The effect of training on the Temporal Dominance of Sensations (TDS) method: a study with milk protein hydrolysates

Scott C. Hutchings^{a*}, Aude de Casanove^b, Pascal Schlich^c, & Dolores O’Riordan^b

^a Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville, Victoria, Australia

^b Institute of Food and Health, School of Agriculture and Food Science, University College Dublin, Belfield, Dublin, Ireland

^c Centre des Sciences du Goût et de l’Alimentation, CNRS, INRA, Univ. Bourgogne Franche-Comté, F-21000 Dijon, France

Abstract

The Temporal Dominance of Sensations (TDS) method could be an alternative approach to trained panels for the sensory analysis of protein hydrolysates. However, the amount of training required for accurate TDS results is still unclear. Furthermore the masking of unpleasant tastes in protein hydrolysates using sweeteners is often only partially successful. The aim of this study was: (1) To undertake Temporal Dominance of Sensations (TDS) with protein hydrolysates using the same group of panelists as they progress through different levels of training: as untrained panelists, familiarized panelists, and trained panelists. (2) To examine the effect of increasing sweetness on the suppression of sensory attributes using a continuous temporal method (TDS). Four products were assessed: a casein hydrolysate at 10% wt/wt with 4 levels of sucralose (0%, 1.5%, 3% and 6% equivalent sweetness). Similar TDS results were obtained for all three levels of training for each product, however consensus of selection and product discrimination increased with training. As sweetness

increased bitterness was suppressed however cheesiness increased. Sweetness peaked before bitterness, followed by cheesiness, however temporal changes were small and subtle.

Practical applications

This work attempted to understand if the Temporal Dominance of Sensations (TDS) method, a technique showing promise with consumers, could be used with hydrolysates, to assess how much training with TDS and hydrolysates would be required to generate accurate results. It also attempted to understand how the masking of unpleasant tastes in bioactive hydrolysates can be improved. Results suggest a TDS panel of untrained panelists may be suitable for assessment of hydrolysates, however training still provided the best quality data. Masking with compounds such as sweeteners can be effective, however unpleasant after tastes often remain. This work also represents a first attempt to understand the aftertaste profile of a protein hydrolysate (and attempts to mask aftertaste with a sweet masking agent) using a temporal sensory method. Results showed dominating aftertaste attributes declined very slowly after swallowing of the hydrolysates. Attributes dominating during tasting in the mouth also dominated after swallowing.

Keywords

TDS; consumers; training; protein hydrolysates; taste masking;

1. Introduction

There is growing interest in the bioactivity of milk protein hydrolysates (Nongonierma et al., 2016). Milk protein hydrolysates have the potential to offer functional benefits for glycaemic management, cardiovascular health, and appetite modulation (Nagpal et al., 2011). However, these hydrolysates also have a range of unpleasant sensory attributes (bitterness in particular) (Leksrisompong et al., 2010; Newman et al., 2014) that have a significantly negative impact on consumer acceptability.

Sensory assessment of protein hydrolysates has typically used trained quantitative descriptive analysis with continuous scales (Leksrisompong et al., 2010, Liu, Jiang, and Peterson, 2013; Newman et al., 2014) or category scales (Hoyle and Merrit, 1994). However, sensory research using trained panels with milk protein hydrolysates is difficult, not only due to the extensive time required to train a panel (Newman et al., 2014), but the unpleasant nature of hydrolysates often causes panelists to leave panels during training or shortly after training. Consequently, rapid sensory profiling methods need to be considered when working with hydrolysates. Using such methods it is possible to use panelists without any or relatively little training (Delarue et al., 2014). One technique which offers the potential to be conducted with minimal training and can measure temporal changes in sensory perception, is the Temporal Dominance of Sensations (TDS) methodology.

Temporal Dominance of Sensations (TDS) is a sensory methodology used to assess the perception of multiple sensory attributes with time (Pineau et al., 2009). The technique requires panelists to select a dominating attribute from a pre-generated list of sensory

attributes relevant to the product under analysis (Hutchings et al., 2014a). If and when the dominant sensation changes, the panelists elects a different dominating attribute. Once data is collated a temporal profile can be established to describe the many attributes of a product, either throughout the mastication process (Saint-Eve et al., 2011) or throughout period of time a beverage or semi solid is manipulated in the oral cavity (Bruzzzone et al., 2013; Zorn et al., 2014), as well as after swallowing (Meillon et al., 2009). Research suggests that TDS can give matching and complementary results to traditional trained time intensity panels and descriptive panels (Humiski & Aluko, 2007; Pineau et al., 2009, Albert et al., 2012; Di Monaco et al., 2014; de Lavergne et al., 2015). However, little information is currently available to understand if TDS is suitable to be used for protein hydrolysates, and little is known regarding what level of training is necessary for accurate TDS results with hydrolysates.

In other food categories, TDS has been used with consumers (eg Thomas et al., 2016), familiarized panelists (eg Hutchings et al., 2017), and highly trained panelists (Pineau et al., 2009). Furthermore there is increasing interest in using TDS with consumers, in particular to draw links between the selection (and selection patterns) of dominating attributes and liking (Thomas et al., 2015). Only Rodrigues et al. (2016) has compared performance between a small group of consumers (n=10) and a different small group of familiarized panelists (n=10) with chocolate. Research with descriptive panels shows that training will improve panelists performance, increasing attribute discrimination between products (Chambers et al., 2004), and it will also improve reproducibility (Chambers and Smith, 1993). However, TDS is a different methodology to conventional trained panels using intensity scales, and to date no assessment of panelist performance has been conducted to understand how the same panelists improve or change in their use of the TDS technique as they are trained.

Furthermore, a range of techniques have been employed in attempt to suppress bitterness and other undesirable sensory attributes of protein hydrolysates. The use of salts, flavours and modification of tastant distributions, are examples (Leksrisompong et al., 2012; Hutchings et al., 2015). One of the most widely used and cost effective approaches is the use of sweet masking agents (Newman et al., 2015). However, even the use of sweet masking agents fail to completely suppress unpleasant sensory attributes. Little is currently known about time based (temporal) changes in the sensory attributes of milk protein hydrolysates during perception in the mouth and after swallowing. A lack of knowledge also exists regarding the changes in temporal perception (in mouth and after swallowing) as the level of a sweet masking agent is increased in milk protein hydrolysates. It is postulated greater knowledge in these two areas could lead to improved approaches for masking in hydrolysates.

Therefore, the aim of this study was: (1) to understand changes in the responses of TDS panelists with milk protein hydrolysates as the same group of panelists progressed through different levels of training: as an untrained panelist, familiarized panelist, and trained panelist, and (2) to examine the effect of increasing levels of a sweetener (sucralose) on the suppression of sensory attributes in milk protein hydrolysates during manipulation in the mouth and after swallowing using a time based methodology (TDS).

