Proceedings of the Nutrition Society (1998), **57**, 603–607

The annual meeting of the Scottish Section of the Nutrition Society was held at Queen Margaret College, Edinburgh on 6 and 7 April 1998

Symposium on 'Taste, flavour and palatability'

Taste and flavour perception

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Sensory science has developed considerably over the past 50 years. A comprehensive review into sensory evaluation was published by Amerine *et al.* (1965). Since then, considerable research has been undertaken by a number of workers into the many facets of sensory science and sensory evaluation.

The present paper attempts to demonstrate the relationships between the individual senses and their influence on taste and flavour perception of food and beverage products.

It is hoped that what is a very superficial view of a huge area will provide sufficient interest, information and reference for those who wish to study the subject in greater detail.

Flavour is the sensation realized when a food or beverage is placed in the mouth, and the overall sensation of flavour is the result of a combination of responses to receptors present on the tongue and in the mouth, throat and nose. These sensory receptors produce signals in the nervous system and enable us to differentiate between products and environments in sensory terms.

The final criteria by which food is judged and wins acceptance relate to sensory properties. How does it look? How does it taste? How does it smell? Individuals use their senses to determine first whether a product is edible and second whether it pleases them. The first is a judgement, the second a reaction, and the more favourable the reaction then the more likely is the product to be acceptable.

Each of the five senses of sight, smell, taste, touch and hearing has a role to play in the sensory evaluation of food and beverage products, and each sense is associated with different types of receptors. Combinations of some or all the senses and other accompanying sensations are associated with taste and flavour perception, influencing palatability and acceptability. The relationship between the different receptors and the senses and related sensations is outlined in Table 1.

Smell: olfactory sensation

Smell is a highly complex sense that, although highly developed, is less-well developed in man than in other animals (Proetz, 1953; Bhargava, 1959). The sense of smell has been widely researched, and much of the literature relating to the anatomy and physiology of the olfactory system is based on research in animals other than man (Wysocki, 1979; Meredith, 1983). It is still, however, a sense that is not completely understood (Guyton, 1991).

The chemoreceptors involved in the sense of smell are the olfactory cells, which are located in the olfactory epithelium at the top of the nasal cavity. The epithelium is covered by millions of hair-like cilia, which sense odorous molecules and stimulate olfactory sensations (Tortora & Anagnostakos, 1984).

For any substance to be smelled, air must be present and the substance must be volatile, i.e. in a gaseous state, so that the particles may enter the nostrils during sniffing. Optimal contact is achieved within 1–2 s (Laing, 1983). The substances must be water soluble to allow the gaseous particles to dissolve in the mucus of the olfactory cells, and lipid soluble to dissolve in the largely lipid plasma membrane of the olfactory hairs, so initiating an impulse that is received in the brain (Tortora & Anagnostakos, 1984). The mechanism by which receptors generate the signals sent to the brain, and the way in which the brain is involved in translation of the information to achieve odour perception, strength and quality, has been researched by Moncrieff (1951), Beets (1978) and Maruniak (1988).

Olfactory cells respond very quickly to stimuli, and some odours can be detected at very low concentrations. Some S-containing compounds such as ethyl mercaptan are detectable at μg/l levels, whilst others such as citrus and mint aromas are detectable at mg/l levels (Lawless & Heymann, 1997). This concentration is the detection threshold, i.e. the

Table 1. The relationship between the different receptors and the senses and related sensations associated with taste and flavour perception (From Guyton, 1991)

Receptor type	Sense and related sensations
Chemoreceptors	Smell and taste
Electromagnetic receptors	Sight
Mechanoreceptors	Touch and sound
Thermoreceptors	Temperature
Nociceptors	Pain

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lowest concentration at which the odour is smelled. It is sometimes called the minimal identifiable odour.

Much of the research into what influences sensitivity to the sense of smell revolves around the threshold levels of the individuals taking part in the tests, each one being his or her own standard. Work by Stevens *et al.* (1988) and Lawless *et al.* (1995) indicate that there is considerable variability both within and across individuals, where individual variation in odour thresholds depends on physiological and experimental aspects of the investigation.

