Evaluation of Satiety Levels in Intuitive and Non-Intuitive Eaters Using Rasch Analysis

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Abstract

Obesity is a global problem generally associated with overeating over extended periods of time, and this is a problem for non-intuitive eaters who are less responsive to satiety and hunger signals. The selection of different foods affects the satiety differently so that the development of enhanced satiety foods aid the non-intuitive eaters in controlling food intake. Satiety research is hampered by the variation in terminologies and questionnaire instruments. Assessment of an instrument to measure people, items or products using conventional test theory methods (CTT) is problematic since they use ordinal-level data where the total score is based on the summation of raw categorical scores. Rasch analysis, a Modern Test Theory method (MTT), has been introduced as an alternative to the conventional way. This thesis aimed to employ the Rasch model to assess the latent instruments to measure intuitive eating (IE) and satiety. Firstly, we worked on the Intuitive Eating Scale 2 (IES-2) dataset to characterise the participants based on their intuitive eating levels. Then Rasch analysis has been applied to measure the 5-Factor Satiety Questionnaire to select a set of items to measure overall satiety. Lastly, we combined these two by recruiting the people and using the satiety items to test the effect of fibre and capsaicin-enrichment noodles on satiety. A Principle Component Analysis of Rasch residuals (PCAR) demonstrated that all 23 items of IES-2 could not function as a single total unidimensional Rasch measure however, 4 unidimensional Rasch measures was found that coincided with the 4 subscales that were previously identified using confirmatory factor analysis by Tylka and Kroon Van Diest (2013). The majority of respondents were classified into 2 out of 4 statistical levels in the measure Unconditional Permission to Eat, 3 out of 5 levels in Eating for Physical Rather Than Emotional Reasons, 3 out of 5 levels in Reliance on Internal Hunger and Satiety Cues and 2 out of 4 levels in Body-Food Choice Congruence. The 5-Factor Satiety Questionnaire instrument failed to confirm that it was unidimensional, but it was built in 5 dimensions. The intuitive eating measures and selected satiety items from Rasch analyses then have been further explored by evaluating the effects of fibre and capsaicin noodle meals on satiety by different intuitive eaters using Mental Hunger items. Development of fibre-enriched noodles was made by substituting wheat flour with 25% (w/w) of 3 different oat fibre flour types (BG14, BG22 and BG28. Results demonstrated that DF amount was inversely correlated to the firmness and elasticity but directly correlated to the stickiness textural properties. BG28 fibre-enriched noodle was chosen for the satiety trial based on the highest DF content, promising cooking quality and texture properties. The incorporation of BG28 and capsaicin to the noodle development significantly reduced Mental Hunger measure and ad libitum intake compared to control noodle meal ($p<0.05$). However, the effect of IE levels on satiety could not be assessed due to the small number of participants tested different noodle meals. In summary, Rasch analysis application offers an alternative approach in examining and developing measurement in food science and nutrition research. Manipulating food ingredients, especially dietary fibre is vital in the satiety domain to cater to individuals with different intuitive eating levels.

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Abbreviations

ANOVA	Analysis of variance
BG14	Oat fibre flour BG14
BG14 Noodle	Noodle enriched with 25% of BG14 oat fibre flour
BG22	Oat fibre flour BG22
BG22 Noodle	Noodle enriched with 25% of BG22 oat fibre flour
BG28	Oat fibre flour BG28
BG28 Noodle	Noodle enriched with 25% of BG28 oat fibre flour
BG28CAP Noodle	Noodle enriched with 25% of BG28 oat fibre flour and capsaicin
CAP	Capsaicin
CAP Noodle	Noodle enriched with capsaicin
DF	Dietary fibre
IDF	Insoluble dietary fibre
IES-2	Intuitive Eating Scale-2
MF	Mental Fullness
MH	Mental hunger
MNSQ	Mean-square
Outfit	Outlier-sensitive fit
PCAR	Principal component analysis on residuals[1]
PCM	Rasch Partial Credit Model
PF	Physical fullness
PH	Physical hunger
RSM	Rasch Rating Scale Model
SDF	Soluble dietary fibre
SE	Standard error
TDF	Total dietary fibre

[1]Standardised model residuals in Rasch analysis

Chapter 1
INTRODUCTION

1.1 Background of study

According to World Health Organization (WHO), worldwide obesity has increased nearly tripled since 1975 with approximately 1.9 billion adults were categorised as overweight (body mass index (BMI) >25kg/m^2) and 650 million of them were obese (BMI >30kg/m^2) in 2016 (WHO, 2020). Furthermore, in 2019, more than 340 million children and adolescents (aged <19 years) globally were classified as overweight or obese. This global epidemic has been associated with major risk factors for many chronic diseases, including cardiovascular diseases (CVD), diabetes mellitus, hypertension and stroke, musculoskeletal disorders (e.g., osteoarthritis) and certain cancers such as endometrial, breast, ovarian, prostate, liver, gallbladder, kidney, and colon (Akil & Ahmad, 2011; Al-Goblan, Al-Alfi, & Khan, 2014; Jernigan, Tergas, Satin, & Fader, 2013; Karen & Chang, 2011; L. K. King, March, & Anandacoomarasamy, 2013; Kyrgiou et al., 2017; Ortega, Lavie, & Blair, 2016; WHO, 2020).

Many studies proved that obesity is driven by unhealthy diets which lead to excessive energy intake (Barlow, Reeves, McKee, Galea, & Stuckler, 2016; Fock & Khoo, 2013; Kuzbicka & Rachon, 2013; Vernarelli, Mitchell, Rolls, & Hartman, 2015; WHO, 2004). To control obesity, the National Institutes of Health National Heart, Lung, and Blood Institute (NHLBI) recommended obese and overweight individuals to adopt long-term nutritional adjustments by reducing their caloric intakes (NHLBI, 2000).

In general, these dieting strategies demonstrated weight loss and reduction in blood glucose, fat, cholesterol levels and blood pressure (Fock & Khoo, 2013; Samaha et al., 2003). Unfortunately, they have been proven ineffective in achieving long-term and sustainable weight reduction and have been directly associated with many negative health consequences (Neumark-Sztainer, Wall, Story, & Standish, 2012; Strychar, 2006; Yancy, Olsen, Guyton, Bakst, & Westman, 2004). They still have adverse clinical effects such as headache, constipation, muscle cramps and diarrhea (Yancy et al., 2004). For example, restricting carbohydrate intake in the low carbohydrate diet promotes ketosis from gluconeogenesis, resulting in fluid loss and may require greater demands on the kidney and liver for excess urea and ammonia metabolism excretion (Jeor et al., 2001). The persons who practice very low-calorie diet should be monitored by trained physicians to avoid adverse effects such as severe negative nitrogen balance and electrolyte changes associated with starvation and did not suitable to be practiced for long-term (Atkinson et al., 1993; Strychar, 2006).

In addition, they tend to provide inconsistent results, such as higher body mass index (BMI) (Enriquez, Duncan, & Schur, 2013; Quick & Byrd-Bredbenner, 2012; van Strien, Herman, & Verheijden, 2014) and higher weight re-gain compared to they lost on their diets (Field et al., 2003; Mann et al., 2007; Neumark-Sztainer et al., 2006; Pietiläinen, Saarni, Kaprio, & Rissanen, 2012). Moreover, the failure in dieting would promote psychological distresses (Ackard, Croll, & Kearney-Cooke, 2002; Appleton & McGowan, 2006; da Luz et al., 2018; Hawks, Madanat, & Christley, 2008; Johnson & Wardle, 2005) and unhealthy eating disorders (e.g. binge eating, emotional eating, external eating, restricted dieting, preoccupation with food etc.) (Goldschmidt, Wall, Loth, Le Grange, & Neumark-Sztainer, 2012; Heron, Scott, Sliwinski, & Smyth, 2014; Holmes, Fuller-Tyszkiewicz, Skouteris, & Broadbent, 2014; Limbers, Young, & Beaujean, 2016; Mikhail & Kring, 2019; Samaha et al., 2003; Stein, Lee, Corte, & Steffen, 2019; Stice, Presnell, & Spangler, 2002).

Despite mounting evidence of dieting failures to the individual physical and mental health and behaviours, it leads the people to shift from the traditional dieting to non-dieting approaches as part of healthy lifestyles. The non-dieting approaches typically weight neutral and emphasise eating in response to physiological cues, enhancing body acceptance, promoting healthy eating behaviours and increasing physical activities while minimising weight discrimination (Bacon, 2010; Bacon & Aphramor, 2011; Clifford et al., 2015; Napolitano & Foster, 2012; R. E. Wilson, Marshall, Murakami, & Latner, 2020). There are a variety of terms used to describe the non-dieting approaches with different concepts and methodologies; such as Intuitive Eating (IE), Health at Every Size (HAES), Mindful Eating, Mindfulness Eating and Size Acceptance (Avalos & Tylka, 2006; Gast & Hawks, 2000; Greene et al., 2011; Hawks, Merrill, & Madanat, 2004; Humphrey, Clifford, & Morris, 2015; Miller, 2017; O'Reilly, Cook, Spruijt-Metz, & Black, 2014; Penney & Kirk, 2015; Tylka & Kroon Van Diest, 2013).

The first approach, intuitive eating, had been promoted as an adaptative form of eating to encourage people to intrinsically moderate in the amount and type of food, promoting a healthy diet and self-regulation of an individual's weight by maintaining a strong connection with the internal physiological signs of hunger and satiety rather than external and emotional cues (Tribole & Resch, 2012). The intuitive eaters are not preoccupied with food or dieting and do not have discrimination on particular food by labelling them as “good” or “bad” (Tylka & Kroon Van Diest, 2013). Moreover, they are more concern to enhance their body’s functioning and innately hear their bodies’ signals about hunger and satiety without affected by emotions and surroundings (Avalos & Tylka, 2006; Tribole & Resch, 2012).

However, there is scarce information on the relationship between IE and satiety measurement, either from cross-sectional or intervention studies (Barad et al., 2019; Camilleri et al., 2017; Horwath, Hagmann, & Hartmann, 2019; Mensinger, Calogero, Stranges, & Tylka, 2016). The researchers more focused on monitoring food intake using self-reported food intake using food diary (Camilleri et al., 2017) or using Fruit and Vegetable Screener (Barad et al., 2019), assessing diet quality using Food Frequency Assessment (FFQ) (Carbonneau et al., 2017; Horwath et al., 2019) and measuring changes in BMI and body size (Mensinger et al., 2016). It has not yet been established whether IE levels can influence satiety in terms of changes in subjective satiety evaluation after having particular foods. Such information is important for food scientists designing high-satiated food products for specific groups based on their eating behaviours. The demands for enhanced satiety products rise since the public starts to accept them as products that claim to stave off hunger (Bilman, Kleef, Mela, Hulshof, & van Trijp, 2012; Hetherington et al., 2013).

Many factors can influence satiety, including environmental, physiological, food and behavioural factors (Benelam, 2009). It is crucial to understand how these factors may have consistently differing and meaningful effects on satiety. Different macronutrients exhibit different satiating power (Chambers, McCrickerd, & Yeomans, 2015). For instance, after eating high protein food, satiety levels are higher than carbohydrate and fat-rich foods even though they are equal in calories (Blundell & Macdiarmid, 1997; Gerstein, Woodward-Lopez, Evans, Kelsey, & Drewnowski, 2004; Marmonier, Chapelot, & Louis-Sylvestre, 2000). Besides that, dietary fibres (DF) also have contributed to beneficial effects on satiety in many ways (Baldassano et al., 2018; Brownlee, 2011; Ng & Brownlee, 2017). The DF’s abilities to bulk foods, increase viscosity, form gel in the stomach, and ferment in the gut system make them superior in increasing satiety (Slavin & Green, 2007). Moreover, the bright sides of DFs on satiety are because they displace available calories and nutrients from the diet. When eaten in the same volume as other macronutrients, the DF is still equally satiating with less energy (Slavin & Green, 2007). DF's chewy texture increases mastication time and contributes to the sensory signalling and concentration of satiety hormones increment (Fiszman & Varela, 2013; Li et al., 2011; Slavin & Green, 2007). The contribution of noncaloric bioactive ingredients such as spices and herbs on satiety also has received attention (Janssens, Hursel, & Westerterp-Plantenga, 2014; Ludy & Mattes, 2011; Westerterp-Plantenga, Smeets, & Lejeune, 2005).

Individual expressions or sensations cannot be shared directly with others. Thus, transferring that such experiences into measurements are not easily interpreted (Lim, 2011). The researchers came out with many scaling instruments to quantify sensation (see examples in Table 1.1). However, the rating scales analyses are heavily rely on the Classical Test Theory (CTT) (Boone, 2016), including measuring satiety and intuitive eating. In CTT, the analysis of rating scales data is decomposed as the sum of a true score variable and an error variable (Spearman, 1904). However, in an instrument, a sum of raw scores cannot be used to achieve an accurate comparison between respondents because it cannot ignore the differences in difficulty across the items (Boone, 2016). The analysis using CTT could be augmented by using Rasch Measurement Theory (RMT). Rasch analysis allows researchers to use ordinal raw scores by converting them into interval-level data to the Rasch composite score and expressing the respondent's ability to account for the unequal difficulties across all test items on the continuum linear logit scale that accounts for the latent trait (Andrich, 2011; Bond & Fox, 2007). The application of Rasch analysis is widely employed in education, psychology and health studies (Amin et al., 2012; Hagquist, Bruce, & Gustavsson, 2009; Moreton, Wheeler, Walsh, & Lincoln, 2012); however, it has not raised broad attention in food-related researches. Therefore, exploring Rasch analysis applications will help scientists establish standard instruments and data analysis in food science fields.

Table 1.1 Examples of ordinal rating scale used in human sciences

Scale	Scale Categories	Application	Reference
Likert Scale	5-point or 7-point from "Strongly disagree" to "Strongly agree"	Consumer attitude	Likert (1932)
Numerical Rating Scale (NRS)	10-point from "no pain" to "Worst pain imaginable"	Pain measurement	Younger, McCue, & Mackey (2009)
PedsQL 4.0 Generic Core Scales	5-point from "never" to "almost always"	Child care measurement	Varni, Seid, & Rode (1999)
Intuitive Eating Scale-2	5-point from "Strongly Disagree" to "Strongly Agree"	Intuitive eating measurement	Tylka & Kroon Van Diest (2013)
Eating Attitudes Test (EAT-26)	6-point from "Never" to "Always"	Eating disorder attitudes and behaviour measurement	Garner, Bohr, & Garfinkel (1982)

1.2 Literature review

1.2.1 Intuitive eating

1.2.1.1 Concept of intuitive eating

Intuitive eating (IE) was coined in 1995 by two registered dietitian nutritionists Tribole and Resch (Tribole & Resch, 2012). IE has been proposed as an eating style for creating a healthy relationship with food, body and mind. They stress out that the intuitive eaters rely on biological hunger and make food choices without experiencing guilt and ethical dilemma by honouring fullness and hunger and enjoying eating (Tribole & Resch, 2012).

Tribole and Resch (2012) underlined ten core principles of IE as guidelines to the audiences to normalise relationship with food, focusing on weight loss should be put on the back burner because of the emergence and maintenance of natural weight and body shape are acknowledged as a potential outcome.

Principles of Intuitive Eating (IE) (Tribole & Resch, 2012)

1. Reject the diet mentality
2. Honour your hunger
3. Make peace with food
4. Challenge the food police
5. Feel your fullness
6. Discover the satisfaction factor
7. Cope with your emotions without using food
8. Respect your body
9. Exercise-feel the difference
10. Honour your health-gentle nutrition

1.2.1.2 Instruments used to measure intuitive eating

The first instrument, the Intuitive Eating Scale (hereby known as IES-H) was developed by Hawks et al. (2004) to measure the concept of IE built in with four components. Its components were; intrinsic eating (i.e., motivation to eat is based on inner cues), extrinsic eating (i.e., eating is based on external cues such as mood, social and food availability), anti-dieting (i.e., disagreement with dieting behaviours), and self-care (i.e., focus on body acceptance, regardless of size). A study using IES-H (Hawks, Madanat, Hawks, & Harris, 2005) showed that intuitive eaters were associated with better health indicators. The female college students with high IES-H scores significantly have a lower body mass index (BMI), reduced fats levels, and improved cardiovascular risk than the low intuitive eaters.

Another IE instrument was the Intuitive Eating Scale (labelled as IES-T); (Tylka, 2006) which assessed the principles proposed by Tribole and Resch (2012) and also to evaluate the relationship between IE and psychological well-being. A series of four studies were conducted on nearly 1300 college women during the development and evaluation of IES-T. The IES-T uncovered three key components of IE using exploratory factor analysis (EFA); which were 1) reliance on internal hunger and satiety cues (RHSC) to guide food intake; 2) permission to eat unconditionally (UPE); and 3) eating for physical rather than emotional reasons (EPRE). IES-T scores were internally consistent and stable over 3-week period. The total IES-T and its subscales were negatively related to eating disorder symptomatology, body dissatisfaction, poor interoceptive awareness, pressure for thinness, internalisation of the thin ideal and BMI. However, they were positively correlated to several indexes of well-being and did not related to impression management. Tylka and Kroon Van Diest (2013) has revised the 21-item IES-T to the latest version named Intuitive Eating Scale-2 (IES-2). The revised version scale purposely developed in order to improve certain limitations of the previous scale. The details of IES-2 have been discussed in subsection 1.2.1.3.

Dockendorff and colleagues (2012) adapted IES-T (Tylka, 2006) to construct new instrument Intuitive Eating Scale-Adolescents (IES-A) to assess IE in adolescent population with an additional key component of IE, which was “trust in internal hunger and satiety cues”. Their findings showed that high IE adolescents had lower BMI, lower body dissatisfaction scores, and better mood management, as this group was vulnerable to hormone fluctuations and peer pressure to blend in, affecting their mood and life satisfaction (Dockendorff et al., 2012).