2. Methodology

2.1 Product formulations and serving size

Formulations used for TDS testing were based on one casein hydrolysate (10% wt/wt), sweetened to four different levels using sucralose (Camida, Tipperary, Ireland):

Product 1 (10% wt/wt hydrolysate, 0% sucralose), Product 2 (10% wt/wt hydrolysate, 0.0025% sucralose (1.5% sucrose equivalent)), Product 3 (10% wt/wt hydrolysate, 0.005% sucralose (3.0 % sucrose equivalent)), Product 4 (10% wt/wt hydrolysate, 0.01% sucralose (6.0 % sucrose equivalent)) (Sucrose equivalents were based on sucralose having a potency of 600 times that of sucrose by weight (Weit & Beyts, 1992)).

The sweetness levels were selected to understand changes in the sensory properties of the hydrolysates with a gradual increase in sweetness without generating excessively sweet products. Sweetness levels were also selected to generate products with subtle differences in their sensory profile to allow product discrimination using TDS to be assessed at each training level.

Whenever served, each product was served as a 10mL unit, inside a disposable 20 mL clear plastic cup, labelled with a randomised 3 digit code. Products were prepared at least one day prior to serving by solubilising the casein hydrolysate with a magnetic stirring bar for 1 hour at 20 °C in solubilised in demineralised water (VWR Chemicals ®, Dublin, Ireland). They were then stored overnight in a refrigerator (7°C), but brought back to 20 °C for the TDS sessions. They were disposed of after a maximum of 48 hours.

2.2 Attribute selection of the product formulations

Consumer attributes of the four products were generated by a group of 12 volunteers who did not participate in the main study (6 male, 6 female, age 22-32 years, average age: 27 years).

These volunteers were consumers who were also new to TDS. Each participant tasted the products described in Section 2.1 in a randomised order, recorded a list of words to describe the sensations they could pick up both while the product was in their mouth and after swallowing. Attributes were then collected by the researcher on a board in front of the room, and the list refined by discussion amongst the 12 consumers. After the session the final list of attributes was formed by consensus of the researchers of this study, by removing subjective, duplicate (or very similar to another attribute), or ambiguous terms. The terms were as follows: Sweet, Bitter, Salty, Cheesy, Burnt, Metallic, Dry/rough, Musty, and No Taste. The 'No Taste' attribute was added as an option for panelists to use if attributes could no longer be picked up during TDS (particularly for the aftertaste period). References and definitions were then selected for the attributes (Table 1). References were selected to generate a moderate intensity with respect to the products used in this study, corresponding to a lower central point on an intensity scale that would be used by a conventional trained panel.

2.3 Panelists, Training stages and TDS sessions

Twenty consumers were selected for the study (10 male and 10 female), age range 21-35 years, average age: 28 years). All participants undertook the TDS task three times: (1) as untrained panelists, (2) as familiarized panelists, and (3) as trained panelists (i.e. each panellist progressed through every training stage). In total, panelists completed 6 sessions: session 1 (TDS task as an untrained panellist), session 2 (TDS task as familiarized panellist), session 3 (training), session 4 (training), session 5 (training), and the session 6 (TDS task as trained panellist). For each session, the four product formulations were served in replicates

of three ($4 \times 3 = 12$ samples in total per session). The alternative option for the experimental design, where three different groups of consumers were subjected to the three training protocols was considered but not used to avoid differences in the individuals making up each group influencing conclusions.

None of the panelists had taken part in any TDS study before, and none of the panelists had been involved in trained sensory panel of any kind before. Panelists did not suffer from any oral diseases and were not taking any medications that could influence their ability to taste food products. All panelists were non-smokers. All panelists were fluent in English. All panelists who took part in this research gave informed consent, and the study was approved by the University College Dublin Human Ethics Committee (Application LS-14-21). Sessions were conducted a minimum of 2 days and a maximum 7 days apart. The experimenter read off a script to ensure training was consistent for every panelist. No more than 2 panelists were trained or tested at any single time. Panelists were told not to eat or drink anything other than water any closer than 90 minutes before each session.

The TDS task was undertaken using FIZZ sensory software (Biosystems, Couternon, France) on desktop computers, in standard sensory booths with standard white light. Booths were temperature controlled at 20 °C. Samples were served in a randomised order with randomised three digit codes (different randomised codes were also used at each session). Panelists were instructed to pour the entire sample in their mouth, immediately click start, and then as soon as possible select the most dominant sensation (*the sensation that triggers the most attention*). If and when that dominant sensation changed, they should select another attribute. At 15s panelists were alerted by the software to swallow, and then continue undertaking the TDS task until 60s at which point the data collection stopped. No

instructions were given about how to manipulate/move the product in the mouth, apart from an instruction to assess the sensations ‘in a way that is natural for you’. There was a 2 minute break between every product, where the panelist was instructed to take a bite of cream cracker (TowerGate Cream Crackers, Lidl UK, London, UK) and a sip of mineral water (Ballygowan ®, Britvic Ireland Ltd, Dublin, Ireland). Attribute order of TDS terms was randomised across panelists, but was the same for an individual panelist within the same session. Attribute order was also randomised for an individual panelist from session to session. At the end of every session (at the completion of the TDS task as an untrained, familiarized, and trained panelist), panelists were asked the following question: how confident are you about the TDS results that you gave? They answered the question using a 100mm visual analogue scale, anchored ‘not at all confident’, and ‘very confident’ at each end.

The protocol describing the six sessions every panelist undertook is described below:

2.3.1 Session 1: Untrained panelist

The first session for every participant was undertaken as an untrained panelist. The researcher gave panelists a five minute explanation about dynamic sensory perception, and then a five minute explanation about how to undertake TDS. Specifically, the following information was read out to the panelist:

What is dynamic sensory perception:

Sensory science is the study of how we experience food (tastes, flavours, smells, textures). This study will assess dynamic sensory perception, which investigates how sensory perception changes with time (e.g. as we chew food or sip a beverage). For example, when

you take a sip of wine you might initially taste a fruity flavour, but then a few seconds later you might taste a woody flavour, and then perhaps a sour taste, and then after you swallow, you might experience different flavours/tastes.

To measure dynamic sensory perception in this study we will use a method called Temporal Dominance of Sensations (TDS).

Instructions on how to use TDS:

To conduct the TDS task, pour the entire 10mL sample into your mouth, immediately click start with the mouse, and then begin assessing the sensations of the sample. As soon as possible, select your first dominant attribute, and then, if and when the dominant sensation changes, you can change your choice. You can select as many or as fewer attributes as you want, and can return to the same attribute as often as you want. While the sample is in your mouth, you can move it inside your mouth as little or much as you want, but try not to swallow. At 15s you will see an alert to swallow, please swallow when you see this. After swallowing continue the same process of selecting (and changing your selection) of dominant attributes until the time is up. You can select as many or as little attributes as you want, and can return to the same attribute as often as you want. The dominant attribute is the attribute that is triggering your most attention at that point in time. Now please conduct the TDS task for the 12 samples provided.

Then they entered the sensory booth and were required to immediately undertake the technique.

2.3.2 Session 2: Familiarized panelist

The second session, the researcher provided panelists with a list of definitions for every attribute, and then also provided a training reference for every attribute that the panelist could either taste or smell. The definition and references for each attribute is summarised in Table 1. Between tasting/smelling each reference, panelists would cleanse their mouth with mineral water. Following this reference training (which took approximately 20 minutes), panelists then entered the sensory booth to undertake the TDS task again).

