Sensory Assessment of Food Qualities

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1 Introduction

What is quality and how should we measure it? Not an easy question to answer, so we will begin by examining what the current practices are throughout the existing food chain from primary producer to consumer.

The primary producer mostly easily measures quality by the value of the sale of the product, which is often related to its appearance and composition. Normally this results in a grading system by which a standard set of parameters are measured such as size, shape, degree of damage, uniformity of colour and some more descriptive compositional variables such as fat content, sugar content, *etc*. These generally agreed 'grades' allow the producer to set targets for his production and husbandry.[1] The manufacturer, on the other hand, will relate his product quality again to composition, but also to sensory characteristics which he believes the consumer values. The retailer has an even more direct measure which can be simply related to the speed at which the product disappears from the shelf and the number of subsequent complaints received on the performance of that product in the consumer's home. Finally, the consumer makes a complicated assessment of quality which relates to a whole host of factors which in many cases are not properly understood. Notice that all these measurements relate to existing products in the food chain, against which quality criteria or quality assurance can be set. A quite different issue is the fundamental understanding of how and why consumers recognize quality and subsequently pay for it. Let us begin at the easier end of this problem, by understanding some of the criteria for the measurement of the quality of existing products. This is usually known as quality control or quality assurance.

2 Quality Control and Quality Assurance

There are certain mandatory measurements that the law requires to be made on

[1] United States Department of Agriculture, *U.S. Standards for Grades of Slaughter Cattle*, USDA, Washington, 1997. United States Department of Agriculture, *U.S. Standards for Grades of Fresh Tomatoes*, *Fed. Reg.*, 1977, **42**, 32 514.

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raw materials and finished products throughout the food chain. First, they must be safe, that is to say free of toxins, bacteria and other hazards which may be encountered when the food is ingested. Next, the law frequently defines compositional requirements to be given such as protein, fat and water content, the presence of additives, whether these are as processing aids, preservatives or texture and flavour improvers, and finally the nutritional contents, amino acids, carbohydrate and calorie level, nutrient balance, *etc*. These legal requirements are usually embodied in national legislation of composition and labelling. The extent to which labelling is required to describe the product itself continually changes and is constantly subject to revision. Innumerable texts have been written on this subject so it will not be discussed further here.

There is, however, another set of optional measurements which in most cases are designed to standardize the product at the point of delivery or the point of manufacture. The law does not require these measurements to be made but frequently producers, whether of primary or manufactured products, use these techniques simply to assure themselves and their customers that the product is of a constant and reliable performance, so that consistency at the point of purchase is assured to the consumer relative to their expectation. Ideally these tests would be on-line or immediately post-line with regard to the manufacturing process, relate exactly with consumer perception and preference, and be cheap. This, at the moment, is quite impossible, although the search for instrumental methods which directly relate to consumer perception is constantly under investigation. In the absence of accurate instrumental methods, human tasters are frequently employed. Note that they are not required to make judgements of their personal liking of a product, merely to assess whether there is consistency in the appearance, taste, texture, *etc*., of a particular product form. Amongst these experts we can place wine tasters, tea tasters, cheese tasters, *etc*. These individuals, by virtue of the fact that they taste many products, have a developed accuracy in measuring sensory parameters. In quality assurance there is no particular interest in the method by which accuracy is achieved, only that it is reproducible. Since this is a fairly routine task, there is a danger that the expert will be fatigued and not maintain the standards of accuracy.

There are, therefore, other methods which are purely objective and derived from some physical or chemical device which produces measurable quantity by a standard method.[2] Provided the instruments are properly calibrated and maintained there should be no drift in these quality assurance tests. Amongst these tests we note that the methods are usually related to the assumed quality that the consumer perceives. For example, we have 'tenderometers', which are mechanical devices measuring forces in deformation involved in the fracture of a food which are believed to relate to the same sensory parameter. In fact, in quality assurance the exact correlation is not necessary since the objective of quality assurance is to maintain the product with the same objective value of the measurement, rather than to understand the product's actual performance during eating. In quality assurance we are only concerned with the drift in a

[2] American Oil Chemists' Society, *Official Methods & Recommended Practices of the AOCS*, 4th ed., 1990, official method Cd 16-81, official method Cc 16-60.

particular product from its standard performance. It is always assumed that this performance already intrinsically has a valuable quality, otherwise the product would never have been bought in the first place. It is important to recognize that quality assurance measurements made on products are required to detect deviations from an accepted norm in flavour, colour, texture *etc*. They do not have an exact correlation or relationship to true perception by the consumer. There is a somewhat mistaken belief that a series of highly quantifiable and highly correlated feedback quality control tests would be of value. In many cases they would be interesting, but the expense which they would add to any manufacturing process would put a product outside the range of its competitors. Instead, the only requirement for a better commercial solution is to standardize the process and the raw materials and simply measure that the resultant product has not deviated significantly from the norm.

So much for the practice of quality assurance in the production world; we now turn to the attributes which consumers measure when making their own personal quality judgements.

3 Consumers and Quality

Simply by considering our own behaviour, we can recognize that we make an enormous range of judgements when purchasing any product. In the case of foods which are purchased on a regular basis and are relatively cheap (compared to other consumer goods such as cars, televisions, refrigerators, *etc*.), our judgements are rapid and frequently not subject to a process of conscious thought. Instead, we behave in a somewhat scripted fashion.[3] That is to say, we have an in-built set of behaviour patterns which we carry out almost automatically. These judgements have been derived and defined by the simple frequency of the operations we carry out. There appear to be two types of properties we measure when choosing a product. They are intrinsic and extrinsic qualities. The intrinsic properties relate to the product's appearance and our remembrance of comparable performance in terms of flavour, texture, convenience of preparation, stability, *etc*. All these are the properties of the product itself. In addition, however, we superimpose on these qualities our expectations of its performance, our own habits of use and any information we have acquired on its price, its market position and the influence of its brand image through advertizing. We *perceive* these properties so rapidly that we scarcely remember doing it. This perception process is only the first stage of our action. The second, which determines whether we choose to purchase, is determined by our judgement as to whether we like the product for both its intrinsic and extrinsic properties. A successful product in the marketplace fulfils all of these attributes and then becomes part of our accepted product usage. With this in mind, it is not too surprising therefore that the simple question to the average consumer 'Why do you like that?' can result in the answer 'I don't know, I just do!' The task of quality investigation therefore becomes a problem of disentangling the enormous number of rapid subconscious judgements that are

[3] R. P. Abelson, *Am. Psychol.*, 1981, **36**, 715.

Figure 1 Consumer test questionnaire

Turkey soup sample

Dear Homemaker

Accompanying this questionnaire is a sample of Turkey Soup. Prepare the soup according to the directions within the test period. After using the soup, please indicate how much you like or dislike it. Use the scale to indicate your attitude by checking at the point which best describes your feeling about the soup.