Next, IES-P was used to validate IES among pregnant women (Paterson, Hay-Smith, Treharne, Herbison, & Howarth, 2018). The IES-P was similar to IES-T (Tylka, 2006) with modified instructions accounting for food safety. The IES-P has shown stable scores over five weeks and acceptable for the New Zealand pregnant population. A study to examine the relationship between IE and gestational weight gain showed that IE total mean scores and its three subscales increased across pregnancy (Paterson et al., 2019). In summary, there was an association between IE and lower gestational weight, but not babies’ birth weight.

1.2.1.3 Intuitive Eating Scale-2 (IES-2)

1.2.1.3.1 Limitation of the original IES-T instrument

Tylka and Kroon Van Diest (2013) identified some limitations with the previous IES-T (Tylka, 2006). The tenth principle IE articulated by Tribole and Resch (2012), measuring *gentle nutrition* (a tendency to make choices that honour individual's health and body functioning) was not assessed in the original IES-T. Tribole and Resch (2012) emphasised that gentle nutrition is important to the intuitive eating experience, as it gives freedom to the individuals to choose nutritious foods to help their body function well. Thus, in order to access this principle and measure the extent to which the individuals match their food choices with their bodies' needs, Tylka and Kroon Van Diest (2013) added items to the IES-2 and labelled it Body-Food Choice Congruence (BFCC).

Secondly, 13 out of 21 of IES-T items were written to assess the absence of IE attitudes and behaviours and focussed on resistance to dieting and emotional eating. So that, items were added and properly written in IES-2 to assess the presence of intuitive eating attitudes and behaviours with the purpose to replace some of IES-T items without affecting its psychometric integrity (Tylka & Kroon Van Diest, 2013). Moreover, those items in EST-T were analysed using reverse score because they were written to measure the absence of IE. It was possible to miscalculate the total and subscales scores, so they were re-written to be positively scored in IES-2.

Low internal consistencies has been found in IES-T RHSC subscale scores with Cronbach's alpha estimate in the range low to mid (Tylka, 2006; Tylka & Wilcox, 2006). The range was at the low end of the acceptable limit suggested by Nunnally and Bernstein (1994). With addition and replacement items was believed could improve internal consistency reliability estimates of IES-2. The participation in IES-T consisted entirely of women limited the investigation of its psychometric properties (Tylka, 2006).

1.2.1.3.2 Construction of IES-2 instrument

The IES-2 was constructed from 11 original items and 12 added items with integrated of BFCC component to the IES-T. Exploratory and confirmatory factor analyses upheld the hypothesis that IES-2 was constructed from 4 factors, namely Eating for Physical Rather Than Emotional Reasons (EPRE, 8items), Unconditional Permission to Eat (UPE, 6 items), Reliance on Hunger and Satiety

Cues (RHSC, 6 items), and Body-Food Choice Congruence (BFCC, 3 items) (See table X). The IES-2 was largely being invariant across gender, with men had significantly higher scores than women in IES-2 total scores and EPRE scores. The IES-2 validity was established with the IES-2 total scores and most IES-2 subscale scores showed positive associations with body appreciation, self-esteem, and life satisfaction, and negative associations with eating disorder symptomatology, interoceptive awareness, body shame and BMI (Tylka & Kroon Van Diest, 2013). The internal consistency coefficients of IES-2 were adequate for all subscale scores (α=0.87 and 0.89 for women and men, respectively) and test-retest reliability was supported across a 3-week period (r=0.88 and 0.92 for women and men, respectively). The IES-2 instrument is adapted and translated into other languages to cater to specific populations such as French (Camilleri et al., 2015), German (Ruzanska & Warschburger, 2017a), Turkish (Bas et al., 2017) and Malay (Swami et al., 2020).

1.2.1.4 Relationship between IE and health and wellbeing

It was proven in numerous studies that people who practise eating intuitively have positive associations with health well-beings, life satisfaction, positive affect, self-esteem, body images, internal body orientation, lower BMI, better image functioning, as well as positive outcomes to treat eating disorders (Barad et al., 2019; Bruce & Ricciardelli, 2016; Camilleri et al., 2016; Denny, Loth, Eisenberg, & Neumark-sztainer, 2013; Gast, Madanat, & Nielson, 2012; Horwath et al., 2019; Keirns & Hawkins, 2019; Richards, Crowton, Berrett, Smith, & Passmore, 2017; Ruzanska & Warschburger, 2019; Tylka & Kroon Van Diest, 2013). The positive relationship between IE measure with health and wellbeing are presented in Table 1.2 below.

Table 1.2 Relationship between intuitive eating (IE) with health and wellbeing

Health and wellbeing correlates	Instrument	Participants	Findings	Reference
Lowering BMI and weight stability	IES-2	11,774 men and 40,389 women aged ≥18 years	IE was inversely associated with overweight and obesity	Camilleri et al., 2016
	IES-2	1405 women and 1195 men across 3 studies	IE was positively related to body appreciation, self-esteem, and satisfaction with life IE was inversely related to BMI	Tylka & Kroon Van Diest, 2013
	IES-H	391 university students	IE was inversely related to BMI	Hawks et al., 2004
	IES-T	2287 young adults	IE was inversely associated with BMI in both genders	Denny, Loth, Eisenberg, & Neumark-Sztainer, 2013
Quality of dietary intake and eating patterns	IES-2	Male and female university student	EPRE and BFCC subscales positively associated with vegetable and fruit intake	Barad et al., 2019
	IES-2 German translation	5238 German- and French-speaking parts of Switzerland adults	UPE subscale moderately correlated with poorer diet quality scores EPRE, RHSC and BFCC subscales have small positive and negative correlations with food intake	Horwath et al., 2019
Physical and psychological health improvement	IES-H	Female university students	IE was not associated with state anxiety or trait anxiety	Herbert, Blechert, Hautzinger, Matthias, & Herbert, 2013

Physical and psychological health improvement	IES-T	Emerging, early and middle-aged adult females	IE positively associated with body acceptance by others, body appreciation, perceived social support	Augustus-Horvath & Tylka, 2011
	IES-T	female university students	IE positively associated with body acceptance by others, body appreciation, body function	Avalos & Tylka, 2006
	IES-T	female university students	IE negatively associated with dieting and bulimia/food preoccupation IE positively related to positive affect, self-esteem, proactive coping, optimism, unconditional self-regard and psychological hardiness	Tylka & Wilcox, 2006
	IES-2	Male and female university students	IE positively associated with body appreciation, self-esteem, positive affect and life satisfaction IE negatively associated with body surveillance, body shame, poor interoceptive awareness and negative affect	Tylka & Kroon Van Diest, 2013
	IES-2	male and female online community	IE was negatively associated with poor interoceptive awareness and food preoccupation IE was positively associated with life satisfaction, positive affect and body appreciation	Tylka, Calogero, & Daníelsdóttir, 2015
	IES-A	400 adolescent girls	IE was negatively associated with social appearance comparison and self-objectification	Andrew, Tiggemann, & Clark, 2015

			IE was positively associated with body acceptance and body appreciation	
Eating disorders and obesity prevention	IES-2	male and female online community	IE was negatively associated with rigid control and flexible control eating, binge eating and food preoccupation	Tylka et al., 2015
	IES-T	Mid-age females	IE was associated with a decrease in binge eating frequency	Madden, Leong, Gray, & Horwath, 2012
	IES-T		IE was negatively associated with dieting and bulimia/food preoccupation	Tylka & Wilcox, 2006
	IES-T	Female university students	IE was negatively associated with disordered eating	Shouse & Nilsson, 2011

Notes

IES-A = Intuitive Eating Scale for Adolescents

IES-H = Intuitive Eating Scale (Hawks et al., 2004)

IES-T = Intuitive Eating Scale (Tylka, 2006)

IES-2 = = Intuitive Eating Scale-2 (Tylka & Kroon Van Diest, 2013)

IE = Intuitive eating

EPRE= Eating for Physical Rather Than Emotional Reasons subscale

UPE=Unconditional Permission to Eat subscale

RHSC= Reliance on Hunger and Satiety Cues subscale

BFCC= Body-Food Choice Congruence subscale

BMI=Body Mass Index

Many studies have been published on intuitive eating as healthy eating practice that could relate to regulation of appetite and lower BMI (refer Table 1.2). Intuitive eaters are described to be less likely to overindulge in food in the absence of hunger and to allow their emotions or environmental cues to guide their food intake (Birch, Fisher, & Davison, 2003). Moreover, they are believed to have stronger awareness of physiological signals of hunger and satiety, and less likely to engage in behaviours that may lead to weight gain (e.g. eating when not physically hungry, binge eating) than restrictive dieters (Hawks et al., 2005; Madden et al., 2012; Tylka, 2006). Hawks and co-workers (2005) concluded that intuitive eaters were not only have significant lower BMI, but they also improved health condition with lower triglycerides level, higher of high-density lipoproteins (HDL) and decreased cardiovascular risk.

A growing body of literatures have examined the overlap of intuitive eating with eating disorders such as dietary restraint, emotional eating and external eating (Barrada, Cativiela, Van Strien, & Cebolla, 2018a; Ruzanska & Warschburger, 2017b; van Dyck, Herbert, Happ, Kleveman, & Vögele, 2016). In general, three intuitive eating subscales have shown inverse correlation with each of these maladaptive eating patterns (Barrada et al., 2018a). The UPE and ERHSC subscales have strong inverse correlations with dietary restraint and emotional eating, respectively. EPRE and RHSC subscales showed moderate negative associations with external eating. A few study found that the respondents trust their body to tell them the amount of food they should eat and when to stop eating when they reach satiation, plus had lower odds of dieting, binge eating and chronic eating behaviours (Bacon, Stern, Van Loan, & Keim, 2005; Denny, Loth, Eisenberg, & Neumark-Sztainer, 2013; Tylka, 2006; Tylka & Wilcox, 2006). These findings call into question the novelty of IE instruments to represent the respective opposite poles of the long-standing eating disorders.

1.2.2 Satiety

1.2.2.1 Definition of satiety

Satiety is a post-ingestive process that leads to inhibition of further eating and reflects any changes occurring in the intervals between eating episodes due to food digestion's cognitive and physiological effects (Bellisle & Blundell, 2013;

Blundell et al., 2009). Satiety also is defined as the absence of motivation to eat until the next meal (Chapelot, 2013).

1.2.2.2 Measurement of satiety

Satiety could be quantified by assessing intensity, duration and intake. The satiety usually is evaluated by the subjective sensation levels (intensity) over a certain period after a meal (duration) and the amount of food eaten at the next meal (intake) (Chapelot, 2013). The former approach is called subjective evaluation, while the other two are objective evaluations. They are several protocols used to measure satiety, as proposed by Forde (2018) (see Figure 1.1). Each protocol or study design has their own objectives, for instead, by applying Protocol A the researcher can measure subjective ratings of satiety-related perceptions following a fixed portion of a food that differ in energy content. This allow the researchers to investigate the effect of different nutritional composition intakes on satiety perceptions and energy intake based on food diary record at post-ingestive period. The satiating properties of preload test meal and its impact on energy intake in ad libitum meal could be measured using Protocol B. For example, in study done by McCrickerd and colleagues (2020), they tested the effectiveness of four different strategies for presenting a lower-calorie beverage as preloads by introducing them to the panellists using four different label information and sensory quality. They recorded appetite ratings, ad libitum lunch intake, and self-reported food diary. Protocol C is similar to Protocol A with a possibility to measure later ad libitum intake to reflect standard meal patterns.

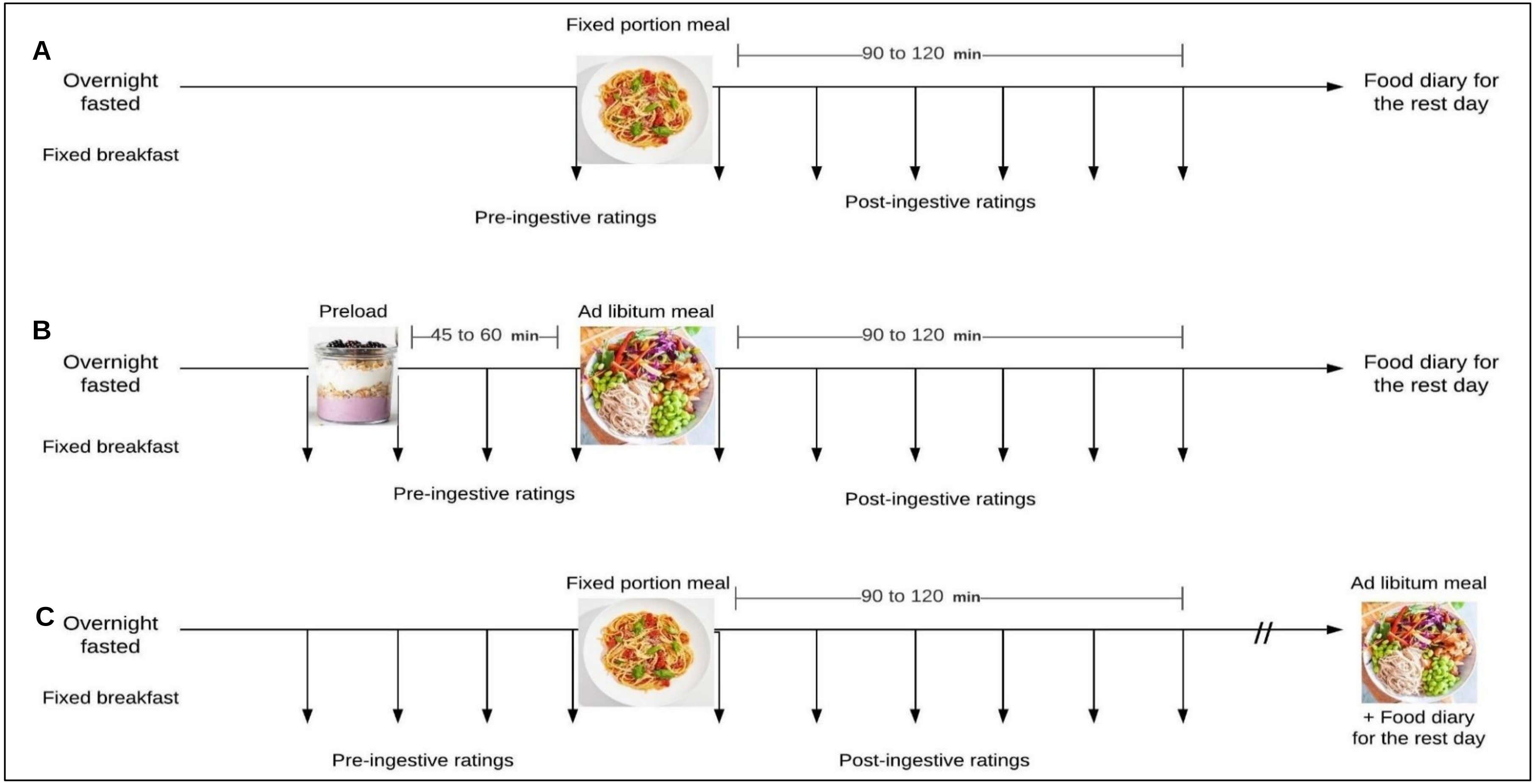

Figure 1.1 Example of trial protocols for the measurement of satiety. A = satiety using a fixed portion meal; B =preload test meal; and C=preload test meal with a second meal. Adapted from Forde (2018).

1.2.2.2.1 Satiety subjective evaluation

The intensity of satiety is tracked by rating the sensation changes over time at regular intervals after preloads, fixed portions or ad libitum test meals (Forde, 2018). The scaling of satiety intensity is usually captured using a line scale, called a visual analogue scale (VAS) (Blundell et al., 2010; Holt, Brand-Miller, & Stitt, 2001; McCrickerd et al., 2020; Merrill, Kramer, Cardello, & Schutz, 2002; Stubbs et al., 2000). The VAS is formed horizontally or vertically unipolar scale of varying lengths with minimum and maximum intensity levels anchored at the 2-sided ends. The VAS scales are popular among the researchers because they are easy to understand and quick to use and simple to interpret and predictive of later energy (Forde, 2018). The VAS also shows good reliability intergroup and sensitivity to test meal manipulations (Blundell et al., 2010; Flint, Raben, Blundell, & Astrup, 2000; Stubbs et al., 2000). However, VAS shows some limitations, such as differences in individuals applying and understanding how VAS works (Lesdéma et al., 2016; Raben, Tagliabue, & Astrup, 1995). The usage of variety of different terms on the scale made the VAS do not necessarily represent a single measurement dimension (Cardello, Schutz, Lesher, & Merrill, 2005). Moreover, placements of verbal labels along the scale which did not represent magnitudes of satiety at equally spaced intervals and the reluctancy of participants to fully-utilise the scale by avoiding extreme responses may misuse the usage of VAS (Cardello et al., 2005; Livingstone et al., 2000).

The second scale commonly used to measure satiety is known as the category scale. The category scales work on the same principle as VAS, where the participants are required to self-report their feelings of satiety-related in response to the questions (Benelam, 2009). Moreover, both VAS and category scales have been shown to have similar discrimination power (Jeon, O'Mahony, & Kim, 2004). This scaling technique involves choosing discrete response alternatives to signify increasing sensations on the horizontal or vertical line with choices of integer numerical responses, simple checkboxes or word phrases/labels (Lawless & Heymann, 2010). The participants are instructed to rate the given alternatives that best representative of their satiety perceptions. Each question represents only one sensation on a category scale; e.g., hunger and fullness could not be on the same scale anchors as it could not be assumed to have linear or inverse between these two sensations (Forde, 2018). The usage of integers or phrases/labels is not preferred because they tend to cause bias in participants such as the participants may have their favourite numbers or tendencies to use some numbers more than others (Giovanni & Pangborn, 1983). The ‘central tendency’ or ‘regression’ effect that results in under-use of the end categories of the scale reduces the scale's effectiveness (Stevens & Galanter, 1957) and limits the ability to discriminate among different intensity levels of more extreme sensations. A distinct issue with the category scaling is that the labelled points on the scale rarely define equal intervals (Cardello et al., 2005) and the unclear intensity adjective or adverb at the high end anchor of the scale (Lawless & Heymann, 2010).