2.3.3 Session 3

The third session focused on training panelists how to use the TDS technique. It involved each panelist undertaking TDS with a different casein hydrolysate that had a slightly different sensory profile to the main study, but at the same concentration of 10% wt/wt in demineralised water and using the same 4 sucralose levels (4 sucralose levels x 3 reps = 12 samples). A different hydrolysate was chosen to avoid repeated exposure to the main hydrolysate during training. However this different hydrolysate also had a sensory profile that was relevant to all attributes available for TDS (the main hydrolysate was used only for sessions 1, 2, and 6).

All other conditions were the same as the main sessions. For this session, the researcher stood behind the panelist in the sensory booth to observe their behaviour. The researcher paid close attention to the action of pouring the product into the mouth (ensuring the entire product was poured into their mouth at the beginning), and checked for any delays from pouring the product into the mouth to clicking start, time to first attribute and the trends in attribute selection. If the researcher noticed unusual behaviour (e.g. not pouring all of the

sample into mouth, not taking and bite cracker followed by a sip of water between samples, clicking start before they had poured the product into their mouth, an unreasonably large delay to clicking start or first attribute, the panelist not giving attention to the computer screen/task throughout the 60s data collection period), then the researcher would comment to the panelist in between samples. If the researcher observed unusual trends in attribute selection, such as selecting only one attribute throughout the entire sequence on several occasions, the researcher would check with the panelist ‘if this was their experience?’, and ‘did they know they have the option to change attribute selections as often as they wanted?’. The researcher also encouraged the panelist to ask any questions they had. The panelist was never told they should be selecting a certain attribute or a certain number of attributes.

2.3.4 Session 4

The fourth session involved training the panelists on attribute identification. Panelists were blind folded, and were served the 8 original references in a randomised order (with the exception of no taste) at the same concentration as during session 2. They were asked to correctly identify each reference. If they got any reference incorrect, it was served again after the 8 references and they were told what it was. The blindfold task was then repeated by serving the 8 references diluted to 50% of the original concentration (or created to deliver 50% of the approximate strength for ‘musty’ and ‘burnt’), where panelists had to again identify the attribute at a weaker strength. Again if a reference was identified incorrectly they were corrected. The blindfold task was then repeated again with the references diluted to 25% (or created to deliver 25% of the approximate strength for ‘musty’ and ‘burnt’).

2.3.5 Session 5

The fifth session involved repeating session 3 again, using the same hydrolysate used in session 3 (4 sucralose levels x 3 reps = 12 samples in total). However, the researcher did not stand behind the panelist as in session 3 (the panelist undertook the task alone). The panelist was encouraged to ask any final questions they had regarding the technique. Following the session, the researcher checked the results of the panelist to check the technique was being used as expected. In rare cases any unusual results (such as those described in Section 2.4.3 were noted and discussed with panelists).

2.3.6 Session 6: Trained panelist

The sixth session involved the panelist completing the final TDS session as a trained TDS panelist.

2.4 Data analysis

2.4.1 Dominance rates(%) and duration of dominance (s)

To produce TDS curves, dominance rates and significance/chance limits were calculated using standard methods originally introduced by Pineau et al. 2009.

To statistically compare differences in TDS results between formulations and training levels, the duration of dominance was calculated (in seconds) for every selection made by each panelist of each attribute, as undertaken by Galmarini et al. (2017). For each attribute, a 3-way mixed model ANOVA was then undertaken with SPSS on the dominance duration data,

with training level, product type, and panelist as the three factors. Panelist, the panelist x training level interaction, and the panelist x product type interaction were treated as random factors. Differences due to product type, training level, and the product x training interaction, were tested by the ANOVA. To understand overall differences between products and training levels, a MANOVA was undertaken with SPSS across all attributes using the same 3-way mixed model design. A MANOVA was also undertaken separately for each training level across all attributes, using a 2-way mixed model, with product type the factor to be tested by MANOVA, and panelist as the random factor. The latter MANOVA allowed changes in overall discrimination with increased training to be assessed.

2.4.2 Parameters to assess TDS behaviour

To investigate basic behaviour of the TDS technique, the following parameters were derived from the raw data: the number of attributes used, the number of selections (the same attribute can be selected more than once), and the time to first attribute (s). The average time per selection (s) was also calculated.

Each parameter was statistically analysed using a 3-way mixed model ANOVA in SPSS (version 20.0 for Windows) (IBM Corp., USA). Product type (4: 0% sucrose equivalent, 1.5% sucrose equivalent, 3.0% sucrose equivalent, 6.0% sucrose equivalent), training level (3: untrained, familiarized, and trained), and panelist were the three factors. Panelist, the panelist x training level interaction, and the panelist x product type interaction were treated as random factors. Differences due to product type, training level, and the training x product interaction, were tested by the ANOVA.

2.4.3 *Intra-panelist repeatability*

Intra-panelist variability was analysed by rating the consistency of each panelist across the three replicates for each product. At every 1s interval, a given panelist could show either no agreement (all three attribute selections differed), two out of three attributes agreed, all three attributes agreed or there was no selection of any attribute at that time point. For each panelist counts into each of these 'repeatability categories' were then undertaken across all time intervals for each product. The method is based on that applied by Hutchings et al. (2014 a & b). For statistical analysis, a Generalised Linear Mixed Model was undertaken on the counts of each category using SPSS. The data was assumed to have a Poisson distribution. The level of training and the category were the within panelist factors, panelist was the random effect.

3 Results

3.1 TDS curves

3.1.1 Product 1: 0% equivalent sweetness

Figure 1 shows the TDS curves containing the results for Product 1 (10% wt/wt casein hydrolysate without the addition of sucralose) for all three levels of training (A: untrained panelists, B: familiarized panelists, C: trained panelists). Bitter was the most highly selected dominant attribute throughout the 60s data collection period in all cases. Bitterness tended to peak around the swallowing point, and declined very slowly throughout the after taste period (maintaining high dominance levels up to 60s). Similar trends were observed between all training levels, however the selection of bitter reached a maximum of 50% dominance for the untrained and familiarized panelists, but was larger for the trained panelists, up to 65%. Cheesy was also selected at high dominance rates, peaking early into the period after the product was poured into the mouth (after 5-10s), but also maintaining a presence around the significant level throughout much of the aftertaste period. Cheesy was selected at a dominance rate of 20-25% by the untrained and familiarized panelists throughout most of the 60s period, although was selected at lower rates by the trained panelists (below the level of significance). Like cheesy, salty peaked early after product entry into the mouth (after 5-10s), however was only selected at rates above the significance level for untrained panelists. The dry/rough sensation was selected around the significance rate (18-20%) by the familiarized panelists only (30-40s). The selection of the 'no taste' attribute was selected at the later stages of data collection at a significant rate (18-20%) by the trained panelists only (50-60s), but was selected at rates below the level of significance for the untrained and familiarized panelists.