Please write any comments you have regarding the soup in the space provided. A completely frank and honest opinion will help us determine the product that will best suit consumer needs.

Signature: ______________________ Address: ____

Homemaker

Like extremely ___ Comments: ____________________

Like very much ___

Like moderately ___

Like slightly ___

Neither like nor dislike ___

Dislike slightly ___

Dislike moderately ___

Dislike very much ___

Dislike extremely ___

made in deciding a product's quality and identifying which of these can be manipulated successfully to produce some improvement.

Use of Consumer Questionnaires

Although many consumers cannot give a detailed description of why they prefer or like a product, they are always prepared to give a view. We can begin by controlling the input variables on the samples provided to the consumer whilst asking them to state their liking. Figure 1 shows a simple and typical questionnaire in which the variables are controlled. Notice that the consumers have no information on the extrinsic variables of brand, price, market position, *etc.*, but are given a sample in which their liking is scored under the well-established hedonic liking scale. The input of any consumer will be influenced therefore by their expectation of the product, their habits of usage and their perception of its intrinsic properties. Provided a reasonably high score for liking is achieved, we have learnt that whatever the properties were and however they were judged, the overall product is acceptable. Notice the consumer is given an opportunity to comment. This is not necessarily required but frequently consumers are happy to do so; if a common statement across a broad sector produces a simple comment, then this provides some outline information on what parameters may be determining their overall liking. The selection of consumers to be interrogated is in the hands of the experimenter, so that by using this simple technique, differences in liking between various demographic groups can be mapped.

This is known as a monadic test (only one sample is used), but similar methods can be made more and more sophisticated. For example, in a Paired Comparison Test, two samples are presented to the consumer who is asked to choose the preferred sample. If the difference in formulation or process is known by the experimenter, then a direct relationship between manufacturing process and preference can be drawn. The robustness of the result obviously depends on the number of consumers sampled, and in comparison tests an analysis referring to the Assured Judgement (*i.e.* the probability that the choice is outside a simple random phenomenon) is given by:

$$\text{Assured judgement} = NP + (0.5 + Z\sqrt{N})P$$

where N = number of subjects, P = probability of chance = $\frac{1}{2}$ and Z = deviate value. Thus for 24 panellists

$$\text{AJ} = 24/2 + \frac{0.5 + 1.96}{2}\sqrt{24} = 17.05$$

Therefore if 18 panellists agree, their judgement can be assured to be outside random chance.

At the next level of sophistication a triangle test can be used in which three samples are presented, one of which is different from the other two. The consumer is requested to identify the odd sample and asked the subsequent question of whether the duplicates are preferred or the odd sample is preferred.

A further extension of the Paired Comparison method is the 'Rank Order Method'. All samples of a set to be compared are presented at the same time. The task is to rank the samples in order from least to most preferred on some predefined dimension. It has the advantage that more than two samples can be evaluated in one test. However, since considerable concentration is required by the consumer, it is more appropriate to carry out these tests in a controlled environment. The significance of the rank ordering can again be subjected to mathematical analysis and frequently the Friedman test is applied.[4]

The above examples relate to consumer liking or preference, which they find easy to score. It is possible to probe consumer perception using similar methods provided that the stimuli presented are very simply different from each other. For example, it is equally possible to carry out paired comparison, triangle and rank order tests with consumers in which the levels of a single attribute are measured such as sweetness, saltiness, toughness, *etc*. Again, if the formulations or processing of the presented samples is carefully controlled, one can obtain direct relations between the product and its perceived attributes.

Trained Panellists

We noted earlier that individuals who regularly taste foods are capable of developing highly sophisticated articulation of what they are sensing, the classic example being the wine connoisseur. Whilst some of these individuals may have highly developed senses of taste and smell, the significant difference between them

[4] J.H. Pollard, *Handbook of Numerical & Statistical Techniques*, Cambridge University Press, Cambridge, 1977.

Figure 2 Taste panel parameters for assessing ice cream

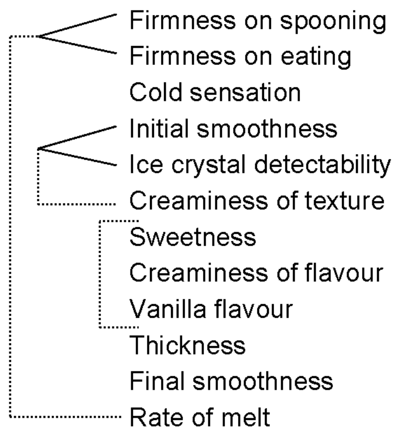


Figure 3 Taste panel questionnaire for ice cream

<u>**Vanilla ice cream**</u> cc

1. **FIRMNESS TO SPOONING**

   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 — 20-21

   Soft … Firm

2. **INITIAL FIRMNESS ON EATING**

   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 — 22-23

   Soft … Firm

3. **CHEWINESS**

   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 — 24-25

   None … Chewy

4. **COLD SENSATION**

   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 — 26-27

   Warm … Cold

5. **INITIAL SMOOTHNESS**

   etc.....

16. **OVERALL LIKING**

   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 — 50-51

   Dislike … Neither like nor dislike … Like

   Any comments: ____________________

and an average consumer is that they are not behaving in a scripted fashion but are applying conscious thought and memory to the sensations they perceive while consuming particular products. Most individuals are capable of carrying out such tasks, but require training in the process of conscious thought and articulation during consumption. An example of this is given in Figure 2, which provides a list of attributes perceived by an average group of consumers when faced with an ice cream, most of whom were not conscious of all the attributes

