Development of a Measure of Oral Perception of Hotness

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

Clarification of contributions

The case studies described in this thesis have been carried out by a research team led by Dr Peter Ho.

The contributions of the other members of the team to the case studies are listed below:

Dr Peter Ho provided guidance for all case studies.

Dr Zheng Li contributed to the instrument development and data collection for studies I and V.

Miss Xuan Liu and Miss Yuan Tian contributed to data collection for studies III and IV

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Abstract

Chilli is increasingly consumed in the United Kingdom and there is a demand for foods with chilli. The current method for measuring the oral perception of hotness only involves the rating of the perceived hotness intensity of foods. This is an incomplete measure as other factors which also affect the consumption of chilli should be included in measurement of hotness intensity. Tolerance to, liking of, and perception of the hotness of chillies are the main factors which affect a consumer's rating of hotness of foods with chilli, and should be considered in the measurement. The aim of this research was to develop an objective measure of the oral perception of foods with chilli. A survey was developed using a focus group to understand consumers consumption drivers. Tolerance tests were then conducted to determine attributes which were important for the measurement of tolerance. Overall liking test was conducted with these groups to determine if liking of foods with chilli influenced rating of hotness intensity of these foods. Finally, significant factors identified as having an impact on measurement of the sensations evoke by chilli were used in the final measure. The rating scale Rasch model was used to model data collected from the survey and all sensory tests data were modelled with Many Facet Rasch model. Survey data gave 3 clusters which had significantly different consumption drivers ($p = 0.03$). Tolerance test showed that consumers differed significantly in their tolerance levels ($p < 0.01$). Liking the burn of chilli did not influence the measurement of hotness intensity of chilli tomato soups ($p < 0.10$) and was not used in the final measurement. A single measure comprising of tolerance levels and hotness intensity was used in the measure oral perception of hotness of tomato soups. This information is useful in new product development.

Table of Contents

Lists of tables

Lists of figures

Chapter 1 Introduction

Chilli is a popular spice which is extensively consumed throughout the world and is valued for its colour, flavour and heat (Ahmed et al., 2002; Pino et al., 2007). It is the world's most popular condiment, it is eaten by more than a quarter of the world's population each day, and has the highest trade interest in the food, medical and chemical industries (Bray, 1993; Smith, 2015). The food industry is the largest consumer of chilli peppers, where they are used as colouring and flavouring agents in sauces, soups, processed meats, snacks, candies, soft drinks and alcoholic beverages (Pino et al., 2007).

Chilli is grown globally and its world production has been on the increase with significant rise in production levels since late 1990s from 2.5 million tonnes to around 7 million tonnes in the last decade (Subbiah and JeyAkumAr, 2009). India is the largest exporter of chili followed by China, Indonesia, Japan, Mexico, Uganda, Kenya and Nigeria (Rajput and Parulekar, 1998; Subbiah and JeyAkumAr, 2009). According to reports from the Centre for the Promoting of Imports (2019), the import of fresh chilli peppers from developing countries has increased from an average of 30,000 to 40,000 tonnes between 2013–2015 to 40,000 to 45,000 tonnes in 2016 and 2017. The United Kingdom is one of the leading importers of chilli and its importation has more than doubled between 2015 and 2017 from 15,000 tonnes to 31,000 tonnes. It is also the largest end market of chilli products (CBI, 2019).

Chilli has become mainstream and has been infused into general food trends, as evident by the sales of fresh chilli which has increased by 42% in two years, with more restaurants introducing larger variety of foods with chilli on their menus, and one in five consumers eating more foods with chilli than they previously ate (Gelski, 2017). There has also been an increase in chilli and chilli containing products on supermarket shelves. Supermarkets now offer a larger variety of products which have chilli in them. Figure 1.1 shows some selections of food products with chilli which are available on supermarket shelves. According to the Centre for the promoting of imports (2019), this continuously growing popularity of chilli is driven by the growing ethnic population. All these are indications of a rapidly growing market for foods with chilli and increased consumer interest in the consumption of foods with chilli in the United Kingdom.

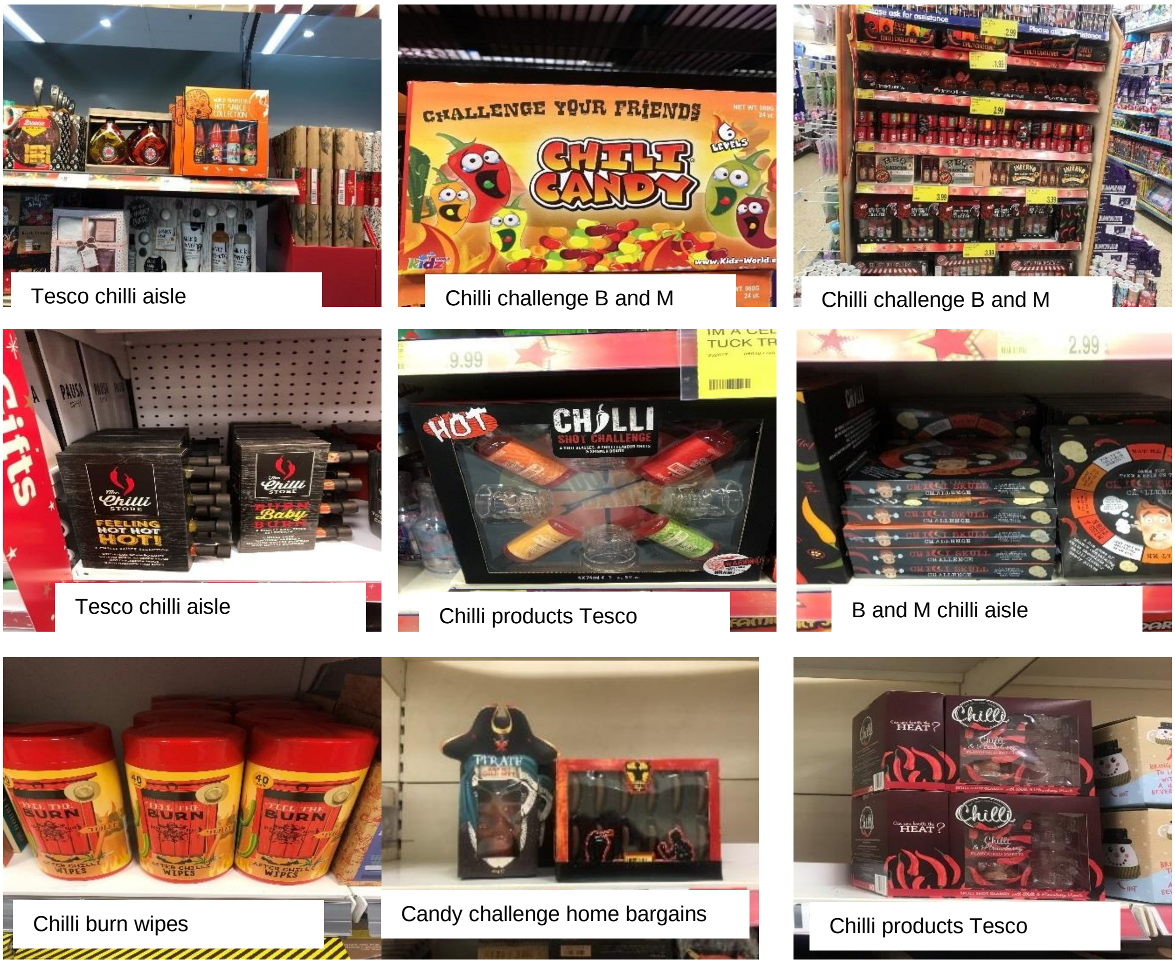


Figure 1.1: A selection of some products on the shelves of some supermarket as at December 2018

1.1 Varieties of chilli and chemical composition

There are many varieties of chilli ranging from bell peppers which have no heat at all and are sweet, to the Carolina Reaper which is currently the hottest chilli in the world (Rowland et al., 1983; Pepperhead, 2019). Other well-known varieties of chilli are Trinidad scorpion, bhut jolokia also called ghost pepper, scotch bonnet, habanero, Thai pepper and jalapenos (Barceloux, 2009).Consumer preferences are constantly evolving, their desire for hotter foods are also growing, and there is increasing interest in higher heat levels and different heat flavours (Kalsec, 2018). This has resulted in hotter chilli spices constantly being bred in other to develop hotter chilies which satisfy the needs of the evolving consumers. Every species of chilli varies in appearance, shape, colour, flavour and level of hotness (Ghosh et al., 2016). For example, when Guzmán and Bosland (2017) studied the different profiles of chillies, they reported that, habanero chilli had a delayed onset of development of heat sensation, a flat duration, with its heat located at the back of the throat and lingering. The hotness intensity of habanero pepper was classified as very hot. In comparison, Jalapeno pepper had a flat duration, rapid development of heat, which was located at both the tip of the tongue and front of the mouth and unlike habanero pepper, its hotness intensity was classified as hot.

Capsaicinoids are the chemical compounds responsible for the hotness of chilli. All parts of chilli fruits have different concentrations of capsaicinoids, with the placenta having the highest concentration and the seeds have the lowest capsaicinoid concentration (Supalkova et al., 2007). The seeds of chillies sometimes absorb capsaicinoids from the placenta because of their proximity to the placenta, raising their capsaicin concentrations (Pradhan et al., 2018). Figure 1.2 shows the internal structure of chilli fruit.

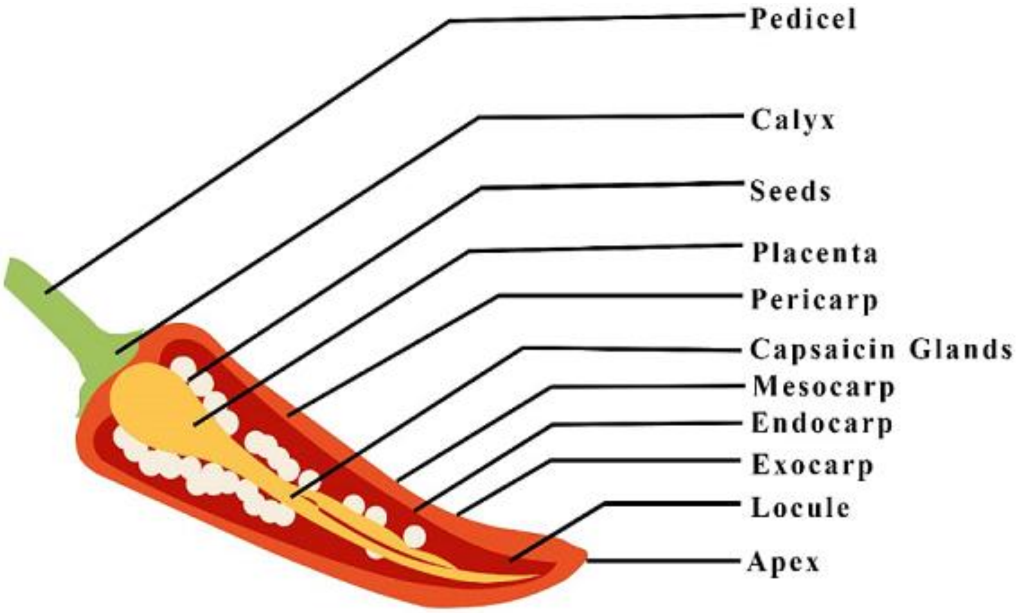
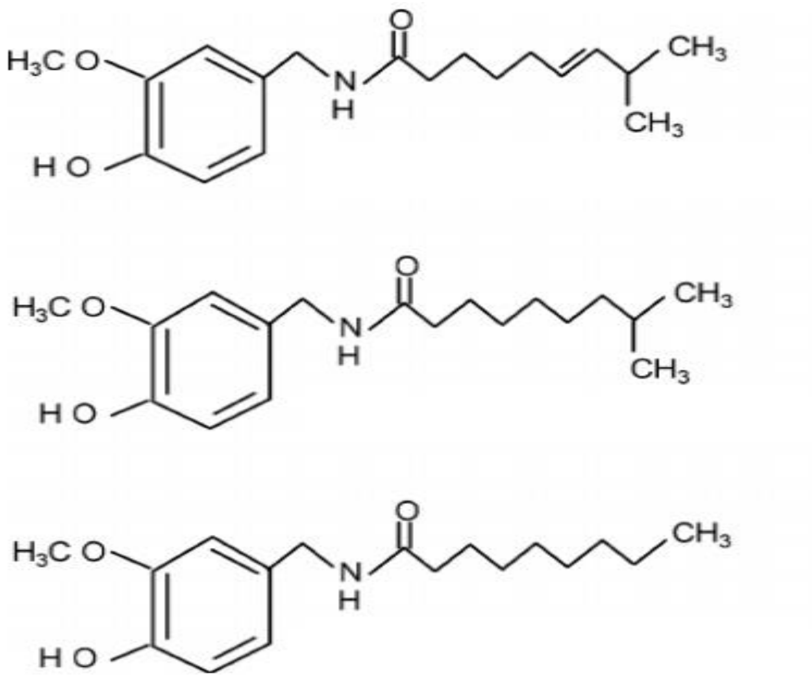


Figure 1.2 : Internal structure of chilli fruit

The level of hotness of a chilli is directly related to the amounts of Capsaicinoids present in the chilli, such that the higher the Capsaicinoids content in chilli, the hotter the fruit will be (Bodnar et al., 1983). Capsaicinoids consist mainly of capsaicin, dihydrocapsaicin, and nordihydrocapsaicin, with capsaicin being the most abundant, figure 1.3 shows the chemical structure of capsaicin, dihydrocapsaicin, and nordihydrocapsaicin.



a

b

c

Figure 1.3: Chemical structure of Capsaicin (a), dihydrocapsaicin (b), and nordihydrocapsaicin (c).

When capsaicin (8-methyl-*N*-vanillyl-6-nonenamide) is isolated from chilli fruit, it is a pungent off-white crystalline compound, which is insoluble in water but is freely soluble in ethyl alcohol and chemically belongs to the methyl-vanillyl none amide class (Eissa et al., 2007).

1.2 Mechanism of action of capsaicin

Capsaicin is capable of inducing intense excitation in sensory fibres, causing thermal pain and leading to long-term impairment of these nerves (Marsh et al., 1987). The hot sensations associated with capsaicin occurs when the afferent nerve endings in the mouth become excited following exposure to capsaicin (Lynn, 1990). Transient receptor potential vanilloid 1(TRPV1) is the endogenous receptor for capsaicin and responsible for this burning sensation (hotness) of chilli. It is also known as the vanilloid receptor 1 and is the same nociceptor which responds to heat pain from temperatures higher than 42.5

^{O}C (Caterina et al., 1997). Besides hotness, other sensations have reportedly been evoked by chilli and capsaicin. Sensations such as burning, itching, irritation, prickling, stinging, tingling, warmth, pain and bitterness have been recorded (Cliff and Heymann, 1992; Reinbach et al., 2007; Nolden et al., 2016; Guzmán and Bosland, 2017).

1.3 Health benefits of capsaicin

Chillies have been reported to have different vitamins and phytochemicals, these include but are not limited to carotenoids, Vitamin C, phenols, and foliates (Phillips et al., 2006). The nutrient content, concentration, and type of bioactive contents will vary among the different types of chilli (Ghosh et al., 2016). Capsaicin is often used as a food additive in various foods and has been reported to have several benefits to humans, such as, anti-inflammatory properties (Spiller et al., 2008; Choi, 2019), antimicrobial properties (Careaga et al., 2003), weight management (Yoshioka et al., 1995; Cichewicz and Thorpe, 1996; Yoshioka et al., 1998; Yoshioka et al., 1999; Yoshioka et al., 2004; Westerterp-Plantenga et al., 2005; Ludy and Mattes, 2011a), because of these many benefits, low toxicity and potent efficacy, there is increasing interest in the consumption of capsaicin (Bort et al., 2019).

Chapter 2 Literature review

2.1 Drivers of consumption

The consumption of chilli is clearly on the increase, therefore understanding what drives this consumption is of importance in product development of foods which contain chilli. This information is also useful in understanding the types of products the consumers of foods with chilli are interested in. The major drivers of consumption of foods containing chilli are perception of hotness intensity, liking of these foods and tolerance to them (Rozin, Paul and Schiller, 1980; Ahmed et al., 2002; Eertmans et al., 2005). Rozin, Paul and Schiller (1980), defined tolerance to chilli as the degree of acceptance of a level of chilli hotness. The perception of intensity of hotness, liking of hotness and tolerance to the hotness of foods maybe interrelated such that any one of these factors may have an impact on any of the other two factors. Although, it may be difficult to isolate any one of these factors, they are ultimately dependent on the concentration of capsaicin in the food. Several other factors have been reported to affect these three drivers of chilli consumption. These factors include (but are not limited to) familiarity and habit, cultural influences, gender, genetics, and personality.

2.1.1 Familiarity and habit

Exposure to chilli is a strong determinant of an individual's preference for foods with chilli and enhances their liking for the burning sensation of chilli (Stevenson, Richard J. and Yeomans, 1995; Ludy and Mattes, 2012). Liking the burn of chilli leads to increased consumption of foods with chilli which then causes the consumer to have higher tolerance levels for these foods (Rozin, Paul and Schiller, 1980; Byrnes and Hayes, 2013; Byrnes and Hayes, 2015). This is evident by the fact that regular consumers of foods with chilli will often rate its burn as less intense than non-frequent consumers (Lawless, H. et al., 1985; Cowart, 1987; Stevenson, R. J. and Yeomans, 1993; Stevenson, Richard J and Prescott, 1994), a phenomenon called desensitisation is responsible for this.

Desensitisation can been defined as a reduced perception of the sensation to the hotness of chilli as a result of continuous exposure. This process occurs when the continuous use of chilli destroys the part of the system that is utilized in sensing it (Cowart, 1981; Lawless, H. et al., 1985; Karrer and Bartoshuk, 1991; Stevenson, Richard J and Prescott, 1994). Desensitisation involves several changes in the primary sensory neuron, from physiological to morphological. These changes are dependent on capsaicin dose, route of administration and susceptibility of the neuron and its processes (Nolano et al., 1999). Desensitisation may occur after a single application of capsaicin, with time delays of as little as between 2.5 - 5 minutes and can last for days. When this process occurs, hotness levels that had been previously been perceived as too hot can become less hot and more acceptable to the desensitised person (Green, 1989; Karrer and Bartoshuk, 1991). For these reasons, frequent eaters and likers of chilli often rate the chilli burn sensation as significantly less intense and more pleasant than infrequent eaters and non-likers (Lawless, H. et al., 1985; Prescott and Stevenson, 1995; Stevenson, Richard J. and Yeomans, 1995; Ludy and Mattes, 2012; Tornwall et al., 2012). This means that the more familiar a person is to chilli, the lower their rating of the sensations which it evokes and the higher the liking of these sensations.

2.1.2 Cultural influences

Culture is a powerful influence which determines human behaviour and it often dictates the pattern of exposure, preparation and flavouring of foods and therefore provides a medium for facilitating spice acceptance (Rozin, Paul and Schiller, 1980; Nayeem, 2012). Because cultural values which encourage childhood exposure to foods serve as a strong influence in food preferences, the age of introduction to food often plays a role in preference and consumption. In many cultures, chilli is an integral part of their culture and traditions (Bosland et al., 2012) and a person who is introduced to foods with chilli at an earlier age is more likely to continue eating it. Rozin and Schiller (1980) conducted a study on chilli in which their sample population was made up of both Americans and Mexicans. They reported findings that Mexican culture which supported chilli consumption had more people with higher tolerance levels and preferences for chilli when compared to Americans who did not have a culture of eating chilli.

2.1.3 Gender

Gender is an important factor which is related to the consumption of chilli. Females and males differ in their genetic compositions and consumption of chilli, perception of intensity of the burn, and liking of these foods. Females have also been reported to rate the burn of chilli as more intense than males (Stevenson, R. J. and Yeomans, 1993). Compared to females, males have been reported to have stronger preferences for the burn of chilli (Logue and Smith, 1986; Alley and Burroughs, 1991; Byrnes and Hayes, 2015).

2.1.4 Genetic factors

The preference for, and consumption of, foods with chilli have been shown to be influenced by both taste phenotype and oral anatomy (Alley and Burroughs, 1991; Bartoshuk, Linda M. et al., 1994; Duffy, 2007). When Genetics and shared environmental conditions are being jointly considered, the former plays a more important role in explaining the variation of responses to oral heat sensations (Tornwall et al., 2012).

One of the chemical substances which highlights the genetic differences in taste in an individual is 6 n- Propylthiouracil which is commonly known as PROP. This is a bitter component which can only be tasted by some not all individuals and the ability to taste the bitterness of this substance is an inherited characteristic. This trait which results in tasting the bitterness of PROP is more common in women than in men (Whissell-Buechy and Wills, 1989; Bartoshuk, Linda M. et al., 1994). Using the ability to taste PROP solutions, researchers have divided individuals into tasters and non-tasters. Tasters perceive PROP to be moderately to intensely bitter, while non-tasters perceive these compounds to be weakly bitter or tasteless. In 1994, Bartoshuk, Linda M. et al further subdivided tasters into medium-tasters and super-tasters. Super-tasters had a more heightened taste of bitterness compared to medium tasters, and this status was assigned based on thresholds and on the mean ratio of intensity ratings of PROP solution relative to NaCl solutions. Super-tasters have been reported to have lower preference for foods with chilli (Tepper et al., 2009) as their perception of the heat from chilli is more heightened than in medium tasters causing them to dislike these foods compared to other taster categories.

There are contradictory reports as to whether PROP status plays a role in sensitivity to Capsaicin Karrer and Bartoshuk (1991), Synder et al (1996), and Tepper and Nurse (1998) all reported that tasters experienced stronger oral burn from capsaicin while non-tasters experience little oral burn. On the other hand, Ludy and Mattes (2012); Tornwall et al. (2012); Catanzaro et al. (2013) have reported that PROP scores did not predict consumption of Capsaicin.

2.1.5 Personality traits

Personality traits can be defined as a characteristic of an individual that exerts persuasive influences on a broad range of trait relevant responses (Ajzen, 2005). Personality traits show their effect on food choices through the negotiation of values by the individual with the personality traits (Furst et al., 1996). For this reason, personality traits can determine the preference for and consumption of foods with chilli. Preference for foods with chilli has been linked to higher levels of anger traits, machismo, strength, daring and sensation seeking personality traits (Rozin, Paul and Vollmecke, 1986; Terasaki and Imada, 1988; Byrnes and Hayes, 2013; Ji et al., 2013). Various personality traits and their effects on spicy food consumption have been reported for example sensation seeking trait, food neophobia and food involvement. Preference for foods with chilli has been linked to higher levels of anger traits, machismo, strength, daring and sensation seeking personality traits (Rozin, Paul and Vollmecke, 1986; Terasaki and Imada, 1988; Byrnes and Hayes, 2013; Ji et al., 2013). Various personality traits and their effects on spicy food consumption have been reported. For example, sensation seeking trait, food neophobia and food involvement are a few which have been studied in relation to foods with chilli.

2.1.5.1 Sensation seeking trait

This human trait is characterized by the need for “varied, novel and complex sensations and experience and the willingness to take physical and social risks for the sake of such experience” (Zuckerman, 1979, p.10). The sensation seeking scale has been used to measure consumer’s liking for foods with chilli. The theory is that sensation seekers like dangerous activities and also enjoy foods with chillies because liking of these foods can be seen as a kind of thrill seeking, and they will enjoy this apparently dangerous stimulus (chilli) which provides the thrill without any harm (Rozin, Paul and Schiller, 1980; Rozin, P. et al., 1982). The original sensation seeking scale (Zuckerman et al., 1964) has been replaced with Arnett inventory of sensation seeking (Arnett, 1994) which consists of 20 items with 2 subscales, novelty subscale and intensity subscale. These items are measured with a 4-point scale (from “describes me very well” to “does not describe me at all”). Higher composite score, correlates to higher tendency of sensation seeking in an individual. Terasaki and Imada (1988) and Hayes et al. (2013) reported a significant and positive correlation between high sensation seeking traits and preference for spicy foods.

2.1.5.2 Food neophobia

The food neophobia scale was developed by Pliner and Hobden (1992). They defined food neophpbia as the extent to which individuals are hesitant to try novel foods. This scale measures a person’s distrust and avoidance of novel foods, dishes, and cuisines. It consists of 10 items and respondents are instructed to score statements on a 7-point scale (1= “strongly disagree” to 7= “strongly agree”). The higher their scores, the more food neophobic they are.

This personality trait makes it hard for individuals who measure high on the scale to try new and unfamiliar foods. Food neophobia has been associated with lower preferences for spices and ethnic foods which often have chillies in them (Pliner and Hobden, 1992; Eertmans et al., 2005).

2.1.5.3 Food involvement

This scale was developed by Bell and Marshall (2003) and is defined as the level of importance of food in a person’s life. It is the extent to which people enjoy talking about food, entertain thoughts about food during the day, and engage in food-related activities. This scale consists of 12 items, respondents are required to endorse the statements on 7-point scale (1= “strongly disagree” to 7= “strongly agree”. High total scores on the food involvement scale means the individual being measured is food involved in comparison to someone who scores lower on the scale. Eertmans et al., (2005) reported a direct relationship between spices and food involvement and a negative relationship between spices and food neophobia.

Personality and genetics are not considered in this research.

2.2 Segmentation of chilli consumers using consumption drivers

Consumers of foods with chilli have different motivations to consume these foods. These motivations can be habitual, cultural, or behavioural and can be a useful tool in differentiating between consumers of chilli. Consumer segmentation involves categorisation of consumers into similar groups based on one or more important characteristics which they share in common (Wedel and Kamakura, 2012). segmentation means division into categories and can be used to identify consumers with similar characteristics. For example, similar attitudes, habits, and beliefs, these similarities are then used to understand consumers behaviour and patterns. The Information gathered can be useful for product development and improvement and for developing better marketing strategies (Næs et al., 2010). Understanding the drivers of consumption facilitates distinguishing of different categories of people who consume or are likely to consume foods with chilli. This information can then be used for segmentation. To adequately segment consumers, several stages are involved, these are; defining research problem and identifying important variable for segmentation, design research to adequately collect the desired variables, and finally, collect data, analysed and interpret (Wind, 1978). Traditional segmentation involves using variables such as demographic and geographic information. When these basic variables are used in consumer segmentation, they do not provide adequate information about the clusters which have been derived from segmentation and do not predict consumer behaviours and patterns.

Therefore to create a predictive segmentation model, several variables including ; but not limited to demographics, geographic, psychographics and behavioural can be combined to gain a more in depth knowledge of consumers and how they behave and their choices (Hollywood et al., 2007). It may also provide useful information which may help in understanding the product needs for the specific types of consumers. Such information is useful for new product development and marketing. Table 2.1 shows some variables which can be used for consumer segmentation (Onwezen, 2018).

Table 2.1: Variables for consumer segmentation (Onwezen, 2018)

	Person characteristics	Context or Situation
General	Demographics, trait-level psychographics	Country, neighbourhood
Domain specific	Specific psychographics like attitudes, norms, and innovativeness	Consumption moment, purchase moment, usage situation and product

Understanding what motivates consumers of foods with chilli to consume these foods is pertinent in segmentation and these drivers are potential criteria for segmentation. Several questionnaires have been used to investigate the consumption habits of consumers of spicy foods. The questionnaire by (Lawless, H. et al., 1985) collected information about the frequency of consumption and liking of chilli, Esmaillzadeh et al. (2013) obtained information on the frequency of consumption of spices, Sun et al. (2014) collected information on the frequency of consumption of chilli, age of introduction and preferred chilli strength, Lv et al. (2015) collected information of the frequency of consumption of foods with chilli and major spices used. Table 2.2 shows the summary of questionnaires which have been used to investigate consumption habits of consumers of spicy foods. Of all these questionnaires, the one by Lawless, H. et al. (1985) is most frequently used by researchers who have investigated foods with chilli (Reinbach et al., 2007; Ludy and Mattes, 2012; 2011; Byrnes and Hayes, 2013; 2015). This might be because it was comprehensive enough and collected more information about frequency of consumption of a wide range of spicy foods, liking of taste and burn, and the perception of chilli in foods. However, it provides limited information about understanding consumption drivers chilli.

Table 2.2: Questionnaires for measuring consumption habit

	Questionnaire	Question item	Scale measurement	References
1	Hedonics of capsaicin containing foods questionnaire	i) Frequency of ingestion of all types of pepper in foods including Mexican, Indian, Chinese, and other foods that contain pepper and cause tingling or burning. Brynes and Hayes (2013) modified and included Thai and Korean)	7 point category scale: 1=once a year or less, 2=less than once a month, 3= 1-3 times per month, 4= once a week, 5=3-4 times a week, 6= every day and 7= more than once a day	Lawless et al., 1985)
		(ii) 'How much do you like the taste of chili pepper in your food?	9-point hedonic scale: 1 = dislike extremely to 9 = like extremely	
		iii) 'How much do you like the burn of chili pepper in your food?	9-point hedonic scale: 1 = dislike extremely to 9 = like extremely	
		(iv) 'I think chili pepper makes food taste better',	True/False	
		(v) Without hot spices, I find that food tastes too bland'.	True/False	
		(vi) I find it hard to appreciate the flavours of food when the food contains hot spices	True/False	
2	Spicy food eating habit questionnaire	How often have you eaten spicy food during the past month?	Never and only occasionally/ 1-2 days per week/3-5 days per week/Daily or almost everyday	(Sun et al., 2014)
		If you eat spicy foods more than once a week, at what age did you start eating spicy food?	………………………	
		What strength of spicy food eating do you prefer?	Weak/Moderate/Strong	
3	Assessment of spicy food consumption questionnaire	During the past month how often did you eat hot spicy foods?	Never or almost never/Only occasionally/1 or 2 days a week/3 to 5 days a week/6 or 7 days a week	(Lv et al., 2015)
		When you eat spicy foods, what is the major source of spices usually used? (only for those who selected the last three categories from the question above)	Multiple choices allowed Fresh pepper, Dried pepper, sauce, oil, Others or don't know	

	Questionnaire	Question item	Scale measurement	References
4	Spice intake survey	Type of spice used	………..	(Siruguri and Bhat, 2015)
		Frequency of usage and intake	Daily /1, 2, or 3 times per week/1 - 2 times per month/Occasionally/Never	
		Quantity of spice used in routine dishes which includes details of type of dishes prepared in which spices are added, the type and quantity of spices added per dish, the frequency of preparing the dish	………………….	
		The quantity of the prepared dish consumed by the adult individual in order to calculate the portion size of the added spice consumed	…………………….	
5	Dietary habits questionnaire	How often do you use spicy foods? (Chilli pepper, curry ginger, cinnamon, and turmeric) during the week?	Never/1-3 times per week/4-6 times per week7-9 times per week/More than 10 times per week	Esmaillzadeh *et al.* 2013)

2.2.1 Current segmentation of consumers of foods with chilli

Current segmentation of consumers who eat chilli is assigned based on “user”/ “non-user” status or “liker”/ “non-liker” status (Lawless et al., 1985; Ludy and Mattes, 2012; 2011; Byrnes and Hayes, 2013; 2015). This is classification is achieved by recording a person’s self-reported annual consumption of chilli or by using their self-reported information about the liking or disliking of chilli, often using questionnaires which have been shown in table 2.2 to assign consumers to groups. However, this provides very little information to make predictions about different types of consumers.

The incomplete information which is often provided by the current methods of segmentation into broad group such as user/non-user, likers/non-likers segments, necessitates further segmentation as these classifications do not provide sufficient information about drivers of consumption and cannot be used to predict consumer behaviour and pattern. This view is also supported by Reinbach et al., (2007) who reported that when consumers of chilli were segmented into user and non-liker groups, there was no significant difference in the segmentation criteria which had been used to segment them into these groups.

