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Sensory systems guide our acceptance and consumption of food and beverages

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Our chemical senses evolved to identify nutritive foods and potential toxins, thereby increasing the likelihood of survival and reproduction of individuals who have these capabilities. Thousands of years of securing foods that were nutritionally sound preceded our ability to combine and cook foods. The advancement of mixing multiple foods together and applying heat tremendously increased the palatability and flavour options we had when consuming essential nutrients. In the present, the art of a good chef/cook or product developer is to combine nutrients in such a way as to produce a flavoursome food that we want to consume repeatedly. In commercial terms, a good food-product-developer is one who can create an appetitive food at a low cost. As salt, sucrose, and fat are all cheap and appetitive, they are integral ingredients in many of today’s processed foods. However, a diet rich in salt, sugar and fat has led us down a path of obesity and many diet related diseases. There is no easy answer to overriding what our senses tell us to eat, but an understanding of how our senses work may eventually help us develop a healthy appetitive food supply. What follows is a review on modalities involved in flavour perception and the role they play in flavour.

1.0 Flavour perception

The positive expectations of consuming a food begin when we visualize it and handle it, but the majority of sensory information comes when we take the first bite. The perceived flavour of the food is derived when three independent sensory systems are activated, 1/taste, 2/smell, and 3/oro-nasal somatosensations (irritation, thermal, texture) making flavour a multi-sensory experience (Figure 1).
2.0 Taste

It is widely accepted that there are five major categories of taste quality: sweet, sour, salty, bitter, and savory (umami). Taste is the essential foundation upon which flavour can be constructed and is elicited when saliva-soluble compounds stimulate taste cells in the mouth and throat areas. The majority of taste receptor cells are organized into rosette-like structures called taste buds, which are embedded in folds or lingual bumps called papillae. These papillae are located on the tongue; fungiform papillae occur at the anterior of the tongue, vallate papillae occupy the posterior sides of the tongue and circumvallate papillae are located at the back upper surface of the tongue. In addition, there are large numbers of taste buds on the soft palate and throat in humans, but these do not occur in papillae. Taste buds contain quality-specific taste cells housing receptor mechanisms responsible for detecting compounds that elicit taste qualities (sweet, sour, salty, bitter, umami) (Huang et al., 2006; Mueller et al., 2005). All taste qualities can be experienced at all sites in the oral cavity that contain taste buds; thus, the often-recited theory of a tongue map is incorrect. For example, the tongue map states that the tip of the tongue is sensitive to sweet, the back of the tongue is sensitive to bitter. To convince yourself that areas of the tongue respond to all qualities, dip the tip of your tongue into solutions of tonic water or strong coffee to assess bitterness, honey to assess sweetness, salt water to assess saltiness, lemon juice to assess sourness, and consummé to assess umaminess. As you will find, all five qualities may be elicited from the tip of the tongue.

The tongue is a very complex organ that we almost certainly will learn in the coming years has a greater role in food acceptance and rejection than merely the identification of 5 taste qualities.
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3.0 Smell

Given the small number of taste qualities, it is not surprising that the immense diversity of flavours we associate with foods are primarily derived from the sense of smell, via the volatile chemicals that are released in the oral cavity when food or liquids are chewed and swallowed. These volatile chemicals are known to activate a large family of receptors (up to 350 in humans) (Buck, 1992). Olfactory receptors are located high in the nose, and odorants must travel through an aqueous mucus layer to reach the receptors. There are two routes of activation, orthonasal - when the subject actively sniffs food, or retronasal - where the aroma from the ingested food travels via the back of the mouth/throat. Both routes of activation can result in different flavour perceptions, primarily because food in the mouth is manipulated during mastication creating dynamic release patterns of volatile compounds. In addition, when a food is in the mouth, the tongue is also sending signals to the brain that influence how we perceive aroma (see Flavour as a unitary percept). In practice we see wine judges/connoisseurs actively sniff a wine prior to tasting in the mouth, the active sniffing (orthonasal) provides information that may be masked if the wine was only tasted (retronasal).

