12 Design of Food Structures for Consumer Acceptability

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12.1 THE CONSUMER PERSPECTIVE

During the 1990s consumer-led product development was introduced, so that products were produced that met consumers' current and future needs, in addition to the strategic objectives and technical capability of the industry (Costa and Jongen, 2006). Scientific and technical developments in food production and distribution have increased food availability, and as a result, the amount of choice available to the consumer. Today's market is a competitive buyer's market, rather than a seller's market, where the consumer has become the driving force of product development, but often also of fundamental research. It is important to understand the underlying needs or wants that motivate consumers to purchase and consume food products, and the success of food products should be measured by acceptance, liking, purchase and consumption.

The aim of this chapter is to draw together the research on consumer acceptability and food science and engineering that is related to the design of food structures that consumers should accept, like and consume, and that will ideally improve health and nutrition.

The current chapter will begin by explaining "acceptability", and the different aspects of the consumption experience that have an impact on liking, choice and consumption. Included in this section will be literature that shows the impact that the food itself, the context and the consumer can have upon liking and acceptability. There will also be a brief overview on how consumer acceptability can be measured, and how it can be linked to sensory analysis. In the second section of this chapter the current consumer food trends will be described, giving an overview of the areas of food research that can address these trends, particularly related to health, and literature that brings together food science and consumer acceptability.

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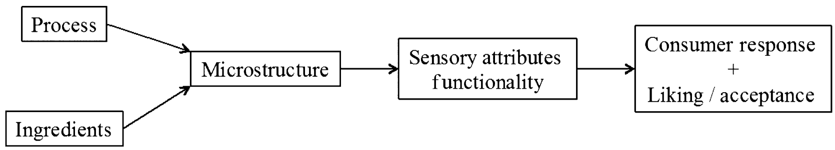

Fig. 12.1 The microstructure approach. Adapted with permission from Norton and Norton (2010) Designer colloids-towards healthy everyday foods? *Soft Matter* 6(16), 3735–3742. Reproduced by permission of The Royal Society of Chemistry http://dx.doi.org/10.1039/C001018A.

Norton and Norton (2010) describe the *microstructure approach*, indicating the link between the process and ingredients, microstructure, sensory properties/release of actives/binding, and finally consumer response (an adapted version of this illustration is presented in Fig. 12.1).

This approach highlights the importance of understanding the consumer when designing food structures, and of the link between all aspects of the food production and consumption process.

12.2 WHAT IS CONSUMER ACCEPTABILITY?

In order to consider how food structures can be designed for consumer acceptance, we should have an understanding of what is meant by *acceptance*. Consumer acceptance is related to, and encompasses, hedonics (i.e. liking and pleasantness), palatability, perceived quality, preference, choice and purchase behaviour, and consumption or intake. The sensory characteristics of a food are of huge importance for acceptability; the appearance, taste, smell, texture and mouthfeel will determine if you like the food or not. However, acceptance of food is not limited to the attributes of the food itself; other factors such as the context in which it is eaten, who are you with and how you are feeling can all be powerful determinants of acceptance (Cardello, 2003). Acceptance is affected by many factors, including *sensory* (the food itself), *situational* (the place) and *cognitive* (the person) influences, but also by price, advertising, branding and packaging. Many models of food acceptance have been proposed (for a review see Meiselman, 2007), each of which propose a number of influences on acceptability, giving varying weights to the different factors.

This section of the chapter will begin with an introduction to how acceptance can be measured experimentally (both directly and indirectly), followed by the sensory, situational and cognitive influences on acceptance which will be discussed in more detail, with examples from the literature and references for further reading. An illustration of the different influences and their impact on liking and acceptance, and in turn choice, purchase and consumption is presented in Fig. 12.2.

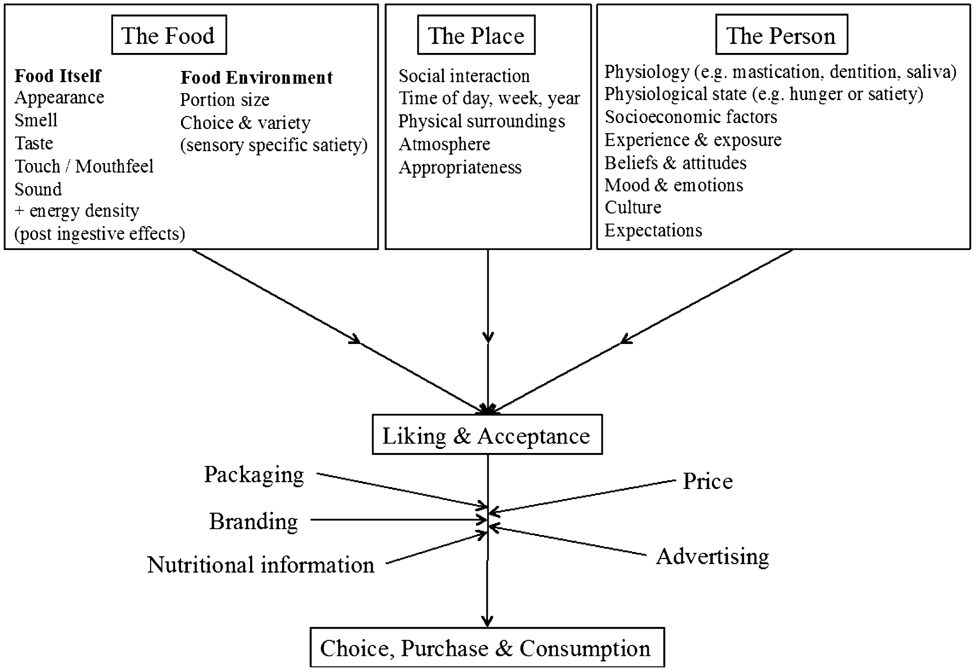

Fig. 12.2 An illustration of the impact that different factors (i.e. The Food, The Place and The Person) can have on liking and acceptance, and in turn choice, purchase and consumption.

12.2.1 Measuring consumer acceptability

In research settings *affective attitudinal measures* can be used to gain information about consumer acceptability, as they yield information about the appeal of products and can be used to compare ratings between products, or between individuals. For example, liking/disliking questions can be used to gain information about pleasantness or palatability, or preference questions can also be used to gain an insight into the choices that consumers make between alternatives.

