Campden BRI
Station Road
Chipping Campden
Gloucestershire
GL55 6LD, UK

Tel: +44 (0)1386 842000
Fax: +44 (0)1386 842100
www.campdenbri.co.uk

Review of Current Salt Replacing Ingredients

This review has been compiled as part of Campden BRI's work into researching salt reduction options within the industry.

Contact:

Sarah Chapman
+44(0)1386 842212
sarah.chapman@campdenbri.co.uk

We are also conducting research into the effect of reducing salt levels on the processing and final product quality of bread. For further information on this, contact:

Charles Speirs
+44(0)1386 842284
charles.speirs@campdenbri.co.uk

or

Fred Gates
+44(0)1386 842093
fred.gates@campdenbri.co.uk

Although specific results from these member-funded research projects are confidential to members, we are very happy to talk to anyone who is looking for a centre of expertise to help them reduce salt in their product formulations.

Originally issued Feb 2012

Amended Sept 2014

1: Introduction

The UK's food industry is under continuing pressure from the government, health officials and retailers to reduce the amount of salt in their food products. Recent statistics from the British Nutrition Foundation shows that the average adult consumes between 9-12g of salt per day, compared to the recommended daily amount of 6g (Gilbert and Heiser, 2010; Henderson *et al*., 2003).

High sodium intake can lead to high blood pressure, which is a major risk factor for cardiovascular diseases and strokes (Elliot *et al*. 1996), both of which are leading causes for increased rates of mortality in the UK (Bolhius *et al*. 2011). The majority of the population receive most of their sodium intake from processed foods (about 75%). Nutritionists predict that a reduction in salt consumption to 6g per day would lead to a reduction of 2.5 million deaths worldwide per year (He *et al*. 2008; Macgregor and Sever, 2003).

Food manufacturers are being encouraged to produce products with lower salt contents, within target guidelines, drawn up by the Foods Standards Agency (FSA), and now managed by the Department of Health under the Responsibility Deal (FDF, 2011). However, they face complications, as the consumer will expect "reduced salt" products to exhibit the same flavour and appearance as the original version, but be healthier because of the reduction in salt.

This review focuses on the approaches developed for salt reduction, including salt replacers, flavour enhancing ingredients and other novel methods.

2: Sodium Chloride

Sodium chloride, generally known as salt, is one of the most widely used ingredients in today's food industry, because of its functionality and low cost (Albarracin *et al*. 2011). In food, salt performs a variety of key functions, including flavour enhancement, improving texture, facilitation of processing and, in some situations, its contribution to food preservation.

Processed foods are responsible for 75% of daily salt intake (Beeran and Morley, 2011). The largest salt contributors include processed meats (18%), bread and bakery products (13%), dairy products (12%) and sauces and spreads (11%) (Mhurchu *et al*. 2010). The recent EU Regulation provision of food information for consumers requires food packaging to show the level of salt present in foods. This is calculated by multiplying the sodium content by 2.5.

2.1: Salt reduction and the impact on the food industry

Efforts are being made by food manufacturers to decrease the salt content of processed foods. Tables were drawn up by the FSA that highlighted the salt content of 80 processed food types, including meat, bakery and snack products, and the levels to be targeted and reduced. The tables also declared the target salt levels for 2010 and 2012 (Mhurchu *et al*. 2010).

Salt reduction has its technical difficulties; there are many factors to consider. Added salt is not the only source of sodium in food; other ingredients such as yeasts, as well as functional ingredients including leavening agents, stabilisers, emulsifiers and flavour enhancers contribute to the sodium level; these are not easy to replace and will increase costs (Heidolph *et al*., 2011). However, due to the

rising demands for low salt/sodium products (Verma *et al*. 2009), manufacturers need to quickly and efficiently develop ways which will meet this demand, ensuring that the reduced salt versions are as good as the original products.

Properties that need to be addressed when reducing salt include:

- **Flavour:** A simple reduction in salt will have negative effects on the flavour of food (Verma *et al.* 2009; Gillette; 1985).
- **Texture:** Will be affected, especially in reformed meat products, as the binding capability will be significantly reduced by the reduction in salt, leading to a decline in quality (Terrell *et al*. 1983).
- **Safety and shelf life:** Will be affected as salt is an important ingredient for the preservation of processed meat products, especially cured meat products. Therefore manufacturers need to address this issue before reducing salt to ensure the safety of food products.
- **Functionality:** Is an issue particularly associated with bakery products such as bread. Reduction of salt will affect gluten development, which is necessary for the bread to rise evenly (Food and Drink Federation, 2009). Salt is also an important factor in the Maillard reaction, which is responsible for the golden brown crust on bread (Heidolph *et al*. 2011). Therefore reducing the salt content significantly in bakery products may have a negative impact on the organoleptic quality of the products.

2.2 What has the food industry done to help reduce salt?

Despite the complications of reducing salt, there have been developments of new methods, some of which are proving successful (Daniells, 2010). Current salt reduction methods follow three main approaches reduce, replace and enhance. This includes reduction of salt by stealth, the use of salt substitutes, e.g. potassium chloride and the addition of ingredients that enhance the flavour, e.g. Mono-Sodium Glutamate (MSG) and yeast extract.

