The role of sensory perception and sensory evaluation in the development of reduced sodium foods

INTRODUCTION

Many disease risk factors are associated with ‘unhealthy’ food and drink consumption, including excessive consumption of sodium or salt. According to the Centres for Disease Control and Prevention, too much sodium can increase blood pressure and the risk for a heart attack and stroke (1). In January 2013, the World Health Organisation (WHO) published guidelines saying that adults should consume no more than 2g of sodium, or 5g of salt per day. According to the WHO, public health measures to reduce sodium can include negotiating with food manufacturers to reduce the amount of salt in processed foods (2). Government enforced limits on salt use have become a reality with the March 2013 signing of legislation requiring mandatory sodium reductions in several foodstuffs in South Africa by June 2016 (3). The possibility of similar legislation being implemented in other countries or regions is a topic of some discussion within the media, and political and commercial circles.

Along with a range of other challenges (such as safety, cost, process, shelf-life, etc.), the sensory properties of reduced salt products are often key to their success. In the modern world, many consumers will expect to be able to purchase foods that are healthy and that also taste good. According to Dr. Leon Bruner, Chief Science and Regulatory Affairs Officer for the Grocery Manufacturers Association: “Reducing sodium in products without negatively affecting consumer acceptance must be taken into consideration, because a ‘healthy food’ will not promote health if it is not purchased or eaten” (4). Understanding the sensory profile of food and drinks and how this relates to liking, acceptance and choice is therefore a key tool in the challenge to develop reduced salt foods.

The effect of salt reduction on the sensory profile of food and drinks

The most obvious effect of reducing salt in foods is to reduce saltiness, but other effects are also likely. For example reducing salt may increase bitterness, decrease sweetness, and decrease positive flavours associated with saltiness and sweetness (5). The problem is compounded by the fact that some salt substitutes or replacements can taste bitter, particularly potassium chloride (KCl) (6). Reduced salt foods will often need to be reformulated to ‘add back’ missing flavours, or with new ingredients that will mask bitterness.

In addition to taste and flavour, reducing salt can also affect appearance and/or texture of some food products. For example, Pietrasik and Gaudette (7) found that salt reduction adversely affected some textural characteristics of restructured hams, and that hams containing reduced amounts of salt had different colour attributes compared to that of the control salt level ham.

FACTORS OF RELEVANCE TO SALTY TASTE PERCEPTION AND LIKING

There are a range of factors which can inform both the design of reduced salt food and drinks, and research
to develop these. These factors include thresholds and sensitivities, inherent vs. learnt preferences, adaptation and habituation, personal habits and motivations, and cultural norms and practices.

The detection threshold, recognition threshold, and supra-threshold perceived taste intensity for a given concentration of a basic tastant (including salt), will vary from person to person. Thresholds and perceived intensities will also vary depending on the food and drink context.

In general, liking for most context-appropriate taste stimuli, will show something like an inverted U-shaped trend, increasing with concentration up to a certain point, flattening out, and then decreasing. Therefore, finding the optimum level and its concentration range for a particular food or drink formulation and/or target consumer group can be very important for successfully designing reduced salt foods.

It is believed that environmental factors, including exposure to salty foods may have a large influence on salt taste preference [8, 9]. This is different for example, from sweetness for which there is a clear preference from birth [10]. A potential implication of any learnt liking for saltiness is the importance of children’s diets in establishing their preferences for salty taste. But there is also the possibility that changes (reductions) in salt level in the diet later in life could also affect adult preferences for salty taste [11].

It has been reported that a preference for salt in children that is greater than that in adults emerges between three and eleven years of age, and possibly peaks in the teens [12]. On the other end of the life span, studies of changes in taste perception of basic tastes with ageing are considered by some researchers as not conclusive. The confounding variables include the medium in which tastants are evaluated, and the diversity of older adults [13]. On the other hand, in a systematic review, Methven et al. [14] found that salt detection thresholds increased with age, although the average threshold for older people was found to be below the levels of salt found in most foods. Although variation in sensations from salt have been found to be associated with differences in hedonic responses to high sodium foods and thus sodium intake [15]; it should be noted that given the complexities of individual tastes and perceptions, it is not certain that a reduction in saltiness perception will necessarily always affect pleasure or acceptance of a food or drink. The difference threshold is the amount of salt that needs to be added or taken away for a difference in saltiness to be detected. The difference threshold will vary depending on the individual, the food and drink context, and the original salt concentration. The situation is quite complex in foods because there are mixture effects; reducing saltiness may cause other tastes and flavours to become more prominent and potentially mask the salt that is present. If more is known about salt difference thresholds within various foods, it can be easier to design reformulations.

