CHAPTER 1

Time-Dependent Measures of Perception: An Introduction

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1.1 Introduction

Perception of a product is a dynamic process. This description concerning drinking beer (Bickham, 1997) is a great example outlining one of the many temporal sensory journeys encountered by consumers when interacting with products.

> From the moment the bottle is opened and the beer is poured into a glass, our ears are greeted by the hiss of escaping carbon dioxide. Our eyes are attracted by the sparkling clarity of a Pilsener, the hazy sheen of a Weizen, or the black depth of a stout. We patiently wait for the creamy head to slowly collapse, leaving wisps of Belgian lace on the sides of the glass. As we bring the beer to our lips, our nose detects the aroma of citrusy hops in an American pale ale, bittersweet chocolate in a porter, or perhaps fruity, spicy esters in a Trappist ale. Finally, we imbibe, savouring the malt, hop, and ester flavours before swallowing to let the hop alpha-acids wake the taste buds on the back of the tongue. We take another drink and swish the beer through our mouth to evaluate the body and mouthfeel. Ah, this seems like a well-made beer – but wait! What is that lingering aftertaste? Does it taste like cooked cabbage, or is it perhaps reminiscent of newly mown grass? Is that a hint of paper or leather in the background?'

Wine, chocolate, ice cream and chewing gum are all further obvious examples of food products whose sensory properties change dynamically during oral processing, but in fact all food and beverages will be warmed, mixed and manipulated to some degree in the mouth resulting in changeable sensory profiles. Of course, it is not just simply foods which exhibit temporal sensory profiles – for example, the vibrancy of lipstick, persistency of a hair dye and the intensity and nature of perfumes, cologne, air fresheners, fabric conditioners and deodorants are all attributes which also change overtime and are regarded as quality attributes by the consumer. Descriptive techniques at different time points have been widely adopted and adapted for many different types of products including foods, beverages, fragrances, cosmetics, personal care and household products.

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1.2 Development of Time-Dependent Techniques for Dynamic Changes in Sensory Attributes

Measures made at a single time point, such as those obtained through traditional descriptive analysis techniques (Kemp et al., 2016) require assessors, or even consumers, to make an evaluation at one time point and hence do not capture the full temporal sensory encounter. Such evaluations are likely to be an integration of the whole experience (Dijksterhuis and Piggot, 2000), or depending on the assessor or tasting protocol, specific to a certain point in time. Thus, it is not surprising that temporal methods that captured dynamic changes began to be developed alongside other sensory techniques. The need to measure attribute intensity over time was initially recognised in the literature as an important aspect of taste perception in 1937 by Holway and Hurvich (1937). In the fifties, Sjostrom (1954) began quantifying the temporal response and, over the next three decades, developments in the technique and particularly its data acquisition methods (for example: Jellinek, 1964; Meiselman, 1968; McNulty and Moskowitz, 1974; Larson-Powers and Pangborn, 1978; Lawless and Skinner, 1979; Birch and Munton, 1981; Munoz et al., 1986; Guinard et al., 1985; Lee, 1985) saw its wide application to taste and flavour perception (Cliff and Heymann, 1993). Not surprisingly, there have been several useful published reviews of the technique to which the reader is directed (Lee and Pangborn, 1986; Cliff and Heymann, 1993; and Dijksterhuis and Piggott, 2000).

Initially, time–intensity (TI) data were collected at discrete time points defined by the investigator. However, the development of chart recorders and computer programs allowed for the collection of continuous data. Nowadays, the choice between discrete and continuous TI (CTI) techniques is related to the objective of the test – for short events, CTI is ideal but for longer investigations, e.g. the intensity of fabric conditioner fragrance on laundry, judgements made at discrete well-defined time points are most effective. Chapters 8 and 9 in this text provide an updated look at developments in discrete and CTI methods, respectively, and provide guidance on specific methodological considerations and data analysis techniques. Each also provides useful case studies highlighting the effective application of these techniques.

