Effect of Panel Type and Ethnicity on Apples in Singapore Using Temporal Dominance Method

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Abstract

Recently, there has been an increased in oral processing studies focusing on the detection of changes in sensational attributes of food product in real time. However, the integration of sensational and emotional attributes with liking is a relatively new line of enquiry, yet if pursued may enable a deeper understanding of the sensory and emotional experience of consumers. This study successfully trials a new system combining temporal dominance of sensation (TDS), emotion (TDE) and liking (TDL) to examine the impact of training and ethnicity on the real time sensory evaluation of popular apple varieties currently being sold in Singapore. A short training (60 minutes) with food references was proven to be highly beneficial and had generated a higher dominance rate, faster first dominant attribute detected, lower variation in the dominant attribute selected and frequent complex textural attributes chosen, showing a better understanding of the terms used. The number of attributes used and dominant end time were however not affected by training. Contrary to TDE, a positive emotional or sensational attribute dominant did not relate to a direct relationship with liking. Non-dominant sensational or emotional attributes might have interfered in the liking observed. Training aside from improving the understanding of attributes used was also found to close the gap between hedonic scores and frequency liking counts. Ethnicity effects were subsequently examined using a Semi Trained Panel consisting of 8 Chinese, 7 Indian and 6 Malay with differing results observed. Chinese were more expressive and positive in the attributes chosen in TDS and TDE while Malay was the opposite. *Fibrous* (Chinese and Indian) and *floral* (Chinese) were picked up more readily by different ethnicities. Differences in product where Granny Smith evoked disliking in Malay and Indian, was positively rated by Chinese. These variations could mainly be due to differences in cultural practises and diet. The incorporation of TDS and TDL provided better product understanding than the narrow hedonic range obtained. Furthermore, the mapping of TDS, TDE and TDL curves suggested the ability to condense information allowing dynamic relation to be drawn in a single graph. However, due to the qualitative nature of the graphs, the interpretation of result might be subjective.

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Table of contents

List of figures

List of tables

1. Introduction

When shopping for fresh food products like apples, extrinsic properties of the product for instance, colour and size will first capture the consumer's attention (Seppä *et al.*, 2015, Gamble *et al.*, 2006). However, repeat purchase (i.e. if the consumer is going to buy the product again and how regularly) will depend on how much the product is preferred in terms of its inner sensory properties (flavour and texture) (Rosenthal, 1999). Therefore, it can be argued that the sensory preference of a fresh food product in relationship to its flavour and texture are the ultimate drivers of food choice (Endrizzi *et al.*, 2015, Huotilainen *et al.*, 2006) and accordingly, the major factor for predicting market potential of a new product.

Since, Singapore does not grow any apples locally; apples which are available in the supermarkets are mainly imported from China, South Africa, New Zealand, USA, France and Argentina (Figure 1) (USDA, 2012). A new apple cultivar to have a chance of being successfully introduced into Singapore needs to maintain its quality over an extended shelf life whilst demonstrating comparable or superior eating quality and a competitive price point over current offers (Endrizzi *et al.*, 2015).

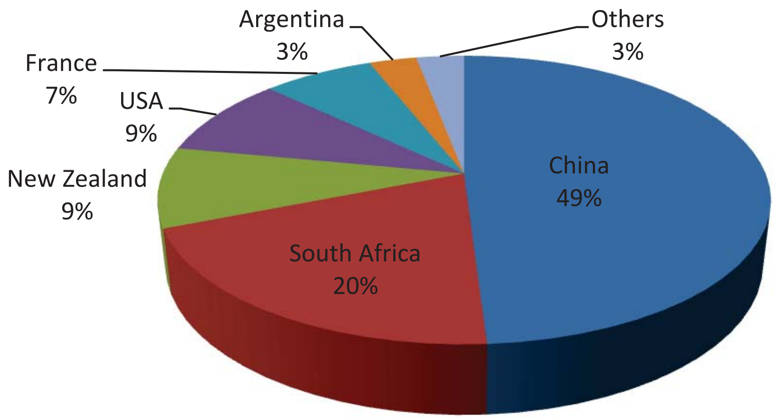


Figure 1 : Countries which supply apples and pears to Singapore. (Based on data from USDA, 2012)

New insights in terms of a product's sensory performance will, therefore, be a necessary approach for food companies wanting to generate a competitive advantage. Unfortunately, most studies looking into the sensory aspect of apples used static (not time-dependent) measures of sensory perception (Endrizzi *et al.*, 2015, Varela *et al.*, 2005, Seppä *et al.*, 2015), with overall basic sensory differences perceived. For this reason, the oral processing of apples and its relationship to dynamic (time-dependent) sensory performance is an area needing investigation (Panouillé *et al.*, 2014, Di Monaco *et al.*, 2014). When an apple is eaten, a number of complex physiological processes (including saliva secretion, tongue movement, breathing and swallowing) all play a part in the perceived sensory time-dependent changes (Di Monaco *et al.*, 2014). Therefore, understanding the interplay between these physiological processes and sensory responses require a dynamic sensory method.

There are various dynamic sensory methods practised. Progressive profiling is one where several sensory attributes are rated at selected time interval when tasting. Sequential profiling, on the other hand, evaluates the product at set time points of 0, 30 and 60 seconds of five trained attributes maximum, repeating the process eight times. An extension of all profiling methods is Time-Intensity (T-I) analysis where evolution of the single attribute over time is reflected on a graph (Ng *et al.*, 2012). As T-I only allows the rating of one attribute, the method has evolved into temporal dominance of sensation (TDS) to include a larger list of attributes.

TDS is a relatively new technique which requires subjects to select the dominant attributes ("the sensation that triggers the most attention") out of a list of all potential attributes that might exist over the course of consuming the product. Sensory evaluation occurs continuously via a computer screen from first bite through to the final swallow point. The follow on techniques of TDS are temporal dominance of emotion (TDE) (Jager *et al.*, 2014) and temporal dominance of liking (TDL) (Thomas *et al.*, 2015, Carr and Lesniauskas, 2015) which were explored in recent years. There is no study to date which has applied all three methods concurrently. However, to use TDS, TDL and TDE successfully will require some formal training. For example, the training of subjects has shown to generate quicker textural attribute selection and greater dominance rates in biscuits (Cheong *et al.*, 2014). The effects of training on TDE and TDL have yet been investigated. Also, Abbas *et al.* (2013) and Jean-Pierre *et al.* (2015) found that different ethnicities vary in their choices and preferences of food outside Singapore. Singapore being a multi-ethnicity country with varying dietary patterns for each ethnicity, little is known if differences in preference might be observed in the same product tested.

Therefore, this study aimed to investigate differences between group of panels (Semi Trained and Untrained; different ethnic groups) in terms of attributes selection for sensation, emotion and liking using the dynamic (time-dependent) temporal dominance techniques. It is hypothesized that similar attributes will be chosen between both panels (Semi Trained and Untrained), with a faster selection time and higher dominance rate for the Semi Trained Panel. Furthermore, it is hypothesized that different ethnicities will select different sets of attributes.

The study was undertaken with the following objectives:

1. To investigate if there are differences in the attribute chosen for TDS, TDE and TDL between Semi Trained and Untrained Panels.

2. To investigate how ethnicity impacts on the attributes chosen for TDS, TDE and TDL using a Semi Trained Panel.

3. To develop and comment on the usefulness of the technique combining TDS, TDE and TDL for new product development.

2. Literature Review

Apple is the second most consumed fruit (fresh and processed uses combined), following oranges (Geisler, 2013) with a wide variety of apples in Singapore to choose from. However, no one has investigated the ideal sensory attributes of apples.

Static sensory methods are insufficient in tracking the attributes changes as the methods only allow the selection at one single time point. Therefore, to track the sensory perception changes over time, dynamic sensory methods can be used. Aside from textural attributes, liking and emotion could be gathered, investigating the combination of these methods.

Additionally, Singapore being a multi-ethnicity country, there may be variation observed between the various ethnicities. This area although was explored in other countries, little was done in Singapore.

Due to the limited research around these areas, this study will investigate panel types and ethnicities variation by applying temporal dominance (TD) methods using apples. Therefore, an overview on apple as a commodity for Singapore, oral processing, temporal measures of the sensory responses to sensation, emotion and liking; and factors affecting TD methods including panel types and ethnicities variation will be covered in the following sections.

2.1 Apples Consumption in Singapore

Today, Singapore consumers enjoy a wide variety of fruits due to an established pool of traders who have a diversified network of overseas producers. Singapore traders ensure a stable supply of high-quality fruit which are competitively priced. As a result, Singapore's fruit imports have grown at a steady state of 5.8% per annum over the past five years, reaching 1.73 billion in 2012 (Singapore FVA, 2014). In 2013, Singapore imported 414,774 tonnes of fruit which was around a 7% increment from 2012 import figures (Chávez *et al.*, 2014). The consumption of fruit was measured at 70 kg per capita in 2013 exceeding the consumption of all meats – chicken (32 kg), pork (17 kg), beef (2 kg) and mutton (2 kg) (Chávez *et al.*, 2014).

Most Singapore consumers purchase apples from supermarkets and local wet markets. Globally, the top 5 cultivars that contributed to most of the world apple production are Red Delicious, Golden Delicious, Gala, Fuji and Granny Smith (Yamane, 1990).

China and South African apples are the cheaper options for local consumers, while consumers with greater purchasing power tend to go for New Zealand and France apples which are more expensive and are considered to be of a premium quality (Seppä *et al.*, 2015).

Regarding the relative cost of each apple variety over the decade (2004 to 2014), the price of an apple has increased from SGD$0.34 to SGD$0.45 (Singapore Department of Statistics, 2014). Consumers, in turn, may have a higher expectation in apple quality such as physical properties (fruit shape, size, colour, texture and flavour) and biological properties (soluble solids content and acidity) (Harker *et al.*, 2003). In the study by Lund *et al.* (2006) consisting 45 Granny Smith consumers in New Zealand, the correlation of apple characteristics such as freshness and appearance to purchase price were investigated. Appearance of an apple highly influence consumer's liking and preference which impacts on the price consumers are willing to pay. Subsequently, consumers preferred apples which were recently harvested with a harvest duration of less than two months. However, after tasting, preference for apples which were recently harvested dropped from ~90% to ~55%. Therefore, taste is still the determining factor when purchasing apples.

2.2 Oral processing

The properties of food are altered via sequential (continuous) physicochemical operations during the eating process (Chen, 2014). For brittle solid foods, the eater imposes mechanical processes (e.g., first bite, grinding, high and low-speed shearing) and the eater's oral physiology imposes physical and chemical processes (e.g., increases in temperature, enzyme-mediated breakdown and dilution by saliva).

Chen (2009) describes the eating process as a collection of operations performed over a series of phases. The main outputs, which change over time, are related to the sensory perception of the food driven by the physiological process of breaking down the food matrix. These operations change the original food properties over time where the sum total is known as "oral processing". Thus, oral processing research is a multidisciplinary approach which includes the study on physics of eating (Chen, 2009, Dalgleish, 2006, Foster *et al.*, 2011, Boehm *et al.*, 2013), sensory perception (Bradbury, 2004, Saint-Eve *et al.*, 2009, Chen, 2014) as well as cognitive function (Rolls, 2010, Grabenhorst *et al.*, 2010). Also, it is a transportation process of food from the formation of a bolus in the mouth through the oral-pharyngeal-oesophagus tract into the stomach for further digestion (Chen, 2014).

2.3 Sensory Evaluation

During oral processing, the biological and chemical changes in food generate different sensory properties over time. Hence, sensory evaluation was first developed to evoke, measure, analyse and interpret human responses to food through the use of senses (Lawless and Heymann, 2010). Conventional sensory methods utilise consumer panel (affective test, hedonic type test) or trained panel (descriptive test, analytical test). These tests however only provide a single point evaluation and are liable to miss some significant product information especially on the changes in sensory properties of the food product in the mouth during chewing (Di Monaco *et al.*, 2014, Elortondo *et al.*, 2007).

The objectives of this study are to understand how products are perceived by consumers during the course of mastication and how their hedonic reactions are affected. Therefore, time-dependent sensory methodologies should be used. These are discussed in the following sections.

2.3.1 Time-dynamics methods

Starting from 1937, relationship between the intensity of a factor to the total sensory evaluation duration on understanding the perception of a product has been increasing examined (Holway and Hurvich, 1937). Since then, time-dynamics methods are used in both food and non-food studies (Lawless and Heymann, 2010).

Initial time-dynamics methods used a clock to track time by the panellists (Jellinek, 1964). This time-keeping responsibility placed on the panellists could be a source of distraction. McNulty and Moskowitz (1974) then made improvements to the time-dynamics method when evaluating oil-in-water emulsions by giving audible cues to inform panellists to score the perceived intensities of the attributes on the ballot. Later, Larson ‐ Powers and Pangborn (1978) conducted a study looking into perceived sweetness in beverages and gelatine sweetened with sucrose or synthetic sweeteners using a moving strip-chart recorder connected to a foot pedal for starting and stopping the chart. Thereafter, Sensory Measuring Unit for Recording Flux (SMURF) was developed by Birch and Munton (1981) for time-dynamics scaling. SMURF consists of a knob graded from 1 to 10, connected to a potentiometer which fed a variable signal to a strip-chart recorder hidden from the panellists. This method, however, requires some degree of mental and physical coordination as panellists have to chew the sample, record the attributes and grade the attributes using the knob. Even without the use of an electronic device, the progress from using a clock to SMURF showed constant improvement and update to the time-dynamics methods.

The appearance of desktop computers added to the hike of time-dynamics methods utilisation between 1980s to 1990s. Progressive profiling is one such method developed to first measure changes in texture during mastication of cheese (Jack et al., 1994). The rating is done on a list of predefined attributes during each chew using a 5-point scale. Real time curves are produced with the ability for the attribute with the highest score to be determined over the course of the experiment without considering dominance. Another method called Time-Intensity (T-I) records the change in the perceived attribute's intensity over time (Peyvieux and Dijksterhuis, 2001). T-I can however only evaluate one or two attributes per run; and so to build up a full dynamic sensory profile, multiple runs are required (Larson-Powers and Pangborn, 1978, Lawless and Heymann, 2010, Thomas et al., 2015). As all time-dynamics methods measure the change during mastication, sequential profiling is designed to investigate the lingering effect of food products. Panellists are required to rate five trained attributes simultaneously at stipulated time points of 0, 30 and 60 seconds after tasting with the procedure repeating eight times (Methven et al., 2010). An extension of T-I method which is of high interest currently is the temporal dominance of sensation (TDS).

2.3.2 Temporal Dominance of Sensation (TDS)

This method was first developed by Larson-Powers and Pangborn (1978) at the "Centre European des Sciences du Gout" in the LIRIS lab and was first presented at the Pangborn Symposium in 2003 by Pineau, Cordelle and Schlich (Di Monaco *et al.*, 2014, Labbe *et al.*, 2009).

In this descriptive sensory method, instead of only one to two attributes tested in T-I, panellists are now provided with a predetermined list of ten attributes maximum ideally (Pineau *et al.*, 2012). Also, if the attributes use were simple enough to be understood by naive panellists, TDS requires almost no training making it a consumer orientated technique (Thomas *et al.*, 2015, Di Monaco *et al.*, 2014)

The panellists will iteratively assess the dominant sensation at over time, and possibly also score its intensity, until the dominant sensation ends and thereafter selecting a new dominate sensation or stop the test when the test food is swallowed (Labbe *et al.*, 2009, Pineau *et al.*, 2012). 'Dominant' at a given time is defined to be the attribute which catch the panellist's attention and thus triggers them to select it (Labbe *et al.*, 2009, Pineau *et al.*, 2009). That being said, it is not necessarily the one with the highest intensity. For example, sweet or melting can be the most intense sensation at a given time for flavoured chocolates, but minty or fruity may be the most striking sensation catching the panellist's attention. Hence, minty or fruity should be chosen as the dominant sensation. The chosen attribute is registered till the dominant perception changes; which panellist will indicate the new dominant attribute. Panellists are free to choose the same attribute several times so long as it is dominant or to never select an attribute (Jager *et al.*, 2014, Di Monaco *et al.*, 2014, Labbe *et al.*, 2009). After each mastication sequence for all panellists have ended, results can be displayed at panel level for each attribute or translated into a dominance rate graph for each product tested. A "chance level" line and "significance level" line in each dominance rate graph is usually included (Labbe *et al.*, 2009).

"Chance level" is defined as the expectation of the dominance rate of one attribute calculated by

$$Po = 1/P$$

Equation 1: Chance level.

P: being the number of attributes considered.

"Significant level" is defined as the upper limit of the confidence interval for the expected dominance rate (Pineau *et al.*, 2009). The calculation is based on an approximation of the normal distribution from equation 1 above:

$$Ps = Po + 1.645\sqrt{\frac{Po(1 - Po)}{n}}$$

Equation 2: Significant level.

- *Ps*: lowest significant index ($\alpha = 0.05$)
- *Po*: chance level, the expectation of the dominance rate of one attribute calculated by $Po = 1/P$, with P being the number of attributes considered.
- *n*: number of evaluations (number of subjects* replications)

Depending on the objective of the study, the x-axis can be set to standardised time. For example, if the study objective focus on the happening just before swallowing, instead of a TDS curve with actual consumption duration; a standardised time TDS curve is perfect as it displays changes in mastication period from first score to swallowing. This is done to achieve greater consensus across the panel (Labbe *et al.*, 2009, Pineau *et al.*, 2009). However, if in-mouth duration time is important, non-standardised TDS curve is preferred (Di Monaco *et al.*, 2014).

TDS is a rapid and multi-attributes temporal method which highlights the interactions among attributes at a particular time over a set period (Déléris et al., 2011, Le Révérend et al., 2008, Di Monaco et al., 2014). It was examined by Labbe et al. (2009) using 9 flavoured gels with 43 experienced panellists comparing between Quantitative Descriptive Analysis (QDA) and TDS on a 10 cm unstructured linear scale, anchored at the extremities with ‘‘not at all intense” to ‘‘very intense”. TDS was scaled after each dominate attribute was selected. A correlation was observed between bitterness and temperature of the gels in QDA while in TDS, bitterness was correlated only to sourness but not to the temperature of the gels. These results demonstrate the limited availability of information on attributes interaction when using conventional profiling methods. TDS and QDA were again compared using 2 Italian extra-virgin olive oils blended with tomato and canned whole bean using 13 trained panellists with 3 hours of training. The results from the two methods in this instance were found to be in good agreement. The authors focused on the ability of TDS to describe the complex interactions between food through the dominant attributes detected over time (Dinnella *et al.*, 2012). Additionally, TDS is considered to be highly sensitive as an attribute of lower intensity could be picked up easily compared to QDA, showing suitability of TDS in studying consumer responses. ‘Halo-dumping’ effects defined as an association caused by carrying-over an impression is prevented in TDS which in turn, true rating of the attribute will be obtained (Di Monaco et al., 2014, Teillet et al., 2010, Ng et al., 2012)..

TDS can also assist in samples matching. Cadena and Bolini (2011) applied TDS to six samples of ice cream using 29 panellists whom had 6 hours of training. A multiple time-intensity analysis similar to a principal competent analysis scatterplot which characterized the profile and consumer acceptance of the product, presenting two or more sensory attributes of all the six samples of ice cream was simultaneously generated with TDS curves. This allowed the authors to successfully matched the ice cream which was lighter with reduced sugar and fat content to a traditional recipe.

On the flip side, TDS is perceived to be quite demanding for panellists as they will need to continuously focus their attention on the dominant perception during the whole period of tasting, thus having the possibility of inducing restricted rather than normal chewing pattern (Lawless and Heymann, 2010). Additionally, artificial response can be brought about by TDS as most protocol is conducted in non-naturalistic environment such as laboratory which enhanced analytical mind-set (Delarue and Blumenthal, 2015).

TDS has been used in the testing on a wide variety of products like dairy (Pineau *et al.*, 2003, Pineau *et al.*, 2009), flavoured gels (Labbe *et al.*, 2009, Devezeaux de Lavergne *et al.*, 2015b), sausages (Devezeaux de Lavergne *et al.*, 2015a) and even breakfast cereal (Lenfant *et al.*, 2009) to name a few. In TDS, panellists are able to detect the different textural aspects of the food product. Hence, it was initially thought to only be applied in solid food products due to its longer oral residence time. It was recently found that TDS could also well be applied to liquid food products (Engelen and de Wijk, 2012). However, TDS is difficult to apply to food products with strong flavour (Di Monaco *et al.*, 2014). Kawasaki *et al.* (2016) used TDS to study the concentration of three basic tastants (NaCl, lactic acid and monosodium glutamate), using 8 experienced panellists consisting of 8 attributes. It was discovered that food containing a high concentration of those three basic tastants was labelled as indescribable by the panellists. Reason being, it was too concentrated, above the recognition threshold to be pick up.

2.3.3 Temporal Dominance of Emotion (TDE)

Similar to the way TDS is carried out, this dynamic descriptive sensory method can also be applied to emotion as it is clear that there are more to food choices than sensation alone. Human eating behaviour whilst influenced by cues from food, the body, and the social and physical environment, is also affected by and associated to emotions- “the primary motivational system for human beings” (Desmet and Schifferstein, 2008). Thus, there is a need to look at a broader perspective on how consumers experience a food product in associating emotions which like many other perceptions, are not a single response but a series of dynamic events that unfold over time (Sander *et al.*, 2005).

Many food products are developed to entice our emotions. Macht and Dettmer (2006) compared the emotions generated between consuming chocolate and apple. It was found that chocolate elicited joy with elevated mood compared to eating an apple in healthy German woman (n=37) aged between 19 and 30 years old. Therefore, pleasure related to a product goes beyond sensory simulation. It also includes anticipation and memories related to past experiences (Wolfe, 2009). Factors that may indirectly affect the taste of food include association of the food to memories, positive emotions evoked by good times or the ambiance of the place. Similarly, cultural values and previous food consumption experiences are factors that might further impact emotions (Organ *et al.*, 2015). Food evoked emotions are also dependent on the internal state of the individual, such as the nutritional state (time since last meal, hungriness, or thirstiness), mood and overall physical state (fitness or fatigue) (Desmet and Schifferstein, 2008).

There is limited research which applies TDE to measure mood in relation to food consumption. Jager *et al.* (2014) compared ten TDS and TDE attributes shortlisted based on check-all-that-apply's frequency questionnaire in five dark chocolate samples by 62 panellists. Food which evoked similar emotions for example, 'product makes me feel happy' or 'this product excites me', produced similar temporal dynamics and interactions. It was also observed that some sensory attributes were related to a particular emotion which in chocolate, cocoa was related to energetic while dry to aggressive. Although emotional attributes are more stable with longer duration of significance, a lower average number of attributes are selected compared to sensory attributes. Furthermore, measuring food-evoked emotions contributed to better comprehension of consumer's liking ratings and could probably be a useful tool in differentiating products with similar hedonic scores by the different emotional responses the products induced (Jager *et al.*, 2014).

Another study looking at the development of a common emotion lexicon was carried out in four different countries (France, Germany, Italy and UK) with around 350 panellists each (Thomson and Crocker, 2013). A higher number of positive emotions chosen were observed across all 4 countries which the study concluded that people tend to look at emotions rewarding to them. The conclusion was drawn by using two phases of test where the first phase used questionnaire with 3 to 20 feelings grouped according to similarity whilst the second phase allowed panellists to cluster similar emotions in an online survey.