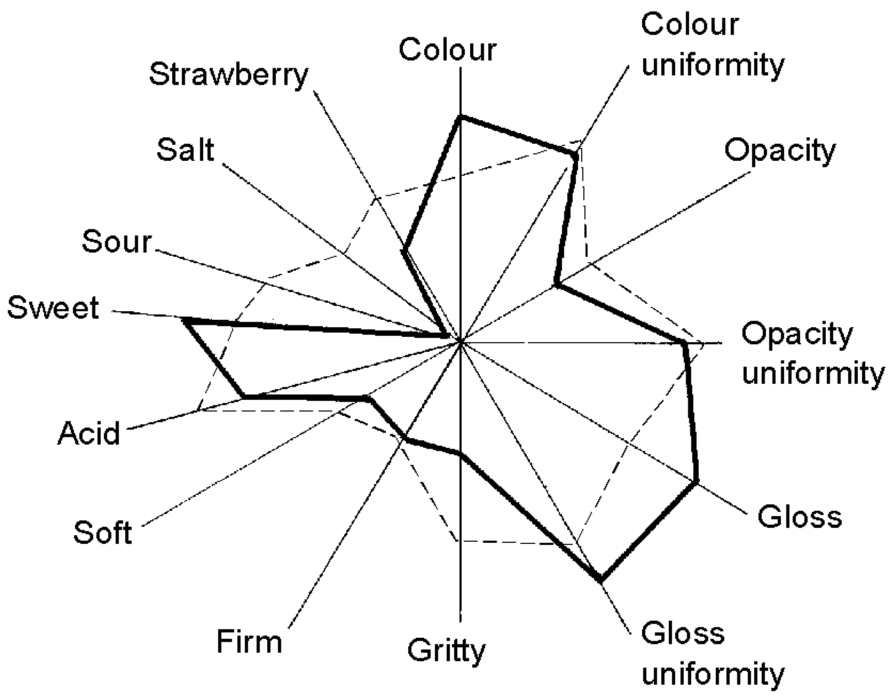


Figure 4 Profile analysis of a food product

they were detecting until asked to record them. The process of turning a group of individual consumers into a trained panel capable of quantifying all of these attributes requires that the individuals agree on the descriptors used and the level at which the attribute is detected. This is achieved by a training set in which the samples exhibit a variation in all of the descriptors. It is remarkable how quickly a consensus can be reached by individuals on both the descriptor of the attribute and the levels to which it is absent or present in a range of samples. When acceptable agreement has been reached, the panel can be considered 'trained'. It is now possible to present novel samples to this group, who will produce a score on each of the individual parameters assessed. There has been considerable experimentation in the best scale on which panellists should be asked to score,[5] but a simple linear scale from 0 to 10 relative to the training samples is frequently adequate. An example of a typical panellist questionnaire is given in Figure 3 and a dozen or more individual parameters can be scored on any one sample.

Presentation of Trained Panel Data

A trained panel can be considered as a measuring device capable of producing quantitative scores on a significant number of attributes from any presented range of products of similar type. Each sample presented can be described in n-dimensional space, where n is the number of individual parameters scored for

[5] H. L. Meiselman, in *Measurement of Food Preferences*, ed. H. J. H. MacFie and D. M. H. Thomson, Blackie, London, 1994, p. 1.

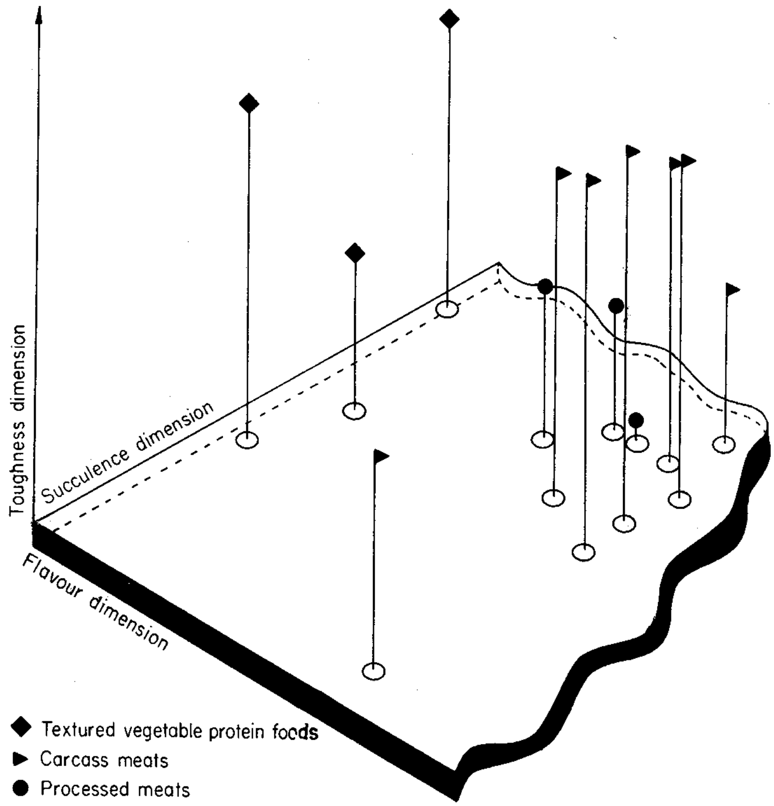


Figure 5 Three-dimensional plot of meat and textured vegetable products

each sample. These parameter scores can be considered a fingerprint of the product properties by which samples can be compared (Figure 4). For more than two or three products, however, this comparison becomes difficult and a simplified representation is often required. This means that the dimensions must be reduced to a handleable or visualizable set. A convenient method to do this is Principal Component Analysis, the details of which are described in Horsfield and Taylor.[6] This is particularly useful if the Principal Components can be reduced to a set of three, when a three-dimensional map can be produced. In Figure 5 the main perceived differences in the properties of a set of meat and analogues are presented. The reduced dimensions are Toughness, Succulence and Flavour, each of which contain a primary set of attributes, weighted by their significance in discriminating between the present sample. In this particular example the same set of samples were presented to untrained consumers who were requested to give their liking scores. Their preference can be overlaid on the perception map, providing an indication of those parameters or parameter sets which are most important in determining consumer liking.

[6] S. Horsfield and L. J. Taylor, *J. Sci. Food Agric.*, 1976, **27**, 1044.

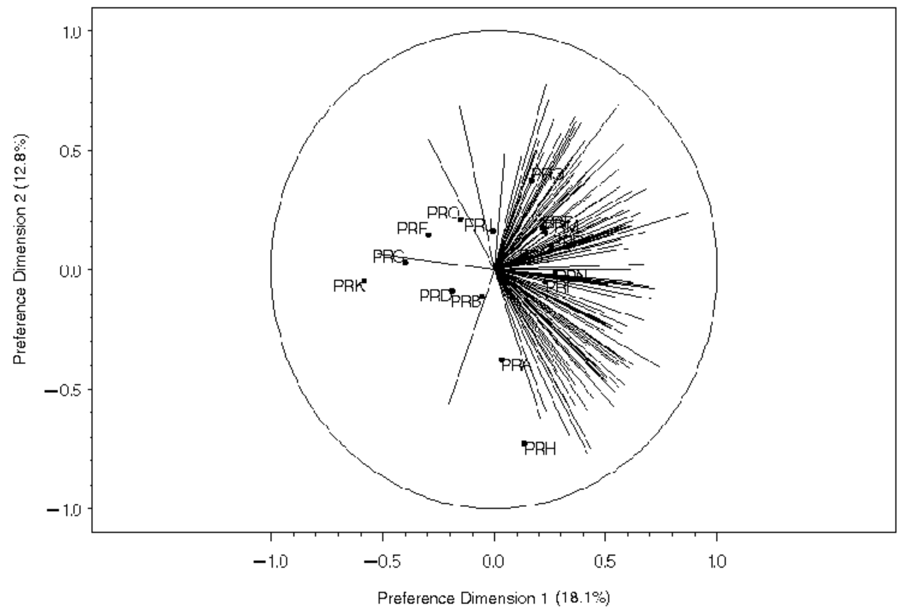


Figure 6 Preference map of food products

There are many alternative methods of presenting perception data and matching it with preference (or liking). An example of a simpler preference map, represented in circular coordinates, is given in Figure 6. Thus we now have methods which allow a combination of trained panellists and untrained consumers to provide quantitated data relating the difference in products, first to their perceived attributes and second to whether these attributes are desirable. Whilst these provide very valuable correlations between product, formulation, processing and consumer response, they are only correlated and still cannot be related to the causal reasons for perceived differences. To go further we must examine the physical and physiological processes involved in eating and drinking, *i.e.* we must obtain a direct connection between the physical or chemical stimulus and the sensory response.