Taste: gustatory sensation

Taste or gustatory sensations occur with stimulation of the chemoreceptors in taste buds on the tongue, soft palate and throat, the majority being on the tongue. The taste buds are small protuberances containing gustatory cells that are stimulated through a taste pore, which is a small opening in the taste bud, so called because of its shape. The rough surface of the tongue is caused by papillae which vary in size and shape. The circular circumvallate papillae contain taste buds; these are the largest papillae and form an inverted 'V' shape at the back of the tongue. Fungiform papillae are mushroom shaped and occur on the tip and sides of the tongue, and most fungiform papillae also contain taste buds (Arvidson, 1979). Moderate numbers of taste buds are present in foliate papillae, which are present in the folds along the sides of the tongue, and other taste buds occur in the palate at the back of the throat. It has been shown that people with higher taste sensitivity possess a greater number of taste buds (Bartoshuk *et al.* 1994). The structure of the taste buds and nerves that innervate the tongue on contact is well documented in a wide range of physiology texts.

Saliva is an important component of taste function because when we taste, we taste in solution with saliva acting as a solvent. Chewing stimulates secretion of saliva, as do the stimuli of thought, sight and smell, and combination of these factors may lead to anticipation of the taste sensation before the product is placed in the mouth. Hence, the well-known expression: 'It makes my mouth water'.

It is generally accepted in sensory science that there are four primary tastes, which stimulate taste buds at specific areas of the tongue. Each primary taste is designated as such by the responses of taste buds to different chemical stimulants. Studies on single taste buds have demonstrated that most taste buds can be stimulated by more than one primary taste stimulus, with one or two predominating (Collings, 1974). As a general rule, however, the specificity theory works well for training sensory panellists to differentiate between the four primary tastes: sweet, sour, salty and bitter. Separate standard solutions are used to demonstrate the taste sensations, where sweet is predominantly recognized at the tip and front of the tongue, sour and salt at the sides, and bitter at the back. The standards normally used to demonstrate the four primary tastes are:

sweet	sucrose,
salt	NaCl,
sour	citric acid,
bitter	caffeine or quinine sulfate.

It can be appreciated, therefore, that sensory evaluation of food and beverage products requires complete coverage of all areas of the tongue in order to enable a complete picture of the taste sensations to be made.

Experience in panel selection has shown that in many instances individuals confuse the sensations of bitter and sour. This occurs not because they are unable to differentiate, but because these two tastes are often present together in products such as lemons and grapefruit, and the result is confusion about specificity. In a training situation, it is quite easy to demonstrate the difference using the appropriate standard stimulus. By concentrating on the specific areas that are most sensitive to these tastes, i.e. sour at the sides and bitter at the back, confusion can be eliminated.

Some substances normally associated with one particular taste sensation may demonstrate other sensations over a range of concentrations. Saccharin, which has considerable use as an intense sweetener, can taste bitter as well as sweet to some individuals. Work by Helgren *et al.* (1955*a,b*) demonstrated that some individuals recognize a bitter taste in saccharin at certain concentrations. This bitterness was originally thought to be due to different preparation procedures, but was actually shown in the Helgren *et al.* (1955*a,b*) study to be inherent in the particular structure of saccharin.

As for the sense of smell, wide variations exist between individuals in their taste sensitivity. Evidence of anatomical influences on the different sensitivities between individuals has been provided by Miller & Bartoshuk (1991), who correlated counts of papillae and taste buds with taste sensitivity. Bitter substances particularly feature in taste sensitivity differences, and of particular interest is the phenomenon of bitter taste blindness, which was initially studied using phenylthiourea, originally called phenylthiocarbamide. Fox (1932) and Blakeslee (1932) discovered that 20 % of the population were unable to taste any bitter sensation. More recent studies into taste blindness have been carried out using the compound 6-*n*-propothiouracil, which correlates with phenylthiourea response but is less toxic (Lawless, 1980).

The same problems of conducting research into sense of taste mechanisms exist as those for research into sense of smell. Lawless & Heymann (1997) cite a number of texts that review the physiology and psychophysics of the senses of taste and smell (Carterette & Friedman, 1978; Finger & Silver, 1987; Getchell *et al.* 1991).

In practical terms the senses of taste and smell contribute greatly to the appreciation and evaluation of food, not least because of their importance in flavour. In the case of flavour perception, taste and smell must be considered not in isolation as individual senses, but in combination with each other and with the other senses, particularly with textural attributes associated with the sense of touch.