3.1.2 Product 2: 1.5% equivalent sweetness

Figure 2 shows the TDS curves containing the results for Product 2 for all three levels of training (A: untrained panelists, B: familiarized panelists, C: trained panelists). With the addition of some sucralose (1.5% equivalent sweetness) to the casein hydrolysate (10% wt/wt), bitterness perception is somewhat reduced, and the perception of cheesy becomes more dominant. Bitterness dominance rates tend to peak near or around the swallowing point, and cheesy dominance rates tend to peak just after the swallowing point. The selection of the bitter attribute and cheesy attribute are well above the level of significance for all three training conditions for most of the 60s period. Selection rates of bitter fluctuate between 40%-20% for all levels of training, while the selection rates of cheesy fluctuate between 45-20% for the untrained panelists, 40-20% for familiarized panelists, and 35-20% for trained panelists. The dry/rough sensation was selected at a significant rate by the familiarized panelists only (18-25% at 30-45s), and approaching significance for the trained panelists (25-35s). The 'no taste' attribute was selected at a significant rate at the later stages of data collection (45-60s) by the trained panelists (peaking at 32%).

3.1.3 Product 3: 3.0% equivalent sweetness

TDS results for Product 3 are shown in Figure 3 for all levels of training (A: untrained panelists, B: familiarized panelists, C: trained panelists). In product 3, sucralose is added to the casein hydrolysate (10% wt/wt) at a level of 3.0% equivalent sweetness, which causes a notable increase in the dominance of the sweet attribute, and a decrease in the dominance of the bitter attribute (the cheesy attribute remains selected at high dominance rates). The dominance rate of the sweet attribute peaks very quickly (after 5-9s), but declines after swallowing. As the level of training increases an increase in the selection rate of sweet is

observed, peaking at 28% for untrained panelists, 33% for familiarized panelists, and 50% for trained panelists, at the early stages of perception. Cheesy, as observed with product 2, tends to peak slightly after the swallowing point. The cheesy attribute is selected at higher rates by the untrained and familiarized panelists. The selection of bitter hovers around the level of significance (approximately 18%) for all levels of training throughout the first 20-35s, but is slightly greater in duration for the untrained panelists. Once again the dry/rough attribute is selected at a significant rate by only the familiarized panelists, 18-27% from 30-52s, approaching significance with the trained panelists over a similar time period. The 'no taste' attribute selected at a significant rate by only the trained panelists, 18-27% from 45s-60s.

3.1.4 Product 4: 6.0% equivalent sweetness

TDS results for Product 4 can be seen in Figure 4 for all three training levels (A: untrained panelists, B: familiarized panelists, C: trained panelists). For product 4, sucralose is added to the casein hydrolysate (10% wt/wt) at a level of 6.0% equivalent sweetness. This high sucralose addition causes an even greater increase in the dominance of the sweet attribute and a further reduction in the dominance rate of bitter. As observed for Product 3, sweetness dominance rates peak very quickly after the product enters the mouth (after 5-6s), before slowly declining but remaining significant throughout the 60s period. When the level of training increases the dominance rate of the sweet attribute increases (peaking at 55%, 60%, and 83% for untrained, familiarized, and trained panelists respectively). Cheesy peaks around the swallowing point for untrained panelists, and slightly after the swallowing point for familiarized and trained panelists, and remains significant for much of the aftertaste period. Cheesy dominance rates are greatest for the untrained panelists (40%), followed by the familiarized panelists (30%), and then the trained panelists (25%). The dry/rough attribute is

again selected at a significant rate by the familiarized panelists only (at 18-19% for 39-43s), but is also selected at significance by the trained panelists (17% for 29-32s). The 'no taste' attribute selected above the level of significance by trained panelists only, approximately 18% from 48-60s.

3.2 TDS Parameters

3.2.1 Number of attributes used

The number of attributes used differed significantly between products ($F(3,57) = 4.95$, $P < 0.005$) (Table 2). Pairwise comparisons (Least Significant Difference) showed panelists used significantly less attributes with the sweetest formulation (Product 4). The number of attributes used declined significantly with increased training ($F(2,38) = 9.77$, $P < 0.0005$). There was no significant interaction between training level and products ($F(6,114) = 0.56$, $P > 0.05$). Pairwise comparisons (Least Significant Difference) showed the trained panelists used significantly less attributes than untrained or familiarized panelists.

3.2.2 Number of selections

The number of selections differed between products ($F(3,57) = 3.41$, $P < 0.05$), where less selections were made for the sweetest formulation (Product 4) (Table 2). The number of selections made also declined significantly with increased training ($F(2,38) = 6.97$, $P < 0.005$). As observed with the number of attributes used, pairwise comparisons (Least Significant Difference) showed the trained panelists made significantly less selections

compared to untrained or familiarized panelists. There was no significant interaction between training level and products ($F(6,114) = 0.37$, $P > 0.05$).

3.2.3 *Time to first attribute*

Panelists made a selection significantly faster with the sweetest and most bitter formulations (Products 1 and 4) according to pairwise comparisons (Least Significant Difference) (Table 2). Time to first attribute declined with training but this effect was not statistically significant ($F(2,34) = 1.71$, $P > 0.05$), although it did differ significantly between products ($F(3,51) = 3.80$, $P < 0.05$). There was no significant interaction between training level and products ($F(6,114) = 0.95$, $P > 0.05$).

3.2.4 *Average time per selection*

The average time also differed significantly between products ($F(3,57) = 2.99$, $P < 0.05$), where greater time was spent per attribute in the case of the sweetest formulation (Product 4) according to pairwise comparisons (Least Significant Difference) (Table 2). The average time per selection differed significantly by the level of training ($F(2,38) = 9.76$, $P < 0.0005$), where trained panelists spent significantly greater time on an attribute before changing selection according to pairwise comparisons (Least Significant Difference). There was no significant interaction between training level and products ($F(6,114) = 1.41$, $P > 0.05$).

3.2.5 *Confidence*

In response to the question ‘how confident are you about the TDS results that you gave?’, untrained panelists, familiarized panelists, and trained panelists all reported high average levels of confidence (around 75/100, Table 2). Confidence levels increased slightly with training, but this increase was not statistically significant ($F(2, 38) = 1.08, P > 0.05$).

3.3 *Intra-panelist variability*

Figure 5 summarises the results of the analysis for intra-panelist variability. Little change is observed in intra-panelist variability from the untrained to the familiarized panelist. However, once panelists reached the stage of trained panelists, an increase in repeatability is observed in some of the products. To test for a significant training effect on intra-panelist repeatability, the training x category interaction was assessed using the Generalised Linear Mixed Model. No significant training x category interaction was observed for Product 2 ($F(6, 228) = 0.2, P > 0.05$), or Product 3 ($F(6, 228) = 1.7, P > 0.05$). The training x category interaction was approaching significance for Product 1 ($F(6, 228) = 1.9, P = 0.08$) and significant for Product 4 ($F(6, 228) = 2.9, P < 0.05$).

3.4 *Duration of dominance (s)*

Results from the 3-way mixed model ANOVA are found in Table 3&4. A significant difference between products was observed for the sweet, bitter, cheesy, metallic, and salty attributes. A significant difference between training levels was observed for the duration of selection of the sweet, salty, dry/rough, and no taste attributes. A significant interaction between training and product type was also observed for the sweet and bitter attributes.

