THE ROLE OF SALT IN FOOD MANUFACTURE

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Abstract: Salt has a long history of use as a flavouring, flavour enhancer and preservative, but it has other important properties which contribute to the final quality of food. The technological roles of this multi-functional ingredient are described together with examples of foods where its use is important. Examples given include its use in baking, where it contributes directly to the quality of dough fermentation in bread making through its impact on yeast activation, as well as the more obvious effect on flavour.

Not all sodium in manufactured food is the result of salt addition and estimates based on the 1998 United Kingdom National Food Survey demonstrate that 17% of the sodium in foods is attributable to that naturally present in food ingredients. Sodium intakes from domestic food purchases are very similar to estimates from 11 years earlier. Information is also provided on food eaten outside the home.

1. INTRODUCTION

Salt is a crucially important component of food as it provides flavour, flavour enhancement, preservation and palatability to food. For many years there has been a controversy about the role sodium plays in hypertension and this has led to recommendations that sodium intakes should be reduced on a population basis. For the most part these recommendations have not been supported by scientific evidence and have not been implemented by the United Kingdom.

The purpose of this paper is to explore the role of salt in food manufacture and to provide an updated estimate of the average sodium intake of the United Kingdom population. This includes the identification of sources of sodium in the United Kingdom diet, including an assessment of how much of the sodium is either naturally present in foods and food ingredients or is added as salt or sodium-containing food additives.

Salt is widely distributed throughout the world in the form of dissolved salt in seawater, salt lakes and sub-terranean brine streams, as well as being deposited as rock salt in many countries. The oldest method of obtaining crystalline salt is by solar evaporation, but large quantities are either mined as rock salt or dissolved underground and extracted as brine.

For food use, the brine is treated to remove unwanted impurities and the addition of a free-flow agent becomes necessary to aid handling and storage. Sea salt and rock salt are increasingly used in food applications, often perceived as having potential health benefits due to the residual trace amounts of other mineral elements.

2. TECHNOLOGICAL FUNCTIONS IN FOOD

Although salt is best known for its effects on flavour and for its ability to preserve food against microbiological spoilage, it has a wider range of functions in a variety of food categories. An earlier paper by Druce (1) included a review of salt in food technology and the various roles of salt identified there remain relevant today.

Documentary evidence for the use of salt in cooking extends over five thousand years (2), demonstrating the long tradition of salt in food. Until the advent of refrigeration it also provided the main means of preservation. This explains why salt was such an important component of food and why it was seen almost as a currency in some early societies.

The main technological functions of salt are summarised in Table 1.

Table 1

Functions of salt in food

Sensory effects:
- flavour
- flavour enhancer
Preservative
Texture modifier
Fermentation modifier
Synergistic effects

Although it is possible to classify the various functions in this way, salt is often multi-functional in its role as an essential ingredient of many manufactured foods.

Salt interacts with other food components to enhance their natural activity. Flavours, textures and water binding properties are synergistically enhanced by salt in the examples below.

2.1 Sensory effects

It almost goes without saying that salt is a flavouring ingredient in its own right by providing a characteristic salty flavour, either by virtue of its presence in a food product or by addition at the table.

Absence of salt makes many foodstuffs insipid, bland or almost tasteless. On the other hand, it is very easy to over-salt foods, so the area of optimum acceptability is relatively narrow in practice. Baked products, particularly bread and biscuits, cheese, breakfast cereals, and even some sweet products such as meringues rely on salt for optimising their acceptability.

The precise influence of salt on flavour depends very much on the particular nature of the product, particularly the properties of the other ingredients. For example, the effect of salt in frankfurters is altered by the fat content over the range from 5% to 12% (3). Salt is a very important factor in determining the acceptability of cheeses. It reduces bitterness and acidity and this is likely to be due to inhibitory effects on casein hydrolysis as much as the taste of salt *per se* (4). Salt is an important determinant of consumer acceptability in cured meats and replacement of salt by other compounds, such as potassium, magnesium and calcium chlorides, can have a detrimental effect on acceptability (5).