Texture

Whilst the senses of taste and smell have been briefly discussed, and are major influences in the perception of flavour, the sense of touch and its relationship to product texture and accompanying tactile sensations in the mouth and nose also has a role to play. The textural properties of a product are perceived by the mechanoreceptors, and may relate to a wide range of sensations such as chewy, crisp, crunchy, smooth and oily. Other associated sensations, such as the cooling of menthol, the bite and burn of pepper and the pungency of alcohol, may produce an irritant stimulation involving the trigeminal nerves described as 'chemesthesis' (Green & Lawless, 1991).

Flavour

The combination of the senses of taste and smell together with tactile sensations of the sense of touch, provide the flavour of a product. When a food or drink product is placed in the mouth the primary tastes are recognized on the tongue, along with the textural and other associated sensations within the mouth and on the palate. Identity is conferred as a result of the volatile components moving from the back of the mouth into the olfactory area where the smell mechanism operates. In real terms, where a loss of the sense of taste is indicated, it is in fact a loss of the sense of smell (Murphy & Cain, 1980). This can be illustrated by the example of the common cold where we can detect the primary tastes, textural attributes and related sensations but not the actual identifying characteristic due to the volatile components. This is because the detection mechanism, the olfactory epithelium, is not able to send the impulses to the brain because the volatile components are impeded by mucus on the surface. This results in an imbalance: the individual has a distorted impression of flavour due to an inability to recognize the volatile components that confer identity. Perception of the combined attributes of the components of flavour by an individual is a combination of physiological and psychological responses that may influence consumer behaviour in relation to food selection, evaluation and acceptance (Lawless & Heymann, 1997).

Taste and flavour perception in product evaluation

Appeal relates to the senses, and the flavour of a product may be the final criterion by which food is judged and wins acceptance by consumers. Reflecting product quality, flavour also indicates to a certain extent something of the processing history of the product as it was developed from the raw materials (Dixon, 1970).

In the case of commercially-available food products, the sense of sight applies to the appearance of the pack or container, the appearance of the product in the pack, and finally the product itself. Initial assessment of quality of products is often made by consumers based on appearance and particularly colour, which indicates ripeness of fruits and vegetables and freshness of meat. The senses of smell and taste indicate typical or expected characteristics such as degree of freshness, appropriateness and quality of flavour, or perhaps an undesirable or unexpected characteristic such as taint from packaging (Lawless & Heymann, 1997). The sense of touch relating to the textural properties of a product and the accompanying mouth sensations may be appropriate or not, and may relate to incorrect storage conditions (Dethmers, 1979). The sense of hearing, which may not normally be considered an important aspect of a food product, can play a role in influencing the acceptance of a product. This applies particularly to some texture attributes such as crisp, crunchy, 'snap, crackle and pop', which are all associated with certain types of foods. If the expected sound does not accompany the eating sensation then some quality factor is deemed to be lacking (Vickers & Wasserman, 1979).

When considering sensory attributes in flavour evaluation, the same attributes may elicit a positive or negative response depending on the product under consideration. What is desirable and acceptable in one product may be unacceptable in another. For example, a certain intensity of bitterness is acceptable in both coffee and beer and varies with type in both cases. It is not, however, a desirable attribute in grapes, bananas and pears.

As well as the intensity of sensory attributes as they combine to produce the overall flavour sensation, order of appearance may play an important part in acceptability. In a study of 'what makes flavour leadership', Sjöstrom & Cairncross (1953) studied a range of brand leaders and listed several factors in common, i.e.:

(1) early impact of appropriate flavour;
(2) rapid development of full flavour in the mouth;
(3) no undesirable characteristics developed;
(4) no residual linger on swallowing;
(5) no undesirable aftertaste.

These factors apply to the eating sequence and are relevant in any situation where flavour is being assessed.

The role of the senses in flavour perception forms the basis for sensory evaluation, which has developed into a recognized discipline involving food-related and behavioural sciences. As well as basic research, sensory scientists are involved in a wide range of activities relating to food and beverage products. These include new product development, ingredient and process modification, product optimization and consumer research (Lawless & Heymann, 1997). It is beyond the scope of the present paper to consider all these activities, but one or two will be discussed.