4 Stimulus Response Measurement

The relationship between a physical or chemical stimulus and the response of a human being is rarely linearly related. Figure 7 shows the result of plotting (on log–log scale) the relation between a physical stimulus such as an electric voltage, weight, sound or light, to the response recorded by a human being. In general the relation is described by Stevens' Law:[7]

$$R = KS^n$$

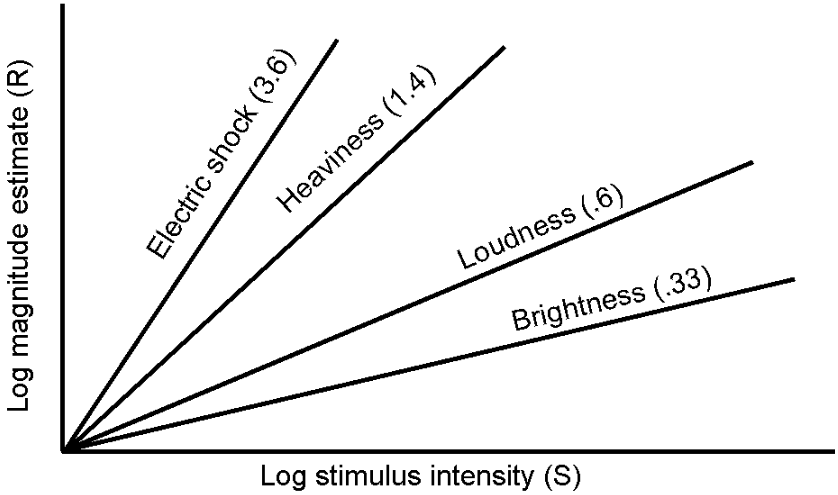
or

$$\log R = \log K + n \log S$$

where R is the response, S is the Stimulus, n an exponent and K is a constant.

[7] S. S. Stevens, *Science*, 1958, **127**, 383.

Figure 7 Quantification of stimuli



The exponent *n* can be either less than one (*i.e.* the human is less than linearly responsive to the stimulus) or much greater than one, where the human is more sensitive and more reactive as the size of the stimulus increases. It has been argued that this is a simple protection mechanism which we have evolved to be highly sensitive to those external stimuli which may damage us. Notice that these results were obtained by using external stimuli which are easily controlled and measuring the subsequent human response. One of the problems in studying the sensory properties of foods is that whilst we can quantify the response (by using trained panellists), we are frequently unsure of the stimulus causing it, since the perception process takes place in the closed vessel of the mouth where a whole host of mechanoreceptors, chemoreceptors, *etc*., are distributed. We will begin by examining a simpler case where the quality of the food is perceived external to the mouth, where stimuli are more obviously presented.

Colour and Appearance

These topics have been recently and comprehensively reviewed by Hutchings.[8] Some of the more significant issues are mentioned here.

Colour. We use our colour perception to estimate degrees of ripeness (*e.g.* tomatoes, bananas), extent of cooking (meat, cereal products) and even anticipated flavour strength (tea, fruit juices). Considerable progress in representing colour vision in terms of the three primary colours red, green and blue has been achieved, so that colour matching can be performed by illuminating with only three wavelengths.[9] The colour quality is given by the proportions of each illuminant. To separate this quality from the overall intensity, the colour value is normalized by dividing by the total intensities of the three wavelengths. Thus the colour of a sample (C) is given by

[8] J. B. Hutchings, *Food Colour & Appearance*, 2nd ed., Aspen, Gaithersburg, 1999.
[9] W. D. Wright, *The Measurement of Colour*, 4th ed., Hilger & Watts, London, 1969.

$$C = r[R] + g[G] + b[B]$$

where r, g and b, the chromaticity coordinates, are:

$$r = \frac{R}{R + G + B};\ g = \frac{G}{R + G + B};\ b = \frac{B}{R + G + B}$$

This is the basis of Tristimulus Analysis.

Gloss. This is the surface property by which a material appears shiny or lustrous and, in sensory assessment, panellists use these terms. The obverse, however, can be described as dull, grainy or crystalline, indicating the size of surface roughness which can be detected. Clearly the stimulus derives from specular reflectance, so that goniophotometric equipment can be used to quantify and correlate with human perception.

A gloss factor (GF) has been defined as

$$GF = (I_s - I_d)/W_{1/2}$$

where I_s is the peak height at the specular reflectance angle, I_d is the diffuse reflectance intensity and $W_{1/2}$ is the specular peak width at half-height.

For many real samples, having curved surfaces, the observer makes measurements simultaneously over the array of reflectance angles. Not surprisingly, therefore, the simple measurement of GF is often not sufficient to describe stimuli completely.

Translucency. This is the property by which light penetrates and disperses into and through a material. Light scattering and absorbing entities in the structure contribute to the perceived effect. Panellists are usually asked to score specimens from 'clear' to 'opaque', translucent falling in the mid-range of this scale. Some success in relating the panellist scores to the Kubelka–Munk scattering coefficient for model emulsions has been achieved.[10]

Uniformity. Rarely are food products uniform in any of the above parameters. The observer notes the spatial differences in all these properties, which relates to heterogeneity within food materials or between them. Thus, marbling is a difference in colour and translucency across the surface of raw meat, bruising is a colour and gloss difference at and below the surface of fruit and vegetables, and the quality of a plate of peas or sweet corn relates to the sum of all these visual observations exhibited by the population presented to the observer. This is essentially a form of pattern recognition, and the observer compares all the visual information with some 'stored images' of previous experiences. To attempt to understand the complexity of stimuli being analysed by the observer, we need the equivalent optical resolution and computing power available in the human eye and brain. This is now becoming available, as rapid, digital data capture, image processing and reconstruction become available. The necessary physics to create Virtual Reality will be vital in understanding how patterns become interpreted into quality judgements.

[10] R. J. Birkett, in *Proc. 5th Congr. Int. Colour Assoc.*, Monte Carlo, 1985, vol. 1.