A hybrid technique for scaling has been introduced due to the issue with magnitude estimation data, which only give ratios among sensations but unable to explain in any absolute sense whether those sensations are weak or strong (Lawless & Heymann, 2010). It is based on Borg's (1982) work where the semantic descriptors were assumed to be placed on a ratio scale with a defined perceptual intensity level. All the individuals should experience the same perceptual range. A labelled magnitude scale (LMS) has been developed by Green, Shaffer, and Gilmore (1993) to obtain a better quantitative estimate of a variable's intensity. The LMS does not only focus on measuring perceived stimulus intensity (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006; Green et al., 1993), but it also works to measure satiety (Cardello et al., 2005; Solah et al., 2015; Zalifah, Greenway, Caffin, D’Arcy, & Gidley, 2008), stimulus liking (the labelled magnitude scale LAM) (Chung & Vickers, 2007; Lim, Wood, & Green, 2009; Schutz & Cardell, 2001) and perceived degree of dissimilarity between stimuli (Kurtz, White, & Hayes, 2000). These scales were based on magnitude estimates of the relative spacing of verbal anchors (Green et al., 1993), representing how participants try to preserve the stimuli' subjective magnitudes' ratios. The LMS is drawn on a horizontal or vertical line with deliberately spaced labels with verbal high end anchor phrase “strongest imaginable.” (Green et al., 1993)(see Figure 1.2).

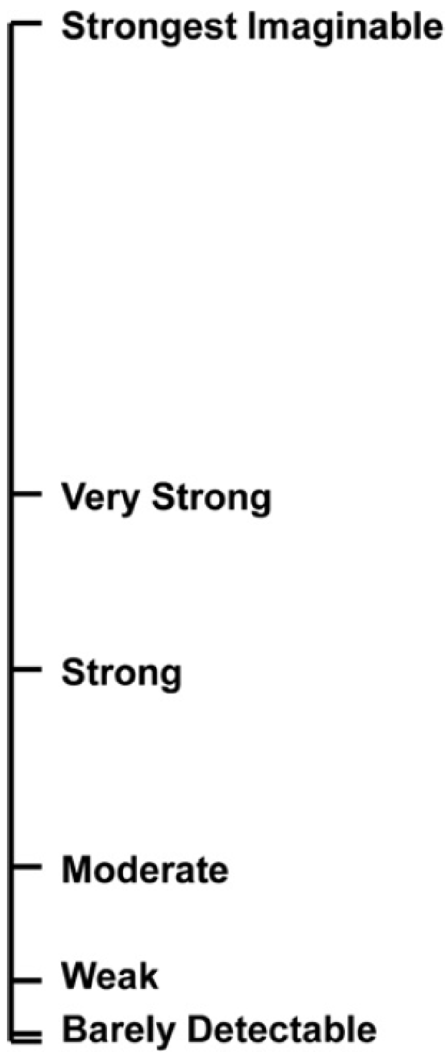

Figure 1.2 The labelled magnitude scale (LMS) of Green et al. (1993)

A specified LMS for satiety measurement was constructed by Cardello et al. (2005) with named the satiety labelled intensity magnitude (SLIM) to assess the perception of satiety. The SLIM scale was constructed with eleven phrases at positions corresponding to their geometric mean magnitude estimates on 100-mm vertical line bidirectional hunger-fullness scale then transformed to a -100 to +100 scale, with “greatest imaginable fullness” and “greatest imaginable hunger” at the end-point anchors (Figure 1.3). A few studies showed that the SLIM scale is more sensitive and more reliable over VAS and category scales, besides it is practical to measure perceived satiety in a diverse population (Cardello et al., 2005; Zalifah et al., 2008).

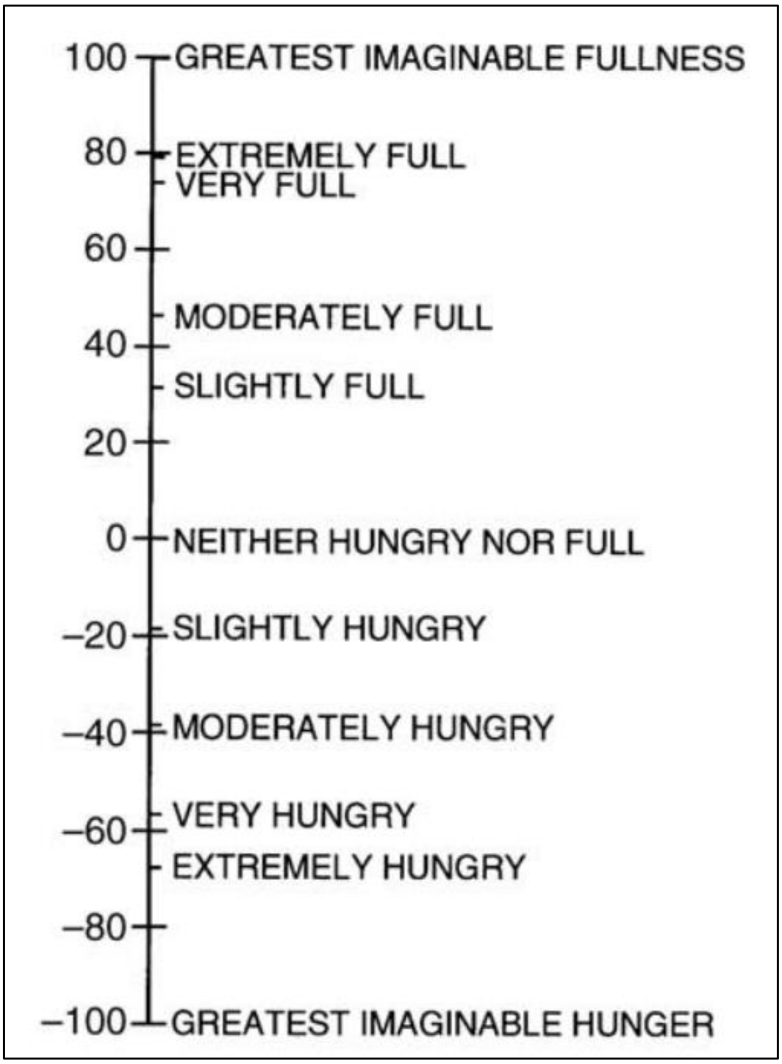

Figure 1.3 The satiety labelled intensity magnitude scale (SLIM) of Cardello et al. (2005)

Some researchers have used a pictorial method when scaling hunger and fullness sensations. This method is suitable for participants who have poor literacy or avoid asking for a translation of scale instructions or anchors (Forde, 2018). In a study done by Lowe and colleagues (2000), they found that significantly higher increases in hunger during the fast were when measured using the pictorial as opposed to the verbal instrument. The “Teddy the Bear” scale has been developed for use in children for whom abstract satiety sensations can be challenging to interpret and quantify (Bennett & Blissett, 2014).

1.2.2.2.2 Satiety objective evaluation

Measuring satiety by duration could be calculated by measuring the time to next meal and/or the amount of energy intake in the next meal (Forde, 2018). A few experimental conditions need to be considered for measuring the duration of satiety (Chapelot, 2013). It requires the participants to have the test meal and next meal request without knowing the time gap between them and accustomed to having a sedentary occupation during the satiety trial. The major challenge to practice this procedure is to time-blind the participants to minimise or remove the putative effect of time conditioning on meal requests (Chapelot, 2013). It is recommended to assess the duration of satiety by measuring the delay until the next meal request or assessing energy intake during a satiety trial (Hallschmid, Higgs, Thienel, Ott, & Lehnert, 2012).

The measurement of food intake is widely used when measuring satiety in conjunction with subjective ratings. There are a few approaches to measuring food intake using different measurements, including calories, volume, weight, etc. The food intakes are estimated by calculating calorie intakes recorded in the food diary, ad libitum test meals or at the subsequent meal after a test food is eaten, food intake for the remainder of the day (Karalus & Vickers, 2016; Krop, 2019; McCrickerd et al., 2020; Rolls, Roe, & Meengs, 2007).

1.2.2.3 Biomarkers of satiety

Biomarkers of satiety and satiation are known as physiologic measures that relate to subjective rating and food intakes. These biomarkers can act as indicators of appetite or causal factors of appetite (Diplock et al., 1999). Biomarkers of satiety can be categorised into two groups: 1) Physical measures and 2) hormonal and biochemical measures (De Graaf, Blom, Smeets, Stafleu, & Hendriks, 2004).

1.2.2.3.1 Physical measures

The physical measures include body temperature and diet-induced thermogenesis (DIT). The heat production and losses during macronutrients' metabolism could be quantified as integrative measures of energy, nutrient balance, or both (Friedman, 1998). The body temperatures can be measured using infrared scanning techniques at various body parts (Pavlidis, Eberhardt, & Levine, 2002). The DIT requires facilities to measure indirect calorimetry, including respiration chambers and ventilated hoods. It is challenging to measure

DIT because the participants are needed to sit still for long hours in respiration chambers to avoid random error in DIT measurements (De Graaf et al., 2004).

1.2.2.3.2 Hormonal and biochemical measures

Cholecystokinin (CCK), ghrelin, glucagon-like peptide 1 (GLP-1), leptin and peptide YY (PYY) were recognized as having roles in controlling satiety and appetite. These peptides hormones are released from several parts throughout the gastrointestinal system. CCK is released in response to fats, proteins and carbohydrates (Desai, Dong, Harikumar, & Miller, 2016; Gibbons et al., 2016; Okonkwo, David, & Adebayo, 2020). Its roles stimulate the pancreatic exocrine secretion and gall bladder contraction to digest the nutrients, regulating the gastric emptying and intestinal transit and stimulating satiety signals in the brain (Cao, Wu, & Cai, 2016; Y. Li & Owyang, 1994; Okonkwo et al., 2020; Simasko, Wiens, Karpiel, Covasa, & Ritter, 2002).

Ghrelin, an endogenous peptide hormone, is produced mainly by gastric endocrine cells and enters the blood circulation. Ghrelin is known as “hunger hormone” and has positive effects in enhancing appetite, food intake and body weight, reduce fat utilisation and growth hormone release (Cummings et al., 2001; Sato et al., 2012). Ghrelin plays an important role in glucose homeostasis by stimulating glucagon production and inhibiting insulin secretion (Pradhan, Samson, & Sun, 2013; Verhulst & Depoortere, 2012). The secretion of ghrelin depends on energy availability. During fasting or chronic caloric restriction, the ghrelin level increases to stimulate food intake and fat storage and prevent life-threatening falls in blood glucose (Alamri, Shin, Chappe, & Anini, 2016). On the other hand, leptin is responsible for the long-term energy balance regulation by suppressing food intake (Klok, Jakobsdottir, & Drent, 2007). This “satiety hormone” is released abundantly from fat cells in human adipose tissue. Adipose tissues release leptin into the circulatory system, followed by signals to the brain, informing the body's energy status (Ahima & Antwi, 2008; Singh et al., 2012). Leptin works as a feedback mechanism to the hypothalamus in the brain to inhibit food intake and regulate body weight and energy homeostasis (Ahima & Antwi, 2008; Klok et al., 2007). Besides that, leptin also is suggested to control meal size, food digestion and absorption in the intestines in incorporation with other satiety peptides (Attele, Shi, & Yuan, 2002; Picó, Oliver, Sánchez, & Palou, 2003).

GLP-1 is cleaved from proglucagon and released from the lower gastrointestinal tract in response to meals. It affects satiety by suppressing glucagon concentrations, slowing gastric emptying, and stimulating insulin biosynthesis, leading to a slow transition of nutrients into the distal gut and decreased food intake and appetite (Meier & Nauck, 2005; Shah & Vella, 2014). Peptide YY (PYY) is a short peptide hormone released from cells in the ileum and colon in proportion to the calories ingested together with GLP-1 (Vincent & Le Roux, 2008). It acts as a stimulator on the Y2 receptor in the hypothalamus to inhibit appetite stimulant neuropeptide Y release (Batterham et al., 2003, 2002). PYY has demonstrated an increase in energy expenditure, improved insulin sensitivity, reduced appetite, food intake and body weight (Batterham et al., 2006; Perry & Wang, 2012; Vrang, Madsen, Tang-Christensen, Hansen, & Larsen, 2006).

Factors such as age, gender and BMI play potential for abnormal hormonal responses to foster overconsumption in individuals. A study by English *et al.* (2002) demonstrated that ghrelin is failed to be suppressed during eating process in obese individuals. It is supported with another finding where ghrelin level decreased after meal in obese men (Carroll, Kaiser, Franks, Deere, & Caffrey, 2007). Moreover, peak insulin responses delayed higher and more sustained postprandial glucose have been found in obese individuals compared to healthy men. Associations between adipose mass and hormone concentrations led to obesity-related dysregulation of the hormones involved in hunger/satiety, thus promote overconsumption and weight gain (Frühbeck, Gómez-Ambrosi, Muruzábal, & Burrell, 2001). Gender play role in modulating postprandial hormone secretion besides altering endocrine responses to a variety of nutritional challenges (Carroll et al., 2007; Diamond et al., 1993; Frühbeck et al., 2001). Men had greater fasting and postprandial glucagon and a subtle postprandial decline in plasma leptin than women (Carroll et al., 2007). Women tend to have higher satiety level than men due to the difference in concentration of sex hormones like estradiol, which increases the satiating power of endogenous CCK to be involved in the control of food intake (Butera, 2010; Geary, 2000). Ageing leads to a decline in food intake and hunger response and increased satiety; and this phenomenon often referred to as anorexia of aging (Giezenaar et al., 2016; Gregersen et al., 2011; Hays & Roberts, 2006). Besides that, the older people tend to be more sensitive towards satiating effects of CCK than in younger persons, thus resulting in decreased appetite ratings and energy intake (MacIntosh et al., 2001).

1.2.2.4 Factors affecting satiety

1.2.2.4.1 Macronutrients and food texture

Macronutrients

Foods with high satiating effects result in a prolonged intermeal period or reduced subsequent meal intake. Macronutrients exhibit different effects on satiation and satiety independently of the energy values. The hierarchy of satiating effects of macronutrients is proposed in order of protein > carbohydrate > fat (Blundell & Macdiarmid, 1997; Gerstein et al., 2004). A review discussed in detail about effect of macronutrients can be found in Chambers et al. (2015). Dietary fibre has been discussed over the years as food ingredients that provide beneficial effects on satiety. The details of effect of dietary fibre have been discussed in subsection 1.2.3.

Food texture

Food texture plays a key role in controlling satiation, satiety and food intake (Chambers et al., 2015). A systematic review and meta-analysis done by Stribiţcaia and colleagues (2020) concluded that the food texture may influence satiety through differences in food intake, appetite responses and hormone release. Food in the form of solid and/or semi-solid seem to suppress more the satiety ratings than the liquid versions (Flood-Obbagy & Rolls, 2009; Hogenkamp, Mars, Stafleu, & de Graaf, 2012). The mechanical processing in the mouth (e.g. mastication of solid food) slows the consumption rate and enhances oro-sensory exposure time, which might trigger the satiety cascade's early stages, including satiety-related cognitions, initial cephalic phase responses and satiety hormone release (Forde, van Kuijk, Thaler, de Graaf, & Martin, 2013; Li et al., 2011; Zijlstra, Mars, de Wijk, Westerterp-Plantenga, & de Graaf, 2008).

Viscosity supports a role for texture in satiety, with appetite suppression higher in high viscous food than low viscous food (Russell & Delahunty, 2004; Tsuchiya, Almiron-Roig, Lluch, Guyonnet, & Drewnowski, 2006; Zhu, Hsu, & Hollis, 2013). A study by Solah and colleagues (2010) found that the participants felt less hunger after having high viscous alginate-based breakfast drinks than the low viscous version. Yeomans et al. (2014) also found the same finding where the appetite was suppressed after consuming high viscous drinks compared to low viscous drinks. They speculated that their findings were related to gastric distension and slower gastric emptying rate in high viscous food (Solah et al., 2010; Yeomans et al., 2014).

In addition, textural complexity and aeration of foods have shown significant effects on satiety and appetite control (Stribiţcaia et al., 2020). Inhomogeneity in a food texture led to a decrease in hunger and desire to eat and increased fullness ratings, which may affect the post-absorption processes that lead to a slowing effect of hunger (Tang, Larsen, Ferguson, & James, 2016). Krop et al. (2019) found that hydrogels with high lubricating properties led to reduced subsequent snack intakes. The incorporation of bubbles into beverages promoted satiety with reduced hunger and increased fullness feelings (Melnikov et al., 2014). It is supported with study by Rolls and colleagues (2000), where the satiety increased after eating yogurt-based milkshakes that had been incorporated with air compared to normal milkshakes.

1.2.2.4.2 BMI and gender differences

People in different groups of BMIs may respond differently towards satiety. The obese participants tend to have greater energy intake because they have greater gastric capacities than lean participants (Kim et al., 2001). However, the normal-weight bulimic patients have been found to have larger gastric capacity than some obese people, which explain that binge eating may contribute to the differences (Geliebter & Hashim, 2001). Satiety-related hormones also altered in obese people. Ghrelin levels in obese are found significantly lower than lean participants, which could be maximally suppressed due to excess fat storage (English et al., 2002). Lower PYY release also contributed to reduced satiety in obese people (Batterham et al., 2003). It is important to consider body composition and BMI as a factor in measuring satiety, and it could not be assumed that the outcomes would be the same in people with different BMI categories (Blundell et al., 2010). Gender differences also may affect satiety responses. In general, women require less energy than men, so that, they tend to eat less and feel more satiated than men (Bédard et al., 2015; Benelam, 2009). Hormone fluctuations during the menstrual cycle may affect women's energy intake and expenditure and eating behaviours (Davidsen, Vistisen, & Astrup, 2007; Dye & Blundell, 1997).

