Katsiari *et al*., 1997). Limited success was achieved with mixtures in cured ham, but no progress with alternative salts was reported (Armenteros *et al*., 2011). Hand *et al*. (1982) describe the sensory properties of frankfurters when NaCl is replaced with magnesium, potassium and lithium chlorides. Magnesium is shown to be unacceptable in all concentrations as a replacement, but limited success was achieved with potassium (30%). Results for lithium show similar sensory properties to sodium in this case, however, it is not approved for food use. Using a mix of NaCl, KCl, MgSO4 and lysine.HCl in the place of NaCl for ground pork has been shown to have a minimal impact on sensory properties, whilst reducing overall sodium levels (Wettasinghe and Shahidi, 1997). Ornithyltaurine is produced in work by Nakamura *et al*. (1996) and used as a replacement in a model food and a soy sauce product, claiming replacement levels of 90 and 50% respectively, above which an unacceptable sourness was experienced.

To combat the negative effects of bitterness from the potassium content, bitter blockers can be used. Previous studies have identified adenosine 5′-monophosphate (AMP) to be able to block the bitter receptors, and so potentially allow higher levels of replacement with potassium salts (Ming *et al*., 1999).

Another common example is the use of glutamates, such as monosodium glutamate and calcium glutamate (MSG and CDG, respectively), both of which have a strong umami taste and some saltiness, and have been shown to retain consumer's liking of the product (Ball *et al*., 2002). With respect to MSG, the disadvantage to this is that the sodium component still remains, and the strong flavour introduced is limited in its application to certain foods. These replacements are not enough to maintain product flavour with reduced sodium levels.

8.3.3 Enhancers

Enhancers work by increasing the perception of other flavours or of salt within a final product, helping to mask the reduction in flavour with the removal of the sodium. This is sometimes as simple as increasing the amount of spices or flavourings within a product. However, the main disadvantage here is the cost of the additional flavourings, which compared to salt, will be higher. One approach in this area is to increase the savoury aroma release from a product, which has been shown to increase the overall saltiness perception in low/medium-salt-containing solutions (Nasri *et al*., 2011). The authors expose test subjects to the aroma of sardines while assessing solutions of increasing salt concentration. Enhancement is significant at the lower levels of salt concentration, but reduces with increasing concentration. Similar work in cheese reveals an enhancement of salty taste when certain aromas, normally associated with salt are used within the cheese (Lawrence *et al*., 2011).

Encapsulated ammonium salts are patented to provide salty taste enhancement, although minimal details are given (Lee and Tandy, 1994).

8.3.4 Complex microstructure and delivery profiles

Current trends in salt reduction tend towards the control of delivery, and more efficient use, of the salt contained within a product. This approach assumes that not all the salt contained within a product is perceived. This is demonstrated by the varying salt perception reported across different products containing equal levels of salt (Koliandris *et al*., 2010). In the first instance, controlling the shape, size and deposition of salt crystals has been shown to affect saltiness perception. This approach is mainly limited to solid products, since the salt crystals do not dissolve. Kilcast and Angus (2007) attemped to alter salt perception in crisps by applying fixed amounts of a range of salt crystal shapes. They showed that finer grades of crystal lead to enhanced perception, which was attributed to faster dissolution rates, and therefore, more salt transporting to the taste buds. Shepherd *et al*. (1989) attempted a similar, but more restricted, study on meat paté. They studied the effects of large or small salt crystals applied to the surface or incorporated into the bulk of the paté. Findings in this case were the same as with the crisps: an enhanced saltiness for the smaller topical crystals. Additionally, both samples with salt applied to the surface were shown to be saltier than samples with salt distributed throughout the product. However, overall liking in the products with topically applied salt was much lower, suggesting this approach is unsuccessful, in terms of hedonics, for this product. The limited number of different samples tested, however, could be improved by varying the ratio of salt applied to the surface and mixed into the product, in the hope of achieving a balance of liking and salt enhancement. As previously mentioned, the inhomogeneous distribution of salt in food products has been shown to enhance saltiness perception. One example of this has been in bread, Noort *et al*. (2010) examined the response of panellists consuming bread with different levels of salt distributed within the samples. This work shows that for solid products at least, the perception of saltiness can be enhanced, to allow a salt reduction of almost 30%, without affecting quality. While the migration of salt in the bread studied is relatively slow, the continued contrast of salt concentration cannot be maintained, making it difficult to implement into a commercial product without a mechanism to prevent diffusion. To address this, the encapsulation of the salt (using a high-melting-temperature fat) was considered in follow-up work, which slows movement, while maintaining the desirable salt enhancement qualities (Noort *et al*., 2012). A similar study using gels as model food products also suggests the use of the same technique for sugar reductions. This study also highlights the potential for structural (and subsequent textural) differences throughout the product as a result of the salt reduction (i.e. its effect on gel strength), although no significant effects on sensory properties were seen in this instance (Holm *et al*., 2009).