The altering of the food matrix, which involves pulsing different salt levels throughout foods, can also enhance the flavour (Heidolph *et al*. 2011) and is another new method involved in salt reduction, which will be covered in detail in a future review.

The above methods can not be applied to all foods. There is not one solution for reducing salt in all foods. One main consideration is whether the salt is present in solution or as solid crystals.

3: Reduction of salt by stealth

Reduction of salt by stealth is a process involving the gradual stepwise reduction of salt in foods over an extended period of time, so that it is not detected by the consumer (Liem *et al*., 2011). Girgis *et al.* (2003) carried out a study on sliced white bread that involved a one-quarter reduction of the salt content over a six-week period; the results obtained showed that the reduction went undetected. Manufacturers known to have used this method include Kellogg's who started reducing salt in 1998, with reductions of 50% in some of their leading brands (Katz and Williams. 2010). They also reported to have reduced the salt content of their corn based products (Corn Flakes, Frosties and Crunchy Nut) and their rice based products (Rice Krispies, Coco Pops and Ricicles) by 30% (Kellogg's, 2011).

Heinz have reported reducing salt content using the stealth method and achieving reductions of 40% in Heinz Beans, 39% in Cream of Tomato Soup, 63% in pasta shapes, 38% in Heinz Salad Cream, 51% in HP Sauce and 29% in Heinz Tomato Ketchup (Heinz, 2011). The decrease in salt has not sparked any consumer rejection and some products will continue to have salt levels reduced further in order to meet the 2012 salt guidelines.

Results of reduction of salt by stealth are positive; however, the amount of salt that can be reduced is limited, as a large reduction will eventually make the product unpalatable and less appealing to consumers (Beauchamp *et al.* 1982). The time needed to successfully reduce salt by this method is generally at least a year, meaning that if salt targets were to decrease further, with a tight deadline to adhere to, food manufacturers could not depend on this method to reduce salt effectively in all food products. Therefore the food industry is also focussing on keeping the strong salty flavour in food, but at a lower sodium level (Dötsch *et al.* 2009).

4: The use of salt substitutes and replacers

The drive from the government to reduce salt in foods has involved much research into improving the acceptability of reduced salt foods (Dötsch *et al.* 2009). This research has led to the development of numerous salt replacing ingredients to enhance the salty flavour and, in some cases, to replicate the function of salt without affecting the sodium content of the foods. Salt substitutes, which are other mineral salts, can impart a salty flavour to food. Potassium chloride (KCl) and modified potassium chloride work best as salt replacers, as other mineral salts such as ammonium chloride, calcium chloride and magnesium sulphate deliver unwanted flavours, which limits their use (Heidolph *et al.* 2011).

4.1 Potassium Chloride

Potassium chloride is the most popular alternative for replacing sodium chloride (Dötsch *et al.* 2009). It stimulates the same receptors as salt, which helps maintain the salty flavour, and can allow a salt reduction of up to 25% (Brandsma, 2007). It can be used alone or in a blend consisting of potassium chloride and sodium chloride (Henney *et al.* 2010).
Current potassium chloride ingredients used for the reduction of salt include:

- Pansalt is a 100% substitution for sodium chloride which has the same taste as normal table salt.
- KCLean Salt® by Wixon is a blend of potassium chloride and sodium chloride and is claimed to achieve up to a 50% reduction in a wide range of products (Wixon, 2011).
- AlsoSalt is a blend of potassium chloride and lysine, which claims to be a 100% replacement for sodium chloride as well as claiming it can reduce sodium by 100% (Anon, 2011a).
- Kalisel is a new salt replacing ingredient which contains potassium chloride, and can be used in bakery products, processed meats and poultry (Anon, 2011b).

There are more examples of ingredients containing potassium chloride, and other salt substitute products included in Table 2.

Frye *et al* (1986) investigated replacing sodium chloride with potassium chloride in a tumbled ham product. They used a 50% blend of potassium chloride and sodium chloride. Their results indicated that the ham blended at this ratio had acceptable sensory and water binding characteristics.

Verma *et al* (2009) also investigated the reduction of sodium, using a salt substitute blend of potassium chloride, citric acid, tartaric acid and sucrose in low fat chicken nuggets. Their results indicated that the saltiness, juiciness and appearance of the low fat chicken nuggets containing the salt substitute blend were similar to the full salt product. However, the texture, flavour and overall acceptability scores were reduced.

Although potassium chloride is popular, there are health and sensory concerns regarding the product. Potassium chloride can generally only substitute up to 30% of salt content in majority of food products; this is because at higher levels, potassium chloride has a noticeable metallic flavour (Brandsma, 2007), which some consumers find unpleasant. The use of potassium chloride to replace salt is more effective in strong, hot flavoured products. In bland or slightly weaker flavoured foods, the bitter, metallic taste is more evident.

There has been concern about an increased consumption of potassium chloride and the health of renal patients, where high intake could have negative health effects. This is because the body is unable to excrete excess amounts, therefore increasing health problems such as the calcification of artery walls and cardiac arrhythmias (Doyle and Glass. 2011).