Consumers have been segmented based on some criteria, such as their food related lifestyle; wine related lifestyle; wine involvement; lifestyle and motives; healthiness and sustainability perception; taste and firmness preference of tomatoes; tomato attributes and consumer preference; emotional attachment to meals; tourist attitudes; intentions and travel planning behaviour related to food; organic food related lifestyle of Thais; satisfaction with food-related life and beliefs; motivation in typical cuisine restaurants; beliefs and behaviours about local foods and ; young consumers attitudes and behaviour towards food quality (Li et al., 2002; Ryan et al., 2004; Causse et al., 2010; Brunner and Siegrist, 2011; Piqueras-Fiszman and Jaeger, 2016; Verain et al., 2016; Jetsadalak and Suwunnamek, 2019; Jürkenbeck et al., 2019; Levitt et al., 2019; Witzling and Shaw, 2019; Savelli et al., 2019; Liu and Grunert, 2020). Segmentation is not limited to food related studies as it has been used in segmentation based on; environmental consciousness of European consumers (Golob and Kronegger, 2019), low emission vehicle buyers (Obrecht et al., 2019), spectator motivation for consumption of electronic sports (Choi, 2019), energy demand management (Singh et al., 2019). It might therefore be important to see what segments exist within chilli consumers and how this information might be useful for food product development.

2.2.1.1 Factor analysis

Segmentation information is often collected using surveys which have been developed and is fit for purpose. After this information has been collected from consumers using the desired segmentation criteria, it is then analysed to ensure that questions used in the surveys are grouped based on similar themes. For example, survey questions which collect information about taste preferences will be in a different group from that which probes about health related preferences. A tool which can be used to explore themes within a survey is factor analysis. It is often used for theory and instrument development and it is useful in examining the interrelations amongst questions or statements which are believed to be important for measurement (Pett et al., 2003). There are of two basic types of factor analysis: confirmatory factor analysis (CFA) and exploratory factor analysis (EFA).

2.2.1.1.1 Confirmatory factor analysis (CFA)

Confirmatory factor analysis is used when an instrument already has previously established themes or factors within a survey and the investigator needs to confirm the factors which exist in an instrument. In this case, the researcher conducts a CFA for the purpose of confirming the preestablished factors.

2.2.1.1.2 Exploratory factor analysis (EFA)

Exploratory factor analysis is used when there are no preconceived ideas of factors which exists within an instrument, it seeks to explore factors which might exists within this instrument. When performing and EFA, the researcher has no preconceived idea of what factors exist in the instrument and the purposed of the EFA is to explore what factors exist in the instrument. EFA evaluates the dimensionality of items from a questionnaire by uncovering the smallest number of factors which can used to explain the correlation between the interpretable factors (Nunnally, 1994). EFA has been used by Renner et al. (2012) to determine factors which were present in the eating motivation survey which they developed. EFA to determine factors in a survey, in order to segment wine consumers (Li et al., 2002). EFA would be used during this research to explore the factors which may exist in the developed survey.

2.3 Measurement of sensations

Chilli is well known for its ability to evoke hot sensations when in contact with the mouth and skin. This hot sensation caused by capsaicin can persist from several minutes to several days (Reinbach et al., 2007). When chilli is in contact with the mouth, its hotness can be described by several attributes such as; hot, sharp, heat, biting, fiery, (Eissa et al., 2007). Hotness is a heat sensation which is caused by the activation of pain receptors in the tongue of mammals (Nilius and Appendino, 2013). It is defined as the total intensity and duration of burn sensation in the throat and mouth perceived during and after ingestion of chilli (Reinbach et al., 2007) and is quantifiable.

2.3.1 Quantification of hotness

The perceived intensity of oral hotness is influenced by the concentration of capsaicin, the profile of the Capsaicinoids in the chili product, the temperature at which the food is served and the food matrix used (Lawless, H., 1984; Prescott et al., 1993; Baron and Penfield, 1996; Allison and Work, 2004; Kostyra et al., 2010; Guzmán and Bosland, 2017). Other components present in food such as milk, cream, oil, and sugar have been reported to reduce the perception of hotness of chilli in the food (Kostyra et al., 2010). The total hotness of capsaicin in food can be quantified using two common methods; sensory evaluation and instrumental methods.

2.3.1.1 Sensory evaluation

Sensory evaluation is a scientific method which can be used to evoke, measure, analyse and interpret responses to products which can be perceived using the human senses (Lawless, H.T. and Heymann, 2010), It is an integral part of product development. It is for this reason that before food or beverages are produced, distributed or marketed, sensory evaluation is carried out to ensure that sensory qualities of the food are acceptable to consumers (Tuorila and Monteleone, 2009). For sensory analysis to be conducted, several elements are required: a clear objective, an appropriate test environment, panellists (trained or untrained), appropriate sensory test which can achieve set objectives and validation of results (Kilcast, 1999). The test objectives need to be clear as it determines the type of test which would be conducted and how the data would be analysed. Test environment should have separate sensory booths for panellists, free of interfering odours and noise (Lawless, H.T. and Heymann, 2010). Panellists are one of most important aspects of sensory. Therefore it is imperative that they are in optimal physiological condition when undertaking sensory testing (O'sullivan, 2016). To prevent sample bias, samples must be presented in such a way that prevent bias which can be cause by first-order and carry-over effects from samples and affect test results. First order effects occurs when the first sample in a sensory sequence of samples is scored differently to the other samples while carry over occurs when flavour, taste, aftertaste or other effects are not completely cleansed from the palate in between samples and subsequently interferes with perception of samples (O'sullivan, 2016). A good palate cleanser is one which sufficiently reduces residual sensations which have been left by preceding samples.

2.3.1.1.1 Types of sensory test

There are three main types of sensory tests; discriminatory, descriptive and quantitative affective tests (Lawless, H.T. and Heymann, 2010). Discriminatory tests determine if there are any differences present between test samples. Descriptive tests identify and quantify different sensory characteristics using sensory profiles. Quantitative affective tests investigate consumer’s preferences and acceptance with the end goal of determining the acceptability of products. Table 2.3 shows a summary of sensory tests, objective and sample size required for various sensory tests.

Table 2.3 Classification of test methods in sensory analysis (Lawless, H.T. and Heymann, 2010)

Sensory tests	Objective	Types of test	Panel characteristics	Panel size
Discrimination	Determine if there are differences between products.	Analytic	Screened for sensory ability, knowledge of test method, mostly trained panels.	25-40
Descriptive	Determine the degree of differences in specific sensory characteristics.	Analytic	Screened for sensory knowledge, ability, and motivation.	10-12
Affective	Determine extent of liking and acceptability of products.	Hedonic (liking)	Screened for familiarity product with product.	75-150

2.3.1.1.2 Scoville heat test (SHT)

The SHT is an organoleptic test and is a type of descriptive sensory test. It was devised by an American pharmacist Wilbur Scoville in 1912, and is the oldest method of sensory method for quantifying the amount of chilli/capsaicin in food. The SHT is a dilution test, which is performed by soaking pulverized chilli in ethanol and diluting the filtrate with sugar solution. The resulting solution is then given to five trained tasters. Serial dilution is continued until at least three of the five tasters in the panel can no longer perceive the hotness of the solution on their tongues. The corresponding extent of dilution is then regarded as a standardized measure of the hotness of the tested chilli.

The heat level of chilli is based on this dilution, which is rated in multiples of 100 Scoville heat units (SHU). If a type of chilli has 50,000 SHU this means that its alcoholic extract needs to be diluted 1:50,000 for the human tongue to no longer perceive it as hot. Using the SHU, five levels of pungency have been classified: non-pungent (0–700 SHU), mildly pungent (700–3,000 SHU), moderately pungent (3,000–25,000 SHU), highly pungent (25,000–70,000 SHU) and very highly pungent (>80,000 SHU) (Weiss, 2002).

Gillette et al. (1984) reported a variation of up to 50% amongst laboratories using the Scoville method and they identified several disadvantages which have been associated with this method. These are; heat build-up, increased and rapid fatigue in tasters, increased taste threshold, ethanol bite in samples, and poor reproducibility. To objectively quantify the amount of chilli in food, instrumental methods are required. Figure 2.1 shows typical SHUs of common chilli.

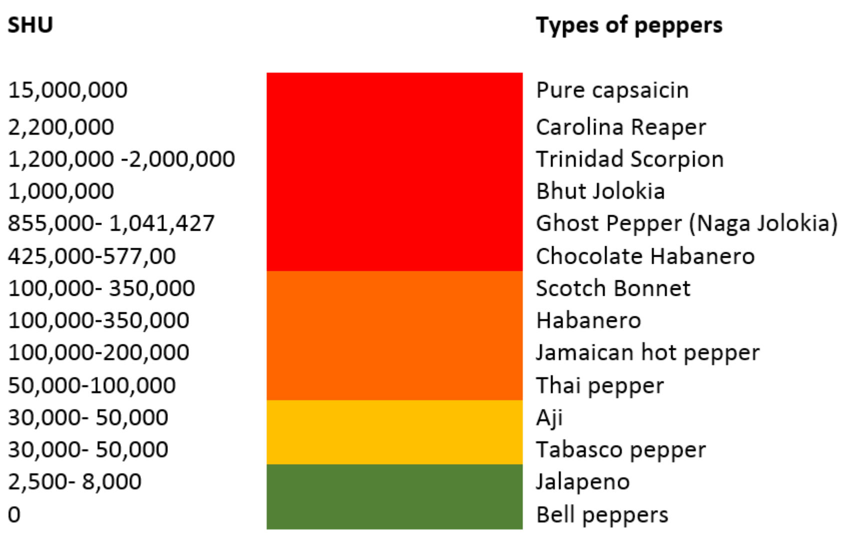


Figure 2.1: SHU of common varieties of chilli

2.3.1.2 Instrumental methods: High performance liquid chromatography (HPLC)

The second method for quantifying the amount of chilli in food is high performance liquid chromatography (HPLC) and is the most common and accurate method for quantifying the amount of chilli in food. This method of quantification of capsaicin was developed by Sticher et al. (1978) to overcome the inaccuracy and unreliability of the SHT. The precision, accuracy, and reproducibility of the HPLC method makes it the most used method for quantifying the hotness of chilli. Several researchers have utilized HPLC in quantifying the amount of capsaicin (Chiang, 1986; Henderson et al., 1999; Al Othman et al., 2011; Orellana-Escobedo et al., 2012; Tilahun et al., 2013; Welch et al., 2014). To get the SHU equivalent, the ppm is multiplied by 15.

Although HPLC method provides a more accurate and reproducible information about the amount of capsaicin present in a food, this does not reflect the actual perception of hotness of the consumer. Knowing the quantity of chilli present in the food through HPLC does not give information on how this hotness would be perceived by various individuals. Only human sensory data can provide the best models of how consumers are likely to perceive the hotness of a product and this cannot be replaced by any known instrumental method (Álvarez and Blanco, 2000; Lawless, H.T. and Heymann, 2010) for this reason, there is still a need to perform sensory tests using consumers of chilli.

2.4 Measurement of perception of hotness

Sensory methods provide information on consumers' actual perception of hotness relative to the amount of capsaicin that is present in the food eaten. Oral perception cannot be measured directly, without the use of rating scales. Several sensory scales have been used to determine the consumer perception of hotness or other sensory attributes, and the most popular scales are the line scale, category scale, and category-ratio scale.

2.4.1 Category scale

The category scale is the oldest method of scaling and provides a choice of responses to signify increasing sensation experiences of a product (Lawless, H.T. and Heymann, 2010). This scale provides only numbers, with no description of categories available for interpretation of the categories. Panellist are required to select a category (number) on the scale that best describes their perception of the attribute that is being measured (Figure 2.2).

Intensity

1 2 3 4 5 6 7 8 9

weak strong

Figure 2.2: category scale

2.4.2 Line scale

The line scale is a horizontal or vertical line, which is anchored with descriptors representing the extremes for the given attribute and contains, no intermediate descriptors (Stubbs et al., 2000). For example to measure the intensity of spiciness, anchors are "not spicy at all" and "as spicy as I have ever experienced" (Ludy and Mattes, 2011b). Figure 2.3 shows an example of line scale for used for rating the intensity of spiciness in tomato soup. Responses are scored by measuring the distance from the left end of the scale to the right.

In this type of scale, panellists are required to select any point on the line scale that indicates their degree of perception to the attribute that is being measured.

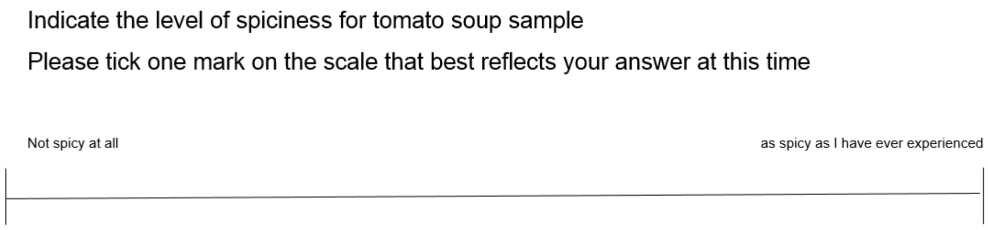


Figure 2.3: Line scale

2.4.3 Category- ratio scale

The category-ratio scale is a hybrid scale that combines the features of a category scale and a ratio scale (Lawless, H.T. and Heymann, 2010). An example of this type of scale is the generalised labelled magnitude scale (gLMS) (Green and Silverman, 1993; Bartoshuk, Linda M et al., 2004). The gLMS ranges from “strongest imaginable sensation of any kind” to “no sensation at all”. The levels of sensation being described on the gLMS are not limited to food experiences. For this reason, it provides a basis for comparing the sensory experience of food with other life experiences and thus more information about the attribute being measured. Responses are scored by measuring the distance from the bottom of the scale, to the position marked on the scale by the panellist. The gLMS has 7 unequally spaced points anchored by “no sensation” = 0, and “strongest imaginable sensation of any kind” = 100, as shown in figure 2.4. When compared to the other scales, the gLMS provides more description of scale categories thus extracting more information than the other scales. When using this scale, panellists are required to select any point on the scale that represents their perception of the attribute that is being measured. The categories of the gLMS were modified and used in this research to measure sensations.

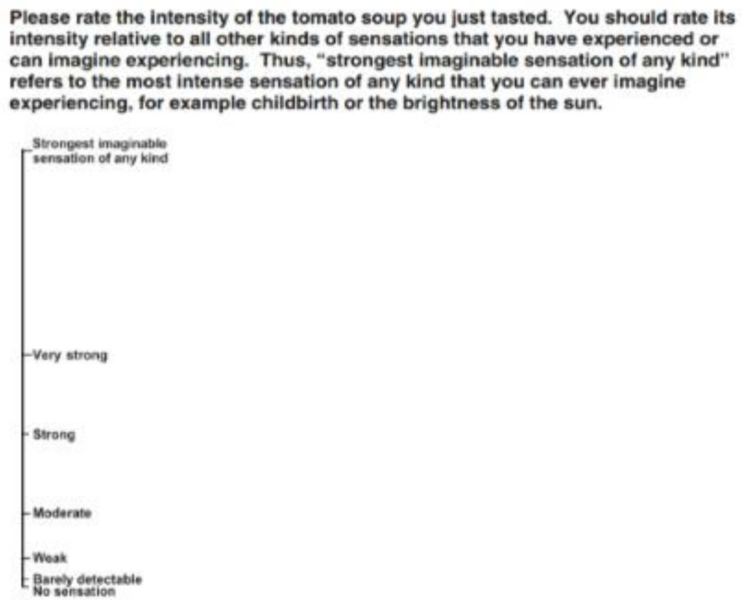


Figure 2.4: Generalized labelled magnitude scale (Ludy and Mattes, 2011b)

2.5 Measurement of liking of hotness

The liking of food has been measured using the 9-point hedonic scale which was developed by Peryam and Pilgrim (1957). This scale is a bipolar scale which consists of negative and positive categories anchored by a mid-point (Figure 2.5). The 9-point hedonic scale is the most used scale in the measurement of liking of foods and was used to measure liking of food throughout this research.

Rate how much you like the heat of sample 456

☐Dislike extremely

☐Dislike very much

☐Dislike moderately

☐Dislike slightly

☐Neither like nor dislike

☐Like Slightly

☐Like moderately

☐Like very much

☐Like extremely

Figure 2.5: A 9-point hedonic scale

2.6 Measurement of tolerance

Measurement of hotness and liking of chilli or spicy foods have been documented (Rozin, Paul and Schiller, 1980; Rozin, Paul et al., 1981; Rozin, P. et al., 1982; Ludy and Mattes, 2011b; Ludy and Mattes, 2011a; Ludy and Mattes, 2012; Byrnes and Hayes, 2013; Byrnes and Hayes, 2015). However, these do not provide sufficient information through which tolerance can be measured. If tolerance has an impact on the rating of oral perception of hotness and the liking of the hotness, there needs to be methods through which tolerance can be effectively measured. Tolerance tests have been previously conducted by Rozin, Paul and Schiller (1980). Their study used corn cheese snacks which were coated with capsaicin ranging from 0 to 262, 000 Scoville units. Participants were required to eat the corn cheese snack and stop when they stopped liking the heat level of the snacks, tolerance levels were defined as the levels at which snacks were accepted. Similarly, in the study by Rozin, Ebert and Schull (1982), crackers containing up to 8500

SHU of chilli and participants were required to rate liking over time and were required to stop when samples got too hot to bear. Finally, Stevenson, R. J. and Yeomans (1993) conducted a tolerance test using tomato juice with capsaicin ranging from 1 ppm to 256 ppm, participants were requested to rate the burn of samples and were told to stop when they thought the hotness of the capsaicin solution would be too hot to bear.

At higher concentrations such as 70 ppm when compared to lower concentrations like 0.5 ppm, capsaicin causes a response that is associated with burning and causes pain. Hotness intensity and pain ratings of capsaicin have not been used directly in the measurement of tolerance to capsaicin in food and by extension chilli, yet it is well known that capsaicin causes pain when in contact with the mouth. It was therefore important to investigate the influence pain had on the measurement of tolerance.

Tolerance is best measured using higher concentrations and since pain is caused to the consumer at these high concentrations , it follows that tolerance should be measured by the hotness of the chilli/ capsaicin , the amount of pain it causes, and the capability to withstand the pain which the capsaicin caused. To this end, the information from the three aforementioned attributes might be important for the estimation of tolerance.

2.6.1 Measurement of pain

Pain has been as defined the conscious awareness of the sensory experience that is unpleasant, distressing or disturbing (Woolf, 2007). It is occurs when the peripheral terminals of a subgroup of sensory neurons are activated by stimuli which could be noxious chemicals, mechanical or thermal (Caterina et al., 1997). In addition to burning and other sensations, capsaicin is also known to cause pain sensation upon exposure (Simone et al., 1989; Tominaga et al., 1998; Szallasi and Blumberg, 1999). The various dimensions of the pain experience can be influenced by the intensity of the stimulus, its duration and the location of the pain on, or within, the body (Iadarola et al., 1998). Several scales have been used in the estimation of pain, the visual analogue scale (VAS), the numeric rating scale (NRS), the verbal rating scale (VRS), and the McGill pain questionnaire (Aitken, 1969, Jensen et al., 1986, Stevenson and Yeomans, 1993, Melzack, 1995). Table 2.4 summarises the common pain scales. Because measurement of pain is complex and sometimes hard to express, it is helpful to use to have a scale that provides adequate description for each category. The subjective pain scale developed by Mankoski (2013), meets this criterion. It consists of 11 categories (table 2.5) which have description for each category, allowing the person in pain to have descriptors which can be used to convey amount of pain they perceive.

Table 2.4: Summary of some pain scales

No	Scale name	items/ questions	Scale measurement	source
1	Visual analogue scale (VAS)	Mark a 100 mm line to indicate pain intensity	10-cm line (11-point scale) (0-no pain to 10- worst imaginable pain)	(Aitken, 1969)
2	Numeric rating scale (NRS)		11, 21 or 101-point scale no pain and pain as bad as could be or worst pain	
3	Verbal rating scale (VRS)		5-point scale No pain to maximum pain	
4	McGill pain questionnaire	4 items Where is your pain?~~?~~ What does it feel like? 20 categories How does this change with time? How strong is it?	 Continuous, rhythmic, brief 5-point scale (mild, discomforting, distressing, horrible, excruciating)	(Melzack, 1975)

Table 2.5: The subjective pain scale

Raw score	Categories	Description
0	No pain	No pain, feeling perfectly normal
1	Very mild	Very light barely noticeable pain
2	Discomforting	Minor pain, e.g. lightly pinching the fold of skin between the thumb and first finger with the other hand, using fingernails
3	Tolerable	Very noticeable pain, e.g. an accidental cut, a blow to the nose causing a bloody nose or a doctor giving you an injection
4	Distressing	Strong deep pain, e.g. an average toothache, the initial pain from a bee sting or minor trauma to the body part such as stubbing your toe real hard
5	Very distressing	Strong deep, sharp pain such as sprained ankle when you stand on it or mild back pain
6	Intense	Strong deep, sharp pain e.g. a bad headache combined with several bee stings or a bad back
7	Very intense	Strong deep, sharp pain which completely dominates your senses causing you to think unclearly e.g. average migraine headache
8	Utterly horrible	Pain so intense you cannot think clearly, comparable to a real bad *migraine headache
9	Excruciating unbearable	Pain so intense you cannot tolerate it and demand pain killers
10	Unimaginable unspeakable	Pain so intense you will go unconscious shortly

According to Nielsen et al. (2009) pain measurement is made up of two components, pain sensitivity and pain tolerance. They defined pain tolerance as maximum pain intensity that a person is willing to endure and the former as the amount of pain a stimulus evokes. They reported that since pain tolerance is influenced by motivation and psychological factors and can be under or over reported due to wrong use of scale, a more balance measurement of pain would be one which considers in it measurement pain tolerance and pain sensitivity. For this reason, tolerance was modelled as shown below.

$$\text{Tolerance} = \text{stimulus tolerance} + \text{pain sensitivity}$$

this same model can be applied to other sensations such as numbing, irritation, itching, which are evoked when capsaicin is consumed.

2.7 Measurement and its building blocks

The purpose of measurement is to provide a practical and consistent way to summarise responses that respondents make to convey their view, through instruments such as surveys and sensory tests (Wilson, 2004). Development of any measurement tool requires a well thought out process ensuring that every stage contributes substantially to the final aim of the measurement tool. According to Wilson (2004), there are four building blocks needed in the development measurement tools. These are construct, item design, outcome space and measurement model (figure 2.6).

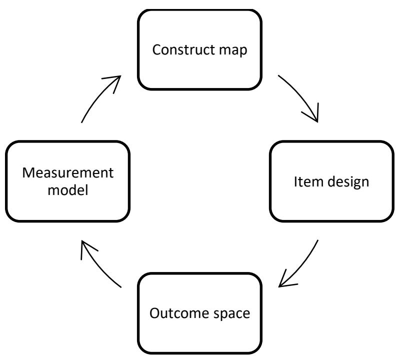


Figure 2.6 Four building blocks of measurement adapted from Wilson (2004)

2.7.1 Construct map

A construct map represents conceptual stage of developing a measurement tool, it is a visual representation of the measurement instrument of interest. Cronbach and Meehl (1955) defined a construct as hypothesised characteristics of respondents, which cannot be observed directly, and can only be interpreted through responses to carefully selected items. An item when mentioned in this research refers to survey questions or sensory attributes.

A construct map should have a clear and concise definition of the content of construct that is to be measured (Wilson, 2004), therefore this stage of measurement involves predictively ordering respondents and items or attributes in a way that gives meaning to the measurement of interest. For example, a construct map for a survey to understand the consumption habits and attitudes of respondents who consume foods with chilli would have the potential locations of items and respondents on the construct map (figure 2.7). This visual representation makes it possible to generate important items which would be useful in understanding reasons for consumption of foods with chilli.

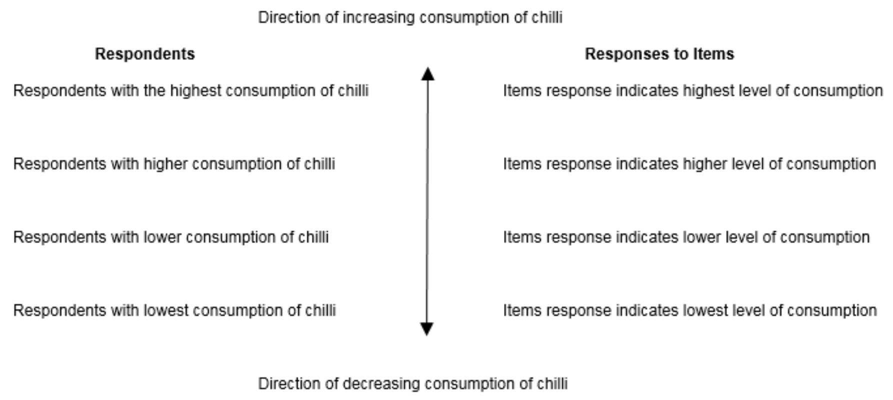


Figure 2.7 Construct map in construct consumption of chilli

2.7.2 Item design

Item design involves translating the construct map into reality by seeking out items which would be pertinent in the achievement of the measurement goal. It involves the description of a group of items or the item pool from where specific items are drawn from in an instrument (Wilson, 2004). In the development of a new instrument, this phase would involve research into existing instruments and the use of respondents who are familiar with the construct being measured to determine which items would be necessary for measurement. It also entails screening items to ensure that the final pool of items is fit for purpose. For example, in the development of the survey the use of focus group and existing literature to generate items falls in this stage. This is also applicable in sensory studies.

2.7.3 Outcome space

Wilson (2004) defined outcome space as a set of categories that are well defined, finite, and exhaustive, ordered, context specific and research based (p.62). The outcome space deals with ensuring that the items are capable of measure the latent variable of interest. For the survey in this research, the latent variable of interest is the drivers of consumption of foods with chili. In this phase, categories which effectively capture responses of the respondents were considered. This entailed deciding which rating scale was used and for which tests. For example, deciding to use the 8-point intensity scale in the tolerance test instead of another Likert scale. Choosing the right rating scale is important as it determines the usefulness of the information which is collected from surveys or tests.

2.7.4 Measurement model

Measurement model is the final phase and involves relating the information which has been obtained from the developed instrument to the original construct which was speculated from the construct map to see if the instrument measures what was set out to be measured when the process began. Measurement should be objective (invariant), this means it must meet the measurement criteria as postulated by Engelhard Jr (2013) p10, an objective measure is any measure that meets the following conditions:

Person's measurement
The measurement of persons must be independent of the particular items that happen to be used for the measuring: item-invariant measurements of persons.
A more able person must always have a better chance of success on an item than a less able person: non-crossing person response functions.
Item calibration
The calibration of the items must be independent of the particular persons used for calibration: person-invariant calibration of test items
Any person must have a better chance of success on an easy item than on a more difficult item: non-crossing item response functions.
Variable map
Items and person must be simultaneously located on a single underlying latent variable: The instrument must be designed to represent and measure one latent variable at a time.

Rasch model meets the criteria of invariance. It was the main statistical tool used throughout this thesis.

2.7.4.1 Rasch model

Rasch model is a modern psychometric approach developed by Rasch (1960). It ensures that the fundamental scaling properties of an instrument are assessed together with traditional psychometric assessments of reliability and construct validity (Gibbons et al., 2011). The principle of Rasch models is based on the premise that a person who has greater ability than another person should have a greater probability of solving any item in that set, also, an item being more difficult than another would mean that for any person the probability of solving the easier item should be greater than the probability of solving the more difficult item (Rasch 1960). It involves learning and applying the science of developing, examining and analysing the performance and quality of measurement instruments that are completed by individuals, these instruments could be tests and surveys (Boone et al., 2014). Conducting Rasch analysis makes it possible to evaluate the validity and reliability of a measurement device much more thoroughly than can be done in a traditional analysis (Boone et al., 2014). Rasch analysis has been applied extensively in medical and education fields for example it has been used to develop an instrument for measuring quality of life (Tennant and Conaghan, 2007), it has also been used to validate the stroke impact scale (Duncan et al., 2003)**,** (Koopmans, 2013) showed the use of Rasch analysis in evaluating work performance. Rasch model is being increasingly used in food science, Fischer et al., 2006 used Rasch modelling to measure consumers' food-handling behaviour, Álvarez and Blanco (2000) used Rasch modelling in studying the reliability of sensory data from a trained sensory panel, Garcia et al. (1996) have demonstrated the use of Rasch modelling in a study examining the sensory quality of Iberian ham. In a survey on the food safety and more recently Ho (2019) used Rasch model to measure the overall liking of cured ham. Rasch model may therefore be the appropriate measurement tool for developing objective measures for consumers' perception of hotness of foods which have chilli. There are four main Rasch models.

2.7.4.1.1 Dichotomous Rasch model

The dichotomous Rasch model (Rasch, 1960) is the simplest Rasch model and it is used to treat binomial responses. For example, yes/no answers or a rating scale with only two categories like agree and disagree. The software used in this estimation is called WINSTEPS®, however the dichotomous Rasch model equation is

$$\mathbf{log}\left(\frac{(\mathbf{P_{ni}})}{(\mathbf{1-P_{ni}})}\right) = (\boldsymbol{\theta}_{\mathbf{n}} - \boldsymbol{\delta}_{\mathbf{i}})$$

Where $(\mathrm{P_{ni}})$ = probability of person (n) rating survey question (i) as agree,

$(1 - \mathrm{P_{ni}})$ = Probability of person (n) rating a survey question (i) as disagree,

θ_{n} is the ability of the person (n), and δ_{i} is the difficulty of survey question (i).

When a set of responses have more than 2 answers, like a 9-point hedonic scale, the Rasch dichotomous Rasch model cannot be used. In this case, the rating scale Rasch model, the partial credits Rasch model are used.

2.7.4.1.2 The Rating scale Rasch model (RS- Rasch model)

The Rating Scale model (Andrich, 1978) is used when there are more than two categories on a rating scale for example the 9- point intensity scale, and when the categories of the scales for all the items in the survey or test are all the same throughout that survey or test. Similar to the Rasch dichotomous Rasch model, WINSTEPS® software is used in this estimation, however the Rasch equation for the rating scale is:

$$\mathbf{ln}\left(\frac{\mathbf{P_{nik}}}{\mathbf{P_{nik-1}}}\right) = \boldsymbol{\theta}_{\mathbf{n}} - \boldsymbol{\delta}_{\mathbf{i}} - \boldsymbol{\tau}_{\mathbf{k}}$$

Where $\mathbf{P_{nik}}$ is the probability that a person **n** responds to category **k** of rating scale item **i**,

$\mathbf{P_{nik-1}}$ is the probability that the same person chooses adjacent category **k-1** of a rating scale on same item **i**,

$\boldsymbol{\theta_n}$ is the agreeability of person **n**, $\boldsymbol{\delta_i}$ is the difficulty of item **i** and

τ_k is boundary estimate between category k and k-1

The RS- Rasch model was used for survey data in this research.