CTI was designed to follow the perceptual intensity of a single attribute, and has been useful to investigate key product attributes, such as mint flavour in chewing gum, but it is rare for products to vary in just one characteristic over time. Methods have since been developed which track the intensity of more than one attribute, such as progressive profiling (Jack et al., 1994); the dynamic flavour profile method (DeRovira 1996), sequential profiling (Methven et al., 2010) and dual-attribute TI (DATI; Duizer et al., 1996, 1997). The last is the subject of Chapter 10.

Changes in attribute intensity are not the only changes that occur to sensory properties over time and, although TI continues to be a well-used tool in the sensory toolbox, the 21st century has seen the development of new approaches which enable other aspects of a sensory temporal profile to be explored. The most notable development has been the technique that emerged from Pascal Schlich's laboratory at INRA, Dijon, called temporal dominance of sensations (TDS; Pineau et al., 2003, 2009), recently reviewed by Di Monaco et al. (2014). Rather than focusing on single attribute intensities, this approach considers all product attributes from which the panel then identify those that are perceived to be dominant at any time during consumption. It captures data that allows the sequence of dominant sensations experienced during product interactions to be described. It is not proposed as a replacement to TI but as a complementary and different way of looking at the temporal profile experienced by the consumer over time. Chapter 11 provides a comprehensive review of the technique, aspects of data analysis and presentation and considerations relating to the practical application of the technique.

The application of the aforementioned techniques has often been restricted to single bites or sips of products but this is rarely representative of real situations where individuals consume multiple bites or sips of the product. The TDS approach has already been extended to multiple sips with success (Jappinen 2014; Zorn et al., 2014; Hort et al., 2015). Where researchers have required a fuller sensory profile of how attribute intensity for a full range of sensory characteristics evolves during repeated exposure to a product, multi-sampling TI has provided a solution. Essentially, assessors perform a series of single-attribute evaluations across multiple sips/bites of the product. This approach is the subject of Chapter 12, which contains two interesting case studies on measuring the temporal profiles of ice cream and tea.

The measurement of temporal changes in sensory attributes appears to have been re-energised in that last few years with new methods such as temporal order of sensations (TOS; Pecore et al., 2009) and temporal check-all-that-apply (TCATA; Castura et al., 2014a,b) methodologies presented at recent Sensory meetings, which are already available within some commercial data collection and analysis software programmes. Although these approaches do not have dedicated chapters in this book, they are described in the final summary chapter.

The use of time-dependent measures continues to evolve. In the early years, the focus was on development of the original TI approach, its data collection and analysis, and its application to understand fundamental elements of taste and aroma perception one attribute at a time. Developments in techniques that have enabled multiple attributes to be considered concurrently have seen broader application of the technique beyond technical understanding to much wider product development applications.

1.3 Time-Dependent Methods as Tools in Sensory Evaluation

Time-dependent methods are a distinctive subset of descriptive analysis techniques that allow the changes in the temporal sensory profile of a product to be monitored. Like all descriptive techniques, they generally provide detailed, precise, reliable and objective information concerning the sensory attributes of a product. However, uniquely, they are focused on capturing information about the dynamic changes in an attribute or attributes, whereas other descriptive techniques provide a profile of an overall impression of an attribute or an attribute at a single time point. Non-time-dependent descriptive techniques provide an overall sensory profile of the product, although sometimes temporal elements are captured by stating the stage during consumption/use at which a measure is taken – for example, initial sweetness, sweetness in the mouth, sweet aftertaste. This provides useful information and researchers should consider whether such a level of information is sufficient for their particular objectives before investing in what are often more time-consuming and costly approaches with time-dependent techniques (Lawless and Heymann, 1998). However, where detailed temporal information is needed, time-dependent approaches should be employed and can provide insightful data.

In parallel with most other descriptive techniques, time-dependent methods use humans as measuring instruments under controlled conditions (to minimise bias) in order to generate, in this case, temporal data. The length of time-dependent studies often means that fewer assessors are used, owing to the practical considerations of time and resource. In most time-dependent techniques, assessors who have good sensory abilities for the attributes under evaluation are selected and trained in the sensory properties of interest and the protocols involved. More recent methods, however, have been trialled with consumers with some success, but more research is required to understand the value of such data.