Although there is a risk to people with kidney problems, an increase in potassium could be very beneficial to other consumers. According to Dötsch *et al* (2009) the reduction of salt and the increase of potassium in the diet can help reduce blood pressure (Geleijnse *et* al. 2003).

As a result of these issues, some food manufacturers are looking for better alternatives to enhance taste, with a better sensory profile, and no potential health issues for the consumer (Brandsma, 2007).

4.2 Modified Potassium Chloride

Due to the bitter /metallic taint associated with replacing salt with potassium chloride in foods, modified potassium chloride has been developed, which exhibits the same functional properties as pure potassium chloride (Nu-Tek, 2011), whilst having a less noticeable taste. This is achieved by the modification of the size of the crystal structure of potassium chloride (Anon, 2011c). Products developed containing modified potassium chloride includes Low-So Salt replacer, which is a blend of modified potassium chloride and rice flour. See Table 2 for a more detailed product list and functionality.

Nu-Tek trialled its modified potassium chloride product in cheddar cheese. They claimed that the sensory attributes of the cheese were just as acceptable as cheese with a standard sodium level, and the shelf life and the texture were also not affected (Isakson 2011).

Pasin *et al* (2008) investigated the replacement of salt with modified potassium chloride in the development of pork sausage patties. The results obtained clearly indicated that the replacement of 75% salt with modified potassium chloride was well accepted in sensory trials. Therefore using modified potassium chloride that does not exhibit the same bitter aftertaste as the standard potassium chloride could be a positive replacement product.

4.3 Other mineral salt replacers

Other salt reducing ingredients have been developed, which contain a blend of milk proteins. The blends are generally used to enhance the flavour of a product, have no bitter aftertaste and are claimed to reduce salt by up to 25%.

A product called “Lacto Optitaste” has been developed by Armor Proteines using the cracking milk process, which produces a mineral compound that gives a salty flavour. Armour Proteines have trialled their product in reduced salt soups, sauces and cheese and have claimed that the taste and microbiological and physical properties of the foods were just as good as standard products (Anon, 2012). Although this product is not an additive and is “clean label”, there is the negative impact of placing an allergen into a product, due to it being derived from milk; therefore this may prevent manufacturers placing it into their products despite the claimed results.

5: Salt and Flavour Enhancers

Another route that food manufacturers are keen to explore is the use of taste enhancers. These have the ability to increase the perceived salty taste, without the high sodium content, by increasing the flavour of products by activating taste buds linked to the umami taste receptors (Brandsma, 2006). In low sodium products the umami receptors can counter balance the lack of sodium, creating the illusion that more salt is present, thereby enhancing the taste; this is especially useful in reduced sodium foods, because as the salt is reduced, the taste enhancing ingredients can be increased, giving a flavoursome product without the high salt content. The umami taste receptors are stimulated by three primary compounds, which are glutamic acid, iosinate and guanylate (Ault, 2004).

All foods contain umami inducing compounds; however, levels vary, with certain foods, including peas and tomatoes, being naturally high in glutamic acid (Brandsma, 2007). Ingredients and additives which exhibit numerous umami characteristics and higher levels of glutamic acid include yeasts, hydrolysed vegetable protein and mono sodium glutamate, all of which are generally used in foods to enhance flavour.

5.1 Glutamic Acid

Glutamic acid is an umami inducing compound and is naturally found in foods. Examples include; protein rich plant and animal foods such as mushrooms, tomatoes, corn and beef (Belitz *et al*., 2009). Glutamic acid is also commercially produced through the fermentation of molasses or the hydrolysis of vegetable protein. It is often combined with sodium, to yield mono sodium glutamate (Ault, 2004; MBM, 2010).

5.2 *Mono Sodium Glutamate (MSG)*

MSG, a combination of glutamic acid and sodium, is the most commonly used taste enhancer in foods. It has a low sodium content of 12g/100g compared to 40g/100g in sodium chloride. It imparts a savoury taste, which stimulates the umami taste receptors, which increases the flavour and perceived saltiness of savoury foods (Henney *et al*., 2010).

MSG has been widely used in foods because of its functionality; it is cheap and easily manufactured and can be used at relatively low concentrations, yet offers a significant impact on the flavour, which is a necessary development in the reduction of salt. Ball *et al* (2002) investigated the use of MSG in a lower sodium soup to see whether they could replicate the same organoleptic properties as a high salt soup. Results demonstrated that the soup with lower salt and MSG was more preferred over the soup with high salt, because the flavour delivery was enhanced.

However, MSG has its disadvantages, being linked with possible health implications including hyperactivity, sickness and migraines (Kilcast and den Ridder, 2007). These disadvantages mean the public prefer products to be MSG free, making it an unpopular choice for food manufacturers to use as a flavour enhancer (Geha *et al.* 2000). Therefore food manufacturers are keen to trial alternative natural flavour enhancers such as yeast extracts.

5.3 *Hydrolysed Vegetable Protein (HVP)*

Hydrolysed Vegetable Protein is a taste enhancer containing high levels of glutamate, making it a suitable product to help initiate the umami reaction. It is commonly found in savoury products, like gravies, soups, sauces, and snack and meat seasonings, as it helps give a strong beefy note.