2.7.4.1.3 Partial credits Rasch model (PC- Rasch model)

The Partial credit model (Masters, 1982) is used when there are different rating scales (with different number of categories) used within a survey or test. For example, a 7-point Likert scale and a 5-point Likert scale used within the same survey or test. The software used in this estimation is also WINSTEPS®. However the Rasch equation for partial credits is;

$$\mathbf{ln\left(\frac{P_{nik}}{P_{nik-1}}\right) = \theta_n - \delta_i - \tau_{ik}}$$

Where $\mathbf{P_{nik}}$ is the probability that a person **n** responds to category **k** of rating scale item **i**,

$\mathbf{P_{nik-1}}$ is the probability that the same person chooses adjacent category **k-1** of a rating scale on same item **i**,

$\boldsymbol{\theta_n}$ is the agreeability of person **n**, $\boldsymbol{\delta_i}$ is the difficulty of item **i** and

τ_{ik} is the boundary estimate between category k and k-1 for survey item **i**

2.7.4.1.4 The Many-Facet Rasch model (MFR model)

The Many-facet Rasch model (Linacre, 1989) is used when there are additional facets (besides person's ability and item difficulty) to be accounted for, for example a sensory test involving the consumption of samples. A facet is defined as any factor, variable or component of the measurement which is assumed to affect test or assessment scores in a systematic way (Eckes, 2015). The purpose of a many facet Rasch model is to account for variations, such that context bias is accounted for and eliminated from the interpretation of the result. When the characteristics of the facets are accounted for, the results generalise beyond the specific elements of the assessment such as the particular evaluators, questions, or situations encountered (Lunz and Linacre, 1998). For example, in sensory studies where there are at least three facets, the attributes being rated, the panellists and the products being rated. The software used for this estimation is called FACETS®. However, the equation of the many-facet Rasch model for sensory tests is:

$$\mathbf{ln}\left(\frac{\mathbf{P_{mnik}}}{\mathbf{P_{mnik-1}}}\right) = \boldsymbol{\beta_m} - \boldsymbol{\theta_n} - \boldsymbol{\delta_i} - \boldsymbol{\tau_k}$$

Where $\mathrm{P_{nmik}}$ is the probability of product (m) being rated category (k) in item (i) by assessor (n)

$\mathrm{P_{nmik-1}}$ is the probability of product **(m)** being rated in category k-1 in item (i) by assessor (n),

B_m is degree of severity of evaluating product **(m)**

$\boldsymbol{\theta_n}$ is the agreeability of person **n**, $\boldsymbol{\delta_i}$ is the difficulty of item **i** and

$\boldsymbol{\tau_k}$ is the boundary estimate between category k and k-1

The MFR model is made up of the rating scale many-facet Rasch model (MFR-RS) and the partial credits many-facet Rasch model (MFR-PC). The later is used when the rating scale used in the test or survey all have the same categories. Both MFR-RS and MFR-PC were used for sensory tests data.

2.7.4.2 Rasch analysis quality control checks

To ensure that measures obtained from Rasch model are objective, certain quality control checks are carried out.

2.7.4.2.1 Rating scale quality

Rating scales have to be oriented in the direction of measurement, this means, higher use of scale categories would mean more of the measurement (Eckes, 2015). A major source of misfit is from panellists, using rating scales inconsistently (Pallant and Tennant, 2007). Rating scales not functioning as they should would imply that certain categories are not being used as expected, for example, on a 9-point intensity scale, category 1 being used too few times when compared to other categories would mean that that category is redundant and needs to be collapsed. Category collapse means that certain categories need to be added to another category that either comes before or after it on the rating scale to make a new category which is not being used. (Eckes, 2015) suggested several guidelines and remedial actions that can be taken if the rating scales are not functioning as expected (table 2.6). Scale collapse must be thoughtful and logical (Wright and Linacre 1992; Wright 1996; Bond and Fox, 2013), this means that consideration must be given to meanings of categories of scales before they are collapsed such that a category with negative value or meaning should not be collapsed with one with positive value or meanings.

Table 2.6: Rating scale quality indicators and guidelines adapted from Eckes (2015)

Indicator	Higher Scale Quality	Lower Scale Quality	Remedial Action
Number(N) of responses in each category	$N \geq 10$	$N < 10$	Omit categories, renumber categories sequentially, and collapse categories.
Response frequency across categories	Regular (uniform, unimodal, bimodal)	Irregular (highly skewed, unobserved categories)	Collapse adjacent categories
Average measures of category	Monotonic increase with category	Reversals	Collapse non-increasing, adjacent categories
Model fit of rating scale	$MS^1_U < 2.0$	$MS_U \geq 2.0$	Omit responses, Collapse categories, omit categories
Threshold order	Monotonic increase with category	Disordered thresholds	Collapse adjacent categories
Size of threshold increase (logits)	≥ 1.4 and < 5.	<1.4; ≥ 5.0	Redefine or combine categories; redefine of split categories

MS_U = mean-square outfit statistic

2.7.4.2.2 Fit statistics (Item and persons, and product fit)

Fit statistics are another criterion for assessing the quality of the rating scale, it describes how well a data conforms to the Rasch model. There are two types of fit statistics to consider: infit and outfit statistics. The latter is more sensitive to data outliers. An outfit mean square of > 2 could degrade measurement (Linacre 1999) meaning that the particular category is introducing more noise than useful meaning on the other hand outfit mean square greater less than 0.5 would indicate that the information provided is too predictable. Linacre and Wright (1994), provide recommendations for examining the person and items fit (table 2.7).

Table 2.7: Interpretation of parameter-level mean square fit statistics (Wright and Linacre 1994).

Interpretation of parameter-level mean square fit statistics	
>2.0	Distorts or degrades the measurement system
1.5-2.0	Unproductive for construction of measurement but not degrading
0.2-1.5	Productive for measurement
<0.5	Less productive for measurement, but not degrading. It may also product misleading good reliabilities and separations

2.7.4.2.3 Unidimensionality and local independence

Rasch model assumes unidimensionality and local item independence. Unidimensionality means that all items or attributes in an instrument are measuring the same latent variable, while local item independence makes the assumption that once the latent trait has been accounted for, the residual correlations between items should be close to zero (Makransky et al., 2015).

2.7.4.2.4 Wright maps

A Wright map is a technique through which data from ratings scales and tests can be displayed (Boone et al., 2014). They are positioned such that, in surveys conducted during this research. For example, persons who consume foods with chilli more frequently would be located at the top of the map and items which can be used indicate more consumption would be at the top and vice versa.

2.7.4.2.5 Separation, strata, reliability, and homogeneity index

Separation reliability (R)

Separation is a Cronbach's alpha/KR-20 type of statistic. The equation which is used for calculating the separation reliability is:

$$R = \frac{\sigma_{True}}{RMSE} = 1 - \frac{\sum(SE)^2/n}{\sigma^2_{Observed}} = 1 - \frac{RMSE^2}{\sigma^2_{Observed}}$$

Where,

R is the Separation reliability,

σ_{True} is the standard deviation of measures corrected for measurement error,

RMSE is the root mean square error,

$\sigma_{Observed}$ is the observed standard deviation of measures,

SE = standard error

Separation ratio (G)

Separation is the signal to noise ratio in the data, it compares the dispersion of the measures with the measurement error. It predicts the number of statistically distinguishable levels that can be identified in a sample when the tails of the distributions are considered as merely measurement error (Eckes, 2015)

$$G = \frac{\sigma_{True}}{RMSE} = \frac{\sqrt{\sigma^2_{Observed} - RMSE^2}}{RMSE} = \sqrt{\frac{R}{1-R}}$$

Where

G is the separation,

$RMSE$ is the root mean square error,

σ_{True} is the standard deviation of measures adjusted for measurement error,

$\sigma_{Observed}$ is the observed standard deviation of measures,

R is the Rasch reliability.

Strata (H)

This is also called separation index If the tails of the sample distribution are treated as extreme levels, then the separation G can be interpreted into strata (Linacre, J.M.J.R.D., 2014; Linacre, J.M. and Wright, 2002). Strata can be calculated using the following equation.

$$H = \frac{\sigma_{True} \times 4 + RMSE}{RMSE \times 3} = \frac{G \times 4 + 1}{3}$$

Where

σ_{True} is the standard deviation of measures adjusted for measurement error

$RMSE$ is the root mean square error

G is the separation,

H is the strata.

Homogeneity index (Q)

This index is used to test the null hypothesis that the persons /items measures in the population are all similar after accounting for error in measurement (Eckes, 2015).

$$Q_j = \sum_{j-1}^{J} w_j \left(\hat{a}_j - \hat{a}_+\right)^2$$

Where

$$\hat{a}_{+} = \sum_{j-1}^{J} w_j \, {}^{\hat{a}_j}\!\Big/_{\sum_{j-1}^{J} w_j}$$

$$w_j = {}^{1}\!/_{SE^2}$$

SE_j = standard error that is associated with the estimate of the severity parameter of panellist j

Severity estimate = ʌ on parameter a

Q_j is $df = j - 1$

2.8 Justification of research

Current methods used to measure the oral perception of the intensity of chilli (capsaicin) hotness are based on consumers rating the hotness intensity and liking of the food being tasted (Nolden and Hayes, 2017; Byrnes and Hayes, 2013; Byrnes and Hayes, 2015; Ludy and Mattes, 2012). Based on these methods, food products are labelled as mild, medium, hot, very hot etc. depending on the perception of panellists who sample the foods. Expectedly, ratings of these foods may vary such that samples which have been labelled as hot during a test using one set of panellist, may have a different rating during another test using a different set of panellist. to further buttress this, (Perkins et al., 2002) demonstrated that the labels of hotness levels for commercial salsa products varied greatly between brands, with some samples containing three times as much capsaicin content when compared with others within the same hotness label. This meant that even though the salsas from various brands had same label e.g. “mild” there was a huge variation in the capsaicin contents between brands. This “inconsistency” in labelling can be confusing for existing consumers (Schneider et al., 2014) and may be a deterrent for potential consumers of foods with chilli.

The need to develop methodologies to understand the drivers of consumption and develop methods through which measurement of hotness can be measured with minimal variation in results is necessitated by the constantly growing interest in foods with chilli.

This new measurement which aims to give minimal variation to measurement of the perception of hotness might be achieved by including all factors which have been shown to have an impact in the measurement of oral perception of hotness. Factors such as drivers of perception, tolerance to chilli, liking of chilli and the perception of the hotness of chilli. This new measurement might provide an alternative method to measure the hotness of foods with chilli, with the aim of improving labelling of food products in a bid to satisfy new and existing consumers of foods with chilli. It is therefore important to develop a method that can give minimal variation when used, irrespective of consumer's inconsistency, and also accounts for bias in participants, the Rasch model provides this platform.

2.9 Overview of research

2.9.1 Research aims

The aims of this thesis were to:

1. Develop a survey for segmentation of consumers of foods with chilli using their consumption drivers.
2. Develop a method for measurement of tolerance levels of consumers using capsaicin solutions with varying concentrations.

3. Investigate the influence of liking on perception of intensity of burn and tolerance.
4. Develop an objective measurement for the oral perception of foods with chilli using attributes which have an impact in perception of hotness intensity.

The research objectives were,

1. To utilise focus groups and existing literature to develop a survey for investigating the drivers of consumption of foods with chilli.
2. To investigate the impact of pain measurement on the measurement of tolerance
3. To examine if a relationship existed between liking of burn and rating of burn and tolerance
4. Determine attributes which influence the perception of hotness intensity of foods with chilli.

2.9.2 Research hypothesis

This research tested the hypothesis that a single measurement scale can be developed to measure the oral perception of hotness intensity of chilli

2.10 Conceptual framework

To achieve the objective measurement which this research had set out to develop, it was hypothesized that an objective measurement for the perception of hotness of foods with chilli, would be one that included all components which have been shown to have an effect on the perception of hotness intensity of a food. To test this hypothesis, each factor (Liking of hotness, tolerance, perception of hotness) was tested separately and then included in the overall measurement if they were shown to have a contributory factor to the perception of oral hotness. This theory was put forward considering that tolerance and preference had been reported as two major factor which would affect the perception of hotness of foods with chilli, this is because, people’s preferences and their tolerance levels are the major causes of variation (Rozin, Paul and Schiller, 1980) in the rating of the hotness of chilli.

To understand the factors which drove consumption of foods with chilli, a survey was developed to give insight into consumers and what influenced their consumption of food with chilli. These consumption drivers would also serve as a basis for segmenting the consumers of foods with chilli. Tolerance study was conducted to investigate how tolerance to foods with chilli affected perception of hotness intensity. Pain and hotness intensity were used as first measure of tolerance. This was used because several other pungency attributes had been studied in relation to capsaicin/ chilli, however the pain caused by chilli had not been explored. This study explored the relationship between pain and hotness intensity and once this was proven to have an impact on the perception of hotness intensity, pain was then used together with other reported attributes evoked by capsaicin as a wholistic measure of tolerance.

Liking of the burn of chilli has been reported to have an influence on the perception of hotness. Individuals who liked the burn of chilli have reportedly rated hot samples as less hot and this was investigated using two studies. The first study compared the rating of burn sensitivity, burn tolerance, and burn liking to discern the relationship between tolerance and liking of the burn of chilli using noodles. To validate the first study, the second study investigated how tolerance attributes of chilli tomato soups affected the rating of liking of these soups. The theory was that tolerance to and liking of the hotness of foods would have an effect on the perceived hotness of these foods so much so that they would have to be included in the measurement of the actual perception of the hotness of chilli.

2.11 Thesis structure

This thesis is made up of 8 chapters. The first two chapters introduce the research and review literature. In chapter 3, general materials and methods are provided. Chapter 4 showed information about the survey development and segmentation. Chapter 5 presented 2 studies relating to measurement of tolerance. Study 1 showed how using pain in the measurement of overall intensity was important, study 2 showed how the use of multiple attributes in the measurement of tolerance provided better measurement than using two attributes. Chapter 6 presented 2 studies on the influence of liking on measurement of hotness using 2 different food types, noodles and soups. Chapter 7 showed the development of the combined scale, using only attributes which contributed to measurement of oral perception of hotness and provided general conclusions of the study and the final chapter provided references used in this research.

Chapter 3 Materials and methods

All items and attributes used in this study were developed using the four building blocks of measurement (Wilson, 2014), as adapted by Ho (2019). Figure 3.1 shows the stages which are important in building measurement.

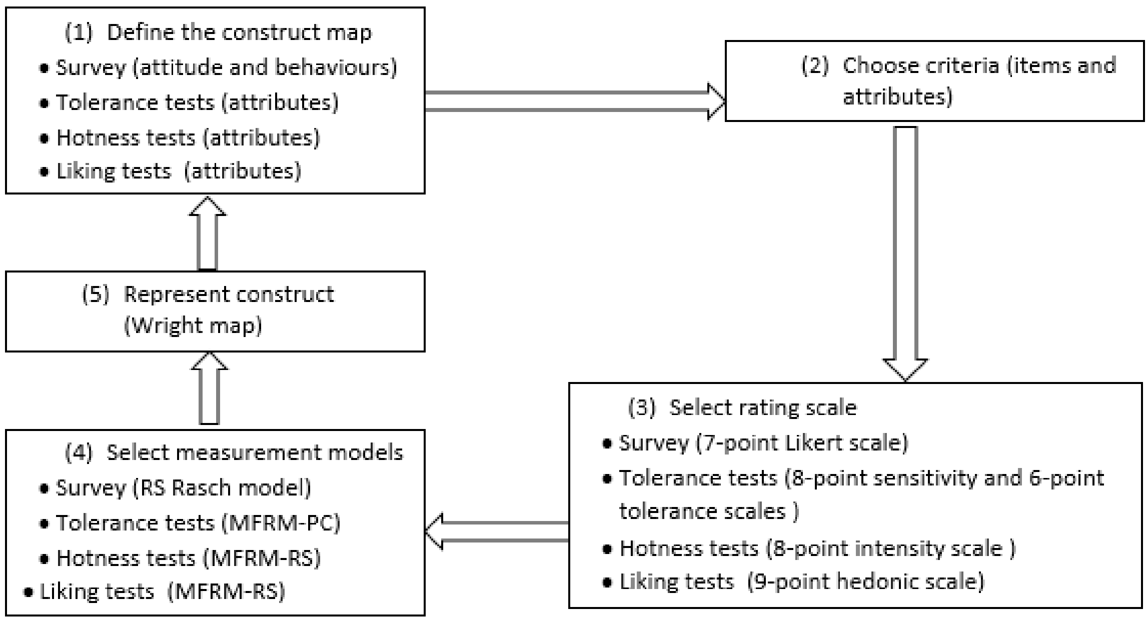


Figure 3.1 Stages of measurement build adapted from Ho (2019) .

3.1 Defining the construct

Construct maps were individually defined for all studies which were conducted for this thesis. For the survey, the construct was defined such that items which represented consumption drivers would be easier to agree to than items which were not consumption drivers for the consumer.

For the tolerance study, the construct was defined such that participants who had higher tolerance levels would be at the top part of the construct map with those with lower tolerance levels located at the bottom, also products which had higher concentrations would be at the top of the map with those which were less intense at the bottom. Prominent attributes would be located at the top of the map with less prominent ones at the bottom (figure 3.1).

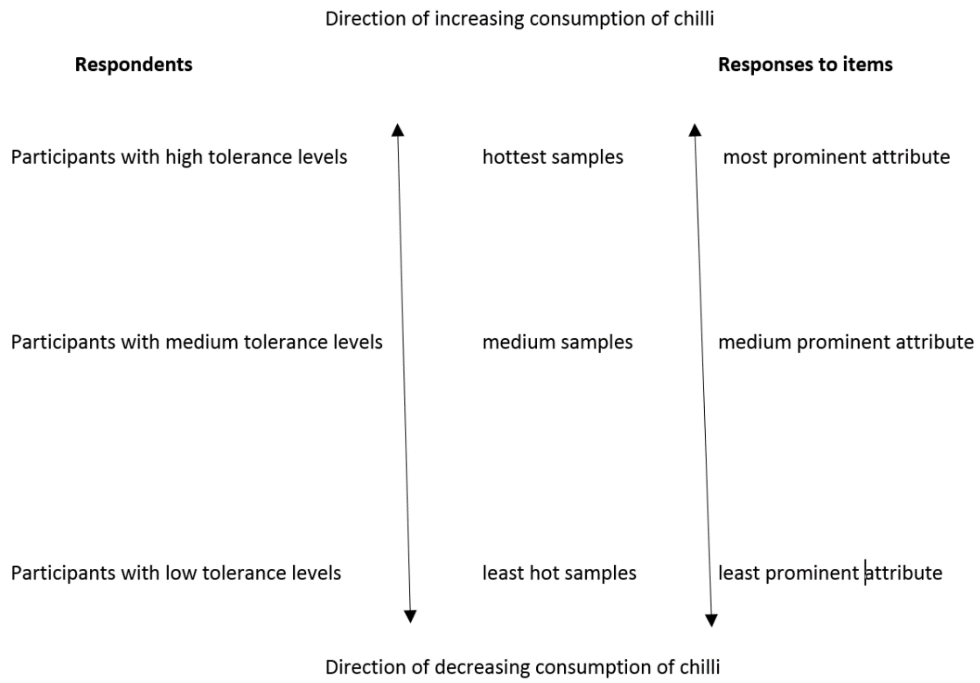


Figure 3.1: Construct map for tolerance studies

The construct map for the hotness study was defined such that participants who used the high end of the 7-point category scale would be at the bottom of the construct map. Participants who perceived the samples as being less intense used the lower end of the rating scale would be located at the top of the construct map. Also, products which had higher concentrations would be at the top of the map and those which were less intense would be at the bottom. Prominent attributes would be located at the top of the map with less prominent ones at the bottom.

For the liking study, participants who liked sample would be at the top of the construct map, with those who disliked samples at the bottom. The most liked products would be located at the top of the map as would be the most prominent/ or most agreed with attribute (figure 3.2).

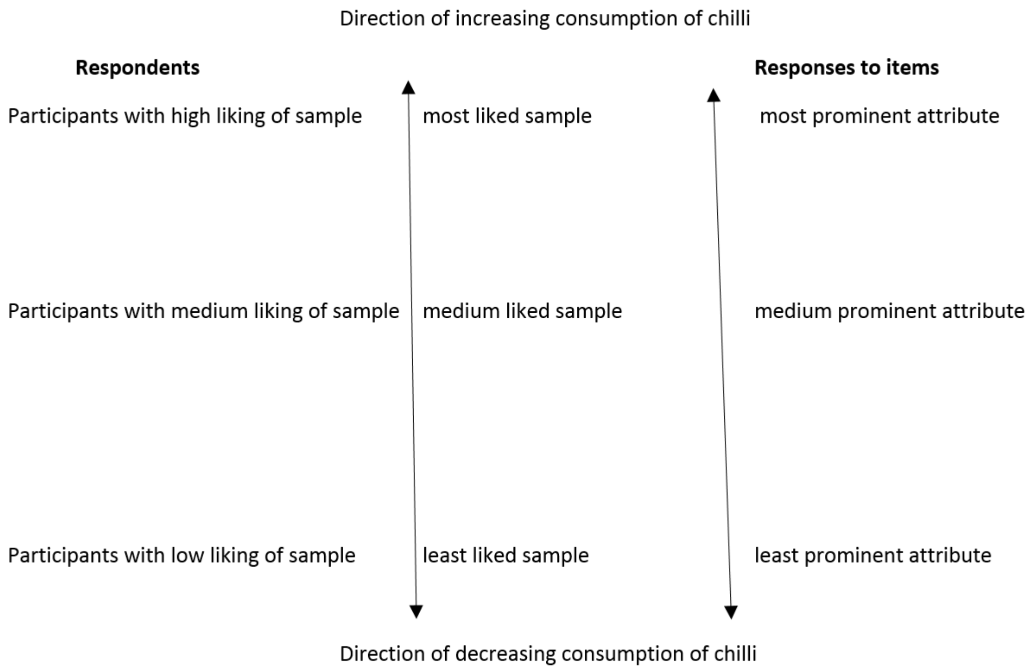


Figure 3.2: construct map for liking studies

3.2 Items design and outcome space

To develop the survey questionnaire, items for the survey were obtained both from existing literature and from a focus group study. Information was obtained from the participants using a 7-point Likert scale, ranging from strongly disagree (1) to strongly agree (7) and a mid-point of neither agree nor disagree (4)

Two separate tolerance tests were conducted, and two sets of attributes were developed. The first set of attributes used were only intensity and pain, which were measured with the 9-point intensity scale and the 11-point subjective pain scale respectively. The second tolerance test was conducted using multiple attributes including pain, to get a more wholistic measurement of tolerance. The attributes used were burning tolerance, burning sensitivity, pain tolerance, pain sensitivity, prickling tolerance, prickling sensitivity, itching tolerance, itching sensitivity itching, irritation tolerance, irritation sensitivity, numbing sensitivity and numbing tolerance. These attributes were rated on the 8-point sensitivity scale or the 6-point tolerance rating scale (table 3.1).

Table 3.1: 8-point sensitivity scale and the 6-point tolerance rating scale

Sensitivity rating scale	Tolerance rating scale
1=None	1=Completely able
2=Barely detectable	2=Slightly unable
3=Slight	3=Moderately unable
4=Moderate	4=Strongly unable
5=Strong	5=Extremely unable
6=Very strong	6=Completely unable
7=Extremely	
8=Strongest sensation ever experienced	

For hotness tests, the 8-labelled categories from the gLMS were used as the rating scale of chose for all attributes which dealt with intensity (table 3.2). This was chosen for being the scale which had a wider range of categories which were adequately labelled to collect information from participants. For liking, 3 attributes were rated-: liking of hotness, liking of flavour, and liking of taste of samples. The 9- point hedonic scale was used in the rating of liking of samples.

Table 3.2: 8-point intensity scale for rating intensity of samples.

8-point intensity scale
1=None
2=Barely detectable
3=Slight
4=Moderate
5=Strong
6=Very strong
7=Extremely
8=Strongest sensation ever experienced

3.3 Measurement model

3.3.1 Statistical analysis

3.3.1.1 Exploratory factor

Exploratory factor analysis was used to determine the factors within the survey after all items were generated. Factor analysis was conducted using the ***psych*** package **on** R**.** The criteria used to select appropriate factors were the Root Mean Squared Error of Approximation (RMSEA) and RMSEA, lower bound (RMSEA.LB). Factor solutions with RMSEA and RMSEA.LB lower than 0.06 (Hu and Bentler, 1999) and 0.05 (Preacher *et al. 2013*) respectively were selected to aid in the selection of the best factor. The reliability of each factor was then checked using Cronbach alpha. Values closest to 1 imply that the factor can be used to describe each dimension. Using the factors that had been obtained from the principal axis factor analysis, Rasch analysis was conducted.

3.3.1.2 Cluster analysis

Rasch measures were further analysed using R. mclust package was used to determine the most appropriate cluster solution. K-means clustering was used to conduct cluster analysis. Independent t-test was used in comparing the 2-

cluster solution. Independent test has 2 assumption, equality or variances and normality. Levene's test was used to test normality assumption if this assumption was not held, a Welch t-test was conducted. To check normality, Shapiro-Wilks test was conducted. If normality did not hold, the Mann-Whitney test was used. For cluster solutions that were greater than two, one factor ANOVA and multiple comparisons were applied. One factor ANOVA was conducted using R, (RcmdrPlugin.NMBU package).

3.3.2 Select measurement model (Rasch model)

RS-RM was used for data analysis in the survey by fitting data to WINSTEPS®, this was because there were only 2 facets and each item used equal category rating scales, on the other hand, The MFR model was used in the analysis of all the sensory tests by fitting all sensory data into FACETS ®. This was because in all sensory test, there were at least 3 facets, persons, items (attribute) and the products.

3.3.2.1 Quality control checks

Quality control checks for all Rasch data generated were made using the criteria outlined in section 2.7.4.2. Figure 3.3 summarises the procedure.

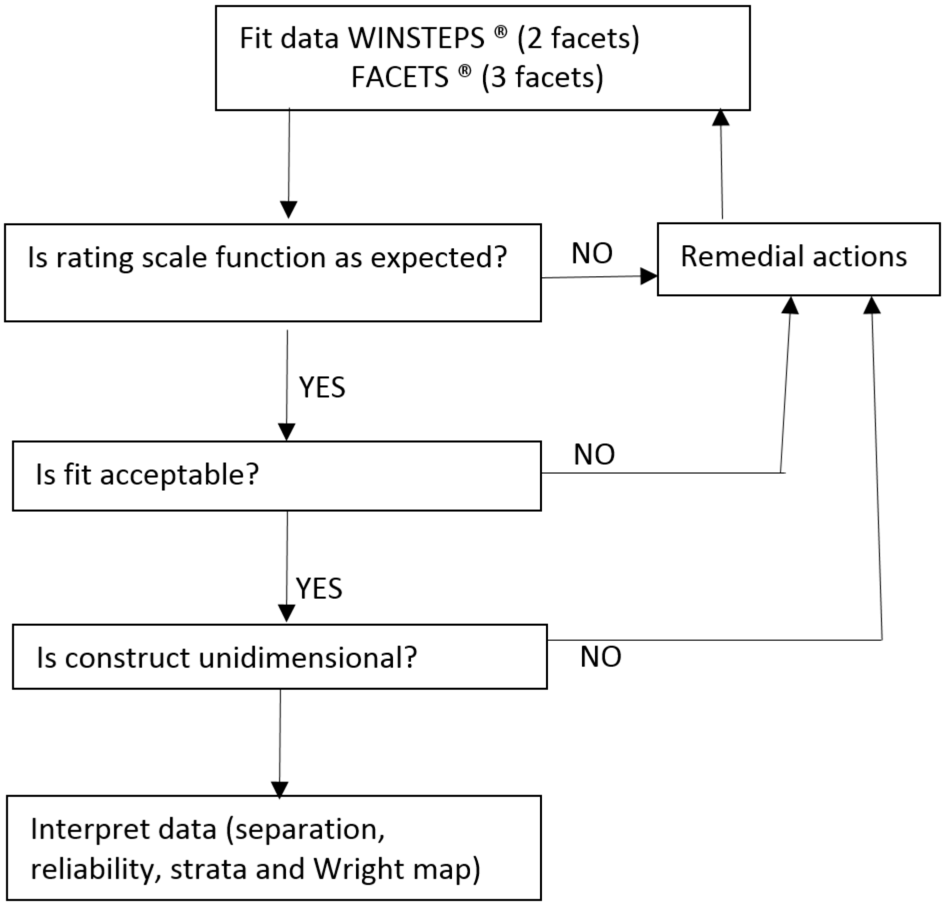


Figure 3.3: Schematic for fitting Rasch model

3.3.2.2 Division into statistically significant levels using Rasch measure and standard error values

Panellist were divided into statistically significant groups using their Rasch logit measures and standard error values. To get the logit measure for this division, an Anchorfile= was generated from FACETS®, data for every raw score was then included in the Anchorfile=. In Labels+ an unanchored person was included for each raw score. Finally, the new Anchorfile= was analysed. The newly generated persons measure and standard error were then used in the pairwise comparison to obtain statistically significant groups.

3.3.2.3 Unidimensionality and local item independence check

Unidimensionality of attributes and local item (attribute) independence were checked for using Winsteps (Linacre, 2017). To do this, a Winsteps control data was created by combining the panelist and products in to one facet and attributes to another facet. This was done so that Principal Component Analysis on standardized residual (PCAR) and standardized residual correlations (Linacre, 2017; Smith 2002) could be compared for unidimensionality and local item dependence respectively. Unidimensionality was examined with Principal Component Analysis of Rasch residuals (PCAR) and by comparing standardized residual correlations respectively obtained from Winsteps® (Linacre, 2017b). The check for unidimensional was done by comparing the disattenuated correlations of the subsets of items with the highest (cluster 1) and lowest loadings (cluster 3) on the first unrotated PCAR component (Ho, 2019). To interpret disattenuated correlations, values of < 0.57 would likely indicate that the two set of items were are from different latent variables, on the other hand, values of > 0.82 would indicate that they most likely belong a single latent variable (Linacre, 2017b, Ho 2019). The assumption of local item independence was tested using values from table 23 in Winsteps® (Linacre, 2017b). This was done by comparing residual correlation of pairs of items. If the correlation value was > 0.3 items were considered locally dependent (Linacre 2019).

3.4 Sample preparations and test procedures

3.4.1 Capsaicin solutions

The first capsaicin sample was prepared using Byrnes and Hayes 2016, where capsaicin powder was diluted in 95% ethanol and was the further serially diluted to give the desired concentrations. This was not used for the rest of the research because the presence of alcohol in the sample excluded persons who were not allowed to consume alcohol either for religious or person reasons. Excluding these participants would have exerted a strain on participant numbers which was challenging to recruit. For this reason, a second method without the use of alcohol was used for all studies requiring capsaicin solutions.

3.4.2 Chilli powder and soups

3.4.2.1 Sample preparation

Dried habanero chilli samples used throughout this study were purchased in one batch from South Devon chilli farm, Wigford cross, Loddiswell, Devon, United Kingdom. This was then milled using Kenwood food processor KMC515 and used in powder form throughout this study, for the making of chilli extract liquid and chilli tomato soups, All soup bases were made using Morrison’s chopped tomatoes, garlic, onions, Knorr vegetable stock cubes, water and Morrison’s vegetable oil purchased from Morrison’s supermarket, Leeds, United Kingdom.

3.4.2.1.1 Soup trial 1

This experiment was conducted to set levels for the hotness of soups for studies using chilli tomato soup. 800 g of Morrison’s chopped tomatoes, 32 g of garlic, 218 g of onions (2 medium onions) 2 Knorr® vegetable stock cubes, 1 litre of water, 20 g of Morrison’s vegetable oil were prepared and placed in a pan on the hob. When soup was cooked, 90 g of soup base was transferred to 5 clean beakers and dried milled chilli ranging from 0.2 - 1 g was added to samples. A trial was conducted using five colleagues, two of which were low users of chilli, and four high users. The set levels of hotness of the soups derived from adding 0.2 - 1 g of chilli powder to soups was not satisfactory as there was an overlap in hotness perception, with some soups giving the same perceived degree of hotness. This resulted in another trial with a better spread of weight of chilli powder used in soups.