1.2.2.4.3 External factors

Besides internal factors that control satiety, the external factors also may affect responsiveness to satiation and satiety signals. Suppressed ghrelin levels and elevated satiety hormones (PYY and GLP-1) have been detected after performing acute exercises (Deighton, Karra, Batterham, & Stensel, 2013; King, Wasse, Broom, & Stensel, 2010; Martins, Morgan, Bloom, & Robertson, 2007; Ueda et al., 2009). Many studies show no absolute energy intake changes after acute exercise(Balaguera-Cortes, Wallman, Fairchild, & Guelfi, 2011; Deighton, Barry, Connon, & Stensel, 2013; Finlayson, Bryant, Blundell, & King, 2009), but some reported increases (Bilski et al., 2013; Martins et al., 2007) or decreases (Sim, Wallman, Fairchild, & Guelfi, 2014) in energy intake after acute exercise. Regardless of energy intake changes in response to exercises, relative energy intake after exercise is invariably lower than control groups in both genders (Thackray, Deighton, King, & Stensel, 2016).

Restriction of sleep hours has been associated with a reduction in leptin and increases in ghrelin hormones (Spiegel, Tasali, Penev, & Cauter, 2004; Taheri, Lin, Austin, Young, & Mignot, 2004).Moreover, lack of sleep hours increase obesity risk, as the subjects tend to eat more because they have more available time, less physical activity due to tiredness and unhealthy eating (Knutson, 2007). Besides that, people tend to increase their energy intakes and be less responsive to satiety signal when distracted by watching television or other gadgets (Higgs & Woodward, 2009; Temple, Giacomelli, Kent, Roemmich, & Epstein, 2007). Eating intakes are significantly higher when people eat with others rather when eating alone. It is because eating behaviour is strongly influenced by social contexts such as cultural expectation and peer eating norms (Higgs & Thomas, 2016).

People who exhibit impairment in appetite control tend to overconsume more than their needs and weight gain (Blundell & Finlayson, 2004; Dalton, Finlayson, Esdaile, & King, 2013). Those people may have weak satiety response towards food and may susceptible to overeat and obese (Blundell & Gillett, 2001), because they may experience an altered or weakened recognition and response to internal hunger and satiety cues (Drapeau, Hetherington, & Tremblay, 2011). Weak satiety responsiveness is not limited to obese people, as it can happened in those with healthy BMI as well (Drapeau et al., 2013). With that argument, it is important to classify those individuals based on their intuitive eating behaviour in order to control their overconsumption without restricting diet.

1.2.3 Beta-glucan

Foods that enhance satiety assist the people to improve the nutritional quality of their diets beside to resist environmental factors to eat unconditionally and curb excessive energy intake. Enhanced satiety is believed to offer numerous potential benefits to those with weight management goals (Hetherington et al., 2013). The role of dietary fibre (DF) in promoting satiation and satiety has been extensively documented and shown to have modest long-term effect on weight-loss (refer 1.2.3.2). The variation in structures and physiological functions of DF (Slavin & Jacobs, 2010) is thought to affect satiety in many ways such as hydration, solubility and viscosity and fermentability. Different DFs exhibited different effects on satiety and energy intake (Slavin & Green, 2007; Wanders et al., 2011), so that is important to choose the suitable DF into our diets. β-glucan is well evidenced for positive health effects (European Food Safety Authority (EFSA), 2011) beside it is proven efficiently control satiety as discussed in the next subsections.

1.2.3.1 Chemical structures and Functionalities of β-glucan

Beta-glucan (β-glucan) is a water-soluble viscous polysaccharide mainly located in the subaleurone and endosperm cell walls of cereal grains (oats, barley, rye and millets), mushrooms, lichens, seaweed/algae and microorganisms (yeast, fungi and bacteria) (Daou & Zhang, 2012; Kaur, Sharma, Ji, Xu, & Agyei, 2020). β-glucans are composed of β-D-monomer units linked at β-(1-3) and β-(1-4)- or β-(1-6)- glycosidic bonds, depending on the source (Chen & Raymond, 2008). A schematic representation of the basic molecular structure of β-glucan is presented in Figure 1.4.

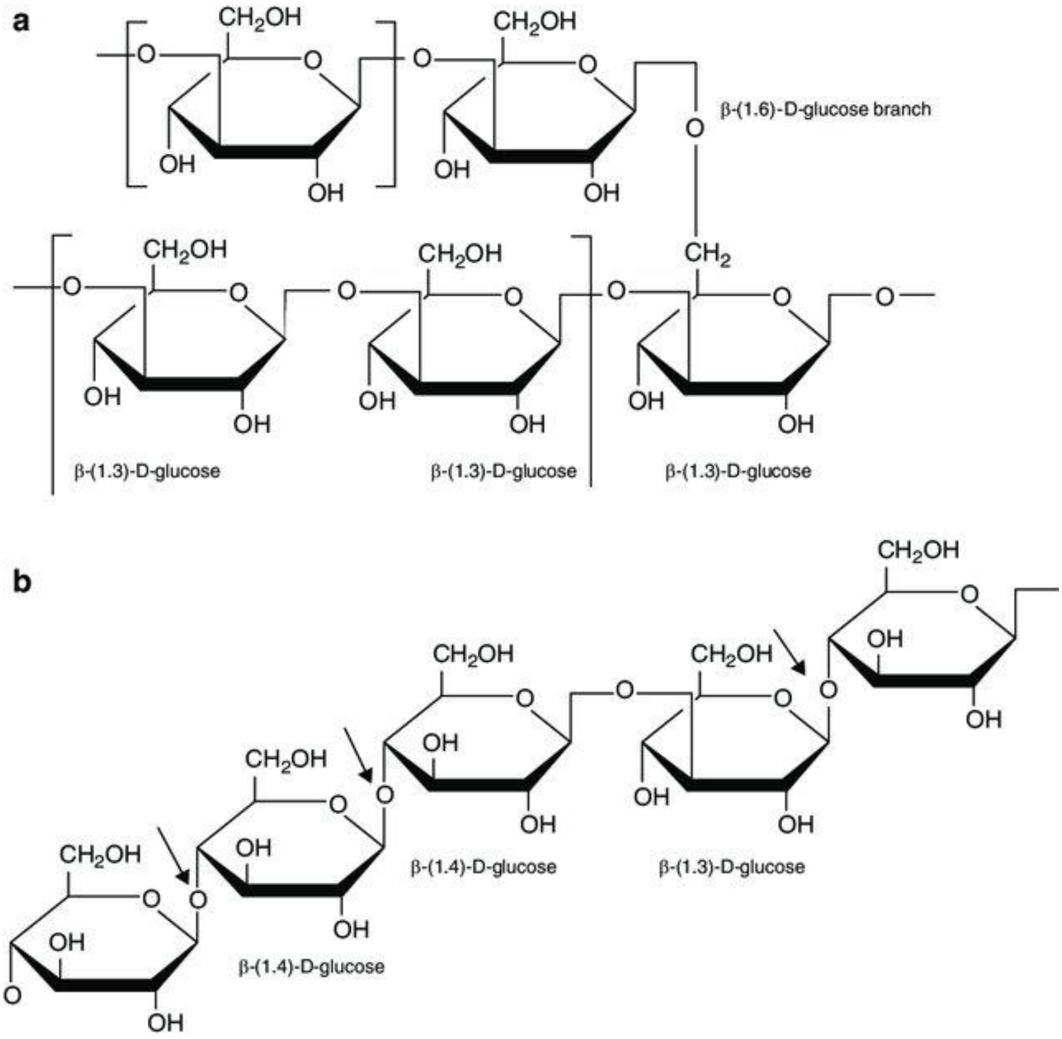

Figure 1.4 Basic structure of B-glucans. Figure 1.4 (a) refers to B-glucan with combined bonds B-(1-3) and B-(1-6) glycosidic bonds in yeast, and Figure 1.4(b) refers to B-glucan with combined bonds B-(1-3) and B-(1-4) glycosidic bonds in cereals.

The bond types of β-glucan, degree and branching pattern affect the molecular weight (MW) and alter the conformation (helical formations, ring conformations, structure, etc.) of β-glucan (Kaur et al., 2020; Stone, 2009). Such variations affect the biological activities and functionality of β-glucan, including molecular weight, water retention properties, solubility and viscosity. The abundance of hydroxyl groups that participate in hydrogen bonding with water makes the β-glucan very hydrophilic and gives strength to hold water in both soluble and insoluble forms (Ahmad & Kaleem, 2018; Tejinder, Bhupinder, & Harinder, 2000). The solubility of β-glucan is influenced by their structures, which is depends on the molecular weight, chain length and degree of branching (Havrlentová et al., 2011; Kaur et al., 2020). β-glucan solubility properties are of nutritional, sensorial and rheological importance (Aktas-Akyildiz et al., 2018; Havrlentová et al., 2011; Kaur & Sharma, 2019). Molecular weights, solubilities and concentrations influence the viscosity of β-glucan (Butt, Tahir-Nadeem, Khan, Shabir, & Butt, 2008; El Khoury, Cuda, Luhovyy, & Anderson, 2012). β-glucan with high MW exhibits a higher viscosity than low MW β-glucan and can form viscous gels and pseudo-plastic solutions (Theuwissen & Mensink, 2008; Vaikousi, Biliaderis, & Izydorczyk, 2004; Wang et al., 2017). In an environment where the concentration is low, the β-glucan can create highly viscous solutions and stable over a wide pH range (Butt et al., 2008; Chen & Raymond, 2008).

1.2.3.2 Health benefits of β-glucan

β-glucan has received much attention over the last four decades on its biological effects on health (Jayachandran, Chen, Chung, & Xu, 2018). It is well evidenced to improve health conditions such as lowering cholesterol levels, lowering blood pressure, improving glycemic control and immune-modulation and reducing the risk of cardiovascular diseases, obesity and hyperlipidemia (Baldassano et al., 2018; Bozbulut & Sanlier, 2019; Chen & Raymond, 2008; Daou & Zhang, 2012; Jayachandran et al., 2018).

Tiwari and Cummins's (2011) meta-analysis study showed that the findings in reviewed 30 studies proved that β-glucan intakes successfully decrease total cholesterol, LDL cholesterol, and triglyceride/triacylglycerol levels. The viscosity properties of β-glucan to entrap whole micelles containing bile acids in the intestinal and prevent their reabsorption in the terminal ileum made β-glucan an excellent vehicle lowering cholesterol (Theuwissen & Mensink, 2008; Wang et al., 2017). Moreover, short-chain fatty acids (SCFA) also play an important role in reducing cholesterol. The oat β-glucans pass into the large intestine undigested and then fermented to the main SCFAs such as acetic, propionic and butyric acids, which have a hypercholesterolaemic effect (Chen & Raymond, 2008). The propionic:acetate ratio may retard lipid metabolism by inhibiting cholesterol synthesis (Daou & Zhang, 2012).

Viscous β-glucans slow the gastric emptying rate and lengthen intestinal transit time. As a result, it reduces the enzyme diffusion and stimulates the formation of the unstirred water layers and decrease glucose transport to the enterocytes (El Khoury et al., 2012). The reduction of glucose absorption rate into the bloodstream causes the reduction in postprandial insulin concentrations (Bozbulut & Sanlier, 2019; de Oliveira Silva, de Moura, de Oliveira, Peconick, &

José Pereira, 2017). The SCFAs responsible for activating peroxisome proliferator receptor (PPAR) γ to increase the expression of insulin-sensitive glucose transporter type 4 (GLUT4) (Song, Sawamura, Ikeda, Igawa, & Yamori, 2000). As a result, plasma blood glucose levels reduced because of glucose transportation to adipose tissues by GLUT4 (Huang & Czech, 2007).

It was reported that β-glucans responsible for glycaemic controlling (Chen & Raymond, 2008). However, its effectiveness depends on a few factors such as amount and period of consumption, physicochemical properties, processing methods and food matrixs (Cloetens, Ulmius, Johansson-Persson, Åkesson, & Önning, 2012; El Khoury et al., 2012). A systematic review done by Andrade et al. (2015) suggested that at least 6g per of β-glucans per day over 4 weeks would improve glycemia and glycolised hemoglobin control. The European Food Safety Authority (EFSA) recommended to include at least 4g of oat or barley β-glucan in daily intake to achieve such health benefits (EFSA, 2011).

1.2.3.3 Promising effects of β-glucan on satiety

β-glucan roles in regulating satiety and satiation have been extensively studied and has been proved that β-glucan positively associated with increased satiety and reduction in energy intake. Food products enriched with β-glucans exhibit a lower glycemic index (GI) and insulin index (II) than control products with the same amount of available carbohydrates, without affecting sensory properties and palatability (Chillo, Ranawana, Pratt, & Henry, 2011; Jenkins, Jenkins, Zdravkovic, Würsch, & Vuksan, 2002; Mäkeläinen et al., 2007). Studies done by Reyna-Villasmil et al. (2007) and Shimizu et al. (2008) showed that high β-glucan diets' ingestion increased weight loss in overweight subjects over 8 to 12 weeks. A meta-analysis done by Rahmani et al. (2019) showed that β-glucan consumption significantly affected the reduction of body weight and BMI. Consumption of the β-glucan-enriched meals seems to significantly reduce energy intakes (Aoe et al., 2014; Belobrajdic et al., 2016; Ng & Brownlee, 2017; Vitaglione, Lumaga, Stanzione, Scalfi, & Fogliano, 2009b). Satiety subjective ratings also reported that β-glucan enhanced satiety and related feelings (Pentikäinen et al., 2014; Vitaglione et al., 2009b).

1.2.4 Rasch Measurement

1.2.4.1 Overview of Rasch Measurement Theory

Rasch models are the mathematical formulas, which was developed by the Danish mathematician George Rasch (Rasch, 1960), for constructing measures for the probability of success (*P*) based on the difference between a person's ability (θ_n) and an item's difficulty (δ_i) on the latent trait (Bond & Fox, 2015). The θ_n and δ_i are expressed on a logits scale, whereas the average logit is arbitrarily set at 0, with the positive logits indicating higher-than-average probabilities and negative logits indicating lower-than-average probabilities (Bond & Fox, 2015).

1.2.4.2 The family of Rasch models

1.2.4.2.1 Dichotomous Rasch model

The Rasch dichotomous model is the simplest member of the Rasch family models. The model predicts the conditional probability of a binary outcome (e.g. correct/incorrect or Yes/No) given the person's ability and the item's difficulty (Andrich & Marais, 2014; Engelhard, Rabbitt, & Engelhard, 2018; Tanaka, Engelhard, & Rabbitt, 2020). The Rasch dichotomous model can be mathematically expressed as follows in Equation 1.1.

$$\mathbf{ln}\frac{\boldsymbol{P_{ni}}}{\mathbf{1}-\boldsymbol{P_{ni}}} = \boldsymbol{\theta_n} - \boldsymbol{\delta_i}$$

Equation 1.1

Where:

P_{ni} = probability of person (n) on item i scoring a correct

$1 - P_{ni}$ = probability of person (n) on item i scoring an incorrect

θ_n = Ability of person n

δ_i = Difficulty of item i

1.2.4.2.2 Rasch Rating Scale Model (RSM)

The second Rasch model is the Rasch Rating Scale Model (RSM) (Andrich, 1978). This polytomous Rasch model is the extension of the dichotomous model to the case in which items have more than two response categories (eg. Likert-type scale). The RSMs have been applied in many data sets that use rating scales such as Likert scale (Chang, Ailey, Heller, & Chen, 2013; Chien & Brown, 2012; Hardigan & Carvajal, 2008; Lerdal et al., 2017), intensity scale (Erhart, Ravens-sieberer, Dickinson, & Colver, 2009; Rutherford, Nixon, Brown, Briggs, & Horton, 2016), frequency scale (Amin et al., 2012; Erhart et al., 2009; Khadka, Gothwal, McAlinden, Lamoureux, & Pesudovs, 2012; Nielsen, Ørnbøl, Vestergaard, Bech, & Christensen, 2017) and Students' attitudes towards science scale (SAS) (Boone, Staver, & Yale, 2014; Oon & Fan, 2017). Each item threshold (k) has its own difficulty estimate (τ) where there is a 50% likelihood of a person chooses one category over another (Bond & Fox, 2015). The RSM model uses the same set of threshold estimate (τ_k) for all attributes or modalities in the study and the log-odds form of the RSM model is expressed as below (Equation 1.2):

$$\ln \frac{P_{nik}}{P_{nik-1}} = \theta_n - \delta_i - \tau_k$$

Equation 1.2

Where:

P_{nik} = probability of person (n) choosing category k of rating scale on item i

P_{nik-1} = probability of person (n) choosing category k-1 of rating scale on item i

θ_n = Ability of person n

δ_i = Difficulty of item i

τ_k = threshold estimate between category k and category k-1

1.2.4.2.3 Rasch Partial Credit Model (PCM)

The second polytomous Rasch model is known as Rasch Partial Credit Model (PCM). In a survey instrument that comprises of a mix of response with different labelled categories from item to item or having different response options (some five, and some seven categories), the PCM can be used (Masters, 1982). The Rasch PCM provides a set of individual threshold estimates (τ_{ik}), for individual sensory attribute or modality (Bond & Fox, 2015) to replace threshold estimate (τ_k) that used in RSM. The PCM could be applied in dataset that have the same category scale for all question item; such as IES-2, Major Despression Inventory (MDI) and PedsQL 4.0 Generic Core Scales data under certain considerations

(Amin et al., 2012; Nielsen et al., 2017). The principal equation of PCM (Equation 1.3) is:

$$\ln \frac{P_{nik}}{P_{nik-1}} = \theta_n - \delta_i - \tau_{ik}$$

Equation 1.3

Where:

P_{nik} = probability of person (n) responds category k of rating scale to item i

P_{nik-1} = probability of person (n) responds category k-1 of rating scale to item i

θ_n = Ability of person n

δ_i = Difficulty of item i

τ_{ik} = threshold estimate between category k and category k-1 for item i

In selecting the Rasch model, either RSM or PCM, to be used in the analysis for polytomous data, we may need to consider a few aspects. At the beginning of rating scale development, if the items are intended to share the same number of rating categories (e.g. Likert scale IES-2 survey with 5 categories), it is suggested to apply RSM over PCM (Linacre, 2000). However, if the individual items are designed to have different categories numbers on the same test, then PCM is more favoured. Moreover, in a rating instrument with the same number categories but have different meanings for the categories (e.g. 5-category pain intensity and 5-category patient attitude), PCM models will be used because the different categories interpret differently for the items. In learning evaluation, the students will be graded based on their performances at a few levels. For example, they will be graded partially on their understanding of the subjects taken based on their pop quizzes' performances in the classes, midterm and final examinations. PCM is applied because the partial marks have been awarded in each test in an ordered way so that each increasing score represents an increase in the underlying students' ability (Bond & Fox, 2015).