The most commonly used scales for measuring preference and acceptance are nine-point hedonic scales (Peryam and Pilgrim, 1957) and visual analogue scales (VAS, i.e. line scales), both of which are often anchored (for example, from "dislike extremely" to "like extremely"). However, these scales may be insensitive, or result in ceiling effects (i.e. participants rate all samples at the top of the scale so that it becomes difficult to differentiate between samples). Alternatively, the labelled magnitude scale (LMS) is a scale which is anchored with verbal descriptors of different intensities, where the upper limit is "the strongest imaginable sensation" (Green *et al.*, 1993). The labelled affective magnitude scale (LAM; Schutz and Cardello, 2001) is an extension of the LSM, where the limits are “greatest imaginable liking” and “greatest imaginable disliking”.

Future research may also consider the “appropriateness” of foods for particular situations (Lähteenmäki and Tuorila, 1995; Cardello and Schutz, 1996). According to the authors, liking of a food combines with perceived appropriateness of the food in that situation (for example the type of occasion, the meal time or one’s mood) to determine overall acceptance. Cardello *et al*. (2000) show a positive correlation between ratings of expected liking/disliking in different situations and ratings of appropriateness for the situation. However, inappropriateness does not necessarily lead to low hedonic ratings (Kramer *et al*., 1992). Cardello *et al*. (2000) also suggest using a measure of “satisfaction”, which implies a generalised appreciation of the food, and as such provides information about the food’s value, utility or adequacy for the situation.

However, it is often questionable whether preference or hedonic ratings are good predictors of actual behaviour. Garber *et al*. (2003) argue that, although acceptability of a food is the most basic criterion for its introduction to the marketplace, it provides no information on the likelihood of being selected for purchase over available alternatives that are all acceptable. Consumer choice in the marketplace is affected by price, image, packaging and advertising; the consumer makes a compensatory decision, giving up the benefits offered by alternatives, to gain the benefits provided by the selected product. It has been argued that estimates of willingness to pay (WTP; the maximum price a buyer is willing to pay for a given quality of a good) can be a sensitive and valuable method for assessing the intrinsic value of a product (Lange *et al*., 2002). There are a number of methods of assessing WTP, including directly asking consumers how much they would be willing to pay, conducting experimental auctions where participants bid for a product (and often ultimately pay for it if they win) (see Lohéac, 2007 for an introduction to the method) or choice-based conjoint analysis. Conjoint analysis is a statistical technique that can be used to determine how consumers value different features of products, to enable a part-worth contribution of each of the components to liking. For example, Bower *et al*. (2003) investigated the interplay of taste, price and information (about a health benefit) on the intention to buy and willingness to pay for a fat spread.

Traditionally, hedonic or affective responses are assessed using direct measures, such as questionnaires and interviews. However, the data could be flawed by response bias or social desirability (the tendency for participants to answer in a way that they believe will be viewed in a favourable way, i.e. under-reporting bad behaviour or over-reporting good behaviour). Indirect measures, such as the implicit association test (IAT; Greenwald *et al*., 1998) could prove useful for measuring attitudes towards foods. IAT is a computer-based reaction time task, where attitudes are inferred experimentally according to response patterns towards stimuli. This method is implicit as it is thought to measure automatic processes that are outside conscious awareness. The task typically involves rapidly categorising two target concepts, with the assumption that faster responses are as a result of stronger association in memory. This method has been used for the assessment of food stimuli according to likes and dislikes (Lamote *et al*., 2004), and also brand preferences (Maison *et al*., 2004).

Eye-tracking may also be a valuable technique in order to understand the visual attention given to foods or packaging. The technique uses technology that can track eye movements, typically using a video camera, in order to track the location and line of sight, to determine whether consumers look at certain information or images, and for how long. For example, Jones and Richardson (2007) used eye-tracking to investigate consumer attention to nutritional information presented on food packaging.

Brain imaging may also provide useful information in some situations. Electroencephalography (EEG), and event-related potential (ERP), could be used in the understanding of events occurring during consumption of food. EEG is a non-invasive technique which involves electrodes being attached to the scalp that measure electrical signals that originate from cortical post-synaptic potentials of millions of synchronously activated neurons; it is a real-time measure of brain electrical activity (Ohla *et al*., 2012). The electrical signal is then averaged and time-locked to the onset of a stimulus, resulting in a waveform of positive and negative peaks, which is called an event-related potential (ERP). The ERP's amplitude, latency or distribution across the scalp can then be compared across experimental conditions. The latency of the peaks is related to the type of processing: early peaks reflect sensory stimulus processing, whereas later peaks denote cognitive processing (e.g. the evaluation or characterisation of the stimulus). This technique offers extremely accurate temporal resolution (i.e. in milliseconds), but poor special resolution. Alternatively, functional magnetic resonance imaging (fMRI) measures changes in blood flow and blood oxygenation (blood-oxygen-level-dependent, or BOLD, contrast) as an indicator of neural activity, and offers excellent spatial resolution. fMRI can detect changes throughout the brain, rather than just across the cerebral cortex, as in EEG. It has been used to study activation when viewing foods with different energy densities (Killgore *et al*., 2003; Simmons *et al*., 2005). EEG and fMRI may also be combined to attain high temporal and high spatial resolution data.

Palatability and liking are also linked to satiety and speed of eating. In their review paper Bellisle *et al*. (2000) indicate that increasing palatability was related to an acceleration in eating rate, mainly as a result of a reduction in chewing time and number of chews. Highly palatable foods weren't chewed very much, and were swallowed rapidly. Furthermore, eating rate was fastest at the beginning of the meal, and as satiation developed eating rate decelerated and chewing increased. As such, measuring eating rate could be used as another indirect measure of acceptability, although the method of data collection needs to be considered in order to keep the consumption experience as close to reality as possible.

A number of direct and indirect methods for measuring consumer acceptability have been highlighted, which could be used in order to measure differences in acceptability between products, or between individuals.

12.2.2 Factors affecting acceptability

As already mentioned, acceptability of food is affected by the sensory appeal of the food itself, by the situation and the environment in which it is consumed, and by the mood, prior experience and expectations of the person. In the following sections each of these influences will be described more fully.