Currently, time-dependent methods can be separated into those which track the intensity of attributes over time and those which focus on the order in which attributes occur. In either case, the attributes of interest first need to be identified. When tracking intensity, the focus may be on one attribute; for example, tracking the bitterness profile of beer or the sweetness of a new sweetener over time, or several attributes may be of interest, such as tracking the intensity of different aroma notes in a fabric softener over several days. In such investigations, training assessors to recognise the attributes of interest and to use a scale repeatedly to evaluate their intensity will be a crucial first step. When evaluating the order in which sensations are perceived, again a key process early on is familiarisation of the panel with the perceivable product attributes, although the length of training may depend on the type of assessors. For both categories of techniques, references can be used to help train assessors but if the project is long term then the effect of time on the sensory properties of the references themselves could become problematic and so would need consideration. When/if using consumers, less time will be focused on this training stage but care needs to be taken in terms of the lexicon of terms employed as to whether it might be too technical. A secondary stage with these types of approach (TDS, TCATA, TOS) is also deciding how many attributes to include in the list. Practice runs and discussions during training can facilitate elimination of attributes that are not likely to be selected during the final evaluation.

In general, time-dependent methods can be more complex and demanding on the assessor than other descriptive techniques. For all methods, training in the protocol is essential. Recording observations while concentrating on perception can be difficult, especially over short time periods. In such cases, considerable practice is required with the recording mechanism which nowadays tends to be a mouse on a scale or a touch screen. If assessing products on or using hands or arms etc. the assessor may need to use a voice recorder to shout out their perceptions according to a timer. For some trials, assessors may need to learn specific protocols to minimise bias; for example, chewing to a metronome, applying cosmetics and creams at a certain rate and so on, all of which takes considerable practice to obtain consistency across products.

Owing to the level of control required in most time-dependent methods, studies on short-term dynamic changes in products tend to take place in a specialist sensory laboratory. Even longer-term studies, for example of the effectiveness of air fresheners, may invite assessors back to the laboratory over several days to evaluate products. Some consultancies, for example, have specially designed labs to enable personal-care products to be tested on the premises. Longer-term evaluations, however, may take place out of the lab, especially if researchers are interested in the response in a more realistic context such as the home. Alternatively, where the product and objective dictate, samples can be prepared in advance to represent different time points (e.g. fabrics stored for different lengths of time, fragrances sprayed on blotter strips at various time points prior to evaluation) enabling different discrete time points to be evaluated in one session.

General rules regarding sample presentation and presentation order apply to time-dependent techniques but, depending on the length of the evaluation, the number that can be assessed in any one session may become problematic. Time-dependent techniques are effective ways of investigating products which have stimuli with a long time course but, often, these stimuli also create carry-over effects which call for the need of very effective palate cleansers or similar, or may mean only assessing one sample per session. The temporal nature of these studies can also mean that adaptation to stimuli is an important consideration.

Indeed, it is not possible to discuss the temporal nature of sensory perception without considering the physiological mechanism known as adaptation. Humans are programmed to respond to changes in the environment so that they can react quickly if such changes are harmful. Essentially, the nervous system becomes desensitised to any constant stimulus, enabling brain capacity to be reserved for the detection of changes in the environment which are potentially more dangerous. The level of adaptation depends on the modality; for example, adaptation to light is not usually complete, whereas it can be for aroma and touch. For the sensory scientist, this phenomenon can be problematic and, if not controlled, can impact on the validity of data collected from assessors. Controlling adaptation may be more problematic for, or indeed could be considered an inbuilt aspect of, time-dependent methods. Consequently, a whole chapter has been dedicated to this phenomenon in this book. Chapter 4 introduces the concepts and mechanisms behind adaptation in the context of sensory evaluation and provides insights into controlling its effects. Adaptation also features in discussions concerning the theory of sensory memory and, indeed, can also have an important role in the dynamics of liking. Chapters 5 and 6 thus also provide interesting reading for those interested in this phenomenon.