The details of criteria of Rasch model procedures have been discussed in Subsection Materials and Methods in Chapter 2.

1.3 Outline of thesis

1.3.1 Aim

The study aims to apply Rasch analysis in measuring satiety in different groups of intuitive eating levels

1.3.2 Objectives

1. To categorise individuals by measuring their intuitive eating behaviours based on the Intuitive Eating Scale-2 (IES-2) measures using Rasch analysis.
2. To select a set of satiety items from 5-Factor Satiety Questionnaires that could measure overall satiety using Rasch analysis.
3. To produce noodles enriched with dietary fibr to achieve optimal cooking and texture properties.
4. To measure the impact of consuming dietary fibre and/or capsaicin enriched noodles on satiety in participants with different intuitive eating levels.

Chapter 2

Segmentation of individuals with different intuitive eating levels using the Rasch model analysis

2.1 Introduction

In an environment where obesity becomes a part of living style, people become concerned about its significant health problems. These traditional diet strategies for losing weight encourage people to restrict their energy intake (Hill, 2004; Lowe & Timko, 2004). Even though, in general, these dieting strategies demonstrated positive feedback on weight loss and health improvement, they have been associated with many negative consequences (Strychar, 2006; Yancy et al., 2004). The restrictive dieters tend to regain higher weight and body mass index (BMI) and challenging to maintain weight reduction for a longer-term (Enriquez et al., 2013; Mann et al., 2007; Pietiläinen et al., 2012; van Strien et al., 2014). It is also possible that dieting associated with psychological distresses (Ackard et al., 2002; Appleton & McGowan, 2006; da Luz et al., 2018;Hawks et al., 2008; Johnson & Wardle, 2005) and unhealthy eating disorders such as binge eating, emotional eating, external eating, restricted dieting, preoccupation with food etc. (Goldschmidt et al., 2012; Heron et al., 2014; Holmes et al., 2014; Limbers et al., 2016; Mikhail & Kring, 2019; Samaha et al., 2003; Stein et al., 2019; Stice et al., 2002).

Consequently, many scholars shifted their focus from a weight-focused to non-diet healthy eating approach (Carbonneau et al., 2017; Miller, 2017; Reel, 2012; Tribole & Resch, 2012). Intuitive eating (IE) was promoted as an adaptative form of eating to encourage people to eat based on their body's internal ability to regulate their nutritional needs (Tribole & Resch, 2012). The systematic reviews conducted by Bruce and Ricciardelli (2016) and Van Dyke and Drinkwater (2014) have shown that intuitive eating could be considered an approach to developing a healthy eating lifestyle with less disordered eating withdrawals. There are a few instruments used to measure IE such as Intuitive Eating Scale (IES) and Intuitive Eating Scale-2 (IES-2) (Hawks, Merrill, & Madanat, 2004; Tylka, 2006; Tylka & Kroon Van Diest, 2013). In short, even though the instruments are different, the principle of intuitive eating is still the same; to foster a dynamic attunement between mind, food, and body.

Previous studies used a few analyses to test IES-2 instrument effectiveness in different population groups (Barrada, Cativiela, Van Strien, & Cebolla, 2018b; Camilleri et al., 2015; Duarte, Gouveia, & Mendes, 2016; Swami et al., 2020; Tylka & Kroon Van Diest, 2013; van Dyck et al., 2016). The Confirmatory Factor Analysis (CFA) was performed to test the dimensionality of the models used (Barrada et al., 2018b; Camilleri et al., 2015; Duarte et al., 2016). Tylka and Kroon Van Diest (2013) conducted principal axis factor (PAF) analyses to determine the number of factors (dimensions) presented in the instrument. The anti-image correlation matrix revealed any pairs of highly correlated items (local dependency) (Tylka & Kroon Van Diest, 2013). The fitness derived from the CFA model was then compared with the fit of an exploratory structural equation model (ESEM) (Barrada et al., 2018b). Composite Reliability(CR) and Average Variance Extracted (EVA) were used to examine the construct reliability and convergent validity of the scale (Duarte et al., 2016). Test-retest reliability of the IES-2 was assessed through Intraclass Correlation Coefficients (ICC), and internal consistency was estimated with the ordinal alpha coefficient or Cronbach's coefficient alphas (Camilleri et al., 2015; Duarte et al., 2016; Tylka & Kroon Van Diest, 2013).

Although the results of CFAs showed an adequate internal consistency for all four dimensions scores, established test-retest reliability across 3-week study and construct validity through positive and negative associations with the study variables in the original IES-2 (Tylka & Kroon Van Diest, 2013), it had been found to have difficulties in confirming the 4-factor structure using different sets of data. Some other results in different groups supported the 4-factor structure of original IES-2 (Bas et al., 2017; Carbonneau et al., 2016; Ruzanska & Warschburger, 2017a; van Dyck et al., 2016), while some studies failed to do so (Camilleri et al., 2015; Khalsa et al., 2019; Saunders, Nichols-Lopez, & Frazier, 2018; Swami et al., 2020). A few items were eliminated from the CFA and EFA analyses to support the 4-factor structure proposed in the parent study (Akırmak, Bakıner, Boratav, & Güneri, 2018; da Silva, Neves, Ferreira, Campos, & Swami, 2020). All of the analyses above have been based on the Classical Test Theory (CTT). A CTT total score is based on the summation of raw categorical scores (Lord & Melvin R Novick, 1968). Even though the CTT method is widely used because of its simplicity and easy understanding of its tangible statistics, it is not suitable for interval-level data measurements (Petrillo, Cano, McLeod, & Coon, 2015). It is also sample- and scale-dependent, leading to serious logical drawbacks to the instrument when the dataset changed (Petrillo et al., 2015).

Rasch Measurement Theory (RMT) has gained attention in many health clinical trial assessments(Chang et al., 2013; Erhart et al., 2009; Pallant & Tennant, 2007; Rutherford et al., 2016). RMT is a Modern Test Theory (MTT), or also known as latent trait theory, converting the raw categorical scores to interval-scaled measures into a Rasch composite score or measure[1] (Bond & Fox, 2015). It incorporates a method for ordering the respondents according to their ability in answering the questionnaires and ordering items according to their difficulty/agreement (Bond & Fox, 2015). Moreover, with one Rasch model, it can fulfil the requirements of fundamental measurements (such as converting category scale to linear interval scale) and examining the data that may misfit the model (William J Boone et al., 2014). The Rasch measurement model is suitable for the IES-2 survey because it allows the connection between observations of respondents and items in a way that indicates high intuitive eaters are believed to have a higher probability of agreeing with most of the IES-2 statements while the low intuitive eaters are expected to less agree with them. It is important to assign the individuals based on their eating behaviours to allow the researchers to design an appropriate program for the specified groups effectively.

2.2 Aim of the chapter

This study aimed to examine Rasch models' application in evaluating intuitive eating in a sample of healthy adults.

To achieve this aim, the following objectives were achieved:

1) To examine the unidimensionality of the Intuitive Eating Scale-2 (IES-2) (Tylka & Kroon Van Diest, 2013) construct using Rasch analysis
2) To cluster the participants into appropriate groups based on their IES-2 measure using Rasch statistical levels

[1] In Rasch analysis, the ordinal-level scores are transformed to the linear Rasch measures. The unit measurement for Rasch measures is logit (log odds unit) and the value of 0.0 logits is routinely allocated to the mean of the item difficulty estimates.

2.3 Materials and Methods

2.3.1 Participants

A total of 625 consented participants (23.4% men and 76% of women) participated in the study with a range age from 18 to 74 years. The majority of participants self-identified as Asian (92.9%), and the other participants were identified as White (4.2%), mixed ethnic (1.8%), Black (0.8%), and Others (0.3%). Eight participants (1.3%) preferred not to reveal their ethnic identification. Eligible participants were generally healthy and more than 18 years old.

Table 2.1 Demographic characteristics of participants in the survey

	All participants	**Males**	**Females**
Number of participants[#]	625	146	475
Age range (years)	18-74	18-74	18-64
BMI (kg/m^2)	24.59±5.16	25.65±4.76	24.33±4.90
BMI classification*			
Underweight	36 (5.9%)	5 (3.5%)	31 (6.6%)
Healthy weight	216 (35.4%)	38 (26.8%)	177 (37.9%)
Overweight	119 (19.5%)	30 (21.1%)	89 (19.1%)
Obese	240 (39.3%)	69 (48.6%)	170 (36.4%)
Ethnicity*			
Asian	573 (92.9%)	124 (85.5%)	446 (95.1%)
Not Asian	44 (7.1%)	21 (14.5%)	23 (4.9%)

BMI = body mass index (mean±SD)

[#]The number of participants for individual groups were not tally to total number of participants because there were some participants did not provide their information

*The number and percent of participants in each category

2.3.2 Survey procedures

The study was approved by the MaPS and Engineering joint Faculty Research Ethics Committee (MEEC FREC) University of Leeds (Ethics reference: MEEC 16-040 amendment January 2019). The participants were invited via social media networks (e.g., emails, Facebook, WhatsApp and text messages) to complete the survey online. The interested participants were given a link to www.onlinesurveys.ac.uk. They were needed to click the link given and been directed to the survey page to complete the survey. They were required to provide their consent by clicking the button on the bottom of the informed consent page to indicate that they had understood what it means to participate in this study before being allowed to proceed to answer the survey. The survey was divided into two sections. The first section was a survey about individuals' agreement on the 23 given statements using Intuitive Eating Scale – 2 (IES-2) questionnaires and the second part was about some demographic-related questions. The participants could not return to review or amend that page once they had clicked on the continue button at the bottom of each page. The survey took around 10 to 15 minutes to complete. The survey was entirely voluntary, and the participants had the right to withdraw at any time during the study.

2.3.3 Survey questionnaires items

The 23-item Intuitive Eating Scale-2 (IES-2)(Tylka & Kroon Van Diest, 2013) was used in this study. Items were rated using a 5-point category scale: Strongly Disagree (Category 1), Disagree (Category 2), Neutral (Category 3), Agree (Category 4), and Strongly Agree (Category 5). The items were randomly arranged in the online survey.

Table 2.2 Intuitive Eating Scale-2 (IES-2) Questionnaire Items (Tylka & Kroon Van Diest, 2013)

Item Statements	Code*
I try to avoid certain foods high in fat, carbohydrates or calories.	Q1R
I find myself eating when I am feeling emotional (e.g., anxious, depressed, sad), even when I am not physically hungry.	Q2R
If I am craving a certain food, I allow myself to have it.	Q3
I get mad at myself for eating something unhealthy.	Q4R

I find myself eating when I am lonely, even when I am not physically hungry.	Q5R
I trust my body to tell me WHEN to eat.	Q6
I have forbidden foods that I don't allow myself to eat.	Q7R
I use food to help me to soothe my negative emotions.	Q8R
I find myself eating when I am stressed out, even when I am not physically hungry.	Q9R
I am able to cope with my negative emotions (e.g., anxiety, sadness) without turning to food for comfort.	Q10
When I am bored, I do NOT eat just for something to do.	Q11
I trust my body to tell me HOW MUCH to eat.	Q12
When I am lonely, I do NOT turn to food for comfort.	Q13
I find other ways to cope with stress and anxiety than by eating.	Q14
I allow myself to eat what food I desire at the moment.	Q15
I do NOT follow eating rules or dieting plans that dictate what, when, and/or how much to eat.	Q16
Most of the time, I desire to eat nutritious foods.	Q17
I mostly eat foods that make my body perform efficiently (well).	Q18
I mostly eat foods that give my body energy and stamina.	Q19
I rely on my hunger signals to tell me when to eat.	Q20
I rely on my fullness (satiety) to tell me when to stop eating.	Q21
I trust my body to tell me WHAT to eat.	Q22
I trust my body to tell me when to stop eating.	Q23

*the items with letter R were analysed with the reversed scores.

2.3.4 Data analysis using Rasch measurement

2.3.4.1 Fitting the Rasch Model

The IES-2 data were analysed using the Rasch measurement model using software package Winsteps Version 4.3.3 (John M. Linacre, 2019). The IES-2 data were analysed using the Rasch Rating Scale Model (RSM) because all the items on the IES-2 survey shared the same number of response categories; which were five categories. The models were repeatedly examined until the data fit the Rasch models. There were 10 RSM models in this study, which five original models and another five revised models.

2.3.4.2 Global model fit

The Global fit of the data to the RSM model was first examined to ensure the data fit the model. The acceptable fit was achieved when more than 95% of the absolute standardised residuals were less than 2; with less than 5% and 1% were equal or greater than 2 and 3, respectively (Linacre, 2018). If the data did not fit the Rasch RSM model, it has been suggested to use another model besides RSM, the Partial Credit Model (PCM) or examine misfit responses or increase the data size.

2.3.4.3 Proper functioning of a rating scale

The proper functioning of the categories used in the rating scale used was examined by following Linacre's guidelines and criteria, as listed in Table 2.3 below;

Table 2.3 Guidelines used for assessing the proper functioning of a rating scale (Linacre, 2002) (adapted from Ho (2019))

Metric	Description
Item-level indices of polarity	Items should be oriented in the same direction as the latent variable, as it is essential for measure stability, fit accuracy, sample description and inference. Point-biserial or point-measures correlations☐ can be used to identify items that have reversed polarities when both positively and negatively-orientated items are used.
Category frequency	At least ten observations of each category are helpful for fit accuracy and sample inference but essential for measure stability
Observation distribution	Uniform distribution of observations are useful for optimal step calibration and when considering collapsing categories. Helpful for measure stability and sample inference.
Average measures	Values should increase monotonically up the scale categories, as it helpful for measure stability but essential for fit accuracy, sample description and inference

OUTFIT Mean Squares	Values less than 2.0 are helpful for measure stability, sample description and inference but essential for fit accuracy.
Threshold calibrations	Values increase monotonically up the scale categories (i.e. ordered thresholds). Helpful for sample inference.
Minimum distance between threshold	0.45, 0.7, 0.81 for a 9-,6- and 5- category scale respectively. Helpful for sample inference.
Maximum distance between threshold	No larger than 5 logits to avoid gaps in the variable. Helpful for measure stability

Category frequencies and distribution were used to indicate the numbers of responses for each category and the skewness of respondents towards the scales (Bond & Fox, 2015) and might be essential for measuring stability. The average measures by category should have advanced monotonically up in the Rasch rating scale; in other words, the higher measure combinations, the higher categories, or vice versa (Linacre, 2002). Failure in producing average measure with monotone increment might affect model's fit accuracy. The Rasch-Andrich thresholds, known as rating scale thresholds or step calibration (Tennant & Conaghan, 2007) should increase monotonically with the categories. If it fails to perform as suggested, it leads to 'step disordering'. Thus, it will degrade the resulting measures' interpretability, as the higher category is less chosen than the lower category. It is recommended to correct the disordered Rasch-Andrich thresholds by collapsing the categories into the appropriate numbers. The minimum and maximum distance between 2 adjacent threshold estimates also need to be considered to avoid redundant categories in defining a distinct point on the variable or avoid significant gaps in the variable (Bond & Fox, 2015; Linacre, 2002). The global fit and proper functioning of new re-collapsed categories were then re-examined and repeated for adequacy.

2.3.4.4 Items and Persons Fits

Fit is a core in Rasch measurement, and it is vital to ensure the data conform to the Rasch models (Bond & Fox, 2015). The mean square (MNSQ), the unstandardised form of the fit statistics, explained the average value of the squared residual for the items to represent the item performance differences between the Rasch model theoretical expectation and actual data matrix (Bond & Fox, 2015). The outfit statistic (referred to the OUTFIT MNSQ) is more sensitive to the outliers on the latent variable and is easier to identify and correct the issues of fit (Boone et al., 2014; Cauffman & MacIntosh, 2006). Rasch measurement model is assumed to measure a one-dimensional latent variable; where the probability of a person responds to an item is known as a logistic function of the relative distance between the person ability and item difficulty location on the same linear scale (Tennant & Conaghan, 2007). The persons can be ranked or grouped into different intuitive eating levels by their responses such as emotional eating, consciousness, hunger or fullness feelings, level of stresses, trust in own body, etc. However, the individual ratings that define these variables are not accessible for a general conclusion about intuitive eating because those variables are 'latent'. Measurements of latent variables must be inferred by scientific theory from observations of person behaviours (Bond & Fox, 2015). For example, hunger and fullness variables are inferred from observations like the amount of food they consume and the duration of eating processes.

Linacre (2019) interpreted the four levels of mean squares fit statistic values by Wright and Linacre (1994) as shown in Table 2.4. It has been suggested that the estimates with OUTFIT MNSQ ranged between 0.15 to 1.5 are adequate to fit the data to the Rasch models. It is because the mean-squares for this range produce an average close to 1.0 (Wright & Linacre, 1994). The MNSQ values between 1.5 to 2.0 could be due to unexplained variance or noise in the data; however, they do not affect the measurement. The estimates with OUTFIT MNSQ larger than 2 tend to distort the measurement by misfitting the Rasch models; while those with OUTFIT MNSQ less than 0.5 are less productive and tend to lead the model to be overpredicted with inflated reliability statistics. The estimates with OUTFIT MNSQ out of range between 0.5 to 2.0 were considered misfit and removed from the analysis. After determining the misfit items, the specific unexpected responses of individuals with z-residuals of ≥2 or <-2 were removed. The analyses were re-run until the acceptable ranges of MNSQ were achieved (Boone et al., 2014).

Table 2.4 Interpretation of parameter-level mean-square MNSQ fit statistics (Linacre, 2019; Wright & Linacre, 1994)

Value	Implication for Measurement
>2.0	Off-variable noise is greater than useful information. Degrades or distorts the measurement. Always remedy the large misfits first and be considered for removal.
1.5-2.0	Noticeable off-variable noise. Neither constructs nor degrades measurement.
0.5-1.5	Productive of measurement and indicate adequate fit for the estimates to the RASCH models.
<0.5	Overly predictable and less productive for measurement, but not degrading. It may produce misleadingly good reliabilities and separations.