Originally, butter was salted to aid its preservation during transport across the world, but despite the advent of refrigeration and the availability of a range of unsalted and salted butters, salted versions remain popular. Both bread and biscuits require sufficient salt to achieve an acceptable flavour. Optimum acceptability is usually achieved between 1.1% and 1.5% in the case of bread, depending on the particular product.

In many cases it is difficult to distinguish between the direct effects of salt, the masking of undesirable flavours and flavour enhancing interactions with other flavouring ingredients. Salt is often a component of flavourings or mixtures of spices and in cheese the salt level determines a number of important characteristics including flavour.

2.2 Preservative

Salt has been used as a direct preservative for thousands of years, particularly for the extended storage of meat and fish. The preservative action of salt is through a reduction of water activity. This is related to the amount of salt in the water phase rather than the amount in the product *per se*. The salt level and its influence on water activity, in combination with other factors including pH and temperature, are the primary determinants of microbial growth. This is true for the inhibition of both food pathogens and spoilage organisms.

In dried foods shelf-life is extended as a result of water activity being reduced to a level which does not permit microbial growth. In higher moisture content foods the water activity can be reduced by the inclusion of hydrophilic ingredients such as salt or sugar. The optimum concentration of salt may not be achievable in practice due to flavour levels which become unacceptable in many cases, but combined with other preservatives added to the food and appropriate use of refrigeration, salt retains a very important, though often unnoticed, role in maintaining the safety of food during normal storage.

There are many examples where salt contributes significantly to product safety during storage and these include, meat products, fish products, cheese, butter and preserved vegetables.

Salt is a very important contributor to the preservation of meat products such as ham, bacon, sausages, frankfurters, salami, corned beef and many others. It may be added as dry salt or brine and is used in combination with techniques such as drying, soaking and fermentation as well as in combination with other preservative compounds. Similarly, in smoked fish salt plays an important preservative role. In salted fish it acts through direct microbial inhibition, enzyme inhibition and dehydration.

In cheese, particularly those which are not commercially sterile, salt has a vital role in helping to prevent the growth of undesirable bacteria. Pickled vegetables employ salt to prevent undesirable fermentation and to discourage spoilage organisms in acid preservation conditions. Salt is also an essential ingredient of many sauces, enabling ambient stable products to be formulated without additional preservatives.

In preserved meat products salt and nitrite are normally used together to control the growth of pathogenic organisms, including *Clostridium botulinum*. The action also depends on pH and it has been suggested that the level of salt addition in common use could not be reduced further without placing products at risk (6).

Salt may also act similarly with other preservatives and in combination with spices to inhibit mould growth.

In many cases, as discussed further below, salt is being used in combination with other preservative ingredients or contributory factors to enhance their activity. Its role in this respect is especially important in preventing the growth of anaerobic pathogens such as *Clostridium botulinum*.

2.3 Texture modifications

Salt increases the ionic strength in food, enhancing the strengths of ionic bonding between components and reducing inter particle distances. The nett effect observed is a 'toughening' of food texture.

In many foods texture can be as important a determinant of acceptability as flavour. Salt has a major effect on the texture and succulence of meat products. This is through a combination of preventing the meat becoming dry and the solubilising of proteins to create a binding effect between individual pieces of meat. In products such as frankfurters, the fibrous nature of the meat is reduced to an almost rubbery texture and the degree of binding is very high.

Among its other roles, salt is an important determinant of cheese texture. Salting of cheese reduces the water content and affects the rate of ripening, both of which influence the final texture.

Salt is essential in many pickled vegetables, not just for its contribution to preservation, but also for its influence on product texture by maintaining firmness in products such as pickled onions or crispness in sauerkraut.

