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Adapting and enhancing sequential profiling to understand the effects of successive ingestion, using the sensory characteristics of high intensity sweeteners as a case study

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ABSTRACT

Sensory science is continuously adapting to improve the assessment techniques available. Temporal methods evaluate the effect of time on the perception of sensory characteristics; however few techniques investigate the effect of total product ingestion. Sequential profiling offers the most complete assessment of attributes over successive ingestion, however it involves minimal product volumes compared to consumer eating and drinking behaviour. This study aimed to modify sequential profiling to increase the total ingestion volume and include a wider range of attributes in a case study of sugars and sweeteners. The ever increasing consumer demand for low-calorie sweetened products has highlighted the need to understand the sensory profiles of high-intensity sweeteners, particularly when ingested in larger volumes as in diet drinks. Increasing the number of attributes and the ingestion volume was found to enhance the sequential profiling method, allowing more significant differences between sweetening agents to be determined, which could be crucial to ensure consumer acceptance in the longer term. Understanding the effect of successive ingestion is a key stage in the development of sweetened products, especially with the successful enhancement of sequential profiling outlined in this study.

1. Introduction

Descriptive sensory methodologies are the most common sensory techniques today, used to judge single point evaluations of stimuli (Lawless & Heymann, 2010; Moussaoui & Verela, 2010). However, product consumption is not a static process, with oral processes such as salivation and mastication influencing the perception of a wide range of aroma, flavour and texture attributes (Foster et al., 2011). This has led to the development of temporal sensory assessment methods to measure the effect of ingestion and track perceptual changes (Lawless & Heymann, 2010).

Time–intensity profiling (*T–I*), originally developed to assess specific attribute persistence in products, involves the judgement of a single characteristic over a period of time, which results in an attribute intensity curve throughout the ingestion period (Larsonpowers & Pangborn, 1978). *T–I* has been a widely used and accepted method, however assessing a single attribute at a time is a limitation of this technique, making it time consuming to conduct and requiring numerous repeats to understand the temporal profile of key product attributes (Ng et al., 2012). Dual-attribute *T–I* (DATI) slightly overcomes the singular attribute assessment issue; however the complexity of assessors rating two attributes at the same time in a very short sequence has limited its widespread usage (Dijksterhuis & Piggot, 2000).

A more recent alternative temporal technique is Temporal Dominance of Sensation (TDS), which studies the sequence of dominant sensations within a product over time (Pineau et al., 2009). The exact definition of dominance is unclear and can vary depending on the study. Depending on the study specific objectives, previous investigations have considered dominance to be the sensation capturing the assessors attention throughout profiling or the appearance of a new sensation during consumption which may not be the most intense (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009; Meillon, Urbano, & Schlich, 2009; Pineau et al., 2009). This in turn gives some ambiguity to the sensation being judged, not just for the assessors, but also across different TDS studies which makes comparisons problematic. Up to ten attributes can be assessed during TDS and as it is intended to be an intuitive technique requiring minimal training time, which reduces the duration of these studies compared to *T–I*. Whilst more recent studies have investigated the effect of small scale successive

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ingestion using TDS, methodological concerns have been expressed over the repeatability and panellist performance during TDS tasks (Pineau et al., 2009; Zorn, Alcaire, Vidal, Giménez, & Gastón, 2014). Furthermore, due to the nature of TDS data output, further development is required to improve method reproducibility across studies (Pineau et al., 2009). These current temporal methods have highlighted the need for more multi-attribute assessment measures, which are more realistic to typical ingestion behaviour, involving larger consumption volumes and understanding the effect of ingestion.

Sequential profiling aims to measure these factors by assessing the effect of successive ingestion on multiple sensory characteristics of products (Methven et al., 2010). This technique involves trained sensory panellists consuming 40 mL of a beverage over a series of eight 5 mL drinks rating up to five attributes throughout the ingestion period. The effect of successive ingestion is determined by scoring attributes immediately after swallowing each 5 mL drink, and twice more after 30 and 60 s as after-effects, over the full 40 mL consumption volume. This gives 24 assessment points to assess all five attributes over the ingestion period, without palate cleansing, to represent the repeated sipping of a beverage (Methven et al., 2010). Sequential profiling provides an alternative to other temporal methods by characterising more than one or two attributes at once, unlike time–intensity, and assesses attributes of secondary rather than primary dominance in contrast to temporal dominance methods (Withers, Lewis, Gosney, & Methven, 2014). However, sequential profiling is still somewhat remote from consumer sipping behaviour, as consumers generally consume larger volumes of beverages than 40 mL. Additionally, the assessment of only five attributes could limit the sequential profiling methodology, as more complex products may require further attributes to fully understand the product temporal successive ingestion profile. Therefore, further development would help to refine and enhance the sequential profiling method for use with complex products in larger volumes.