In addition, when a study utilises emotions which are frequently used or are familiar to the panellists, higher acceptance of the product was observed (Gmuer *et al.*, 2015). Furthermore, lesser confusion will occur thus obtaining results of higher accuracy (Gmuer *et al.*, 2015). Therefore, training on the definition of various emotions used in a study besides from calibrating the panellists, also helps to familiarise them to the emotions.

2.3.4 Temporal Dominance of Liking (TDL)

Alongside sensation and emotion information gathered from temporal changes in food, construction of preferences could be drawn from the dynamic hedonic response scale when included in the study. This could help in developing appealing food products linked to sensory arousal or memorable sensory-hedonic perceptions (Delarue and Blumenthal, 2015).

Taylor and Pangborn (1990) were reported to be the first to integrate liking to a continuous measurement. Liking of a food even for product with similar sensory perception could vary over time when masticated. Therefore, two new methods to measure the dynamic of liking in a one bite consumption event was proposed by Sudre *et al.* (2012). Forty-nine consumers (20 - 35 years old) from Switzerland tasted 3 wheat flake cereals coded as WFA, WFB and WFC in 2 tests. The first test used on overall liking evaluation while the second measured the liking of the products at four time points (beginning of mastication, in the middle of mastication, just before swallowing and just after swallowing). Similar results were observed in the two methods applied for all three samples, suggesting sufficiency of overall liking in evaluating liking of a product.

However, overall liking of a product can be formed during the early stage of sampling (i.e. first few chews of a product). This was proven by Thomas *et al.* (2015) where 64 consumers of flavoured cheese (aged 19 to 66 years old) were recruited to sample six commercial flavoured fresh cheeses. It was found that the classical liking measurement (collected 1 min after tasting began) using 9-point hedonic scale might have been graded even before the sample was swallowed. Therefore, static hedonic rating is dependent on the panellist's definition of overall liking. It means that the overall liking of a product can be rated at three different scenarios- at the start of sampling, at the end of sampling or as a sum of the entire sampling experience where at undefined time point, different results will be obtained.

To further close the gap, alternated temporal driver of liking which includes a liking scale immediately after TDS during each sip of the two oral nutritional supplements was investigated by Thomas *et al.* (2016). The supplements which differed in energy density and volume were used on a panel of 65 French consumers aged 40 to 60 years old. Liking while dominant defines as the average liking scored by consumers for a product accounting for all dominant descriptors was calculated. However, as liking while dominant was tabulated from the static liking scores obtained for each dominant attribute considering interaction, the single liking average might not have accounted for all the attributes in a product.

The best way to incorporate liking could still be integrating TDL with TDS, obtaining dynamic liking ratings that could reduce potential biases caused by correlating static liking scores to TDS data with interference from other non-dominant attributes. Cao (2014) looked at the role of food structure using gel of varying hardness on bitterness perception using 10 trained panellists. The combination of methods allowed panellists to rate the liking of the product until it was swallowed, generating time-dependant monitoring with TDS and better discrimination between the samples. Useful correlation results were drawn using the TDS and TDL data where bitterness and acceptability were negatively correlated.

Recently, Meyners (2016) also attempted to correlate liking scores with TDS in flavoured cheeses using 64 consumer panellists. Firstly, panellists rated liking over time. Then TDS was performed using 8 attributes. The results provided additional insights on the TDS attributes chosen. For example, the attribute 'cooked herbs' was a negative driver of liking in cheese while 'garlic', 'salty' and 'sour' were the opposite. Similarly, Thomas *et al.* (2015) used the same research method on flavoured cheese from Meyners (2016) and demonstrated a high correlation between TDS profile to drivers of liking. The study concluded that when an attribute was cited as dominant, it would lead to either a decrease or an increase in liking.

Relationship between emotional liking and the price consumers were willingness to pay consisting samples of high, medium-high, medium-low and low quality Australian Shiraz wines were investigated (Danner *et al.*, 2016). From the 350 consumer's results gathered, conclusion was drawn that a wine which was better preferred evoked a higher number of positive emotions. Furthermore, a strong association observed between higher number of positive emotions to willingness to pay significantly is good news to food manufacturers.

In addition, emotions can be related to likings as well. For instance, when a food product deviates from someone's memory, disappointment can be felt relating to incompleteness or disturbance (Doets and Kremer, 2016). In another study by Mojet *et al.* (2015), it was found that positive emotions lead to higher liking than negative emotions. It was further confirmed by Gutjar *et al.* (2015) that food choices in terms of liking was correlated to food-evoked emotions. There is however no research which utilises TDL together with TDS and TDE.

2.4 Factors impacting Temporal Dominance of Sensation, Emotion and Liking

<u>2.4.1 Attribute List</u>

Recently in the literature, there has been some advice in terms of the best practice for TDS. Pineau *et al.* (2012) reviewed 21 TDS datasets collected under different conditions to examine the usage of attribute list by panellists during the TDS experiment, particularly on the number (3 to 17 attributes), types (texture and/or taste and/or aroma) and position of the attributes on the list. From various papers reviewed by Pineau *et al.* (2012), at least one attribute was selected from an attribute list of less than 10 terms whereas, a subset of attributes were selected when the attribute list became longer.

Similarly in a study by Pineau *et al.* (2012), it was suggested to keep within 8 to 10 attributes. Fifteen TDS studies analysed by Di Monaco *et al.* (2014) found that panellists behaved differently with respect to the number and to the attributes they used, when the attribute list had more than six attributes. It was also discovered that on average, panellists used about four attributes to describe a single sample which attributes order did not affect the attributes chosen. Moreover, a shorter list of attributes prevent fatigue in the panellists.

The most common way in building an attribute list is to use a trained panel (Sasaki *et al.*, 2014). Firstly, the panel will be provided with samples of different products with similar sensory attributes to define the product scale, noting down all the perceived sensations. Secondly, all sensations perceived from the panel will be collected and compared under the guidance of a panel leader in group discussions, during which irrelevant descriptors are eliminated and synonyms are combined. Finally, only the most frequently cited attributes are selected and kept for analysis (Di Monaco *et al.*, 2014, Lenfant *et al.*, 2009, Meillon *et al.*, 2009).

It has been suggested that the attribute position should be kept balanced across panellists to minimise order effects as the attributes at the top tend to be selected frequently (Pineau *et al.*, 2012). However, the attributes should remain the same for a given participant during the entire evaluation, facilitating him or her in the learning of the terms and scoring intensities during an evaluation (Di Monaco *et al.*, 2014).

2.4.2 Panel Training

Pineau *et al.* (2012) advocates the use of a panel which is provided with some degree of training in the attributes used as it was observed that different people have different definitions for each attribute used or have different taste sensitivities on the various attribute in TD experiment. Furthermore, Cheong *et al.* (2014) investigated on the oral breakdown and dynamic sensory perception of three biscuits with different hardness using 24 panellists. Two sessions were conducted where the first was without training and the second had attributes explanation training carried out before the evaluation. By only explaining the attributes, it increased agreement between panellists on the dominant attributes selected with higher dominance rate. Interestingly, a shorter time to the first chosen dominant attribute was also observed, suggesting the added benefit of training. Contrastingly, Meillon *et al.* (2009) recommended that judges should not be over-trained in order to avoid individual typed-responses which is a tendency for subjects to quote descriptors in the same order for all products.

In TD methodology, the training should be more oriented to attribute definition in order to achieve a list of dominant attributes with high dominance rate than to describe the product of interest (Pineau *et al.*, 2012). Meyners (2016) had similar findings using flavoured fresh cheeses comparing between 64 consumers and 11 trained panellists. Difference curve for trained panellists showed no differentiation between the products at 5% significant level, suggesting better discrimination in consumer panellists. Hence, a short training on attributes definition is sufficient.

2.4.3 Ethnicity

Unpublished data from the focus groups conducted under the wider MBIE project (reference number 20999) led by Grigor (2016) concluded that perception and description of the same food varied across different ethnicities. Distinct differences in culture do exist in terms of food choices. Some ingredients are associated to one's ethnicity. For example till today, coconut milk is used widely in the Malay cuisine, while spices are used in the Indian cuisine (Ternikar, 2014, Almerico, 2014). Therefore, food has the ability to draw emotional connections, sense of belonging and ethnic pride in the various ethnic community (Almerico, 2014).

It was agreed by Organ *et al.* (2015) that cultural values played a part in food perceived emotions. The study used 2 food festival surveys either from a collection of local food suppliers serving a purely local group of customers or from major annual events which attract regional or national audiences. The surveys were gathered 6 months apart by 246 participants to examine engagement and subsequent food choices. Another interesting finding was the association between increased engagement in the various culture to a food product which elicited positive emotions, thus leading towards repeat purchase of the food product.

Looking at the complementary and alternative medicine in the three main ethnicities (468 participates) in Singapore, it was observed that each ethnicity's traditional practises had been diversified. Even though the traditional Malay typically uses Jamu and Indian uses Ayuverdic, it has been skewed towards using traditional Chinese Medicine (TCM) in recent years. Therefore from the study by Lim *et al.* (2005), cross cultural practises interaction were observed between the ethnicities.

Food besides from being affiliated to each ethnic culture, is associated to warmth, good feelings and memories (Almerico, 2014). Additionally, food enables establishment of connection with each other easily as it can be shared among people in various setting be it in formal or informal gathering (Garrett *et al.*, 2006, Tu *et al.*, 2010, Onwezen and Bartels, 2013, Ternikar, 2014).

Furthermore, practices for each ethnicity in Singapore was examined to be different. Malay was thought to have the lowest brand loyalty with high inclination to agree with other ethnicities while Chinese adhered to group norms for the sake of one's 'face' and Indian tended to have lower level of tolerance for uncertainty, risk and anxiety (Jung and Kau, 2004, Abbas *et al.*, 2013). However, due to modernisation, economic determinants had dominated cultural determinants today (Jean-Pierre *et al.*, 2015).

Examining the relationship of culture and emotions in a cross-cultural study involving 129 students from Singapore and 145 students form the United States, differences were seen between and within person cross-culturally. Singaporeans are concluded to have stronger association of emotions to cultural practices (Koh *et al.*, 2014).

Although it was found that food choices differ in various culture, no study focus on using TD in food product recruiting the various ethnicities in Singapore. Ethnicity affecting the process of TD using panellists from Singapore is thus unclear. Hence, an understanding on the impact of using different ethnicity groups from Singapore can be gathered from this study.

2.5 Conclusion

Certainly, TDS alone is able to categorise changes in sensory properties over time but unable to inform the underlying emotion and liking relating to the particular dominant sensation. Emotions and likings are found to impact on food choices. Hence, it will be interesting to apply other novel sensory methods such as TDE and TDL together with TDS to draw a holistic sensory profile. Varying degree of panel training will be investigated to determine the differences in attributes selection. Along with TDL, a static hedonic scale will be included in this study to allow comparison of the method with frequency liking from TDL.

From the different panels results, one of the panel will be used to examine the difference in attribute selection from different ethnic groups in Singapore using TD, the first of its kind to be done.

A deeper understanding of a food product can be understood when two TD techniques were combined in some studies mentioned earlier. Therefore, with all the results, this study will be the first to combine TDS with TDL and TDE to draw interactions between sensations, emotions and likings to help product developer in creating new food products.

3. Materials and Methods

3.1 Apple cultivars

A total of nine apple varieties (Table 1) used in this research, four were from Heartland Fruits New Zealand (Eve, Divine, Royal Gala (2) and Ambrosia) and another five purchased from Cold Storage and Fairprice supermarkets being popular market samples available in Singapore (Royal Gala (1), Pink Lady, Granny Smith, Jazz and Fuji). Efforts were made to ensure that all apples were of similar weight, however, Pink Lady was of a lower weight (average of 160.0g to 180.0g for all apples and an average of 120.0g for Pink Lady). All apples were delivered to Food Innovation & Resource Centre on 1st September 2014 and they were kept in a refrigerator at 4°C (Sanyo, Model SRR-J1281VS) before sensory evaluation.

Table 1: Apple cultivars and their country of origin.

Cultivar	Country of Origin
Ambrosia*	New Zealand
Royal Gala (2)*	New Zealand
Divine*	New Zealand
Eve*	New Zealand
Jazz	New Zealand
Royal Gala (1)	New Zealand
Pink Lady	South Africa
Fuji	China
Granny Smith	South Africa

*Produce from Heartland Fruits

3.2 Samples Preparation

Apples were removed from the chiller, washed and held at room temperature for 2h before each session. When panellists were ready, the unpeeled apples were cut using an apple divider (EKCO Housewares) into eight slices (around 6.0cm in length x 2.0cm in width and an average of 19.8g for all apples; around 4.5cm length x 2.0cm width and an average of 12.5g for Pink Lady) and served immediately. Chopping boards and apple dividers were washed to prevent transmission of flavour after cutting each sample. The slices were then placed in transparent plastic cups (79.0mm x 46.0 mm) labelled with a random 3-digit code representing the apple which remained the same throughout that session. Sample codes were changed for the next repetitive session. Samples were arranged accordingly to a balanced serving order randomised within each serving set to reduce physiological and psychological effects including contrast, convergence and carry over effect (Lawless and Heymann, 2010).

3.3 Panellists selection for TDS, TDL and TDE sessions

The three main ethnic groups in Singapore (Chinese, Indian and Malay) were recruited for this study. Testing was conducted at Singapore Polytechnic's Chemical & Life Science, consumer insight suite.

Forty-two panellists aged between 21 and 64 with a mean age of 35 were selected. The panels consisted 21 Untrained Panellists of 8 Chinese, 6 Indian and 7 Malay and 21 Semi Trained Panel of 8 Chinese, 7 Indian and 6 Malay. Differences between the panels were further elaborated in section 3.4. Panellists were selected on the inclusion criteria of having self-assessed good oral and general health. They had complete dentition with no history of recent orthodontic treatment or jaw injuries, had natural mastication and salivation and were non-smoker. All panellists were frequent computer users and spoke fluent English.

Based on the approval and recommendations from the Ethics Review Committee (Singapore Polytechnic), all panellists were informed of the study with a written form including information on the aim of the study and anonymity issues. Signed consent was acquired prior to any session taking place and study sessions only proceeded after all panellists agreed to the study.

3.3.1 Descriptor Generation for TDS and TDE

Eleven (3 male, 8 female) Singaporean expert panellists who had more than 50 hours of training in sensory evaluation assessed four of the apple samples (Granny Smith, Royal Gala, Fuji and Pink Lady). Panellists were asked to consume at least half of each apple slice presented and generated sensory attributes describing each sample. Attributes generated were discussed and the ten most frequently cited sensory attributes were selected and used for analysis (Table 2). Panellists who participated in the sensory attributes generation were not allowed to participate in the study. Definitions for all sensory attributes were derived from Bonany *et al.* (2013) and Corollaro *et al.* (2013).

Emotional attributes (Table 3) were selected based on the frequency of appearance reported in Thomson and Crocker (2013), Jager *et al.* (2014) and Desmet and Schifferstein (2008).

Table 2: TDS attributes generated with description and references used for Semi Trained Panel. (Bonany *et al*., 2013[1]; Corollaro *et al*., 2013[2])

Attributes	Description	References	Preparation
Crunchy[2]	Sound produced by the sample during first 5 molars chew	Dry breakfast cereal	Kellogg's Corn Flakes
Firm[1,2]	Force required to bite the apple	Raw carrot	Cut into strips (2cm x 4 cm)
Juicy[1,2]	Amount of liquid released on mastication	Watermelon	Cut into cubes (4cm x 4cm)
Grainy[2]	Number/size of fragments/granules produced during chewing	Shortbread Biscuits	Walkers Pure Butter Shortbread Fingers (3cm x 2cm)
Fibrous[2]	Degree of flesh breaking during chewing in think and fibrous fragments/ granules, until the mouthful is ready to be swallowed	Raw celery	Cut into strips (3 cm x 5 cm)
Floral[1]	Intensity of floral flavour	Floral tea	2 Dilmah's Pure Camomile Flower tea bag steeped into 440ml of 95°C water for 4 minutes
Sweet[1,2]	Sweet flavour sensation	Sucrose solution	2% sucrose solution
Sour[1,2]	Sour flavour sensation	Citric acid solution	0.08% citric acid solution
Bitter[2]	Bitter flavour sensation	Caffeine solution	0.05% caffeine solution
Astringent[2]	Tactile sensation of dryness in the mouth	Chinese tea	2 Oolong tea bag steepted into 400ml of 95°C water for 2 minutes

Table 3: TDE attributes generated with description. (Desmet and Schifferstein, 2008[1]; Thomson and Crocker, 2013[2]; Jager et al., 2014[3])

	Attributes	Description
Positive	Happy[2]	Feeling pleased or glad
	Satisfied[1]	Feeling of gratification
	Interesting[3]	Feeling arouse or hold an interest
	Pleasant[2]	Feeling of enjoyment
	Desire[1]	Feeling of crave/want
Neutral	Surprised[1]	Feeling of wonder or astonishment
Negative	Disappointed[1,2]	Feeling of sadness caused by failure to meet expectation
	Displeasure[3]	Feeling of dissatisfaction
	Boring[1]	Find something uninteresting
	Disgusted[3]	Feeling of strong distaste

3.3.2 References Generation for TDS

After TDS attributes were generated, references listed in Table 2 were sourced by referring to literatures from Dinnella *et al.* (2012) and Hutchings *et al.* (2014). The references were assessed for suitability in Singapore context by the project group.

3.4 Warm-up and Training Procedure

Panellists were told to eat lightly 2 hours before the session. Warm-up session (10 minutes) was conducted in a group before the start of each sensory evaluation. The session was used to explain the concept of temporal dominance testing, to align panellists with the definitions for sensational or emotional attributes used in the study depending on the test conducted as TDS and TDE were conducted on separate days. Also, the warm-up aimed to inform panellists the sensory protocols to follow during testing. Panellists were welcome to ask questions at any point for clarification.

The 21 panellists who formed the Semi Trained Panel in this study had an extra hour of training on the different TDS attributes with references (Table 2) before the actual sensory evaluation. Semi Trained Panel were familiarised to the definition of each TDS attribute by the use of references to form a better understanding. Simulated TDS test using two samples of grapes (Kyoho and green grapes) were used to further adapt the Semi Trained Panel to the methodology.

3.5 Experimental Procedures

Each panellist attended two sessions, one for TDS with TDL and one for TDE on separate days. Panellists sampled 27 slices of apple in a 3 hours session. A total of 9 samples in each round were tasted (3 samples per set for 3 sets in total) with 1 min and 5 min break between each sample and before the next set was served respectively. After each round, panellists would rest for 30 mins. Three rounds of sampling were conducted in order to achieve replicate sets of results. Apple samples were arranged in a randomised balanced order and panellists were reminded to check the sample code with the code reflected on screen to ensure that they consumed the correct apple.

Data collection was done similar to the protocol outlined by Lenfant *et al.* (2009) and Hutchings *et al.* (2014) using Fizz Software (FIZZ network, version 2.47 B, Biosystemes, Courtenon, France). Attributes used in TDS and TDE were defined as per Table 2 and 3 respectively. TDL was incorporated with TDS (Figure 2) and panellists were to assess their liking towards the attribute (like, neutral or dislike) during each dominant attribute selection. Static overall acceptability (Figure 3) of each apple using a 7-point scale was collected after each TDS sequence when panellists pressed on the ‘stop’ button and before tasting the next sample. TDE data was collected as per Figure 4 by selecting the dominant emotions.

When seated at their individual booth which was operated under normal lighting conditions (Figure 5), panellists would input their tray number. Panellists were instructed to start the evaluation process by biting at least half of the sample and immediately click on the ‘start’ button. Selection of the attributes (Figure 2 for TDS and Figure 4 for TDE) which were the most dominant at any time point commenced. As the dominant attribute changed, panellists were required to select the new dominant attribute. Panellists were informed that they did not have to use all the attributes in the list and were free to choose the same attribute several times. Immediately after the sample was swallowed, panellists selected the ‘stop’ button. During each run, panellists were free to naturally chew the sample i.e. no instruction was given in terms of how the sample should be eaten.

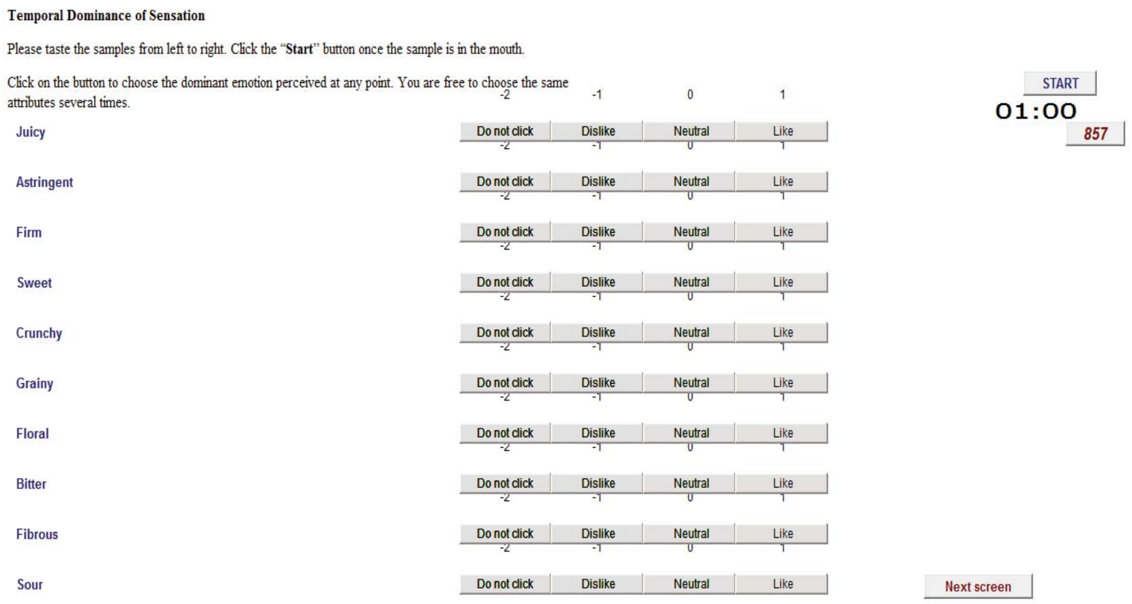
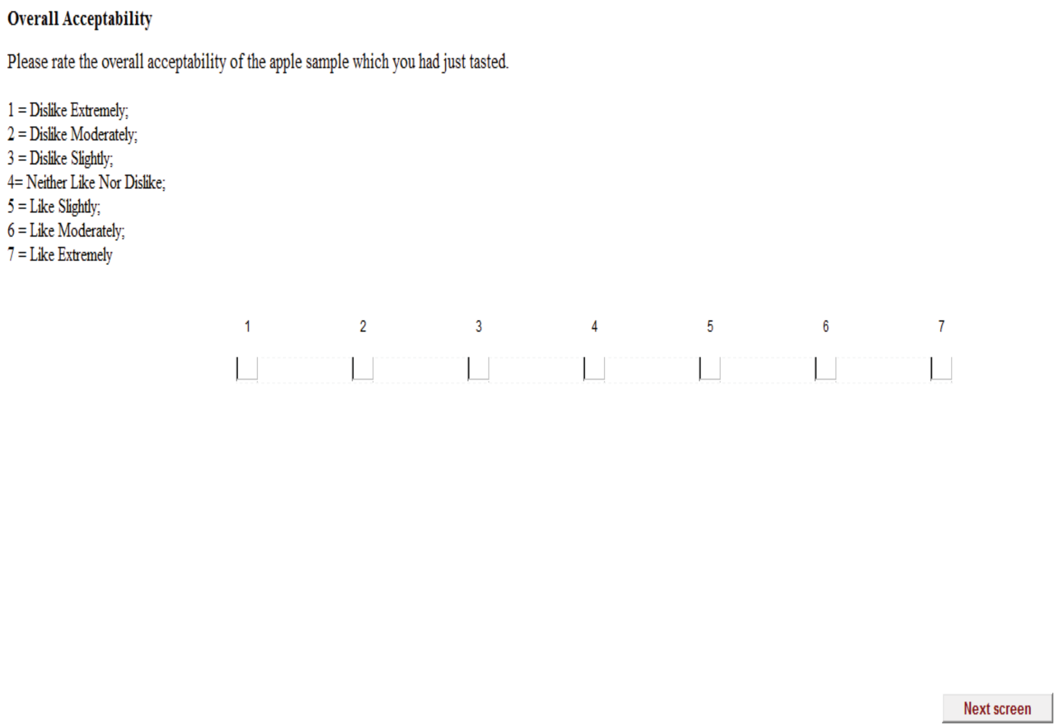


Figure 2: Sample sensory evaluation form for TDS and TDL, where degree of liking towards the attribute was represented by ‘dislike’ as -1, ‘neutral’ as 0 and ‘like’ as 1. (Note: the “do not click” column was required due to limitation with the FIZZ software).