5.4 Yeast extracts

Yeast extracts are natural taste enhancers, which the food industry is commonly using as replacements for MSG and other artificial taste enhancers. They contain “free” glutamic acid, which is gives a good umami taste, and is low in sodium, that makes them a good substitute for salt replacement, and flavour improvement and enhancement (Brandsma, 2007).

Yeast extracts have been used in the food industry since the 1950’s, and have changed significantly in terms of quality, taste and functionality. There has been development of more natural and lower sodium yeasts extracts, and they can be used in a variety of savoury foods. Yeast extracts consist of the water-soluble contents of the cell, which is made up of concentrated amino acids, peptides, carbohydrates and salts. From this concentration two types of extract can be produced, using two different methods; autolysed yeast extract and hydrolysed yeast extract.

Autolysed yeast extract is produced through the processing of used bakers or brewers yeast. The cell walls are broken down by the application of either heat or salt. This allows the enzymes present in the cell to break down the protein and other cell components. The soluble components are then separated from the insoluble components, and are then concentrated and pasteurised, before being used in the desired application (EURASYP, 2009). The production of hydrolysed yeast extracts involves the use of an acid or alkali, which initiates the hydrolysis of peptide bonds, releasing the glutamic acid.

Yeast extracts can be added to any savoury system, and are commonly used in sauces, gravies, seasonings and snacks. The strong meaty notes are also used to mask any unwanted bitterness from the addition of potassium chloride in solution. This is beneficial as the bitter notes from potassium chloride limit the amount put into foods, meaning that the levels could potentially be increased in products containing yeast extracts (Searby, 2006). There are several yeast extracts available for food manufacturers, such as the Springer range including Springer2000, and the Maxorite range, including Maxorite Delite, KojiAji and Super YE (See Table 2 for a more detailed product list).

Negative characteristics of yeast extracts includes tainting of the flavour if put in foods at a high level. Yeast extracts tend to give a strong meaty/beefy flavour, which some consumers may dislike, therefore manufacturers may need to limit the amount used or find an alternative solution.

5.5 Other natural sources of glutamic acid

Seaweed is a natural rich source of glutamic aid, and has been used in Asian cuisine, as it provides a richer fuller taste in soups and stews. This method is now being marketed and trialled in the western world as a method of salt reduction. One example of this is Organic Mineral Salt produced by Seagreens®. They claim to have achieved a reduction in salt using this product whilst maintaining the flavour of the foods investigated. Seagreens® consists of 50% sea salt and 50% *Ascophyllum nodsum* seaweed (Seagreens Organic Mineral Salt, 2010).

Tomatoes have been used to provide a richer, rounder taste to soups and stews for many years; this is because tomato serum is naturally high in glutamic acid. This high level of glutamic acid has enabled LycoRed to separate the taste enhancing compounds present in tomatoes, without the tomato taste present. The new flavour enhancer is called SANTE, and can be used in a wide range of products from fruit juices, prepared meat products and ready meals to baked goods. The company claims that this flavour enhancer is superior to other flavour enhancers including yeast extract, as it has the ability to balance flavour profiles, it has no distinct taste that may taint foods, and it is stable at most pH's and therefore is able to be used in most applications (Anon, 2011d; Bernhardt, 2010).

5.6 Herbs and Spices

Herbs and spices can also play an important role in salt reduction, as they can maintain high flavour intensity, not a salty one (Gillette, 1985). The addition of paprika, chilli, dill, mint, oregano and basil has the ability to increase the flavour of a seasoning, even when the salt has been reduced; this is particularly useful in seasonings for meat products, snack seasonings and sauces. This salt alternative is a cheap and more natural method of increasing flavour; however, the inclusion of herbs and spices is limited, by the strength of their own flavours.

6. Modified Structure of Sodium Chloride

There has been investigation regarding influence of different sizes of the salt crystal and the rate of dissolution. It is thought that salt crystal shape and size influences the rate at which the crystal dissolves on the tongue and therefore the delivery of the salty taste. It is thought that the smaller the particle size, the faster the rate of dissolution and therefore the rate of perception of salt is increased. This has been supported by a study carried out on potato snacks, in which a potato snack containing the finer salt crystals gave a more rapid release of saltiness than larger crystal sizes (Kilcast and den Ridder, 2007).

There have also been patents developed for enhancing the perception of flavour using a reduced particle size. Jensen *et al* (2011) patented a seasoning and method, which consisted of a particle size of 20 micron. Johnson *et al* (2008) patented a seasoning and a method that contained 20 micron particle size sea salt and flavourings.

Eminate has developed and patented a process in which the physical structure is re-engineered into microscopic particle sizes. The new product, called Soda Lo®, is to be marketed and sold by Tate and Lyle in 2012 (Watson, 2011). Soda Lo is claimed to have the ability to reduce salt up to 50%, but can deliver a stronger, saltier flavour, compared to table salt, and can still be declared as salt on packaging (Bouckley, 2011). It is thought that the microscopic particle sizes are detected more rapidly on the tongue than the original particle size of salt, thus leading to an increased and stronger salty flavour (Watson, 2010).

Eminate has investigated the reduction of salt using Soda Lo in a variety of products, including sausages and cheese products. See Table 1 for their results.

Table 1: The claimed effect of Soda-Lo on the salt content and sensory attributes of products.