Results from the 3-way mixed model MANOVA are also found in Table 3. A significant overall training effect was found, as was a significant product effect. A significant training x product interaction was also observed. A two-way mixed model MANOVA was then conducted at each training level. At every training level a highly significant overall difference was found between products according to the two-way mixed model MANOVA. However, as the level of training increased, the F-value increased.

4 Discussion

4.1 The effect of training on TDS behaviour

TDS behaviour, measured in this study by the number of attributes selected, the number of selections, time to first attribute, and average time per selection, did not change from untrained panelists to familiarized panelists (Table 2). However, TDS behaviour changed significantly once panelists undertook the TDS task as trained panelists (Table 2). Trained panelists selected less attributes and made less selections, and spent greater time on a given attribute. While it was predicted training (described in Section 2.4.3-2.4.5) would increase attribute selections and reduce time per attribute (perhaps by enhancing the ability of panelists to detect rapid and subtle changes in sensory perception), in fact the opposite has been observed. It is hypothesised that training has instead given panelists greater clarity to identify the most critical attributes which are dominating (and thus retain their selection on a given attribute for longer). Rodrigues et al. (2016) also reported a group of familiarized panelists selected less attributes than different group of consumers in a TDS study with chocolate.

Training was also expected to speed up the reaction time for panelists to select their first attribute. As TDS experience increased from untrained to familiarized to trained panelists, a reduction in time to first attribute can be seen (Table 2), however this effect was not statistically significant. This result suggests that untrained panelists were relatively competent at making a fast decision regarding their first dominant sensation. In contrast, Rodrigues et al. (2016) reported a group of familiarized panelists took significantly longer to make the selection of their first attribute in comparison to a group of consumers.

Intra-panelist repeatability did not change significantly from untrained to familiarized panelists, but increased once panelists were fully trained for products 1 & 4. This suggests that the training procedure improved the ability of panelists to understand what each attribute was, and improved their ability to consistently identify it when it was dominating. However, the overall similarity in repeatability across the data set also suggests untrained panelists were undertaking TDS in a reasonably repeatable fashion.

Similar trends in TDS profiles can be seen for all levels of training (Figures 1-4, Table 4). However, some differences in attribute selection were observed. The rate of sweetness selection increased from untrained to familiarized to trained panelists, while the selection of salty decreased. The selection of dry/rough was greater for familiarized panelists in comparison to untrained and trained panelists. Understanding these differences is complex, but may be explained by training providing panelists with greater exposure to hydrolysates and improving their ability to identify what attributes really are dominating, or perhaps by training changing the focus of their attention, and thus changing their perception of what is dominating. The selection of no taste was also greater for trained panelists in comparison to familiarized and untrained panelists. By training improving attribute identification this may also give panelists the confidence to select 'no taste' as the dominating feature of their experience towards the end of the 60s period as sensations decline. This would also reduce the prevalence of guessing an attribute during this period. Multivariate analysis revealed the groups at all training levels were able to discriminate between the four protein hydrolysate formulations. However, a significant product x training interaction according to a two-way MANOVA, and increasing F-values according to a one-way MANOVA with each level of training, shows that training increased the degree of discrimination between products (Table 3). Overall this suggests that while the untrained panelists were undertaking TDS effectively,

the training process used in this study improved the consensus among panelists and the ability to discriminate between products. This finding reflects results found in similar studies undertaken with descriptive panels (Chambers et al., 2004). However, in the case of TDS it must also be considered that training might over simplify the responses of panelists, installing “learnt behaviour” in the way panelists select attributes and their sequences.

4.2 Taste masking and temporal changes in the perception of protein hydrolysates

The results of this study showed the temporal trends in sensory perception during oral processing and after swallowing of the hydrolysates (Figures 1-4). As sweetness increased the dominance of most other attributes were reduced, however the dominance of cheesy was in fact increased until sucralose content reached 6% sucrose equivalent. In general, temporal trends showed sweetness (when present) peaked early (after 5-10s), well before swallowing at 15s. Bitterness (when present), tended to peak around the swallowing point. Cheesiness tended to peak slightly after swallowing. The sensation of dry/rough (when present), which can be attributed to astringency, peaked well after swallowing. However, temporal changes were not as large as what is often observed with solid food products (Laguna et al., 2013; Hutchings et al., 2014b), as most attributes which showed high dominance rates when the product was experienced prior to swallowing, usually continued to show high dominance rates for much of the aftertaste period. Results showed aftertastes lingered for a long period of time with the hydrolysates, throughout most of the 45s after taste period. Previous TDS studies using beverages focusing on aftertaste can show similar results in terms of smaller temporal changes (eg blackcurrant juice, Ng et al. 2012), but can also show larger temporal changes in some cases (eg with wine, Galmarini et al., 2017).

Sweet masking agents have been shown to suppress bitterness in previous research with traditional trained panelists on protein hydrolysates using intensity scales (Leksrisompong et al., 2012; Newman et al., 2015). Suppression of bitterness with sweet compounds has also been shown with a number of other bitter tastants (Keast & Breslin, 2003). The TDS curves in this study (Figures 1-4) illustrate a reduction in bitterness dominance rates and an increase in sweetness dominance rates with the addition of sucralose, from Product 1 (0% sucralose) to Product 2 (1.5% sucralose) to Product 3 (3.0% sucralose) to Product 4 (6.0% sucralose). The suppression of bitterness by sweet tastants occurs as a result of cognitive mixture suppression (Kroeze & Bartoshuk, 1985), where the presence of both bitter and sweet tastes reduces the perceived intensity of both sensations by the brain. An increase in the dominance rate of cheesiness observed in Product 2&3, perhaps occurs by shifting the perception of bitterness to the background, exposing cheesy notes. Decreasing dominance rates of salty and metallic as the sucralose content increases is also likely to result from suppression via increasing sweetness (Keast & Breslin, 2003; Lawless et al., 2004).

4.3 Recommendations for the use of consumers with TDS and for the use of TDS with hydrolysates

The similar trends observed between products at each training level, the relatively small increase in repeatability with training, and the effective discrimination between products at all training levels, suggest that TDS can be undertaken with protein hydrolysates and it can be undertaken with untrained panelists with protein hydrolysates. High levels of confidence following the TDS sessions at all levels of training were also observed. Intuitively undertaking TDS with a liquid product such as hydrolysates, where oral processing is short,

and where temporality is more subtle, is more difficult than undertaking TDS with a product that is masticated and where temporality is more obvious. The observation that consumers could discriminate between products using TDS with this 'difficult' type of product may provide even greater validation for the use of TDS with consumers than with previous studies with easier products (ie products that are chewed). **However, further studies are still needed to enhance understanding of consumer use of TDS with other types of food products.**

The results also showed that dynamic changes in dominance rates for the hydrolysates were only subtle. This may suggest that temporal methods for hydrolysates are not always necessary, depending on the studies objectives. While TDS allows rapid profiling that is more time efficient than a static method such as QDA, a rapid static method such as CATA (Check all that apply), may be equally appropriate to consider in the future. However, TDS still gives a more detailed description of the nature of aftertaste with hydrolysates than CATA.