12.2.2.1 *Sensory*

Food is experienced through all the sensory modalities, which are anatomically independent, but integrate in a multimodal manner. When consuming food it is assessed using: *vision* (the food's appearance, which includes colour, shape and gloss); *smell/olfaction* (sensations stimulated by volatile odour compounds, which are experienced as a result of both orthonasal and retronasal stimulation); *taste/gustation* (sensations stimulated by the basic tastes: sweet, sour, salty, bitter and umami/monosodium glutamate); *touch/somesthesis* (both tactile perception or mouthfeel and chemesthesis, i.e. pain, touch and thermal perception experienced by the trigeminal nerves) and *sound/audition* (sound via air and bone conduction, indicating texture, for example perception of crunchiness or crispness) (Fisher and Scott, 1997). It is worth noting that, in reality, it is likely that consumers use the word "taste" to describe gustatory, retronasal olfaction and touch sensations, rather than gustation alone, as is used in research.

Specialised brain regions receive and process information from the different sensory modalities, whilst other areas of the brain (and even single neurons) are responsible for the integration of this information. For example, the orbitofrontal cortex (OFC) responds to a variety of senses, including taste, olfactory, texture, temperature and visual inputs, and also the pleasantness of foods. Edmund Rolls has conducted a great deal of research in this area (for example see Rolls, 2005, 2007). Multiple senses have also been shown to facilitate perception, in a phenomenon know as *cross-modal summation* whereby subthreshold concentrations (i.e. not strong enough to be perceived) of selected gustatory and olfactory stimuli are detected when presented together (Dalton *et al*., 2000).

Sensory analysis is the "identification, scientific measurement, analysis and interpretation of properties (attributes) of a product as they are perceived through the five senses of sight, smell, taste, touch and hearing" (Lyon *et al*., 2000). Sensory analysis can use untrained consumers, or trained assessors, and can be concerned with objective analytical quality (for example, flavour intensity), or subjective judgments such as liking, preference or acceptability (Lyon *et al*., 2000). Sensory analysis is conducted under controlled and standardised conditions without the influence of package, label, price, nutritional information or any other product information. It can encompass discrimination (if differences exist between products), description (describe and measure differences between products) and preference or hedonics (liking and acceptability). Consumer acceptability or preference data can often be combined with sensory analysis in order to determine the relationship between sensory characteristics and liking. A number of texts can be consulted for more detail on sensory analysis, including Carpenter *et al*. (2000), Lawless and Heymann (1999), MacFie (2007), Meilgaard *et al*. (2007) and Resurreccion (1998).

Just-about-right (JAR) scales can be used when testing with consumers (rather than a trained panel). They are used to measure the desirability of a specific attribute (the deviation from ideal), and the optimum levels of an attribute in a product (Lawless and Heymann, 1999). Scales typically consist of five or seven points ranging from too little to too much for a given attribute, with a mid-point of "just about right". The consumer is required to determine the intensity of the attributes, and rate them according to its distance from the ideal level of the attribute. If the intensity is ideal, the consumer should rate the attribute as "just about right", but if it is not ideal they should choose the point on the scale that best represents the mismatch between the intensity and the ideal point (Rothman, 2007). JAR and hedonic ratings can also be combined to provide directional information that can be used for the reformulation of the food (for example with the use of penalty analysis). However, it should be noted that there is controversy of the use of

JAR questions, as some feel that they rely too heavily on the assumption that consumers know what the ideal point is, and that they understand the terminology and the sensory attributes.

Finally, understanding the physical properties of foods related to their sensory attributes might teach us something about acceptability. For example, creaminess perception is thought to be a combination of thickness and smoothness, and as such, understanding rheology (viscosity) or tribology (friction and lubrication) could provide valuable information related to acceptability. Similarly, understanding fracture or compression could be valuable when considering first bite, crispiness or crunchiness perception. Researchers are beginning to compare analytical techniques with perception, in order to understand the link between sensory attributes and the physical properties of foods.

12.2.2.2 *Situation and environment*

Although the sensory characteristics of food are incredibly important, situational or environmental factors can also have an effect on acceptance. Social factors (who we are eating with), temporal (at what time we eat, and how long we have to eat) and environmental factors (the physical surroundings) can also affect acceptability (Rozin and Tuorila, 1993). Different authors have attempted to separate contextual influences. For example, Rozin and Tuorila (1993) separate context into *simultaneous* (contextual factors present during the consumption event) and *temporal* (past or anticipated future events that enter the person's mind during the consumption event). Although the authors believe that this distinction is important, they highlight that it is difficult to distinguish between these influences, as there is an interplay with the different factors. They also highlight the importance of the bite, the dish, the meal and the pattern of eating over the course of days, months and years.

Wansink (2004) separates environmental factors into the *eating environment*, which is independent of the food itself (for example, atmosphere, social interaction or distraction), and the *food environment*, which is related to how the food is presented (including salience, structure, package, portion size or variety). Meiselman *et al*. (2000) showed that identical foods served in different environments were liked differently (i.e. restaurant > sensory laboratory > student dining hall). Ratings of sensory attributes (flavour, texture and colour) also differed, and suggested that consumers' expectations might underlie the differences observed (the effect that expectations have on liking and acceptability will be introduced in the following section). Edwards *et al*. (2003) conducted a similar study, comparing identical foods across 10 different locations (both institutional and restaurant settings). They found a significant effect of location on acceptability ratings, with the food served at home being ranked the highest, followed by restaurants, diners and fast food restaurants, with food consumed in military and hospital food services being rated the lowest. A study by de Graaf *et al*. (2005) unveiled a more complex relationship between acceptability and environment, suggesting that food type also affected the disparity been ratings of foods in different environments. The authors found that ratings of snack foods were more similar across the two settings, than ratings of entrees were. The authors suggest that this may be as a result of normal consumption behaviour (i.e. snacks are typically consumed in many different environments, whilst main courses are normally consumed in the context of a meal), the amount of variability in quality of main courses as opposed to snacks, and possibly the amount consumed (the main course was larger than the portion of snack food). However, the study does highlight the need to understand the relationship between environment and food type.