The type of the data generated from time-dependent techniques will depend on the approach that is taken. TI data are by their very nature quantitative and are either collected at discrete time points or continuously. Initially, TI studies employed clocks or audible cues to note the time course of the sensation and assessors rated intensity at specific discrete time points. In the 1970s, Larson-Powers and Pangborn (1978) and Lawless and Skinner (1979) both independently developed strip-chart recorders to register the continuous time course of a sensation. Birch and Munton (1981) then developed the sensory measurement unit for recording flux (SMURF) apparatus, which, instead of using a pen on a moving chart recorder, employed a potentiometer which converted the signal to a strip-chart recorder as assessors turned a dial controlling a variable resistor. In all such approaches, the TI curves were then manually digitised, which was time consuming and laborious. Computers allowed the electronic collection of on-screen data and, not surprisingly, such advances saw an increase in the number of TI studies. Today, computerised systems are available through different software companies for the collection of discrete time–intensity (DTI) and CTI data, which has considerably enhanced the ease and availability of data collection and processing. Such data are then further processed to provide average TI curves across individual assessors or a panel, and several approaches have been suggested in terms of how to best achieve this; for example, Overbosch et al. (1986), Liu and Macfie (1990) and Ledauphin et al. (2006), and are discussed in more detail in Chapter 9. Finally, certain parameters are extracted, such as maximum intensity, time to maximum intensity, area under the curve and time of sensation duration, to characterise the key features of the dynamic sensation. Analysis of variance is then typically applied to these data to identify differences across products for each of the key temporal features.

More recent techniques, such as TDS, TOS and TCATA, focus on evaluating the proportion of observations citing the occurrence of a particular attribute over time. This is continuously collected in TDS and TCATA and at discrete time points in TOS. The latter two methods enable more than one attribute to be considered at any time point. Further detailed information concerning data analysis and presentation for these methods is available in Chapter 11 (TDS) and the summary chapter at the end of this book (TOS, TCATA).

Ultimately, choosing which time-dependent method to use for an investigation will depend on the specific objective of the investigation and resources available. CTI and DTI, together with multi-sampling techniques, provide a considerable amount of detail but are very time consuming. Having assessors focus and attend to a single or a few attributes temporally may also mean that the data collected are biased and that, in a more comprehensive evaluation of a product, for example a quantitative descriptive analysis (QDA) profile, those attributes may be perceived differently. More rapid methods, such as TCATA, provide results much more quickly, but do not give the depth of information that might be required and may miss important information about more subtle attributes. A further discussion of the relative merits of the different techniques is provided in the final summary chapter of this textbook. It is, however, worth noting that, as with all sensory approaches, it is not always appropriate to judge methods in isolation. The power of time-dependent techniques is often realised when they are combined with others. For example, QDA can provide a rich profile of key sensory attributes in a product, but combining that with TI of critical attributes or a TDS to identify the dominant attributes can be most powerful. In the 20th century, combining temporal methods with physicochemical data gave insights into what was driving the dynamic changes observed by consumers and, more recently, time-dependent methods have been combined with measures of liking and emotional response to gain deeper insights into the consumer-affective response to the dynamic sensory nature of products.

1.4 Time-Dependent Measures of the Affective Response

During developments of the single-attribute, TI technique, Taylor and Pangborn (1990) also applied the approach to measuring liking response to chocolate milk over 80 seconds. They concluded that, like sensory attributes, hedonic response is not static but varies from the first sip to swallowing and during aftertaste. The technique was also applied to liking of basic tastes (Yoshida et al., 1992) and, more recently, the temporal dominance approach was used with cereals (Sudre, Pineau et al., 2012) and cheese (Thomas et al., 2015) by replacing attributes with 'levels of liking' as a different approach to recording dynamic changes in liking during a consumption event.

What is also evident is that the liking response to further ingestion of the same stimulus also brings about decreases in liking and a tendency to want to eat less of that product over short time periods. This phenomenon, known as sensory-specific satiety, has evolved to enable omnivores to eat a varied diet to obtain the nutrients they need to survive. It has clear implications for food choice behaviour, health and wellbeing, but it also has implications for the number of samples from which we can reliably collect data in sensory and consumer tests. Chapter 3 in this book provides a detailed look at the concept of sensory-specific satiety and the methods that can be used to measure its effects.