The mastication duration was set at one minute for each sample as recommended by Pineau *et al.* (2012). The order of the attributes presented on the computer screen was randomized across panellists to reduce first order and carryover effects but the same order was kept for each panellist throughout each session (Forde *et al.*, 2013, Pineau *et al.*, 2012).

Unscented wet tissue papers (125.0mm x 180.0mm) from Daiso Japan and filtered water (eSpring® Water Purifier) were provided to the panellists for cleaning their fingers and palate.



Overall Acceptability

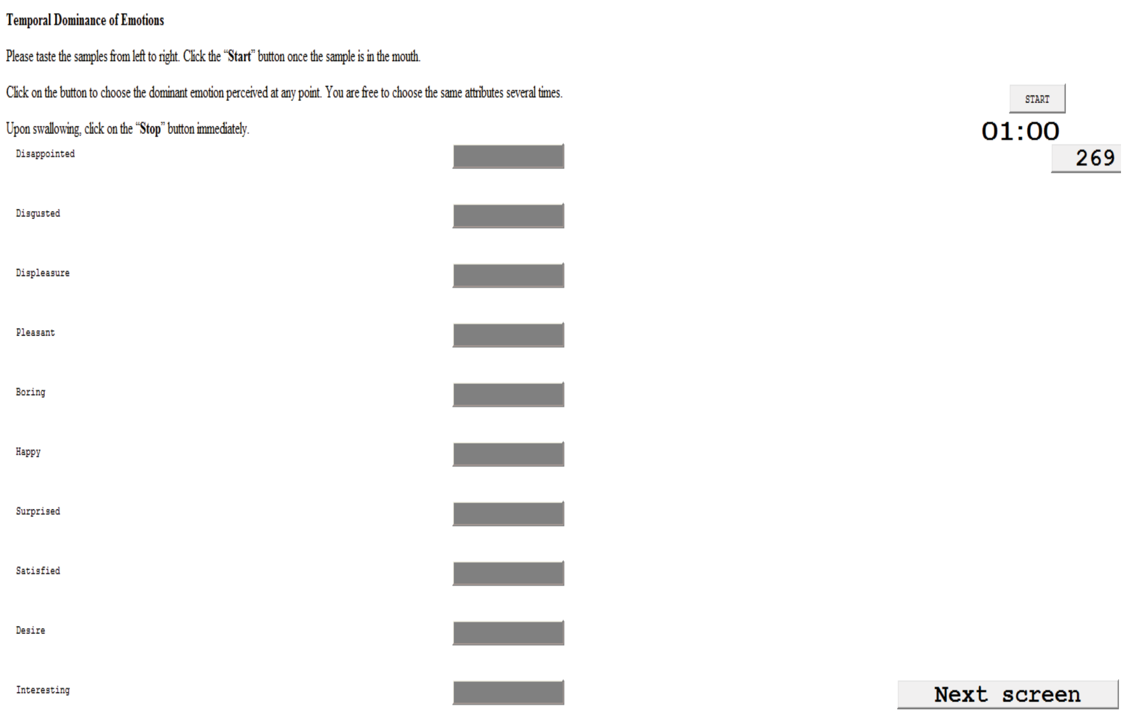
Please rate the overall acceptability of the apple sample which you had just tasted.

1 = Dislike Extremely;
2 = Dislike Moderately;
3 = Dislike Slightly;
4= Neither Like Nor Dislike;
5 = Like Slightly;
6 = Like Moderately;
7 = Like Extremely

1 2 3 4 5 6 7

Next screen

Figure 3: Sample sensory evaluation form for product acceptability after TDS using 7-point hedonic scale.



Temporal Dominance of Emotions

Please taste the samples from left to right. Click the "**Start**" button once the sample is in the mouth.

Click on the button to choose the dominant emotion perceived at any point. You are free to choose the same attributes several times.

Upon swallowing, click on the "**Stop**" button immediately.

START
01:00
269

Disappointed
Disgusted
Displeasure
Pleasant
Boring
Happy
Surprised
Satisfied
Desire
Interesting

Next screen

Figure 4: Sample sensory evaluation form for TDE.

Figure 5: Example of a sensory session in progress.

3.6 Data Analysis

3.6.1 Generation of Standardised Time TDS and TDE Graphs

TDS and TDE data were treated similarly as listed out where data were computed, showing the panellist's individual dominance attributes for the various replication for each apple variant (Figure 6a). Timing were then standardised ('Start' (x=0%) and 'Stop' (x=100%)) shown in Figure 6b, accounting for the differences in mastication behaviours and oral processing time between panellists. In actual analysis of data in this study, the results were classified into different panels or ethnicities, depending on the objective of that section. In Figure 6a and 6b, individual result was reflected in the graph as an example to prevent overcrowding of data points. Raw panel dominances curves (Figure 6c) showing dominance rate (%) against standardised time (%) were generated with a 5% standardised time interval between each time period. Dominance rates at 5% significance used in most of the TD studies were calculated by dividing the total number of an attribute selected (across all panellists and repetitions) by the total number of panellists and repetitions, then converted to percentage dominance (Di Monaco *et al.*, 2014, Ng *et al.*, 2012, Pineau *et al.*, 2009, Thomas *et al.*, 2015). A higher percentage of dominance rate of an attribute indicates a higher consensus among panellists to the specific attribute being dominant at a given time. The raw curves were transformed into smoothed curve (spline) as shown in Figure 6d.

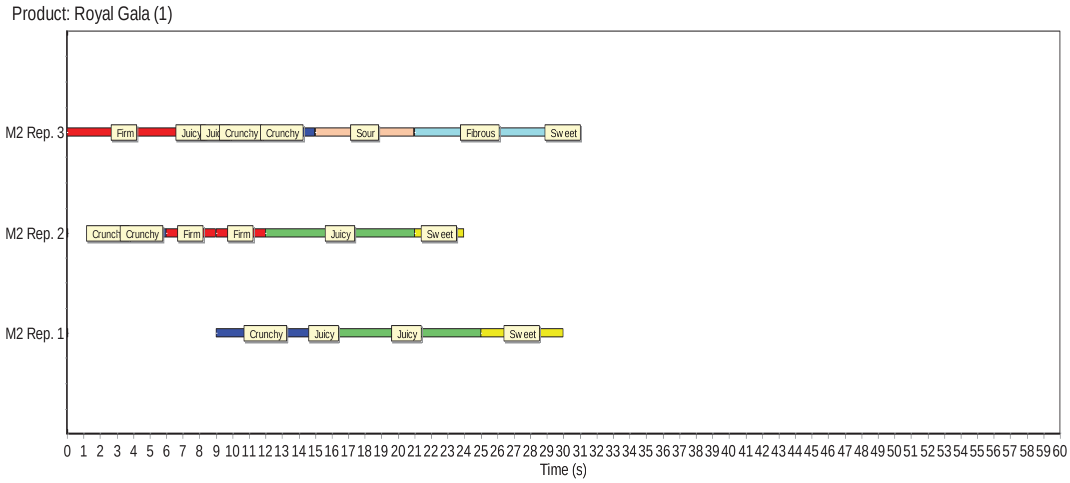


Figure 6a: Panellist's individual raw dominances was generated over time (s).

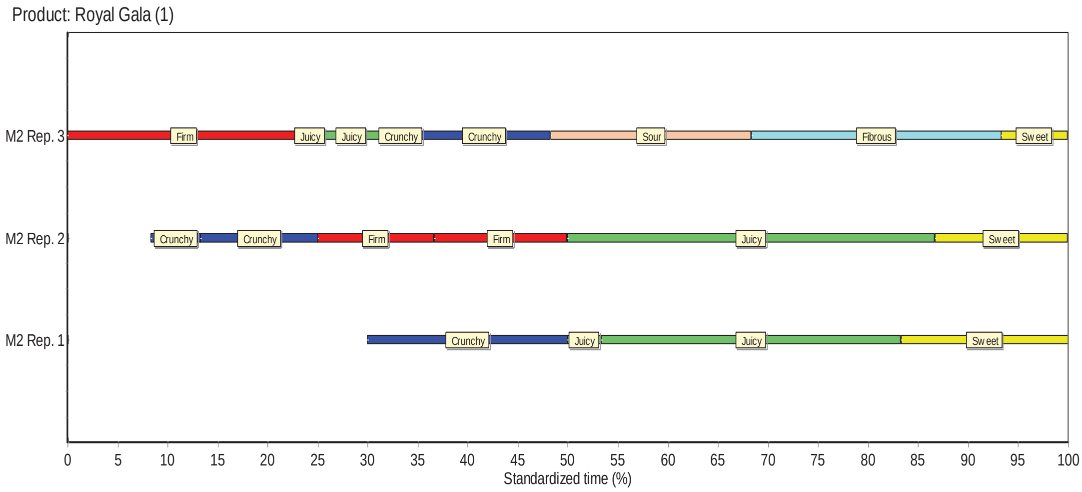


Figure 6b: Panellist's individual raw dominances was generated over standardised time (%).

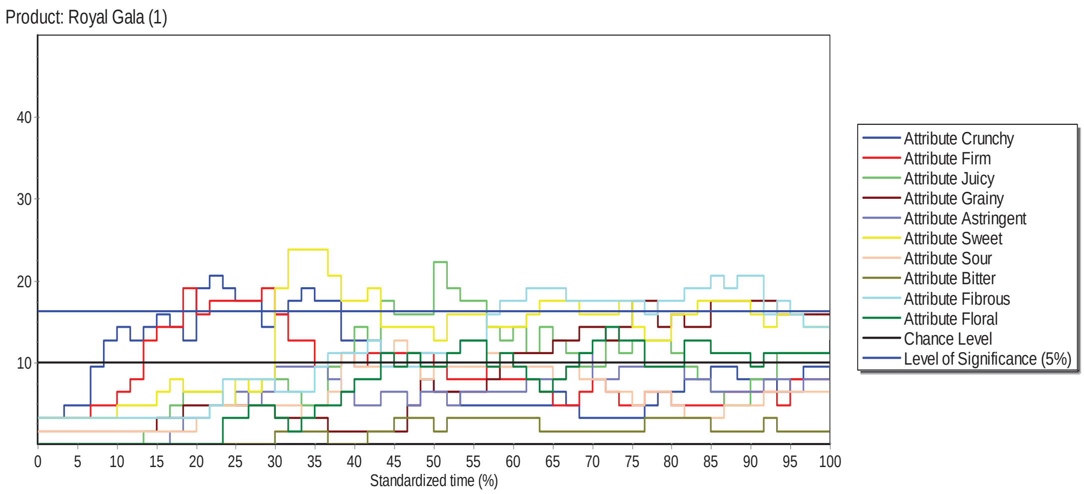


Figure 6c: Raw curve of panel dominances of all panellists in respective panel or ethnicities were generated over standardised time (%).

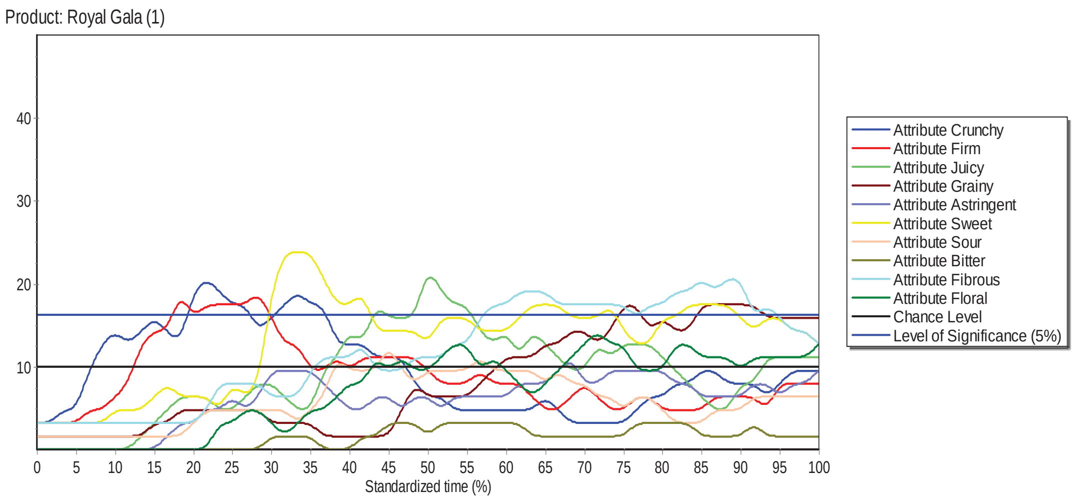


Figure 6d: Smoothed (spline) curve of panel dominances of all panellists in respective panel or ethnicities were generated over standardised time (%).

TDS and TDE curves rely solely on the selection of an attribute being dominant, no data concerning attribute intensity was shown (Di Monaco *et al.*, 2014).

3.6.2 Generation of Standardised Time TDL Graphs

Liking rated with dominant attributes extracted from TDS result files were treated as TDL data. The raw scores ranged from -1 to 1 which total counts were tabulated for all attributes against standardised time were reflected in Figure 7a. Average liking scores (Figure 7b) were calculated against standardised time with chance level and significant level calculated using equation 1 and 2 (page 8). Any scores above 0.33 were considered as *like* (1), between 0.33 to -0.33 were considered as *neutral* (0) and below -0.33 were *dislike* (-1). Dominance rate (%) of the liking scores were calculated by multiplying the average liking scores in Figure 7b by 100. Response rate (%) was also calculated against standardised time to measure the percentage of panellists who responded to the selection of liking scores (*like*, *neutral* or *dislike*) from the dominant attribute (Figure 7c). Scores were shifted as seen in Figure 7d to the next standardised time scale as at standardised time point 0% (start of the test), there should not be any attribute detected. Temporal dominance graphs were plotted similarly to those generated from Fizz for TDS and TDE, with the addition of response rate (%) on the secondary x-axis (Figure 8).

3.6.3 Static Overall Liking and Acceptability

Two types of scores were tabulated, first from the 7-point hedonic liking scale which were assessed at the end of each mastication sequence (Figure 3) and second from frequency liking counts from the 3-point hedonic scale (Figure 2) included with TDS retrieved from

the FIZZ program results. Mean hedonic scores (‘dislike extremely’ to ‘like extremely’)

				Standardised Time (%)							
Panel	Rep	Attribute No	Attribute	0.0	1.7		93.3	95.0	96.7	98.3	100.0
C3	2	1	Attribute Crunchy								
C3	2	2	Attribute Firm								
C3	2	3	Attribute Juicy						1	1	
C3	2	4	Attribute Grainy			. . .					
C3	2	5	Attribute Astringent								
C3	2	6	Attribute Sweet				1	1			
C3	2	7	Attribute Sour								
C3	2	8	Attribute Bitter								
C3	2	9	Attribute Fibrous								
C3	2	10	Attribute Floral								
			.						.		
			.						.		
I6	1	1	Attribute Crunchy								
I6	1	2	Attribute Firm								
I6	1	3	Attribute Juicy								
I6	1	4	Attribute Grainy								
I6	1	5	Attribute Astringent			. . .	0	0	0	0	
I6	1	6	Attribute Sweet								
I6	1	7	Attribute Sour								
I6	1	8	Attribute Bitter								
I6	1	9	Attribute Fibrous								
I6	1	10	Attribute Floral								

	Standardised Time (%)								
Total Count:	0.0	1.7			93.3	95.0	96.7	98.3	100.0
Like	5	5			27	28	29	28	0
Neutral	4	4			25	24	23	24	0
Dislike	1	1			10	11	11	11	0

Figure 7a: Liking scores of each attribute against standardised time where 1 is like, 0 is neutral and -1 is dislike. Total counts for all panellists for all 3 repetitions for 9 apples were obtained.

	Standardised Time (%)							
	0.0	1.7		93.3	95.0	96.7	98.3	100.0
Like	0.079	0.079		0.429	0.444	0.460	0.444	0.000
Neutral	0.063	0.063	. . .	0.397	0.381	0.365	0.381	0.000
Dislike	0.016	0.016		0.159	0.175	0.175	0.175	0.000
Chance Level	0.1	0.1		0.1	0.1	0.1	0.1	0.1
Level of Significance (5%)	0.162	0.162		0.162	0.162	0.162	0.162	0.162

Figure 7b: Average liking counts against standardised time with chance and significant level calculated.

		Standardised Time (%)							
		0.0	1.7		93.3	95.0	96.7	98.3	100.0
Dominance rate (%)	Like	8	8		43	44	46	44	0
	Neutral	6	6	. . .	40	38	37	38	0
	Dislike	2	2		16	17	17	17	0
	Chance Level	10	10		10	10	10	10	10
	Level of Significance (5%)	16	16		16	16	16	16	16
	Response Rate (%)	16	16		98	100	100	100	0

Figure 7c: Dominance rate of average liking scores against standardised time with response rate (%) calculated.

Standardised Time (%)

		0.0	1.7	. . .	93.3	95.0	96.7	98.3	100.0
Dominance rate (%)	Like	0	8		41	43	44	46	44
	Neutral	0	6		41	40	38	37	38
	Dislike	0	2		16	16	17	17	17
	Chance Level	10	10		10	10	10	10	10
	Level of Significance (5%)	16	16		16	16	16	16	16
	Response Rate (%)	0	16		98	98	100	100	100

Figure 7d: Dominance rate (%) of average liking counts and response rate (%) were shifted to the next standardised scale.

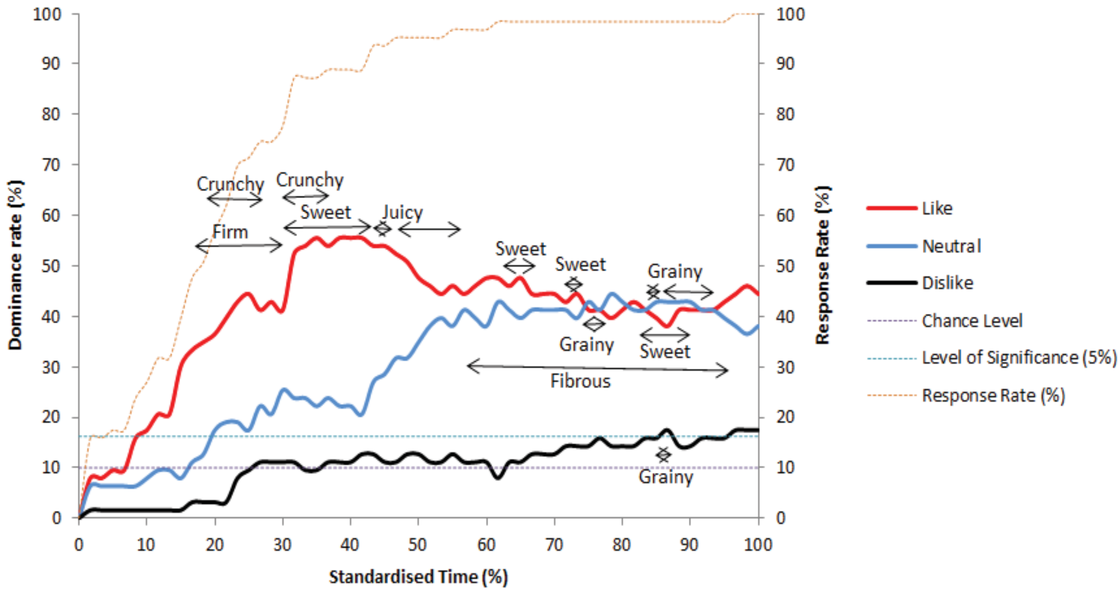


Figure 8: Example of panel dominance graph for TDL.

were calculated for each panel type and each ethnicity from the Semi Trained Panel. Frequency of liking counts were calculated for each apple using the rating mentioned in section 3.6.2 from all panellists. For example, if a panellist selected a dominant attribute in TDS with the accompanying liking category (‘like’, ‘neutral’ or ‘dislike’), it would be taken as a count in the respective liking category. Hence referring to Figure 7a, if a panellist selected *neutral* on an apple for the attribute *astringent* at four time points (93.3 %, 95.0%, 96.7% and 98.3%), the count would be computed as 4. Thereafter for each apple, the frequency counts from the different liking categories were tabulated for all panellists and attributes by panels and ethnicities.

3.6.4 Intra-Subject Variability

The mean basic behaviour of using TD method on sensation and emotion was investigated. Raw data (number of attributes selected during each mastication cycle, time for the first dominant attribute recorded (s) and time to the last dominant attribute recorded (s)) from all three replicates were reviewed manually for each sequence in FIZZ (Hutchings *et al.*, 2014, Cheong *et al.*, 2014, Galmarini *et al.*, 2017). The data provided behavioural information to different groups of panellists (panel types and ethnicities).

3.7 Statistical Analysis

Analysis of variance (ANOVA) using General Linear Model option in Minitab 17 was used to assess the significant difference of hedonic liking scale (dislike extremely to like extremely) between panels and apple types; and ethnicities within Semi Trained Panel and apple types. Fisher's least significant difference procedure was subsequently used to create confidence intervals for all pairwise differences between factor level means where significant difference was detected at $\alpha=0.05$, with reference to the method used by Jager *et al.* (2014) and Thomas *et al.* (2015).

Effects between panels and apple types; and ethnicities within Semi Trained Panel and apple types from the frequency liking counts in section 3.6.3 were calculated using a Chi-square test where significant difference was detected at $\alpha=0.05$.

4. Results

4.1 Panel Type Effect

4.1.1 Effects of Panel Type on Sensations

The TDS curves for all apple varieties are shown in Figure 9 and Figure 10 (for Untrained and Semi Trained Panel respectively). The order of attributes selected were slightly different between both panels. Initial dominant attributes for the Untrained Panel (Figure 9) in most apple varieties were observed to be *juicy* and *sweet* followed by *grainy* or *crunchy* (except for Royal Gala (2) where *crunchy* was detected at the start of the curve) and finally ending with *juicy*, *firm* and *fibrous* (with the exception of Divine where *floral* and *juicy* were detected last). For Semi Trained Panel (Figure 10), the initial dominant attribute for most apple varieties was textural attribute *crunchy* (for Eve, Jazz and Ambrosia, it was *grainy*). This then progressed to flavour attributes *sweet* and/or *juicy* and ended with textural terms *fibrous*, *grainy* or *firm*.