Whilst environmental factors are interesting from a theoretical perspective in order to understand the impact they have on liking, it is also important to consider when conducting research. Studies are often conducted in laboratories, preventing consumers from being affected by environmental distractors, so they can focus on the sensory and/or hedonic aspects of the food being tested. As such, strict experimental control allows for greater accuracy and reliability. However, the research described suggests that when asking consumers to rate food, the environment should be similar to the real-life consumption setting, especially when the aim is to be predictive of actual behaviour. Thus, naturalistic, or quasi-naturalistic environments may be adopted more and more for consumer testing. However, there will always need to be a balance between controlled experimentation and ecological validity!

In multicomponent meals, acceptability is also affected by the other foods that are served. It has been shown that when a meal is evaluated, liking of the main course is most critical for acceptance (Rogozenski and Moskowitz, 1982; Turner and Collison, 1988), and both King *et al*. (2004) and King *et al*. (2007) showed that serving food as part of a meal and offering a choice has the largest positive impact on acceptability. Again, this highlights a mismatch between the methodology employed in a research setting (where consumers are often just given one test product, and probably do not get the opportunity to make choices), and real life.

The variety that is experienced during a meal is also important. This is closely related to the phenomenon of *sensory specific satiety* (SSS) (Rolls *et al*., 1981; Rolls, 1986), whereby food tastes pleasant when we are hungry, but neutral when it is eaten to satiety. Primate studies indicate that neurons that respond to a particular taste stop responding when that taste is eaten to satiety (Rolls, 2004a). Rolls (2004b) also describes how visual neurons in the OFC only respond to the sight of food if hunger is present. Participants often consume more when a variety of foods are presented; Rolls (2004b) highlights how appetite reduction is only seen for the food that is eaten to satiety; an enhanced appetite may been seen for other foods. The amount of variety experienced from meal to meal (i.e. monotony or boredom) may also be important (Stubenitsky *et al.*, 1999; Hetherington *et al.*, 2000).

12.2.2.3 *Cognition, prior experience and expectations*

Consumers vary enormously. Individuals not only vary in their sensitivity to tastants (particularly bitterness), but also in how different attributes drive overall acceptance (Moskowitz and Krieger, 1993). Other factors, such as experience, beliefs, attitudes, ideals, motivations, mood and emotions can affect choice and acceptability of food, as can physiological influences (for example dentition, masticatory behaviour or saliva production), physiological state (for example, hunger and satiety), and cultural and ethnic influences. For example, Winkielman *et al*. (2005) investigated the impact of affective primes (i.e. by presenting happy or angry faces) on the assessment of value and consumption of beverages. The authors showed that subliminal smiles caused thirsty participants to consume more of the drink, and increased their wanting and willingness to pay for it, whilst frowns had the opposite effect.

The amount of experience, or exposure, that someone has with a particular food can also affect acceptance. Food *neophobia* refers to the reluctance to consume or avoidance of novel or unfamiliar foods, and affects acceptance: an unfamiliar food may not be perceived as acceptable, and as such will be rejected. Prior experience can also mediate food choice and acceptability.

Many questionnaires have been developed to separate consumers according to personality traits and attitudes, including the Food Neophobia Scale (FNS) (Pliner and Hobden, 1992), Food Choice Questionnaire (Steptoe *et al.*, 1995), Three-factor Eating Questionnaire (TFEG) (Stunkard and Messick, 1985) and the Dutch Eating Behaviour Questionnaire (van Strien *et al.*, 1986). Such questionnaires can be valuable for explaining likes and dislikes, and also for highlighting a target subset of consumers when producing or marketing foods.

The expectations that consumers have about foods also have an important role in judgments of foods. Expectations are developed through previous exposure to foods, and on currently available information, which may be presented on packaging or as a result of advertising and social exchanges. Expectations affect the way in which individuals view food attributes or like a food. They may improve or degrade the perception of a product, even before it is tasted, with consumer satisfaction being strongly related to the degree of disparity between expectations and actual product performance (Deliza and MacFie, 1996). There are a number of models to predict the outcomes of situations in which there is a discrepancy or disconfirmation between expectations and actual product characteristics:

1. Assimilation: actual perception becomes similar to expectations;
2. Contrast: perception moves in the opposite direction to expectations;
3. Assimilation–contrast: assimilation occurs if the disconfirmation is low and contrast occurs if the disconfirmation is high;
4. Generalised negativity: disconfirmation will lead to decreased product satisfaction under any circumstances.

The majority of research on the role of expectations on sensory and hedonic aspects of products has supported an assimilation model of these effects (Cardello, 2003). The model predicts that when expectations are high, but actual quality of the food is low (a state of "negative disconfirmation"), perceived acceptability will assimilate the higher level of expectation, and lead to increased liking. However, if expectations are low, but the actual quality is high (a state of "positive disconfirmation") perceived acceptability will assimilate the lower expectation, and as a result liking will decrease. Thus, if expectations are low the model predicts liking will suffer, but if expectations can be raised liking should increase.

Expectancy effects have been observed for tastants. Carlsmith and Aronson (1963) administered a series of iso-intense (of the same intensity) solutions of sucrose and quinine sulfate to participants who rated them for perceived intensity of sweetness or bitterness. Prior to presentation, an expectation was created by the experimenter, who told participants that the solution they are about to taste would either be sweet or bitter. The cue and the stimulus were either congruent or incongruent. Results showed that: (1) if you were told you would be getting a bitter solution, but actually tasted a sweet solution you rated it as less sweet than if you received a sucrose solution that confirmed an expectancy and (2) if you were told you would be getting a sweet solution but you actually got a bitter solution you rated it as more bitter than if you received a quinine solution that confirmed an expectancy. The authors suggested that this finding is consistent with *cognitive dissonance theory* i.e. disconfirmed expectations about both solutions resulted in negative affect towards them, lowering perceived sweetness and increasing perceived bitterness (both reflecting reduced pleasantness).