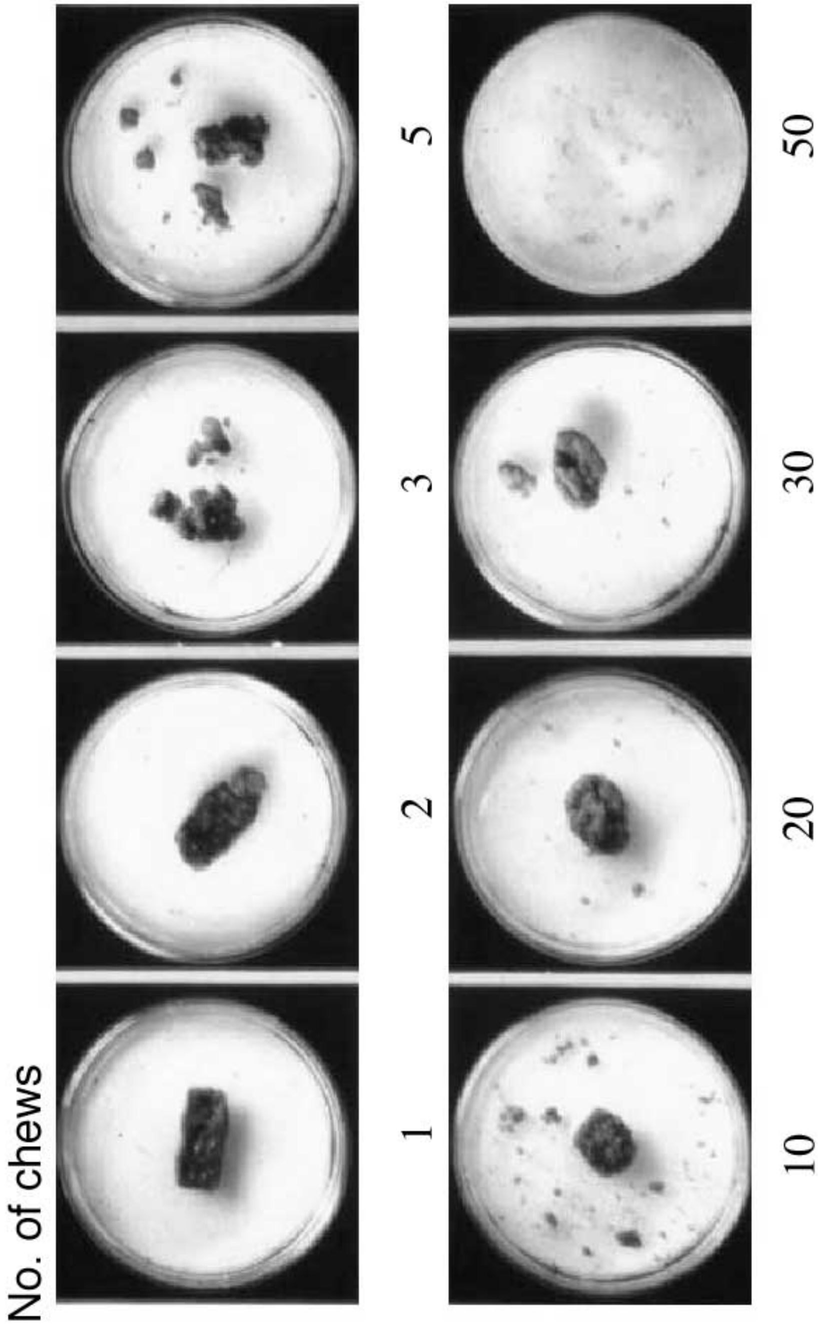


Figure 8 Chewed Longissimus dorsi muscle

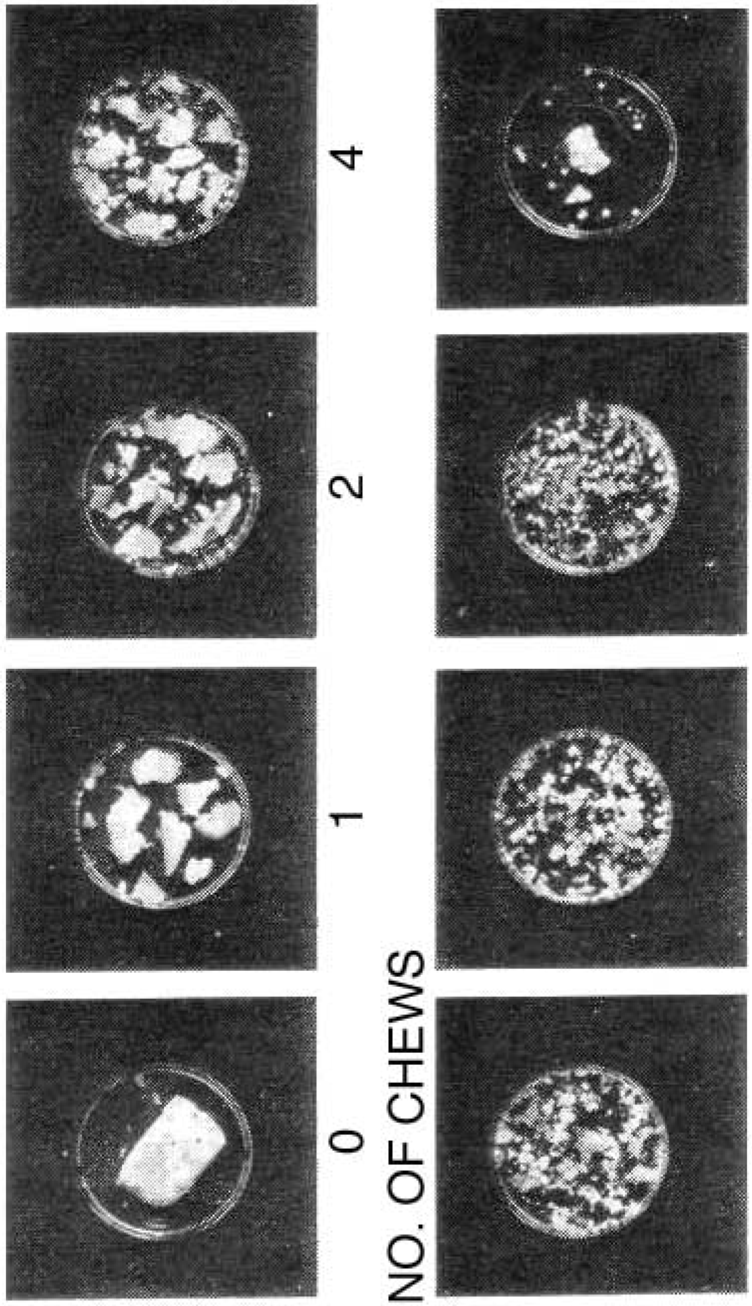


Figure 9 Chewed cracker biscuit

Figure 10 Sequence of breakdown of food during mastication

Initial impression →	**Initial breakdown** →	**Ball formation** →	**Secondary breakdown**
Heaviness	*Moistness I*	*Ease of ball formation*	*Time to paste*
Resilience	*Initial crumbliness*	*Density of ball*	*Particulateness*
Firmness	*Rate of breakdown*	*Stickiness of ball*	*Final particle size*
	Particle size	*Moistness II*	*Moistness III*
	Particle roughness		*Ease of clearance*
	Stickiness		