Our past sensory experiences are important in creating expectations which we use to make decisions on product choice. But how effective are we at remembering sensory experiences? Chapter 5 takes a comprehensive look at what is currently known about sensory memory. In discussing the approaches to measuring it, the authors make reference to some interesting experiments indicating that we are much better at recognising when something has changed, as opposed to being able to describe the actual sensations associated with the original encounter. The authors go on to indicate how this understanding could be used to develop more effective consumer research and marketing strategies. For example, remembered sensations are often inaccurate and the size of such discrepancies may impact on repurchasing behaviour and, hence, recommendations are made for testing sensory memory for products prior to any launch decisions being made. In addition, data based on first impressions of a product are shown to be misleading and understanding how preferences develop over several exposures is shown to be more relevant, and hence more predictive of purchase behaviour.

As we know through our own personal experiences, food preferences also change over longer time periods. Several factors drive these changes but ensuring that we use that understanding to develop and choose appropriate sensory methods to measure consumer response is central to facilitating the launch of products that will be successful. Chapter 6 explores the dynamics of liking and the important influences on preferences throughout an individual's lifespan, including short- and long-term effects, together with situational and contextual factors. This is followed by a useful description of methods proposed to help researchers lower the risks associated with product boredom and hence improve the prediction of long-term liking and marketing success. The authors also highlight the significance of using a more consumer-centric and less reductionist approach in evaluating the hedonic response and the importance of consumer segmentation for situational appropriateness of product use.

1.5 Applications of Time-Dependent Measures of Perception

Time-dependent methods can be applied in similar situations to other types of descriptive analysis, although the focus is obviously on products and contexts where the time element is important.

1.5.1 Product Characterisation

As they are what time-dependent measures were designed for, it is not surprising that such methods have mainly been applied to characterise the temporal profiles of products. There are no doubt many examples within an industrial context, which, for commercial reasons, have not been published but, for example, the descriptions of Walkers® Sensations® crisps, certainly point to a clear understanding in industry of the importance of a product's temporal characteristics: the experience of Mexican Chipotle crisps, for instance, is described as 'First the deep, smoky flavour of chipotle chilli gives way to sweet pimento and onion, before finishing with a spicy, lingering heat'; and that of Thai Sweet Chilli crisps as 'with every tasty crunch, experience the savoury flavours of delicious chilli, onion and herbs building to a moreish kick of sweet, satisfying heat' (http://sensationscrisps.co.uk).

Published works demonstrating the use of time-dependent methods for investigating food and beverages are now numerous and can be divided across many product categories; a range of examples is given in Table 1.1. Although this list is not complete, it serves to demonstrate the wide application of these techniques. Literature concerning the use of time-dependent sensory methods with personal, pharmaceutical and household care products is much more limited, probably due to commercial sensitivity. It tends to be restricted to the application of DTI or CTI; for example, Farage et al. (2006) investigating temporal sensory and cutaneous effects of feminine hygiene pads, Farage (2005) investigating the irritability of facial tissue over repeated use and Westerink and Kozlov (2004) looking at temporal freshness of oral care products. However, newer approaches are now being adopted, as can be seen in Chapter 13 and are starting to appear in the literature, with Boinbaser et al. (2015) demonstrating the application of TCATA to characterise the dynamic sensory profile of cosmetic creams.

1.5.2 Product Development

As the temporal sensory signature of a product has an impact on consumer liking, it is an important element for consideration during the development and/or optimisation of any type of product. Owing to commercial sensitivity and protection of competitive advantage, the use of time-dependent measures in the development of commercial products is rarely reported in the literature. Nevertheless, it is applied across both the food and non-food industries.

Time-dependent measures are used to produce market overviews by describing and comparing the perceived sensory characteristics of products on the market that change with time, such as comparison of current products and competitors for benchmarking and monitoring, category or market review, identification of opportunities, such as temporal sensory characteristics and combinations that are not delivered by the market or the current product range. Temporal sensory data can be linked to consumer data, such as hedonics, to enable sensory-based consumer segments to be identified and targeted.

Table 1.1 Examples of the application of temporal methods to product characterisation.