2.4 Fermentation modifier

The principle of fermentation is applied to many types of food, including bread, meat, dairy products and vegetables.

In the case of bread, salt has an important role in controlling the yeast fermentation as a result of increased osmotic pressure. The outcome is to limit carbon dioxide production, resulting in even textured bread with many relatively small gas cells, creating the type of bread which is desirable in many parts of Europe. Insufficient salt results in excessive fermentation which will produce sour dough with many large gas cells, giving bread with a very open texture (7).

Salt plays a role in the processing and preservation of both fermented and unfermented vegetables. Storage in brine prevents the growth of undesirable micro-flora and light salting has a similar inhibitory effect without preventing fermentation by desirable organisms, such as lactic acid producing bacteria. Examples where salt performs this function are sauerkraut, pickles, soya sauce and various condiments. Similar principles apply in fermented sausages and in cheese production. In cheese production salt is used to control the activity of the starter culture and to control the pH at the desired level. The amount of salt is very dependent on the type of cheese. Starter cultures normally require a low level (around 1% or less) of salt to stimulate their growth, but they are inhibited by 2.5 – 3% or above. In other words, the optimum range of addition for satisfactory fermentation and exclusion of undesirable organisms is quite narrow.

2.5 Salt as a multi-functional ingredient

As indicated above, salt rarely performs only a single function in a food. It usually has a number of roles which together determine the overall quality of the end product, often working in combination with other ingredients in complimentary ways. Bread, cheese and meat products are particularly good examples of the multi-functional role of salt, though many other foods could also be cited.

The baking process depends on salt at the appropriate level of inclusion to activate and control the yeast to produce the optimum degree of fermentation. This is a major determinant of the physical nature of the final product. Unleavened bread products, such as chapatis, contain no salt, whereas European breads need salt for a number of reasons. As well as the effects on yeast, salt has a direct effect on wheat gluten, making it more stable and less elastic. As the salt level is increased the mixing time has to be longer, and the energy input greater, in order to achieve optimum dough development. Thus, the amount of salt added has to achieve the balance of physical effects on the dough and effects on fermentation which give the desired overall product characteristics (8). Flavour is also a significant factor in determining acceptability, and in the United Kingdom the optimum level lies around 1.3% in the finished bread. Sour dough breads may have lower levels, but these then have very different eating characteristics.

Salt is a key factor in cheese production as a fermentation modifier, texture modifier, preservative and flavouring. Salt encourages the growth of the starter culture and at the same time inhibits undesirable organisms. It also assists the enzyme activity during manufacture and the liberation of enzymes which have a role in flavour development. The salt level is critical in preventing bitterness in the cheese which would otherwise result from the hydrolysis of caseins. Salt is frequently applied externally to cheeses where a hard rind is required to protect the cheese during maturation. The range of salt levels encountered across the very many cheeses found in Europe is a reflection of this complex mixture of interactions between salt and other components in order to produce cheeses with characteristic physical and organoleptic properties (4).

Preserved meat products also rely on salt to modify texture, contribute to preservation, optimise flavour and even alter the colour. The succulence of such products would be compromised without the use of salt, though excessive levels cause toughness. As a preservative it is mostly used in combination with nitrite or other preservatives, e.g. sulphur dioxide in British sausages. The effectiveness of these preservative systems is enhanced by the presence of salt.

The list of examples is virtually inexhaustible, but the three cited above serve to illustrate the multi-functional role of salt and the complex interactions involved in optimising product quality.

3. SALT SUBSTITUTES

A small number of products can be found on the market which offer reduced sodium alternatives to table or cooking salt. In all cases it is possible only to replace some of the sodium chloride, otherwise an acceptable flavour cannot be maintained. Usually, potassium chloride is introduced in place of sodium chloride, perhaps in combination with other compounds, such as magnesium chloride or ammonium chloride. In most cases, between a quarter and one third of the sodium chloride is replaced in this way.