Although the order of the initial dominating attributes were slightly different for Semi Trained and Untrained Panels, the TDS profiles of most apples had *crunchy* as the dominating sensation, mainly at the early stages of the mastication cycle (between 8% to 17% standardised time for Semi Trained Panel and 15% to 40% standardised time for Untrained Panel), whereas *fibrous* dominated attention during the later stages of the mastication cycle (from 56% standardised time for Semi Trained Panel and 64% standardised time for Untrained Panel).

The Semi Trained Panel had higher cohesion displayed by a lower frequency of attributes repetition along the curves for all apples and higher attributes dominance rate above the line of significance (Figure 10) were the main differences between the two panels. Additionally, *firm*, *astringent* and *floral* were used more frequently in Semi Trained than Untrained Panel, properly due to the higher conceptual complexity of those attributes.

Royal Gala from the same country of origin but different cultivators, represented by Royal Gala (1) and Royal Gala (2) saw slight differences in the attributes generated as seen in Figure 9 and 10. In Semi Trained Panel, the additional attribute *grainy* was detected in Royal Gala (1) while for the Untrained Panel, the additional attribute *firm* was detected in Royal Gala (2). The differences aside from being driven by panel types could also be attributed to cultivar differences or difference in the harvest duration.

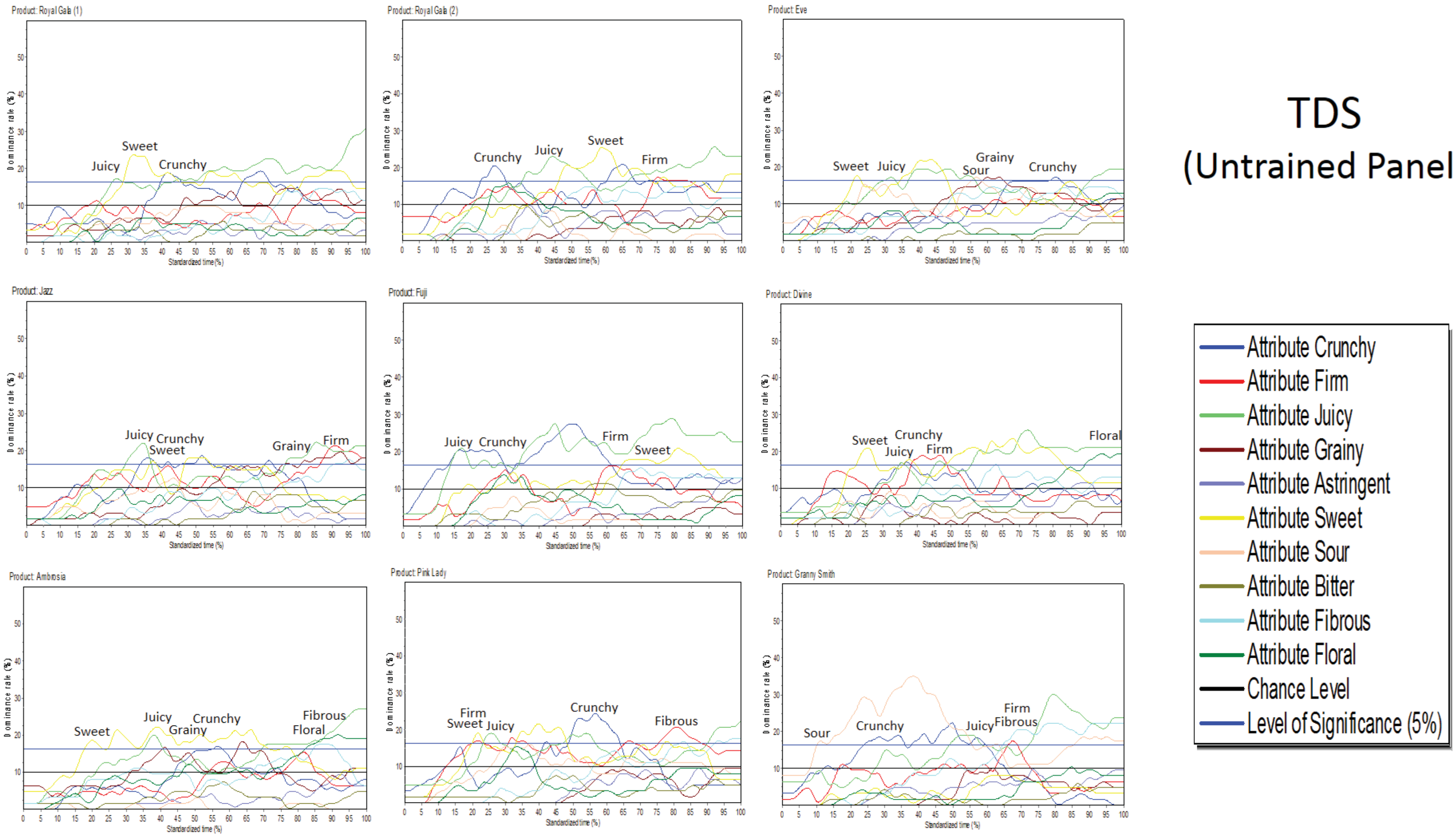


Figure 9: Temporal dominance of sensation (TDS) curves showing the dominance rate of each attribute for Untrained Panel where sweet and juicy were the initial sensory attributes observed for most apples.

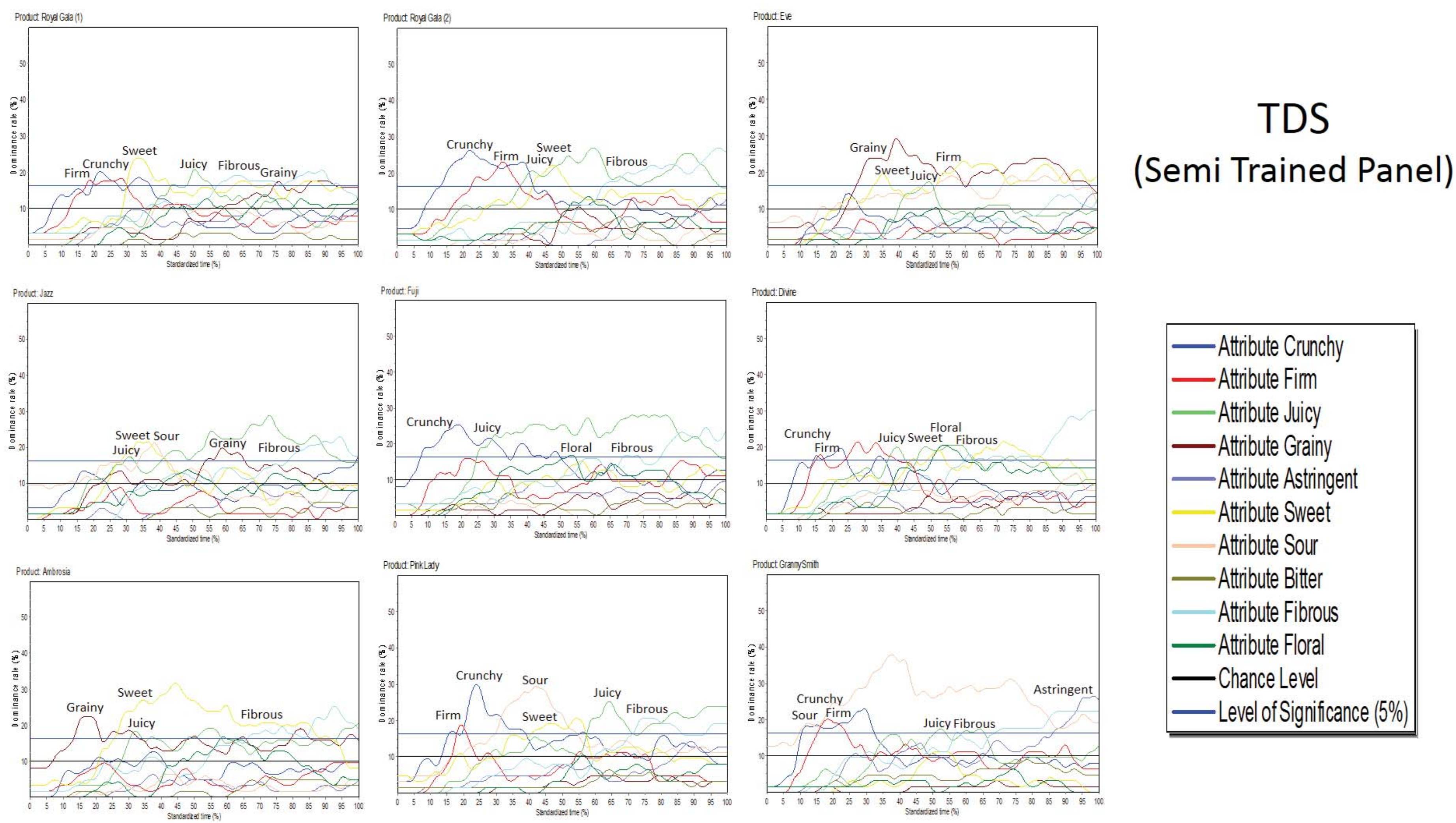


Figure 10: Temporal dominance of sensation (TDS) curves showing the dominance rate of each attribute for Semi Trained Panel where crunchy and grainy were the initial sensory attributes observed for most apples.

Table 4: Mean number of dominant attributes (number of attributes ± S.D.) used in the entire TDS period between panels.

Type of Apple	Semi Trained	Untrained	P-value[1]
Royal Gala (1)	4.56 ± 0.3	4.65 ± 0.3	N.S.
Royal Gala (2)	4.27 ± 0.3	4.76 ± 0.3	N.S.
Eve	4.14 ± 0.3	4.35 ± 0.3	N.S.
Jazz	4.52 ± 0.3	4.67 ± 0.3	N.S.
Fuji	4.56 ± 0.3	4.38 ± 0.2	N.S.
Divine	5.02 ± 0.3	4.71 ± 0.3	N.S.
Ambrosia	4.21 ± 0.3	4.41 ± 0.3	N.S.
Pink Lady	4.54 ± 0.3	5.06 ± 0.3	N.S.
Granny Smith	4.91 ± 0.3	5.06 ± 0.3	N.S.
P-value[2]	N.S.	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.

Alongside the TDS curves, the total number of attributes used, time to first and last dominant attribute selection were collected (Table 4 to 6). For both panels, the average number of dominant attributes used were between 4 to 5 for all apple varieties (Table 4), suggesting that regardless of panel type, the number of attributes chosen were similar.

Table 5: Mean time (s ± S.D.) for first dominant attribute recorded for TDS between panels.

Type of Apple	Semi Trained	Untrained	P-value[1]
Royal Gala (1)	6.14 ± 0.8	7.54 ± 0.8	N.S.
Royal Gala (2)	5.98 ± 0.7	6.40 ± 0.6	N.S.
Eve	6.54 ± 0.6	6.84 ± 0.9	N.S.
Jazz	5.54 ± 0.5	6.30 ± 0.8	N.S.
Fuji	5.67 ± 0.6	6.40 ± 0.9	N.S.
Divine	5.54 ± 0.6	6.51 ± 0.8	N.S.
Ambrosia	4.91 ± 0.5	6.71 ± 1.0	N.S.
Pink Lady	4.95 ± 0.5	4.81 ± 0.4	N.S.
Granny Smith	3.95 ± 0.3^{B}	5.92 ± 0.7^{A}	0.017
P-value[2]	N.S.	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[A-B] Upper case with different letters indicate means different between panels as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)

The first dominant attribute recorded ranged between 3.00 to 6.00s (Table 5) for the Semi Trained Panel while a slight delay of between 4.00 to 7.00s was observed for the Untrained Panel with most apples falling between 5.00 to 6.00s. Comparing attributes of Granny Smith between the two panels, a collection of attributes at the start in the

Semi Trained Panel (Figure 10) compared to only *sour* being dominant initially for Untrained Panel (Figure 9) might have led to an earlier attribute selection time observed in Semi Trained Panel for Granny Smith (P=0.017).

Table 6: Mean time (s ± S.D.) for end of dominant attribute recorded for TDS between panels.

Type of Apple	Semi Trained	Untrained	P-value[1]
Royal Gala (1)	30.97 ± 1.6[a]	31.30 ± 1.6	N.S.
Royal Gala (2)	29.68 ± 1.4[ab]	28.76 ± 1.5	N.S.
Eve	27.92 ± 1.5[abc]	28.84 ± 1.8	N.S.
Jazz	27.73 ± 1.4[abc]	28.06 ± 1.6	N.S.
Fuji	31.60 ± 1.7[a]	30.33 ± 1.7	N.S.
Divine	30.73 ± 1.6[a]	26.17 ± 1.7	N.S.
Ambrosia	26.22 ± 1.5[bc]	26.44 ± 1.2	N.S.
Pink Lady	24.75 ± 1.2[c]	25.56 ± 1.2	N.S.
Granny Smith	29.25 ± 1.4[ab]	28.46 ± 1.3	N.S.
P-value[2]	0.012	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[a-c] Lower case with different letters indicate means different within panel as determined by Fisher's least significant different test (LSD) at 95% confident interval (p<0.05)

The last dominant attribute recorded for the both panels were similar between 24.00 to 31.00s. However, significance was observed within the Semi Trained Panel (P=0.012) where the last dominant attribute selected was the slowest for Fuji (31.60s) and the fastest for Pink Lady (24.75s). In addition, lower variation in the Semi Trained Panel was observed from a slightly lower standard deviation calculated for first and last dominant attributes recorded (Table 5 and 6).

4.1.2 Effects of Panel Type on Emotions

The TDE curves for all apple varieties are shown in Figure 11 and 12 for the Untrained and Semi Trained Panel respectively. For the Untrained Panel (Figure 11), the initial emotions for all apples were either pleasant or satisfied which were positive except for Fuji and Granny Smith where boring and displeasure were experienced, respectively. The curves also ended with positive emotions like satisfied and pleasant with the exception for Royal Gala (1) (boring), Fuji (displeasure) and Ambrosia (disappointed). Fuji had negative emotions from the start (boring) to the end (displeasure) of the curve. Although Royal Gala (2) had sensational profile (Figure 9) similar to Granny Smith, the dominant emotional attributes (Figure 11) were different. The dominant emotional attributes for Royal Gala (2) were not as negative as Granny Smith. Therefore, attributes which were dominantly selected but not significant might have contributed to the negative emotions for Granny Smith.

For the Semi Trained Panel (Figure 12), generally positive emotions were observed. Positive emotions such as *pleasant*, *happy* and *satisfied* were reflected initially except for Royal Gala (2) (*boring*) and Granny Smith (*displeasure*). The curves also ended with mainly positive emotions (*pleasant*, *happy* and *satisfied*) except for Royal Gala (2) and Fuji where *disappointed* dominated.

Table 7: Mean number of dominant emotion (number of attributes ± S.D.) used in the entire TDE period between panels

Type of Apple	Semi Trained	Untrained	P-value[1]
Royal Gala (1)	2.83 ± 0.1[bc]	2.96 ± 0.2	N.S.
Royal Gala (2)	2.56 ± 0.1[c]	2.72 ± 0.2	N.S.
Eve	2.94 ± 0.2[abc]	2.93 ± 0.2	N.S.
Jazz	3.00 ± 0.2[ab]	3.14 ± 0.2	N.S.
Fuji	3.02 ± 0.1[ab]	3.04 ± 0.2	N.S.
Divine	3.25 ± 0.2[ab]	3.26 ± 0.2	N.S.
Ambrosia	3.29 ± 0.2[a]	2.88 ± 0.2	N.S.
Pink Lady	3.18 ± 0.2[ab]	3.16 ± 0.2	N.S.
Granny Smith	3.00 ± 0.2[ab]	3.04 ± 0.2	N.S.
P-value[2]	0.034	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[a-c] Lower case with different letters indicate means different within panel as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)

Table 8: Mean time (s ± S.D.) for first dominant emotion recorded for TDE between panels.

Type of Apple	Semi Trained	Untrained	P-value[1]
Royal Gala (1)	6.14 ± 0.5[B]	8.47 ± 0.6[A]	0.005
Royal Gala (2)	5.54 ± 0.6	6.77 ± 0.6	N.S.
Eve	5.92 ± 0.6	6.05 ± 0.7	N.S.
Jazz	5.81 ± 0.5[B]	8.32 ± 0.7[A]	0.004
Fuji	5.76 ± 0.5	7.02 ± 0.6	N.S.
Divine	6.35 ± 0.5	7.91 ± 0.7	N.S.
Ambrosia	5.92 ± 0.6	6.49 ± 0.6	N.S.
Pink Lady	5.86 ± 0.5	6.60 ± 0.4	N.S.
Granny Smith	6.52 ± 0.6	6.77 ± 0.6	N.S.
P-value[2]	N.S.	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[A-B] Upper case with different letters indicate means different between panels as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)

The number of dominant emotions (Table 7), time to first (Table 8) and last (Table 9) dominant emotion were also tabulated. Both panels had between 2 to 3 dominant emotions chosen (Table 7). For the Semi Trained Panel, Royal Gala (2) (2.56) had the lowest dominant emotions used and Ambrosia (3.29) had the highest (P=0.034).

Time taken for the first dominant emotion (Table 8) to be recorded was between 5.00 to 6.00s for Semi Trained Panel while a slightly later timing of between 6.00 to 8.00s was noted for the Untrained Panel.

Table 9: Mean time (s ± S.D.) for end of dominant emotion recorded for TDE between panels

Type of Apple	Semi Trained[1]	Untrained[1]	P-value[1,2]
Royal Gala (1)	22.06 ± 1.1	24.75 ± 1.1[a]	N.S.
Royal Gala (2)	19.41 ± 1.0[B]	22.90 ± 1.0[Aabc]	0.013
Eve	19.57 ± 1.0	20.56 ± 0.9[c]	N.S.
Jazz	19.97 ± 1.0[B]	22.89 ± 1.1[Aa]	0.042
Fuji	21.60 ± 1.2	22.58 ± 1.2[abc]	N.S.
Divine	21.02 ± 1.0[B]	25.40 ± 1.2[Aab]	0.005
Ambrosia	20.62 ± 1.0	21.60 ± 1.2[bc]	N.S.
Pink Lady	19.48 ± 0.8	20.79 ± 0.9[bc]	N.S.
Granny Smith	23.00 ± 1.1	25.19 ± 1.3[abc]	N.S.
P-value[2]	N.S.	0.006	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[A-B] Upper case with different letters indicate means different between panels as determined by Fisher's least significant different test (LSD) at 95% confident interval (p<0.05)
[a-c] Lower case with different letters indicate means different within panel as determined by Fisher's least significant different test (LSD) at 95% confident interval (p<0.05)

The dominant emotion end time (Table 9) for both panels were similar with the Semi Trained Panel between 19.00 to 23.00s and the Untrained Panel between 20.00 to 25.00s. Significant differences were observed within the Untrained Panel (P=0.006) where Eve (20.56s) had the earliest end time while Divine (25.40s) was the latest. The Untrained Panel took a longer time in selecting the first and last dominant emotions (Table 8 & 9). This observation was demonstrated clearly in Royal Gala (2) (P=0.013), Jazz (P=0.042) and Divine (P=0.005) between the two panels.

4.1.3 Effects of Panel Type on Likings

TDL curves for Untrained Panel (Figure 13) and Semi Trained Panel (Figure 14) were compared. The Untrained Panel had a higher dominance rate for liking throughout the standardised time duration for all apples. *Grainy* was *disliked* in Ambrosia while *fibrous* and *sour* were *disliked* in Granny Smith. Eve, Pink Lady and Jazz seemed to be the most

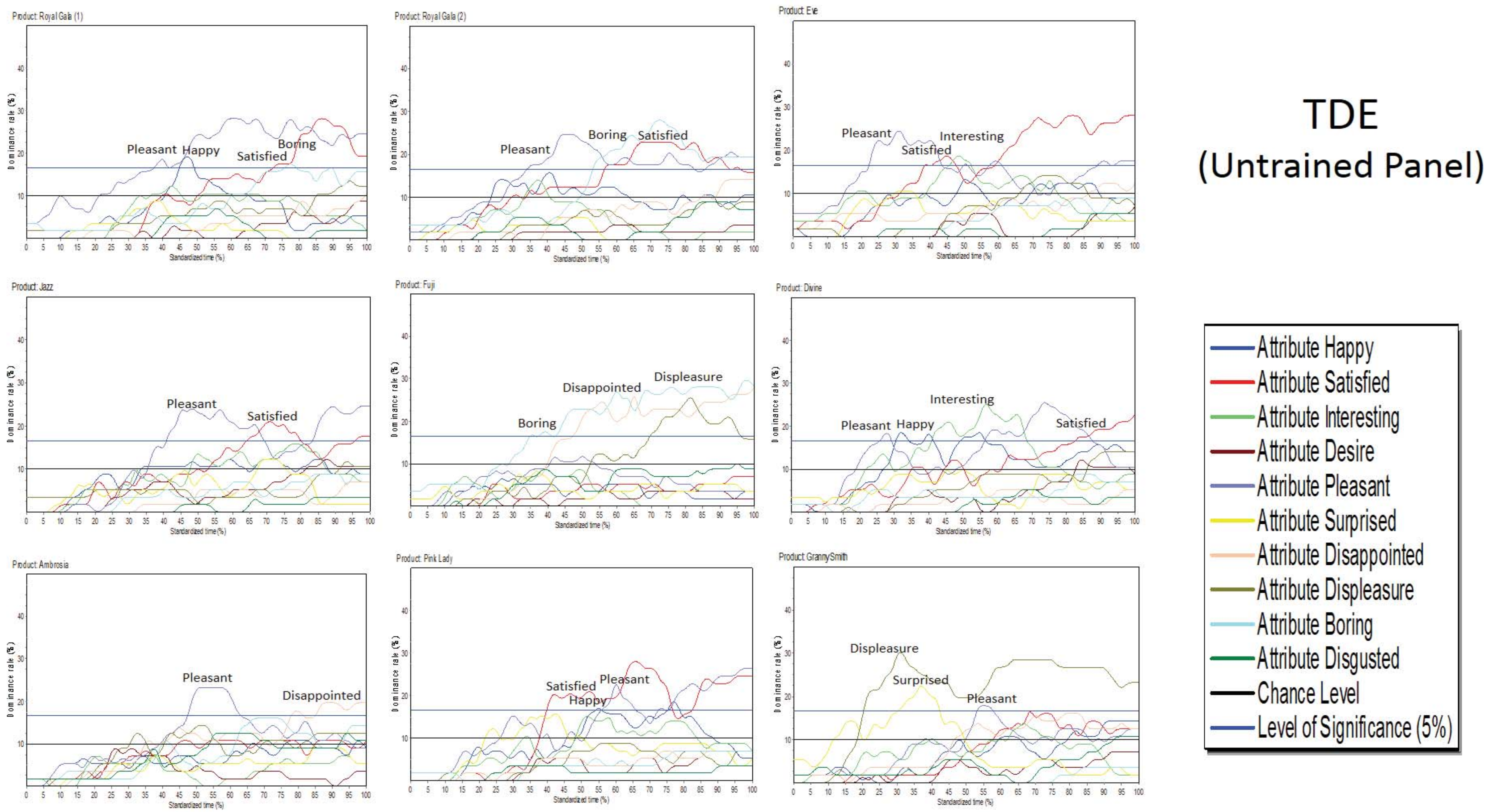


Figure 11: Temporal dominance of emotion (TDE) curves showing the dominance rate of each attribute for Untrained Panel where most apples had initial positive emotions.