Product Type	Salt Reduction	Sensory score
Sausages	25%	N/a
Cheese	50%	No effect on flavour
Vegetarian Sausages	33%	No effect on flavour

(Minter, 2010)

The results indicate that there can be a significant reduction of salt when using Soda Lo, and that the sensory attributes are not affected in different food types. The claimed reduction of salt in cheese, vegetarian sausages and sausages by Eminate is significant, as all have a high sodium content.

7.0 Conclusion

With the high demand from the government, retailers and consumers for a reduction of salt in foods, manufacturers are having to find new ingredients or improved production methods to produce quality lower salt food products. Because of this high demand, new salt replacement ingredients and production methods have been developed for use in various food products. This review has outlined developments in salt replacers and new methods, including reduction by stealth, replacement of salt with minerals and modified minerals, as well as the inclusion of yeast extracts. It has also demonstrated the issues surrounding salt reduction from the effect on flavour, texture and shelf life of products to the problems associated with new ingredients. It can be said that direct replacements for salt cannot be easily achieved; however, with product reformulations, new process developments and quality and sensory issues addressed, there are combinations of approaches that offer potential for further reduction of salt levels in foods.

Table 2: Listing current salt replacing ingredients and flavour enhancers

Product title	Supplier and contact details	Function of product	Manufacturers claims	Composition of product	Manufacturer's suggestions	
Low-So Salt replacer	Malabar www.malabarsuperspice.com	Salt reducer	Dependent on product, but has found a 42% sodium replacement in french fries and 25% reduction in ham.	Modified potassium chloride, rice flour.	Salty snacks Meat products Cheese products	
KcLean™ Salt	**Wixon** www.wixon.com	Salt reducer	Up to 50% reduction.	Proprietary ingredient, sodium chloride and potassium chloride.	Soups Sauces Meats products Frozen entrees Cheese products Meal kits Cereals Dressings Canned foods Battered and breaded products Baked goods French fries	
Kalisel	Kali http://www.kali-gmbh.com	Salt reducer	Up to 30% reduction	Potassium chloride	Bakery products Pre prepared meals Processed meats and poultry Soups and sauces Cheese products Beverages Baby food	
Salt Trim ®, Salt Trim ® Plus, Sea Salt Trim®	Wild Flavours Inc. www.wildflavors.com	Salt reducers	Up to 50% removal of salt	No information available	Soups Processed meat products Pizza Canned foods Salty snacks Sauces Dressings Tomato juice	
Lacto Optitaste	Armor Proteines http://www.armor-proteines.com/ENG/gamme.php	Salt reducer	Dependent on the product, 20% less sodium in cooked meat products, 25% less sodium in baked goods. 30% less sodium in soups	Milk mineral blend	Meat products Baked products Soups Cheese	
Pansalt®	Oriola http://www.oriola.com/	Sodium reducer	100% substitution leading to a ≈77% reduction in sodium	Sodium chloride, potassium chloride, magnesium sulphate and lysine hydrochloride	All applications	

Sub4salt®	Jungbunzlauer www.jungbunzlauer.com/	Salt reducer	100% substitution, leads to a 35% reduction in sodium. Degree of substitution depends on the product	Sodium gluconate, sodium chloride, and potassium chloride	Soups Bakery products Meat products Snacks	
LomaSalt RS50 with $NaNO_2$	www.lohmann-inc.com	Salt reducer	30% reduction in sodium levels	No information available	Cured meat and sausages	
Saltwise™	Cargill www.**cargill**.co.uk	Salt reducer	Between a 25-50% reduction in sodium dependent on the product. At 33% consumer testing showed acceptance for both Salt wise and standard salt products.	No information available	Meat products Salted snacks Prepared foods Frozen meals Processed cheese Soups Sauces and gravies Salad dressings	
Mycoscent	S Black http://www.sblack.com	Salt reducer	Up to 50% reduction in salt for snack food products, a 20-40% reduction in savoury dishes.	Derived from myco-protein.	Snack foods Bakery products Ready meals Soups Sauces and gravies Stock cubes Meat products	
Salt reducer N100 Salt reducer N200	PTX Food Corp. ptxhome2@aol.com	Salt reducer	No Information available	No information available	No information available	
Dr Lohmann's Premix salt replacer	Dr PaulLohmann® www.lohmann-inc.com	Salt replacer for direct usage. Salt reducer.	100% replacement for direct usage and up to 50% reduction in sodium levels.	No information available	No information available	
AlsoSalt	www.alsosalt.com	Salt replacer	100% replacement, 100% reduction in sodium	Potassium chloride and lysine	All applications	
Nu-Tek's-modified potassium chloride	www.nu-tekproducts.com	Salt replacer	No information available	Modified potassium chloride	Processed foods Seasonings Meat and poultry Snack foods	
LomaSalt RS 100, LomaSalt RS Extra, Lomasalt 50 Neutral, Lomasalt 50 Classic	Dr PaulLohmann® www.lohmann-inc.com	Salt replacer	100% replacement of sodium.	No information available	Bakery products Meat, fish and dairy products Processed foods Snacks Condiments	