So far, salt substitutes have achieved limited success in the marketplace, the value of the United Kingdom market being estimated at around £3.5 million in 1999 (9), representing 19% of the value, but only 4% of the volume of the discretionary salt market. This small market is growing at about 7% per year. Finland, on the other hand, has an estimated market value of £2.2 million but with a population which is one tenth of that of the United Kingdom. This may be a reflection of a strong awareness of cardio-vascular disease among the Finnish population.

4. INTAKE AND SOURCES OF SODIUM IN THE UNITED KINGDOM

Various estimates have been made of the average sodium intake of the United Kingdom population (e.g. 10,11) and these often provide information on the proportions of the average intake contributed by the various food categories. In addition to this, it has been established that discretionary salt, i.e. salt added at the table and in cooking, accounted for 15% of the total intake, most of the remainder coming from the rest of the diet. (12) In an earlier study (13) we estimated the average sodium intake and, in addition, estimated how much of that intake was attributable to sodium naturally present in foods and food ingredients and how much was from non-salt, sodium-containing food additives. The estimates were derived from the 1987 National Food Survey (14) and average sodium intake was calculated to be 2593 mg per day, 22% of which was sodium naturally present in foods and 78% of which was added sodium.

4.1 Methods

A similar estimate has been undertaken to determine whether the pattern of data has changed after a further ten years. Food intake data were taken from the results of the National Food Survey (1998), which included data on food eaten away from home in addition to data on household food consumption. The previous exercise used the 1987 Survey data which was confined to household consumption. It is recognised that there are inherent inaccuracies and variability in food consumption surveys and that an increasing proportion of food is consumed away from the home. Nutritional data used to calculate sodium intake came from McCance and Widdowson's Composition of Foods (5th Edition) and subsequent supplements (15, 16, 17). The number and range of individual foods covered in those publications is significantly greater than it was in the editions available ten years ago.

Table 2
Sources of sodium intake from food eaten at home during 1998 (mg/d)

Food Group	Natural	Added	Total
Milk & Cream	161.6	0	161.6
Cheese	3.7	93.5	97.2
Meat & Meat Products	80.3	514.7	595.0
Fish	24.1	57.2	81.3
Eggs	19.5	0	19.5
Fats	0.7	152.2	152.9
Sugars & Preserves	1.5	0	1.5
Vegetables	40.9	214.3	255.2
Fruit	6.8	2.0	8.8
Cereals	14.2	902.4	916.6
Beverages	4.1	0.7	4.8
Soft Drinks	18.8	0	18.8
Alcoholic Drinks	3.9	0	3.9
Confectionery	5.8	1.0	6.8
Miscellaneous	65.2	256.1	321.3
Total (mg/d)	451.1	2194.1	2645.2

For each type of food considered, a best estimate was made of how much sodium would have been naturally present. For example, in raw meats all the sodium was classified as natural, whereas in a product like bacon, the natural sodium content was taken to be that found in the equivalent cuts of pork. The consumption data were applied to these figures to obtain the natural sodium intakes. Thus, the total intake could be sub-divided into natural and added. Table and cooking salt was excluded from the estimates.

4.2 Results

The results are summarised in Table 2

The total sodium intake was calculated to be 2645 mg per day, which was close to the figure of 2540 mg per day presented in the 1998 Survey. This small difference gives confidence that the basis of the estimates presented here is reasonably sound. Within the total daily intake of 2645mg, the natural sodium intake was 451 mg per day (17%), with added sodium accounting for the remaining 2194 mg per day (83%). The comparable figures from our previous estimate based on the 1987 data were 2593, 580 and 2014 mg per day for total, natural and added sodium respectively. There were no sodium data for comparison in the 1987 Survey. The proportion of natural sodium in the diet is a little lower (17% vs. 22%) and the added sodium higher (83% vs. 78%) than the comparable 1987 data, but that may be as much due to changes in food consumption patterns and analytical data as to any changes in sodium addition to foods. For example, consumption of milk and cream, major contributors of natural sodium to the diet, fell during the eleven year period in question. The 1998 data reveal that the major contributors of dietary sodium were cereal products (35%) and meat and meat products (22%). These compare with 38% and 21% respectively in the estimates derived from the 1987 data.