Product category	References	Time-dependent method
Beverages	Larson-Powers and Pangborn (1978)	TI
	Veldhuizen et al. (2006)	TI
	Methven et al. (2010)	SP
	Ng et al. (2012)	TDS
	Barron et al. (2012)	TDS
	Dinnella et al. (2013)	TDS
	Gotow et al. (2015)	TI
	Charles et al. (2015)	TDS
Beer	Sjostrom (1954)	TI
	Neilson (1957)	TI
	Jellinek (1964)	TI
	Pangborn et al. (1983)	TI
	Schmidt et al. (1984)	TI
	van Buuren (1992)	TI
	Issanchou and Porcherot (1992)	TI
	Francois et al. (2006)	TI
	Fritsch and Shellhammer (2008)	TI
	Vazquez-Araujo et al. (2013)	TI TDS
Spirits	Piggott et al. (2000)	TI
	Deleris et al. (2011)	TDS
Gelatine and gelled systems	Larson-Powers and Pangborn (1978)	TI
	Eilers and Dijksterhuis (2004)	TI
	Bayarri et al. (2007)	TI
	Labbe et al. (2009)	TDS
	Saint-Eve et al. (2011)	TDS
Meat/fish and meat/fish products	Duizer et al. (1996)	DATI
	Zimoch and Gullett (1997)	TI
	Peyvieux and Dijksterhuis (2001)	TI
	Reinbach et al. (2007)	TI
	Ventanas et al. (2010)	TI
	Albert et al. (2012)	TDS
	Fuentes et al. (2013)	TI
	Fuentes et al. (2014)	TI
	Lorido et al. (2014)	TI
	Lorido et al. (2015)	TI
Potato snacks	Rama et al. (2013)	TI
	Marques Freire et al. (2015)	TI
Salad dressings	Wendin et al. (2001)	TI
	Guinard et al. (2002)	TI
	Chaya et al. (2004)	TI
Cheese and cheese products	Jack et al. (1994)	PP
	Wendin et al. (2000)	TI
	Echols et al. (2003)	TI

Table 1.1 (Continued)

Product category	References	Time-dependent method
Chocolate and chocolate products	Birch and Ogunmoyela (1980)	TI
	Pangborn and Koyasako (1981)	TI
	Lee (1985)	TI
	Janestad et al. (2000)	TI
	Ledauphin et al. (2006)	TI
	Le Reverend et al. (2008)	TI & TDS
	Sook Chung and Lee (2012)	TI
	Lenfant et al. (2013)	TI
	Morais et al. (2014)	MTI & TDS
	Palazzo and Bolini (2014)	MTI
Ice-cream	Moore and Shoemaker (1981)	TI
	Lallemand et al. (1999)	TI
	Frost et al. (2005)	TI
	Cadena and Andre Bolini (2011)	TI
	Varela et al. (2014)	TDS
Chewing gum	Duizer et al. (1996)	DATI
	Davidson et al. (1999)	TI
	Ovejero-Lopez et al. (2005)	TI
	McGowan et al. (2005)	TI
Wine	Pickering et al. (1998)	TI
	Meillon et al. (2009)	TDS
	Meillon et al. (2010)	TDS
	Baker and Ross (2014a)	TI
	Baker and Ross (2014b)	TI
	Goodstein et al. (2014)	TI
	Sokolowsky et al. (2015)	TI & TDS
	White and Heymann (2015)	TI
Taffy	Kuesteni et al. (2013)	MATI
Sea salt	Drake and Drake (2011)	TI
	Vella et al. (2012)	TI
Olive oil	Bertuccioli and Monteleone (2014)	TDS
Biscuits/breads	Lim et al. (1989)	TI
	Barylko-Pikielna et al. (1990)	TI
	Machado Alencar et al. (2015)	TI
Liquid dairy/yogurt	Pineau et al. (2009)	TDS & TI
	Bruzzone et al. (2013)	TDS
Water	Teillet et al. (2010)	TDS
Fruit/fruit fillings	Harker et al. (2003)	TI
	Agudelo et al. (2015)	TDS
Sorghum	Kobue-Lekalake et al. (2012)	DATI
Food combinations	Dinnella et al. (2012) (extra virgin olive oil/vegetables)	TDS
	Paulsenet al. (2013) salmon/sauce	TDS

TI, time intensity; TDS, temporal dominance of sensations; MTI, multiple time intensity; DATI, dual attribute time intensity; PP, progressive profiling; SP, sequential profiling.