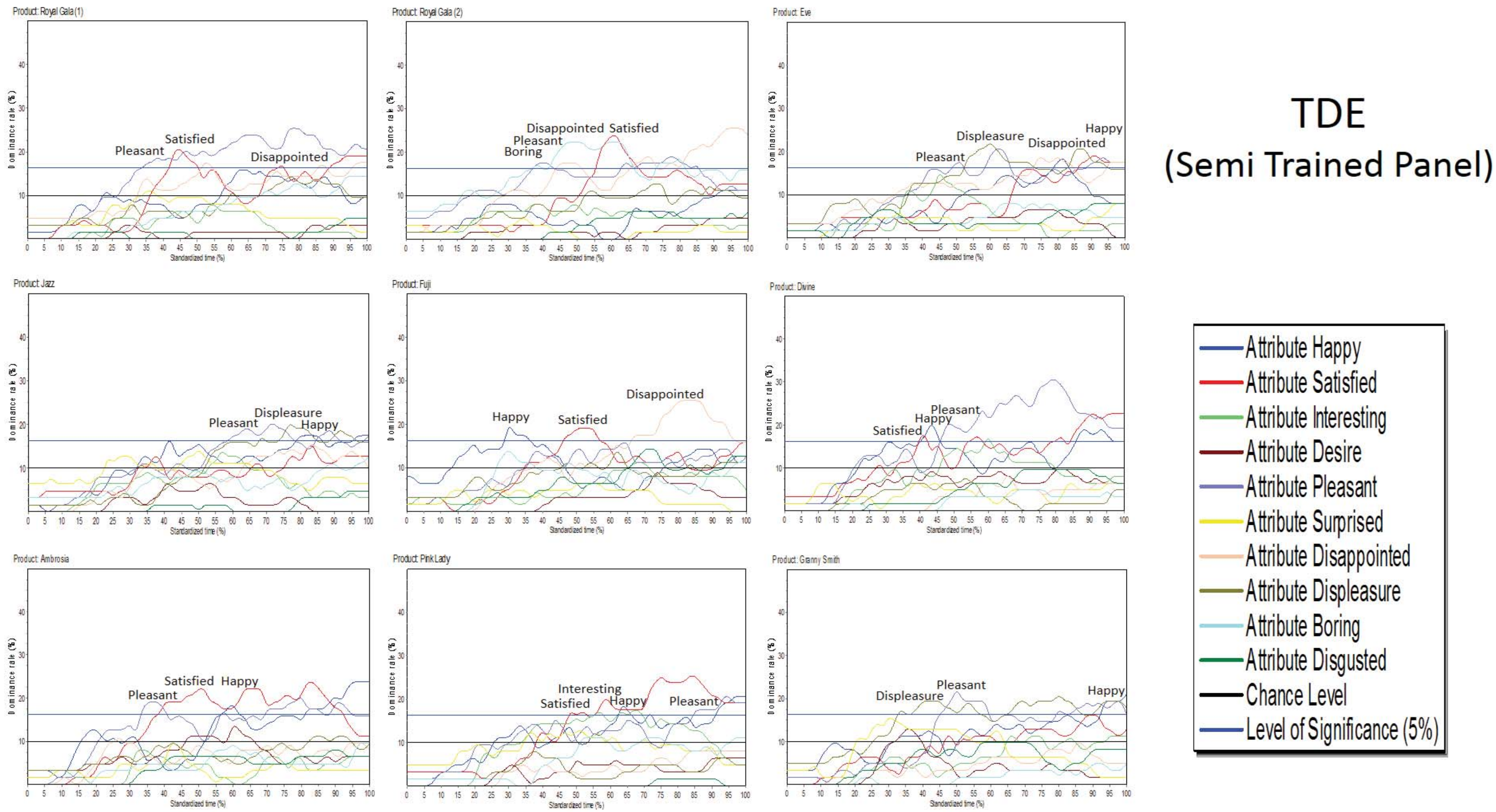


Figure 12: Temporal dominance of emotion (TDE) curves showing the dominance rate of each attribute for Semi Trained Panel where most apples had initial positive emotions.

liked apples among the 9 apples as they had high *liking* curves and a low *dislike* curves which were below the level of significance. Semi Trained Panel on the other hand (Figure 14) had either *neutral* or *dislike* curve intercepting the *like* curve after 50% standardised time with mainly *grainy*, *fibrous* and *sour* dominant in the *dislike* curves. Only Divine and Pink Lady had *liking* curve dominating the entire standardised duration with non-significant *dislike* curve observed. The attributes *disliked* in the other apples were not observed in the *dislike* curves or in the *like* and *neutral* curves of Divine and Pink Lady in high frequency. Those attributes were thus associated to *dislike.*

Table 10: Mean hedonic scores[1] (scores ± S.D.) of apples (n=9) evaluated between panels.

Apple	Semi Trained	Untrained	P-value[2]
Royal Gala (1)	3.92 ± 0.2^{Babcd}	4.46 ± 0.2^{Aab}	0.037
Royal Gala (2)	4.41 ± 0.2^{a}	4.25 ± 0.2^{bc}	N.S.
Eve	4.38 ± 0.2^{ab}	3.89 ± 0.2^{c}	N.S.
Jazz	4.24 ± 0.2^{abcd}	3.83 ± 0.2^{c}	N.S.
Fuji	3.79 ± 0.2^{Acd}	3.05 ± 0.1^{Bd}	0.005
Divine	4.29 ± 0.2^{Babc}	4.81 ± 0.2^{Aa}	0.033
Ambrosia	3.76 ± 0.2^{d}	4.03 ± 0.2^{bc}	N.S.
Pink Lady	4.29 ± 0.2^{abc}	4.51 ± 0.2^{ab}	N.S.
Granny Smith	3.89 ± 0.2^{bcd}	3.76 ± 0.2^{c}	N.S.
P-value[3]	0.048	<0.001	

[1]Hedonic scores from 1 to 7 where 1 being "dislike extremely" and 7 being "like extremely"
[2] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[3] N.S. represents a P-value that was not significant among apples within the panel.
$^{A-B}$ Upper case with different letters indicate means different between panels as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)
$^{a-d}$ Lower case with different letters indicate means different within panel as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)

Apart from the TDL curves, hedonic scores were also collected after each evaluation seen in Table 10. Frequency liking counts from the dominant attributes selected were also tabulated (Table 11). The mean hedonic scores from the Semi Trained Panel (P=0.048) were around 3 to 4, between the *dislike slightly* to *neither like nor dislike* range. Frequency liking counts showed that the Semi Trained Panel *disliked* (P<0.01) Royal Gala (2) (085) the least and Granny Smith (646) the most. This was in line with the mean hedonic score where Royal Gala (2) had the highest *liking* score.

The mean hedonic scores (Table 10) of all apples from the Untrained Panel were quite narrow, falling in the *slightly disliked* range to the *neither like nor dislike* range (P<0.001). For frequency liking counts (Table 11), Royal Gala (2) (85) had the lowest count in the *dislike* option while Granny Smith (646) had the highest. Divine had the lowest *neutral* counts (248) while Jazz had the highest *neutral* counts (709). Pink Lady

(935) was the apple with the highest *liking* counts and Ambrosia (346) had the least *liking* counts (P<0.01).

Between panels, similar hedonic scores were observed for all apples with the exception for Royal Gala (1), Divine and Fuji. Liking counts as shown in Table 11 were significantly different within panel for all apples and for most apples between panels.

A better discrimination was observed in the frequency liking counts than hedonic scores due to the higher significant rate in the former. Generally, the Untrained Panel had higher *like* counts, possibly related to the sensational attributes selected as lesser attributes which elicited disliking like *fibrous*, *sour* and *grainy* were observed.

4.1.4 Conclusion

An hour of training gathered numerous benefits as the Semi Trained Panel had a higher dominance rate, a faster first dominant attribute selected, a decrease repetition of attributes along the curves and a lower variation in the dominant attributes chosen for both TDS and TDE. Additionally, complex textural attributes were chosen more frequently by the Semi Trained Panel, displayed the usefulness of training in benchmarking the attributes. The inclusion of TDL complimented the TDS data allowing liking to the dominant sensational attributes to be easily rated. However, frequency liking counts did not relate fully to the static hedonic scores where frequency liking counts were more discriminative.

In the next section on ethnicity, only the Semi Trained Panel's data will be examined as the reduction in variance related to the selection of attributes (through attribute training) will help identify differences in the TDS, TDE and TDL curves related solely to ethnic groupings (if present).

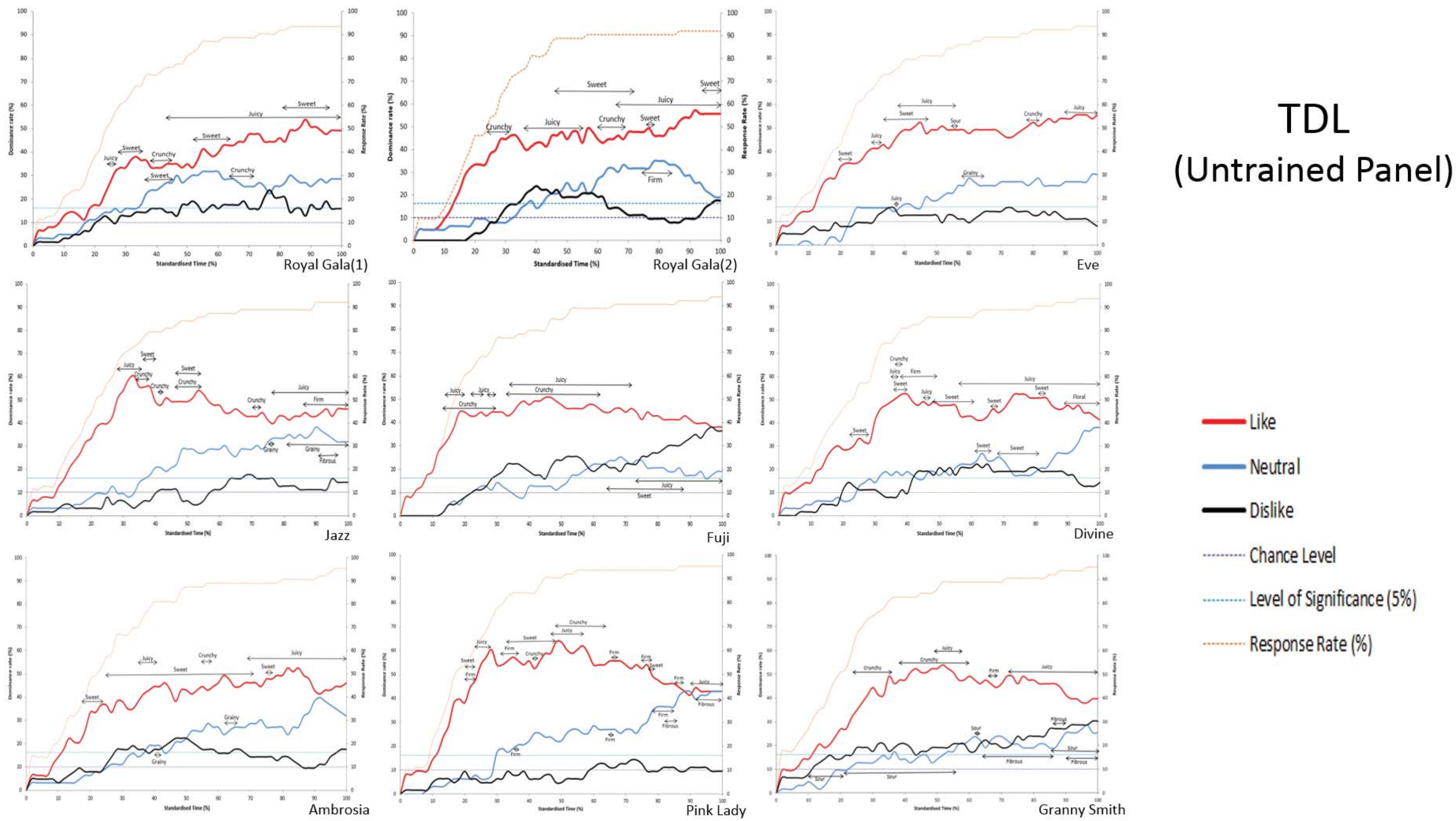


Figure 13: Temporal dominance of liking (TDL) curves showing the dominance rate of each attribute for Untrained Panel where high dominance *liking* rate was observed throughout.

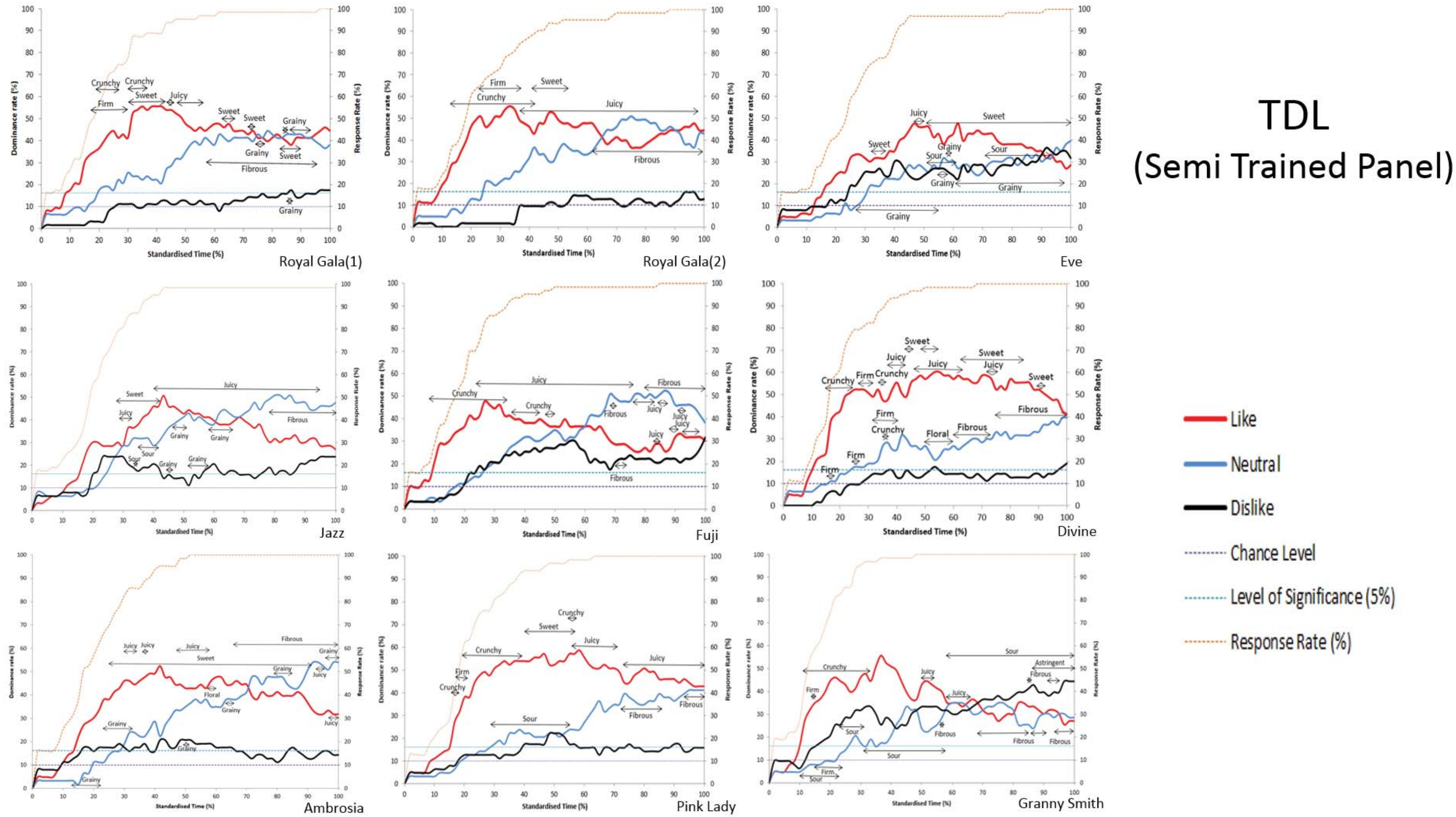


Figure 14: Temporal dominance of liking (TDL) curves showing the dominance rate of each attribute for Semi Trained Panel. *Neutral* or *dislike* overrides the liking curves after 50% standardised time.

Table 11: Frequency of *dislike*, *neutral* and *like* counts (n=9) of apples evaluated between panels.

Apple	**Dislike**			**Neutral**			**Like**		
	Semi Trained	**Untrained**	**P-value**[1]	**Semi Trained**	**Untrained**	**P-value**[1]	**Semi Trained**	**Untrained**	**P-value**[1]
Royal Gala (1)	229	295	<0.01	641	463	<0.01	882	753	<0.01
Royal Gala (2)	85	128	<0.01	383	283	<0.01	453	488	N.S.
Eve	237	154	<0.01	256	259	N.S.	348	469	<0.01
Jazz	358	196	<0.01	709	461	<0.01	688	885	<0.01
Fuji	428	422	N.S.	669	305	<0.01	699	875	<0.01
Divine	147	178	N.S.	248	249	N.S.	594	522	<0.05
Ambrosia	151	188	<0.05	343	227	<0.01	346	380	N.S.
Pink Lady	304	177	<0.01	519	487	N.S.	935	999	N.S.
Granny Smith	646	421	<0.01	489	345	<0.01	747	855	<0.01
P-value[2]	<0.01	<0.01		<0.01	<0.01		<0.01	<0.01	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.

4.2 Ethnicity Effect

4.2.1 Effect of Ethnicities on Sensations

TDS curves from different ethnic groupings for all apple varieties are shown from Figures 17 to 19. The dominant attributes chosen by the Chinese (Figure 1) lasted over longer standardised time. The textural attribute, *crunchy* was seen at the start of the TDS curves except for *grainy* in Ambrosia while *firm* in Pink Lady and Granny Smith. The last dominant attributes for Chinese on the TDS curves were textural terms like *fibrous* and *astringent* for most apples except for Royal Gala (1) which ended with *floral* and Fuji with *sweet*.

Indian (Figure 16) on the other hand had more flavour attributes such as *sweet* and *sour* at the start of the TDS curves excluding Royal Gala (1), Royal Gala (2) and Fuji with *crunchy* and Ambrosia with *grainy*. The TDS curves ended with mainly textural attributes like *grainy* and *fibrous* except for Eve which finished with *sweet* and Ambrosia together with Pink Lady ended the curves with both *juicy* and *fibrous*.

Lastly, Malay (Figure 17) had mainly flavour attributes like *juicy*, *sour* and *sweet* as the initial dominant attributes except for Royal Gala (1) (*firm*) and Divine (*crunchy*). An equal distribution between textural and flavour attributes were observed at the end of curves.

Comparing between the three ethnicities, Malay and Indian had flavour attributes as the first dominant attributes detected which might be influence from their dietary preferences. *Juicy* and *crunchy* were attributes picked up by all ethnicities at some point along the TDS curves for all apples. *Fibrous* was dominantly detected in Chinese and Indian panellists more often while *floral* was detected in more than half of the sampled apples in Chinese.

The number of dominant attributes used, time to first and last dominant attributes were collected in Table 12 to 14. Chinese had the highest number of dominant attributes ranging between 4 to 6 throughout the mastication cycle (Table 12), with significance detected in Royal Gala (1) (P=0.031), Royal Gala (2) (P=0.042), Eve (P=0.002), Divine (P=0.026), Pink Lady (P=0.009) and Granny Smith (P=0.001). Malay and Indian had identical average number of dominant attributes chosen of between 3 to 4. The first dominant attribute recorded (Table 13) was between 4.00 to 7.00s for Chinese and Malay. Indian were slightly earlier with average ranged between 3.00 to 5.00s which Eve (P=0.034) stood out with a record time of 4.00s compared to 7.00s in Chinese and

Malay. Chinese had slightly earlier dominant attribute end time (Table 14) of between 23.00 to 31.00s while Malay was between 25.00 to 32.00s.

Dominant attribute end time (P=0.013) for Indian was slightly later which ranged between 26.00 to 34.00s with the fastest being Pink Lady (26.05s) and the slowest being Royal Gala (1) (34.86s).

Table 12: Mean number of dominant attributes (number of attributes ± S.D.) used in the entire TDS period between ethnicities.

Type of Apple	Chinese	Indian	Malay	P-value[1]
Royal Gala (1)	5.50 ± 0.5[A]	3.76 ± 0.3[B]	4.22 ± 0.7[AB]	0.031
Royal Gala (2)	5.13 ± 0.5[A]	3.76 ± 0.2[B]	3.72 ± 0.6[B]	0.042
Eve	5.38 ± 0.5[A]	3.38 ± 0.2[B]	3.39 ± 0.5[B]	0.002
Jazz	5.04 ± 0.5	4.14 ± 0.3	4.28 ± 0.6	N.S.
Fuji	5.04 ± 0.5	4.29 ± 0.2	4.22 ± 0.7	N.S.
Divine	5.96 ± 0.4[A]	4.29 ± 0.2[B]	4.61 ± 0.7[B]	0.026
Ambrosia	4.88 ± 0.5	3.71 ± 0.3	3.89 ± 0.7	N.S.
Pink Lady	5.54 ± 0.4[A]	4.10 ± 0.2[B]	3.72 ± 0.6[B]	0.009
Granny Smith	6.13 ± 0.4[A]	4.05 ± 0.2[B]	4.28 ± 0.6[B]	0.001
P-value[2]	N.S.	N.S.	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[A-B] Upper case with different letters indicates means different between panels as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)

Table 13: Mean time (s ± S.D.) for first dominant attribute recorded for TDS between ethnicities.

Type of Apple	Chinese	Indian	Malay	P-value[1]
Royal Gala (1)	7.25 ± 1.5	5.91 ± 1.0	4.94 ± 1.0	N.S.
Royal Gala (2)	6.58 ± 0.9	5.10 ± 1.0	6.22 ± 1.7	N.S.
Eve	7.71 ± 1.0[A]	4.24 ± 0.8[B]	7.67 ± 1.3[A]	0.034
Jazz	6.71 ± 0.9	4.76 ± 0.8	4.89 ± 0.9	N.S.
Fuji	5.88 ± 1.1	5.19 ±1.0	5.94 ± 1.1	N.S.
Divine	6.58 ± 1.3	5.05 ± 0.8	4.72 ± 0.8	N.S.
Ambrosia	4.92 ± 0.5	4.52 ± 0.7	5.33 ± 1.3	N.S.
Pink Lady	4.33 ± 0.5	5.29 ± 1.0	5.39 ± 1.1	N.S.
Granny Smith	4.42 ± 0.3	3.38 ± 0.6	4.00 ± 0.8	N.S.
P-value[2]	N.S.	N.S.	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[A-B] Upper case with different letters indicates means different between panels as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)

Table 14: Mean time (s ± S.D.) for end of dominant attribute recorded for TDS between ethnicities.