2.3.4.5 Unidimensionality and local dependency

Three methods were applied in examining the unidimensionality assumption of the Rasch models used in the study. They were by looking at the eigenvalue at the first contrast on the first rotated Principal Component Analysis of Rasch residuals (PCAR) component, the disattenuated correlation coefficient between the highest (Cluster 1) and the lowest loadings (Cluster 3) in PCAR and by comparing the standardised residual correlations using t-test (Linacre, 2019; Smith, 2002).

Firstly, the eigenvalues of explained and unexplained variances were examined to ensure either the residuals were only at random noise level or might be due to the additional dimensions. Eigenvalues in “first contrast” should be less than 3, so that the residuals can be considered as randomised noise. However, if the value is greater than 3 (i.e. the strength of at least 3 items), it implies that the items' residuals may share the same pattern and an additional dimension may exist (Linacre, 2019).

Next, after looking at the eigenvalue of the first contrast of PCAR (value is greater than 3), the disattenuated correlation coefficient between the highest (Cluster 1) and the lowest loadings (Cluster 3) on the PCAR were inspected. The standardised residuals were used instead of raw data in PCAR so that in unidimensional model, the residuals reflect only the random noises. The disattenuated correlation values were explained in Table 2.5, as recommended by Linacre (2019).

Table 2.5 Interpretation of disattenuated correlation coefficient (Linacre, 2019)

Disattenuated correlation coefficient	Interpretation
Less than 0.57	Cut-off point for the conclusion that the clusters measure different thing
0.71	The clusters are more dependent than independent
0.82	Indicative cut-off point for the conclusion that the clusters measure the same thing
0.87	Definitive cut-off point for the conclusion that the clusters measure the same thing

The independent t-tests were run to assess the Rasch models' unidimensionality (Hammond et al., 2015; Miller, Slade, Pallant, & Galea, 2010) comparing the differences between the two independent estimations measures from the positive and negative loadings of PCAR. The conclusion that the instrument is unidimensional can be drawn when no differences are found between two independent estimations of individual measures (Smith, 2002) or if the proportion of t-tests from a binomial test is less than 5%, specifically the lower bound of the binomial confidence interval (Miller et al., 2010).

Local item independency was examined by looking at the correlation between the residuals between items or persons. The local dependence may occur in items with large positive correlations. Linacre (2019) suggested that the items with correlation close to 0.7 or more may be concerned about dependency because they may share more than half their “random” variance. Local independence's assumption can be tested by comparing reliability estimates of single super-items or ‘testlets’ with original models (Miller et al., 2010; Smith, 2002). A significant decrease in person reliability estimates indicates local dependency among items (Hagquist, Bruce, & Gustavsson, 2009; Miller et al., 2010).

2.3.4.6 Person reliability and separation of measures

Reliability for both persons and items can be estimated in Rasch analysis by comparing person and item reliability (Wright & Masters, 1982). The person reliability indicated the replicability of person ordering that can be expected if a particular sample of persons were given another parallel set of items measuring the same instrument. On the hand, item reliability is the estimate of the replicability of item placements within a hierarchy of items along with the measured variable pathway if the same items were given to another same-sized sample of comparable ability (Wright & Masters, 1982). In an instrument with high item reliability, we can expect consistency in evaluating items based on their difficulty levels. The reliability estimates using Rasch analysis is based on the same concept with Test Reliability reported by Classical Test Theory (CTT) that use Cronbach's Alpha (Cronbach's α) or KR-20 with a slight difference (Linacre, 2019). Cronbach's α usually yielded a higher person reliability coefficient than Rasch measurement because the nonlinear raw scores, including the extreme scores were used in CTT analysis (Schumacker & Smith, 2007). Rasch measures represent persons' ability and items' difficulty as independents of specific test items and specific samples, respectively within standard error estimates. Person separation is used to classify people, while item separation is used to verify the item hierarchy (Linacre, 2019).

2.3.4.7 Wright maps

The relationship between the distribution of estimated person and item measures on each subscale were visualised using the Wright maps along a vertical logit scale.

2.4 Results and discussion

The numbers of steps were examined based on the procedures suggested by Ho (2019) to make sure the Rasch model analysis requirements were met (a summary of the procedure is presented in Figure 2.1), as briefed in subsections below. Nine Rasch RSM models would be discussed in this section. It included five original models (IES2-R5, EPRE-R5, RHSC-R5, UPE-R5 and BFCC-R5) and four revised models (IES2-R4, EPRE-R4, RHSC-R4 and UPE-R4).

2.4.1 Global model fit

The IES-2 survey data fitted the proposed original and revised Rasch RSM models. The global fit statistics showed that the mean close to 0.00 and population standard deviation (P.SD) ranges of 0.94 to 1.01 in all the Rasch models. It indicates that the data used in the original and revised models conform to the basic Rasch model specification that randomness in the data was normally distributed (Linacre, 2012). The global fit statistics with P.SD close to 0.00 showed that the data exhibited a highly significant misfit to the Rasch RSM model, as was nearly always expected (Linacre, 2019). All original and revised Rasch RSM models showed acceptable model fits. There were more than 95% of the absolute standardised residuals fell under value 2; with less than 5% and 1% were equal or greater than 2 and 3 respectively (Linacre, 2018) (Table 2.6).

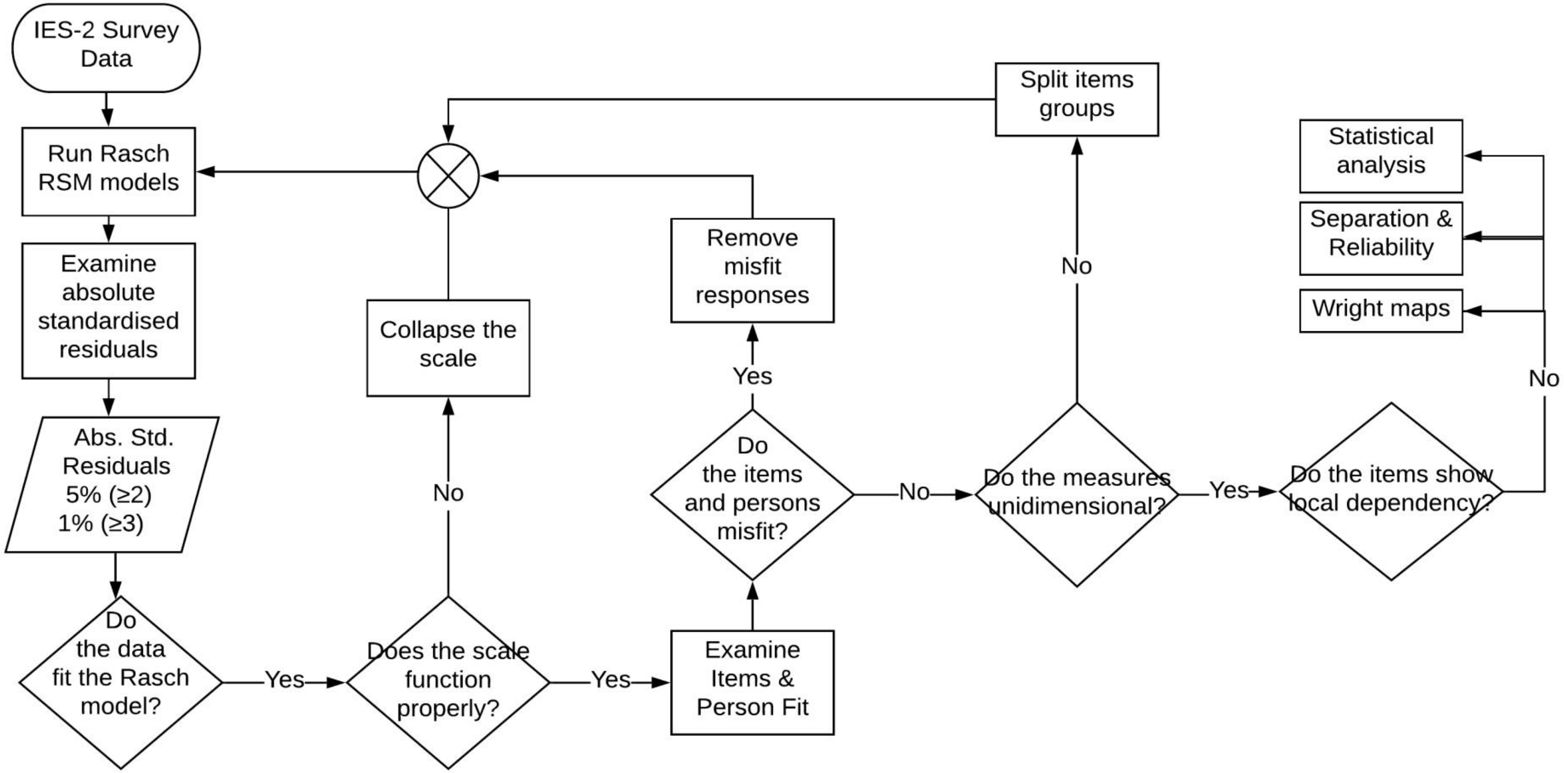

Figure 2.1 Flowchart of procedures used in Rasch Measurement analysis using Winsteps for IES-2 models (summarised from Ho, 2019)

Table 2.6 Summary fit statistics for original and revised Rasch rating scale models (RSM) of IES-2 data

Model	No of items	Global fit			Items MNSQ OUTFIT[4] (%)	Items Reliability[5]	Items Separation[5]	Person Reliability[5]	Person Separation[5]	unidimensionality		
		% Stdres[1]	% Stdres[2]	Total[3]						Eigenvalue[6]	Disattenuated correlations[7]	%t-test (CL%)[8]
Original scale												
IES2-R5	23	0.96(138)	0.12(17)	14346	95.7	0.99	9.59	0.70	1.51	4.4953	0.0058	31.20(27.64)
EPRE-R5	8	1.56(78)	0.28(14)	4995	100.0	0.99	11.34	0.84	2.28	2.0970	0.7397	13.60(11.06)
RHSC-R5	6	3.02(113)	0.11(4)	3737	100.0	0.92	3.34	0.77	1.82	1.5635	0.8454	2.88(1.75)
UPE-R5	6	1.71(64)	0.27(10)	3746	100.0	1.00	15.37	0.58	1.18	1.7780	0.3906	11.20(8.88)
BFCC-R5	3	3.10(58)	0.43(8)	1868	100.0	0.91	3.17	0.72	1.61	1.8074	0.8087	NA
Revised scale[9]												
IES2-R4	23	2.72(389)	0.26(37)	14307	100.0	0.99	9.25	0.73	1.63	4.2739	0.0263	25.92(22.58)
EPRE-R4	8	2.96(148)	0.52(26)	4995	100.0	0.99	10.01	0.82	2.17	2.0213	0.7034	14.72(12.08)
RHSC-R4	6	3.18(119)	0.13(5)	3737	100.0	0.92	3.42	0.75	1.73	1.5510	0.8408	3.04(1.88)
UPE-R4	6	2.48(92)	0.43(16)	3707	100.0	1.00	14.84	0.55	1.11	1.7996	0.3130	4.00(2.65)

[1] Percentage and number of observations (in brackets) of absolute standardised residuals that were ≥2. It should 5% or less.

[2] Percentage and number of observations (in brackets) of absolute standardised residuals that were ≥3. It should 1% or less.

[3] Total number of observations for the Rasch model used

[4] Percentage of unweighted mean squares for items (MNSQ OUTFIT) that fall in range 0.5 to 1.5

[5] Excluding measures for extreme scores

[6] Eigenvalue of unexplained variance in first contrast in PCAR analysis

[7] Disattenuated correlations between the highest and lowest loadings

[8] t-tests between items that had positive and negative loadings in PCAR analysis

[9] The revised models used collapsed RSM with new categories 12234, except for BFCC. The BFCC model with original 5 categories was remained. All the model data were refitted.

2.4.2 Proper functioning of a rating scale

The rating scale functioning assessment of 5-point rating scales for original 23-items IES-2 and four measures of EPRE, RHSC, UPE and RHSC is shown in Table 2.7. The latter four measures were from the fitted items based on the classified of items into four dimensions. The original models IES2-R5, EPRE-R5, RHSC-R5 and UPE-R5, except BFCC-R5, did not meet some of the essential criteria for the proper functioning of a rating scale that had been proposed by Linacre (2002) as described in subsection 2.3.4.3. For instance, the distance between Rasch-Andrich thresholds for categories “Neutral” and “Agree” in the IES2-R5 model was 0.18, which was smaller than the recommended value of 0.81 for a rating scale with five categories (see Table 2.3). The same issue happened in EPRE-R5, RHSC-R5 and UPE-R5 as well, where the distance between Rasch-Andrich thresholds for categories “Neutral” and “Agree” were 0.01, 0.45 and 0.27, respectively. The small values implied that the intervals covered by some of the scale categories were too narrow on the construct and caused one of the categories would never be modal.

Furthermore, the Rasch-Andrich threshold measures in the IES2-R5 and EPRE-R5 models did not increase monotonically up the scale between categories 3 (Neutral) and 4 (Agree). The disorders could be explained by looking at the count numbers in individual category (category frequency). The frequency of responses in category 3 was almost half than of those in category 4 and then led to narrowed category 3 on the latent variable (Table 2.7). Average measures are defined as the averages of the sample set of people who respond or chose in that particular rating-scale category (Bond & Fox, 2015). The values should advance monotonically with the categories values. The observed measures in all models were aligned to expected values because if both values were unparallel, it means that the data did not fit the Rasch model (Linacre, 2019). The disordered threshold of the IES2-R5 measure was supported with category probability curves in Figure 2.2, where the Category 3 (Neutral) was no longer modal. The cross-over between the curves for category 3 and 4 is to the left of that for categories 2 and 3. It has been suggested to collapse either category 2 (Disagree) and category 3 (Neutral) or category 3 (Neutral) and 4 (Agree) into one category to improve the quality of measurements (Bond & Fox, 2015). The same category probability curves that showed Category 3 (Neutral) were no longer modal for EPRE-R5, RHSC-R5 and UPE-R5 measures could be seen in Appendix A1, B1 and C1, respectively.

Table 2.7 Category statistic for the 5-point rating scales of original five measures of Rasch Rating Scale Model (RSM)

			Average measures			Rasch-Andrich Threshold	
Category	Labels	Counts[1]	Observed[2]	Expected[3]	OUTFIT[4]	Measure[5]	│Difference│[6]
IES2-R5							
1	Strongly disagree	623 (4.3)	-0.35	-0.40	1.15		
2	Disagree	2919 (20.3)	-0.10	-0.09	0.99	-1.79	
3	Neutral	3281 (22.9)	0.21	0.22	1.00	-0.05	1.74
4	Agree	6006 (41.9)	0.53	0.53	0.94	-0.23*	0.18**
5	Strongly agree	1517 (10.6)	0.89	0.88	1.04	2.07	2.30
EPRE-R5							
1	Strongly disagree	300 (6.0)	-1.79	-1.74	1.13		
2	Disagree	1232 (24.7)	-0.82	-0.81	1.08	-2.66	
3	Neutral	1008 (20.2)	-0.04	-0.01	0.81	-0.21	2.45
4	Agree	1943 (38.9)	0.99	0.92	0.90	-0.22*	0.01**
5	Strongly agree	512 (10.3)	2.31	2.49	1.16	3.09	3.31
RHSC-R5							
1	Strongly disagree	59 (1.6)	-1.36	-1.82	1.54		
2	Disagree	617 (16.5)	-0.69	-0.62	1.02	-3.58	
3	Neutral	849 (22.7)	0.23	0.28	0.72	-0.48	3.10
4	Agree	1891 (50.6)	1.38	1.34	0.98	-0.03	0.45**
5	Strongly agree	321 (8.6)	3.08	3.19	0.99	4.09	4.12
UPE-R5							
1	Strongly disagree	244 (6.5)	-1.09	-1.22	1.22		
2	Disagree	902 (24.1)	-0.63	-0.58	0.95	-2.20	
3	Neutral	866 (23.1)	0.04	0.09	0.83	-0.21	1.99
4	Agree	1296 (34.6)	0.91	0.85	0.92	0.06	0.27**
5	Strongly agree	438 (11.7)	1.64	1.71	1.11	2.36	2.30

Continued from Table 2.7

Category	Labels	Counts[1]	Average measures: Observed[2]	Average measures: Expected[3]	Category	Rasch-Andrich Threshold: Measure[5]	Rasch-Andrich Threshold: Measure[5]
BFCC-R5							
1	Strongly disagree	20 (1.1)	-2.79	-3.41	1.35		
2	Disagree	168 (9.0)	-1.73	-1.61	1.00	-5.09	
3	Neutral	558 (29.9)	0.43	0.49	0.77	-1.70	3.39
4	Agree	876 (47.1)	2.86	2.75	0.87	1.12	2.82
5	Strongly agree	246 (13.2)	4.66	4.99	1.15	5.68	4.56

[1] Number and percentage (in brackets) of observations used in each category
[2] Modelled average measure in log-odds units (logits)
[3] Expected average measure if data fitted the Rasch model
[4] Unweighted mean square for observations in each category
[5] Location on the latent variable, relative to the centre of the scale, where adjacent categories are equally probable
[6] Absolute difference between Rasch-Andrich threshold values of two adjacent categories
[*] Measure value that does not increase with a higher rating category
** Difference is smaller than the minimum acceptable threshold value (0.81) for a 5-point rating scale