Long term habituation is also important factor to consider. Psychological and physiological adaptation to saltiness levels in specific foods and drinks over longer periods of time may allow consumers to get used to less salt. This is likely to be more successful where changes are made gradually over time, and is commonly referred to as the ‘stealth approach’ [16].

Short term physiological adaptation can reduce saltiness perception [17]. Structure of foods may also result in some salt not being readily accessible to the taste receptors. The result is that much of the salt that is consumed within a food or drink product may not be efficiently perceived. Research into food and salt structures, and their effects on sensory perception, may help to reduce adaptation and/or create structures that are effective for salty taste delivery.

Habits and cultural norms and practices are a related issue. Individuals need to be motivated and informed to reduce sodium in their diet to look for, buy and consume reduced sodium foods. Some individuals may add salt to foods because it is what they have always done, or that is how the society in which they live prepares or serves specific foods and drinks. Individuals may not be consuming salt at the optimum level for their own tastes, and may often not know how much salt or sodium they are ingesting. For example, a recent eight country study [18] revealed that participants largely underestimated their individual salt intake and they also showed difficulties in identifying the main dietary sources of salt.

OVERVIEW OF SENSORY EVALUATION

Sensory evaluation is a scientific discipline that aims to research and understand the sensory properties of products and the hedonic responses to them. In general, sensory evaluation helps to characterise how the attributes and sensory profile of a product are linked to perception, consumer liking, and ultimately consumer choice.

Within the context of salt reduction, the type of questions that sensory evaluation may help to answer, include:

- How is salty taste perceived and how can salty taste be enhanced?
- How much can salt can be reduced without consumers noticing or rejecting product?
- What can be used as a substitute for salt? How much of the substitute is needed?
- Which structures/formulations promote inherent saltiness?
- What do consumers like? What do they expect?
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therefore time-based methods can also be important. The major time-based methods include measurement and evaluation of a single sensory attribute within a bite or sip during consumption of a portion (time-intensity), measurement of the most dominant sensations at discrete time points over the course of a bite or sip during consumption of a portion (temporal dominance of sensations), and measurement of the entire profile of a product at various points during consumption of a portion or a meal, etc. (progressive profiling).

Panels of assessors are often used in objective sensory evaluation, and key outputs are choice frequencies or average scores. Numbers of assessors are chosen to establish a desired level of statistical confidence, and can vary from as low as eight in some sensory profiling applications, to approximately 60 for some discrimination testing situations, such as paired comparison testing (19).

Consumer sensory research methods
Methodologies and techniques that use consumers reporting on how much they like products and specific product attributes, or which products they prefer, are generally referred to as consumer sensory testing. Three of the most common types of consumer sensory research methods which can be used in the area of ‘reduced’ product development include:

- **Overall liking scales** – quantitative scales that give a statistical indication of overall liking or acceptance and whether there are significant differences between samples.
- **Diagnostic measures** – methods such as specific attribute liking scales, Just-About-Right scales, check all that apply techniques, and ideal profiling. These methods use consumers to determine if product attributes are at their optimum level and give an indication of any changes in formulation that may be necessary.
- **Paired preference** – a simple test in which consumers are asked to choose their most preferred product/s sample of two options.

In general, consumer sensory testing is carried out with demographically appropriate consumers. Enough individuals are recruited to establish a desired level of statistical confidence in the results (this often means at least 100).

Combining objective techniques and consumer response
Objective sensory evaluation is useful for understanding sensory profiles and attribute intensities, whereas consumer sensory testing gives information about liking and acceptance. The output of objective and consumer sensory research methods can be combined to understand key drivers of liking for individuals and consumer segments, and to optimise sensory profiles and formulations or processes (see Figure 1). These combined methods are often referred to as preference mapping or modelling.

**Sensory evaluation in recent research**
Below are a few illustrative examples of the use of objective sensory and consumer sensory methods within the development of reduced salt products:

- **Bubowski and Vickers** (20) determined a set of sequential difference thresholds for sodium chloride reduction in plain water, and in water with added tastes to simulate a more complex-flavoured broth, using paired comparison tests and assessors from a trained descriptive panel. From these thresholds, two series of concentrations were established: a 26-step reduction for salt in water, and a 12-step reduction for salt in water with added stimuli. According to the authors, the difference in the number of steps illustrates the importance of product complexity in determining sensitivity to sodium reduction and provides basic information for manufacturers interested in gradually decreasing salt content of foods without being noticed by consumers.

- **Canto et al.** (21) investigated the sensory attributes and consumer acceptance of low-sodium restructured caiman steaks containing microbial transglutaminase (MTG) and salt replacers (KCl and MgCl₂). Sensory profiles were determined by eight experienced and trained assessors using eleven clearly defined attributes. Consumer panellists evaluated cooked steaks using liking and Just-About-Right scales. According to the authors, their findings suggest that the combination of MTG, KCl, and MgCl₂ can be employed as a suitable salt reduction strategy in restructured caiman steaks without compromising sensory attributes and consumer acceptance.