Type of Apple	Chinese	Indian	Malay	P-value[1]
Royal Gala (1)	29.29 ± 2.2	34.86 ± 2.7[a]	28.67 ± 3.3	N.S.
Royal Gala (2)	29.54 ± 2.0	31.48 ± 2.4[ab]	27.78 ± 3.0	N.S.
Eve	29.63 ± 2.3	26.62 ± 2.4[b]	27.17 ± 3.2	N.S.
Jazz	26.46 ± 1.8	29.19 ± 2.2[ab]	27.72 ± 3.2	N.S.
Fuji	27.92 ± 2.4	34.67 ± 2.4[a]	32.94 ± 4.0	N.S.
Divine	31.50 ± 2.4	31.43 ± 2.5[ab]	28.89 ± 3.7	N.S.
Ambrosia	26.58 ± 2.2	26.33 ± 2.1[b]	25.61 ± 3.5	N.S.
Pink Lady	23.29 ± 1.4	26.05 ± 1.6[b]	25.17 ± 3.3	N.S.
Granny Smith	29.42 ± 2.0	26.43 ± 1.8[b]	32.33 ± 3.2	N.S.
P-value[2]	N.S.	0.013	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[a-d] Lower case with different letters indicates means different within panel as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)

4.2.2 Effect of Ethnicities on Emotions

TDE curves are shown from Figure 18 to 20 for all apples from all ethnicities. Initial positive emotions (*pleasant*, *interesting* and *happy*) were seen in all apples among the Chinese panellists (Figure 18). However, the dominant positive emotions (Figure 18) changed to *disappointed* for Royal Gala (2), Eve, Jazz and Fuji at around 60% standardised time. The last dominant attributes observed on the TDE curves for all apples were positive emotions (*pleasant*, *satisfied* and *happy*) except for Royal Gala (2) which *disappointed* was noted.

Indian panellists (Figure 19) exhibited more initial negative emotions such as *disappointed*, *pleasant* and *displeasure* compared to the other two ethnicities. However, for Eve (*pleasant*), Divine (*Interesting*), Ambrosia (*satisfied*) and Pink Lady (*satisfied*), positive initial emotions were observed. Jazz, Fuji and Granny Smith were deemed to be more negative, based on all the emotions obtained throughout the evaluation.

Malay (Figure 20) had mixed emotions consisting positive (Royal Gala (1), Jazz, Divine and Ambrosia), neutral (Pink Lady and Granny Smith) and negative (Royal Gala (2), Eve and Fuji) for different apples. There were however more negative emotions (*disappointed* and *displeasure*) observed in all apples at the end of the TDE curves.

Differences were seen between Chinese and Indian panellists. Chinese panellists had higher number of positive emotions while Indian had a higher number of negative

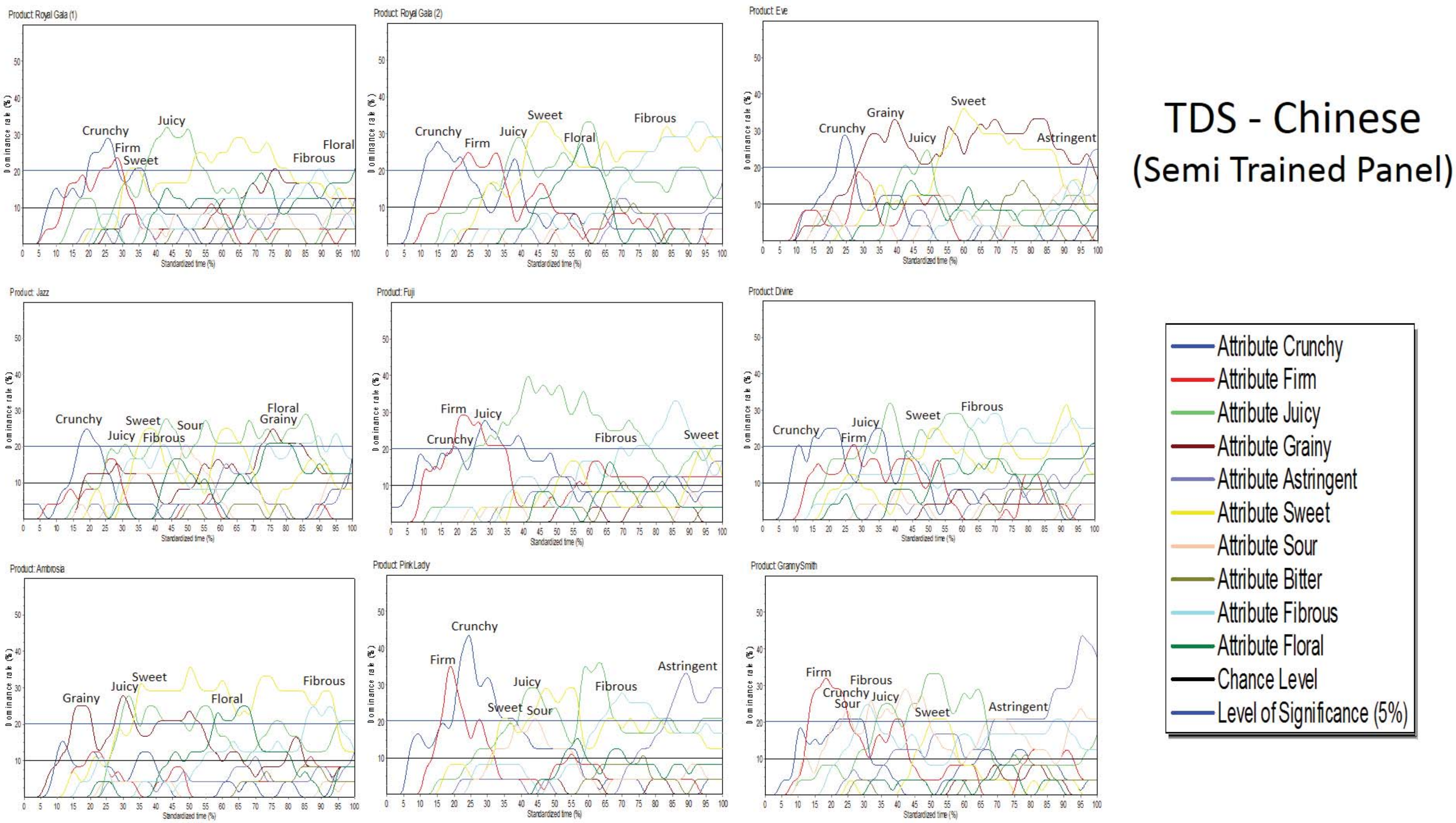


Figure 15: Temporal dominance of sensation (TDS) curves showing the dominance rate of each attribute for Chinese which crunchy was seen at the start.

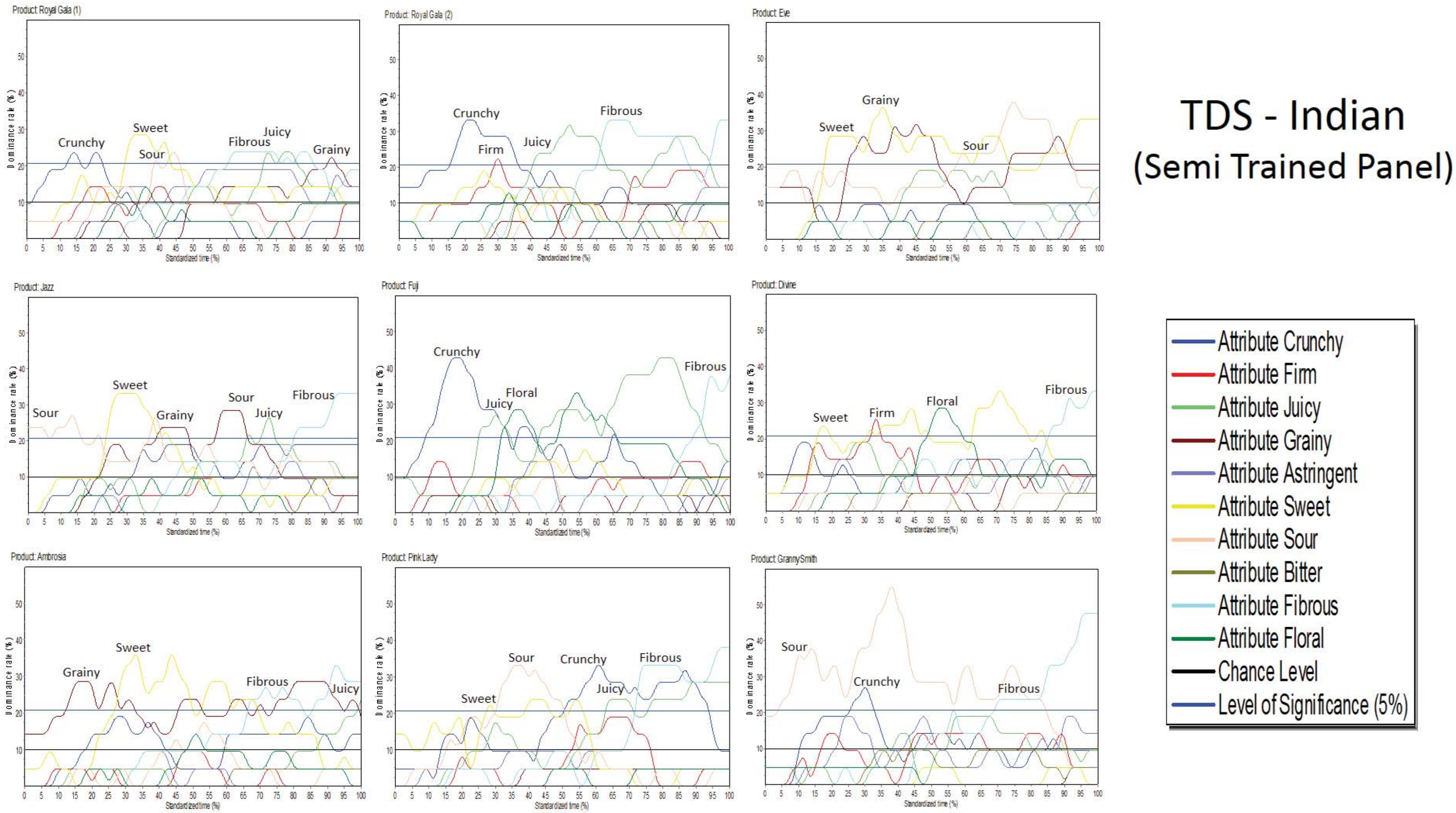


Figure 16: Temporal dominance of sensation (TDS) curves showing the dominance rate of each attribute for Indian where flavour attributes were dominant at the start of curves.

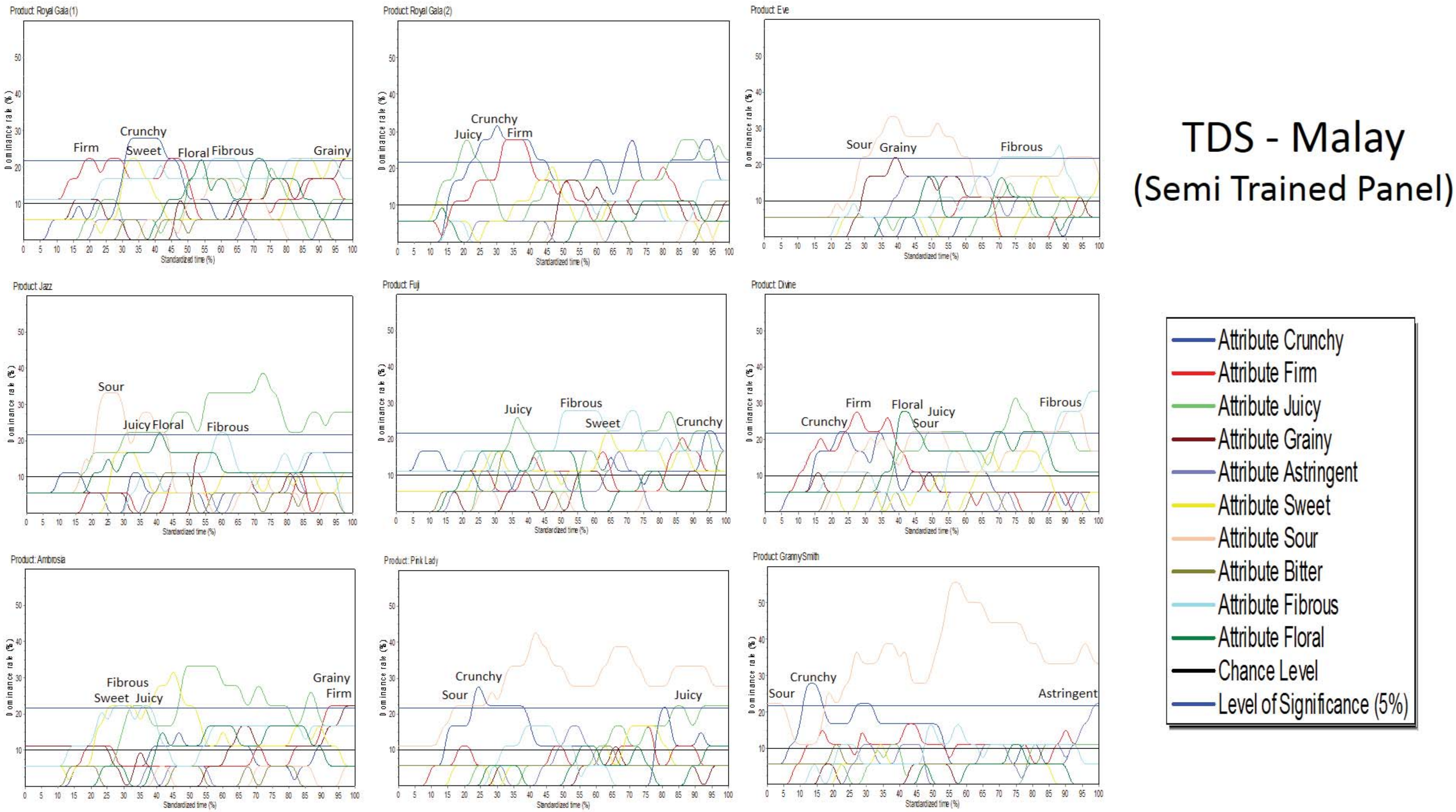


Figure 17: Temporal dominance of sensation (TDS) curves showing the dominance rate of each attribute for Malay where flavour attributes were dominant at the start of curves.

emotions. Common negative emotions observed between ethnicities were *displeasure* and *disappointed*.

Table 15: Mean number of dominant emotions (number of attributes ± S.D.) used in the entire TDE period between ethnicities.

Type of Apple	Chinese	Indian	Malay	P-value[1]
Royal Gala (1)	2.83 ± 0.2	3.05 ± 0.3	2.56 ± 0.3	N.S.
Royal Gala (2)	2.79 ± 0.2	2.48 ± 0.2	2.33 ± 0.2	N.S.
Eve	2.92 ± 0.2	3.10 ± 0.3	2.78 ± 0.3	N.S.
Jazz	3.38 ± 0.2	2.86 ± 0.3	2.67 ± 0.3	N.S.
Fuji	3.21 ± 0.2	2.86 ± 0.2	2.94 ± 0.3	N.S.
Divine	3.33 ± 0.3	3.62 ± 0.3	2.72 ± 0.3	N.S.
Ambrosia	3.67 ± 0.3	3.19 ± 0.3	2.89 ± 0.3	N.S.
Pink Lady	3.50 ± 0.2	3.24 ± 0.3	2.67 ± 0.3	N.S.
Granny Smith	3.46 ± 0.3	2.76 ± 0.3	2.67 ± 0.3	N.S.
P-value[2]	N.S.	N.S.	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.

Table 16: Mean time (s ± S.D.) for first dominant emotion recorded for TDE between ethnicities.

Type of Apple	Chinese	Indian	Malay	P-value[1]
Royal Gala (1)	7.50 ± 0.7[A]	4.19 ± 0.9[B]	6.61 ± 1.0[AB]	0.016
Royal Gala (2)	6.50 ± 0.6	4.29 ± 1.1	5.72 ± 1.3	N.S.
Eve	7.00 ± 0.7[A]	3.91 ± 0.8[B]	6.83 ± 1.3[A]	0.033
Jazz	6.54 ± 0.6	4.76 ± 1.0	6.06 ± 1.1	N.S.
Fuji	6.92 ± 1.1	4.81 ± 0.7	5.33 ± 0.9	N.S.
Divine	6.67 ± 0.7	4.86 ± 0.8	7.67 ± 1.1	N.S.
Ambrosia	6.38 ± 0.7	5.33 ± 1.2	6.00 ± 1.1	N.S.
Pink Lady	5.88 ± 0.5	5.00 ± 0.9	6.83 ± 1.1	N.S.
Granny Smith	7.17 ± 0.9	4.48 ± 0.9	8.06 ± 1.4	N.S.
P-value[2]	N.S.	N.S.	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[A-B] Upper case with different letters indicate means different between panels as determined by Fisher's least significant different test (LSD) at 95% confident interval (p<0.05)

Chinese and Indian had between 2 to 3 dominant emotions selected (Table 15), while Malay had the least of about 2. Chinese and Malay had similar first attribute selection time of between 5.00 to 7.00s and 5.00 to 8.00s respectively. Indian were fastest in the first dominant emotion selection ranging between 3.00 to 5.00s with significant differences (Table 16) observed in Royal Gala (1) (P=0.016) and Eve (P=0.033). Similarities were observed in the dominant emotion end time for the 3 ethnicities to be

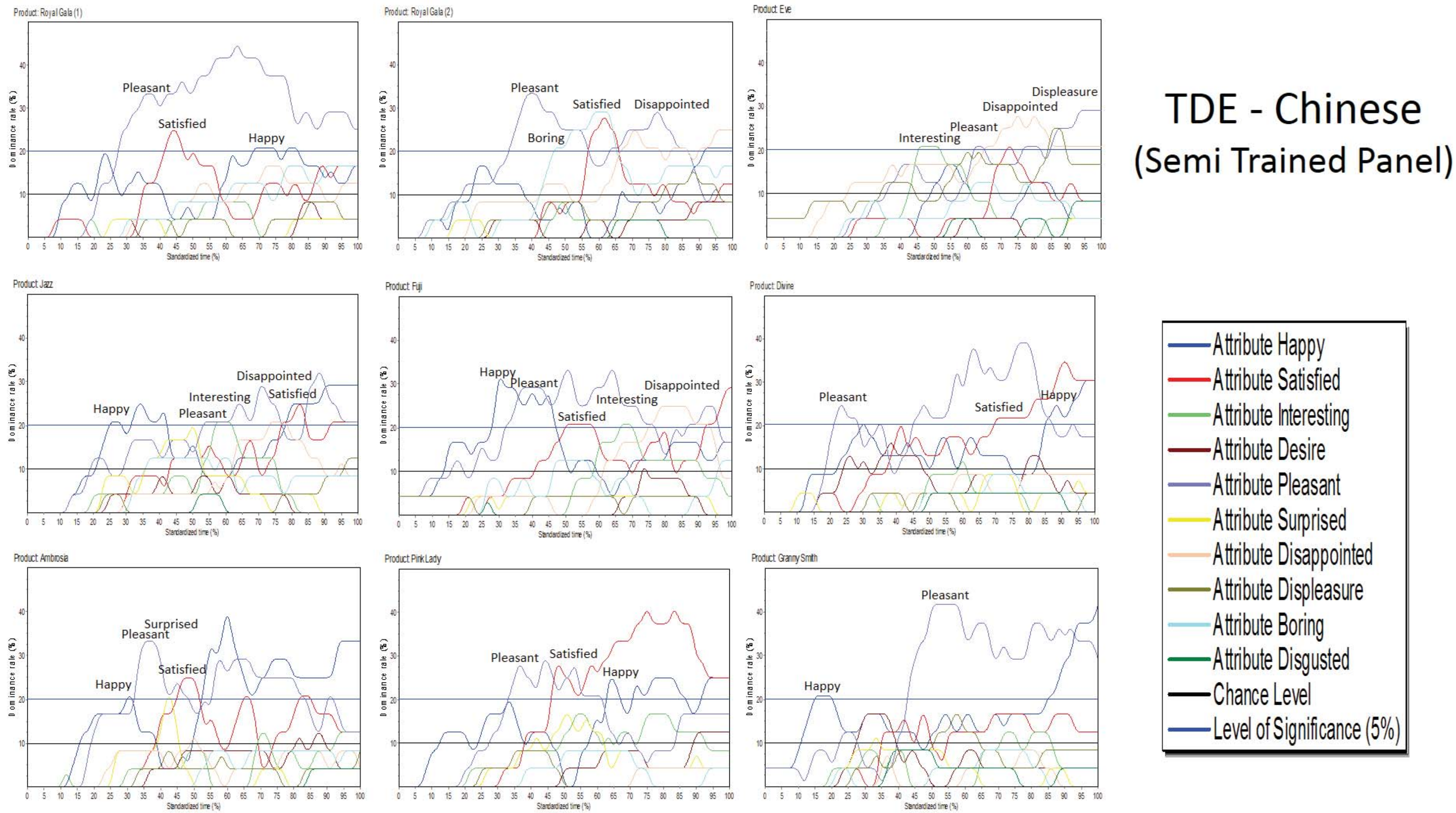


Figure 18: Temporal dominance of emotion (TDE) curves showing the dominance rate of each attribute for Chinese. Initial positive emotions and end negative emotions were observed.

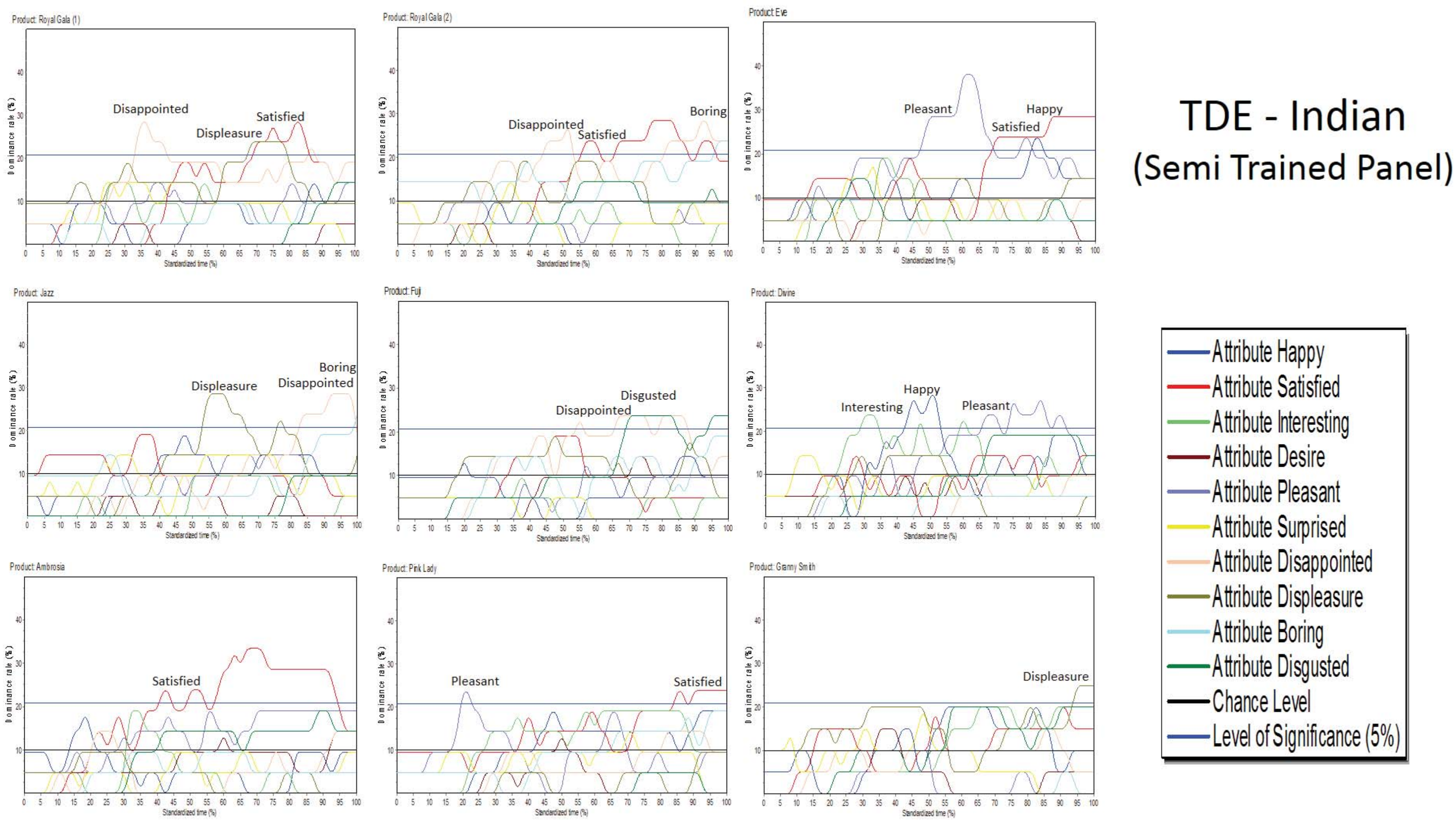


Figure 19: Temporal dominance of emotion (TDE) curves showing the dominance rate of each attribute for Indian. Mostly initial negative emotions were observed.