For solid products, changing the distribution of salt is often easier since there is no physical movement of the food structure (although diffusion in most cases will occur). For liquids, as the salt is generally dissolved, it is more difficult to achieve an inhomogeneous distribution. A method approach to achieve this is by adding fillers to the product which do not contain salt. For example, in an emulsion product Yamamoto and Nakabayashi (1999) showed that salt perception is enhanced by increasing oil content. This effect is attributed to the increase in salt concentration in the aqueous phase when compared to a sample of equal volume containing no oil. The obvious effect on product texture and physical properties on introducing oil, however, would limit this approach in complex products. As an extension to this Busch *et al*. (2010) formulated model soup products with high- and low-salt-containing particulates with the same overall salt level. They showed that the sample with high-salt-containing particles had increased salt perception over the low-salt particulates, which was mostly attributed to the particulate residence time in the mouth for chewing allowing more salt to be perceived. The main barrier to this approach is stability. As these products were prepared fresh the contrast in salt is high, but for a commercial product the salt would likely reach equilibrium before making its way to a consumer. One potential technology has been identified by Frasch-Melnik *et al*. (2010), with the use of a solid crystal shell, using tripalmatin and monoglycerides around salt-containing water droplets in an emulsion system. This shell allows a fixed amount of salt to be delivered when in the mouth, as the shell melts at body temperature. An extension of this system constructs a double emulsion system (W/O/W) to allow the segregation of sodium salts from other flavourings and compounds in the external water phase, as shown in Fig. 8.1 (Frasch-Melnik *et al*., 2010). In a model gel system, Sala *et al*. (2010) have shown that creating structures which release serum on compression can increase the perception of sweetness over gel systems that do not. The work shows that again around a 30% reduction in sugar content could be achieved by this controlled-burst release mechanism. This approach, however, potentially alters the textural properties of products, result in a change in overall acceptability.

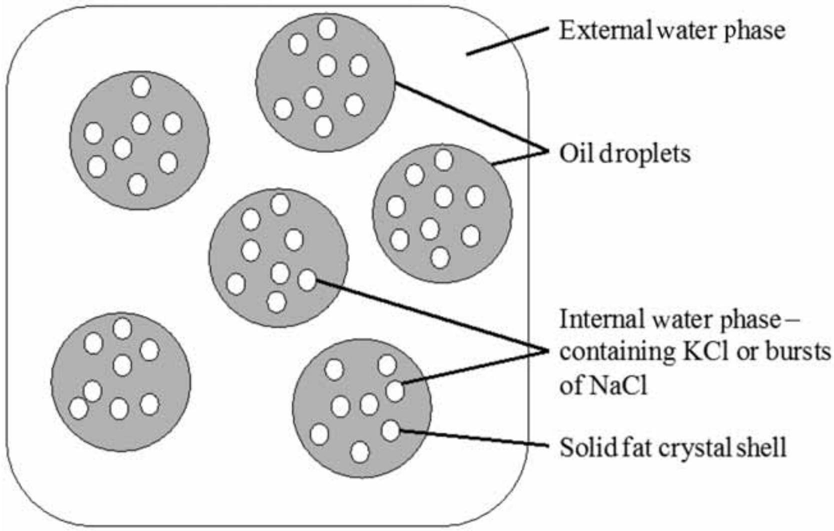

Fig. 8.1 Schematic of a double emulsions system to allow segregation of dissolved species between the internal and external water phases.