3.4.2.1.2 Soup trial 2

For this trial, 200 g of soup which was prepared in the food laboratory was transferred to 6 clean beakers which had chilli powder ranging from 0.5- 5 g added to achieve soups of varying degree of hotness. This trial was conducted on a separate day from the first soup trial but using the same participants. During this trial, it was realised that the reason the hotness of soups overlapped in soup trial 1 was that the particle size of the milled chilli was uneven as the blender could not sufficiently blend the dried chilli to fine particles, and the dried chilli was not as homogenous as it could be. This lack of homogeneity due to the rough nature of the milled chilli occurred because different parts of the chilli fruit have different levels of hotness, therefore if the dried chilli is not finely milled, this will be problematic. This resulted in soup samples not having increasing hotness as it should, given that there was varying weight of chilli powder added to the same quantity of soup. To overcome this drawback with the chilli powder, a final method of making chilli powder into a solution was used for any study which required the use of chilli.

3.4.2.1.3 Chilli stock solution

Solution was prepared using modified ASTM (2006). 2.5 g of ground habanero sample was weighed and combined with 0.2 g of polysorbate-80 and was made up to 100 g with 75°C distilled water. This was then placed on a hot plate stirrer which was preheated for 4 minutes on high heat on medium stirring speed. The hot plate stirrer was set on high heat for 1.5 minutes, then switched to medium heat for 20 minutes of simmering (90°C) and stirring. The extract was then filtered using coffee filter paper. The final stock solution was refrigerated for use in tomato soups or for the studies with chilli extract.

3.4.3 HPLC

The quantity of capsaicin in the chilli tomato soups used in this research was quantified using HPLC.

3.4.3.1 Equipment

An Agilent Technologies 1200 series HPLC with a combined Diode array (DAD) and Fluorescence detector (FLD) was used.

3.4.3.2 Principle of High-performance liquid chromatography

The high-performance liquid chromatography (HPLC) for the purpose of this current research was used to quantity capsaicin and dihydrocapsaicin from extracted test food samples by measuring the wavelength absorbed. The HPLC was equipped with a Quaternary gradient pump, a Diode array detector consisting of high pressure 10 mm 1.7 µl and prep-cell, and a Fluorescence detector. All detector compartments were designed for high intensity and low limit wavelength measurements. The HPLC Column compartment was equipped with a column-identification tag and a C18 column (4.6 x 250 mm, 5 µm) with a column temperature of 30ºC to dictate wavelength of 282 nm to allow the recording of column specific information. The equilibrated column heating and cooling temperature provided a high resolution and separation of capsaicin and dihydrocapsaicin.

The mobile phase used was 99% acetonitrile with a flow rate of 1 mL/min. Autosampler (AS) and column temperature was 30°C to keep the baseline stable for reproducibility and the injection volume for samples by AS was set at 20 µL and pressurized with nitrogen gas. Before the injection of samples by the AS, the column was flushed for 8 min with 45% acetonitrile (Table 3.3). Afterwards, the concentration of acetonitrile was increased steadily from 45 to 90% in 32 min, before eluting with decreasing concentration of acetonitrile from 90 to 45% for 15 min. The separation of capsaicin and dihydrocapsaicin was attained in 55 min and detected by DAD. The data recorded from the process was collected in real time by Nelson (online) method and run control on a computer. The final result of capsaicin detection as recorded from the area of the chromatogram was calculated and presented as percentage capsaicin and dihydrocapsaicin in wet weight.

Table 3.3: Program of gradient elution for soluble sugars separation by HPAEC-PAD

Time (mins)	% Water	% Acetonitrile (99% conc.)
0	55	45
8	50	50
15	45	55
40	10	90
45	55	45
55	55	45

3.4.3.3 Preparation of HPLC eluent

Two eluents were prepared for HPAEC-PAD analysis; HPLC grade water and 99% acetonitrile (HPLC gradient grade; Sigma CN34851).

3.4.3.4 Sample preparation for HPLC

For the estimation of capsaicin and dihydrocapsaicin in test samples, 500 mg of test samples (prepared according section 3.4.2 were suspended in 20 mL of 100% methanol solution. The suspension was sonicated for 60 min in a Grant sonicator (XUB12) at room temperature. For preparation of standard solution, 10 mg of capsaicin or dihydrocapsaicin were suspended in 10 mL of water and then further diluted in 100% methanol to obtain standard solutions within the range of 1 to 1000 µg/mL. Both the sonicated test sample suspension and standard dilutions were filtered through a 0.45 µM polytetrafluorethylene (PTFE) membrane into a HPLC snap vial before injection.

Chapter 4 Segmentation of chilli consumers using their consumption drivers (study I)

4.1 Introduction

Consumer segmentation involves categorisation of consumers into similar groups based on one or more important characteristics which they share (Wedel and Kamakura, 2012). it can be used to identify consumers with similar characteristics, like similar attitudes, habits, and beliefs, these similarities are then used to understand consumers. The Information gathered from segmentation can be useful for product development and for developing better marketing strategies (Næs et al., 2010).

Current segmentation of consumers of foods with chilli are basic as they rely on self-reported annual consumption or self-reported chilli heat level preference. This basic segmentation process does not provide detailed information about the consumers of chilli. There needs to be a method through which consumers of foods with chilli can be segmented by their motivations to eat chilli. A survey provides this medium and detailed information obtained from this process can then be useful for the food industry.

This part of the research was carried out in two stages, the first stage involved a focus groups study, which was used to generate survey items. The second stage used the items generated from the focus group and from existing literature to develop a survey which was then used to collect data about the desired segmentation criteria. The flow chat in figure 4.1 illustrates this process.

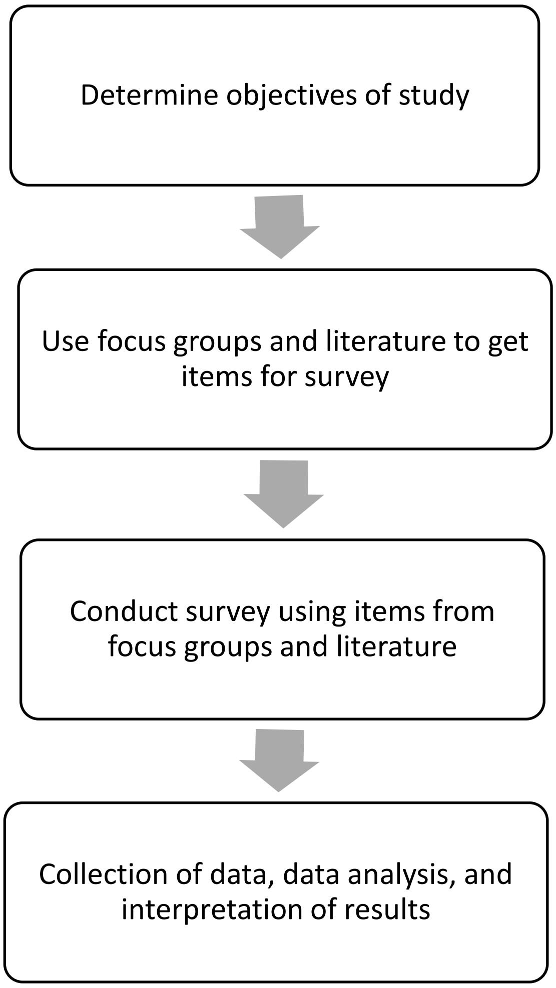


Figure 4.1: Process flow diagram for segmentation process

4.1.1 Aim of study

The aim of this study was to develop an instrument which could be used in the segmentation of consumers of foods with chilli using their consumption drivers.

4.1.2 Objectives of study

The objectives of this study were to:

(1) Develop an instrument using consumption drivers of foods with chilli.

(2) Segment consumers of foods with chilli using the developed instrument.

4.1.3 Research hypothesis

This study tested the hypothesis that consumers of foods with chilli could be segmented using their consumption drivers.

4.2 Materials and Methods

Wilson’s four building blocks of measurement (Wilson 2004) was the foundation through which this survey was built. As discussed in section 2.7, the four building blocks are the construct map, item design, outcome space and measurement model.

4.2.1 Defining the construct

This stage was the conceptual stage of the measurement development. It involved drawing and visualising the measurement instrument of interest whereby a construct map was drawn to visualise the type of items which might be of use to meet the study objectives. Figure 4.2 shows the construct map which was drawn to determine items which might be of interest in development and the type of participants who might be useful in developing items which would be useful in understanding drivers of foods with chilli.

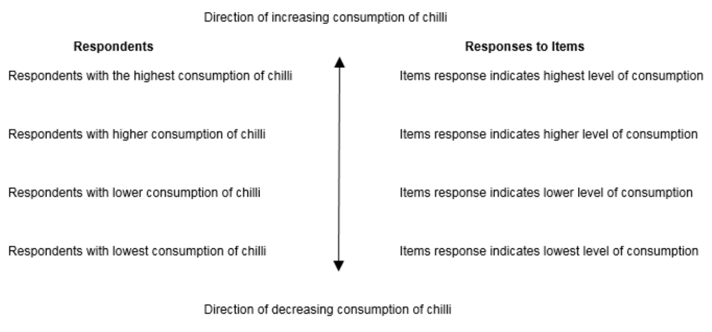


Figure 4.2: Survey construct map

4.2.2 Items design

The items design stage of the study involved bringing the construct map to reality by developing a pool of items which would be used for the survey. The Items were generated in two folds; using focus groups and from adaptations from literature (Rozin and Schiller, 1980, Renner et al. 2012). A focus group was chosen as the preferred method to generate questions for the online survey because It provided the opportunity for synergic discussion amongst participants (Lawless, H.T. and Heymann, 2010).

4.2.2.1 Focus group

The focus group was used to explore the hypothesis that more information could be derived about the consumption drivers of foods with chilli from consumers who consume these foods. Ethical approval was granted for this study (**Ethics number MEEC15-014**). Emails were sent out to students and member of staff of the School of Food Science, University of Leeds. Upon indicating interest, participants were sent a pre-screening questionnaire. These pre-screening questions were used to determine which consumption groups participants belonged to. The pre-screening questionnaire consisted of five questions, which were adapted from hedonics of capsaicin containing foods questionnaire as shown in figure 4.3. A total of 6 participants were recruited, they consisted of 4 high, 1 medium and 1 low self-reported consumers of foods with chilli.

Please answer the following question by marking ☒ in the appropriate box. For each question, Please, tick ONLY one answer. Thank You.

1. Do you like spicy foods?

☐ Yes ☐No ☐Sometimes

2. Frequency of ingestion of all types of spicy foods including Mexican, Indian, Chinese, Thai, Korean and other foods that contain chilli and cause tingling or burning?

☐Always ☐Regularly ☐Occasional ☐ Rarely ☐Never

3. How much do you like the taste of chilli in your food?

☐Like extremely ☐Dislike slightly

☐Like very much ☐Dislike moderately

☐Like moderately ☐Dislike very much

☐Like slightly ☐Dislike extremely

☐Neither like nor dislike

4. How much do you like the burn of chilli in your food?

☐Like extremely ☐Dislike slightly

☐Like very much ☐Dislike moderately

☐Like moderately ☐Dislike very much

☐Like slightly ☐Dislike extremely

☐Neither like nor dislike

5. What strength of spicy food eating do you prefer?

☐Weak ☐ Moderate ☐Strong

Figure 4.3: Pre-screening questions adapted from Lawless et al. (1985)

4.2.2.1.1 Focus group procedure

Consent forms were provided to participants at the beginning of the session and they were required to sign the form before they could proceed with the session. The session was voice recorded and participants were aware they were being recorded. Snacks were provided. During the session, participants were asked open ended questions to stimulate conversation, and to get some understanding of factors which influenced their consumption or non-consumption of spicy foods[1].

4.2.2.1.2 Items from focus group

Focus group participants defined spicy foods as foods with spices e.g. chilli, black pepper, ginger, curries, cloves, and cumin. They also defined spicy

[1] The initial direction of the research was on spicy food, this was then streamlined to foods with chilli after first year, by which time focus group had been held

foods as foods that had ingredients which caused any form of hotness for example, foods with chilli (habanero, jalapenos), mustard, ginger, and wasabi. Some others defined spicy foods with hot and strong substances, which cause pain in the mouth, and burning sensations. However, most of the participants associated spicy foods with foods that contain chilli. The types of spicy foods mentioned were Mexican foods, Thai foods, African foods, Indian curries, Chinese foods, and Pakistani foods. The common reasons for consumption was introduction at a young age similar to what was reported (Rozin, Paul and Schiller, 1980; Ludy and Mattes, 2012). The reasons for continued consumption of spicy foods were given as; “spicy food is part of my culture”, “I have always eaten spicy foods”, “spicy foods are interesting”, “I like the flavours associated with chilli”, “I really really like spicy foods” and “I enjoy the sensations I get from consumption”. Majority of the high consumers of spicy food said that spicy foods were a part of their tradition and culture. This is like what was reported by Rozin and Schiller (1980). Further reasons for consumption were: “I am used to it”, and “it is very delicious”. The low consumption consumer stated that “when a food is too hot it supresses other flavours in food, making it is difficult to appreciate the other flavours in the food”. Also, low consumption of spicy food was a result of not liking the burn caused by high levels of chilli in food. For high consumption of spicy foods, the first exposure to spicy foods was generally at home while to low eater had no early exposure to spicy foods and first contact with spicy food was after they had left home. High users consumed spicy foods every day while low user consume occasionally (about twice a year and very mild spicy foods). The high consumers reported that they always added spices to food especially if the food was bland as opposed to the low user who never added spices to food. The common spices of choice were chilli pepper and black pepper.

4.2.2.2 Items from literature

This stage involved researching and reviewing existing literature in which chilli had been studied and then using either the same questions which had been used in their questionnaires, or questions which arose from the findings of their research. These questions were then pooled together with those from the focus groups and examined to determine if the items were suitable for use in the survey. Some of the questions which were derived from existing literature were like those which were obtained from the focus group. When this occurred, it reinforced the inclusion of any such item in the survey.

After the completion of the item design phase, A total of 72 items obtained. However, if all 72 items were used in a survey, this would result in participant fatigue. To get the final items, a test run was carried out using data from 29 participants to determine which items were of no importance or were too like other items. A total of 35 items were used for the survey.

4.2.3 Outcome space: defining the rating scale

The choice of the rating scale that was used was also considered during this stage of the measurement building block. This process involved choosing an adequate rating scale which provides sufficient information from the survey items by giving the participants the right number of categories to choose from. The rating scale chosen for the survey was the 7-point Likert scale, ranging from strongly disagree to strongly agree with a mid-point of neither agree nor disagree was used to record responses to survey items. This was chosen as it had to have sufficient categories needed to provide information about participant's responses.

4.2.4 Measurement model

Rasch analysis was the desired statistical tool for analysing survey data. Exploratory factor analysis was used to determine the number of factors which existed within the survey. Cluster analysis was also used to determine the number of clusters which were present in the survey population.

4.2.5 Final survey

The final survey consisted of 35 items and also included items that sought to understand the person characteristics of the consumers and non-consumers of foods with chilli such as information about gender, age group, frequency of consumption of foods with chilli, preferred chilli heat, and age of exposure to foods with chilli. The final number of items derived after focus group study and literature review are shown in table 4.1. Original items refer to items as they existed in the original surveys from which they were obtained. The final items are the final modification of items to suit the purpose of this study. For example, item 10 was restructured from "out of family traditions" to "it is my family tradition". Also, item 12 was restructured to give an interpretation of the meaning of bland.

Table 4.1: Original items, final items and source

	Original items	Final items	Source
1		I like the taste	Focus group
2		I like their flavour	Focus group
3	I enjoy eating it	I enjoy eating it	Renner et al., 2012 and Focus group
4	It tastes good	It tastes good	Rozin and Schiller, 1980 and Renner et al., 2012
5		I like the aroma	Focus group
6	I feel good after I have eaten it	I feel good after I have eaten it	Modified from Rozin and Schiller, 1980.
7		I enjoy the sensation (e.g. tearing eyes, running nose etc)	Focus group
8	It is fun to eat	It is fun to eat	Renner et al., 2012 and Focus group
9	I like the burning or tingling feeling	I like the burning feeling I get from eating it	Rozin and Schiller, 1980
10	Out of traditions	It is a family tradition	Renner et al., 2012 and Focus group
11	I’m used to it / I eat it regularly	It is what I usually eat	Modified from Rozin and Schiller, 1980, Renner et al., 2012 and Focus group
12	Food taste bland without chilli	Foods taste bland (tasteless) without chilli	Modified from Rozin and Schiller, 1980.
13		My family eats it and they make me it	Focus group
14		It is my cultural meal	Focus group
15	I want to watch my weight	It helps me to control my weight	Renner et al., 2012
16	In order to fulfil my need for nutrients, vitamins and minerals	Chilli contains minerals and vitamins and has good nutritional value	Renner et al., 2012
17	I want to lose weight	It helps me to lose weight	Ludy and Mates, 2011; Renner et al., 2012

	Original items	Final items	Source
18	It is good for me	I think it is good for me	Modified from Rozin and Schiller, 1980
19	It kills the microbes in food/it is healthy	It keeps me healthy	Modified from Rozin and Schiller, 1980 and Renner et al., 2012
20	It stops me from being sick	It keeps me from getting sick	Rozin and Schiller, 1980
21	My family/partner thinks it is good for me	My family thinks it is good for me	Renner et al., 2012 and /Focus group
22	It makes me feel warm inside	It makes me feel warm inside	Rozin and Schiller, 1980
23		It keeps me warm when the weather is cold	Focus group
24		I like the excitement I get from eating it	Focus group
25		It stimulates my appetite	Rozin and Schiller, 1980
26	It cools me off	It cools me off when I am hot	Modified from Rozin and Schiller, 1980
27	It puts me to sleep	It helps me relax when I am stressed	Modified from Rozin and Schiller 1980, Renner et al., 2012
28	It cheers me up	It cheers me up when I am sad	Modified from Renner et al., 2012
29	I don't want to appear weak	I do not want to appear weak	Rozin and Schiller, 1980
30	It fills me up	It makes me feel full (satisfied)	Modified from Rozin and Schiller, 1980
31	It makes me strong	I think it makes me strong	Modified from Rozin and Schiller, 1980
32	It makes me think clearly	It makes me think clearly	Rozin and Schiller, 1980
33	It wakes me up	It makes me alert	Modified from Rozin and Schiller, 1980
34	My doctor says I should eat it/ It kills the microbes in food	My doctor says I should eat it	Modified from Renner et al 2012/ Rozin and Schiller
35	It makes it easier to chew food	It makes food easier to chew	Rozin and Schiller, 1980

The survey was presented in five sections, the first section was an introduction to the survey, and it gave information about the aim of the study and contact details of the researcher. The second section was the consent page and unless the participant clicked yes, they could not proceed to the rest of the survey. The third section presented the items used in the survey. The statement “I eat foods with chilli because…” proceeded the survey questions. The fourth section had information about consumption habits of participants. The final section collected information about the demographic variables of the participants.

The survey was made available via online survey (www.onlinesurveys.ac.uk) and was distributed online through emails and posters placed at strategic locations at the University of Leeds. It was also posted on Facebook groups for chilli lovers. Paper copies were also provided for participants who did not have access to computers at the time of contact. All paper copies were then manually entered into online survey.

Two hundred and thirty- five respondents participated in the survey. To make the groups large enough to compare, certain modifications were made. The age groups were collapsed such that all age groups above 35 were combined into one group. Also, Arabs, Mixed/Multiple ethnic and others were combined into a group and it was named others.

4.3 Results

4.3.1 Survey

Demographics from survey are reported (figure 4.4), the number of females was almost three times more than males. More participants were in the age group 16-24 years, this was expected as recruiting was done amongst student population. There were more Whites than Asians and any other ethnicity who took part in the survey.

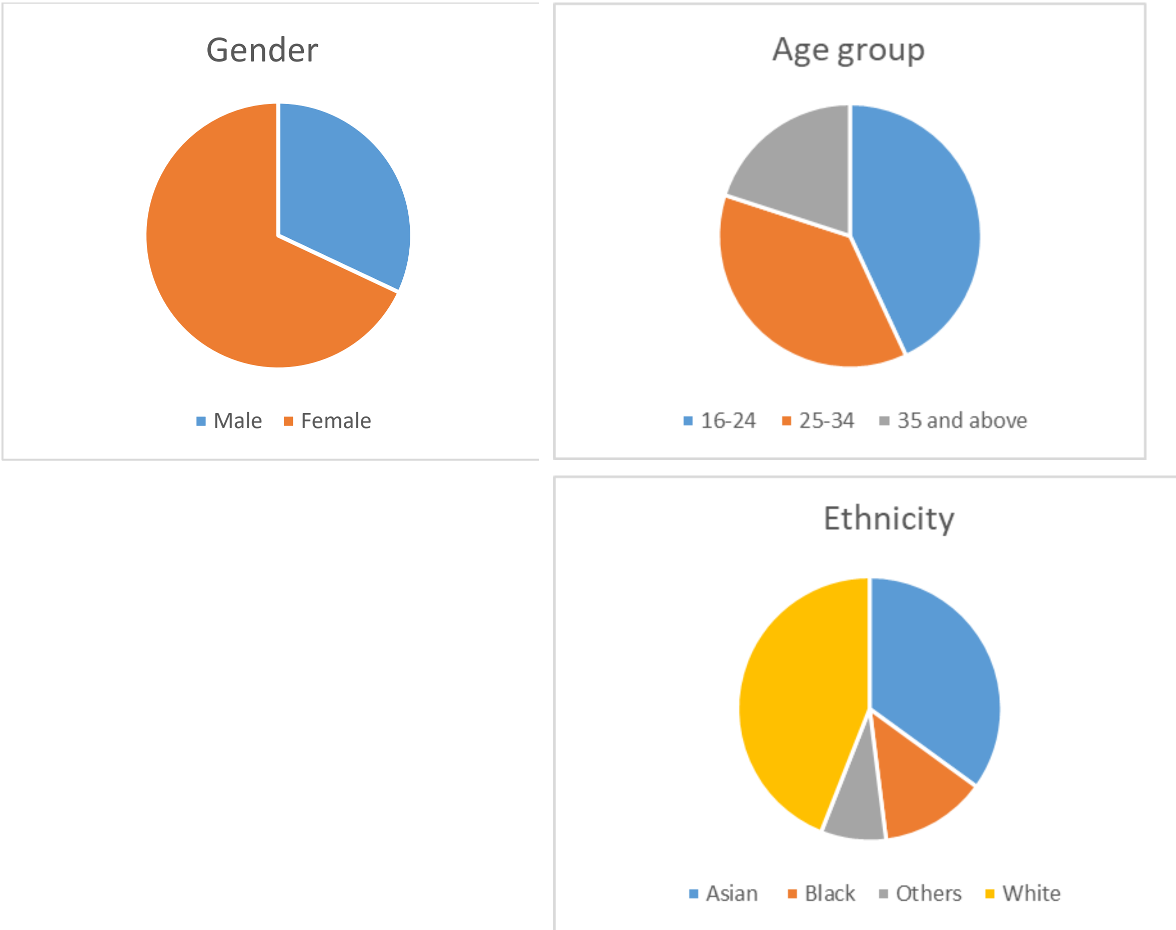


Figure 4.4: Pie charts showing demographic information

4.3.2 Factor analysis

Several factor solutions were explored ranging from 2-factor solution to 8-factor solution, exploring the meanings of all the factors in which items had been grouped along with the RMSEA and RMSEA.LB values (table 4.2). Results showed that the 8-factor solution was the most ideal, only the 8-factor solution met the criteria of having RMSEA.LB below 0.05 (Hu and Bentler 1996).

Table 4.2: Test of suitability of items which are to be used for factor analysis

Number of Factors extracted	Number of factors found	Total number of fitting items	Non-fitting items	RMSEA	RMSEA.LB
3	3	35	-	0.092	0.082
4	4	35	-	0.079	0.069
5	4	32	Q21, Q24, Q35	0.076	0.065
6	4	33	Q21, Q35	0.073	0.062
7	6	31	Q21,Q25, Q31,Q35	0.066	0.054
8	6	27	Q1, Q4, Q21, Q23, Q25, Q31, Q32, Q35	0.059	0.046

The 8-factor solution had 8 non-fitting items, Q4 (I eat chilli because I do not want to appear weak) which was non-fitting because of a negative loading of -0.309. This was expected because this item was adapted from Rozin and Schiller (1980) from their tolerance studies between Americans and Mexicans and this item was endorsed by the Mexicans, this would indicated that Q4 is more appropriate in cultures where eating of chilli is associated with strength and masculinity, this might not be the case with our sample population, resulting in the item being ill fitting. Items Q21 and Q35 (I eat chilli because it keeps me warm and I eat chilli because it makes me feel warm respectively) loaded on the factor MR5. These items were removed as it is not sufficient to have only 2 items on a factor. This was also the case with the factor MR8, where the items Q31 and Q32 (I eat chilli because my doctor says so and I eat chilli because it makes food easy to chew respectively) were the only two items in that factor. After non-fitting items had been removed, the remaining items were then fitted in a 6-factor solution. The resulting RMSEA value was 0.06 and the RMSEA.LB is 0.046 which indicated that this factor solution was optimal. Tables 4.3 and 4.4 present information about the original 8-factor and the final 6-factor solutions. On the 6-factor solution, Cronbach's alpha for all six factors ranged from 0.9 - 0.77 which indicated a high level of reliability in factors (Li et al., 2002).

Table 4.3: 8-factor solution

Number	Loadings	Items	Cronbach alpha	Suggested name
		I eat foods with chilli because		
Q12	0.89	I enjoy eating it		
Q29	0.82	because it tastes good		
Q3	0.69	I like the taste	0.92	Sensory
Q6	0.69	I like the flavour		
Q22	0.85	it is my cultural meal		
Q16	0.83	it is my family tradition		
Q2	0.65	my family eats it	0.84	Family and culture
Q14	0.57	food taste bland without chilli		
Q19	0.49	it is what I usually eat		
Q33	0.35	my family thinks it is good for me		
Q15	0.64	I enjoy the sensation		
Q27	0.63	I like the excitement I get from eating it		
Q34	0.58	I like the burning feeling I get from eating it		
Q28	0.43	it stimulates my appetite	0.86	Pleasure
Q17	0.37	it is fun to eat		
Q30	0.37	it makes me alert		
Q5	0.34	it makes me feel good		
Q26	0.30	it makes me think clearly		
Q13	0.93	it helps me control my weight		Weight
Q8	0.83	it helps me lose weight	0.76	
Q24	0.32	it makes me full		
Q11	0.87	it relaxes me		
Q7	0.67	it cheers me up	0.8	Sensations
Q10	0.48	it cools me down		
Q20	0.82	it keeps me healthy		
Q18	0.75	it is good for me	0.77	Health
Q9	0.44	provides food nutrition		
Q21	0.66	it keeps me warm	0.71	MR5
Q35	0.75	it makes me feel warm inside		
Q31	0.56	my doctor says so	0.74	MR8
Q32	0.49	it makes food easy to chew		

Table 4.4: Final 6-factor solution

Number	Loadings	Items	Cronbach alpha	Suggested name
		I eat chilli because…		
Q12	0.9	I enjoy eating it		
Q29	0.8	it tastes good		
Q3	0.8	I like the taste	0.9	Sensory
Q6	0.8	I like the flavour		
Q19	0.5	it is what I usually eat		
Q5	0.5	it makes me feel good		
Q22	0.8	it is my cultural meal		
Q16	0.8	it is my family tradition		
Q2	0.5	my family eats it	0.82	Familiarity
Q14	0.5	food taste bland without chilli		
Q33	0.5	my family thinks it is good for me		
Q15	0.6	I enjoy the sensation		
Q27	0.7	I like the excitement I get from eating it		
Q34	0.6	I like the burning feeling I get from eating it		
Q28	0.5	it stimulates my appetite	0.85	Pleasure
Q17	0.4	it is fun to eat		
Q30	0.5	it makes me alert		
Q26	0.5	it makes me think clearly		
Q13	0.9	it helps me control my weight	0.76	Weight
Q8	0.6	it helps me lose weight		
Q24	0.3	it makes me full		
Q11	0.6	it relaxes me		
Q7	0.6	it cheers me up	0.8	Sensations
Q10	0.5	it cools me down		
Q20	0.7	it keeps me healthy		
Q18	0.7	it is good for me	0.77	Health
Q9	0.5	It provides good nutrition		

Each factor was named based on the theme of items which were in that factor (table 4.4). The first factor was named sensory appeal, this was because it had items which dealt with tastes and flavours. The second factor was named familiarity because it had items which dealt with long term exposure to foods with chilli. The third factor was named pleasure because this factor had items which dealt with enjoyment. The fourth factor was called weight because it dealt with items relating to weight gain, weight control and being full which meant eating less. The fifth factor was called sensations because it dealt with items relating to how the participants felt. The final factor was named health because it dealt with the participants health requirements.

4.3.3 Rasch analysis

Data for each factor was fitted separated on the RS- Rasch model using WINSTEPS ®.

4.3.3.1 Rating scale effectiveness

Proper functioning of the rating scale was checked using criteria outlined in section 2.7.4.2, and the 7-point rating scale was collapsed to a 4-point rating scale. The two most negative categories were collapsed into one category, slightly disagree and neither agree nor disagree were collapsed into on category, slightly agree and were collapsed into one category and strongly agree remained uncollapsed. The new collapsed categories were then re-numbered. Tables 4.5 and 4.6 show the statistics before and after collapse of the rating scale.