Soda Lo®	Eminate www.**eminate**.co.uk	Physically modified salt. Salt replacer	Up to 50% reduction in non-physically modified salt.	Sodium chloride, gum arabic	Bakery products Processed meats Confectionery Soups Sauces Snacks Breakfast cereals	
Zalt, Zalt ND	PTX Food Corp. Email: ptxhome2@aol.com	Salt replacer	50% less sodium with 100% replacement of salt	Sea salt, natural flavouring, sodium silicate and magnesium carbonate. Sea salt, natural flavouring, potassium chloride, silica, magnesium chloride	Bakery products	
Maxorite delite, Maxarite B salt, Maxarite D salt, Maxarome select, Maxarome pure	www.dsm.com	Flavour enhancer	Up to 50% salt reduction	Yeast extract	Bakery products Dairy products	
KojiAji	Forum Products Ltd www.Forum.co.uk	Flavour enhancer	No information available	Fermented wheat protein, yeast extract and maltodextrin.	Cheese and vegetable flavourings Meat products Mayonnaise and dressings oil reduction Canned foods.	
Ajimate Super RK, Ajinomoto SaltAnswer	Forum Products Ltd www.Forum.co.uk	Flavour enhancer	No information available	Yeast extract, maltodextrin, sugar, vegetable extract.	Herbs and spice mixes Soups.	
Super YE	Forum Products Ltd, www.Forum.co.uk	Flavour enhancer	No information available	Yeast extract, maltodextrin and salt.	Savoury sauces, gravies Meat and poultry products Tomato, celery garlic and onion based products Spice mixes	
Fonterra Savoury Powder	Fonterra www.fonterra.com	Flavour enhancer	Up to a third sodium reduction	No information available	Dairy products Meat products Snack foods Soups Sauces	
Flavour intensifier 20, Flavour intensifier 30, Flavour intensifier 101, Flavour intensifier 301, Savoury Flavour enhancer 101, Savoury Flavour enhancer 201, Flavour enhancer PM	PTX Food Corp. Email; ptxhome2@aol.com	Natural flavour enhancer	No information available	Cultured whey (if considering maltodextrin as a carrier), modified vegetable extract, maltodextrin	Dairy products	

SavorCrave	Wild Flavours www.wildflavors.com/	Umami flavour enhancer	No information available	No information available	Soups Sauces Dressings and marinades Snacks foods Processed frozen foods Seasonings Meat analogues Condiments, dips and spreads Canned and frozen veg	
UnSal20	Ungerer & Company www.ungererandcompany.com/index.php	Flavours with an increased umami or savoury taste.	No information available	No information available	Soups Sauces and gravies Meat products Ready meals Dehydrated foods	
Seagreens® Organic Mineral Salt	Seagreens® - www.seagreens.com/Products/TheMineralSalt.aspx	Flavour enhancer	100% substitution with salt leading to a 50% reduction in sodium intake	50% *Ascophyllum nodosum* wrack seaweed and 50% sea salt	Topical addition	

This table was compiled in January 2012 and was correct at the time of issue. It provides a list of supplier and ingredient information obtained from suppliers. It is likely that ingredient information will change quite quickly.

References

Albarracin W., Sanchez, I.C., Grau, R., Barat, J.M. (2011) "Salt in food processing; usage and reduction: A review". International Journal of Food Science and Technology. 46 (7): 1329-1336.

Anon, (2010) "Flavour Enhancers"- MBM. http://www.mbm.net.au/health/620-640.htm Accessed 15th December 2011.

Anon (2011a) "AlsoSalt salt substitute" Also Salt website; http://www.alsosalt.com/. Accessed 11th January 2012.

Anon (2011b) "KaliSel". Kali Website, available at http://www.kali-gmbh.com/uken/healthcare_food/products/kcl/kcl993.html. Accessed 12th January 2012.

Anon (2011c) "Low-So Salt Replacer™" Malabar website, available at http://www.malabarsuperspice.com/salt_studies.htm. Accessed 12th January 2012.

Anon (2011d) "The salt replacer with a natural origin". International Food Marketing and Technology. 25 (6): 4-6..

Anon (2012) "Lacto Optitaste- will help you reduce your sodium levels" Armor Proteines product information, available at http://www.armor-proteines.com/ENG/Lactosalt-leaflet-A.pdf Accessed 12th January 2012.

Ault A. (2004) “The monosodium glutamate story: The commercial production of MSG and other amino acids”. Journal of Chemical Education. 81 (3): 347-355

Ball, P., Woodward, D., Beard, T., Ghoobridge, A., Ferrier, M. (2002). “Calcium diglutamate improves taste characteristics of lower salt soups”. European Journal of Clinical Nutrition, 56**:** 519-523.

Beauchamp, G.K., (1982) “Sensory and receptor responses to umami: an overview of pioneering work”. American Journal of Clinical Nutrition; 90 (3) 723S-727S.

Beeran, C., Morley, W. (2011) “Salt and fat reduction”. Food and Beverage International. 10 (1): 20-24.

Belitz, H., Grosch, W., Schieberle, P, (2009) “1.2 Amino acids, Peptides and Proteins”. Food Chemistry: 4th Edition.