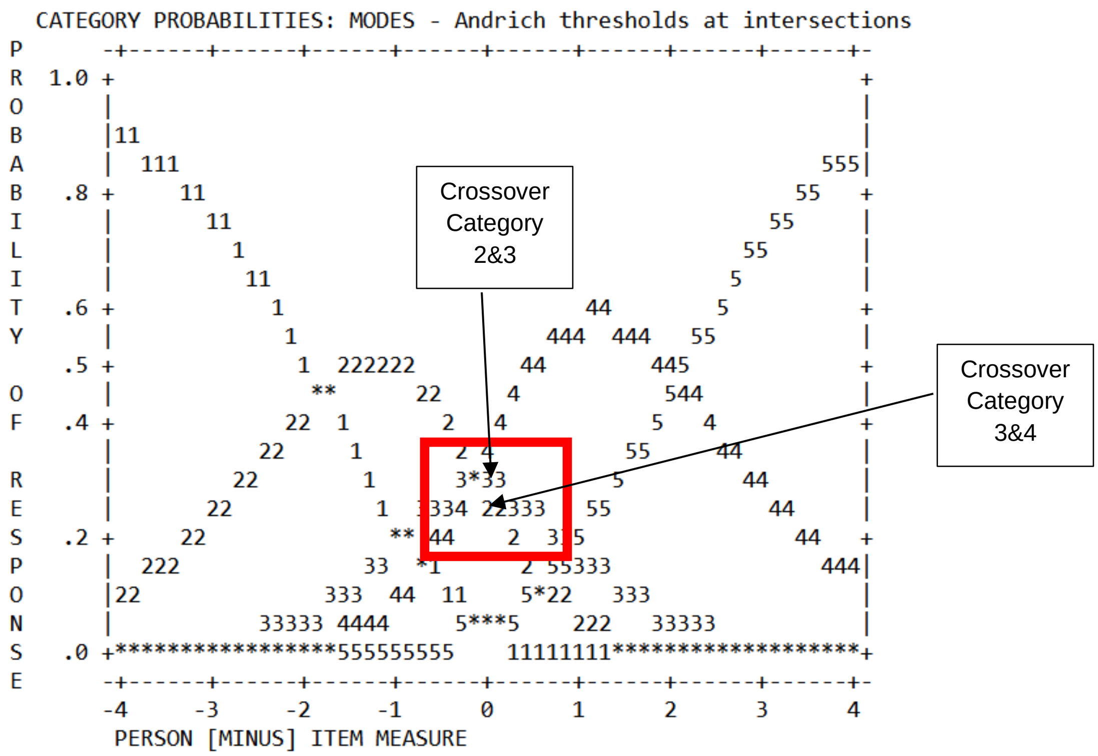

Figure 2.2 Response category probability curves for the original Rasch Rating Scale Model (RSM) for IES2-R5

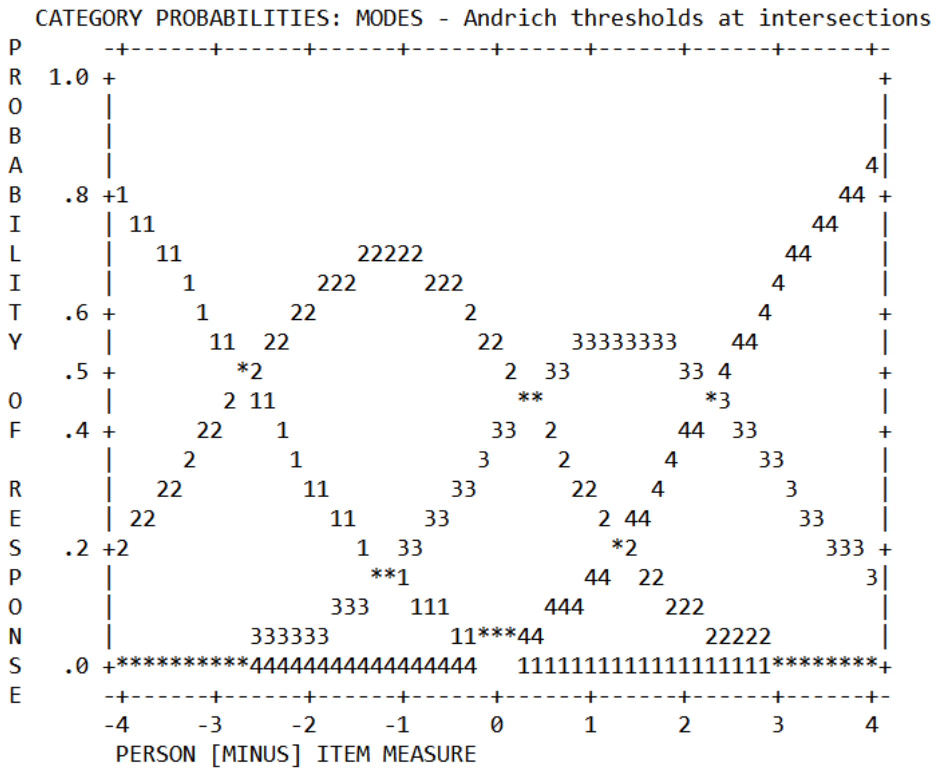

Figure 2.3 Response category probability curves for the revised Rasch Rating Scale Model (RSM) for IES2-R4 after collapsing to 12234 scales.

In deciding which rating scale categories to collapse, there are a few criteria that should be considered. Firstly, the collapsing categories should not be arbitrary or thoughtless (Wright, 1996; Wright & Linacre, 1992); the meaning of two or more collapsed categories should make sense and logic and do not contradict each other. The rating scale categories used in IES-2 data were bipolar; which two alternatives were in opposition along the continuum (disagreement and agreement rating categories), and separated by a precise conceptual midpoint (Neutral category) that makes the transition from one side to the other (Schaeffer & Presser, 2003). Respondents who scored category 3 (Neutral) may have on a par to choose between a weakly positive (Category 4, Agree) or a weakly negative (Category 2, Disagree) towards the agreement of IES-2 items statements. Therefore, there were two possible collapsing categories either collapsing the original Category 3 (Neutral) downward into Category 2 (Disagree), which is known with a new collapsed scale of 12234 or collapsing Category 3 (Neutral) upwards to Category 4 (Agree) with a new scale of 12334. The revised IES-2 model with collapsing category 12234 was chosen as it produced more uniform frequency distribution and yielded higher reliability for both persons and items, compared to model with category 12334 (Bond & Fox, 2015; Linacre, 2002).

Table 2.8 Comparison between original category (Category 12345) with collapsing categories (Category 12234 and 12334) for IES-2 models

Categorisation*	Rasch-Andrich Threshold	Fit	Category measures	Separation		Reliability	
				Person	Item	Person	Item
12345	Disordered	<2.0	Ordered	1.51	9.59	0.70	0.99
12234	Ordered	<2.0	Ordered	1.63	9.25	0.73	0.99
12334	Ordered	<2.0	Ordered	1.38	8.94	0.65	0.99

*Categorization explains that 12345 indicates that five categories used in original rating scale for IES-2 survey. The second codes 12234 explain that Category 2 (Disagree) was collapsed into Category 3 (Neutral). The last codes 12334 explain that Category 3 (Neutral) was collapsed into Category 4 (Agree). The categories with same values (2 and 2, or 3 and 3) have been treated as the same response in the analysis.

It is clearly shown that both collapsing categories (12234 and 12334) improved category threshold of the original model as suggested by Linacre (2002), therefore, to decide which the best collapsing category to be used in further analysis, model validity and reliability for all categories were compared. Table 2.8 shows that category 12234 yielded higher person reliability and better separation for the IES-2 model than the initial model (12345) and model for category12334. The new response category probability curves were improved after categories 2 and 3 were collapsed into one category (Figure 2.3), and the categories used in the rating scale model properly functioned (Table 2.9). The results also worked for EPRE and UPE models when the new collapsed 12234 categories been used, as shown in Table 2.9. The revised category probability curves showed that new category represents a distinct modal of the collapsed categories for EPRE-R4 and UPE-R4 models (Appendix A2, B2 and C2). For RHSC model, after collapsing to new category 12234, the Rasch-Andrich threshold between categories 2 and 3 was 5.11 (Table 2.9). Even though the value was larger than the suggested maximum acceptable threshold distance (Ho, 2019; Linacre, 2002), the collapsed categories 12234 was chosen to be used in RHSC model, as the recommended value only helps in maintaining the stability of the model measure. Moreover, the categories 12234 produced higher reliability and separation for both person and items, than categories 12334 (see Appendix B3). In further analysis, the IES-2, EPRE, RHSC and UPE measures would use the revised collapsing categories 12234 (hereby known as IES2-R4, EPRE-R4, RHSC-R4 and UPE-R4, respectively). Since the BFCC measure with the original 5 categories (12345) (BFCC-R5) followed all 10 criteria for the proper functioning of a rating scale (Table 2.8), further analysis for the BFCC measure would be analysed using the original 5 categories.

Table 2.9 Category statistic Rasch Rating Scale Models (RSM) for IES-2, EPRE, RHSC and UPE using revised scale categories 12234

Category	Labels	Counts[1]	Average measures: Observed[2]	Average measures: Expected[3]	OUTFIT[4]	Rasch-Andrich Threshold: Measure[5]	Rasch-Andrich Threshold: |Difference|[6]
IES2-R4							
1	Strongly disagree	623 (4.4)	-0.56	-0.73	1.12		
2	Disagree &	6200 (43.3)	-0.05	-0.02	0.98	-2.67	
2	Neutral						
3	Agree	6002 (42.0)	0.64	0.62	0.90	0.34	3.01
4	Strongly agree	1482 (10.4)	1.26	1.25	1.03	2.32	1.98
EPRE-R4							
1	Strongly disagree	300 (6.0)	-2.66	-2.71	1.06		
2	Disagree &	2240 (44.8)	-0.84	-0.78	0.93	-3.73	
2	Neutral						
3	Agree	1943 (38.9)	1.14	1.02	0.86	0.27	4.00
4	Strongly agree	512 (10.3)	2.81	3.05	1.30	3.46	3.19
RHSC-R4							
1	Strongly disagree	59 (1.6)	-2.09	-2.62	1.17		
2	Disagree &	1466 (39.2)	-0.52	-0.46	0.94	-4.79	
2	Neutral						
3	Agree	1891 (50.6)	1.59	1.55	0.91	0.32	5.11*
4	Strongly agree	321 (8.6)	3.60	3.65	1.04	4.47	4.15
UPE-R4							
1	Strongly disagree	244 (6.6)	-1.81	-2.09	1.16		
2	Disagree &	1768 (47.7)	-0.69	-0.60	0.89	-3.33	
2	Neutral						
3	Agree	1292 (34.9)	1.03	0.95	0.89	0.50	3.83
4	Strongly agree	403 (10.9)	2.30	2.34	1.10	2.83	2.33

[1] Number and percentage (in brackets) of observations used in each category
[2] Modelled average measure in log-odds units (logits)
[3] Expected average measure if data fitted the Rasch model
[4] Unweighted mean square for observations in each category
[5] Location on the latent variable, relative to the centre of the scale, where adjacent categories are equally probable
[6] Absolute difference between Rasch-Andrich threshold values of two adjacent categories
* Difference exceeds the maximum distance of the acceptable threshold value (5 logits)

2.4.3 IES-2 measures

Table 2.6 shows that only 1 out of 23 items (4.3%) of IES-2 items in the original IES2-5R model fall out of a range between 0.5 and 1.5, with item Q7R (Not Allow Forbidden Foods) OUTFIT MNSQ value of 1.65 (Table 2.10). The OUTFIT MNSQ value 1.65 is in range between 1.5 to 2.0 where the presence of squared residuals in the item Q7R were just noticeable and could be neglected. By removing the responses with z-residuals of ≥2 or <-2 in item Q7R to bring down the OUTFIT MNSQ to value below 1.5 (OUTFIT MNSQ was 1.39) increased the item Q7R measure from 0.74 to 0.89 (see Table 2.10). However, the refitting step did not affect the total mean measure and total OUTFIT MNSQ of IES2-5R. It also did not give obvious differences in individual item measure and standard error for the rest 22 items. It explained why the OUTFIT MNSQ value 1.65 neither constructed nor degraded the IES2-5R measure (Linacre, 2019; Wright & Linacre, 1994). Further inspection on fit statistics suggested that all items fitted well the revised IES2-4R model with OUTFIT MNSQ range between 0.73 to 1.36 (Table 2.10).

Table 2.10 **The Rasch measure, standard error (SE) and Outfit MNSQ statistics of IES-2 items within the original (IES2-R5) and revised (IES2-R4) models**

Item[1]	Statement[2]	IES2-R5 measure		IES2-R4 measure	
		Measure±SE	Outfit MNSQ	Measure±SE	Outfit MNSQ
Q1R	I try to avoid certain foods high in fat, carbohydrates or calories.	0.81±0.04	1.31	1.13±0.07	1.19
Q2R	I find myself eating when I am feeling emotional (e.g., anxious, depressed, sad), even when I am not physically hungry.	0.63±0.04	1.06	0.78±0.07	1.21
Q3	If I am craving a certain food, I allow myself to have it.	-0.77±0.05	1.30	-1.00±0.06	1.36
Q4R	I get mad at myself for eating something unhealthy.	0.66±0.04	1.20	1.01±0.07	1.24
Q5R	I find myself eating when I am lonely, even when I am not physically hungry.	0.20±0.04	1.13	0.12±0.06	1.13
Q6	I trust my body to tell me WHEN to eat.	-0.32±0.05	0.86	-0.46±0.06	0.83
Q7R	I have forbidden foods that I don’t allow myself to eat.	0.74±0.04	1.65	1.29±0.07	1.27
Q8R	I use food to help me to soothe my negative emotions.	0.64±0.04	0.99	0.85±0.07	1.04
Q9R	I find myself eating when I am stressed out, even when I am not physically hungry.	0.53±0.04	0.95	0.62±0.07	1.02
Q10	I am able to cope with my negative emotions (e.g., anxiety, sadness) without turning to food for comfort.	-0.19±0.04	0.83	-0.29±0.06	0.84
Q11	When I am bored, I do NOT eat just for something to do.	-0.05±0.04	1.04	-0.17±0.06	0.98
Q12	I trust my body to tell me HOW MUCH to eat.	-0.09±0.04	0.85	-0.18±0.06	0.83
Q13	When I am lonely, I do NOT turn to food for comfort.	-0.14±0.04	0.91	-0.27±0.06	0.87
Q14	I find other ways to cope with stress and anxiety than by eating.	-0.55±0.05	0.82	-0.72±0.06	0.76
Q15	I allow myself to eat what food I desire at the moment	-0.51±0.05	1.01	-0.66±0.06	1.05

Q16	I do NOT follow eating rules or dieting plans that dictate what, when, and/or how much to eat.	-0.16±0.04	1.42	-0.34±0.06	1.34
Q17	Most of the time, I desire to eat nutritious foods.	-0.31±0.05	1.10	-0.39±0.06	1.17
Q18	I mostly eat foods that make my body perform efficiently (well).	-0.22±0.05	0.84	-0.18±0.06	0.92
Q19	I mostly eat foods that give my body energy and stamina.	-0.44±0.05	0.79	-0.50±0.06	0.88
Q20	I rely on my hunger signals to tell me when to eat.	-0.22±0.05	0.85	-0.31±0.06	0.81
Q21	I rely on my fullness (satiety) to tell me when to stop eating.	-0.14±0.04	0.88	-0.19±0.06	0.80
Q22	I trust my body to tell me WHAT to eat.	0.05±0.4	0.82	0.08±0.06	0.80
Q23	I trust my body to tell me when to stop eating.	-0.16±0.04	0.79	-0.23±0.06	0.73

[1] the items with letter R were analysed with the reversed scores.

[2] Question: To what extent do you agree or disagree with the statements listed

2.4.4 Dimensionality and local dependency of the Rasch models

The eleventh column in Table 2.6 shows that the eigenvalue of the unexplained variance in the first extracted PCAR contrast in the IES2-5R model was 4.50. It shows that the first contrast had a strength of about 4 to 5 items to create an additional dimension. The values suggested that the contrast between the strongly positively loading items (Cluster 1) and the strongly negatively loading items (Cluster 3) measuring different things (Linacre, 2019). Cluster 1 was made up of 8 items that belong to the EPRE factor, while Cluster 2 consisted of BFCC items. The UPE and RHSC items were located in Cluster 3. It had been supported with the disattenuated correlation of 0.006 and lower bound values of the binomial confidence interval of approximately 30% between the positive and negative loadings on the first PCAR contrast of IES2-5R model (Table 2.6). The disattenuated correlation between cluster loadings was 0.006 (Cluster 1-3), 0.451 (Cluster 1-2), and -0.079 (Cluster 2-3), which below than minimum cut-off point 0.57 where the clusters measure the same thing (refer to Table 2.5).

The lower bound values of binomial confidence interval exceeded 5%, which may reject the unidimensionality criteria because there were significant differences between the two extreme loadings (Miller et al., 2010). Therefore, it was suggested to split the items into individual subsets based on their first PCAR contrast loading clusters (see Figure 2.4). Then, the new Rasch models contain a new set of items from different loading clusters were reanalysed and revised separately, followed by the PCAR test. The IES2-4R model exhibited the eigenvalue in the first contrast was 4.27, disattenuated correlation between Cluster 1 and 3 (0.0263) and lower bound values of binomial confidence interval t-test (22.58%); so that, it was suggested to analyse the IES2-4R model with the same procedures as IES2-5R model.