Table 4.5 Category statistics for the 7-point rating scale for the different factors

Category Labels	Category Score	Observed Count (%)	Average Measures		Outfit MNSQ	Rasch-Andrich Threshold
			Observed	Expected		
Sensory appeal						
Strongly disagree	1	52 (4%)	-1.97	-2.40	2.03	
Disagree	2	45 (3%)	-1.13	-1.29	1.33	-2.27
Slightly disagree	3	64 (5%)	-.54	-.48	1.20	-1.22
Neither agree nor agree	4	114 (8%)	.17	.30	1.23	-.67
Slightly agree	5	257 (18%)	1.12	1.17	.89	-.08
Agree	6	461 (33%)	2.18	2.24	.74	1.10
Strongly agree	7	416 (30%)	3.66	3.55	.93	3.14
Pleasure						
Strongly disagree	1	218 (13%)	-1.55	-1.60	1.14	
Disagree	2	182 (118%)	-.94		1.13	-1.20
Slightly disagree	3	136 (8%)	-.50	-.51	.97	-.45
Neither agree nor agree	4	334 (20%)	-.20	-.10	1.38	-1.20
Slightly agree	5	389 (24%)	.27	.28	.82	-.06
Agree	6	288 (17%)	.76	.73	.93	.80
Strongly agree	7	103 (6%)	1.41	1.32	.94	2.11
Health						
Strongly disagree	1	51 (7%)	-2.18	-2.65	1.92	
Disagree	2	63 (9%)	-2.12	-1.96	.89	-3.41
Slightly disagree	3	46 (7%)	-1.04	-1.05	.92	-1.20
Neither agree nor agree	4	229 (32%)	-.04	.02	.79	-2.12
Slightly agree	5	182 (26%)	1.11	1.06	.89	.78
Agree	6	100 (14%)	2.10	1.99	.94	2.11
Strongly agree	7	36 (5%)	2.89	3.14	1.26	3.84
Familiarity						
Strongly disagree	1	276 (23%)	-1.47	-1.42	1.05	
Disagree	2	209 (18%)	-0.84	-0.92	1.15	-0.96
Slightly disagree	3	89 (8%)	-0.38	-0.53	0.72	0.14
Neither agree nor agree	4	192 (16%)	-0.22	-0.17	1.04	-1.12
Slightly agree	5	163 (14%)	0.16	0.18	1.06	0.17
Agree	6	145 (12%)	0.54	0.61	1.02	0.51
Strongly agree	7	104 (9%)	1.26	1.19	0.92	1.27

Category Labels	Category Score	Observed Count (%)	Average Measures		Outfit MNSQ	Rasch-Andrich Threshold
			Observed	Expected		
Weight						
Strongly disagree	1	159 (23%)	-2.41	-2.35	1.08	
Disagree	2	126 (18%)	-1.66	-1.59	.77	-2.23
Slightly disagree	3	67 (9%)	-0.77	-0.93	0.90	-0.62
Neither agree nor agree	4	205 (29%)	-0.28	-0.30	0.68	-1.74
Slightly agree	5	78 (11%)	0.56	0.37	1.08	1.00
Agree	6	46 (7%)	0.94	1.09	1.35	1.25
Strongly agree	7	25 (4%)	1.44	1.86	1.48	2.34
Sensations						
Strongly disagree	1	176 (25%)	-2.55	-2.90	1.44	
Disagree	2	145 (21%)	-2.03	-1.79	.86	-2.91
Slightly disagree	3	72 (10%)	-0.94	-0.91	.81	-.63
Neither agree nor agree	4	157 (22%)	-.18	-.15	.97	-1.31
Slightly agree	5	91 (13%)	.75	.58	.73	.76
Agree	6	36 (5%)	1.36	1.39	.98	1.89
Strongly agree	7	29 (4%)	2.40	2.41	.96	2.20

Table 4.6: Category statistics for the 4-point rating scale for the different factors

Category Labels	Category Score	Observed Count (%)	Average Measures		Outfit MNSQ	Rasch-Andrich Threshold
			Observed	Expected		
Sensory						
Strongly Disagree	1	52 4%)	-3.96	-4.70	1.74	
Disagree	2	223 (16%)	-.84	-.73	1.04	-4.66
Agree	3	718 (51%)	2.55	2.57	.79	-.25
Strongly Agree	4	416 (30%)	5.79	5.74	.97	4.91
Pleasure						
Strongly Disagree	1	218 (13%)	-3.49	-3.69	1.17	
Disagree	2	652 (40%)	-1.16	-1.05	1.06	-3.49
Agree	3	677 (41%)	.83	.80	.93	-.12
Strongly Agree	4	103 (6%)	2.67	2.56	.94	3.61
Health						
Strongly Disagree	1	51(7%)	-5.71	-6.20	.77	
Disagree	2	338 (48%)	-1.72	-1.63	.85	-6.95
Agree	3	282 (40%)	2.47	2.36	.92	.79
Strongly Agree	4	36 (5%)	4.84	5.21	1.19	6.16
Familiarity						
Strongly Disagree	1	276 (23%)	-3.29	-3.27	1.04	
Disagree	2	490 (42%)	-1.11	-1.14	0.87	-2.82
Agree	3	308 (26%)	0.54	0.60	1.02	0.20
Strongly Agree	4	104 (9%)	2.51	2.45	0.94	2.62
Weight						
Strongly Disagree	1	159 (23%)	-5.93	-5.67	.70	
Disagree	2	398 (56%)	-2.27	-2.35	.70	-5.50
Agree	3	124 (18%)	1.40	1.32	1.66	0.71
Strongly Agree	4	25 (4%)	3.57	4.45	1.57	4.80
Sensations						
Strongly Disagree	1	176 (25%)	-5.12	-5.55	1.55	
Disagree	2	374 (53%)	-2.13	-1.96	1.00	-5.34
Agree	3	127 (18%)	1.63	1.41	.65	.85
Strongly Agree	4	29 (4%)	4.46	4.34	1.06	4.49

4.3.3.2 Item and panellists fit

The outfit mean square was investigated for all the factors; sensory appeal, health, familiarity, pleasure, sensations, and weight using criteria as described in section 2.7.4.2, the outfit mean square for all these factors were less than 2.0, which implied that they had adequate fit to the Rasch model. Also, panellists fit values indicated that panellists fit the Rasch model requirement

4.3.3.3 Unidimensionality and local item independence

Unidimensionality was checked for all factors (section 3.3.2.3). The results showed that all factors were unidimensional, this was because the first contrast of most of the factors except weight was less than 2 (Linacre, 2019). Although the unexplained contrast of weight was just over 2, the disattenuated correlation was 1 which indicated that this factor was most likely unidimensional. Table 4.7 shows the values of unexplained first contrast and disattenuated correlations for all six factors.

Table 4.7: Values of unexplained first contrast and disattenuated correlations for 6 factors

Factor (number of items)	unexplained first contrast	Disattenuated correlations	
Sensory appeal (6)	1.6786	Item clusters	
		1-3	0.8398
		1-2	1.0000
		2-3	1.0000
pleasure (7)	1.7970	Item clusters	
		1-3	0.7553
		1-2	0.9685
		2-3	0.8628
Health (3)	1.7785	Item clusters	
		1-3	1.0000
Familiarity (5)	1.5784	Item clusters	
		1-3	0.8554
		1-2	1.0000
		2-3	1.0000
Weight (3)	2.0634	Item clusters	
		1-3	1.0000
Sensations (3)	1.6192	Item clusters	
		1-3	1.0000
		1-2	1.0000
		2-3	1.0000

Local item dependency was also checked for each factor. Because no pairs of items had residual correlation of pairs of items > 0.3 (Linacre 2019), there was no local item dependency between items within factor.

4.3.3.4 Wright maps

Figure 4.5 presents Wright maps for sensory, familiarity and weight factors and figure 4.6 presents the Wright maps for health, pleasure, and sensations factors. Using the sensory Wright map to explain all right maps, at the top of the wright map, measure, person, and item can be seen. Measure represents the Rasch measures, persons represents the panellists, and item represents the survey items in that factor. Beneath the first line, <more> and <rare> can be seen, these both indicate participant ability and item difficulty respectively.

In the body of the Wright map, panellists are represented by . and #. Items are also shown the right hand side of the map. At bottom of the map, <less> and < freq> are shown and like the first line, where <more> and <rare> can be seen, <less> and < freq> indicate participant ability and item difficulty. At the very bottom of the map, it shows the number of participants which are represented by . and #. For example, on the Wright maps of sensory, familiarity, and pleasure, # =3 while for sensation and weight factors, # = 6 and for health # = 4. To get the number of participants who find it hard to agree with an item, the numbers of # and . beneath that item is counted and multiplied by the number they represent. For the item I eat chilli because it cheers me up in the sensation factor, between 142-178 participants found it difficult to endorse this item, compared to only 23-30 participants who found it hard to agree with the item I eat chilli because I like the taste in the sensory factor.

Participants at the top end of the Wright map have higher abilities which is interpreted to mean that they were more agreeable to items compared to participants at the bottom who were less agreeable to the items. Items at the top of the map were harder items to agree with than the items which were at the bottom of the Wright map.

The Wright map for sensory factor shows that the easiest item for most participants to agree with was they like the taste of chilli. Other items that were easy to agree with was that they enjoyed eating it and that the like the flavour of chilli which had the same level of difficulty. The hardest item to agree with in the sensory factor was they ate chilli because it is what the usually eat. Although this item was the most difficult to agree with in this factor, most participants still agreed with this item as shown by the number of participants located above that item.

The Wright map for familiarity factor shows that the easiest item to agree with was that food taste bland without chilli, while the item my family thinks it is good for me was the hardest item to agree with. This item may have been hard to agree with as most of the participants are above the age in which they would be compelled to eat meals because of their family influence.

The Wright map for weight factor shows that items in this factor were generally harder for the participants to agree with. This is shown by the location of the participants on the Wright map. Most participants were located at the bottom of the Wright map in this factor. This meant that the sample population were more generally more likely to consume chilli for sensory reasons than weight reasons. In this factor, the hardest item to agree with was I eat foods with chilli because It helps me control my weight and the easiest to agree with was that they consumed food with chilli because it made them full.

The Wright map for health factor shows that the hardest item to agree with was they consume chilli because it keeps them healthy whereas the easiest item to agree with was that participants consume chilli because it is good for them.

The Wright map for pleasure factor shows that the hardest item to agree with was I eat chilli because it helps me think clearly and the easiest item to agree with was they ate foods with chilli because it made them think clearly.

The Wright map for sensation factors showed that the item I eat foods with chilli because it cheers me up was the easiest item to agree with compared to the item I eat chilli because it cools me down, items in this factor and in the weight factor were the hardest items to generally agree with.

Comparing all wright maps, sensory items were easier for participants to agree with as most of the participants are located at the top of the sensory Wright map when compared to other wright maps, and very few participants are located at the bottom of the sensory Wright map. Consequently, items in the weight and sensation factors were harder to agree with.

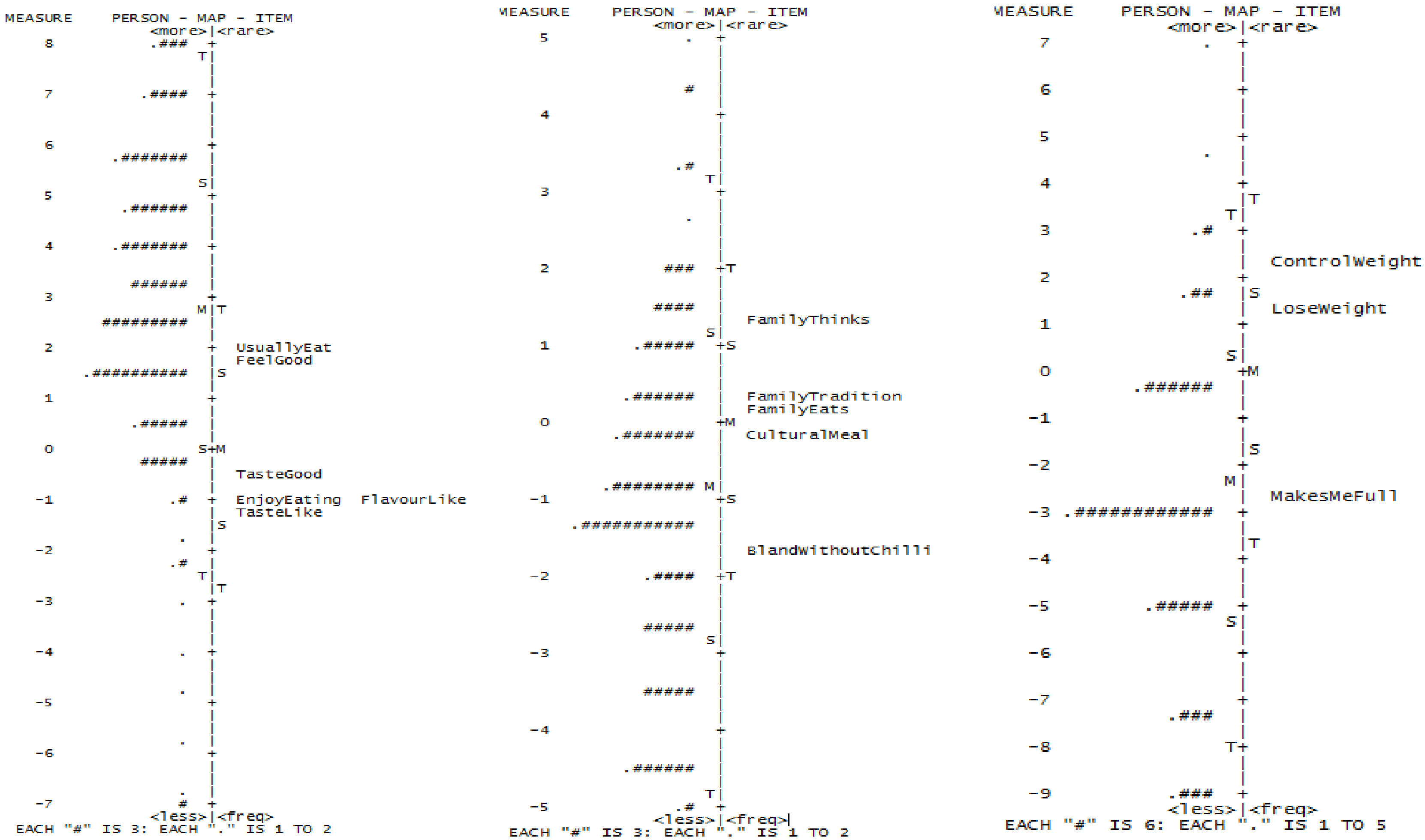


Figure 4.5: Wright maps of sensory, familiarity and weight

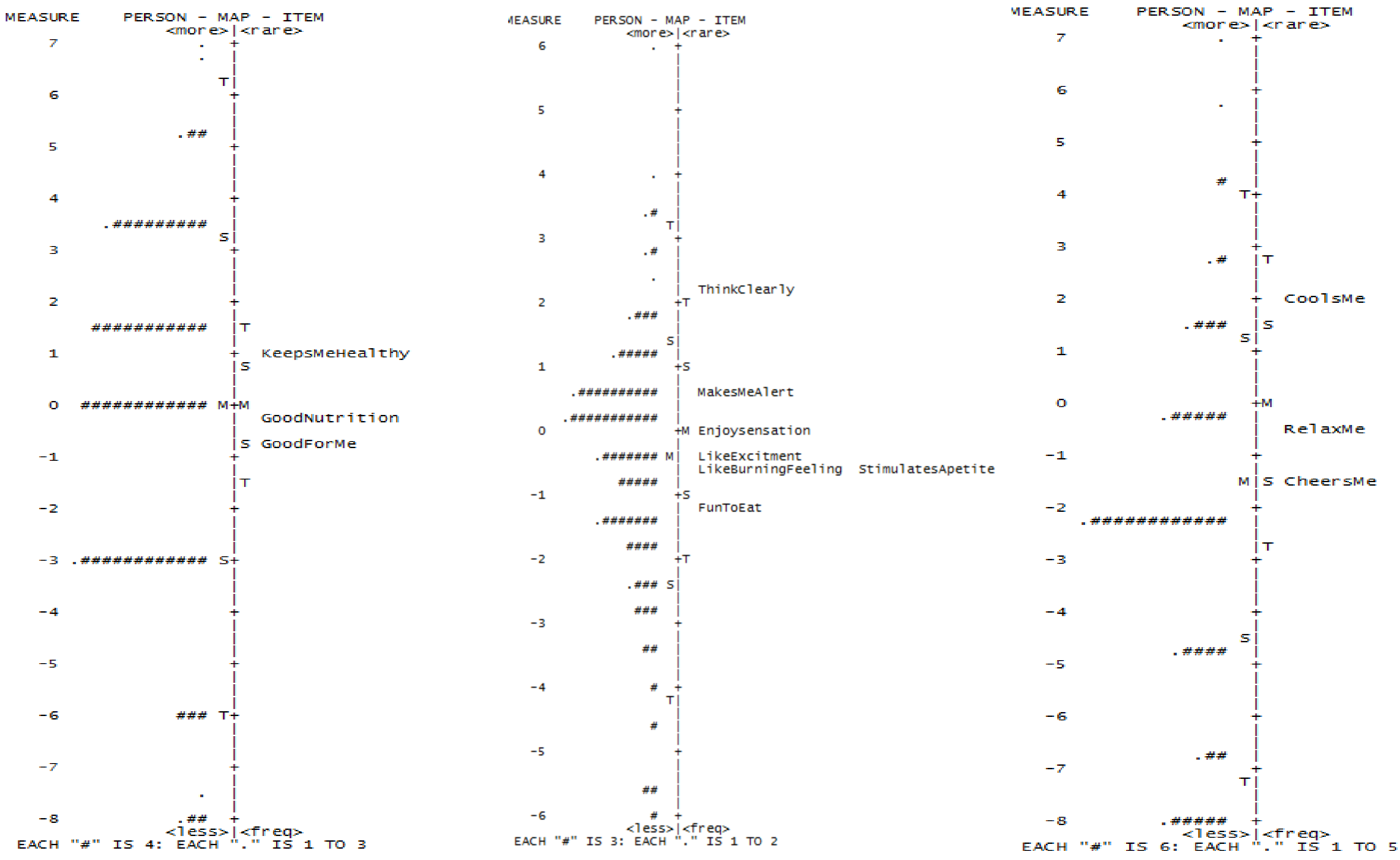


Figure 4.6: Wright maps of health, pleasure and sensations

4.4 Cluster analysis

Using model based clustering in R package *mcclust*, 3 clusters were suggested. Cluster 1 had one hundred and twenty-eight members, cluster 2 has fifty-eight members and cluster 3 had forty nine members. Multiple comparison indicated that clusters were significantly different from one another on all factors (p 0.03). Table 4.8 shows the summary of the multiple comparison results for the three clusters. A graph was used to visual the differences between the mean of the clusters on all clusters (figure 4.7). As can be seen, cluster 3 had consistently higher mean on all factors, followed by cluster 1 and finally cluster 2. Figures 4.8 and 4.9 provide demographic information about all the clusters.

4.4.1 Cluster:- The medium heat cluster

This cluster consisted of one hundred and twenty eight members and was made up of mainly age groups 16-34 years, They had a medium burn preference, consumed foods with chilli with medium heat levels and ate it often. The age of introduction to foods with chilli was mainly between 0-16 years. They liked the burn and taste of chilli. The major consumption driver in this group was pleasure, followed by health reasons, the least drive for consumption was sensation.

4.4.2 Cluster 2: - The low heat cluster

This cluster consisted of fifty eight members and was also made up of age group 16-34 years. Members of this cluster rarely ate foods with chilli and when they did, it would be consumed chilli in low levels. They also liked the taste and burn of chilli but at low levels. The greatest drive for consumption in this cluster was familiarity and sensory. This cluster was least concerned with health benefits obtained from chilli.

4.4.3 Cluster 3: - The high heat cluster

This cluster consisted of forty nine members and was made up of younger demographic of the sampled population, as they were made up mainly of the age group 16-24 years, who had high levels of self-reported consumption of chilli. They always consumed foods with chilli, and they liked the taste and burn of chilli. The major driver of consumption for this cluster was the sensations which they got from chilli and they also consumed chilli for weight reasons. For members of this cluster, familiarity was not a consumption driver.

Table 4.8: Cluster means and p-value from Kruskal Wallis test

	Total	Cluster 1 (Medium)	Cluster 2 (Low)	Cluster 3 (High)
		128	**58**	**49**
Sensory		124.04^b	63.51^c	166.70^a
Pleasure		128.43^b	52.04^c	168.83^a
Familiarity		118.49^b	81.39^c	160.05^a
Health		126.30^b	45.61^c	181.99^a
Sensations		116.91^b	56.17^c	194.04^a
Weight		122.11^b	48.23^c	189.82^a

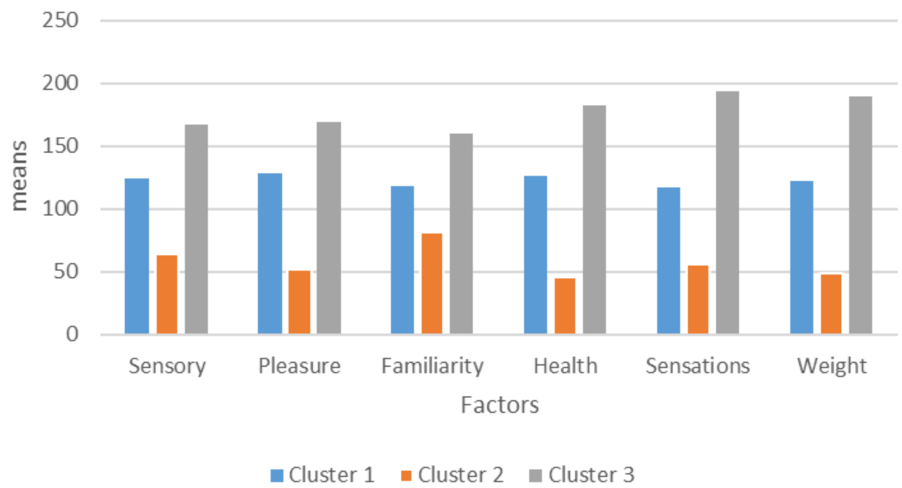


Figure 4.7: Illustration of means of the six factors

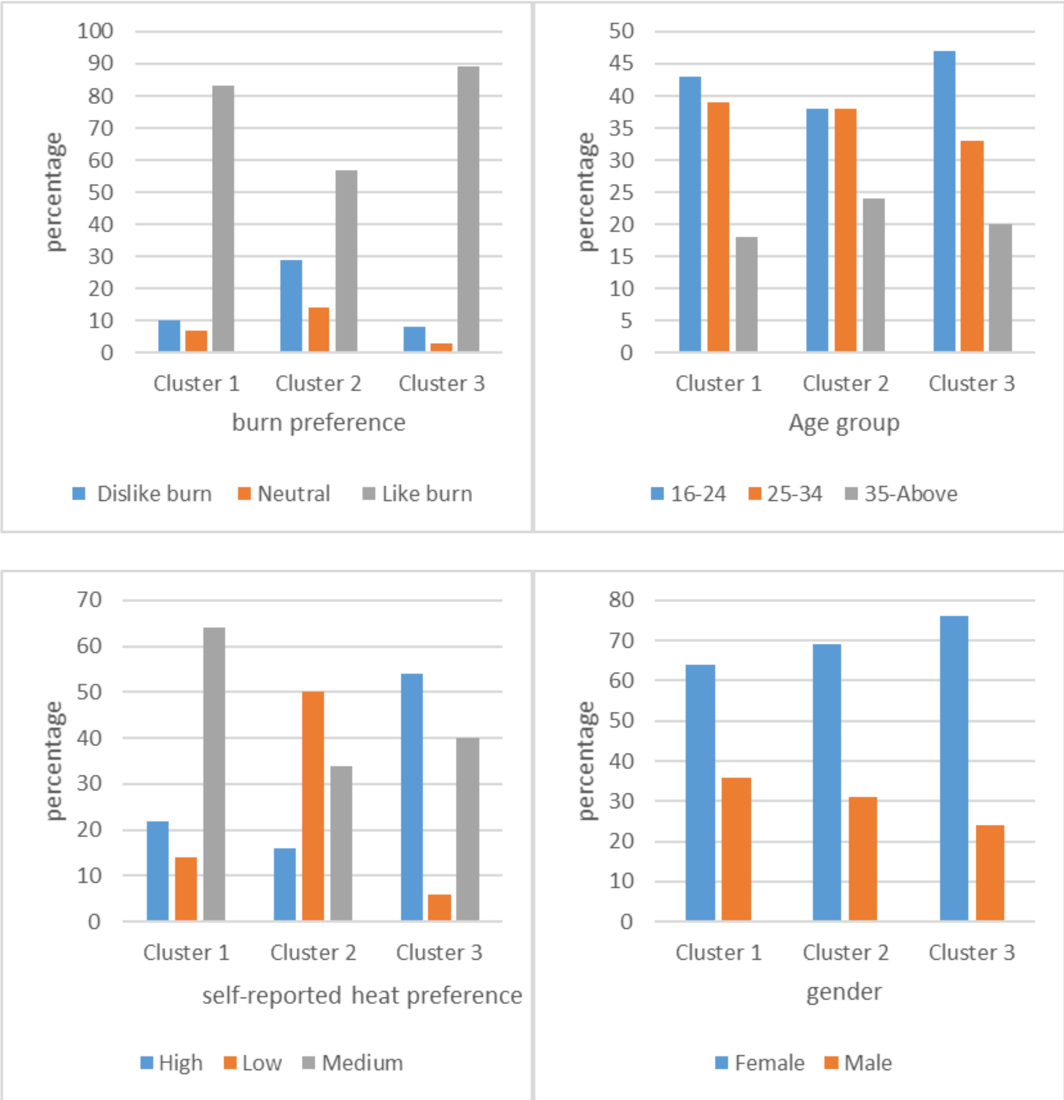


Figure 4.8: Age group, self-reported heat preference, burn preference, and gender

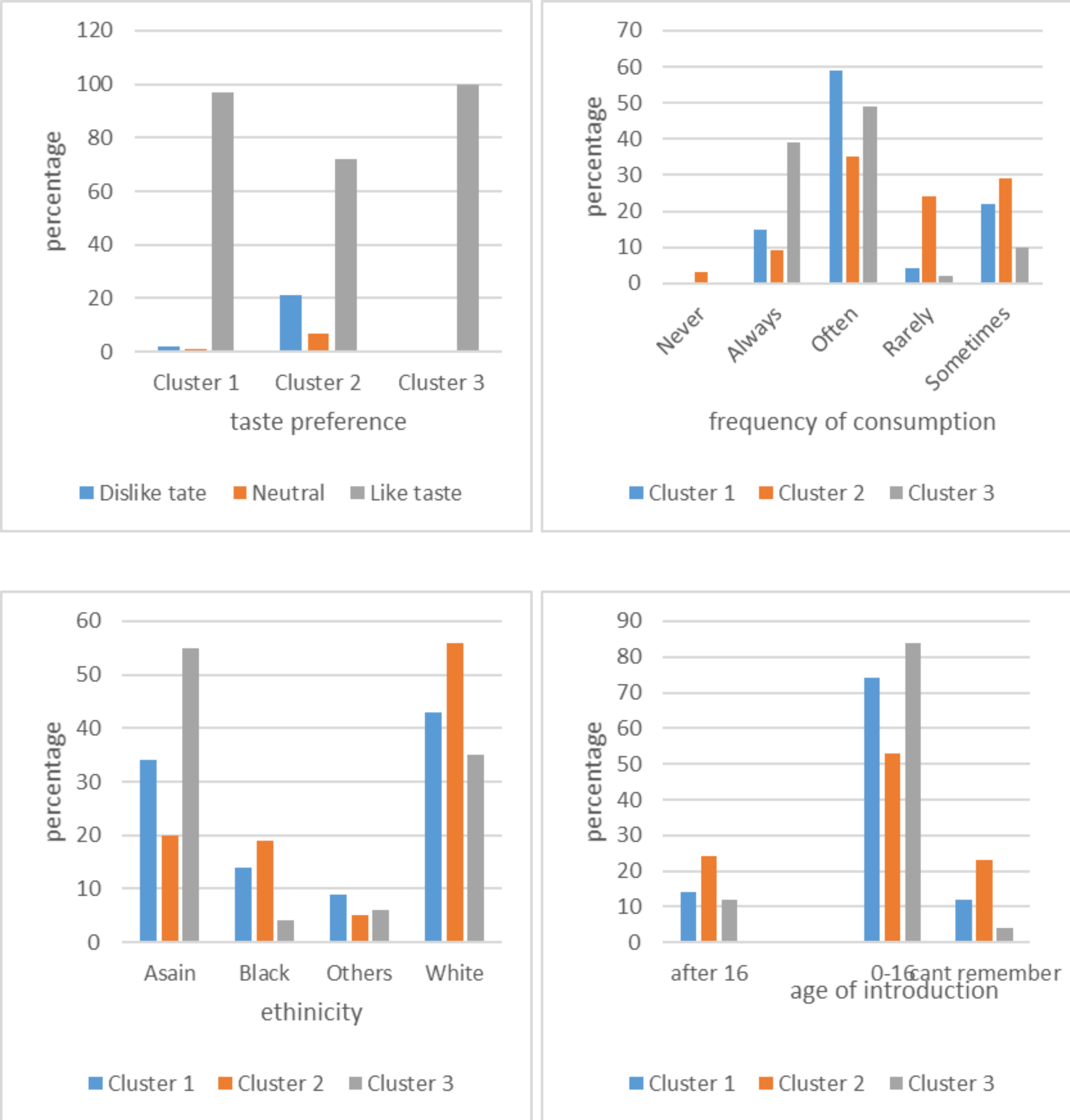


Figure 4.9: Taste preference, frequency of consumption, age of introduction and ethnicity

4.5 Conclusions

This study set out to develop a survey which was made up of a set of items which were considered as the drivers of consumption for consumers of foods with chilli. This aim was achieved using a focus group and literature to develop a survey and then getting a final survey consisting of 27 items. Using the information gathered from the survey, the sample population was segmented into 3 distinct clusters. This result showed that indeed it is possible to segment participants using their drivers of consumption, making the need to segment based on user or liker status obsolete.

This result of this survey can be of value to the food industry in the development of foods with chilli, and marketing for a targeted market.

Chapter 5 : Studies II and III: Determination of attributes for the measurement of tolerance

5.1 Introduction

Several sensations have been reported to be evoked by capsaicin when it is ingested, these include burning, stinging, hot, tingling, numbing, warming, heat, fiery, biting (Cliff and Heymann, 1992; Reinbach et al., 2007). The sensations have been studied and have been investigated in respect to their association with capsaicin.

Tolerance to the burn of chilli is an important factor in the consumption of foods with chilli as it determines the acceptance of varying levels of capsaicin concentrations. Tolerance has been defined by Rozin, Paul and Schiller (1980), as the level of acceptance of a given level of capsaicin. The level of acceptance of chilli is then determined by the level of acceptance of all the sensations which are evoked by capsaicin on consumption. These sensations have an important bearing on the estimation of an individual's tolerance to chilli because a wholistic measurement of tolerance would require measurement of all the sensations which are evoked when chilli is consumed.

The need to measure tolerance arises from the relationship which exists between tolerance and consumption, where the better a person's ability to tolerate chilli, the more likely they are to consume it. Although this relationship does not exist in isolation as other factors such as the actual perception of hotness, the heat level of the food and the liking of the level of hotness also have bearing in consumption.

Since tolerance is a part of this complex relationship, it makes the measurement of tolerance levels important in understanding levels of chilli concentrations which are best suitable for consumers. This would also help understand the role of tolerance levels of consumers on the consumption of foods with chilli. Since consumers tolerance levels in addition to the actual perception of the hotness of the food would determine their consumption of foods with chilli, there needs to be a measure of a persons’ tolerance to capsaicin. Tolerance has previously been measured (Rozin, Paul and Schiller, 1980; Rozin, P. et al., 1982; Stevenson, R. J. and Yeomans, 1993) and it has not been measured using parameters that this study explored. Figures 5.1 and 5.2 show the attributes evoked by capsaicin which were measured in this chapter.