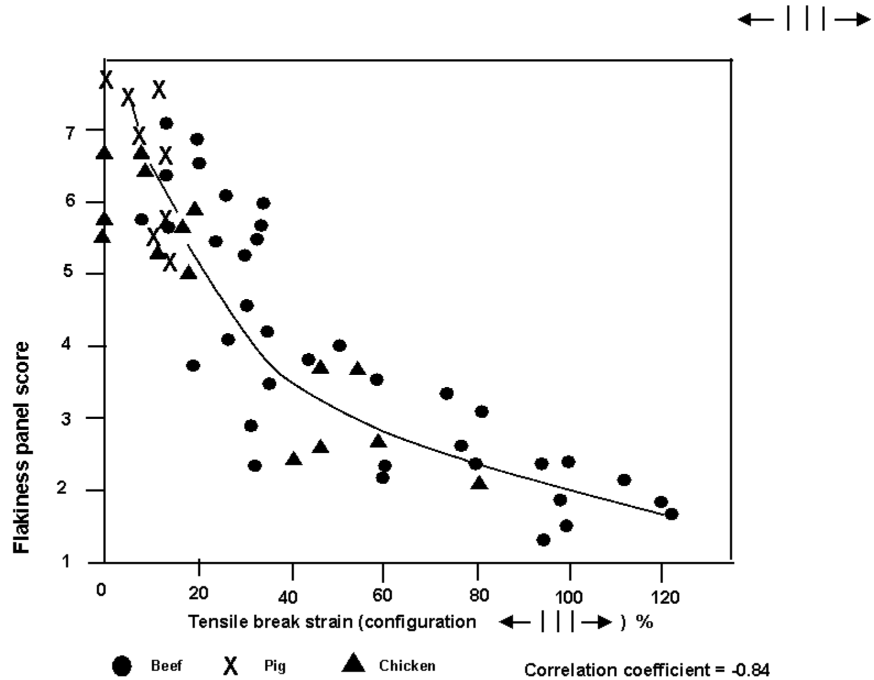
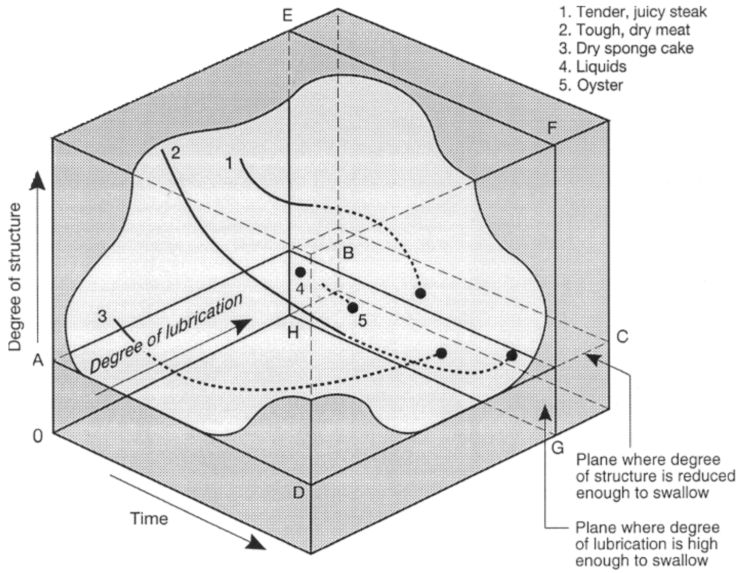


Figure 11 Relation between panel flakiness scores and tensile break strain

Texture

We begin by qualitative observation of the breakdown pathway of obviously different foods. Figures 8 and 9 show the sequential breakdown of whole meat and a cracker biscuit. Notice that a similar process of fracture and reassembly occurs in these samples. Swallowing is associated with the reassembly process. By comparison, Figure 10 shows the parameters described while eating, but ordered in the sequence in which they occur. We see that physical properties of an initial structure are recorded together with subsequent size and shape of particles, liquid adsorption and release and assembly to a swallowable bolus, and the clearance of material from the palate. Thus texture perception is clearly the measurement of the whole comminution process and we cannot therefore expect the stimuli to be

Figure 12 The mouth process model



understood and quantified by simple measurements of the intact food piece. Only the initially perceived attributes are likely to be stimulated from the mechanical properties of the intact food. When reasonable physical tests on the material are related to panellist sensory response, we obtain encouraging correlations. For example, in Figure 11 we show the tensile break strain when cooked meat is pulled at right angles to the fibre direction, compared with the perceived flakiness score. The whole meat kingdom appears to lie on a smooth curve. Note that this is not a simple linear response but shows a relationship more appropriate to Stevens' Law. Conceptually, we can describe texture perception as a process measuring the critical dimensions of 'structure' and 'degree of lubrication' as a function of chewing time.[11] This is shown schematically in Figure 12. Five typical foods are marked on this figure which are (1) a tender juicy steak—structure reduction is mechanically easy and the material also contains sufficient water to lubricate its breakdown; (2) tough, dry meat—more extensive structure reduction is requires lubrication is drawn from saliva and the process takes longer; (3) dry sponge cake—little mechanical work has to be done but extensive saliva mixing is required before swallowing; (4) oyster—the material is close to the swallowable state provided the overall size of the piece is appropriate; (5) liquids, immediately swallowable. Some further evidence for this process has been obtained by asking panellists to score lubrication in the mouth as a function of chewing time. Figure 13 shows three foods. First an orange, from which juices are expressed rapidly on chewing. Second an apple, which releases liquids progressively as cells are ruptured during chewing. Third a dry biscuit; on initial chewing the dry particles require lubrication by saliva. Referring to Figure 12, as well as being capable of perceiving the entire breakdown process, it would appear that our overall

[11] J. B. Hutchings and P. J. Lillford, *J. Texture Studies*, 1998, **19**, 103.