In new product design and development, time-dependent measures can be used to help define a precise sensory target, which can be developed using experimental design and modelling to link physicochemical properties, obtained via instrumental measures, to sensory and consumer data, and are particularly helpful at different stages of consumer/product interaction, such as before, during and after product use.

Product optimisation can use time-dependent measures to improve liking, reduce costs, create value or substitute ingredients, although discrimination techniques may be more appropriate when matching the current product or when sensory differences are expected to be very small.

Competitive advantage can be protected through the use of temporal sensory data in patent support and copyright or trademark protection by helping to define signature sensory characteristics that form part of a branding mix, or a perception that is an integral part of the product.

One of the key issues in product development has been the production of healthier variants of the foods consumers like to eat. This has meant trying to reduce salt, sugar and fat levels or finding replacements which mimic their sensory properties. Both strategies, however, have been shown to impact the temporal profile of the new variants and, hence, the application of time-dependent measures of perception has become an important part of many product development cycles and the literature is awash with studies investigating ingredient replacers or reduction strategies.

Barylko-Pikielna et al. (1990) demonstrated that, in bread, reducing NaCl content affected not only saltiness intensity but also several TI parameters and that, indeed, the magnitude of the effect was product specific, dependent on whether it was rye or wheat bread. Lorido et al. (2015) have also recently reported that all saltiness TI parameters were affected by NaCl reduction in ham. Other researchers have focused on investigating possible replacements for NaCl using time-dependent techniques. Using both TI and TDS, Rodrigues et al. (2014) developed a mixture of salts for use in Mozzarella cheese, which elicited no off tastes and so could help to reduce sodium content. However, other researchers have reported that TDS has highlighted additional dominant characteristics from salt substitutes used in cream cheese (da Silva et al., 2014) and butter (de Souza et al., 2013). In the latter, for example, potassium chloride elicited dominant bitter attributes, potassium phosphate sour attributes and monosodium glutamate led to predominant sweet and umami characteristics. Other approaches evaluated using TI techniques involve the topical application of smaller salt crystal sizes, which appears to increase saltiness intensity and the speed to maximum saltiness, thus offering an alternative to sodium reduction (Rama et al., 2013, Marques Freire et al., 2015).

Many of the early studies using TI analysis were applied to sweetness and sweetener perception and this is still an area creating great interest in the literature, with a particular focus on replacements for calorific sugar and, most recently, for natural alternatives. A key issue is that, although equivalent sweetness may be relatively easy to achieve, matching the quality and temporal profile of the sweetness of calorific sweeteners is more difficult. As increasingly more new compounds are found to elicit sweet tastes, the use of time-dependent methods to evaluate their sensory profile is very important. MNEI, a protein-based sweetener, was recently characterised using TI and TDS (Di Monaco et al., 2014), and was shown to have lost its sweetness later than sucrose, although it gave the same TDS signature. Tagatose was also shown to have no undesirable sensory attributes and to have a similar rate of intensity increase for sweetness as sucrose (Fujimaru et al., 2012). Other research has used time-dependent methods for comparing a range of different sweeteners, highlighting potential substitutes for use in specific products. For example, neotame and sucralose were shown to match sucrose well for use in espresso coffee (Azevedo et al., 2015) and sucralose again for jams (de Souza et al., 2013). The latter also highlighted a change in temporal bitterness profile across several of the other sweeteners, which made them unacceptable replacers. In a three-sip TDS approach, Zorn et al. (2014) also highlighted a bitter and off aftertaste from Stevia when used as a sucrose replacer in orange juice. Multiple TI analysis was also used by de Morais et al. (2013) in an investigation looking at the impact of sugar substitutes for use in gluten-free bread. The application of time-dependent measures will clearly continue to be a key aspect of in research to find and use sugar replacers. As highlighted in earlier sections, the application of time-dependent measures has also helped to explain differences in the flavour profile of low- and high-fat foods.