Application of sensory science to product formulation

The role of sensory science in the formulation of products may be of particular interest to nutritionists, food scientists and dietitians who may be involved in the development of food and drink products for particular groups of people with specific dietary requirements or in other situations where sensory factors may cause rejection of a product.

When considering specific functions of individual ingredients, it is important to realize that altering or replacing one of these may have a considerable effect on the overall perception of the product. This may be beneficial, or it may cause an imbalance of the perceived attributes in the modified product compared with the original (MP Woods, unpublished results).

When formulating foods for specific dietary needs, one factor to be considered is that any modification should result in a product that is acceptable from both the specified dietary requirements and the sensory and palatability point of view.

In a formulation programme, if ingredient X is to replace ingredient Y, the questions to be asked are:

(1) what are the functions of the original ingredients in the product under consideration?

https://doi.org/10.1079/PNS19980088 Published online by Cambridge University Press

(2) what sensory attributes are present when the original ingredient is used in the formulations?
(3) will the new ingredient exactly replace the original without any noticeable difference?
(4) if not, what modifications may be necessary?
(5) what level of replacement is possible and practical?

Reformulation should take all these into account and particular attention must be paid to the overall sensory profile of the product (MP Woods, unpublished results).

Of particular interest is the influence of reports by the National Advisory Committee on Nutrition Education (1983) and the Committee on Medical Aspects of Food Policy (Department of Health and Social Security, 1984), both of which produced guidelines for a healthier diet. The National Advisory Committee on Nutrition Education (1983) dealt with general guidelines for a healthy diet in the UK, whilst the Department of Health and Social Security (1984) concentrated on the relationship between diet and CHD. These were followed by a further Committee on Medical Aspects of Food Policy report (Department of Health, 1991) and the Department of Health (1992) report, *The Health of the Nation*, dealing with the connection between diet and health.

Publication of these reports resulted in a wide range of commercially-available products formulated and developed to incorporate some or all elements of the guidelines. In general the advice given in the reports was that the average Western diet needs to change if the health of the population is to improve. The main recommendations include:

(1) lower fat consumption, particularly saturated fat;
(2) lower sugar consumption;
(3) lower salt consumption;
(4) higher fibre consumption.

The most prevalent area for product development has been the introduction of products where fat has been replaced or substituted to a considerable extent.

As well as providing energy and fat-soluble vitamins in the diet, fat has important functional properties in food preparation. These vary depending on the product under consideration, e.g. for spreading, frying, pastry making or cake making. Any replacement or substitution of fat in an existing product must be able satisfactorily to perform the equivalent function accompanied by the appropriate, desirable attributes, which are generally texture related.

The fact that replacement or substitution of fat as an ingredient may alter other attributes, and the perception of the final flavour and acceptability of the product, is demonstrated by Hatchwell (1994). Research into problems relating to the flavour of low-fat desserts showed that, for instance, as the fat level is reduced in ice cream manufacture, less flavouring is needed. Conclusions like this one can only be reached by conducting sensory evaluation tests, using individuals to describe the effects of altering the formulation on the sensory properties.

As well as product development and ingredient replacement there are other situations where attention to sensory properties can make the difference between acceptance and rejection. Flavour masking and flavour modification are two such instances.

Flavour masking and modification

Where some components of a formulation produce a particular sensory attribute that some individuals find unacceptable, it may be possible to mask the undesirable effect of the component. Masking is defined as 'a complete or partial reduction in intensity of a sensation as a function of other stimuli or sensations that are present at the same time' (Lawless & Heymann, 1997). Bitterness and sourness are examples of sensory primary taste attributes where addition of another primary taste, i.e. sweet, or a strong flavour such as blackcurrant, may reduce the perceived intensity of the bitterness or sourness.

Masking is common in everyday eating habits, e.g. the addition of sugar to modify the bitterness of coffee and sour products such as rhubarb, and the extent of masking or modification is determined by the individual preferences of the consumer. As indicated at the beginning of the present paper, the final criteria by which food is judged are governed by the human response. This response is conditioned by the individual's physiological sensitivity to the senses and his or her preferences. Both these combine to provide the overall perception, which encompasses all aspects of sensory science.

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