4.4 Limits of this study

The manner by which TDS was conducted in this study was not natural – panelists were instructed to assess the product for 15s in the mouth before swallowing. This is a longer period of time than what occurs during normal consumption, but was designed to allow sufficient time for panelists to carefully assess sensory properties and use TDS while the product is in the mouth. Future studies could explore allowing panelists to swallow after a natural or shorter period of time. It should also be noted that in this study oral processing patterns were also not controlled as consumers were involved (panelists could manipulate the product in any manner they felt was comfortable), which may have introduced additional

variability into the results. Ng et al. (2012) adopted a similar methodology (including a 15s alert to swallow) with blackcurrant juice.

Findings are also of course limited by design used in this experiment, where TDS was conducted with a group of 20 consumers who were brought through 3 stages of training. The alternative design is to select 60 panelists, break them into three groups of 20 and subject them to three different treatments. The former approach allows all members of the group to be the same at each training level, however the effect of repeated exposure to the same hydrolysates during training cannot be controlled for (although panelists were never told the same product was being served at each training stages). The latter approach avoids this issue, but conclusions can be influenced by differences between the individuals within each group. Furthermore, the training undertaken in this study (panelists had completed 5 x 1 hr sessions) prior to the trained session, could be described as short term. Further research is required to investigate changes in TDS results with even greater lengths of training.

5 Conclusion

The results of this study suggest a Temporal Dominance of Sensations (TDS) panel of untrained panelists may be suitable for assessment of protein hydrolysates, however training increased panel consensus and the ability to discriminate between hydrolysates. Similar TDS curves were produced by the panelists as training progressed from the untrained, familiarised, and trained stage, and the time to first attribute was not influenced by the level of training. As training increased, the number of attributes selected decreased, and the time spent on a given attribute increased. Increasing the sucralose content of casein hydrolysates reduced the dominance rate of bitterness, and increased the dominance rate of cheesiness. Sweetness peaked before bitterness, followed by cheesiness, however attributes changes were subtle – those with high dominance rates during tasting in the mouth also had high dominance rates after swallowing.

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TABLE 1 Attributes used throughout the TDS study, and attribute definitions and references used in the familiarization session with the panelists.

Attribute	Definition	Reference
1. Sweet	Basic taste associated with sugar/sucrose	Sucrose (4% wt/wt)
2. Bitter	Basic bitter taste	Quinine (0.004 %)
3. Salty	Basic taste associated with table salt/sodium chloride	NaCl (0.3 %)
4. Cheesy	Taste associated with cheese	Soluble cheese extract (Mature cheddar)
5. Burnt	Taste associated with burnt food	Burnt toast
6. Metallic	Taste associated with metal	Spatone (Iron water) diluted 1:2
7. Astringent	Roughness, puckering, or tingling on the tongue or surfaces of the mouth	Tannic acid (0.25%)
8. Musty	A mouldy, dusty, dry sensation	Cut raw potato (smell only)
9. No taste	Lacking taste or flavour	

TABLE 2 Differences between product and training level for TDS parameters (mean $\pm$ SE) (n=20).

TDS Parameter	Level of Training	Level of training			
		Untrained	Familiarized	Training	Average for each product across all training levels
Number of attributes used	Product 1 (0% eq. sweetness)	3.53 $\pm$ 0.22	3.66 $\pm$ 0.25	2.67 $\pm$ 0.25	3.29 $\pm$ 0.17 ac
	Product 2 (1.5 % eq. sweetness)	3.60 $\pm$ 0.24	3.80 $\pm$ 0.24	3.08 $\pm$ 0.25	3.49 $\pm$ 0.19 b
	Product 3 (3.0 % eq. sweetness)	3.63 $\pm$ 0.26	3.8 $\pm$ 0.26	2.90 $\pm$ 0.27	3.44 $\pm$ 0.21 ab
	Product 4 (6.0 % eq. sweetness)	3.38 $\pm$ 0.22	3.35 $\pm$ 0.26	2.43 $\pm$ 0.24	3.06 $\pm$ 0.19 c
	Average for each training condition across all products	3.53 $\pm$ 0.20a	3.66 $\pm$ 0.21a	2.77 $\pm$ 0.23b	
Number of selections	Product 1 (0% eq. sweetness)	5.32 $\pm$ 0.45	5.65 $\pm$ 0.59	3.75 $\pm$ 0.45	4.91 $\pm$ 0.36 ab
	Product 2 (1.5 % eq. sweetness)	5.43 $\pm$ 0.44	5.93 $\pm$ 0.57	4.35 $\pm$ 0.50	5.24 $\pm$ 0.41 a
	Product 3 (3.0 % eq. sweetness)	5.35 $\pm$ 0.41	5.68 $\pm$ 0.60	4.02 $\pm$ 0.51	5.02 $\pm$ 0.40 a
	Product 4 (6.0 % eq. sweetness)	5.02 $\pm$ 0.45	5.37 $\pm$ 0.59	3.38 $\pm$ 0.45	4.59 $\pm$ 0.37 b
	Average for each training condition across all products	5.28 $\pm$ 0.39a	5.65 $\pm$ 0.55a	3.88 $\pm$ 0.44b	
Time to first attribute (s)	Product 1 (0% eq. sweetness)	4.13 $\pm$ 0.47	3.85 $\pm$ 0.46	3.28 $\pm$ 0.37	3.76 $\pm$ 0.33 b
	Product 2 (1.5 % eq. sweetness)	4.27 $\pm$ 0.45	4.13 $\pm$ 0.48	3.82 $\pm$ 0.40	4.07 $\pm$ 0.34 ab
	Product 3 (3.0 % eq. sweetness)	5.37 $\pm$ 0.90	4.10 $\pm$ 0.67	4.33 $\pm$ 0.46	4.60 $\pm$ 0.53 a
	Product 4 (6.0 % eq. sweetness)	3.92 $\pm$ 0.45	3.88 $\pm$ 0.63	2.97 $\pm$ 0.37	3.59 $\pm$ 0.35 b
	Average for each training condition across all products	4.42 $\pm$ 0.45a	3.99 $\pm$ 0.49a	3.60 $\pm$ 0.33a	
Average time per selection (s)	Product 1 (0% eq. sweetness)	13.17 $\pm$ 1.40	13.00 $\pm$ 1.37	24.05 $\pm$ 3.40	16.74 $\pm$ 1.49 ab
	Product 2 (1.5 % eq. sweetness)	13.60 $\pm$ 1.47	13.19 $\pm$ 2.06	18.98 $\pm$ 2.67	15.26 $\pm$ 1.65 a
	Product 3 (3.0 % eq. sweetness)	13.40 $\pm$ 1.75	13.97 $\pm$ 2.31	21.39 $\pm$ 3.33	16.26 $\pm$ 2.07 a
	Product 4 (6.0 % eq. sweetness)	14.73 $\pm$ 2.15	15.95 $\pm$ 2.54	26.93 $\pm$ 4.04	19.20 $\pm$ 2.33 b
	Average for each training condition across all products	13.73 $\pm$ 1.45a	14.03 $\pm$ 1.79a	22.84 $\pm$ 3.08b	
Confidence level (100mm VAS scale)	How confident are you about the TDS results that you gave?	72 $\pm$ 3 a	75 $\pm$ 2 a	77 $\pm$ 3 a	

Different letters across each row indicate a significant statistical difference between training level across all products for each parameter after a 3-way mixed model ANOVA using pairwise comparisons (least significant difference) ($P < 0.05$). Different letters (a,b) down each column indicate a significant statistical difference between products across all training levels for each parameter after the 3-way mixed model ANOVA using pairwise comparisons (least significant difference) ($P < 0.05$).