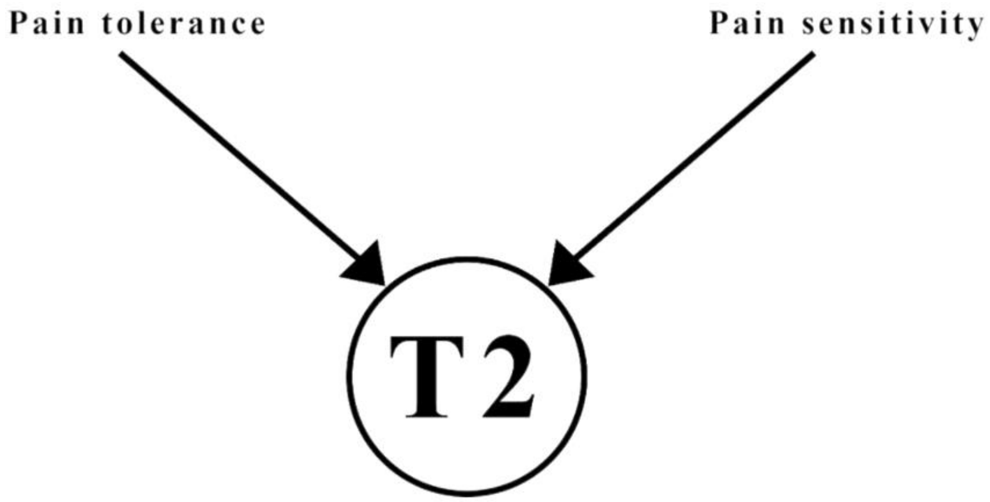


Figure 5.1: T2 attributes of tolerance measurement

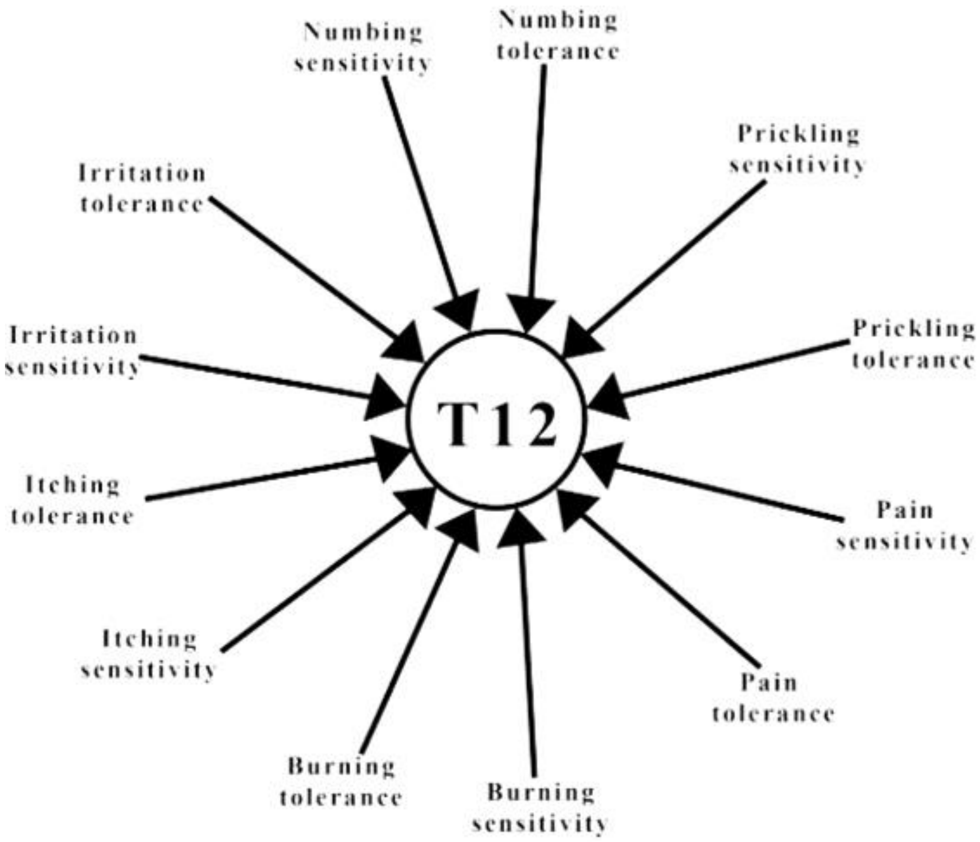


Figure 5.2: T12 attributes of tolerance measurement

The first study in this chapter, (Study II) compared hotness intensity (HI) measurement with and without pain stimulus tolerance (PST) measurement to determine if PST was an important part of measuring HI. The second study (Study III) compared different attributes for measurement of tolerance to determine if measuring with more attributes gave a better measurement of tolerance.

The aim of this chapter was:

Study II: To investigate how pain stimulus tolerance (PST) affected the measurement of hotness intensity (HI).

Study III: To compare different sensations which could be used to measure tolerance and sensitivity of individual using.

5.2 Hypothesis

Study II: This study tested the hypothesis that pain stimulus tolerance (PST) would have an impact on measurement of hotness intensity (HI).

Study III: This study tested the hypothesis that twelve measures of tolerance using multiple attributes provided better discrimination of panellists than two measures using only pain tolerance and pain sensitivity.

5.3 Materials and methods

5.3.1 Tolerance study II

5.3.1.1 Sample preparations: - Capsaicin solutions

Capsaicin solutions were prepared using a modified ASTM method E 1083-00 by (Lee and Kim, 2013) 0.02 g of capsaicin (Sigma Aldrich 360376) was mixed with 0.7 g of food grade polysorbate-80 (Sigma Aldrich W291706) and heated on a hot plate for approximately 5 minutes until capsaicin had dissolved completely. This mixture was transferred to a 100ml volumetric flask and made up using 70 ^{o}C water to give a 200 ppm solution, and serially diluted to 0.15 ppm, 0.5 ppm, 2 ppm, 7 ppm, 15 ppm, 40 ppm, and 70 ppm of capsaicin. Capsaicin samples were kept in the fridge for a maximum of three weeks and were always served at room temperature. On the day of the test, sample were brought out to be served at room temperature.

5.3.1.2 Test procedure

Participants were recruited from the staff and student of University of Leeds by posters and emails. Participants were required to indicate their self-reported chilli intake (low, medium, or high levels), this was used for the purpose of general classification. Ethical approval was granted by MaPs ethics MEEC 15-014. Thirty participants attended two 30-minute sessions on separate days (Nolden and Hayes, 2017) at which they were presented with samples of increasing concentrations and were instructed not to proceed to the next sample if the current solution was perceived as being too hot to tolerate. In the first session, 1.5 ppm, 2 ppm, 15 ppm, 70 ppm were presented in this order while in the next session, 0.5 ppm, 7 ppm, 40 ppm, 120 ppm were presented. At both sessions, samples were served in increasing order so that panellist could stop when solutions were perceived as too hot to bear. All samples were coded with random 3-digit codes.

Prior to the start of the test, participants were given participant information, and consent forms. After signing the forms to give their consent, they were instructed to rinse their mouths with water. They were then told to take entirely 10 ml sample in mouth, hold for 10 seconds, spit out, rate hotness intensity of the sample and pain caused by the solution after 10 seconds. They were required to rinse repeatedly during the 2.5 minutes break after which they were required to rate residual hotness intensity and pain in their mouth. If ratings were greater than weak on the hotness intensity scale and distressing on the pain scale, the participants were required to wait for an extra minute before moving to the next sample (Nolden and Hayes, 2016), this was to allow for extra time for their palettes to be as neutral as possible. Panellists were not allowed to proceed to the next sample if the current sample was intolerable. Data was collected using paper forms which were given to the participants. A practice run was given using water to get participants familiar to the use of both scales. Tolerance to capsaicin solutions was measured using a 9-point intensity scale and an 11-point subjective pain scale. Of all 30 participants, only 14 participants had all the concentrations of capsaicin solutions.

5.3.2 Tolerance study III

5.3.2.1 Sample preparation

Samples were prepared using the modified (ASTM International, 2006). 0.6 g of capsaicin (Sigma Aldrich 360376) was weighed with 20 g of food grade polysorbate-80 (Sigma Aldrich W291706) into 50 m beaker and was heated on a hot plate (low setting) for a minimum of 10 min to dissolve capsaicin. The heated mixture was then quantitatively transferred into a 1 L volumetric flask using hot (about 70°C) spring water. Once the mixture was cooled, it was made up to 1L using 20°C spring water and the refrigerated. The final concentration of the stock solution of capsaicin was 600 ppm. Samples were then serial diluted to achieve test concentrations.

5.3.2.2 Test procedures

On the test days, sample were taken out of the fridge and left at room temperature for at least one hour before being served to participants. Data was collected using RedJade®. Fifty-one participants were recruited from the staff and students of University of Leeds by posters, word of mouth, referrals from friends and emails. Participants were required to enter a verification code online after which they were required to read the participant information form and give consent. At the beginning of the test before any samples were given, there was a page which describe potential sensations which participants might feel. All samples were tasted in one session. 10 ml of samples were served one at a time to participants in 20 ml clear shot glasses in increasing order. Each sample had a randomized 3-digit code. They were instructed to take 5 ml of samples in their mouth, hold for 5 seconds before they swallowed the sample. They were then required to take note of any sensations they felt, using the information which they read at the start of their session, then swallow the sample and wait another 5 seconds, again while waiting they took note of the sensations they felt. They were then required to answer the questions provided. To minimize carryover effect, participants were required to wait for 2 minutes. This time was enforced by the software as they could not proceed to the next sample until this time as elapsed on the screen. During this time, they were required to eat as much plain water crackers and drink as much water as the required to get rid of any residual sensations they had from consuming the capsaicin solutions.

Samples were served to participants in increasing order, this was to ensure that the experiment ended for each panelist when they decided that any perceived sensation was too much to bear or when they reached the highest concentrations, whichever was first, however all participants consumed all products. They rated sensitivity attributes using the sensitivity scale and tolerance attributes using the tolerance scale (Table 5.1).

Table 5.1: Rating scales for tolerance measurement

Sensitivity scale		Tolerance scale	
Raw score	**Scale category**	**Raw score**	**Scale category**
1	None	1	Completely able
2	Barely hot	2	Slightly unable
3	Slightly hot	3	Moderately unable
4	Moderately hot	4	Strongly unable
5	Hot	5	Extremely unable
6	Very hot	6	Completely unable
7	Extremely hot		
8	Strongest hot sensation ever experienced		

5.4 Results

5.4.1 Tolerance study II:

Data was obtained from 30 participants, consisting of 11 males, and 19 females. This consisted of 4 high, 15 medium, and 11 low self-reported levels of preferred heat levels.

5.4.1.1 Data analysis

5.4.1.2 Pain stimulus tolerance (PST)

Pain stimulus tolerance (PST) was fitted with the MFR-RS model on FACETS®. The three facets that were measured were the products (capsaicin solutions), attributes (PST) and consumer. The consumer facet was negatively orientated such that panellist who gave higher PST ratings to solutions had lower Rasch measures and low tolerance. The products facet was positively oriented such that higher measures of product indicated higher likelihood of the product evoking a painful sensation.

5.4.1.2.1 Quality control checks

Quality control checks were carried out as outlined in section 2.7.4.2. The rating scale was collapsed from 11-point PST scale to a to a 5-point scale (table 5.2).

Table 5.2: Summary statistics for PST

Scale category	Raw score	counts used	% of counts	Obs[2]	Exp[3]	Rasch-Andrich threshold ±SE	Outfit MNSQ
Original 11-point scale							
No pain	0	14	8%	-5	-4.81	N/A	0.8
Very mild	1	23	14%	-3.6	-3.75	-4.75 ± 0.36	1.2
Discomforting	2	22	13%	-2.51	-2.55	-3.13 ± 0.3	0.7
Tolerable	3	34	20%	-1.28	-1.29	-2.33 ±0.28	0.8
Distressing	4	26	16%	-0.56	-0.35	-0.52 ±0.26	1.6
Very distressing	5	10	6%	0.48	0.31	0.95 ±0.29	0.5
Intense	6	16	10%	1.14	0.86	0.12 ±0.3	0.6
Very intense	7	15	9%	1.22	1.37	1.18 ±0.32	1.2
Utterly horrible	8	5	3%	1.69	1.81	2.69 ±0.46	1.2
Excruciating unbearable	9	1	1%	2.26	2.12	3.58 ±0.77	0.7
Unimaginable Unspeakable	10	1	1%	2.72	2.32	2.22 ±1.05	0.5
Collapsed 5-point scale							
No pain	1	14	8%	-4.6	-4.45	N/A	0.8
Very mild	2	23	14%	-2.62	-2.69	-4.04 ± .39	0.9
Discomforting/ Tolerable	3	56	34%	0.04	0.08	-2.34 ± .31	0.7
Very distressing/intense/very intense	4	52	31%	2.93	2.89	1.67 ± .25	1.1
Very intense/utterly horrible/ excruciating unbearable /unimaginable unspeakable	5	22	13%	4.65	4.68	4.71 ± .30	1.1

2 Modelled average measure in logits.

3 Expected average measure if data fitted the model.

5.4.1.2.2 Consumer, product, and attribute fit

Fit statistics was checked for consumer, product and attribute (PST) (section 2.7.4.2), Consumer fit were acceptable as they were below 2 except panellists 20, 23 and 26 who had outfit MNSQ values of 2.08, 2.04 and 2.23 respectively, these panellists were retained in the data as their outfit values were slightly over 2. Products fit were acceptable as they were within the recommended range, also attribute fit (PST) was acceptable as it had an outfit MNSQ value of 0.91.

5.4.1.2.3 Reliability, strata, and separation

The separation, strata, and reliability values indicated panellists were distinguishable based on their rating of PST into at least four statistically significant levels (p-value <0.01). Table 5.3 provides statistics.

Table 5.3: Reliability, strata, and separation of PST

Facet	Separation	Strata	Reliability
Consumer	3.10	4.13	0.81

5.4.1.2.4 Wright map

The Wright map presented facets for the consumer, products, and PST ratings (figure 5.3). These facets can be seen at the top part of the map and it showed the Rasch measure, consumers, products, attributes and rating scale. The positive and negative sign before the consumer, products and attribute indicate if the facet is positively or negatively oriented. In this case, consumers and attributes are negatively oriented.

On the left hand side of the Wright map which is the consumer facet, panellist 4 and 26 had the highest Rasch measures as evident from their position on the Wright map. This meant they had the highest pain thresholds. On the other hand, panellist 29 had the lowest Rasch measure and hence the lowest pain threshold. The product facet of the Wright map shows that the 70ppm capsaicin solution was rated as giving the most painful sensation in comparison to the 0.15ppm capsaicin solution. This was expected, as higher doses should evoke higher sensations (Byrnes and Hayes, 2013; Byrnes and Hayes, 2015; Ludy and Mattes, 2012; Ludy and Mattes, 2011b; Simone et al., 1989; Nolden and Hayes, 2017; Nolden et al., 2016).

The Wright map also shows that participants were able to differentiate between the solutions of different concentrations as shown by the position of the concentration of the products on the Wright map. The right-hand side of the Wright map shows the collapsed rating scale and their labels.

```
+-----------------------------------------------------------------+
|Measr|-Consumers       |+Products|-Attributes|RATING             |
|-----+-----------------+---------+-----------+-------------------|
|   4 +                 +         +           + Excruiciating     |
|     | 4               |         |           |                   |
|     |                 | 70ppm   |           |                   |
|     |                 |         |           |  Intense          |
|   3 +                 +         +           +                   |
|     |                 |         |           |                   |
|     |                 | 40ppm   |           |                   |
|     |                 |         |           |                   |
|   2 + 26              +         +           +                   |
|     |                 |         |           |                   |
|     |                 | 15ppm   |           | ------------------|
|     |                 | 7ppm    |           |                   |
|   1 + 3               +         +           +                   |
|     | 1               |         |           |                   |
|     |                 |         |           |                   |
|     | 5               |         |           |                   |
*   0 * 2   9           *         * Pain      *                   *
|     | 24              |         |           |                   |
|     | 12  21          |         |           |  Tolerable        |
|     |                 |         |           |                   |
|     | 10  13  16  7   | 2ppm    |           |                   |
|  -1 + 23              +         +           +                   |
|     | 17  22          |         |           |                   |
|     |                 |         |           |                   |
|     | 6   8           |         |           |                   |
|     | 25              |         |           |                   |
|  -2 +                 +         +           + -------------     |
|     | 27              |         |           |                   |
|     | 11  15  18      |         |           |                   |
|     | 19  30          |         |           |                   |
|     |                 |         |           |                   |
|  -3 +                 +         +           +                   |
|     |                 |         |           |  Very mild        |
|     |                 | 0.5ppm  |           |                   |
|     | 14              |         |           |                   |
|     |                 |         |           |                   |
|  -4 +                 +         +           +                   |
|     |                 |         |           |                   |
|     | 28              |         |           | -------------     |
|     | 20              | 0.15ppm |           |                   |
|     |                 |         |           |                   |
|  -5 +                 +         +           +                   |
|     | 29              |         |           |                   |
|     |                 |         |           |                   |
|     |                 |         |           |No pain            |
|-----+-----------------+---------+-----------+-------------------|
|Measr|-Consumers       |+Products|-Attributes|RATING             |
+-----------------------------------------------------------------+
```

Figure 5.3: Wright map of PST, showing panellist, products, and PST facets and rating scale.

5.4.1.2.5 Division into statistically significant groups

Using method outlined in section 3.3.2.2, Participants were divided into 4 statistical levels by applying pairwise comparison, these were then used as an extra facet in hotness intensity (HI) estimation. These 4 statistical levels are indicated on the Wright map as the blue boxes on the consumer facet on the Wright map.

5.4.1.3 Hotness intensity (HI)

HI was fitted with MFR-RS model on FACETS ®. The three facets that were measured were the products, attributes (HI), and consumer. The consumer facet was negatively orientated such that panellist who gave higher intensity ratings to solutions had lower Rasch measures. The products facet was positively oriented such that higher measures of product indicated high concentration.

5.4.1.3.1 Quality control checks

Quality control checks were carried out as outlined in section 2.7.4.2. The rating scale was collapsed from the 9-point intensity scale to a 5-point scale (table 5.4). Fit statistics was checked for consumer, product, and HI.

Table 5.4: Collapsed and uncollapsed rating scale statistics

Scale category	Raw score	category total	% of raw score	Obs	Exp	Outfit MnSq	Rasch-Andrich thresholds ± S.E.
Original 9-point scale							
Nothing at all	1	8	5%	-7.41	-8.11	1.1	N/A
Extremely weak	2	12	7%	-6.22	-5.68	7.7	-6.97 ± .55
Very weak	3	13	8%	-4.39	-4.56	0.8	-5.21 ± .41
Weak	4	21	13%	-2.94	-2.63	1.1	-4.18 ± .39
Moderate	5	29	17%	-0.22	-0.14	0.6	-1.66 ±.36
Strong	6	25	15%	2.08	1.9	0.6	1.04 ± .32
Very strong	7	28	17%	3.95	4.03	0.9	2.81 ± .33
Extremely strong	8	24	14%	6.58	6.41	0.8	5.39 ± .35
Strongest imaginable	9	7	4%	8.88	8.87	0.9	8.79 ± .53
Collapsed 5-point scale							
Nothing at all	1	8	5%	-11.42	-11.88	1.2	N/A
Extremely weak/Very weak	2	46	28%	-6.66	-6.46	1.2	-11.1 ± 0.54
Weak/Moderate/strong	3	54	32%	0.37	0.37	0.5	-3.13 ± 0.38
Very strong/extremely strong	4	52	31%	6.23	6.16	1	3.27 ± 0.33
Strongest imaginable	5	7	4%	11.31	11.12	0.5	10.96 ± 0.56

5.4.1.3.2 Attribute, consumer, and product fit

Attribute (HI), individual panellists, and product fit were assessed using Outfit MNSQ see section 2.7.4.2, all facets had acceptable fit.

5.4.1.3.3 Reliability, strata, and separation

Both consumers and products had reliability close to 1 (Table 5.5), this meant that panellist could be divided into at least 5 statistically significant levels. Also, each product was distinct in the level of hotness intensity rating with no overlap between products.

Table 5.5: Reliability, strata and separation of HI

Facet	Separation	Strata	Reliability
Consumers	3.58	5.11	0.93
Product	10.92	14.90	0.99

5.4.1.3.4 Wright map

The Wright map presents the consumers, products, and HI ratings (figure 5.4) from the Wright map, similar to the pain Wright map, panellists 4 and 26 had high Rasch measures when compared to other panellists. Consequently, panellist 13 had the lowest Rasch measures when compare to other panellists. Also, the 70 ppm solution was rated as the hottest sample in comparison to the 0.15 ppm solution, as shown on their positions on the Wright map, where the 70 ppm solution is at the top of the Wright map and 0.15 ppm solution at the bottom. This was expected, as higher concentrations of capsaicin would give result in higher intensity. The Wright map also shows that based on intensity ratings, panellists were divided into six groups, this is highlighted by the blue boxes shown on the consumer facet on the left hand side of the Wright map. The collapsed rating scale is shown on the right hand side of the Wright map.

```
+--------------------------------------------------------------------+
|Measr|-Consumers        |+Products|-Attributes|RATING               |
|-----+------------------+---------+-----------+---------------------|
|   9 +                  +         +           + Strongest Imaginable|
|     |                  |         |           |                     |
|   8 +                  + 70ppm   +           +                     |
|     | 26               |         |           |                     |
|   7 +                  +         +           +  Very strong        |
|     |                  |         |           |                     |
|   6 +                  + 40ppm   +           +                     |
|     | 4                |         |           |                     |
|   5 +                  +         +           +                     |
|     |                  |         |           |                     |
|   4 +                  +         +           +                     |
|     | 10               |         |           |  -----------------  |
|   3 + 24               + 15ppm   +           +                     |
|     | 12  2   3   7  9 |         |           |                     |
|   2 +                  +         +           +                     |
|     | 21               |         |           |                     |
|   1 +                  + 7ppm    +           +                     |
|     | 1                |         |           |                     |
*   0 * 16  22           *         * Intensity *  Moderate           *
|     |                  |         |           |                     |
|  -1 + 25  27  30       +         +           +                     |
|     | 8                |         |           |                     |
|  -2 +                  + 2ppm    +           +                     |
|     | 19  5            |         |           |                     |
|  -3 + 23               +         +           +  -----------------  |
|     | 11  15  6        |         |           |                     |
|  -4 +                  +         +           +                     |
|     | 14               |         |           |                     |
|  -5 + 20               +         +           +                     |
|     |                  |         |           |                     |
|  -6 + 17               +         +           +                     |
|     |                  |         |           |                     |
|  -7 + 18               + 0.5ppm  +           +  Very weak          |
|     |                  |         |           |                     |
|  -8 +                  +         +           +                     |
|     | 28               | 0.15ppm |           |                     |
|  -9 +                  +         +           +                     |
|     |                  |         |           |                     |
| -10 + 29               +         +           +                     |
|     |                  |         |           |                     |
| -11 + 13               +         +           + Nothing at all      |
|-----+------------------+---------+-----------+---------------------|
|Measr|-Consumers        |+Products|-Attributes|RATING               |
+--------------------------------------------------------------------+
```

Figure 5.4: Wright map for HI, showing panellist, product and HI facets and the rating scale

5.4.1.4 HI/PST

Recall that panellists were divided into four statistically significant groups using their PST ratings. For comparison to determine if PST influenced the measurement of HI, these 4 groups were used as an extra facet in the measurement of HI. HI/PST was fitted on the MFR-RS model with 4 facets. Consumers facet; which was orientated negatively similar to HI and PST previously fitted, products facet, attribute facet (HI) and the final facet being the four groups from PST labelled level one to level four: which was orientated negatively, same as HI to ensure that levels with higher measures meant higher tolerance levels.

5.4.1.4.1 Quality control checks

Rating scale was not collapsed as it met recommended criteria as it had been previously collapsed from HI model.

5.4.1.4.2 Panellist, product, HI, and PST level fit

Panellist, product, HI, and PST level fit were all acceptable and did not need any remedial action.

5.4.1.4.3 Reliability and separation

All facets had had reliability values close to 1 (table 5.6). Compared to HI which had a strata of 5.11, one strata level has been lost by the addition of the PST levels.

Table 5.6: Reliability, strata and separation for HI/PST

Facet	Separation	Strata	Reliability
Consumers	2.71	3.94	0.88
Product	10.95	14.93	0.99
PST levels	4.59	6.45	0.95

5.4.1.4.4 Wright map

The Wright map (figure 5.5) presents the 4 facets which were fitted to the Rasch model, these facets can be seen at the top of the Wright map. With the inclusion of pain as an extra facet, the number of HI/PST levels reduced from six groups which were seen with HI model to five groups. Also, panellists moved within group levels. This was expected as the addition of the PST being an additional measurement would have an effect, in this case an adjustment as HI was being measured with both HI and PST ratings.

```
|Measr|-Consumers           |+Products|- Pain level|Scale          |
|-----+--------------------+---------+------------+---------------|
|     |least likely to rate|Hottest  |            |               |
|     |intense             |sample   |            |               |
|     |                    |         |            |               |
|     |                    |         |            |               |
|   9 +                    +         +            +Strongest      |
|     |                    |         |            |Imaginable     |
|   8 +                    + 70ppm   +            +               |
|     |                    |         |            |               |
|   7 +                    +         +            + Strong        |
|     |                    |         |            |               |
|   6 +                    + 40ppm   +            +               |
|     |                    |         |            |               |
|   5 +                    +         +            +               |
|     | 10                 |         |            |               |
|   4 + 26                 +         +            +               |
|     |                    |         | levelfour  | ------------- |
|   3 + 12   7             + 15ppm   +            +               |
|     | 24                 |         |            |               |
|   2 + 4                  +         +            +               |
|     | 2    3    9        |         |            |               |
|   1 + 16   22            + 7ppm    +            +               |
|     | 21                 |         | levelthree |               |
*   0 *                    *         *            *  Moderate     *
|     | 1    25   27   30  8|        | leveltwo   |               |
|  -1 + 14                 +         +            +               |
|     | 19                 |         |            |               |
|  -2 + 20   23            + 2ppm    +            +               |
|     |                    |         |            |               |
|  -3 + 11   15   5    6   +         +            + ------------- |
|     |                    |         | levelone   |               |
|  -4 +                    +         +            +               |
|     |                    |         |            |               |
|  -5 +                    +         +            +               |
|     | 17   28            |         |            |               |
|  -6 +                    +         +            +               |
|     | 18   29            |         |            |               |
|  -7 +                    + 0.5ppm  +            +Very weak      |
|     |                    |         |            |               |
|  -8 +                    +         +            +               |
|     |                    | 0.15ppm |            |               |
|  -9 +                    +         +            +               |
|     |                    |         |            |               |
| -10 +                    +         +            +               |
|     | 13                 |         |            |               |
| -11 +                    +         +            + Nothing at al |
|     |                    |         |            |               |
|     |Most likely to rate |Mildest  |            |               |
|     |intense             |sample   |            |               |
|     |                    |         |            |               |
|-----+--------------------+---------+------------+---------------|
|Measr|-Consumers           |+Products|-Pain levels|Scale          |
```

Figure 5.5: Wright map showing panellist, product, PST levels and HI facets

To determine if the inclusion of PST had a significant impact on the measurement, Rasch measures and standard error were compared for HI and HI/PST levels. From figure 5.6, as expected, highest tolerance group gave low ratings of hotness intensity whether pain was included or not, while the lowest tolerant group have high ratings of hotness intensity with and without the inclusion of pain measurement.

When comparing the differences in the data obtained from analysis of hotness intensity data on its own and with pain as an extra facet. In the four groups, there was only one group with a significant difference.

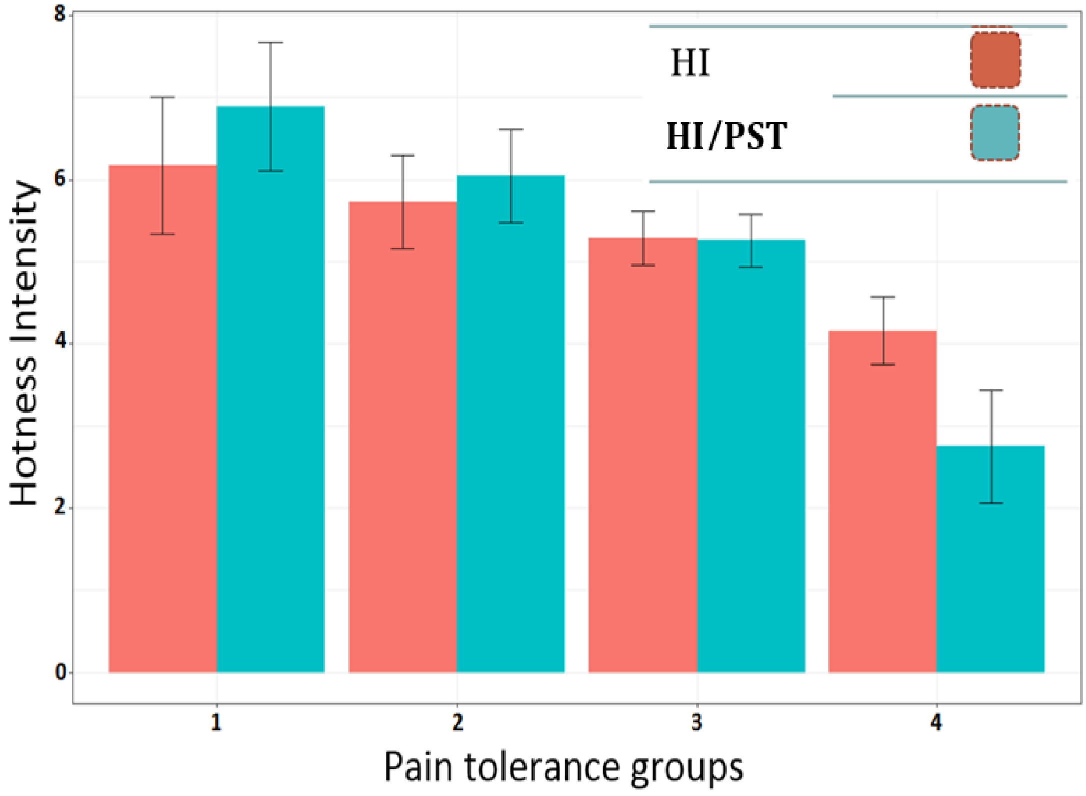


Figure 5.6: Bar graph showing comparison of HI and HI/PST

From the bar graph (figure 5.6), the inclusion of pain measurement, meant that the panellists who had lower tolerance levels (group 1 and group 2) gave a higher estimation of hotness intensity. This meant that pain ratings had some impact on their measurement of hotness intensity. It also meant that their tolerance levels were so low that they perceived the pain caused by the solutions as very intense. In the group 3, pain ratings did not result in any difference in the measurement of hotness level. This meant that the pain they felt was the same as their ratings of the hotness intensity of the solutions. In group 4, pain ratings resulted in the significant reduction of the perception of hotness intensity. This significant reduction might indicated an actual build-up of tolerance levels because if their pain ratings were low compared to other groups, it meant that they had built up their tolerance levels so much so that they felt little or no pain when the consumed capsaicin even at high levels.

5.4.1.5 Conclusions

The inclusion of pain in this measurement of tolerance is unlike what has previously been conducted in tolerance studies (Rozin, P. et al., 1982; Rozin, Paul and Schiller, 1980; Stevenson, R. J. and Yeomans, 1993). However, this study showed that the inclusion of pain in the measurement of tolerance was important in the measurement of tolerance as it served as an extra control measure.

Given the results from the inclusion of pain in the measurement of tolerance, the next study explored the measurement of tolerance using other sensations which had been associated with capsaicin. It also compared tolerance measurement using two attributes and twelve attributes separately.

5.4.2 Tolerance study III

5.4.2.1 Data analysis

The composite measurement (T12) consisted of 12 attributes burn sensitivity, burn tolerance, pain sensitivity, pain tolerance ,prickling sensitivity, prickling tolerance, itching sensitivity, itching tolerance, numbing sensitivity, numbing tolerance, irritation sensitivity, irritation tolerance, while only pain sensitivity and pain tolerance (T2) consisted of 2 attributes. T12 and T2 were separately on fitted their own MFR-PC model, using FACETS ®. Both sets of attributes had three facets were fitted: consumer, products, and attributes. In both cases, products and attributes were positively oriented such that higher product measure implied hotter products and higher attribute measure implied more relevance to measurement. Panellist were negatively oriented so that lower raw score meant higher Rasch measures and higher tolerance.

5.4.2.2 Quality control checks

Rating scale functioning was checked using criteria outlined in section 2.7.4.2. Using these criteria, attempts were made to meet the specified criteria. Finally, all sensitivity scales were collapsed from 8-point scale to 5-point scales while tolerance scales were collapsed from the 6-point scale to 3-point scales.

5.4.2.3 Consumer, attribute, and product fit

5.4.2.3.1 T12

All attributes fit the model and had outfit MNSQ value within the recommended values except irritation sensitivity which had an outfit value of 2.53, as a remedial action, this was removed from the pool of the T12 attributes. A new MFR-PC model was refitted, and fit statistics investigated this time itching sensitivity was misfitting with an outfit MNSQ value of 2.33. Again, remedial action was taken, and new MFR-PC model refitted. Finally, all 10 attributes which were remaining fit the Rasch model with outfit MNSQ ranging from 0.53-1.84. Two panelists (14 and 22) did not have acceptable fit, as they had fit values of 2.10 and 3.46 respectively, these panelists were removed, resulting in acceptable fit.