Bernhardt, S., (2010) “Taste enhancement from tomatoes” The World of Food Ingredients article, available at http://foodingredientsfirst.com/magazine-digits/Taste-Enhancement-from-Tomatoes.html. Accessed 27th June 2012.

Bolhuis, D.P., Temme E.H, Koeman F.T, Noort M.W, Kremer S, Janssen A.M (2011) “A salt reduction of 50% in bread does not decrease bread consumption or increase sodium intake by the choice of sandwich fillings”. Journal of Nutrition, 141**(**12): 2249-2255

Bouckely, B. (2011) “Pioneering micro salt hits UK high street”. Food Manufacture Website. http://www.foodmanufacture.co.uk/content/view/print/980890 Accessed 28th June 2011.

Brandsma, I. (2007) “Low salt high taste”. Innovations in Food Technology; pp: 72-74.

Brandsma, I., (2006) “Reducing sodium a European perspective”. Innovations in Food Technology; pp 25-29.

Cobscroft, M., Tikellis, K., Busch, J.L.H.C., (2008) Salt reduction - a technical overview. Food Australia, 60 (3): 83-86.

Daniells, S. (2010) “Fat crystal innovation shows salt reduction potential”. http://www.foodnavigator.com/Science-Nutrition/Fat-crystal-innovation-shows-salt-reduction-potential. Accessed 3rd January 2012.

Dotsch,M., Busch,J., Batenburg,M., Liem,G., Tareilus, E., Mueller, R., Meijer, G. (2009) “Strategies to reduce sodium consumption: A food industry perspective”. Critical Reviews in Food Science and Nutrition; 49 (10): 841-851.

Doyle, M.E., Glass, K. A. (2011) “Sodium reduction and its effect on food safety, food quality, and human health”. Comprehensive Reviews in Food Science and Food Safety; 9 **(1):** 44-56.

Elliot, P., Stamler J, Nichols R, Dyer A.R, Stamler R, Kesteloot H, Marmot M (1996) “Intersalt revisited: further analyses of 24 hour sodium excretion and blood pressure within and across populations”. British Medical Journal; 312 (7041):1249-1253.

EURASYP (2009) “Yeast extracts” available at European Association for speciality yeast products website; http://yeastextract.info/yeast-extract/how-it-s-made. Accessed 3rd January 2012.

FDF (2009) “Salt: Industry’s efforts make a difference”- Information from FDF- the voice of the food and drink sector, available at https://www.fdf.org.uk/resources/salt-thefactsfinal1.pdf. Accessed 28th November 2011.

FDF (2011) “Salt”- Information from the FDF website. Available at http://www.fdf.org.uk/keyissues.aspx?issue=623 Accessed 16th January 2012.

Frye, C.B., Hand, L.W., Calkins, C. R., Mandigo, R.W. (1986) “Reduction or replacement of sodium chloride in a tumbled ham product”. Journal of Food Science; 51 (3): 836-837.

Gander, P. (2011) “Crystal clear?” International Food Ingredients. (1): 24-26.

Geha, R. S., Beiser, A., Ren, C., Patterson, R., Greenberger, P.A., Grammer, L. C., Ditto, A.M., Harris, K. E., Shaughnessy, M. A., Yarnold, P. R., Corren, J., Saxon A. (2000) “Review of alleged reaction to monosodium glutamate and outcome of a multicenter double-blind placebo-controlled study”. Journal of Nutrition; 130 (4S): 1058-1062

Geleijnse, J.M., Kok, F.J., Grobbee, D.E. (2003) “Blood pressure response to changes in sodium and potassium intake: a meta regression analysis of randomised trials”. Journal of Human Hypertension; 17: 471–480

Gilbert, P.A, Heiser, G., (2010) “Salt and Health: The CASH and BPA perspective” British Nutrition Foundation Bulletin. 30**:** 62-69.

Gillette, M. (1985) “Flavour effects of sodium chloride”. Journal of Food Technology; 39 (6): 47-52.

Girgis, S., Neal, B., Prescott, J., Prendergast, J., Dumbrell, S., Turner, C., Woodward, M. (2003) “A one-quarter reduction in the salt content of bread can be made without detection”. European Journal of Clinical Nutrition; 57: 616-620.

Hazen, C., (2010) “Reducing Sodium-Maintaining Flavor and Functionality”. Food Product Design. pp:84-98.

He, K., Zhao, L,. Daviglus, M.L., Dyer, A.R., Horn, L.V., Garside, D., Zhu, L., Guo, D., Wu, Y.,Zhou, B., Stamler, J. (2008) “Association of mono-sodium glutamate intake with overweight in Chinese adults: The INTERMAP Study”. Obesity; 16 (8): 1875–1880.

Heidolph, B.B., Ray, D.K., Roller, S., Koehler, P., Weber, J., Slocum, S., Noort, M.W.J. (2011) “Looking for my lost shaker of salt... replacer: flavour, function, future”; Cereal Foods World; 56 (1): 5-19

Heinz, 2011., “Reformulating existing varieties and new innovations”- Heinz- Health and Wellness. http://www.heinz.co.uk/ourcompany/aboutheinz/healthwellness
Accessed 9th December 2011

Henderson, L., Irving, K., Gregory J *et al*. (2003) “National Diet and Nutrition Survey: Adults aged 19-64 Years. Volume 3: Vitamin and Mineral intake and Urinary Analytes. London: The Stationery Office.