4.0 Somatosensations are components of flavour

Irritant and textural sensations are perceptual components of flavour.

4.1 Irritation

Free endings of individual nerve fibers in both the mouth and nose mucosa have specialized sensory receptors that respond to both heat and cold both of which evoke thermal and pain sensations. The nerve fibers are not independent sensory systems, but a component of the pain and temperature fibers that occur throughout the skin (Julius & Basbaum, 2001). A common feature of chemical irritation is the long
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time period of to initial sensation relative to that of taste or smell, due to the time taken for the chemicals to diffuse through the skin to engage receptors on the nerve fibers (Green, 2002). The disparity in time onset between the odour/taste and chemesthetic sensations adds complexity to the perception of flavour.

There are a number of chemicals that are capable of activating irritant sensations and different adjectives to describe the sensations; the burn of chili pepper, the warmth of ethanol, the tingle of CO₂, the pungency of wasabi. However, the terminology associated with irritant sensations lacks the qualitative breadth of sense of smell sensations and may be influenced by the taste and smell co-elicited with the irritation. For example, the perceived irritant burn from chili pepper or pungency from wasabi may be the same irritant sensation, but when chilli pepper or wasabi are eaten they appear perceptually distinguishable. This may be due to the interactions of irritation with the taste and odour components rather than the quality of irritation per se.

4.2 Texture

The importance of texture to flavour should not be underestimated. The thought of eating entirely puréed foods would not only modify the pleasure of eating but also cause problems identifying the foods you eat. In a study where subjects were asked to identify pureed foods, only 40% of foods were correctly identified (Schiffman, 1977).

4.2.1 Visual texture

Before we physically contact a food, our eyes tell us much about the object: shape, color, size, and surface characteristics. Walking around the fruit and vegetable department of a supermarket will reveal many examples of visual texture, the limpness of celery or the wilting of spinach are both examples of how sight can
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prepare or predispose a consumer to the quality (and flavour) of a product. Visual texture is primarily influenced by the surface characteristics of foods; if the potato chip looks soggy or the asparagus stalk has developed wrinkles the expectation of the perceived texture, flavour, and liking of the food is affected. By examining the movement of liquids we can assess the viscosity of a drink – a thickshake will appear more viscous than a glass of apple juice. In addition, if the color of a product is incongruent with the flavour (e.g., a blue coloured coffee) the identification and perceived intensity of the attributes of that product will be affected. Our vision provides expectations of texture and flavour even before we have touched or eaten the food, largely due to associations between appearance and flavour.

4.2.2 Auditory texture

When we eat potato chips distinctive sounds are emitted when our teeth break the chip, or when we open a bottle of soda and hear the pressure release signaling a lively carbonated beverage. If the sounds from such examples are not crisp/lively the expectations of freshness and liking of the product will be diminished. Prior to the food entering the oral cavity we have gathered much information on the possible oral tactile texture.

4.2.3 Tactile texture

Oral texture is the perception that arises when food interacts with teeth, saliva, and tactile receptors in the oral cavity (Szcesniak, 2002). The oral mucosa supports many nerve endings beneath the skin that are sensitive to touch, pressure and vibration, and the oral muscles, tendons, and joints are innervated and relay information on jaw position to central processing areas. Teeth are also highly sensitive to pressure and tension. The first bite and manipulations of the food are the most important in assessment of texture. When you bite into a cracker, the first few
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jaw movements collapse the food structure and provide information about the quality and flavour of the cracker. If the cracker is soft to the first bite, we assume it is partially stale. As the process of mastication continues the texture of the food changes as particle size of the food is reduced and a bolus suitable for swallowing is formed with the addition of saliva. The change in texture during eating is responsible for the enjoyment of eating certain foods (Hyde & Witherly, 1993). It is also worth noting that the process of chewing varies among people and this affects the food breakdown and subsequent texture and flavour of the food. While texture descriptors such as hardness may be conceptually understandable and relatively easy to measured on a category scale for hardness [from Philadelphia cream cheese (soft) to rock candy (hard)], other flavour descriptors such as ‘beany’ in soy milks are very complex and involve multiple perceptual phenomena (Keast & Lau, 2006).