Expectations driven by colour can mediate or dominate the sensory experience. Colour is typically the first judgement of a food: it frames an individual's expectations of the sensory properties of a food before it is tasted, and can indicate sweetness, ripeness or texture. Research has shown that colour affects the recognition and identification of flavour (DuBose *et al.*, 1980; Blackwell, 1995; Lavin and Lawless, 1998; Zampini *et al.*, 2008), and is an important feature in food choice (Marshall *et al.*, 2006). In their famous study, Morrot *et al.* (2001) showed that the addition of a red colour to white wine led participants to use red wine desciptors to describe the wine, regardless of their level of expertise (i.e. even wine expects were influenced by the colour of the wine). Shankar *et al.* (2009) investigated whether colour and label information affected ratings of intensity of chocolate flavour and likability of sugar-shell-coated chocolate, where the exterior colour of the chocolate sweet is independent of the flavour of the chocolate interior. Authors found that brown sweets were rated as significantly more chocolatey than green-coated versions. It is clear that colour strongly influences the ability to recognise flavour, with some researchers suggesting that it also exerts a "priming" effect on smell.

Many studies have investigated how label information influences expectations or sensory and hedonic ratings of foods. Researchers have shown that information provided related to fat content can often affect hedonic or acceptability ratings of foods (Kähkönen and Tuorila, 1998; Stubenitsky *et al.*, 1999), which in turn can affect buying probability (Kähkönen and Tuorila, 1999). Labelling has also been found to influence sensory ratings (Kähkönen *et al.*, 1996, 1999; Westcombe and Wardle, 1997; Kähkönen, 2000; Yeomans *et al.*, 2001, 2008), so that expected qualities and the sensory experience combine and affect ratings. In their study, Levin and Gaeth (1988) showed a framing effect, whereby beef samples were either labelled as "25%" fat or "75% lean". Prior to tasting the samples, participants expected the "75% lean" sample to taste better, but, on tasting, hedonic ratings did not differ. This framing effect is more pronounced in studies where the product is not consumed, implying that personal experience plays a prominent role in judgments.

Interestingly, an effect of labelling is observed, even if participants know that the information is false. In their study, Rozin *et al.* (1990) presented participants with two bottles of sugar, and asked them to label one "sodium cyanide, poison" and the other "sugar" (which of the bottles they labelled "cyanide" was up to participants themselves). There was a significant tendency to avoid taking sugar from the bottle labelled "cyanide", although participants knew that the labels were false!

Product packaging also plays an important role in consumer product perception and acceptance. For example, package background colour and information had a significant effect on all rated attributes and upon expected liking (Deliza *et al*., 2003). It has also been found that both colour and shape affect expected liking and willingness to purchase milk desserts (Ares and Deliza, 2010), where colour was particularly related to flavour, whereas shape was more related to texture characteristics. Also, Smets and Overbeeke (1995) found that people are able to match packaging with desserts using both form and colour information.

To summarise, the first section of this chapter introduced consumer acceptability, and some of the direct and indirect methods that can be used to measure it. It also discussed the influence that sensory, situational and cognitive factors can have upon liking. In the second section of this chapter, a number of key food trends that have been cited as important for consumers will be introduced, along with the research that is being undertaken to address these trends.

12.3 WHAT ARE THE CURRENT TRENDS?

Steenkamp (1997) detailed a number of food trends, including growing health concerns ("reduced" foods and functional foods), growing convenience orientation, hedonism (taste and lifestyle-enhancing products), and growing environmental and ethical concerns (free-range, organic, fair-trade, reduced CO_2 emission). Although Steenkamp noted these trends 15 years ago, they are still relevant today, and moving into the future, particularly as governments put strict regulations on the food industry. Some of these trends, and the link between food research and the consumer, will be discussed here in turn.

Health consciousness is one of the dominant drivers of consumer markets in the twenty-first century, and can include the reduction of fats, sugars and salt, in addition to the increase in the consumption of functional foods. It is related to increased consumer understanding of the relationship between diet and health. This is where this section of the chapter will focus.

12.3.1 Fat reduction

Fats and oils are important macronutrients as they provide energy, deliver essential fatty acids and lipid-soluble nutrients, and contribute to the palatability of many foods (Golding and Wooster, 2010). That said, we live an environment which has been described as "obesogenic" (Egger and Swinburn, 1997), where calories are plentiful, highly palatable, cheap, convenient and persuasively advertised; as such, fat is often cited as the leading cause of obesity. Rolls (2007) suggests that increased food intake is due to increased palatability, variety and availability of food. Anatomically, humans have changed little since the evolution of man, and as such stomach distension and satiety hormones still function in a similar fashion. However, modern food is highly palatable, in terms of its taste, smell, texture and appearance. This increased reward value and palatability over-rides satiety signals and leads to overeating.

Fat is energy dense (carbohydrate = 3.75 kcal/g, protein = 4 kcal/g, alcohol = 7 kcal/g, and fat = 9 kcal/g; Food Standards Agency, 2002), but has only a limited effect on suppressing appetite, compared with protein or carbohydrate (Egger and Swinburn, 1997; Stubbs *et al.*, 2000). This can result in "passive consumption", in which excess energy is ingested without a large quantity of food being consumed (Prentice and Jebb, 1995). Furthermore, having a high daily caloric intake from fat is related to an increased risk of cardiovascular disease, cancer, stroke and diabetes. Consequently, reducing dietary fat may reduce energy intake and help prevent obesity and related health problems. However, it is not as easy as simply reducing energy density or fat content. Palatability is positively correlated with energy density, so that high-energy dense foods are perceived as more palatable than low-density foods (Nasser, 2001). Fats are also positively correlated with the perception of taste and texture of foods. Drewnowski and Greenwood (1983) investigated the perception and hedonics of sweet and fatty tastes using different combinations of milk/cream and sucrose. The results indicated a sweetness breakpoint, after which scores of pleasantness declined, whilst hedonic preference ratings for fat continued to rise, and showed no clear breakpoint.

Fats in food provide sensations of creaminess, smoothness, thickness, oral viscosity and flow behaviour, lubrication and also flavour release (Drewnowski, 1992). Flavour compounds tend to equilibrate between the fat phase and the aqueous phase: hydrophobic compounds will partition into the fat phase, and hydrophilic compounds will partition into the aqueous phase (Decker, 2006). Reducing fat in a system exposes flavour volatiles to a more-hydrophilic environment, causing hydrophobic compounds to move from the hydrophilic environment into the gaseous phase (Decker, 2006). Furthermore, fat within food coats the mouth and may block some of the receptors, thus delaying and/or prolonging flavour release. Similarly, removing fat from a food may result in an undesirably heightened experience of flavour at the early stages of consumption. The digestion of fat also plays a role in satiety and energy regulation; fatty-acid release in the upper small intestine leads to the secretion of a range of neuropeptides (cholecystokinin and peptide YY), that alter gastric emptying and eating behaviour (Lundin *et al*., 2008).