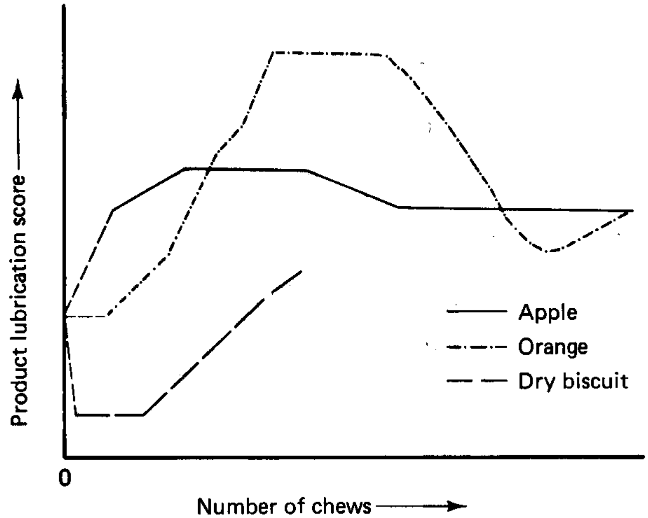


Figure 13 Perceived oral lubrication during chewing

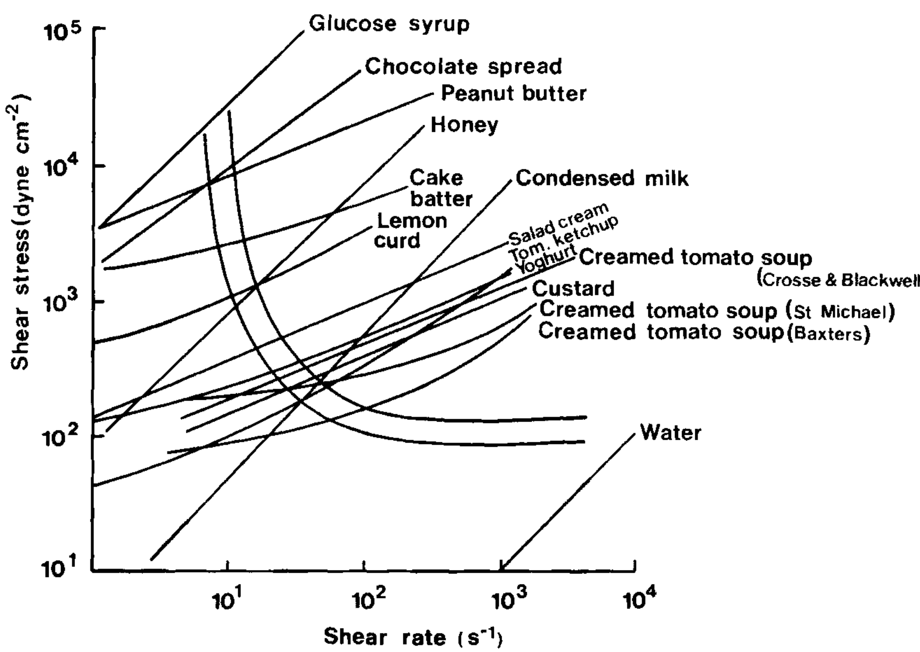


Figure 14 Shear stress–shear rate for foods

preference within a class of foods may relate to specimens which reach the swallowable state in the shortest time.

We can also detect differences in the texture of liquid foods which are more or less immediately swallowable. Shama and Sherman[12] undertook a study of liquid

[12] F. Shama and P. Sherman, *J. Texture Studies*, 1973, **4**, 111.

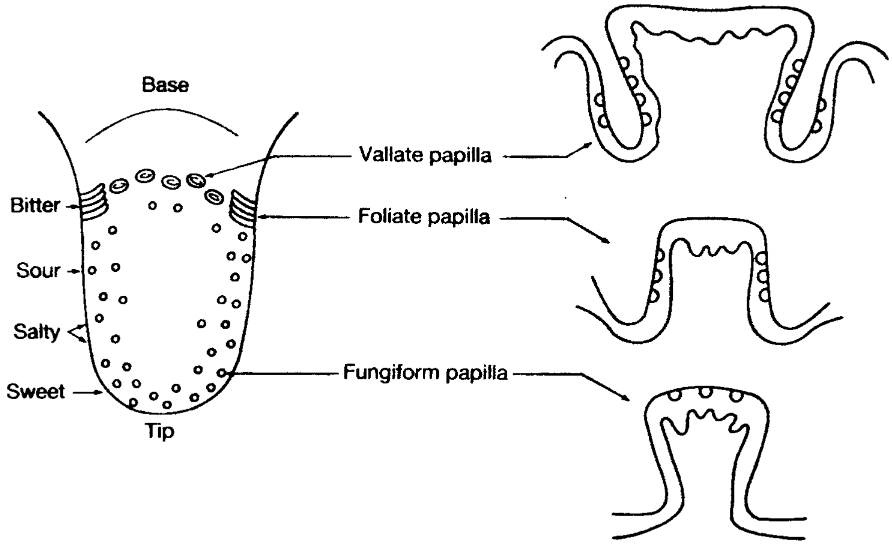


Figure 15 Taste bud distribution on the tongue and shape of papillae (Reproduced by permission from *Lecture Notes on Human Physiology*, ed. J. J. Bray *et al*., Blackwell, Oxford, 1989)

foods of varying viscosities and correlated their actual viscosity with in-mouth perception. Their results are shown in Figure 14, where the shear stress at a given shear rate was measured for each of the foods and panellists were simultaneously asked to score their perception of in-mouth viscosity. The parallel curved lines in Figure 14 show the sensory values. It appears therefore that, for low viscosity liquids, we measure something approaching the shear rate (how fast a sample flows). At higher viscosity the material needs to be pushed between the tongue and the soft palate and so the shear stress becomes the dominant stimulus relating to the perceived properties.

Flavour

It is important to recognize that the sensory property normally described as flavour consists of two elements; these are taste, detected by chemoreceptors in the tongue and soft palate, and odour, detected in the nose by the olfactory receptors. The perception process must therefore be stimulated by the arrival of particular chemical moieties at the site of particular receptors.

Taste. We know something of the location and type of taste buds in the mouth. Figure 15 shows taste bud distribution and something of their physiological form. They are not evenly distributed on the tongue's surface. It is generally believed that bitter receptors are placed further back in the tongue, that sour receptors are dominantly along the side together with salty receptors, and that sweet-taste receptors are predominantly at the front tip of the tongue. These receptors can be stimulated with different molecular species and it is interesting to note that sweet-tasting molecules such as sugar, aspartame, cyclamate and monellin have