The data in the 1987 Survey did not take account of food eaten outside the home to any significant extent, whereas the 1998 Survey provided additional detailed data on this aspect of the national diet. Table 3 summarises the natural, added and total sodium intakes for the food groups identified in that part of the survey.

Table 3
Sources of sodium intake from food eaten away from home during 1998 (mg/d)

Food Group	Natural	Added	Total
Ethnic Foods	1.8	25.6	27.4
Meat & Meat Products	8.1	80.4	88.5
Fish & Fish Products	4.4	2.8	7.2
Cheese & Egg dishes & Pizza	2.7	11.8	14.5
Potato & Vegetable Dishes	5.9	13.1	19.0
Salads	0.9	0	0.9
Rice, Pasta & Noodles	0.1	0.7	0.8
Soup	0.7	7.2	7.9
Breakfast Cereal	0	0.6	0.6
Fruit	0.1	0	0.1
Bread	0	11.4	11.4
Sandwiches & Rolls	5.0	48.2	53.2
Miscellaneous	2.2	24.3	26.5
Ice Cream, Desserts & Cakes	2.0	20.2	22.2
Biscuits	0.3	6.0	6.3
Snacks	0.4	11.3	11.7
Beverages	7.0	3.4	10.4
Soft Drinks	7.2	0	7.2
Alcoholic Drinks	2.7	0	2.7
Confectionery	0.9	2.0	2.9
Total (mg/d)	52.4	269.0	321.4

They do not match the food groups in the main survey exactly, so it was not possible to combine the two. The average sodium intake was calculated to be 321 mg per day, again very close to the figure in the MAFF Survey of 310 mg per day.

What is particularly interesting is that out of the total sodium intake, 16% was natural and 84% was added. Within the limits of the estimates, these proportions were very close to the domestic proportions. The amounts of foods eaten away from the home are increasing and the contribution of these to sodium intake is also increasing. This was estimated as 280 mg/d in 1995, 290 mg per day in 1996 and 310 mg per day in both 1997 and 1998. Nevertheless, the data presented in this paper suggest that the proportion of dietary sodium attributable to added sodium is hardly affected.

James *et al* (12) had determined that discretionary salt, i.e. that added in cooking or at the table, accounted to 15% of total sodium intake. Apart from a small proportion (0.6%) from drinking water, the remainder came from food. Table 4 summarises the proportions contributed by the various sources of sodium using the data derived from the results in this paper.

Table 4
Proportions of sodium intake from various dietary sources

Source	% of total
Discretionary Salt:	
Table	9.0
Cooking	6.0
Food:	
Natural	14.3
Added Salt	62.4
Non-salt food additives	7.7
Water	0.6

When the intakes of sodium eaten in the home are combined with the data for consumption away from home, the total sodium intake from food becomes 2967 mg per day. This is equivalent to a salt intake of 7.5 g per day, but as is clear from the data presented, not all the sodium in food is attributable to salt.

5. CONCLUSIONS

Salt has a long history of food use as a preservative and flavouring ingredient, but its role in food production extends far beyond these. Its multi-functional properties mean that its presence in foods is essential to achieve the desired quality and acceptability.

Domestic intake of sodium from foods by the United Kingdom population has not changed appreciably over the last eleven years, though the proportion of added sodium has risen a little from 78% to 83%. This may well be a reflection of changes in the values and range of analytical data used in the calculations rather than significant changes in addition of salt or other sources of sodium. It is noteworthy that the proportions of natural and added sodium in food consumed at home and the increasing proportion of food eaten away from the home were virtually identical.

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