It is clear that reducing fat within foods is not easy! The food should remain as creamy, thick and lubricating, retain the same flavour release and also provide some fat in order not to alter gastric emptying. A typical approach to reducing the energy density or fat content of food is to replace pure fat with an emulsion. Emulsions are dispersions of two immiscible liquids, where one is distributed within the other as small droplets (i.e. water-in-oil or oil-in-water). Examples exist in margarines and low-fat spreads (fat continuous) and mayonnaise (water continuous). If the aqueous phase is calorie free this is an obvious way to reduce the energy density of fat-containing systems.

Mela *et al*. (1994) investigated the perception of fat in model oil-in-water emulsions with differing fat contents, and showed that increasing the oil content increased viscosity, and this was a dominant factor affecting perceived fat content. Akhtar *et al*. (2006) considered the effect of fat content, rheology and droplet size on the perception of taste, thickness and creaminess in a model oil-in-water emulsions. The authors varied the viscosity of the continuous phase using two hydrocolloids as thickeners (pectin and xanthan), showing that viscosity of the continuous phase was the most significant factor affecting perceptions of thickness and creaminess. The panelists were unable to discriminate between emulsions with varying droplet sizes (0.5 or 2 μm), possibly because the viscosities of these emulsions did not differ, or because the size was below the detection threshold, and fat content also had little effect on thickness or creaminess. In a similar study Vingerhoeds *et al*. (2008) investigated the sensory perception of low-viscosity oil-in-water emulsions, varying the fat type (sunflower oil, high- or low-melting palm fat, or milk fat), fat content (0–40%), droplet size (0.5–6 μm), and the addition of guar gum as a thickener, or the addition of particles. The authors showed that fat content and type and the addition of guar gum had the largest effect on fat-related attributes, including creamy perception, whereas droplet size did not have an effect. Specifically, increasing the volume fraction of oil increased perceived thickness, fattiness, creaminess, slippery mouthfeel and satiation afterfeel; high-melting palm resulted in a grainer texture, whereas milk fat increased fatty and creamy mouthfeel; adding guar gum increased perceived fattiness and thickness (so that a 10% fat thickened emulsion was comparable to a 40% fat unthickened emulsion).

Kilcast and Clegg (2002) investigated the relationship between the structure of model systems, chocolate mousses and artificial creams, and creaminess perception. The authors showed that droplet size had an influence on creaminess (systems with smaller droplets being perceived as creamier; below 4–7μm there is an increase in creamy perception; above it is reduced and replaced with the sensation of grittiness). The authors also showed the importance of aeration, whereby smaller bubbles resulted in creamier mousses, as did the increase in volume fraction of air. Finally, they showed that creamy texture increases with increasing fat content, but also with increasing oil-droplet size (they suggest that this is as a result of aggregated droplets that increase viscosity).

Emulsion structure can also have an effect on digestion, whereby droplet size has an effect of lipolysis (i.e. the enzymatic breakdown of lipids during digestion), whereby smaller droplets that have a greater interfacial surface area, and thus a greater area available for lipase binding, resulted in fastest lipolysis (measured *in vitro* and *in vivo*) (Lundin *et al*., 2008; Golding and Wooster, 2010). This is supported by measurements of blood plasma triglyceride concentration, showing that emulsification results in more efficient digestion and uptake. The physiochemical structure of the fat itself, including triglyceride type and chain length, degree of saturation, solid fat content, and crystal type and structure, can also affect lipid digestion (Golding and Wooster, 2010). As such, emulsions could be designed with microstructures that affect gastric emptying and satiety.

Consumers' growing health concerns and need for hedonism could also be combined to produce foods that are healthy but indulgent, for example in the production of reduced-fat chocolates (Norton *et al*., 2009).

Despite an understanding of the link between fat consumption and health, reduced-fat products are often not included in our everyday diets. Hill *et al*. (2002) state a number explanations for the lack of use of reduced-fat products: consumers feel that their consumption of fat is satisfactory, that reduced-fat diets are difficult to maintain, that such foods have inferior sensory quality, or that consumers may be sceptical or mistrust the health claims. Despite this, shifts have been occurring in some sectors of the market, particularly dairy (e.g. moving from whole milk to semi- and skimmed milks; from butter to margarine and low-fat spreads).

The effect that expectations can have on acceptance was introduced in the previous section of this chapter. Information about fat content has been shown to affect both hedonic and sensory ratings of foods. Whilst Aaron *et al*. (1994) found no significant affect of label ("reduced-fat spread 40% fat" or "full-fat margarine 80% fat") on sensory or hedonic ratings, many researchers have found that labelling significantly affects hedonic ratings. Kähkönen and Tuorila (1998) found that when given information about fat content, participants expected the light version to be less pleasant, and Stubenitsky *et al*. (1999) showed that reduced-fat information had a small negative effect on the acceptance ratings of chocolate snack bars. Kähkönen and Tuorila (1999) found that reduced-fat information decreased pleasantness ratings and buying probability of chocolate bars compared with regular products. Yeomans *et al*. (2001) found that when participants tasted both low-fat and high-fat soups presented with fictitious brand names that implied that the soup was high or low in fat, soups labelled as high in fat were rated as significantly more creamy, and more pleasant, regardless of the actual fat content. The examples presented here indicate how simply thinking that a food is reduced in fat may have an impact on how much you like it, or on your perception of the sensory characteristics, and it is likely that reduced-fat information will have a negative impact.

However, Light *et al*. (1992) investigated the influence of label information on hedonic responses to normal and low-fat versions of ice cream and cheese. Ice cream with information was liked significantly more than when presented without information. When participants knew the fat content of the cheese they tended to prefer the low-fat product over the higher version, possibly due to "impression management" or social desirability: participants were trying to appear healthier than they really were. Furthermore, Tuorila *et al*. (2001) found that participants often chose a fat-free fudge against their hedonic preference, which the authors suggests is evidence that motivated people can accept a less- preferred product when they are informed of its reduced fat content. Wansink *et al*. (2004) suggest that health or diet labels are likely to influence the subjective taste of unhealthy foods, but not foods that are already viewed as healthy, where the label has less of an impact.