8.3.5 Multi-modal approach

As previously stated, the role of salt in foods is more than simply for flavour. Removal of salt requires that the flavour, textural and microbiological aspects of the new product be addressed. It is likely then that methods to successfully reduce salt will need to address each of these items together, so the use of taste, aroma and texture controllers/enhancers with additional preservatives is likely. Combining flavour enhancement methods alone can result in large reductions in salt. Firstly, with the use of non-sodium "salty" compounds a replacement of around 20–30% is identified, with appropriate masking compounds for undesirable flavours. Secondly, the use of flavour enhancers can provide an additional 10–20% reduction. Finally, the use of extra aromas or complex delivery profiles can provide an additional reduction of 10–20%. A schematic summarising the current approaches to salt reduction in foods is shown in Fig. 8.2.

8.4 CONCLUSIONS

Overall, efforts are being made to reduce the levels of salt in processed foods. However, progress is often slow and simplistic. Government legislation is forcing manufacturers to reduce salt levels in food, making it increasingly more difficult to rely on these approaches, so that more

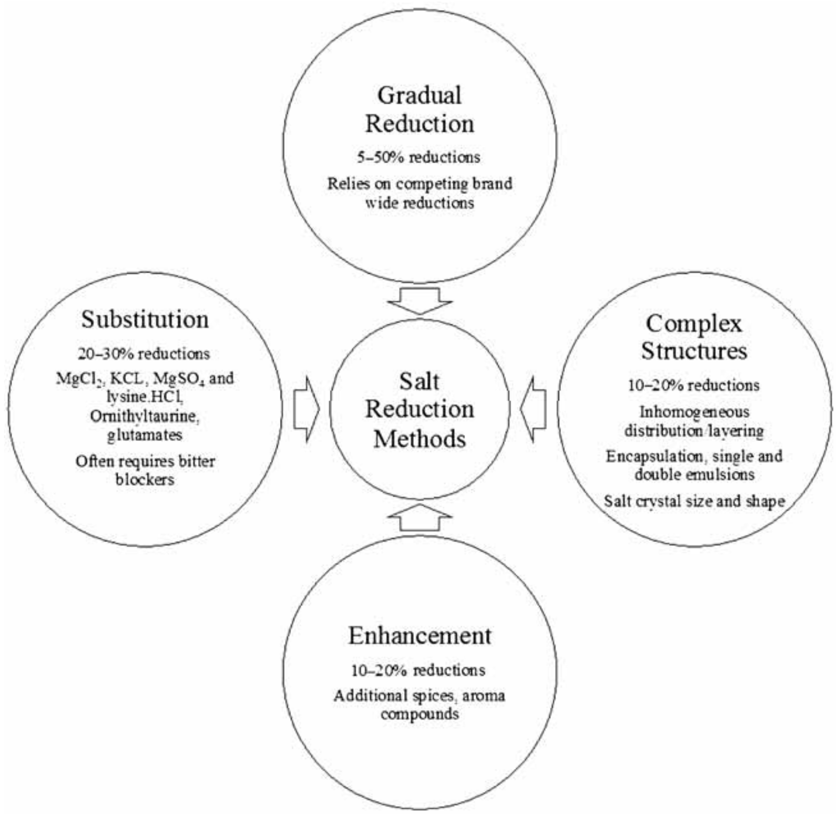

Fig. 8.2 Schematic summarising the current approaches to salt reduction in foods.

complex solutions are needed. These solutions may either be in the form of complex microstructures or in a multimodal approach, building different methods of reduction on top of each other.

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