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TABLE 3 ANOVA/MANOVA results for duration of dominance of attributes

	F		
	Product Effect	Training Effect	Product x Training Interaction
Bitter	34.5 *	0.8	4.5 ***
Burnt	1.05	0.8	1.15
Cheesy	3.9 *	2.7	0.6
Dry/rough	0.8	10.8***	0.1
Metallic	5.7 **	2.1	0.3
Musty	1.2	0.1	0.3
No Taste	2.5	4.6*	0.7
Salty	11.6***	5.8 **	0.6
Sweet	50.6 ***	7.2 **	5.0 **
Overall (MANOVA) (Wilks Lambda)	7.1 ***	3.3 ***	1.4 *
MANOVA was also conducted across all products at each training level. F (untrained panelists) = 4.2 *** , F (familiarised panelists) = 4.4 *** , F (trained panelists) = 5.4***			

Degrees of Freedom for Product effect: 3, 57. Degrees of freedom for training effect: 2, 38. Degrees of freedom for interaction: 6, 114.

Significance levels: * 5%, ** 1%, ***0.1%. Significant effects are highlighted in bold. A significant effect indicates a significant difference between training levels, products, or training x product interaction, for the duration of selection of each attribute across the entire group of panelists.

TABLE 4 Dominance duration (s) of each attribute for each product and each level of training (mean $\pm$ SE) (n=20).

Attribute	Product	Training level			
		Untrained	Familiarized	Trained	Across all training levels
Bitter	Product 1 (0% eq. sweetness)	20.32 $\pm$ 2.97	20.93 $\pm$ 2.63	30.62 $\pm$ 3.88	23.96 $\pm$ 2.73 a
	Product 2 (1.5 % eq. sweetness)	15.32 $\pm$ 2.75	15.80 $\pm$ 1.98	15.08 $\pm$ 2.76	15.40 $\pm$ 1.44 b
	Product 3 (3.0 % eq. sweetness)	9.68 $\pm$ 2.06	6.50 $\pm$ 1.63	6.65 $\pm$ 2.05	7.61 $\pm$ 1.43 c
	Product 4 (6.0 % eq. sweetness)	5.60 $\pm$ 1.25	2.53 $\pm$ 1.00	2.32 $\pm$ 1.11	3.48 $\pm$ 0.89 d
Burnt	Product 1 (0% eq. sweetness)	1.53 $\pm$ 0.60	1.60 $\pm$ 0.69	1.52 $\pm$ 1.06	1.55 $\pm$ 0.61
	Product 2 (1.5 % eq. sweetness)	1.28 $\pm$ 0.72	1.08 $\pm$ 0.63	3.32 $\pm$ 1.50	1.89 $\pm$ 0.80
	Product 3 (3.0 % eq. sweetness)	0.53 $\pm$ 0.33	1.37 $\pm$ 0.86	1.53 $\pm$ 1.19	1.14 $\pm$ 0.55
	Product 4 (6.0 % eq. sweetness)	1.08 $\pm$ 0.75	0.55 $\pm$ 0.37	0.52 $\pm$ 0.45	0.72 $\pm$ 0.30
Cheesy	Product 1 (0% eq. sweetness)	10.95 $\pm$ 1.83	10.07 $\pm$ 2.66	5.87 $\pm$ 2.28	8.96 $\pm$ 1.64 a
	Product 2 (1.5 % eq. sweetness)	17.57 $\pm$ 3.08	14.23 $\pm$ 3.56	13.57 $\pm$ 3.86	15.1 $\pm$ 2.73 b
	Product 3 (3.0 % eq. sweetness)	18.98 $\pm$ 3.60	18.22 $\pm$ 3.13	11.15 $\pm$ 3.02	16.12 $\pm$ 2.28 b
	Product 4 (6.0 % eq. sweetness)	16.53 $\pm$ 3.21	12.33 $\pm$ 2.57	9.63 $\pm$ 3.05	12.83 $\pm$ 2.26 ab
Dry/rough	Product 1 (0% eq. sweetness)	3.02 $\pm$ 1.13	7.00 $\pm$ 1.71	4.42 $\pm$ 1.47	4.81 $\pm$ 1.15
	Product 2 (1.5 % eq. sweetness)	3.42 $\pm$ 1.28	7.97 $\pm$ 1.90	4.73 $\pm$ 1.74	5.37 $\pm$ 1.44
	Product 3 (3.0 % eq. sweetness)	3.45 $\pm$ 1.19	8.20 $\pm$ 1.94	5.35 $\pm$ 2.55	5.67 $\pm$ 1.59
	Product 4 (6.0 % eq. sweetness)	2.57 $\pm$ 1.27	6.03 $\pm$ 1.89	4.22 $\pm$ 1.76	4.27 $\pm$ 1.46
Metallic	Product 1 (0% eq. sweetness)	4.72 $\pm$ 1.37	3.63 $\pm$ 1.08	2.57 $\pm$ 2.19	3.64 $\pm$ 1.04 a
	Product 2 (1.5 % eq. sweetness)	4.25 $\pm$ 1.49	4.57 $\pm$ 1.84	1.17 $\pm$ 0.63	3.33 $\pm$ 1.04 a
	Product 3 (3.0 % eq. sweetness)	3.33 $\pm$ 1.08	3.25 $\pm$ 1.50	1.23 $\pm$ 0.93	2.61 $\pm$ 0.66 a
	Product 4 (6.0 % eq. sweetness)	1.65 $\pm$ 0.67	1.53 $\pm$ 0.70	0.05 $\pm$ 0.05	1.08 $\pm$ 0.36 b
Musty	Product 1 (0% eq. sweetness)	2.22 $\pm$ 0.93	3.05 $\pm$ 1.12	1.93 $\pm$ 0.94	2.40 $\pm$ 0.64
	Product 2 (1.5 % eq. sweetness)	2.78 $\pm$ 1.10	2.53 $\pm$ 0.96	2.63 $\pm$ 1.30	2.65 $\pm$ 0.84
	Product 3 (3.0 % eq. sweetness)	3.15 $\pm$ 1.22	2.65 $\pm$ 1.01	2.47 $\pm$ 1.68	2.76 $\pm$ 0.84
	Product 4 (6.0 % eq. sweetness)	1.87 $\pm$ 0.99	2.10 $\pm$ 0.75	2.15 $\pm$ 1.54	2.04 $\pm$ 0.73
No taste	Product 1 (0% eq. sweetness)	2.90 $\pm$ 1.49	2.13 $\pm$ 1.11	4.65 $\pm$ 1.96	3.23 $\pm$ 1.38
	Product 2 (1.5 % eq. sweetness)	3.88 $\pm$ 1.70	2.55 $\pm$ 1.17	7.38 $\pm$ 2.18	4.61 $\pm$ 1.57
	Product 3 (3.0 % eq. sweetness)	4.25 $\pm$ 1.79	3.73 $\pm$ 1.72	6.32 $\pm$ 2.30	4.77 $\pm$ 1.74
	Product 4 (6.0 % eq. sweetness)	3.38 $\pm$ 1.68	2.33 $\pm$ 1.04	5.00 $\pm$ 1.91	3.57 $\pm$ 1.37
Salty	Product 1 (0% eq. sweetness)	9.83 $\pm$ 2.47	7.73 $\pm$ 2.60	5.15 $\pm$ 1.59	7.57 $\pm$ 1.55 a
	Product 2 (1.5 % eq. sweetness)	3.67 $\pm$ 1.00	2.47 $\pm$ 0.50	2.68 $\pm$ 0.87	2.94 $\pm$ 0.67 b
	Product 3 (3.0 % eq. sweetness)	3.20 $\pm$ 0.90	2.23 $\pm$ 0.43	0.57 $\pm$ 0.32	2.00 $\pm$ 0.41 b
	Product 4 (6.0 % eq. sweetness)	2.25 $\pm$ 0.80	2.37 $\pm$ 0.78	0.13 $\pm$ 0.13	1.58 $\pm$ 0.34 b