5.4.2.3.2 T2

Both T2 attributes fit the model with pain stimulus having an outfit MNSQ value of 0.55 and pain tolerance a value of 1.43. However, panelists 11 and 25 with outfit values of 9.00 and 3.98 did not fit the model and were remove, resulting in acceptable fit for remaining participants. T2 had acceptable product fit.

5.4.2.4 Unidimensionality check

Unidimensionality was checked for attributes in T12, following procedure outlined in section 3.3.2.3. All attributes were found to be unidimensional, and this will imply that the same construct was being measured. This was because the Eigen value of the first unexplained contrast was 2.4 indicating unidimensionality, also disattenuated correlation for all clusters was at least greater than 0.89, unidimensionality was therefore assumed. Unidimensionality check showed that both attributes in T2 measured the same construct because the Eigen value of the first unexplained contrast was 2 indicating unidimensionality. Local item dependence was found in the T12 attributes (table 5.7). These items were not removed from the attribute pools as they measured different aspects of the same tolerance construct. No local item dependence was found in T2.

Table 5.7: Correlation between attributes with local item dependence

Correlation	Attributes	Attributes
0.52	Burning tolerance	Pain tolerance
0.38	Itching tolerance	Irritation tolerance

5.4.2.5 Comparison of panelist strata, reliability and separation for T12 and T2

Only data for panelist are reported as the interest is in panelists. Both sets of attributes have reliability of close to 1 although T12 had greater separation, reliability, and strata (table 5.8). A strata value of 10.06 for T12 indicated that participants could be separated into at least 10 groups (p-value <0.01)

Table 5.8: Comparison between T2 and T12 on separation, strata and reliability

Tolerance measure	Separation	Strata	Reliability
T2	4.26	6.02	0.95
T12	7.29	10.06	0.98

5.4.2.6 Wright maps

5.4.2.6.1 T2

The Wright map showing the location of consumer, products and attributes is shown on figure 5.7. Panelists could not distinguish between both T2 attributes.

5.4.2.6.2 T12

The Wright map showing T12 attributes (Figure 5.8). The least important attributes were itching and irritation tolerance. On the other hand, the most pronounced attribute was burning sensitivity. Panelists could not differentiate between some of the other attributes. This was evident as were located on the same levels on the Wright map.

```
+-----------------------------------------------------------------------------------------+
|Measr|-panellist                |+Products|+Attributes                      | S.1 | S.2 |
|-----+--------------------------+---------+---------------------------------+-----+-----|
|   8 +                          +         +                                 + (5) + (3) |
|     | 24                       |         |                                 |     |     |
|     |                          |         |                                 |     |     |
|   7 + 33                       +         +                                 +     +     |
|     |                          |         |                                 | --- |     |
|     |                          |         |                                 |     |     |
|   6 + 41  47  8                +         +                                 +     +     |
|     |                          |         |                                 |     |     |
|     | 28                       |         |                                 |     |     |
|   5 +                          + 6       +                                 +  4  +     |
|     | 52                       |         |                                 |     |     |
|     |                          |         |                                 |     |     |
|   4 + 13  27                   +         +                                 +     +     |
|     | 10  37  44               | 5       |                                 |     |     |
|     |                          |         |                                 | --- |     |
|   3 + 1   2   5                +         +                                 +     + --- |
|     |                          |         |                                 |     |     |
|     | 11                       |         |                                 |     |     |
|   2 +                          + 4       +                                 +     +     |
|     | 32  38  39  9            |         |                                 |     |     |
|     |                          |         |                                 |     |     |
|   1 +                          +         +                                 +     +     |
|     | 12  17  19  21  31  6    |         |                                 |  3  |     |
|     |                          |         |                                 |     |     |
*   0 * 15  18  35  50  51       * 3       * Painsensitivity  Paintolerance  *     *  2  *
|     |                          |         |                                 |     |     |
|     | 29  43                   |         |                                 |     |     |
|  -1 + 23  49  7                +         +                                 +     +     |
|     | 4   42                   |         |                                 |     |     |
|     |                          |         |                                 |     |     |
|  -2 + 22  3                    +         +                                 + --- +     |
|     | 20  46  48               |         |                                 |     |     |
|     | 30  40  45               |         |                                 |     |     |
|  -3 +                          +         +                                 +     + --- |
|     |                          |         |                                 |     |     |
|     |                          | 2       |                                 |     |     |
|  -4 + 26  36                   +         +                                 +     +     |
|     | 34                       |         |                                 |     |     |
|     |                          |         |                                 |     |     |
|  -5 +                          +         +                                 +  2  +     |
|     |                          |         |                                 |     |     |
|     |                          |         |                                 |     |     |
|  -6 +                          +         +                                 +     +     |
|     |                          |         |                                 |     |     |
|     |                          |         |                                 |     |     |
|  -7 +                          + 1       +                                 +     +     |
|     | 16                       |         |                                 |     |     |
|     |                          |         |                                 | --- |     |
|  -8 +                          +         +                                 + (1) + (1) |
|-----+--------------------------+---------+---------------------------------+-----+-----|
|Measr|-panellist                |+Products|+Attributes                      | S.1 | S.2 |
+-----------------------------------------------------------------------------------------+
```

Figure 5.7: Wright map of panellists, products and attributes facet for T2

```
+---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------+
|Measr|-panellist          |+Products|+Attributes                                                                                                   | BS  |(BT) |(PS) |(PT) |(PrS)|(PrT)|(ItT)|(NS) |(NT) |(IrT)|
|-----+--------------------+---------+--------------------------------------------------------------------------------------------------------------+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----|
|  6  +                    +         +                                                                                                              + (5) + (3) + (5) + (3) + (5) + (3) + (3) + (5) + (3) + (3) |
|     | 28                 |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|     |                    |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|     |                    |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|  5  +                    +         +                                                                                                              + --- +     +     +     +     +     +     +     +     +     |
|     | 33  41  47  8      |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|     | 24                 |         |                                                                                                              |     |     | --- |     | --- |     |     |     |     |     |
|     |                    |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|  4  + 27                 +         +                                                                                                              +     +     +     +     +     +     +     +     +     |
|     | 10                 |         |                                                                                                              |  4  |     |     |     |     |     |     |     |     |     |
|     | 13  25  52         |         |                                                                                                              |     |     |     |     |     |     |     | --- |     |     |
|     | 11                 |         |                                                                                                              |     |     |  4  |     |  4  |     |     |     |     |     |
|  3  + 37                 + 6       +                                                                                                              +     +     +     +     +     +     +     +     +     |
|     | 39  44             |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|     | 1                  | 5       |                                                                                                              | --- |     |     |     |     |     |     |  4  |     |     |
|     |                    |         |                                                                                                              |     |     |     |     | --- |     |     |     |     |     |
|  2  + 21  32  5          +         +                                                                                                              +     + --- + --- + --- +     + --- +     +     +     +     |
|     | 2   38             |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|     |                    |         | Burningsensitivity(BS)                                                                                       |     |     |     |     |     |     | --- | --- | --- |     |
|     | 17  19  51  9      | 4       |                                                                                                              |     |     |     |     |     |     |     |     |     | --- |
|  1  +                    +         +                                                                                                              +     +     +     +     +     +     +     +     +     |
|     | 12  18  3   31  6  |         |Burntolerance(BT)  Painsensitivity(PS)   Paintolerance(PT) Pricklingsensitivity(PrS)  Pricklingtolerance(PrT) |     |     |     |     |     |     |     |     |     |     |
|     | 15                 |         |                                                                                                              |  3  |     |  3  |     |  3  |     |     |  3  |     |     |
|     | 29  35  40  50  7  | 3       |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
*  0  * 23  43  49         *         *                                                                                                              *     *  2  *     *  2  *     *  2  *  2  *     *  2  *  2  *
|     | 4   46             |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|     | 48                 |         | Numbingsensitivity(NS)               Numbingtolerance(NT)                                                    |     |     |     |     |     |     |     |     |     |     |
|     |                    |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
| -1  + 20  42             +         +                                                                                                              +     +     +     +     +     +     + --- +     +     |
|     | 45                 |         |                                                                                                              |     |     |     |     | --- |     |     |     |     | --- |
|     | 26                 |         |                                                                                                              | --- |     | --- |     |     |     | --- |     | --- |     |
|     | 30  36             |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
| -2  + 34                 +         + Itchingtolerance (ItT)                                                                                       +     + --- +     + --- +     + --- +     +     +     |
|     |                    |         | Irritationtolerance(IrT)                                                                                     |     |     |     |     |     |     |     |     |     |     |
|     |                    | 2       |                                                                                                              |     |     |     |     |     |     |     |  2  |     |     |
|     | 16                 |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
| -3  +                    +         +                                                                                                              +     +     +     +     +     +     +     +     +     |
|     |                    |         |                                                                                                              |     |     |  2  |     |  2  |     |     |     |     |     |
|     |                    |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|     |                    |         |                                                                                                              |  2  |     |     |     |     |     |     |     |     |     |
| -4  +                    +         +                                                                                                              +     +     +     +     +     +     +     +     +     |
|     |                    |         |                                                                                                              |     |     |     |     |     |     |     | --- |     |     |
|     |                    | 1       |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
|     |                    |         |                                                                                                              |     |     |     |     |     |     |     |     |     |     |
| -5  +                    +         +                                                                                                              + (1) + (1) + (1) + (1) + (1) + (1) + (1) + (1) + (1) + (1) |
|-----+--------------------+---------+--------------------------------------------------------------------------------------------------------------+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----|
|Measr|-panellist          |+Products|+Attributes                                                                                                   | BS  |(BT) |(PS) |(PT) |(PrS)|(PrT)|(ItT)|(NS) |(NT) |(IrT)|
+---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------+
```

Figure 5.8: Wright map of panellists, products and attributes facet for T12

5.5 Conclusions

Studies in this chapter showed that the used of multiple measurement attributes gave better estimation that the use of fewer attributes. The first study showed that if pain was included as an additional measure in the estimation of hotness intensity where the aim was to measure tolerance, it provided more information that when hotness intensity was considered alone as was done by other researchers in previous studies (Rozin, P. et al., 1982; Rozin, Paul and Schiller, 1980; Stevenson, R. J. and Yeomans, 1993)

In the second study, although T12 attribute give better separation when compared to T2 attributes, showing that when several attributes are used in a measurement it is possible to distinguish panellist at a micro level. this doesn't necessarily mean that T12 attributes were much better than T2 attributes in measuring tolerance levels. Fewer attributes might be important if time constraint is a factor. Further experiments need to be conducted to know which attributes are important in the measurement of tolerance in other to reduce the number of attributes need to conduct a test.

Chapter 6 : Study IV and V: Effect of liking on oral perception of burning sensitivity, burning tolerance and overall tolerance

6.1 Introduction

One of the major factors which has been reported to have an influence on the perception of hotness, besides the concentration of capsaicin present in food and the tolerance levels of the consumer is the liking of the hotness and other attributes which are present in the food (Rozin, Paul and Schiller, 1980; Ahmed et al., 2002; Eertmans et al., 2005). If liking of the hotness of chilli has been used as a major criteria for the classification of consumers of foods with chilli into “likers” and “non-likers”(Lawless et al., 1985; Ludy and Mattes, 2012; 2011; Byrnes and Hayes, 2013; 2015, it is pertinent for this relationship to be explored along with tolerance measurement and rating of hotness intensity. There was therefore a need to investigate the extent that liking of the hotness of foods would affect the rating of the hotness intensity of the consumers and their tolerance levels.

This chapter is made up of two studies, the first study investigated the impact liking of the hotness of noodles had on the rating of burning sensitivity and burning tolerance. The second study investigated the impact of 6 attributes of tolerance on the rating of liking to chilli tomato soups.

The aims of this chapters were to determine:

(1) If participant’s perception of hotness of noodles with varying levels of capsaicin influenced their liking of the burn noodles.

(2) If the liking of chilli tomato soup was influenced by tolerance ratings using six attributes.

6.2 Hypothesis

This study tested the hypothesis that liking of foods with chilli would result in lower perception of hotness intensity and higher tolerance levels.

6.3 Materials and Methods

6.3.1 Study IV: Noodles

6.3.1.1 Sample preparation

Indomine® Instant noodle which was bought from a Chinese supermarket was chosen to be the material of experiment. Noodles were chosen because it was easy to prepare and easier to incorporate chilli into. There were 4 samples, the first was prepared with the soy sauce and chilli powder which came with the noodles. The other 3 samples were prepared using only the soy sauce which came with the noodles and 600ppm concentration capsaicin solutions of varying volumes (4ml, 8ml and 16ml). Table 6.1 shows the content of all samples.

Table 6.1:Contents of sampled noodles

	Sample 1	Sample 2	Sample 3	Sample 4
Soya Sauce	✔	✔	✔	✔
Oil	✔	✔	✔	✔
Chilli powder	✔	✕	✕	✕
Capsaicin solution (600ppm)	✕	4 ml	8 ml	16 ml

Noodles packs were prepared according to manufacturer's instructions. 500 ml of water was boiled in a pot and added 100 g instant noodles. This was boiled for 3 minutes. The noodles were then taken out of water and mixed with the prepared sauces (original sauce, sauce with 4 ml 600 ppm capsaicin, 8 ml 600ppm capsaicin, and 16 ml 600 ppm capsaicin). Using a weighing balance, each noodle sample was rapidly divided in to four approximate weight of 35 g each. Each sample was prepared and served one at a time such that the next sample was prepared as the preceding noodles was being sampled. This ensured that noodles were served hot.

6.3.1.2 Test procedures

Participants were recruited from the staff and students of University of Leeds, by sending out emails and by posters placed at strategic locations at the University of Leeds. Thirty four participants were recruited from the staff and students of University of Leeds by posters, word of mouth, referrals from friends and emails.

On the test days, sample were prepared while participants were seated to ensure the samples were served immediately after cooking as would be the case in real life situations. 35 g of samples were served per participants in a polystyrene bowl coded with randomized 3-digit codes and samples were completely randomised. Using Redjade®, participants were required to enter a verification code online after which they had to read the participant information form and give their consent. At the beginning of the test before any samples were given, there was a page which describe potential sensations which they might feel. They were instructed to answer questions about their burn sensitivity, burn tolerance, overall intensity and liking of the hotness after eating the samples. Before rating each attribute (burn sensitivity and burn tolerance), they were required to have a third of the sample, chewing before swallowing, resulting in 3 bites per sample for evaluation of all the attributes. In between samples, participants were instructed to eat as much plain water crackers and water as they needed to get rid of residual hotness intensity in their mouths. They were then required to rest for 5 minutes before they proceeded to the next sample. Each participant tested every sample. Figure 6.1 is an illustration of how the noodles samples were presented.

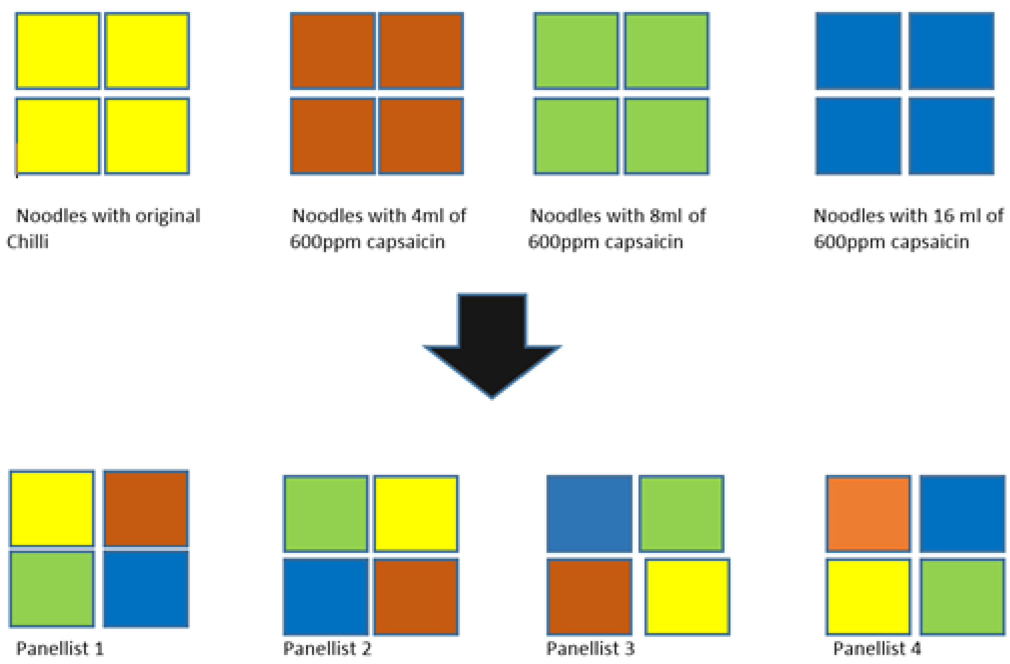


Figure 6.1: schematic of noodles sample preparation and presentation

6.3.2 Study V: Soups

6.3.2.1 Sample preparation

Following the first and second methods which did not yield consistent results, this third method was developed. Soups were prepared using tomato soups and chilli extract made from section 3.4.2. Soup base was made from 880 g Morrison's chopped canned tomatoes, 2 tablespoon of Morrison's vegetable oil, 1 Knorr® vegetable stock cube, 220 g of onions, 15 g of garlic, 5 g of fresh basil, and 100 millimetres of water. This recipe produced approximately 1200 g of soup. All soups were made on the day of experiment using four different Morphy Richards 48822 stainless steel soup maker. Raw ingredients were prepared and placed in the soup maker, the blend function was used to blend all the raw ingredients which were in the blender for 2 minutes. The soup was then cooked using the chunky function for 28 minutes. After which the soup was pureed for 2 minutes to achieve a smooth consistency. Chilli extracts (section 3.4.2) were then added to the freshly prepared soup samples. Four samples of varying hotness were made, containing 0ml of chilli extract in 200 g, 12 mls in 1200 g of soup base, 24 mls of extract in 1200 g soup base, and 48 mls in 1200 g soup based.

6.3.2.2 Test procedure

On the test days, samples were prepared while participants were seated to ensure the samples were piping hot as would be the case in real life situations. Temperature of all soups were held at 50 ^{o}C in the soup makers. 30 g of samples were served per participants in white ceramic bowls with lids and were coded with randomized 3 digit codes and samples were served in completely randomised order using Redjade®, participants were required to enter a verification code online after which they were required to read the participant information form and give consent. At the beginning of the test before any samples were given, there was a page which describe potential sensations which they might feel. They were required to answer questions about their perception of the overall hotness and the liking of the hotness after ingesting the samples. Participants were told to finish the 30 g of soups which was served. They were required to eat at least a spoonful of spoon for each attribute that was to be measured. In between samples, participants were then required to have as much plain water crackers and water as they needed to get rid of residual hotness intensity in their mouths. Before they proceeded to the next sample, they were then required to rest for 5 minutes, this time was enforced by the software.

6.4 Results

6.4.1 Study IV Effect of liking of chilli on oral perception of burning sensitivity and burning tolerance

6.4.1.1 Demographic data

Thirty four panellist participated in this study using noodles, their demographic information are shown in figure 6.2. Most participants consumed foods with chilli often. Over a third of the participants were of Asian origin with participants being either white or classified as others which were made up of other ethnicities. The age group of most participants was between 16-24 years.

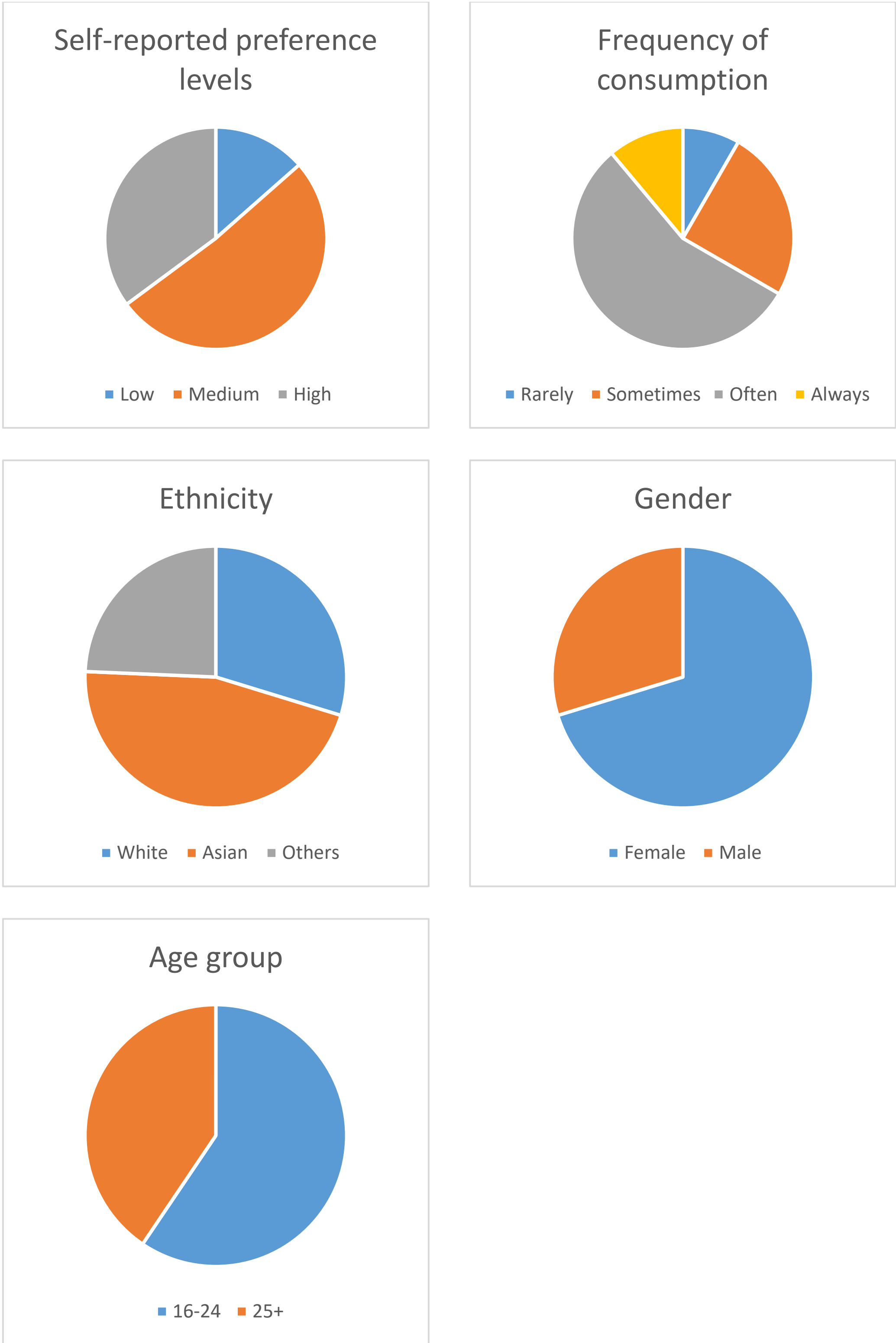


Figure 6.2: Pie charts of demographic distribution of panellists

6.4.1.2 Rasch analysis

Data for the 34 participants were fitted on the MFR-PC model. Burn sensitivity (B) and burn tolerance (BT) were fitted on the same MFR-PC model using Facets (Linacre, 2014). Three facets were fitted, panellists, products and two attributes (B and BT). Products and attribute facets were positively oriented so that high raw score rating implied high Rasch measures which implied that the noodles evoked more of burning sensitivity and burning tolerance. Panellists were negatively oriented so that high raw score rating implied low Rasch measures and less perception to burning sensitivity and burning tolerance. To measure the liking of the participant's burn of chili sample, three facets were fitted; panellist, products and one attribute, burning liking (BL), on the MFR-PC Rasch model. All facets were positively oriented such that higher raw score rating implied higher Rasch measures and higher liking of the noodles.

After data was fitted for all B, BT and BL as described above, the rating scale effectiveness were first investigated and the 9-point hedonic scale which was used to rate BL was collapsed to a 4-point rating scale. Also, the 8-point B scale was collapsed to a 4-point rating scale and the 6-point rating scale BT scale to 3-point rating scale. Table 6.2 shows data before and after collapse.

Table 6.2: Statistics before and after scale collapse for B, BT and BL

Scale category	Raw score	counts used	% of counts	Obs	Exp	Rasch-Andrich threshold ±SE	Outfit MNSQ
Original 8-point B scale							
None	1	7	5%	-2.85	-3.02		1.3
Barely detectable	2	22	15%	-2.25	-2.22	-3.78 ± .44	1
Slight	3	43	30%	-1.31	-1.36	-2.46 ± .26	1.2
Moderate	4	36	25%	-0.64	-0.55	-.78 ± .22	1.1
Strong	5	20	14%	0.17	0.18	.40 ± .26	0.8
Very strong	6	9	6%	0.8	0.86	1.32 ± .36	0.9
Extremely strong	7	4	3%	1.88	1.55	2.01 ± .55	0.5
Strongest sensation ever experienced	8	1	1%	2.19	2.24	3.28 ± 1.10	0.8
Original 6-point BT scale							
Completely able	1	102	72%	-2.93	-2.91		0.9
Slightly unable	2	23	16%	-1.68	-1.74	-.80 ± .23	1.1
Moderately unable	3	9	6%	-1.01	-0.94	-.38 ± .35	1.2
Strongly unable	4	3	2%	-0.15	-0.35	.46 ± .50	0.3
Extremely unable	5	3	2%	0.88	0.15	-.09 ± .61	0.2
Completely unable	6	2	1%	0.03*	0.67	.81 ± .85	1.4
Original 9-point BL scale							
Dislike Extremely	1	2	1%	-0.38	-0.64		1.2
Dislike Very Much	2	3	2%	-.66*	-0.5	-0.98±0.76	0.5
Dislike Moderately	3	4	3%	-0.27	-0.33	-0.7±0.52	1.1
Dislike Slightly	4	6	4%	-.46*	-0.13	-0.64±0.41	0.2
Neither Like nor Dislike	5	9	6%	0.16	0.09	-0.42±0.34	0.7
Like Slightly	6	22	15%	0.4	0.34	-0.68±0.27	1.4
							1.2
Like Moderately	7	38	27%	0.69	0.64	-0.07±0.22	
Like Very Much	8	49	35%	0.95	1.02	0.57±0.2	1.1
Like Extremely	9	9	6%	1.57	1.41	2.92±0.36	0.9
Collapsed 4-point B scale							
None	1	29	20%	-2.25	-2.27		1.1
Barely detectable	2	43	30%	-0.92	-0.97	-2.02 ± .26	1.1
Moderate	3	56	39%	0.32	0.4	-.57 ± .22	1
Extremely strong	4	14	10%	2.19	2.06	2.59 ± .34	0.9
Collapsed 3-point BT scale							
Completely able	1	102	72%	-2.58	-2.56		0.8
Slightly unable	2	23	16%	-0.84	-0.85	-0.18±.24	1.1
Strongly unable	3	17	12%	0.75	0.63	0.18±.34	0.8

Scale category	Raw score	counts used	% of counts	Obs	Exp	Rasch-Andrich threshold ±SE	Outfit MNSQ
Collapsed 4-point BL scale							
Dislike very much	1	24	14%	-1.72	-1.62		0.9
Like slightly	2	60	43%	-0.6	-0.67	-2.24 ± 0.27	1.3
Like very much	3	49	36%	0.13	0.21	-0.03 ± 0.2	1
Like extremely	4	9	7%	1.07	0.89	2.28 ± 0.37	0.8

6.4.1.2.1 Attribute, panellist, and product fit

Fit statistics was checked for all attributes, panellists, and products to ensure they met the criteria in section 2.7.4.2. All models had acceptable fit for products, panellist, and attributes (table 6.3).

Table 6.3: Fit statistics for panellist, products, and attributes

Attributes	Measure ± S.E.	Outfit MNSQ
B	.75 ± .14	1.02
BT	-.75 ± .17	0.99
Products		
16ml in 100g noodles	0.29 ± 0.2	0.81
Original noodles	-0.79 ± 0.2	1.64
8mls in 100g noodles	-1.3 ± 0.21	0.72
4mls in 100g noodles	-2.67 ± .25	0.84
BL	0.00 ± 0.15	0.97
Products		
Original noodles	0.27 ± 0.30	0.26
4mls in 100g noodles	-0.49 ± 0.31	0.27
8mls in 100g noodles	0.20 ± 0.30	0.26
16ml in 100g noodles	0.02 ± 0.31	0.27

6.4.1.2.2 Wright map

The Wright map for B and BT (figure 6.3) showed that the noodles with 16mls of 600ppm capsaicin was perceived as the sample that caused the highest burn sensitivity and was the least tolerable, this was followed by the original chilli noodles, 8ml of 600ppm and finally the noodles mixed with 4mls of

600ppm solution being perceived as the least hot noodles. This was expected as high concentrations of capsaicin should give high burn ratings. It also showed that the most prominent attribute was burning sensitivity and the least attribute burning tolerance, this meant most panellists were able to tolerate the burn of the most noodles sample. Finally, panellists 19, 30, and 60 had the highest Rasch measures and by extension reported low burn sensitivity and high burn tolerance to all the samples. This can be interpreted to mean that these four panellists have higher tolerance levels since it has been reported that higher tolerance levels lead to reporting lower levels of burning sensation (Rozin, Paul and Schiller, 1980; Ahmed et al., 2002; Eertmans et al., 2005).