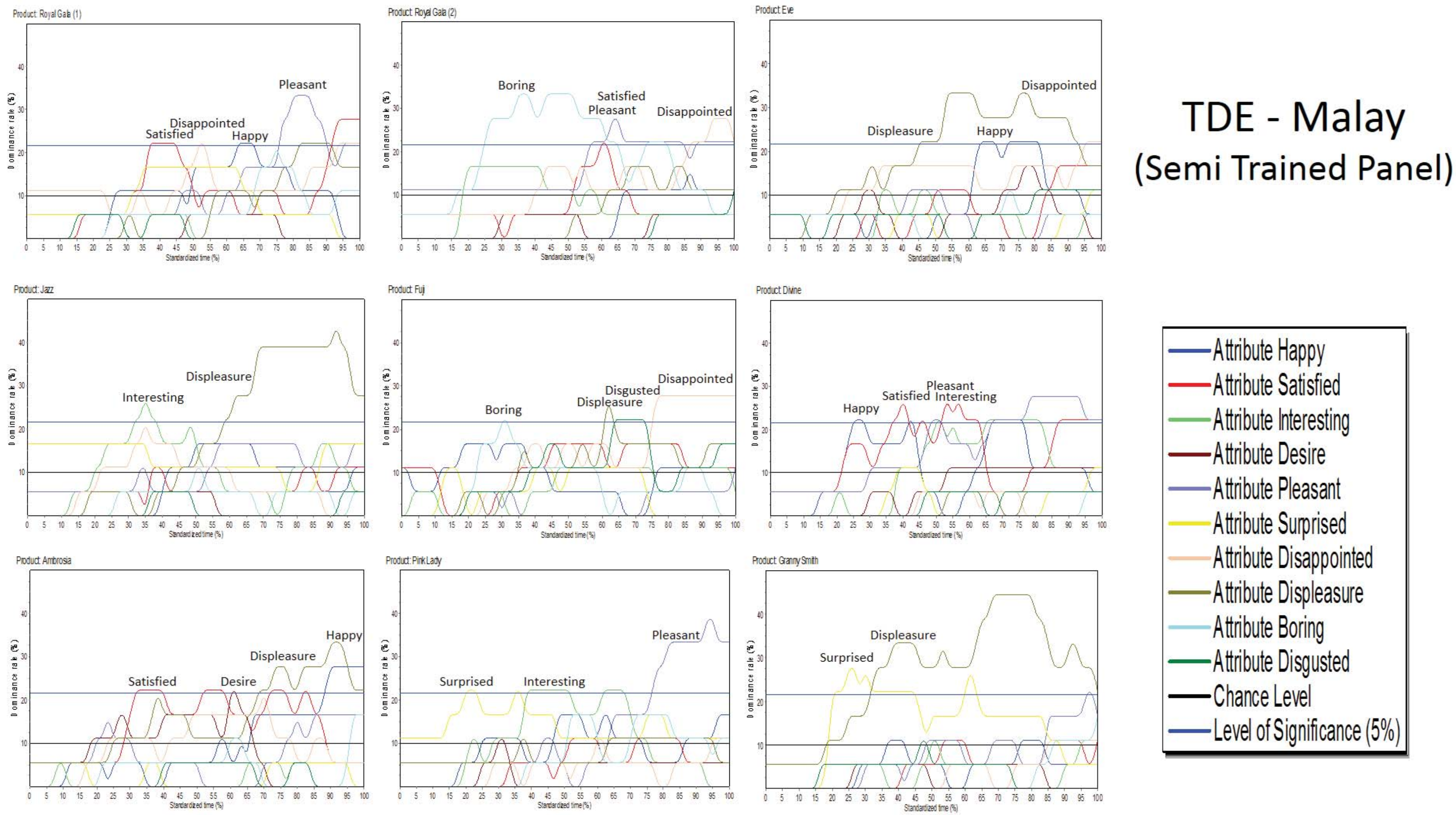


Figure 20: Temporal dominance of emotion (TDE) curves showing the dominance rate of each attribute for Malay. Both positive and negative initial emotions were observed with negative last dominant emotions.

between 18.00 to 24.00s with significance observed in Chinese (P=0.041) with the slowest for Fuji (24.13s) and fastest for Pink Lady (18.17s).

Table 17: Mean time (s ± S.D.) for end of dominant emotion recorded for TDE between ethnicities.

Type of Apple	Chinese	Indian	Malay	P-value[1]
Royal Gala (1)	23.67 ± 1.6[ab]	21.57 ± 2.4	20.50 ± 1.9	N.S.
Royal Gala (2)	19.92 ± 1.5[bc]	18.95 ± 1.5	19.28 ± 2.2	N.S.
Eve	19.04 ± 1.6[c]	21.10 ± 1.6	18.50 ± 1.8	N.S.
Jazz	20.04 ± 0.8[abc]	18.33 ± 1.9	21.78 ± 2.3	N.S.
Fuji	24.13 ± 1.9[a]	20.95 ± 2.1	19.00 ± 2.1	N.S.
Divine	19.75 ± 1.6[bc]	22.33 ± 1.6	21.17 ± 2.3	N.S.
Ambrosia	20.25 ± 1.4[abc]	21.52 ± 1.9	20.06 ± 2.0	N.S.
Pink Lady	18.71 ± 1.1[c]	18.95 ± 1.6	21.11 ± 1.8	N.S.
Granny Smith	23.63 ± 1.8[ab]	20.71 ± 2.1	24.83 ± 2.1	N.S.
P-value[2]	0.041	N.S.	N.S.	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.
[a-d] Lower case with different letters indicate means different within panel as determined by Fisher's least significant different test (LSD) at 95% confident interval ($p<0.05$)

4.2.3 Effect of Ethnicities on Likings

TDL curves for the three ethnicities are reflected from Figure 21 to 23. In Figure 21, the highest percentage of dominance rate in liking was observed in Chinese throughout the TDL curves for most apples except for Fuji, Eve and Granny Smith which had *neutral* or/and *dislike* curve overriding the *like* curve after 70% standardised time. Divine seemed to be the most well liked apple since it had the highest dominance liking which was consistent throughout the sensory duration with *dislike* curve below the level of significance.

In contrast, *neutral* or *dislike* were more dominating after 30% standardised time for Indian (Figure 22). Eve could be seen as the most well liked apple for Indian as the *liking* curve was the highest in terms of percentage, dominating throughout the entire standardised duration. Granny Smith was the least liked as the *dislike* curve overrides the *liking* curve at high dominance rates.

Malay (Figure 23) had the lowest liking dominance rate percentage among the 3 ethnicities. Royal Gala (1), Royal Gala (2) and Divine were the best liked apple as they had the highest *liking* curves observed. Eve and Granny Smith were deemed as the least liked apple with highest *dislike* curves. Granny Smith was *disliked* by the Malay till *dislike* curve dominated from the start. Comparing between the ethnicities, Chinese had the highest liking dominance rate while Malay had the lowest. *Grainy*, *fibrous* and *sour* were attributes disliked by all ethnicities.

Table 18: Mean hedonic scores[1] (scores ± S.D.) (n=9) of apples evaluated between different ethnicities for Semi Trained Panel.

Apple	Chinese	Indian	Malay	P-value[2]
Royal Gala (1)	3.83 ± 0.3^{b}	4.17 ± 0.3^{ab}	3.81 ± 0.4^{ab}	N.S.
Royal Gala (2)	4.17 ± 0.3^{ab}	4.39 ± 0.2^{ab}	4.71 ± 0.3^{a}	N.S.
Eve	4.42 ± 0.3^{ab}	4.28 ± 0.4^{ab}	4.43 ± 0.3^{a}	N.S.
Jazz	4.08 ± 0.4^{ab}	3.94 ± 0.3^{Aab}	4.67 ± 0.3^{Aa}	N.S.
Fuji	2.96 ± 0.3^{Bc}	4.06 ± 0.3^{Aab}	4.52 ± 0.4^{Aa}	0.006
Divine	4.17 ± 0.3^{ab}	4.61 ± 0.3^{a}	4.14 ± 0.3^{ab}	N.S.
Ambrosia	4.13 ± 0.3^{ab}	3.89 ± 0.3^{ab}	3.24 ± 0.3^{b}	N.S.
Pink Lady	4.83 ± 0.3^{Aa}	3.67 ± 0.3^{Bbc}	4.19 ± 0.3^{ABa}	0.021
Granny Smith	4.33 ± 0.2^{Aab}	3.00 ± 0.3^{Bc}	4.14 ± 0.4^{Aab}	0.008
P-value[2]	0.009	0.016	0.047	

[1]Hedonic scores from 1 to 7 where 1 being “dislike extremely” and 7 being “like extremely”
[2] N.S. represents a P-value that was not significant
[A-B] Upper case with different letters indicates means different between panels as determined by Fisher’s least significant different test (LSD) at 95% confident interval ($p<0.05$)
[a-c] Lower case with different letters indicates means different within panel as determined by Fisher’s least significant different test (LSD) at 95% confident interval ($p<0.05$)

The mean hedonic scores are tabulated in Table 18 while the frequency liking counts for each apple are collated in Table 19. It showed that Chinese (P=0.009) had the widest hedonic mean range (2.96 to 4.83) with Fuji (2.96) being *dislike moderately* while Pink Lady (4.83) had the highest hedonic score in the *neither like nor dislike* category. Similar range of hedonic scores were also obtained from the Malay and Indian. For Indian (P=0.016), Granny Smith was in the *dislike slightly* category (3.00) while Divine in the *neither like nor dislike* category at 4.61. Malay scored the lowest (P=0.047) for Ambrosia (3.24) and the highest for Royal Gala (2) (4.71) in hedonic score.

Granny Smith had the highest frequency dislike count in all three ethnicities (Table 19). Despite the high frequency in dislike count, Granny Smith in contrast did not have the lowest liking frequency counts. Generally, the apples with higher liking counts were Royal Gala (1) and Pink Lady.

Comparing between the different ethnicities, slight similarities were observed in the results between hedonic scores and frequency liking counts. Even though Granny Smith had the highest *dislike* counts among all ethnicities, only Indian had the lowest hedonic score. Pink Lady was considered the most liked apple in hedonic scores among Chinese which corresponded to the highest frequency liking counts. A higher number of significant differences were observed between ethnicities for frequency liking counts (Table 19) than hedonic scores (Table 18), showing lesser discrimination among ethnicities for hedonic scoring.

4.2.4 Conclusion

Granny Smith was the apple least *liked* by all the ethnicities. Chinese chose the most number of attributes with higher dominance rate for TDS. They exhibited positive liking and emotions. Indian had the fastest first and a later last dominant attribute start and end time for TDS respectively. Malay was the most negative when sensational attributes were rated for liking. Indian had low hedonic score for Granny Smith with high frequency in *dislike* counts showing strong disliking. Hedonic scores were considered to be less discriminative.

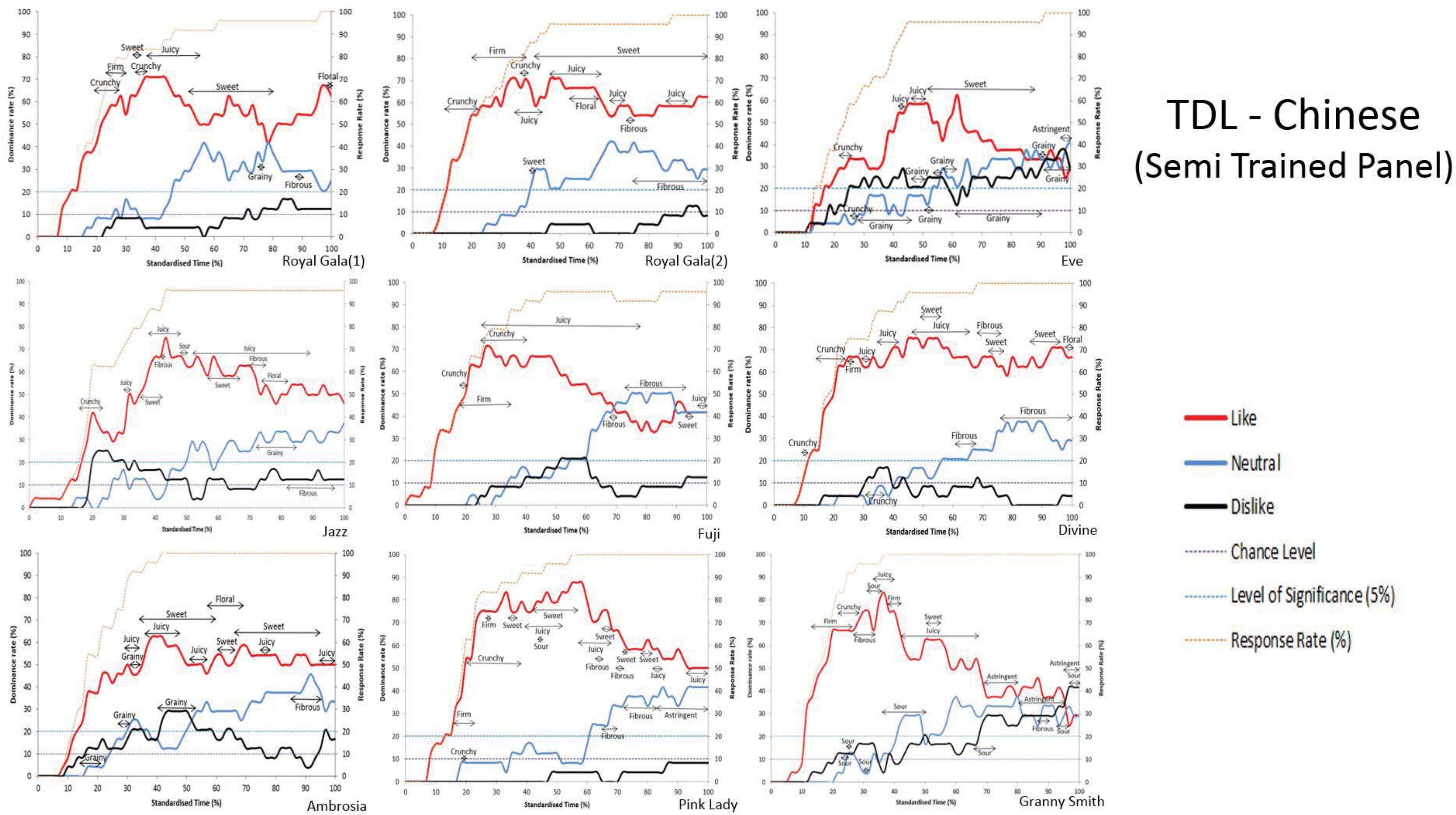


Figure 21: Temporal dominance of liking (TDL) curves showing the dominance rate of each attribute for Chinese, high dominance rate of liking was observed for most apples.

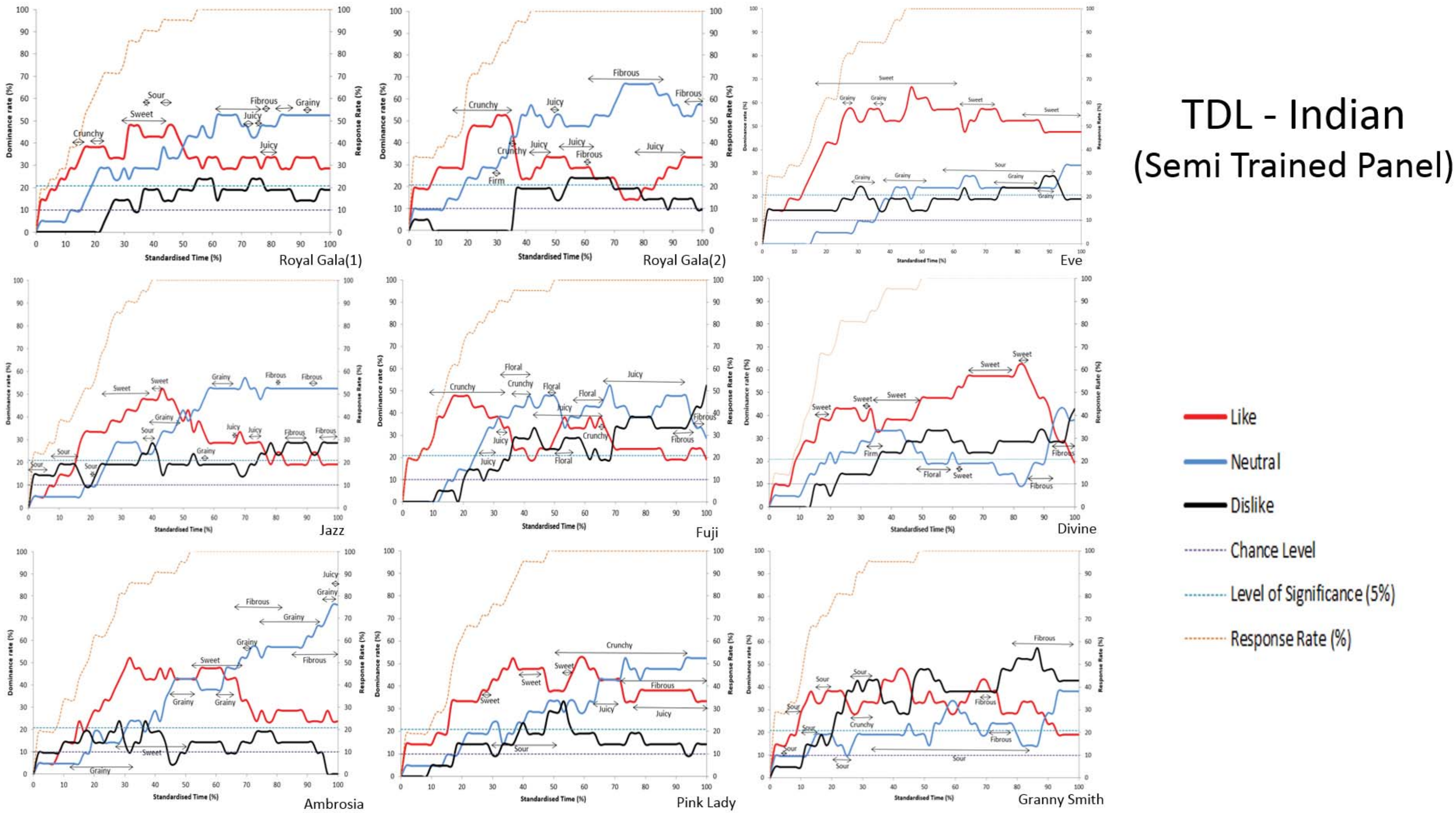


Figure 22: Temporal dominance of liking (TDL) curves showing the dominance rate of each attribute for Indian. Most apples had neutral or dislike after 30% standardised time.

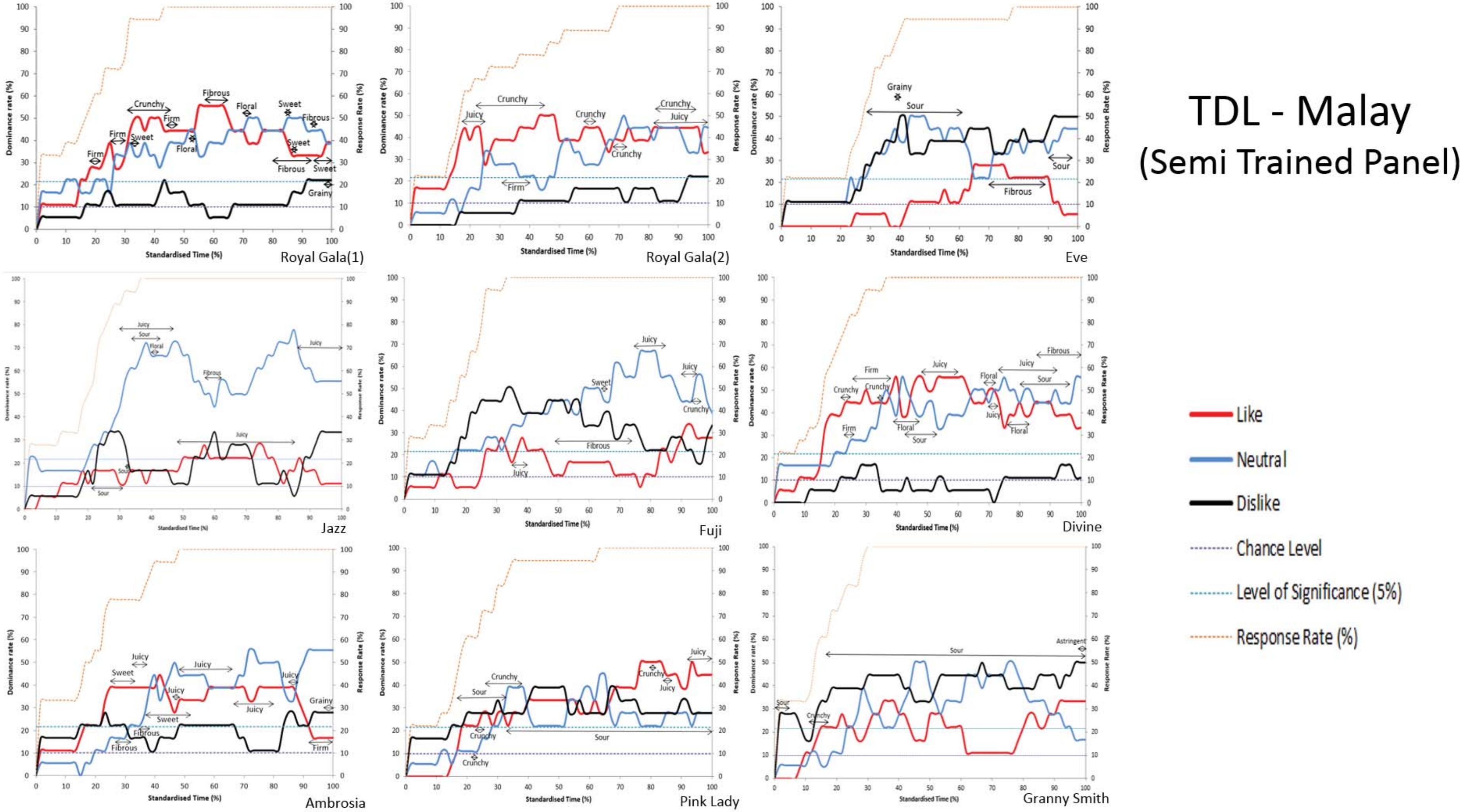


Figure 23: Temporal dominance of liking (TDL) curves showing the dominance rate of each attribute for Malay. Most apples had neutral or dislike after 30% standardised time.