A further concern for food researchers is the evidence that energy density-related information (i.e. "healthy" or "low-fat" labels) has increased consumption by 35–50% (Wansink and Chandon, 2006; Provencher *et al*., 2009; respectively). The authors suggest that when serving size is ambiguous, consumers infer this from other cues, such as prior experience, or information found on the package or nutrition label, such as low-fat information. As such, nutrition labels could create misleading "health halos", in which consumers believe that it is acceptable or appropriate to consume more of a food labelled as being lower in fat. This may be related to food-related guilt: low-fat claims may lead consumers to eat more because it reduces the conflict between the hedonic goal of pleasure gratification, and the long-term goal of health preservation. The authors conclude that consumers may trade off reductions in sensory quality for increased consumption, so truthful labels and claims may not be sufficient to improve eating behaviour. The authors also point out that is important to consider when a low-fat claim would lead someone to eat so much more that it offsets the lower-calorie density of low-fat foods, and how much low-fat labels affect consumption in subsequent meals (overconsumption and the choice of more indulgent extras).

Another concern regarding fat reduction in foods concerns “flavour-consequence learning based on post-ingestive nutritive effects” (for a review see Yeomans, 2006), which suggests that flavour preferences are acquired as they reliably predict post-ingestive effects. This is born out of the understanding that taste predicts the nutritional value and safety of foods in nature. For example, Kern *et al*. (1993) showed that children acquire conditioned preferences for flavours associated with high fat content, and Zandstra and El-Deredy (2011) showed that adults displayed conditioned preferences for yogurt paired with coloured labels that predicted high-energy density. As such, whilst preference may temporarily remain unchanged in reduced-fat foods, if a new relationship is learnt (i.e. that this flavour or colour no longer predicts the presence of energy), liking is likely to reduce, and the product will no longer be consumed. Thus, the challenge is often to gain sustained liking of fat-reduced food products that no longer predict energy.

It is clear that fat reduction in food products, and the consumption of such products, should help to effectively decrease the prevalence of obesity. However, this relies on food products remaining palatable (which will involve control of the microstructure), and requires thought into the most appropriate way to present reduced-fat information to the consumer in order to reduce the effect that expectations have on liking, and also on consumption amount.

12.3.2 Salt reduction

Although the intake of sodium is a nutritional requirement, excessive consumption has been linked to hypertension and stroke. However, the reduction of salt in foods is not as simple as the removal of sodium, as it has an impact on shelf life and stability, but also on flavour perception (for example the suppression of bitterness, Breslin and Beauchamp, 1995), and as such has an impact on consumer acceptability. Although it may be possible to control salt intake over a period of time, so that participants become acclimatised to lower sodium intake, in reality, consumers are likely to reject tasteless or bland products, and select alternatives with higher salt contents. There is therefore a need to produce food products that have lower sodium contents, but still taste salty.

One possibility to optimise the perception of tastants, such as saltiness or sweetness, could be to distribute taste molecules differently within the structure. For example, Holm *et al*. (2009) and (Mosca *et al*. 2010, 2012) investigated the distribution of sugar within layered gelatin structures. The authors produced samples with the same overall sugar content, but with different layers containing different concentrations, finding that the contrast between different layers increased sweetness perception, above that in homogeneous samples. They describe this phenomenon as *sensory contrast*. The same technique has been used to enhance saltiness perception in bread using an inhomogeneous spatial distribution of sodium (Noort *et al*., 2010). This technique could allow for lower concentrations of tastants to be used without compromising on taste and liking. However, currently the taste contrast can not be maintained for a long period of time due to diffusion.

Frasch-Melnik *et al*. (2010) investigated a method of controlling the sodium delivered to the taste buds by producing double (water-in-oil-in-water) emulsions, where the sodium concentration of the two water phases differed. This requires careful control of the microstructure of the emulsions as an osmotic pressure gradient exists in the system. Fat crystals at the interface of the droplets acted as Pickering particles, stablising the emulsions (particularly when emulsions contained tripalmatin in addition to monoglycerides). Whilst authors worked on encapsulating salt into the internal phase (allowing for more accurate measurement of salt release from the internal droplets), this could be reversed in real food systems, so that the consumer only tastes the external water phase (where the sodium is concentrated), and does not perceive the bland internal droplets. Thus, this method could allow for dramatic reductions in sodium, whilst maintaining perception of saltiness.

12.3.3 Self-structuring and satiety

There is also a need to formulate food products that increase satiety (that make you feel fuller for longer). Hydrocolloids have been investigated for their satiating effects. This approach often involves the "self-structuring" of a hydrocolloid *in vivo* in an attempt to achieve a physical effect (feelings of fullness) or to control the release of a macronutrient or another compound. A number of hydrocolloids gel through ionic and acid gelation, meaning that they can be used within products that are liquid on consumption, but gel in the stomach due to its low pH. Hoad *et al*. (2004) measured the perception of hunger and fullness following the ingestion of 1% sodium-alginate-based milk beverages, showing that a stronger gelling (guluronate-rich alginate) beverage was associated with a greater perception of fullness. Furthermore, MRI indicated gelled lumps in the stomach. The authors suggested that the perception of fullness was as a result of: (1) stomach distension resulting from delayed gastric emptying and gelation and (2) altered nutrient absorption, due to nutrient entrapment in the gel matrix. Furthermore, it has been shown that glycaemic response is reduced in foods containing alginate (Wolf *et al*., 2002; Williams *et al*. 2004), which the authors suggest is the result of reduced gastric emptying and nutrient absorption due to the increase in viscosity of the stomach contents. The ingestion of gelled alginate–pectin beverages was also shown to reduce energy intake (Pelkman *et al*., 2007), and Paxman *et al*. (2008) showed that an alginate pre-load decreased daily energy, carbohydrate, protein and fat intake over seven days.

Gellan gum is an alternative hydrocolloid that also gels in low pH environments. Norton *et al*. (2011) investigated the acid-induced gelation of low-acyl gellan gum *in vitro*, suggesting that structuring and de-structuring can be controlled in acidic environments similar to those that are present in the stomach. As an extension of this research, researchers at the University of Birmingham have considered both *in vitro* and *in vivo* effects, particularly on the release of glucose from the gelled network following consumption. This technology could also be used for controlled release of energy during exercise, for increased hydration, or for the release of other nutrients.