- **Vella et al.** (22) used a sensory time-intensity technique to evaluate the temporal profile of salty taste of seven varieties of sea salt and a Kosher, table salt, control. There were few differences in the maximum salt taste intensity, but some differences in the salts’ time-intensity profiles. The authors concluded that, based on the fact that the salts did not show large differences in taste intensity, and many of the salts did not contain less sodium than the Kosher control, using the studied sea salts as a sodium reduction strategy was not viable.

**SENSORY INTERACTIONS AND IN VIVO TECHNIQUES**

An interesting area of research is sensory interactions and cross-modal effects. The key question of relevance is: How do perceptions in one sensory modality affect another, and can these interactions be used to help reduce sodium? For example; how might odour, colour or texture increase salty taste or reduce bitter taste? Sensory and consumer research methodologies are being
THE IMPORTANCE OF CONTEXT

In traditional sensory evaluation, context issues were largely designed out of studies, but now are generally acknowledged as potentially very important. Context effects could be related to the product itself (amount, texture, formulation), how it is eaten (container, cutlery, etc.), what it is eaten with (other foods and drinks), the environment (temperature, lighting, sound, etc.), the volume consumed and frequency of consumption, and type and level of social interaction. Different contextual elements associated with eating are likely to affect perception of saltiness and/or acceptance of reduced sodium food and drinks.

Although traditional sensory methods are often based on sampling small amounts of product, in one consumption event; some newer approaches look at preferences and sensory profiles of products over longer time periods and in terms of consumption of realistic quantities. For example, Methven et al. (26) investigated the effect of repeated exposure on liking of no added salt soup. 37 participants, previously assessed for their preferred salt level in soup, were allocated to either an exposure group that received 20 ml soup samples with no added salt, to a group that received a 280 ml bowl of this soup, or to a control group that received 20 ml soup samples containing salt at a normal commercial range. Soups were presented on eight occasions, at approximately daily intervals. Increases in liking of the no-added salt soup were evident starting from the third daily exposure.

In addition to repeated exposure and amount of food, eating context has been shown to potentially have more of an effect on liking of foods than the salt content itself. For example Lucas, et al. (27) found that liking of hash browns was influenced by whether testing was in a laboratory or dining room environment. In a dining room environment, large decreases of sodium content of food were achievable with only minor decrease in liking and no effect on consumption of the food. The ability to perform well-designed and controlled studies, and observe eating and choice behaviour in realistic environments is important. Some research organisations (such as the Institut Paul Bocuse in France, and Wageningen University in the Netherlands) have designed facilities that play a dual role; serving both as a restaurant, and as a sensory/consumer research laboratory.

As well as the environment of a meal, the cutlery or crockery used to consume food could have an effect itself. Colour, shape and form, is an area where interactions and context may help to design reduced sodium foods or enhance consumer’s acceptance of existing products. Harrar and Spence (28) investigated the shape of the cutlery on taste perception of cheese. Participants identified cheese sampled from a knife as saltier than that eaten from a spoon, toothpick, or fork. The authors hypothesised that in cheese shops, samples are often given directly from the knife, and cheese shops often sell more aged, therefore saltier cheeses; so therefore eating cheese from the knife may have enhanced perceived saltiness.

Some recent research has used behavioural economics tools, combined with more traditional sensory evaluation methodologies, to gain a better understanding of how much individuals value ‘reduced’ or healthier foods and why. For example, Amlt and Hersleth (29) investigated salt replacement and brine injection in smoked salmon from objective descriptive, and sensory hedonic perspectives. In addition to liking, consumer participants also evaluated their willingness to pay within an experimental auction type procedure. Descriptive results showed brine injection samples differed in appearance, taste and texture from dry-salting samples, while NaCl + KCl samples obtained the same sensory profile as NaCl samples. Consumers preferred dry-salting samples, but did not discriminate between salt types, neither in liking nor in willingness to pay. According to the authors, the results indicate a market potential for partially salt-replaced smoked salmon.

CONCLUSIONS

Sensory evaluation, which measures perception and liking of the sensory properties of food and drink, is now seen as an important function in many organisations within the...
food chain. This article has attempted to introduce the role of sensory perception in this area, and to explain how sensory evaluation is a vital addition to the tools available for the development of successful reduced salt food and drinks. The wide range of sensory evaluation techniques means that there is the opportunity to examine the effect of salt reduction on perception in both fundamental and applied ways.

REFERENCES AND NOTES