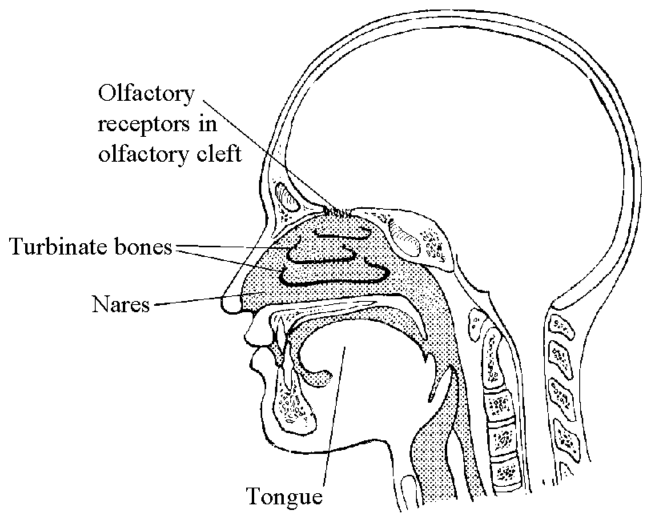


Figure 16 Schematic of human head showing location of olfactory receptors

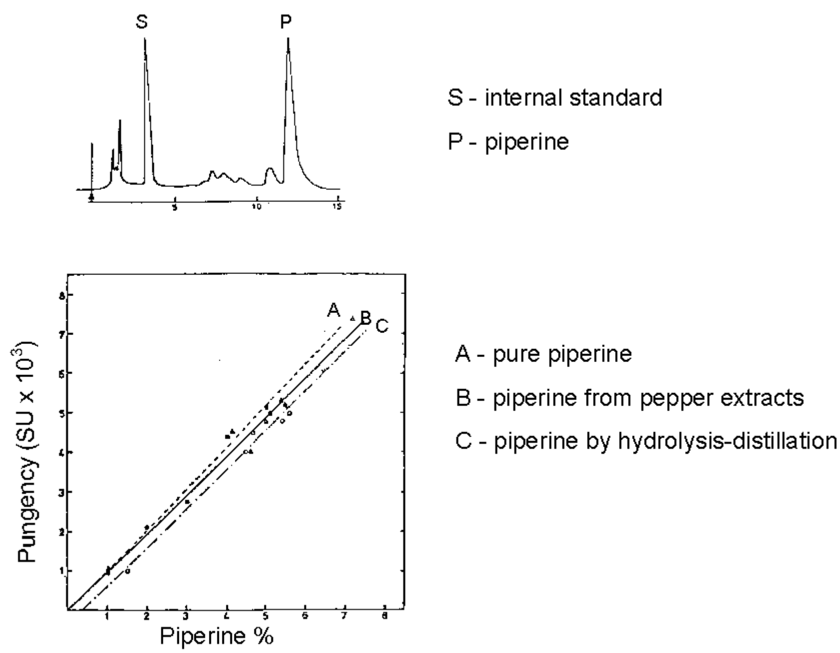


Figure 17 HPLC of pepper and correlation between piperine content and pungency

at first sight remarkably different molecular structures, yet all produce a sweet taste sensation in the mouth. Whilst all are sweet, the nature and duration of the sweet taste is very different for each of these molecules, which presumably relates to their binding constant with the chemoreceptors. In most cases the degree of sweetness is not simply related to the concentration of the active species.[13]

[13] D. E. Walters and G. Roy, *Flavor–Food Interactions*, ed. R. J. McGorrin and J. V. Leland, ACS Symp. Series 633, American Chemical Society, Washington, 1996.

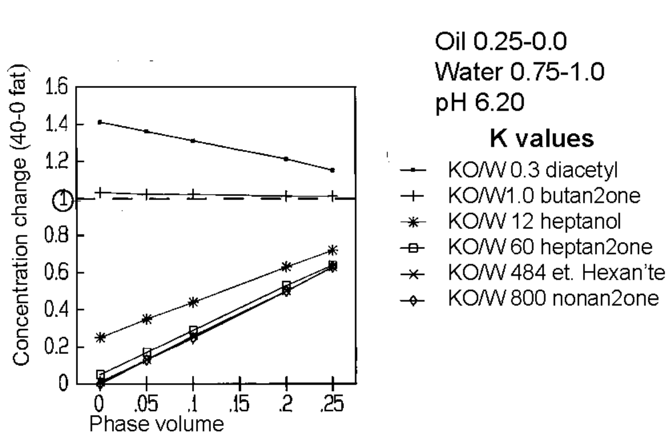


Figure 18 Effect of fat reduction on level of flavour required to give 40% headspace response

Aroma. The detection of odours and aromas takes place in the olfactory cleft in which are positioned thousands of olfactory receptors (Figure 16). The volatiles released from a food or drink enter through the nose or pass round from the back of the throat. The stimulus for odour perception must therefore be the molecular content of the volatile material in space above the food itself. The composition of volatile fraction is easily measured by techniques such as high performance liquid chromatography and in Figure 17 the correlation between sensorily perceived pungency and the piperine content of peppers is shown. In this example the sensory response is directly related to the piperine content. This cannot be a continuous curve since, at high levels of any aroma, saturation can be reached, and no further increase in odour intensity is sensed. The high sensitivity of the chemical detection of volatiles aids flavour analysis and so the production of volatiles by oxidation can be shown to correlate closely with the off-flavour and unacceptability of various soya raw materials. Major complication enters, however, because the detected intensity of odours is not simply related to their concentration in any mixture; some molecular species are much more odour intense than others. During chewing, volatiles will be rapidly sampled as breathing takes place, sweeping the contents of the vapour phase onto the olfactory epithelia. However, the composition of the gaseous phase is not simply related to the composition of the whole food. First, the complex flavour consists of volatile molecules which have differential solubility in aqueous and non-aqueous phases in the food. Therefore, even if equilibrium were reached in the buccal cavity, the concentration in the head space would be dependent on the partition coefficient between individual molecules and their preferred solvent. Figure 18 shows the effect of reducing fat on the levels of independent molecules which is required to give an equivalent flavour to a product containing 40% fat.

There is one further complication which must be considered. The process of mastication also changes the surface structure of all foods and in the case of some fat-continuous emulsions can result in complete inversion to a water-continuous state. This process will be time dependent in the mouth during the chewing process, and this time dependence of structural change will also influence the dynamics of flavour release and therefore the sensory response. With all these complications it would appear that the relation between stimulus and response is almost impossibly complicated. Fortunately, analytical techniques in the gas phase are now so rapid and sensitive that if the nasal cavity is sampled during the mastication process the composition of the volatiles in the nose can be directly related to the sensation of intensity and balance perceived by the subject.

5 Summary

We have seen that, despite the almost unconscious effort of the average consumer, the chemical composition, structure and physical properties of most foods are sampled routinely and at high speed. The stimuli are converted by our neural network to produce a complex time-dependent set of signals to the brain. This combination of signals and its time-dependence is almost certainly compared with an existing database stored in the same brain which relates to previous experience of the product or expectation of its profile of properties. A judgement of quality appears to be made relative to some standard which the individual has already recognized. We have no physical measurement devices capable of carrying out the same number of measurements and signal integration at equivalent speed. It is not surprising, therefore, that one of the most reliable forms of perception measurement and subsequent quality judgement remains a human being.

However, as we tease apart the significance of chemical composition, physical structure and stability of foods, and our measurement devices are improved to match the sensitivity of and rates of detection which our biological senses provide, we begin to understand both the perception and stimuli and their integration into what everybody regards as 'quality'.