Henney, J.E. (2010) “Strategies to reduce sodium intake in the United States” Washington (DC): National Academic Press.

Hunter, F., (2011) “Salt” BBC Health Website. http://www.bbc.co.uk/health/treatments/healthy_living/nutrition/healthy_salt.shtml. Accessed 12th January 2012

Isakson T., (2011) “Sodium reduction in cheese Using Nu-Tek's Modified Potassium Chloride” http://www.ereleases.com/pr/sodium-reduction-cheese-nuteks-modified-potassium-chloride-34384 Accessed 18th August 2011.

Jenson, M., Smith, G., Fear, S., Schilmoeller, L., Johnson, C. (2011) “Seasoning and method for seasoning a food product while reducing dietary sodium intake”. Patent number US 7923047

Johnson, C., Jensen, M., Schilmoeller, L., Smith, G. (2008) “Seasoning and method for seasoning a food product utilizing small particle sea salt”. PCT 20080003339

Katz, B., Williams, L., (2010) “Salt reduction gains momentum”. http://www.ift.org/food-technology/past-issues/2010/may/features/salt-reduction.aspx. Accessed 25th May 2010

Kelloggs.(2011) “Salt Levels in Cereals- Kellogg’s Press Office. http://www.kelloggs.co.uk/whatson/pressoffice/Views/salt-levels-in-cereal Accessed 28th November 2011.

Kilcast, D, den Ridder, C. (2007) “Sensory issues in reducing salt in food products” In Kilcast, D, Angus, F., *Reducing Salt in Foods- Practical Strategies*, 1st Edition, Vol 1, Cambridge, Woodhead Publishing Ltd.

Liem, D.G., Miremadi, F., Keast, R.S.J.(2011) “Reducing sodium in foods: The effect on flavour”. *Nutrients:* 3 (6): 694-711.

Lim, M, Wing, P.L., (2011) “Salt solutions”. International Food Ingredients (2): 35-36
Macgregor, G.A., Sever, P.S., (2003) “Salt - overwhelming evidence but still no action: can a consensus be reached with the food industry?” British Medical Journal; 312 (7041): 1287–1289.

MBM (2010) “Flavour enhancers” MBM Website available at http://www.mbm.net.au/health/620-640.htm Accessed 9th December 2011

Mhurchu, C.N., Capelin, C., Dunford, E.K., Webster, J. L., Neal, B.C., Jebb, S.A.(2010) “Sodium content of processed foods in the United Kingdom: analysis of 44,000 foods purchased by 21,000 households”. American Journal of Clinical Nutrition. 93:594-600.

Minter, S. (2010) “Eminate- BCCC (Soda Lo) presentation. Viewed 25th November 2011.

Nu-Tek (2011) “Modified Potassium Chloride” Nu Tek Website- product Range, available at http://nu-tekproducts.com/modified_potassium.html. Accessed 15th December 2011

Pasin, G., O'Mahony, M., York, G., Weitzel, B., Gabriel, L., Zeidler, G. (2008) “Replacement of sodium chloride by modified potassium chloride (co crystallized disodium-5'-inosinate and disodium-5'-guanylate with potassium chloride) in fresh pork sausages: acceptability testing using signal detection measures”. Journal of Food Science; 54 (3): 553-555.

Searby, L., (2006) “Pass the salt”. International Food ingredients. **(1)**; 1-8.

Terrell, R.N., Quintanilla, M., Vanderzant, C., Gardner, F.A., (1983) “Effects of reduction or replacement of sodium chloride on growth of *Micrococcus, Moraxella and Lactobacillus* inoculated ground pork”. Journal of Food Science; 48 (1)- 122-124.

Verma, A., Sharma, B.D., Banerjee, R. (2009) “Effect of sodium chloride replacement and apple pulp inclusion on the physico-chemical, textural and sensory properties of low fat chicken nuggets”. Food Science and Technology; 43 (4): 715-719.

Watson, E., (2010) “Micro Salt: Coming to a supermarket near you”. Food Navigator website. http://www.foodnavigator.com/content/view/print/354820. Accessed 9th December 2011.

Watson, E. (2010b) “Research: Chilli powder affects salt and flavour perception. Food Manufacturer website, available at http://www.foodmanufacture.co.uk/Ingredients/Research-chilli-powder-affects-salt-and-flavour-perception. Accessed 10th December 2011.

Watson, E. (2011) “Tate and Lyle sees ‘considerable commercial opportunity’ for Soda Lo”. Food Navigator USA website, available at http://www.foodnavigator-usa.com/Business/Tate-Lyle-sees-considerable-commercial-opportunity-for-Soda-Lo. Accessed 9th January 2011.

Wixon (2011) “KCLean Salt- Half the sodium, all the flavour”. Wixon website: http://www.wixon.com/products/brands/brand-kc-lean-salt. Accessed 15th November 2011

Yamaguchi, S., Takahashi, C. (1984). "Interactions of monosodium glutamate and sodium chloride on saltiness and palatability of a clear soup". Journal of Food Science 49 (1): 82-85