5.0 Individual differences

We all have our own flavour worlds. For example, what one person believes is extremely bitter and unpleasant another may like and perceive very little bitterness (Keast, Bournazel, & Breslin, 2003). There will be variation in perception from myriad sources, including sensory adaptation, background noise in the nervous system, as well as a variety of peripheral receptors being activated during the course of eating. Just as each individual has quantitatively distinct facial features (e.g. different shape noses), so they have quantitatively unique sensory systems. The difference in sensory processes among peoples manifests when we respond to flavour-active compounds or foods – one person states that a specific beer is too bitter, another finds it a perfectly balanced beverage. Sensory evaluation of a food has become a valuable scientific tool for product developers to overcome individual differences and minimize the risk of producing a food the general population will
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reject. Sensory evaluation will be a valuable tool in the development of healthy appetitive foods for future generations.

6.0 Flavour as a unitary percept

In general, when we eat foods we do not perceive taste, odours, somatosensations individually, we perceive them together as a unitary flavour (Prescott, 1999). The concept of flavour as a unitary whole is enhanced by the fact that the flavour sensations are perceived in the mouth, rather than the nose where the majority of characterizing information of a food originates. If we drink coffee, we experience all the flavour in our mouth, yet only bitter, sour, and thermal heat (sweetness if sugar is added) have oral origins – the remainder of the flavours originate in the nose. It is during the processing of the sensory information in the cognitive centers of the brain that the perception of the flavour of the coffee (or any food) is transferred to the oral cavity – a phenomenon named taste capture of odour.

7.0 Flavour as a driver of consumption

Salt, sucrose, and fats were nutritionally valuable and scarce to our ancestors, but are now cheap, plentiful and at the heart (pun) of the non-communicable disease epidemics in the developed world. Over millions of years of evolution, our sensory systems were tuned to identify foods containing salt, sucrose, and fat as being crucial for survival. Hence we developed an appetitive response to these foods. With the food supply being plentiful, and food manufacturers producing foods high in salt, sucrose sand fats, the evolutionary requirement of our senses to drive consumption of appetitive foods is leading us down a path of obesity and hypertension. As we learn more about the workings of our sensory systems, food manufacturers, governments and scientists should develop ways to limit over-consumption by utilizing knowledge of our sensory systems, which are undoubtedly the drivers of consumption.
8.0 *Tricking our flavour systems*

Perhaps the best case study regarding the ‘tricking’ of our sensory systems is the development of non-nutritive sweeteners. Now a billion dollar industry, low or no-sugar products deliver sweetness without the added energy of sucrose or other sugars. The non-nutritive sweeteners activate the same receptor as sucrose. However, an ideal mimic of sucrose has yet to be developed, for example we can still differentiate between products made with sucrose or aspartame. The reason we can pick a non-nutritive sweetener is that the taste quality ‘sweetness’ is only one of the dimensions of sucrose, any replacement sweetener must mimic the duration and location of sweetness in the mouth. Through prior exposure to sucrose we are accustomed to its flavour dimensions and we notice when these dimensions (duration and location of sweetness) change. However difficult it may be to create an ‘ideal mimic’ there are currently many adequate non-nutritive sweeteners on the market. As our knowledge advances, we must also attempt to develop adequate replacements for salt and fat by ‘tricking’ our sensory systems.

9.0 *Summary*

Our knowledge of our senses involved during eating has developed markedly over recent years and we will continue to learn more about our sensory systems and how they guide us to appetitive foods. Understanding how our senses work is one step along the path of creating appetitive foods that will not create diet-related disease conditions.
References


Figure 1 Basic schematic diagram outlining the key sensory attributes involved in flavour perception.