sweetness)					
Sweet	Product 1 (0% eq. sweetness)	0.37 ± 0.37	0.00 ± 0.00	0.00 ± 0.00	0.12 ± 0.12 a
	Product 2 (1.5 % eq. sweetness)	3.50 ± 0.99	4.67 ± 1.82	4.77 ± 1.70	4.31 ± 1.25 b
	Product 3 (3.0 % eq. sweetness)	8.05 ± 2.32	9.93 ± 2.44	20.35 ± 4.04	12.78 ± 2.10 c
	Product 4 (6.0 % eq. sweetness)	21.08 ± 3.49	26.33 ± 3.52	33.45 ± 4.25	14.49 ± 3.24 d
Across all products	Bitter	12.79 ± 1.81	11.44 ± 1.18	13.67 ± 1.52	
	Burnt	1.11 ± 0.47	1.15 ± 0.41	1.72 ± 0.67	
	Cheesy	16.00 ± 2.30	13.72 ± 2.21	10.05 ± 2.47	
	Dry/rough	3.11 ± 1.00 a	7.30 ± 1.56 b	4.68 ± 1.56 a	
	Metallic	3.49 ± 1.02	3.25 ± 1.18	1.25 ± 0.73	
	Musty	2.50 ± 0.85	2.58 ± 0.88	2.30 ± 1.25	
	No taste	3.60 ± 1.61 ab	2.69 ± 1.16 a	5.84 ± 1.90 b	
	Salty	4.74 ± 0.81 a	3.70 ± 0.72 a	2.13 ± 0.55 b	
	Sweet	8.25 ± 1.61 a	10.23 ± 1.43 a	14.64 ± 2.13 b	

Different letters (a,b,c,d) down the columns for each attribute indicate a significant difference in the duration of attribute selection between products ($P < 0.05$) according to pairwise comparison tests (Least Significant Difference). Different letters (a, b, c, d) across the rows for each attribute indicates a significant difference in the duration of attribute selection between training levels ($P < 0.05$) according to pairwise comparison tests (Least Significant Difference).

FIG. 1. TEMPORAL DOMINANCE OF SENSATIONS CURVES FOR UNTRAINED (A), FAMILIARIZED (B), AND TRAINED (C) PANELISTS FOR PRODUCT 1 (0% EQUIVALENT SWEETNESS)

FIG. 1. TEMPORAL DOMINANCE OF SENSATIONS CURVES FOR UNTRAINED (A), FAMILIARIZED (B), AND TRAINED (C) PANELISTS FOR PRODUCT 1 (0% EQUIVALENT SWEETNESS)

297x420mm (300 x 300 DPI)

FIG. 2. TEMPORAL DOMINANCE OF SENSATIONS CURVES FOR UNTRAINED (A), FAMILIARIZED (B), AND TRAINED (C) PANELLISTS FOR PRODUCT 2 (1.5% EQUIVALENT SWEETNESS)

FIG. 2. TEMPORAL DOMINANCE OF SENSATIONS CURVES FOR UNTRAINED (A), FAMILIARIZED (B), AND TRAINED (C) PANELLISTS FOR PRODUCT 2 (1.5% EQUIVALENT SWEETNESS)

297x420mm (300 x 300 DPI)

FIG. 3. TEMPORAL DOMINANCE OF SENSATIONS CURVES FOR UNTRAINED (A), FAMILIARIZED (B), AND TRAINED (C) PANELISTS FOR PRODUCT 3 (3.0 % EQUIVALENT SWEETNESS)

FIG. 3. TEMPORAL DOMINANCE OF SENSATIONS CURVES FOR UNTRAINED (A), FAMILIARIZED (B), AND TRAINED (C) PANELISTS FOR PRODUCT 3 (3.0 % EQUIVALENT SWEETNESS)

297x420mm (300 x 300 DPI)

FIG. 4. TEMPORAL DOMINANCE OF SENSATIONS CURVES FOR UNTRAINED (A), FAMILIARIZED (B), AND TRAINED (C) PANELISTS FOR PRODUCT 4 (6.0 % EQUIVALENT SWEETNESS)

FIG. 4. TEMPORAL DOMINANCE OF SENSATIONS CURVES FOR UNTRAINED (A), FAMILIARIZED (B), AND TRAINED (C) PANELISTS FOR PRODUCT 4 (6.0 % EQUIVALENT SWEETNESS)

297x420mm (300 x 300 DPI)

FIG 5. INTERACTION PLOT OF INTRA-PANELLIST REPEATABILITY FOR EACH TRAINING LEVEL. SHOWS AVERAGE TOTAL TIME (S) WHERE THERE WAS NO AGREEMENT, TWO REPLICATES AGREE, OR ALL THREE REPLICATES AGREE, OR WHERE THERE WAS NO SELECTION (MEAN $\pm$ SE). WHERE SIGNIFICANT DIFFERENCES WERE FOUND BETWEEN TRAINING LEVELS (A SIGNIFICANT TRAINING X CATEGORY INTERACTION), AN ASTERISK IS PRESENT, * 5%, ** 1%, ***0.1%.

FIG 5. INTERACTION PLOT OF INTRA-PANELLIST REPEATABILITY FOR EACH TRAINING LEVEL. SHOWS AVERAGE TOTAL TIME (S) WHERE THERE WAS NO AGREEMENT, TWO REPLICATES AGREE, OR ALL THREE REPLICATES AGREE, OR WHERE THERE WAS NO SELECTION (MEAN $\pm$ SE). WHERE SIGNIFICANT DIFFERENCES WERE FOUND BETWEEN TRAINING LEVELS (A SIGNIFICANT TRAINING X CATEGORY INTERACTION), AN ASTERISK IS PRESENT, * 5%, ** 1%, ***0.1%.

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Author/s:

Hutchings, SC;de Casanove, A;Schlich, P;O'Riordan, D

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The effect of training on the temporal dominance of sensations method: A study with milk protein hydrolysates

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