A typical example of products consumed in large volumes is sweetened beverages such as soft drinks. However, consumers are becoming increasingly aware of the health risks associated with high sugar diets (Lustig, Schmidt, & Brindis, 2012; Popkin & Nielsen, 2003), which in turn places pressure on the food industry from regulators to decrease the sugar content of their products (Food Standards Agency, 2008; Nestle, 2013). Therefore sugar alternatives with lower calorie contents are under continuous development and scrutiny to be the ideal sugar replacement. As more and more sweetening alternatives become available, natural options such as stevia are becoming increasingly incorporated into sweetened products, a trend the food industry is keen to embrace (ADA, 2004; Pawar, Krynitsky, & Radar, 2013; İnanç & Çinar, 2009).

Table 1
Sweetening agents selected for sequential profiling and the solution concentrations deemed equi-sweet by the trained sensory panel.

Sweetening agent	Equi-sweet concentration (%)
Sucrose	2.0
Fructose	1.3
Glucose	2.9
Xylitol	2.50
Aspartame	0.01
Acesulfame K	0.01
Sucralose	0.003
Stevia (Reb A)	0.01

Sucrose (Tate & Lyle, London, UK), fructose & xylitol (Now Foods, Bloomingdale, IL, USA), glucose (Thornton & Ross Ltd, Huddersfield, UK), stevia (Vitax Inc, Irvine, California, USA), aspartame (Blackburn Distributions Ltd, Nelson Lancashire, UK), acesulfame K (A Nutrinova Nutrition Specialities & Food Ingredients, Frankfurt am Main, Germany), sucralose (Sports Supplements Ltd, Colchester, UK).

The sensory profiles of high intensity low-calorie sweeteners (HIS) can limit their suitability for food and beverage products. Previously, analysis has been conducted by single sip measures, such as quantitative descriptive analysis (QDA), and even some temporal methods such as TDS and *T–I* (Portmann & Kilcast, 1996; Schiffman, Satterly-Miller, & Bishay, 2007; Tunaley, Thomson, & McEwan, 1987). However, the remoteness of these single sip assessments of sweeteners from consumer usage behaviour, and the lack of larger volume studies highlights the need for repeat measure assessments during product development to fully understand the sensory profile of these sweetening agents.

This study aimed to adapt the current sequential profiling method to assess larger product volumes and a wider range of attributes over successive ingestion, using sweetened solutions as a specific and highly relevant case study.

2. Materials and method

2.1. Samples for sequential profiling

A range of sweetened solutions were prepared in filtered water to assess the effect of successive ingestion on their sensory characteristics (Table 1). The sweetening agents selected for this study are widely used in the food and beverage industry and cover a range of simple sugars, artificial and natural sweeteners. Sucrose, fructose, glucose, xylitol and stevia all dissolved easily at room temperature; whilst aspartame, acesulfame K and sucralose were warmed to 45 °C and thoroughly mixed by hand to dissolve, before being allowed to cool to room temperature prior to serving. Concentrations were initially based on literature (Gater, Zhao, Barnagaud, & Ferris, 2014; Tunaley et al., 1987) and were selected at a reduced level from in-market beverages as these were to be assessed directly in water without other flavours and textures of typical sweetened drinks influencing their perception. Furthermore, sweetness levels were reduced from typical commercial levels to avoid oversaturation of panellist senses, particularly essential if sweetness was found to increase over repeated ingestion. Sweetened solutions were adjusted and refined during training and ranked for sweetness until all panellists agreed that all samples were equi-sweet upon the initial sip.

2.2. Sequential profiling

The trained sensory panel (n = 12, 2 male, 10 female; age range 25–64 yrs, average age 50 yrs, minimum 6 months experience) with expertise in a wide range of profiling techniques, assessed the sweetened solutions. During preliminary training and sample familiarisation, a wide range of attributes were initially selected from the literature (Tunaley et al., 1987) and refined by the trained panel to be relevant to all the sweeteners assessed in this study. In total the panel selected ten attributes to characterise the solutions to be assessed over successive ingestion (Table 2). These attributes covered the full range of differences perceived amongst the sweetening agent solutions.

Sequential profiling methodology was adapted in this present study from the original technique outlined in Methven et al. (2010). For each solution, panellists consumed eight 15 mL aliquots consecutively, and scored the ten attributes directly after consumption, after 45 s and again after 90 s, before moving onto the next 15 mL drink without palate cleansing. Samples were presented monadically on separate days to ensure no carry-over effects of consumption and all samples were presented in a balanced presentation order, with each assessor tasting all products over two replicates. Assessors were instructed to drink the entire 15 mL volume; therefore the total quantity of each solution