Table 19: Frequency of *dislike*, *neutral* and *like* counts (n=9) of apples evaluated between ethnicities.

Apple	Dislike				Neutral				Like			
	Chinese	Indian	Malay	P-value[1]	Chinese	Indian	Malay	P-value[1]	Chinese	Indian	Malay	P-value[1]
Royal Gala (1)	94	173	130	<0.01	286	444	380	<0.01	716	415	398	<0.01
Royal Gala (2)	19	67	61	<0.01	170	331	162	<0.01	401	196	188	<0.01
Eve	165	117	127	<0.01	157	111	175	<0.01	246	292	65	<0.01
Jazz	164	258	198	<0.01	259	438	532	<0.01	657	361	174	<0.01
Fuji	120	288	333	<0.05	332	412	416	<0.01	678	362	171	<0.01
Divine	52	152	51	<0.01	121	157	151	N.S.	456	312	262	<0.01
Ambrosia	100	93	68	<0.05	183	215	197	N.S.	284	198	118	<0.01
Pink Lady	37	181	308	<0.01	270	378	252	<0.01	843	459	318	<0.01
Granny Smith	250	443	426	<0.01	284	260	304	N.S.	681	394	220	<0.01
P-value[2]	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	

[1] N.S. represents a P-value that was not significant between Semi Trained and Untrained Panel.
[2] N.S. represents a P-value that was not significant among apples within the panel.

5. Discussion

The aim of this study was to investigate the impact of training and ethnicity on the attribute selection using TDS, TDE and TDL techniques.

5.1 Panel Type Effect

The first objective was to look at *attribute selection differences in TDS, TDE and TDL between the Semi Trained and Untrained Panels* with the hypothesis that *similar attributes would be chosen in both panels, with a faster selection time and higher dominance rate for the Semi Trained Panel.*

5.1.1 Effect of Panel Type on Sensations

A better understanding of the various terms was observed in the Semi Trained Panel with faster first dominant attribute selected, higher dominance rate and lower standard deviation which demonstrated the benefits of training. Additionally, a decreased repetition of attributes was also reflected in the TDS curves of the Semi Trained Panel. One possible explanation for all these benefits observed was the increased confidence in the Semi Trained Panel after attributes training with references. The results obtained were broadly consistent with the major trends reported by Cheong et al. (2014) and Pineau et al. (2012) where a higher dominance rate and faster attribute selection time were observed when training was given before the actual evaluation. The faster reaction time in Semi Trained Panel for the first dominant attribute indicated the panel's stronger association to the chosen attributes (Koh et al., 2014). Reference food helped in standardisation of the textural and flavour attributes across the panellists in the Semi Trained Panel (Pineau et al., 2012).

Textural attributes were detected at the start of the TDS curves for most apples more frequently by the Semi Trained Panel. These results were relevant as textural attributes for instance *firm* or *crunchy* could be detected during the first bite of the apple. This showed the Semi Trained Panel's ability in obtaining attributes sequence of increased accuracy. Moreover, results suggested the benefit of using food references in allowing better detection of the attributes even with a short training duration. Attributes of higher complexity like *fibrous, astringent* and *floral* were more frequently detected by the Semi Trained Panel (Figure 10) (Daillant-Spinnler *et al.*, 1996) while the Untrained Panel used simpler term like *firm*. This further emphasised assistance of references during training for alignment of the various terms used and also understanding attributes of higher complexity.

Some degree of similarities between the panels could be seen in the number of TDS attributes detected and dominant attribute end time which explained that the use of references will not affect these factors which are never mentioned before in other literatures. These results suggest a limit to the maximum number of attributes a panellist is able to detect (Pineau *et al.*, 2012) and the chewing duration for products in the same category between panellists are similar.

Notably, it was found that the TDS profiles of most apples had *crunchy* as a dominant sensational attribute mainly in the early stage of the mastication cycle whereas *fibrous* became a dominant sensational attribute perceived during the later stage of the mastication cycle. This reveals that *crunchy* is an early chewing sensational attribute in apples while *fibrous* is a chew-down sensational attribute perceived at a later stage of the mastication cycle (Cheong *et al.*, 2014). Reason being, *fibrous* can be perceived only when the fibrous fragments or granules are left in the mouth. Therefore, some chew time is required to break down the apple matrix whereas *crunchy* as define in Table 2 is the sound produced during the first 5 molar chews, thus detection of *crunchy* is in the earlier stage of mastication compared to *fibrous*.

5.1.2 Effect of Panel Type on Emotions

Positive emotions such as *pleasant*, *satisfied* and *happy* were experienced more often than negative emotions such as *displeasure*, *disappointed* and *boring* in both panels. One reason for this observation could be described by Desmet and Schifferstein (2008) and Thomson and Crocker (2013) where healthy individuals consume food which elicit pleasant emotional impact and generally food are associated to positive emotions unless there were previous negative experiences. Therefore, food products driving high negative emotions will loss consumers as repeat purchase will not be committed.

From this study, association of positive sensations like *sweet* and *juicy* to positive emotions like *pleasant*, *satisfied* and *happy*; and negative sensations like *sour, crunchy* and *grainy* to negative emotions like *displeasure* and *boring* were observed. Thomson *et al.* (2010) similarly concluded that in his study, the positive sensations chosen were linked to a certain set of positive emotion profiles in his evaluation on dark chocolates. This sensational to emotional association has been reported to play a part in consumer's future choice behaviour like the decision on repeat purchase (Gutjar *et al.*, 2015, Sosa *et al.*, 2015, Desmet and Schifferstein, 2008, Macht and Dettmer, 2006).

A lower number of dominant attributes were seen in TDE than TDS in both panels. Furthermore, dominant emotion attributes were selected later compared to sensational attributes. This was consistent with the finding from Jager *et al.* (2014) where a slower perception of food related emotions than sensations was reported. The reason for this slower selection has been proposed to be due to the intuitive nature of emotions being harder to describe and less accessible to conscious experience (Jager *et al.*, 2014, Thomson *et al.*, 2010). Also, without references, panellists understanding towards the attribute are not aligned.

Emotion attributes overall were observed to last longer (in standardised time) above significance level than sensational attributes. This observation was especially reflected by the Untrained Panel as the TDE dominance rate for most apples lasted a longer standardised time than the ones generated for TDS (even with a shorter TDE dominant duration denoted by a later dominant attribute start time and an earlier dominant attribute end time). Jager *et al.* (2014) supported this finding where emotional attributes chosen were noted to have higher stability with lesser numbers of repeats of attributes along the curve compared to the sensational attributes.

Unlike TDS with a high dominance rate observed in the Semi Trained Panel, the highest dominance rate for TDE was observed at around 30% in the Untrained Panel. Although references increased Semi Trained Panel's confidence in TDS in this study and also in the studies from Cheong *et al.* (2014); Pineau *et al.* (2012) and González *et al.* (2002), it was difficult to provide references for the emotional attributes as emotions are subjective to each individual. Therefore, only definitions of each emotion was explained to the panellists. Hence, further studies could look into providing panellists with simple physical emotional related references such as chocolate to represent *happy*.

5.1.3 Effect of Panel Type on Likings

The Untrained Panel had a high dominance rate for liking throughout each mastication sequence while the Semi Trained Panel had *neutral* or *dislike* overriding the liking curve starting from 50% standardised time. As sensational attributes were rated together with liking, the differences in dominance rate of liking might be linked to the TDS attributes selected. It was observed that attributes which drive disliking such as *sour*, *fibrous* and *grainy* surfaced throughout the tasting duration more frequently in the Semi Trained Panel than the Untrained Panel which explained the higher dominance of *dislike* and *neutral* curves. Results were consistent to the data collected by Jaeger *et al.* (1998) and Corollaro *et al.* (2013) where some sensational attributes were linked to consumer's experience such as *grainy* which equate to aged apple thus driving the *dislike* scale.

Emotions could be categorised into positive, neutral or negative as seen in Table 3. However, having a positive sensation or emotion does not always equate to liking and vice versa (Mojet *et al.*, 2015). *Firm* which is a fairly important positive sensational attribute in apple (Harker *et al.*, 2008) was regarded as *neutral* in some of the apples in this study. Emotion wise, some discrepancies were observed where negative emotions were found to be *neutral* while some positive emotions to be *disliked*. These findings indicated that non-dominant attributes or synergistic effect from other attributes could have contributed to the liking scores since dominant sensational attributes were rated with liking. This can be prevented only if TDL was tested separately which will require additional sessions.

Comparing between the hedonic scores and frequency liking counts, Semi Trained Panel had Pink Lady scored the highest in both methods. This information further emphasised the benefits of training where higher agreement was observed in the Semi Trained Panel. However, in a finding by Sudre *et al.* (2012), temporal liking of the dominant sensational attributes were better used to track the liking of the dominant attribute over time, not much for overall liking measures. Therefore, frequency liking counts may not be the best in concluding the degree of liking in various apples.

Furthermore, graphs derived from various temporal dominance measures could be mapped onto each other. For instance, in this study, the TDS dominant attributes were mapped onto the TDL curves. This gave a better relation of liking to attributes gathered from TDS and TDE as seen in Figure 13 and 14, presenting a novel method to incorporate dominant liking scales and dominant sensational attributes which gave an overall picture on the liking of the dominant sensational attributes at a glance. However, the process of retrieving the TDL data before incorporating with the dominant sensational attributes was time consuming. Currently, no sensory software is able to capture these data concurrently. This thus pose a gap for sensory software developer to explore.

5.2 Ethnicity Effect

Another objective of this study was to investigate how *ethnicity (Chinese, Indian and Malay) impact on the attribute chosen for TDS, TDE and TDL in Singapore.* It was hypothesized that *different ethnicities will display different sets of chosen attribute.*

Similarities were seen in the attributes chosen in most apples by all ethnicities. *Juicy* and *crunchy* were commonly seen for TDS and *displeasure* and *disappointed* were common in TDE, showing ease in understanding these attribute's definition or detection by the three ethnicities. Some attributes were found more frequently in one ethnicity group than the others like *fibrous* in Indian whereas *floral* in Chinese panellists. The different attributes chosen by the ethnicities might be justified by the varying cultural diet (Koh *et al.*, 2014). For instance, Indian and Chinese in Singapore might practice vegetarianism (Singapore Nutrition and Dietetics Association, 2012). As vegetarians, diet consist higher fibre content which the Indian and Chinese are familiar to or could relate to, making them more readily in detecting *fibrous.* Similarly, *floral* being chosen more frequently by Chinese panellists could also be explained by their cultural practices where flowers like chrysanthemum were widely used in herbal drink, hence the ability to better comprehend this attribute. Therefore, culture plays a part in panellist's attribute selection i.e. when one is familiar with a particular attribute, it will be picked more readily (Bhattacharya, 2015, Jaeger *et al.*, 1998).

Initial positive emotions were seen more frequently in Chinese panellists with high dominance rate in liking for TDL excluding Fuji and Granny Smith. The Indian and Malay panellists tend to have frequent initial negative emotions for most of the apples with higher tendency of selecting *dislike* and/or *neutral* for TDL. Apples might be used in Chinese families as a staple, thus leading to a higher degree of familiarity or association. It was reported by Koh *et al.* (2014) that emotions were dependant on a specific relationship or memory formed on that product. Another explanation could be related to the TDS attributes selected earlier. Liking towards the chosen sensational attributes might differ from each ethnicity, causing variation in liking scores (Engelen and de Wijk, 2012, Thomson and Crocker, 2013).

Chinese panellists were also seen to be more expressive, displaying a richer vocabulary or an increased awareness of the various attributes used (Engelen and de Wijk, 2012). Also, the range of dominant attributes chosen by Chinese panellists were similarly dominant in Malay and Indian panellists combined, suggesting attributes selected by Malay and Indian panellists to be a subset of the Chinese panellists. The ease for Chinese to do food cross culturing or sharing across different ethnicity groups might be the reason for the higher number of dominant attributes observed. Indian and Malay generally have a higher degree of food restriction as most Indian are vegetarian while most Malay are Muslim which halal certified food is a requirement (Abbas *et al.*, 2013).

Malay and Indian had initial flavour attributes like *sour*, *sweet* and *juicy* detected followed by textural attributes. Theoretically, textural terms could be detected during the first bite. The apple matrix only breakdown after a few chews, releasing flavour which explained the flavour attributes. Before swallowing, textural attributes like *fibrous* could be detected due to the granules left in the mouth. The frequent use of spices in Indian and Malay for cooking could have altered their taste buds, resulting in flavour attributes being more important than textural attributes. Therefore, the sequence of attributes detected by the Chinese which started with textural attributes like *crunchy* followed by flavour attributes and end of with textural attributes were regarded to be more accurate.

Different ethnicities have different denotation of an ideal apple which is associated to the different sensational attributes each apple provides. Differences was noted in the apples where the highest and lowest hedonic scores for each ethnicity were Pink Lady and Fuji for Chinese, Divine and Granny Smith for Indian, and Royal Gala (2) and Ambrosia for Malay respectively. Differences were also observed for frequency liking counts where Pink Lady was most liked in Chinese and Indian whereas Royal Gala (1) had highest liking counts for Malay. Hence, differences in liking could be linked to the food texture each ethnicity likes and the food product they are familiar to (Bhattacharya, 2015).

The inclusion of liking with TDS was useful and displayed the novelty of this study, the ability to relate dominant sensational attributes to liking at various time points. Therefore, to investigate the ideal apple for each ethnicity, it is recommended to either include hedonic scores or TDL and conclude it from the TDL curve from the apple with the highest dominant liking rate.

5.3 Usefulness as a technique for new product development

The last objective of this study was to *comment on the usefulness of TD in new product development*.

With a literature search, this is the first study looking into combining TDS and TDL within a test session. A novel way in presenting TDL results was also explored in this study. TDL scores obtained were transformed into a dominance rate graph with dominant TDS attributes at a given standardised time shown in Figure 8. The benefit of using this novel data presentation provided an overall picture of the liking and sensational attributes tied to that particular apple at a specific standardised time. However, the tedious process of extracting TDL data needs to be improved.

The integration of TDL measures with TDS was not only time saving during testing, it reduced fatigue in panellists as they only have to taste one set of samples. It also provided a dynamic description of the product and consumer's degree of liking towards the sensational attributes instead of the traditional static liking point calculated by hedonic scaling- giving information only on the overall liking of the product (Thomas *et al.*, 2015). Asian panellists was found to use a smaller range of hedonic score compared to Americans (Yeh *et al.*, 1998). This finding is true to this study as well where most hedonic scores were found to be near the mid-point which was 'neither like nor dislike'. Therefore, comparing liking counts and hedonic scaling, liking counts were more discriminative, painting a wider picture of the product's liking as the scores could be segregated into like, neutral and dislike. This gave product developer deeper insights on the attributes liked by consumers and refinement of product could be carried out, improving on the dislikes of the products.

However, the qualitative interpretation of TD curves is highly subjective and might led to errors in interpretation and over-generalisation across samples of the dominant attributes which instead of reaping the benefit of the dynamic methodology, could cause inaccurate reporting of results. Therefore, further research can understand how dominance is conceptualised by both consumers and researchers.

For a newly developed food product, emotion and liking elicited thorough the mastication process are important factors affecting consumer's choice (Thomson and Crocker, 2013). The application of TDE and TDL with TDS in this study saw an ability for food manufacturers to understand consumer's choice. This is especially important for products with various sensational effects at different time points. For example, in sugar free products with sweeteners besides from the basic flavour profile, lingering sweetness during mastication process might be present (Zorn et al., 2014). Therefore, a profile of the product including the attribute 'lingering sweetness' overtime is beneficial to study consumer's acceptance for that product. Additionally, synergistic effects might be displayed by the various dominant attributes at any time point allowing the understanding of attributes interaction between sensation, emotion and liking. These data drawn allowed a better comprehension of products tested, not just solely based on textual or flavour attributes which other static sensory tests provide. In this study taking one example by comparing the TDL curves of Granny Smith for all the ethnic groups, sourness is perceived to be a negative attribute for Indian and Malay but it was found that Chinese positively rated it with overall high dominance of liking. Therefore, indicating that Chinese might prefer product which carries a hint of sourness. These data could inform manufacturer how consumer felt about the attribute, integrating a deeper understanding of the product.

6. Conclusion and recommendations

This novel study explored the combination of TDS, TDE and TDL in relation to apples. Similar attributes were obtained for both TDS and TDE with a slight variation in the order of attributes dominance in the two panels. Semi Trained Panel indeed had a faster selection time with a higher dominance rate.

Different ethnicities, showed variations mainly in the attributes chosen which might be due to the various cultural diets and practices. Chinese was seen to be more expressive and had the highest liking dominance rate for TDL. Malay and Indian panellists paid higher attention to flavour attributes. The attribute selections by Chinese panellists were seen as a collective of the attributes selected by Malay and Indian.

The combination of TDS, TDE and TDL showed benefits in providing a more comprehensive story in understanding the sensory changes occurring during oral processing (Cadena and Bolini, 2011). This suggests the suitability of using this method in new food product development (Labbe *et al.*, 2009).

It is recommended that future research could include instrumental tests such as hardness and pH to study and correlate the sensory properties in depth. Also, knowledge of harvest time of the apples could be gathered to understand the variation observed in this study. Food references related to the various emotions could be included. Further TD studies using different food items with the various ethnicities group in Singapore and could be carried out to help validate and expand the conclusions drawn in this study. In addition, the comparison between standardised time versus normal time with this current data set could be explored as standardised time hides some interesting time dependent changes. TDL rating includes a complex combination of attributes that predicts liking rather than a one to one relationship. Therefore, further research can clearly relate the relationships by using multivariate statistics.

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Appendix A: Participant Information Sheet

Instructions to Participant

Please read this form and ask any questions that you may have about this research project. **Your participation is voluntary and you can ask questions at any time during the research.**

1. INTRODUCTION
You are being asked to be in a research of : **Health, Asian food choices and "NZ Inc." (Part 1)** You were selected as a possible participant because 1. we need your participation in the sensory evaluation component of the project 2. You fall within the target consumer group.
2. PURPOSE OF RESEARCH
(a) The purpose of this research is The aim of this research is to discover the sensory and consumer perspectives focussing on several New Zealand food products like honey, yoghurt and meat in Asian markets related to health and wellness. Sensory panels will be recruited. NZ products – honey, yoghurt and meat will be assessed by these panels. Overall, data from this project will be added to build a model of Singaporean consumer behaviour which will be fed back to participating companies and the NZ food business in general. (b) Inclusion criteria Healthy male and female subjects with no inherent allergies to food and food ingredients and age group between 21 to 59 years of age. (c) Exclusion criteria PI will check with subjects if they have any food allergies or sensitivity to any food ingredients or products. If yes, they will be excluded from the study. Subjects will need to have good oral and general health without problem of chewing, complete natural dentition, no history of recent orthodontic treatment or jaw injuries, natural mastication and salivation and are non-smoker. (d) The total number of panellists is expected to be 42.
3. DESCRIPTION OF RESEARCH PROCEDURES
(a) If you agree to participate in this research, you can expect to : Taste a set of nine products per session. You are expected to taste 4 sets of samples during the period of research on different days. Each visit would take about 60 to 120 mins and involve up to 2 sessions. (b) This research is expected to commence and conclude on : starts on 10 May 2014 and ends on April 30 2016

4. RISKS TO BEING IN RESEARCH
(a) The research has the following risks There are no foreseeable risks or discomforts associated with participation in this research. (b) If you experience discomfort as a direct result of your participation in this research, you will receive care from You should seek medical assistance from qualified medical practitioners and to inform Principal Investigator immediately if there are any adverse events
5. BENEFITS OF BEING IN RESEARCH
There is no direct benefit of being in the research. However, your inputs will help researchers to gain a deeper insight into how individuals understand and perceive the role of functional food products within the context of consumer perception and their attitudes. It is anticipated that this research will allow producers of such products to produce better quality products with high nutritional value. Food manufacturers would also be able to produce better products to meet the needs of different consumer groups to suit the lifestyle.
6. PAYMENT (*if any)
$40 cash vouchers for panellists attending sessions on 23 and 24 September 2014 and $30 for panellists attending sessions on 18 and 19 September 2014.
7. CONFIDENTIALITY AND PRIVACY OF DATA
Information collected for this study will be kept confidential. Your records, to the extent of the applicable laws and regulations, will not be made publicly available. However, members of the study team and SP ERC will be granted direct access to your original records and data to check study procedures and data, without making any of your information public. By signing the Informed Consent Form attached, you are authorizing such access to your study and records. Data collected and entered into the data collection forms are the property of Singapore Polytechnic. In the event of any publication regarding this study, your identity will remain confidential.
8. VOLUNTARY PARTICIPATION/WITHDRAWAL
(a) **Your participation is voluntary**. If you choose not to participate, it will not affect your current or future relations with the Polytechnic. (b) You are free to withdraw from this research at any time.
9. CONTACTS AND QUESTIONS
(a) The study has been reviewed by the SP ERC for ethics approval.

(b) The principal investigator for this research is Jasmine Leong. For questions or more information concerning this research you may contact her/him at 68706164. (c) If you believe you may have suffered a research related injury, contact Jasmine Leong at 68706164 who will give you further instructions. (d) If you have any complaints about this research study, you may contact the Principal Investigator at 68706164 or the SP ERC Secretariat at 6772 1591.
10. COPY OF CONSENT FORM
You will be given a copy of this consent form and one will be kept in PI's records file for future reference.

Appendix B: Consent Form

Protocol Title:

Health, Asian food choices and "NZ Inc."

Principal Investigator & Contact Details:

Jasmine Leong, 68706164

I hereby acknowledge that:

1. My signature is my acknowledgement that I have agreed to take part in the above research.
2. I have received a pamphlet (or a copy of this information sheet) that explains the use of my *data* in this research. I understand its contents and agree to donate my *data* for the use of this research.
3. I can withdraw from the research at any point of time by informing the Principal Investigator and all *my* data will be discarded.
4. I do not have any allergies or sensitivity to any food ingredients or products.
5. I will not receive any financial benefits that result from the commercial development of this research.
6. I allow/ will not allow the subsequent use of my data for research activities whether or not related to this research, upon the completion of this research.

* This research has been explained to me in ___________________ (state language), which I understand, by _____________ (name of translator) on ________ (date).

________________________________ ___________

Name and Signature (Participant) Date

________________________________ ___________

Name and Signature (Parent/Legal Guardian) Date

________________________________ ___________

Name and Signature (Consent Taker) Date

________________________________ ___________

* Name and Signature (Translator) Date

**(Please include this section if the subject is unable to understand English and read any of the translated consent documents available.)*