The Wright map for BL was represented in figure 6.4. It showed that the most liked samples were the original chilli noodles and the noodles mixed with 8ml of 600ppm capsaicin and they were both liked equally, indicated by their location on the Wright map. The least liked sample was the least hot sample which was mixed with 4ml of capsaicin solution. This would imply that most of the panellist in this cohort like some sort of hotness in their noodles. The Wright map provides useful information about each panellist in relation to the population which was sampled. The panellist at the top of the Wright map represented those who liked the samples the most and those at the bottom like sample the least. For example, panellist 68 liked samples the most in comparison to panellist 92 who liked samples the least this is shown by their location at the wright map**.**

```
Vertical = (1A,2A,3A,S) Yardstick (columns lines low high extreme)= 0,7,-4,3,End
+-------------------------------------------------------------------+
|Measr|+products|-panellist           |+Attributes      | B   | BT  |
|-----+---------+---------------------+-----------------+-----+-----|
|   3 +         +                     +                 + (4) + (3) |
|     |         |                     |                 |     |     |
|     |         |                     |                 | --- |     |
|     |         |                     |                 |     |     |
|     |         | 19  30  60          |                 |     |     |
|     |         |                     |                 |     |     |
|     |         |                     |                 |     |     |
|   2 +         +                     +                 +     +     |
|     |         |                     |                 |     |     |
|     |         | 17  42              |                 |     |     |
|     |         |                     |                 |     |     |
|     |         |                     |                 |     |     |
|     |         |                     |                 |     |     |
|     |         | 20  27  64  67      |                 |     |     |
|   1 +         +                     +                 +  3  +     |
|     |         |                     |                 |     | --- |
|     |         | 21  24  58  61  72  |      B          |     |     |
|     |         |                     |                 |     |     |
|     |         |                     |                 |     |     |
|     | 16ml    | 14  4   56          |                 |     |     |
|     |         |                     |                 |     |     |
*   0 *         * 12  44  6   68      *                 *     *  2  *
|     |         |                     |                 |     |     |
|     |         |                     |                 | --- |     |
|     |         | 10  11  38  86      |                 |     |     |
|     |         |                     |                 |     |     |
|     |         | 31  88              |      BT         |     |     |
|     | original| 69                  |                 |     | --- |
|  -1 +         + 37  39              +                 +     +     |
|     |         |                     |                 |     |     |
|     | 8mls    |                     |                 |  2  |     |
|     |         | 16                  |                 |     |     |
|     |         |                     |                 |     |     |
|     |         | 2                   |                 |     |     |
|     |         |                     |                 |     |     |
|  -2 +         + 73                  +                 +     +     |
|     |         |                     |                 |     |     |
|     |         | 92                  |                 |     |     |
|     |         |                     |                 | --- |     |
|     |         |                     |                 |     |     |
|     | 4mls    | 3                   |                 |     |     |
|     |         |                     |                 |     |     |
|  -3 +         +                     +                 +     +     |
|     |         |                     |                 |     |     |
|     |         |                     |                 |     |     |
|     |         |                     |                 |     |     |
|     |         | 29                  |                 |     |     |
|     |         |                     |                 |     |     |
|     |         |                     |                 |     |     |
|  -4 +         +                     +                 + (1) + (1) |
|-----+---------+---------------------+-----------------+-----+-----|
|Measr|+products|-panellist           |+Attributes      | B   | BT  |
+-------------------------------------------------------------------+
```

Figure 6.3: Wright map of products, panellists and attribute facets for B and BT

```
+------------------------------------------------------------------------------+
|Measr|+panellist                                  |+products|+Attributes| BL  |
|-----+--------------------------------------------+---------+-----------+-----|
|   2 +                                            +         +           + (4) |
|     |                                            |         |           |     |
|     | 68                                         |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     | 10  2   21  3   42                         |         |           |  3  |
|   1 +                                            +         +           +     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     | 17  37  4                                  |         |           |     |
|     | 69  86                                     |         |           |     |
|     |                                            |Org.  8ml|           |     |
|     |                                            |         |           |     |
*   0 * 12  14  19  30  44  6   60                 * 16ml    * BL        * --- *
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            | 4ml     |           |     |
|     | 24  39                                     |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|  -1 +                                            +         +           +     |
|     | 11  16  20  27  31  38  56  58  67  72  88 |         |           |  2  |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     | 61  64                                     |         |           |     |
|     |                                            |         |           |     |
|  -2 +                                            +         +           +     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     | 73                                         |         |           | --- |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|  -3 +                                            +         +           +     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     | 29                                         |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|     |                                            |         |           |     |
|  -4 + 92                                         +         +           + (1) |
|-----+--------------------------------------------+---------+-----------+-----|
|Measr|+panellist                                  |+products|+Attributes| BL  |
+------------------------------------------------------------------------------+
```

Figure 6.4: Wright map of products, panellists and attribute facets for BL

6.4.1.2.3 Separation, strata and reliability for B, BT, and BL

Separation, strata and reliability statistics for B, BT and BL are shown in table 6.4. It showed that using their reported B and BT to samples, participants were separated into at least 2 statistically significant levels (p-value < 0.01). On the other hand, using ratings of liking of burn of samples (BL), participants could not be divided into any statistically significant groups this meant that panellists did not differ in their liking of the burn of the samples.

Table 6.4: Separation, strata, and reliability statistics for B, BT and BL.

Facet	Separation	Strata	Reliability
B and BT			
Panellist	1.92	2.89	0. 79
Products	5.58	7.77	0. 97
Attributes	6.76	9.35	0.98
BL			
Facet			
Panellist	1.25	2.00	0.61
Products	0.81	1.41	0.39

To test further test this, panellists were separated into two (low and high clusters) statistically significant clusters using their ratings of B and BT, to determine if the low and high clusters differed in their rating of BL. The cluster means of the BL Rasch measures for each cluster was tested for the hypothesis that cluster means were equal. Results (P-value = 0.10) indicated that the sample means were equal. This confirmed what the separation, strata and reliability values had previously indicated. Self-reported preference levels of B/BT low and B/BT high group were not significantly different (p-value 0.7). Finally, when self-reported preference levels were compared with measures of liking, self-reported liking groups did not significantly differ in their rating of burn liking (p-value = 0.06)

Results obtained from this data set showed that liking of burn of noodles sample did not have any influence of the rating of burning sensitivity and burning tolerance this is different from what had been previously reported , where they reported that greater liking caused a reduction in reported burn. Also, there failed to be any relationship between the rating of Burning sensitivity (B) or Burning tolerance (BT) and the self-reported preference levels of panellists nor with liking measures. The result from this study was contrary to what had been reported by other researchers, where liking the burn of chilli resulted in the consumer rating its burn as less intense (Rozin, Paul and Schiller, 1980; Lawless, H. et al., 1985; Cowart, 1987; Stevenson, R. J. and Yeomans, 1993; Stevenson, Richard J and Prescott, 1994; Eertmans et al., 2005; Byrnes and Hayes, 2013; Byrnes and Hayes, 2015). It was therefore important to further test this using a different chilli food medium and different participants.

6.4.2 Study V: Effect of liking on oral perception of tolerance attributes

6.4.2.1 Rasch analysis

Tolerance attributes (TA) consisted of six attributes of pain sensitivity, pain tolerance, burn sensitivity, burning tolerance, warmth sensitivity and warmth tolerance while overall liking (OL) consisted of 3 attributes; liking of flavour, liking of taste. and liking of hotness of each sample.

The TA were fitted on the MFR-PC model with three facets, the products (soups), the panellist, and the 6 tolerance attributes (TA). Products (soups) and attributes were positively oriented such that higher Rasch measures meant more of the attributes being measured and more of the measured attributes being present in the samples. In contrast, panellists were negatively oriented such that high raw score ratings gave lower Rasch measures and implied that the panellist was less tolerant to products. Overall Liking attributes (OL) were also fitted on the MFR-PC model, there were also three facets, which were all positively oriented such that higher raw score of panellists, product (soups) and attribute, implied more that panellist had more overall liking, soups were more liked, and there was the presence of more of the attribute that was being measure respectively. Rating scale effectiveness for TA was checked using criteria outlined in section 2.7.4.2. The 8-point sensitivity scales were collapsed to 5-points while the 6-point tolerance scales were collapsed to 3-point scales. All OL scales were also collapsed from 9-point hedonic scale to 5-point scale.

6.4.2.1.1 Attribute, panellists, and product fit

Fit statistics were also checked for product, panellists, and attribute fit. All products (soups) and attributes fit the Rasch model (table 6.5).

Table 6.5: Fit statistics for soups and attributes

Attributes	Measure ± S.E.	Outfit MNSQ
TA		
Warmth sensitivity	1.54 ± 0.09	1.19
Burn sensitivity	0.46 ±0.10	0.75
Pain sensitivity	0.43 ±0.09	1.02
Burn tolerance	-0.73 ± 0.11	1.34
Warmth tolerance	-0.79 ±0.14	1.50
Pain tolerance	-0.92 ±0.11	1.24
Products		
0ppm	-2.11±0.12	1.44
3ppm	-0.21 ±0.09	0.91
7ppm	0.75 ± 0.08	0.95
10ppm	1.58±0.07	0.99
OL		
Liking of flavour	0.10 ±0.08	0.84
Liking of taste	0.04 ±0.08	0.92
Liking of hotness	-0.14±0.08	1.17
Products		
0ppm	-0.20±0.09	1.28
3ppm	0.16 ±0.09	0.83
7ppm	0.17 ± 0.09	0.75
10ppm	-0.14±0.09	1.04

6.4.2.1.2 Unidimensionality

The results showed that all attributes for both TA and OL were unidimensional, this was shown by the value of the first contrast of most of the factors except weight which were less than 3 (Linacre, 2019), and the disattenuated correlation for all contrast were 1. This indicated that this all attributes were unidimensional.

6.4.2.1.3 Separation, strata, and reliability

The separation data strata data for TA panellist indicated that they could be separated into at least four statistically significant levels (p-value < 0.01). The strata values for both product and attributes indicated that they were statistically different (p-value < 0.01). For OL, panellists could be separated into at least 2 statistically significant levels. However, separation values for attributes indicated that panellist could not differentiate between attributes (p value = 0.07). For products, there was a statistical difference between the liking of all products (p value < 0.01) Table 6.6 presents fit statistics.

Table 6.6: Statistics for panellist, product and attribute fit

Facet	Separation	Strata	Reliability
TA			
Panellist	2.93	4.24	0. 90
Products	17.24	23.32	1.00
Attributes	9.04	12.38	0.99
OL			
Panellist	3.42	2.31	0.84
Products	1.89	2.85	0.78
Attributes	1.26	2.02	0.61

6.4.2.1.4 Wright maps

The wright map of TA (figure 6.5) showed that warmth sensitivity was the most prominent attribute in the soups. This was expected because of the serving temperature which was 50 °C. Also, one of the leading attributes of habanero peppers was warmth (Guzmán and Bosland, 2017) the prominence of warmth attribute compared to the other attributes can be attributed to these two factors. It can also be seen from the Wright map that all tolerance attributes were lowest of the all the TA attributes. This could also be attributed to the fact that the concentrations of the capsaicin in the soups were not high enough to make the attributes intolerable. The least prominent attributes were pain tolerance and warmth tolerance, again this was expected as levels of chilli present in soups were not enough to cause pain which is intolerable. Also, it was possible that pain was not associated with these soups given the levels of capsaicin. At the highest concentration level of 10ppm, it was unlikely that the soups would inflict any pain upon consumption. This was indicated by the capsaicin content as determined by HPLC. As expected, the soup with the highest level of chilli (capsaicin) was the one which had more of the attributes being measured and the one with no capsaicin had less of the attributes. Panellists 33 and 6 had the highest tolerance levels and 36 had the least.

```
+-----------------------------------------------------------------------------------------------------------------+
|Measr|-panellist              |+Products|+Attributes                         |B    | BT  | P   | PT  | W   | WT  |
|-----+------------------------+---------+------------------------------------+-----+-----+-----+-----+-----+-----|
|    5 + HIGHEST TOLERANCE      +         +                                    + (5) + (4) + (5) + (4) + (5) + (3) |
|     |                        |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|     | 33  6                  |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|    4 +                        +         +                                    +     +     +     +     +     +     |
|     |                        |         |                                    |     |     |     |     |     |     |
|     | 32                     |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|     | 31  5                  |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|    3 + 58                     +         +                                    +     +     +     +     + --- +     |
|     |                        |         |                                    |     |     |     |     |     |     |
|     | 20  47                 |         |                                    | --- |     |     |     |     |     |
|     | 63  9                  |         |                                    |     |     |     |     |  |  |     |
|     |                        |         |                                    |     |     | --- |     |     |     |
|     | 18  34  35  46  48  61 |         |                                    |     |     |     |     |     |     |
|    2 + 21  60                 +         +                                    +     +     +     +     +     +     |
|     | 14  45  8              |         |                                    |  4  |     |     |     |     |     |
|     | 11  17  29  43  51  53 |         |                                    |     |     |     |     |  4  |     |
|     | 42  52  62             | 10PPM   | warmth                             |     |     |     |     |     |     |
|     | 40                     |         |                                    |     |     |  4  | --- |     |     |
|     | 13  25  28  30  38  41 |         |                                    | --- | --- |     |     |     |     |
|    1 + 22  26  44  49  50  55 +         +                                    +     +     +     +     +     +     |
|     | 27  56  57             |         |                                    |     |     |     |     |     | --- |
|     | 15  37  59             | 7PPM    |                                    |     |     |     |     |     |     |
|     |                        |         | Burn              Pain             |     |  3  | --- |  3  | --- |     |
|     | 10  16  24             |         |                                    |  3  |     |     |     |     |     |
|     | 19  4   54             |         |                                    |     |     |     |     |     |     |
*    0 * 39  64                 *         *                                    *     * --- *     * --- *     *  2  *
|     |                        | 3PPM    |                                    |     |     |  3  |     |  3  |     |
|     | 36                     |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |  2  |     |     |     |     |
|     |                        |         | Burn tolerance                     | --- |     | --- |  2  |     |     |
|     |                        |         | Pain tolerance    warmth tolerance |     |     |     |     | --- | --- |
|   -1 +                        +         +                                    +     +     +     +     +     +     |
|     |                        |         |                                    |     | --- |     |     |     |     |
|     |                        |         |                                    |     |     |  2  | --- |     |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |     |     |     |  2  |     |
|     |                        |         |                                    |  2  |     |     |     |     |     |
|   -2 +                        +         +                                    +     +     +     +     +     +     |
|     |                        | 0PPM    |                                    |     |     | --- |     |     |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|     |                        |         |                                    |     |     |     |     | --- |     |
|     |                        |         |                                    |     |     |     |     |     |     |
|   -3 + lOWEST TOLERANCE       +         +                                    + (1) + (1) + (1) + (1) + (1) + (1) |
|-----+------------------------+---------+------------------------------------+-----+-----+-----+-----+-----+-----|
|Measr|-panellist              |+Products|+Attributes                         |B    | BT  | P   | PT  | W   | WT  |
+-----------------------------------------------------------------------------------------------------------------+
```

Figure 6.5: Wright map of TA showing panellist, product and attribute facets

```
+--------------------------------------------------------------------------------+
|Measr|+panellist                         |+Products|+Attributes|Hotne|Taste|Flavr|
|-----+-----------------------------------+---------+-----------+-----+-----+-----|
|   4 + MOST LIKELY TO LIKE SOUPS         +         +           + (5) + (5) + (5)|
|     |                                   |         |           |     |     |     |
|     |                                   |MOST     |MOST       |     |     |     |
|     |                                   |LIKED    |PROMINENT  |     |     |     |
|     |                                   |SOUP     |ATTRIBUTE  |     |     |     |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           |     |     |     |
|     | 13                                |         |           |     |     |     |
|   3 +                                   +         +           +     +     +     |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           |     | --- | --- |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           | --- |     |     |
|   2 +                                   +         +           +     +     +     |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           |     |     |     |
|     |                                   |         |           |     |  4  |  4  |
|     |                                   |         |           |     |     |     |
|     | 40                                |         |           |  4  |     |     |
|     |                                   |         |           |     |     |     |
|   1 + 31   35   59   60                 +         +           +     +     +     |
|     | 41                                |         |           |     |     |     |
|     | 44   51   62                      |         |           |     | --- | --- |
|     | 14   18   25   46                 |         |           | --- |     |     |
|     | 21   26   34   8                  |         |           |     |     |     |
|     | 33                                |         |           |     |     |     |
|     | 56                                |         |           |     |     |     |
|     | 27   6                            |3ppm 7ppm| flavour   |     |     |     |
*   0 * 29   49   5    50                 *         * taste     *  3  *  3  *  3  *
|     | 16   17   30   42   47   48   58   63 | 10ppm   | hotness   |     |     |     |
|     | 24   28   37   4    57            |  Oppm   |           |     |     |     |
|     | 36   52                           |         |           |     |     |     |
|     |                                   |         |           |     |     |     |
|     | 20   39   45                      |         |           | --- |     |     |
|     | 43                                |         |           |     | --- | --- |
|     | 11   54                           |         |           |     |     |     |
|  -1 + 15   61                           +         +           +     +     +     |
|     | 38   53                           |         |           |     |     |     |
|     | 19   9                            |         |           |  2  |     |     |
|     | 32   64                           |         |           |     |     |     |
|     | 22                                |         |           |     |  2  |  2  |
|     |                                   |LEAST    |LEAST      |     |     |     |
|     |                                   |LIKED    |PROMINENT  |     |     |     |
|     | 10   55                           |SOUP     |ATTRIBUTE  |     |     |     |
|  -2 + LEAST LIKELY TO LIKE SOUPS        +         +           + (1) + (1) + (1)|
|-----+-----------------------------------+---------+-----------+-----+-----+-----|
|Measr|+panellist                         |+Products|+Attributes|Hotne|Taste|Flavr|
+--------------------------------------------------------------------------------+
```

Figure 6.6: Wright map of OL showing panellist, product and attribute facets

As shown by the Wright map for OL (figure 6.6), the most liked soups were the soups which were the middle soups (which had 3 ppm and 7 ppm of capsaicin) this was similar with data from the noodles study, were the samples in the middle were the most liked products. Similarly, there was no significant difference between OL of the most liked soups (3 ppm and 7 ppm soups) as they were both located at the same position of the Wright map. The most liked attribute was the flavour of the soup, and the hotness of the soup was the least liked attribute. It is uncertain if the hotness of the soup was the least liked because it was too hot or that it was not hot enough. Panellist 13 had the most liking for the soups and panellists 10 and 55 had the least liking for the soups.

Panellists were separated into four groups, TA1 to TA4 using their ratings of TA. TA1 was the group that rated samples as being hottest and TA4 the group that rated samples as being least hot. All groups were then compared using their OL measures. Results showed that (table 6.7) groups differed significantly on their liking (p value 0.03). However the group with the highest liking score TA3 was unexpected as it had previously been reported that the lower the rating of sensations the higher the liking (Stevenson, R. J. and Yeomans, 1993; Stevenson, Richard J. and Yeomans, 1995; Reinbach et al., 2007), and if this was the case, TA4 should have had the greatest liking.

Table 6.7: Multiple comparison of TA groups

	Lowest TA measures (TA1)	2nd lowest TA measures (TA2)	2nd highest measures (TA3)	Highest TA measures (TA4)
Liking measures	14.39[b]	31.95[a]	33.42[a]	30.25[ab]

6.5 Discussion

Both studies in this chapter demonstrated that liking of sensations evoked by chilli did not affect the ratings of burning sensitivity (B), burning tolerance (BT) or tolerance attributes (TA) . This finding is contrary to what had previously been reported where liking of the sensations which chill evoke resulted in reduced rating of intensity of the sensations (Rozin, Paul and Schiller, 1980; Lawless, H. et al., 1985; Cowart, 1987; Stevenson, R. J. and Yeomans, 1993; Stevenson, Richard J and Prescott, 1994; Eertmans et al., 2005; Byrnes and Hayes, 2013; Byrnes and Hayes, 2015).

Both studies which were conducted in this chapter showed that liking of the burn of chilli could not be used as a criterion for segmentation. It also reinforced why the current segmentation based on user or liker status (Lawless et al., 1985; Ludy and Mattes, 2012; 2011; Byrnes and Hayes, 2013; 2015) cannot be helpful in distinguishing between the various types of chilli consumers. Logically, if based on actual consumption of food samples during a sensory session, consumers could not be distinguished, then using self-reported liking of chilli would provide even less information about the consumers of foods with chilli.

Results from the overall liking attributes showed that hotness attribute was the least liked attribute when compared to the taste and flavour of the soups. This should be explored as there is a need to understand if this attribute was the least liked because samples were perceived as too hot or samples were not hot enough for the sampled population.

6.6 Conclusions

If consumers of foods with chilli cannot be differentiated based on their ratings of liking of the sensations it evoked by chilli, it is an indication that liking of chilli might not be of importance in the developing of a measurement for the perception of the hotness of foods. For this reason, the next chapter did not use any data about liking attributes in the development of a measurement of the perception of hotness.

Chapter 7 : Study VI: Development of an objective measure of oral perception of tomato chilli soup.

7.1 Introduction

At the beginning of this research, the aim was to develop a measurement of the perception of hotness using all the factors influenced the actual measurement of the perception of foods with chilli. These major factors had been reported to be tolerance, liking, and the perception of the hotness of the food with chilli which was eaten. To determine the extent to which these factors affected the perception of hotness, which is reported by consumers, individual studies were conducted that explored these factors. The studies from chapter 5 showed that liking of the sensations evoked by chilli did not influence the rating of burning sensation, burning tolerance or other tolerance attributes, therefore, for this finial measurement liking data was excluded.

7.2 Aim of study

The aim of this chapter was to combine all the attributes which had been shown from previous studies in this research to have impact on the measurement of oral perception of chilli using soups and generate a measure of oral perception of hotness.

7.3 Hypothesis

This study tested the hypothesis that a single measure could be developed for the perception of hotness intensity.

7.4 Material and Methods

7.4.1 **Test procedure**

Four tomato soups with chilli were prepared as indicated in section 3.4..2 and were rated by fifty eight panellist for six attributes of sensitivities and tolerances and one attribute of hotness intensity. Overall Intensity was fitted on the MFR-RS model, there were four facets, panellists, products, attributes and TA levels from previous chapter. Panellists and TA levels were negatively oriented which implied that higher Rasch scores and meant higher tolerance levels. Products and attributes were positively oriented which meant that higher Rasch measures meant hotter product and the presence of more of an attribute. When OI was fitted with TA levels, measures were obtained. These were used to separate panellists into 2 groups which were then used to check Rasch's assumption of invariance.

7.5 Results

7.5.1 Rasch model

Data for TA had already been reported in chapter 6. OI was checked for rating scale effectiveness and the 8-point scale was collapsed to a - point scale (table 7.1).

Table 7.1: Original and collapsed OI scale

Scale category	Raw score	counts used	% of counts	Obs	Exp	Rasch-Andrich threshold ±SE	Outfit MNSQ
Original 8-point OI scale							
None	1	40	17%	-6.16	-6.17		0.9
Barely detectable	2	54	23%	-3.7	-3.74	-.78 ± .22	1
Slight	3	45	19%	-1.62	-1.63	-2.46 ± .26	1.4
Moderate	4	43	18%	-0.43	-0.38	-.78 ± .22	0.9
Strong	5	26	11%	0.42	0.55	.40 ± .26	1.2
Very strong	6	23	10%	1.39	1.29	1.32 ± .36	0.7
Extremely strong	7	1	0%	2.7	1.92	2.01 ± .55	0.3
Strongest sensation ever experienced	8	1	0%	3.06	2.39	3.28 ± 1.10	0.4
Collapsed 4-point OI scale							
None	1	40	17%	-2.25	-2.27		0.9
Barely detectable	2	99	43%	-0.92	-0.97	-5.39 ± .26	1
Moderate	3	68	30%	0.32	0.4	1.08 ± .22	1
Extremely strong	4	23	10%	2.19	2.06	4.31 ± .28	0.7

7.5.1.1 Fit statistics

Panellists, product, and attribute fit were checked for both OI and OI/TA models and were found satisfactory.

7.5.1.2 Separation, strata, and reliability statistics

Reliability, strata, and separation shows that for OI panellist can be separated into at least 3 groups and for OI/TA panellists can be separated into at least 2 groups.

Table 7.2: Separation, strata and reliability statistics

Facet	Separation	Strata	Reliability
OI			
Panellist	1.65	2.54	0. 73
Products	13.57	18.43	0.99
OI/TA			
Panellist	1.28	2.03	0.71
Products	3.98	18.49	0.99
Attributes	1.26	2.02	0.61
TA levels	2.70	3.93	0.88

7.5.1.3 Wright maps

The Wright maps for OI (figure 7.1) showed that soups with 10ppm capsaicin was perceived as the hottest soup. Panellists 6 rated samples as less intense when compared to panellists 22, 49 and 50 who are located at the bottom of the Wright map. The Wright map for OI/TA (figure 7.2) shows that an adjustment of panellists was seen when TA levels were added, this is similar with was seen in study II.

```
+-----------------------------------------------------------------------------------------------+
|Measr|-panellist                                                          |+Products|+Attributes|OVERA|
|-----+--------------------------------------------------------------------+---------+-----------+-----|
|   9 +                                                                    +         +           + (4) |
|     |                                                                    |         |           |     |
|     | 6                                                                  |         |           |     |
|   8 +                                                                    +         +           +     |
|     |                                                                    |         |           |     |
|     |                                                                    |         |           |     |
|   7 +                                                                    +         +           +     |
|     |                                                                    |         |           |     |
|     | 21  33                                                             |         |           |     |
|   6 +                                                                    +         +           +     |
|     |                                                                    |         |           |     |
|     |                                                                    |         |           |     |
|   5 +                                                                    +         +           +     |
|     |                                                                    |         |           |     |
|     |                                                                    |         |           | --- |
|   4 + 13  20  31  32  35                                                 +         +           +     |
|     |                                                                    |10ppm    |           |     |
|     |                                                                    |         |           |     |
|   3 +                                                                    +         +           +     |
|     |                                                                    |         |           |  3  |
|     |                                                                    |7ppm     |           |     |
|   2 + 17  25  29  34  48  5   61  9                                      +         +           +     |
|     |                                                                    |         |           |     |
|     |                                                                    |         |           |     |
|   1 + 10  14  15  16  18  4   43  45  46  47  51  53  58  60             +         +           + --- |
|     |                                                                    |         |           |     |
|     |                                                                    |         |           |     |
*   0 *                                                                    *         * overall   *     *
|     | 26  30  37  38  40  44  52  54  55  57  63  64  8                  |3ppm     |           |     |
|     |                                                                    |         |           |     |
|  -1 + 11  19  24  27  28  39  41  42  56  62                             +         +           +     |
|     |                                                                    |         |           |     |
|     |                                                                    |         |           |     |
|  -2 + 36  59                                                             +         +           +  2  |
|     | 22  49  50                                                         |         |           |     |
|     |                                                                    |         |           |     |
|  -3 +                                                                    +         +           +     |
|     |                                                                    |         |           |     |
|     |                                                                    |         |           |     |
|  -4 +                                                                    +         +           +     |
|     |                                                                    |         |           |     |
|     |                                                                    |         |           |     |
|  -5 +                                                                    +         +           +     |
|     |                                                                    |0ppm     |           | --- |
|     |                                                                    |         |           |     |
|  -6 +                                                                    +         +           + (1) |
|-----+--------------------------------------------------------------------+---------+-----------+-----|
|Measr|-panellist                                                          |+Products|+Attributes|OVERA|
+-----------------------------------------------------------------------------------------------+
```

Figure 7.1: Wright map of OI showing panellists, product and attributes facets.

```
Vertical = (1A,2A,3A,S) Yardstick (columns lines low high extreme)= 0,3,-6,8,End
+-------------------------------------------------------------------------------+
|Measr|-panellist                                  |+Products|-levels      | OI  |
|-----+--------------------------------------------+---------+------------+-----|
|   8 +                                            +         +            + (4) |
|     |                                            |         |            |     |
|     | 6                                          |         |            |     |
|   7 +                                            +         +            +     |
|     |                                            |         |            |     |
|     | 21                                         |         |            |     |
|   6 +                                            +         +            +     |
|     |                                            |         |            |     |
|     | 33                                         |         |            |     |
|   5 +                                            +         +            +     |
|     | 13                                         |         |            |     |
|     |                                            |         |            | --- |
|   4 + 35                                         +         +            +     |
|     |                                            | 10ppm   |            |     |
|     |                                            |         |            |     |
|   3 + 20  25  31  32                             +         +            +     |
|     |                                            |         |            |  3  |
|     | 17  29  34  48  61  9                      | 7ppm    |            |     |
|   2 +                                            +         +            +     |
|     | 10  15  16  4                              |         |            |     |
|     | 5                                          |         |            |     |
|   1 + 14  18  43  45  46  51  53  60             +         + levelthree + --- |
|     | 26  30  37  38  40  44  52  54  55  57  64 |         |            |     |
|     |                                            |         |            |     |
*   0 * 47  58  63  8                              *         * leveltwo   *     *
|     | 19  24  27  28  39  41  42  56             | 3ppm    |            |     |
|     |                                            |         |            |     |
|  -1 + 11  62                                     +         + levelone   +     |
|     | 22  36  49  50  59                         |         |            |     |
|     |                                            |         |            |     |
|  -2 +                                            +         +            +  2  |
|     |                                            |         |            |     |
|     |                                            |         |            |     |
|  -3 +                                            +         +            +     |
|     |                                            |         |            |     |
|     |                                            |         |            |     |
|  -4 +                                            +         +            +     |
|     |                                            |         |            |     |
|     |                                            |         |            |     |
|  -5 +                                            +         +            +     |
|     |                                            | 0ppm    |            | --- |
|     |                                            |         |            |     |
|  -6 +                                            +         +            + (1) |
|-----+--------------------------------------------+---------+------------+-----|
|Measr|-panellist                                  |+Products|-levels      | OI  |
+-------------------------------------------------------------------------------+
```

Figure 7.2: Wright map of OI/TA showing panellists, product and attributes facets

7.6 Are measures invariant?

For a measurement to be considered invariant, it must not be dependent on the panellist pool which are utilized within the measurement tool (Wilson, 2004) this means that irrespective of the pool of panellist which are used for a test, ratings of products would be similar. (Boone et al., 2014) provides a method to test for invariance of measurement. Using the suggested method, the 58 panellists were divided into 2 equal halves depending on their Rasch measures and were fit to different RSRM-PC model i.e. top group fit to one model and bottom group fit to another model. Measures and SE were then plotted.

For measurement to be considered sufficiently invariant, 95% of the test subject must fall within the control band. Figure 7.3 shows the plot of the low tolerance group and the medium tolerance group. It shows that most of the test subject fall within the band, however the graph does not allow for certainty that this measure is invariant because of the participant size. To conclude on this, a larger number of participants would be needed for further testing.

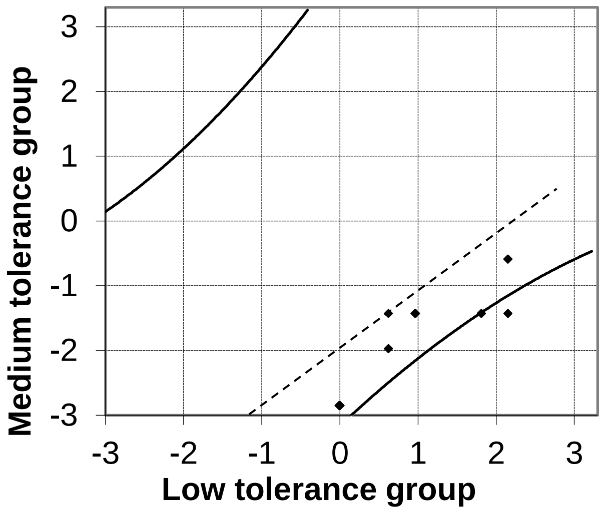


Figure 7.3: Plot of low tolerance group and medium tolerance group,

7.7 General conclusions

7.7.1 Summary of findings of this study

This research developed a survey (chapter 4) by compiling questions from existing literature and from participants from a focus group study. This survey was used to segment consumer of foods with chilli into three heat levels of low, medium and high. These clusters were distinctively different from each other in their consumption drivers. The results may be of importance for new product development because new products can be developed using this information about the different cluster types and can also be used to market to targeted clusters of interest.

Three main factors which had been reported to influence perception of hotness of capsaicin were tolerance, liking and perception of hotness intensity. This research took these factors individually, to determine their effect on perception of hotness intensity of foods with chilli. Before the effect of these factors could be explored, a measurement of tolerance needed to be established. Chapter 5 showed that pain was pertinent in the measurement of tolerance levels for foods with chilli. In a second study in that same chapter, it was shown that a better measurement of tolerance involved multiple attributes called T12 which would cover the range of sensations evoked by chilli, as opposed to only hotness intensity and pain attributes.

In chapter 6, it was shown by two separate studies, using two different types of food samples, that the liking of the hotness of foods did not influence both hotness intensity and tolerance attributes, contrary to what had previously been reported. Because the new proposed measurement was to be made up of attributes which influenced the ratings of hotness intensity, liking was not included as the studies in this chapter showed that liking was not pertinent in the rating of the hotness intensity of foods with chilli.

Finally, this research demonstrated how a single Rasch measure can be developed using factors which have effects on the rating of hotness intensity as contributory attributes to a develop a single measure.

7.7.2 Limitation of study and future work

7.7.2.1 Limitations of study

A major limitation of these studies was the sample size for sensory studies, this was because of the pungent nature of the samples which were used for this study, this made recruiting a very long and difficult process.

Another major limitation was that majority of the participants were some sort of consumers and likers of chilli. It may be useful to validate the results obtained from the sensory studies using consumers as well as non-consumers of foods with chilli.

The use of Rasch model requires knowledge of mathematics and high level of software understanding and was a time-consuming process.

7.7.2.2 Future studies

There needs to be validated by another sample group to determine if the same segment exists. Liking relationship needs to be further explored using a different set of panellists and possibly a different food medium and different concentrations to further investigate if liking indeed does not impact rating of hotness intensity. This measure of oral perception needs to be validated with a larger group so that results can be more certain.

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