1.5.3 Quality Assurance and Quality Control

A product's temporal sensory signature must be consistent if product quality is to be maintained. Ideally, as part of quality assurance, the key elements of a product's temporal signature that are important to consumers are identified and included in the product's sensory specification. The quality panel is trained to recognise these, often in addition to the tolerance range of attribute intensities, measured using classic descriptive analysis. The quality panel should also be aware of potential taints and off flavours that may occur as aftertastes and be sensitive to these during routine quality-control testing.

Many products are characterised by the importance of their temporal nature; for example, the long-lasting flavour of gum and the breath-freshening quality of toothpastes and mouthwashes, the lingering fragrances of air fresheners and fabric softeners. Regular product checks against the specification for these time-dependent elements are critical to maintaining the success of the brand. Quality assurance includes checking the temporal characteristics of key ingredients against purchase specifications, particularly where extracts are used as they may be more variable than single compounds. It also involves regular quality checks of the base products into which the flavours or fragrances are entrapped, such as the gum base for chewing gums or the gels for air freshener fragrances, to ensure appropriate release to give the desired temporal sensory characteristics.

Product quality, including temporal sensory properties, can change during a product's progress through the supply chain and so storage trials may be included in quality-testing programmes to investigate these changes. Sensory changes are due to chemical and physical changes in the product. The focus of this book is on the dynamics of sensation rather than the dynamics of physicochemical properties and, hence, storage trials are beyond its scope.

1.5.4 Marketing

Sensory and consumer research now routinely focuses on the relationship between sensory properties and overall liking, using modelling, such as preference mapping, which enables marketing teams to identify and target consumer segments or regional markets differentiated by sensory preferences. Temporal sensory data can be used in these models to identify consumer segments that are based on time-dependent sensory characteristics, such as consumers that prefer shorter or longer chilli burn.

Time-dependent measures are particularly useful to define and describe the 'sensory journey' of product usage, which can be used directly in marketing and advertising communication; such as the example above for crisps, or it can be linked to other aspects of the product journey, such as emotional benefits, to help describe the overall product usage experience.

1.5.5 Research into Fundamental Aspects of Sensory Perception

The emergence of CTI and, subsequently, other time-dependent methods, provided researchers with an additional tool with which to investigate fundamental aspects of sensory perception, including the development of theoretical and mechanistic perceptual models (Cliff and Heymann, 1993). The initial focus was on taste, but further work has progressed to investigating temporal aspects of trigeminal, aroma, flavour and texture perception and, indeed, the interrelationships between them. A detailed discussion of this research is beyond the scope of this chapter but a short review of the use of time-dependent techniques to understand more fundamental aspects of perception is presented in Chapter 15.

1.6 Summary

It is clear that there is now a better understanding of the temporal nature of perception and the factors that impact on it, although there is still work to be done. Increased understanding has led to the development of methods to measure changes in both sensory and affective responses to products and, although much of this work has been related to food products, there has been considerable application and modification of these techniques to non-food products.

The overall aim of this book is to provide the reader with an overview of the temporal elements of perception, the need to understand such changes, and the methods available in the sensory toolbox used to measure time-dependent characteristics. It is divided into five sections. The current chapter, which makes up Section 1, has provided a general introduction to the measurement of time-dependent perception. Section 2 contains chapters which focus on physiological and psychological aspects influencing time-dependent perception, providing important background understanding to the design of time-dependent investigations and interpretation of temporal data. Although the need to measure temporal elements of perception in foods was recognised back in the 1930s, the first method published to measure it was the TI technique described by Sjostrom and Cairncross in 1953. Other approaches capturing time-dependent elements of perception have since been developed and Section 3 is devoted to chapters which describe the established techniques within the sensory toolbox for evaluating changes in sensory properties over time. Following a general overview of considerations needed for any time-dependent technique, Chapters 8–12 provide background on the specific techniques of discrete point, CTI and DATI, TDS and multiple-sample TI. Section 4 includes chapters giving an overview of the application of different temporal techniques to both food and non-food products and the fundamental understanding of flavour perception. The final summary chapter, making up Section 5, concludes the book by describing some of the recent time-dependent techniques put forward by researchers. It also considers the relative merits of the different approaches and methods available alongside considerations for future developments in the temporal arena.

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