12.3.4 Functional and personalised foods

Functional foods include a range of foods reported to have enhanced health benefits, beyond satisfying basic nutritional requirements. In Siró *et al*.'s (2008) recent review, the authors define functional foods as "food products fortified with special constituents that possess advantageous physiological effects". Such foods may improve one's general physical condition, or decrease the risk of diseases. This can include fortified (additional nutrients) or enriched products (added components not normally found in a particular food), and include probiotics (containing live micro-organisms), prebiotics (non-digestible food ingredients that stimulate the growth or activity of bacteria in the colon), and foods and beverages fortified with vitamins or other functional ingredients, such as antioxidants or dietary fibre. Betoret *et al*. (2011) review the current trends and technologies in functional foods. The current methods for producing functional foods include microencapsulation, whereby the bioactive is protected against degradation (for example oxidation) so that it remains functional during processing, storage and in the GI tract. The encapsulated system could also be designed to give targeted release in a particular part of the GI tract. Siró *et al*. (2008) state that a consumer's acceptance of such products is determined by many things, including familiarity, the nature of the product, and the consumer's health concerns. Urala and Lähteenmäki (2004) found that a number of factors accounted for consumer attitudes towards functional foods: reward from using, confidence, necessity, functional food as medicine, functional food as part of a healthy diet, absence of nutritional risk and taste. Of these factors perceived reward was the best predictor of willingness to use a functional food. However, it is clear that taste is of huge importance (Verbeke, 2006), with the functional foods merely providing added value over the favourable sensory properties of the food. However, the evidence is divided: Tuorila and Cardello (2002) found that liking of a fruit juice with an off flavour (due to the addition of potassium chloride) was higher when accompanied by a health message, but Wansink and Park (2002) found that a label indicating the presence of a "phantom ingredient" led to health claims becoming more believable, but negatively influenced taste perceptions.

An area clearly related to functional foods, but still very much in its infancy is nutrigenomics ("nutrition and genes"), or personalised nutrition. Nutrigenomics uses genetic information to develop diet and health recommendations that are tailored to the nutritional needs of specific groups, or even individuals (Sutton, 2007). This could encompass recommendations about both the adverse and beneficial effects of certain foods according to one's genetic make-up, that have advantages for health management, disease prevention or performance improvement. Manufacturing personalised foods is a challenge, as foods should have a controlled composition, have high bioavailability of active components (in structures that allow for release in specific parts of the GI tract), with good organoleptic and sensory properties. It is unlikely that truly personalised foods (for individual consumers) will be made at large volume, but consumers with specific genetic profiles could be grouped, or foods could be targeted to families. It may also be possible through point-of-sale technology, where a food or beverage could be prepared using a combination of ingredients to suit an individual's genotype, and preferences (Sutton, 2007) or consumption needs (for example, difficultly in swallowing or deterioration of taste in the elderly). Often novel foods and technologies result in consumer sceptism. Ronteltap *et al.* (2009) considered consumer acceptance of personalised foods, suggesting that cost–benefit assessment (i.e. trade-off between pros and cons) had the greatest importance, so that personalised foods should provide clearly recognisable advantages. The challenge for nutrigenomics is to fully identify causal relationships between genome variations, diets, environmental factors and chronic diseases, and to produce food products that taste good (as perceived by individual consumers) that can deliver actives in the right place at the right time!

Ronteltap *et al.* (2007) developed a conceptual framework for consumer acceptance of food innovations, and used evidence in the literature to support the framework. The authors suggest that adoption (or acceptance) of food is determined by four proximal constructs that influence consumers attitudes:

1. Perceived costs and benefits: the trade-off between the costs and benefits of consuming the product, which can be related to its usage (usefulness or ease of use), sensory properties (appearance and taste), health and environmental benefits;
2. Perceived risk and uncertainty: the potential harm and ambiguity associated, which can include safety (health or environmental) concern, emotions and trust;
3. Subjective norm: whether significant others are likely to endorse the behaviour, which can also include social pressure or influence, and is related to social status;
4. Perceived behavioural control: whether the person believes they can actually perform the behaviour (associated with self-efficacy).

These perceptions are in turn affected by three distal determinants:

a. Features of the innovation: including price, product brand and name, complexity, taste, appearance;
b. Consumer characteristics: for example socio-economic status, income, nationality, age, gender, food neophobia, general attitude and values;
c. Characteristics of the social system of which the consumer is part: such as economic, political and social environment.

To summarise, the second section of this chapter highlighted a number of current consumer food trends. These include growing health concern, growing convenience orientation, hedonism and growing environmental and ethical concern. We particularly focused on health, providing examples of fat reduction, salt reduction, self-structuring and functional foods, including nutrigenomics, giving details of the technology that is being used to produce food products that can address these trends, and also the consumer research that should highlight some of the concerns that need to be addressed in order to ensure that foods are accepted by consumers, and that they have a beneficial rather than a detrimental effect on health.

12.4 CONCLUSIONS

The aim of this chapter was to understand how we might design food structures for consumer acceptability. In the modern world, consumers have a huge amount of choice when it comes to what they eat. As such, having an understanding of what consumers want or need will ensure the success of food products. Naturally, this is of extreme importance for the food industry, but also for those of us who are designing food with health benefits – foods can only improve one's health if they are chosen, liked and consumed! The chapter has introduced the concept of consumer acceptability, highlighting the different factors that can affect it (sensory, situational and cognitive influences), and the experimental methods that can be used to measure it (both directly and indirectly). In the second section of the chapter a number of consumer food trends were introduced. Of particular interest is growing health consciousness, which relates to the reduction of both fat and sodium in foods, the use of self-structuring foods for increased satiety and the controlled release of macronutrients, and functional and personalised foods. Details of the types of technology that are being used to produce such foods was given, as was the consumer research that is helping to ensure that the technology is accepted by consumers, but also the challenges when marketing such products to ensure that they are not consumed to excess (undoing any positive effect that they may have on health). It is clear that different disciplines are essential in food design, production and manufacture, and that the consumer should be the driving force behind food design. The challenge will be to create functional or even personalised foods, that taste great, are natural, nutritional, convenient and great value for money!

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