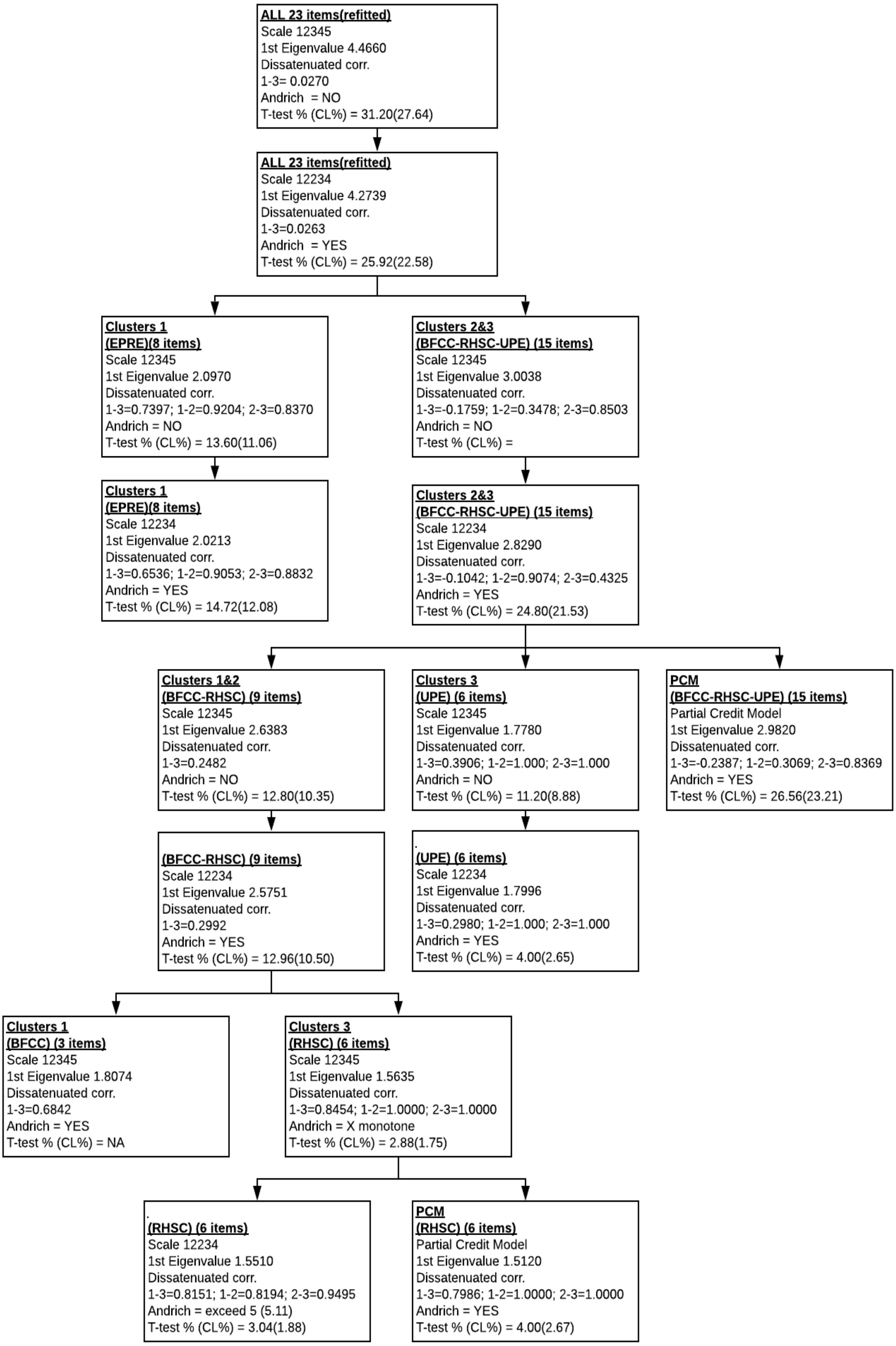

Figure 2.4 Tests for unidimensionality of IES-2 items

Local item dependency (LID) inspection showed that all the residual correlations between items fell below cut-off value (0.7). It explained that the items are independent and do not share their “random” variance with other items (e.g. Meaning, concept etc.) (Linacre, 2019). The unidimensionality analysis was supported by testlet test. The items in the same factor (EPRE, RHSC, UPE and BFCC) were combined to form super-items. The summated score of the item groups was used as the score of the super-items. The data were fitted using the PCM and Rasch analysis was done on the super-items. The eigenvalue of first PCAR contrast decreased to 1.66 and disattenuated correlation increased to 0.6317 (clusters 1-3), 0.6948 (clusters 1-2) and 0.8524 (clusters 2-3). These differences indicated that the PCM model with super-items groups was unidimensional. The item reliability remained the same as the IES2-4R model (item reliability 0.99), indicating no local dependency. As summarised in Figure 2.4, PCAR analysis showed that IES2-5R and IES2-4R models could not be held as unidimensional measures and there were four revised unidimensions derived from these models named EPRE-R4, RHSC-R4, UPE-R4 and BFCC-R5 models. Our findings are comparable with a study done by Swami and collaegues (2020) that examined the psychometric properties of a Bahasa Malaysia (Malay) translation of the IES-2 in a sample of Malaysian adults (all Asians). The exploratory factor analyses (EFAs) with Malay subsamples indicated that IES-2 scores reduced to 4 factors in women and succeed to confirm the parent 4-factor model (Tylka & Kroon Van Diest, 2013), Moreover, their finding showed that the scores on the model had adequate internal consistency and were invariant across sex and ethnicity (Swami et al., 2020).

2.4.5 Rasch analysis of EPRE original (EPRE-R5) and revised (EPRE-R4) models

The fit statistics show that the data used fitted both original EPRE-R5 and revised EPRE-R4 models (Table 2.6). The EPRE-R5 model that used 5-category scale did not function well because the Rasch-Andrich threshold difference between category 3 and 4 was 0.01 (Table 2.7). Therefore the model was revised by collapsing categories 2 and 3 into one category to create a new 4-category RSM model named EPRE-R4. The Outfit MNSQ for items in both EPRE-R5 and EPRE-R4 models were in the ranges of 0.72 to 1.29 (see Table 2.11), which fall in the recommended range of 0.5 to 1.5 (Linacre, 2019; Wright & Linacre, 1994). Therefore, all data in the EPRE items were retained for further analysis. The eigenvalues 2.0970 and 2.0213 in PCAR first contrast supported the assumption that the EPRE-R5 and EPRE-R4, respectively, were unidimensional (Table 2.6). There was no local dependency between item pairs reported in both models, with negative standardized residual correlations between item pairs.

Table 2.11 The Rasch measure, standard error (SE) and Outfit MNSQ statistics of EPRE-R5 and EPRE-R4 models

	EPRE-R5		**EPRE-R4**	
Item[1]	Measure±SE	Outfit MNSQ	Measure±SE	Outfit MNSQ
Q2R	0.77±0.05	1.05	0.98±0.08	1.12
Q5R	0.10±0.05	1.12	0.02±0.08	1.11
Q8R	0.78±0.05	0.97	1.09±0.08	0.92
Q9R	0.61±0.05	0.72	0.75±0.08	0.76
Q10	-0.51±0.05	0.88	-0.60±0.08	0.90
Q11	-0.29±0.05	1.29	-0.42±0.08	1.20
Q13	-0.43±0.05	0.88	-0.57±0.08	0.85
Q14	-1.04±0.06	1.18	-1.25±0.08	1.15

[1] the items with letter R were analysed with the reversed scores.

The EPRE-R4 items and persons' measures have been illustrated in the Wright map. The persons and items are located on the Wright map's left and right sides according to their agreement ability and difficulty, respectively. The person at the top of the Wright map could be considered individuals who are eating because they physically feel hungry rather than follow their emotions in making decisions compared to those at the bottom of the map. There were four reversed-score items (items with labelled F) that were located higher than other items. It did not mean that those items were agreed less than others, but the scores were flipped before analysed. All reversed items had been asked using negative wordings. For instance, for item Q2R, the individuals more agree that they did not use eating as an excuse when they feel emotional even though they were not physically hungry. Moreover, respondents agree that eating was not used as a tool to soothe their negative emotions (item Q8R) rather than eating when they are lonely even though they are not physically hungry (item Q5R).

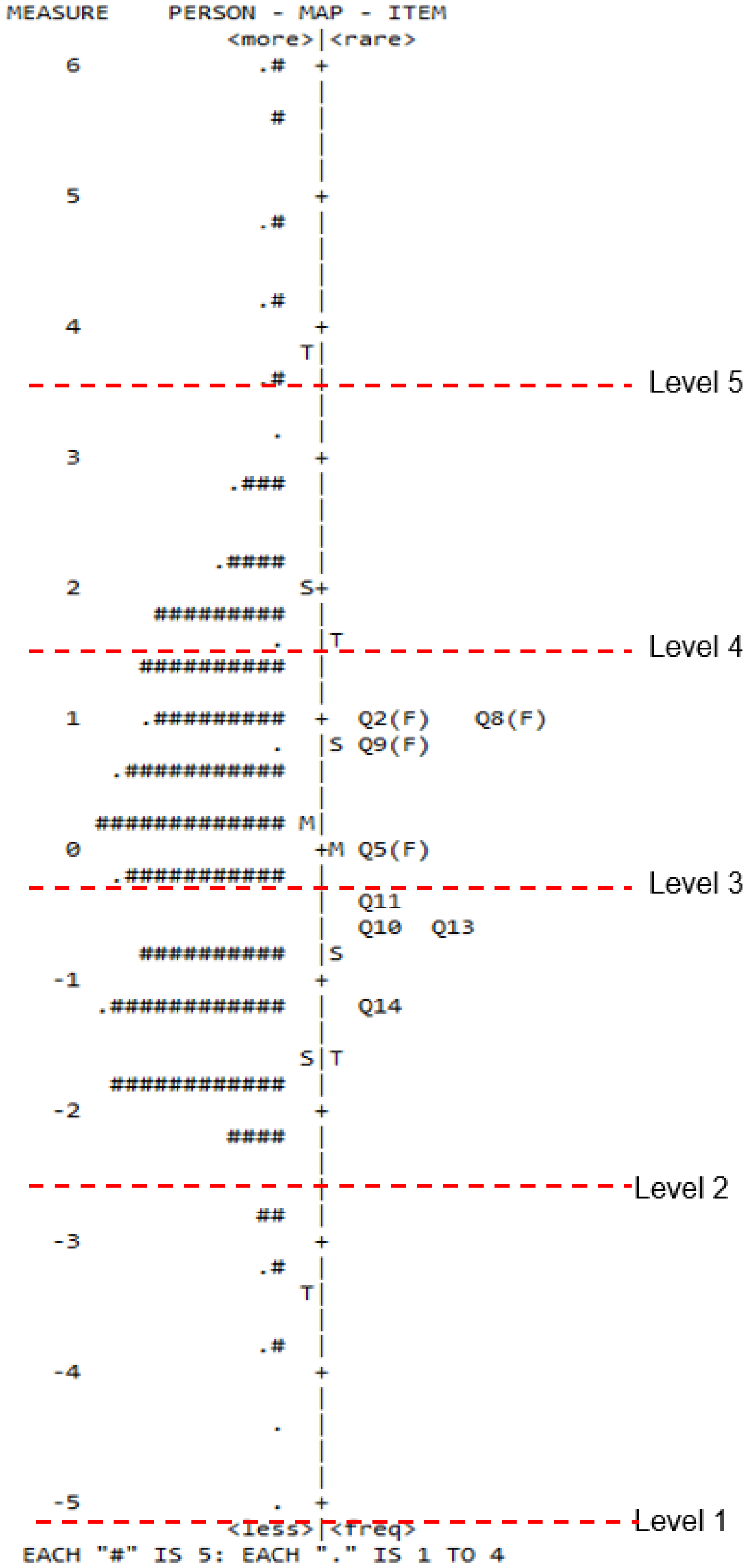

Figure 2.5 Wright map of EPRE-R4 model. The red dash lines present the minimum measures for the next upper levels of Rasch statistical levels

2.4.6 Rasch analysis of RHSC original (RHSC-R5) and revised (RHSC-R4) models

After undergoing Rasch analysis steps, the fit statistics demonstrated that the data fitted the revised RHSC-R4 model with only 3.18% of absolute standardized residuals in the data equal to or greater than 2; 0.13% of them were ≥3 (see Table 2.6). The eigenvalue of raw unexplained variance in the PCAR first contrast was 1.5510, suggested that the assumption of unidimensionality could be held in the RHSC-R4 model. The disattenuated correlation between the item clusters was close to 1 implies that the items in all clusters measure the same things.

Table 2.12 The Rasch measure, standard error (SE) and Outfit MNSQ statistics of RHSC-R5 and RHSC-R4 models

	RHSC-R5		RHSC-R4	
Item[1]	Measure±SE	Outfit MNSQ	Measure±SE	Outfit MNSQ
Q6	-0.34±0.06	1.03	-0.47±0.09	0.97
Q12	0.10±0.06	1.02	0.06±0.09	1.03
Q20	-0.13±0.06	1.21	-0.18±0.09	1.18
Q21	0.01±0.06	0.98	0.05±0.09	0.98
Q22	0.38±0.06	0.87	0.57±0.09	0.91
Q23	-0.02±0.06	0.72	-0.02±0.09	0.74

[1] the items with letter R were analysed with the reversed scores.

The Outfit MNSQ for all RHSC-R4 items ranged from 0.74 to 1.18 (Table 2.12). Item Q22 was the most difficult to agree, with the highest measure 0.57, plotted at the highest of the Wright map (Figure 2.6). On the other hand, Q6 was the easiest to agree with, as its location was on the Wright map's bottom. People felt harder deciding the type of food to eat (item Q22) than trusting their bodies to decide the amount of food and when they would like to eat (items Q12 and Q6, respectively). The persons at the top were considered individuals who trust in their internal hunger and satiety cues and rely more on these cues to guide their eating behavior than those at the bottom.

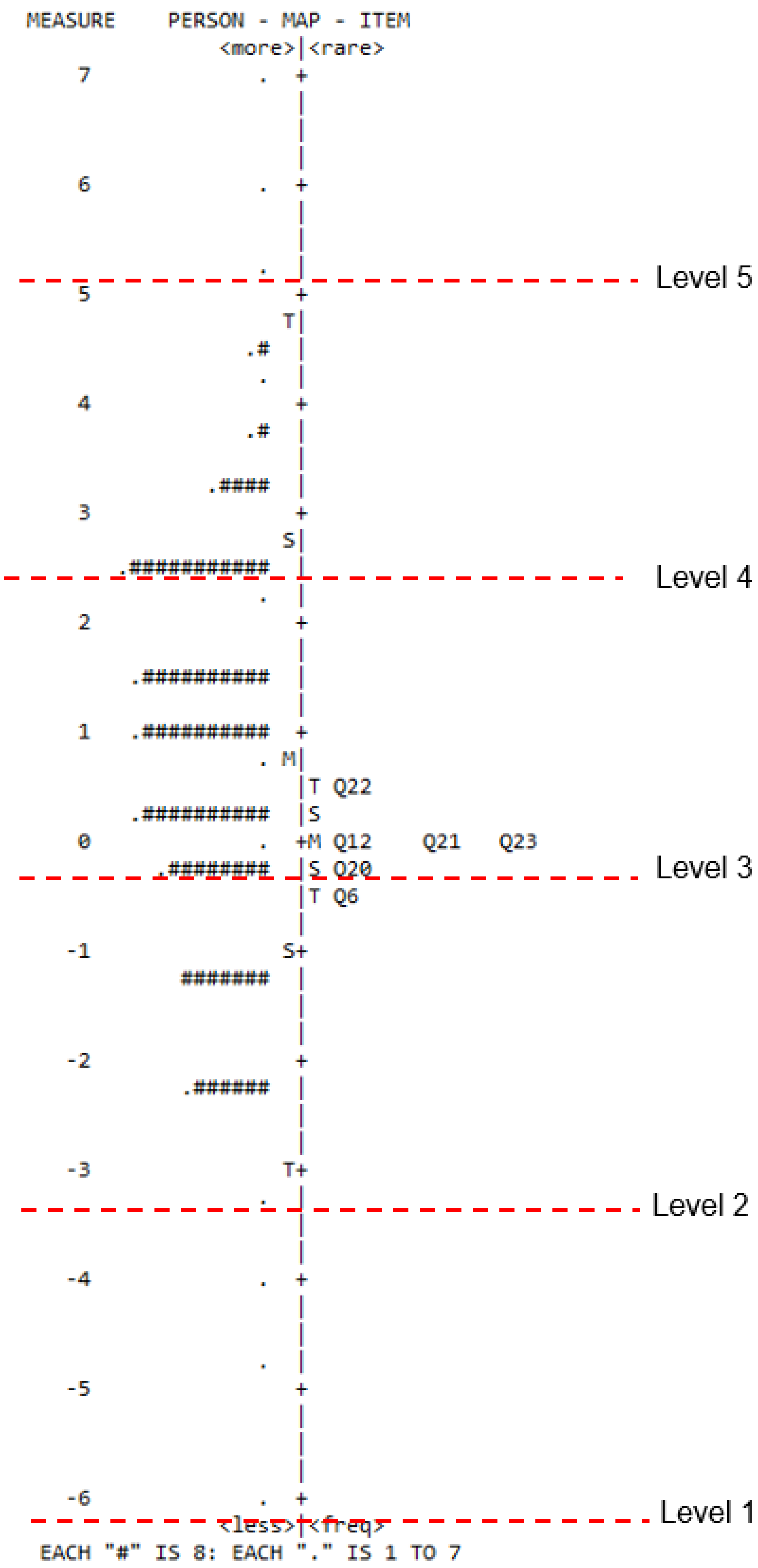

Figure 2.6 Wright map of RHSC-R4 model. The red dash lines present the minimum measures for the next upper levels of Rasch statistical levels

2.4.7 Rasch analysis of UPE original (UPE-R5) and revised (UPE-R4) models

The summary fit statistics show that the data fit the Rasch UPE original and revised models (hereby known as UPE-R5 and UPE-R4, respectively). Both models presented data with more than 95% of absolute standardised residuals below two (Table 2.6) and items MNSQ OUTFIT in the range of 0.77 to 1.27 (see Table 2.13). Table 2.7 shows that the original measure UPE-R5 with five categories did not fulfil proper functioning for the rating scale model. The Rasch-Andrich threshold difference between categories 3 and 4 was 0.27, below the minimum acceptable threshold value (0.81) for a 5-point rating scale model. After collapsing step, the 4-category scale of UPE-R4 functioned adequately (see Table 2.9) and followed the guidelines for the proper functioning of a rating scale (John M. Linacre, 2002). The UPE-R4 model could be assumed as unidimensional with eigenvalue in the PCAR first contrast was 1.7996. Even though the disattenuated correlation between clusters 1 and 3 was 0.3130, only two items were located in cluster 1 and were not enough to form a second dimension. There were no local dependencies between items pair found in the model.

Table 2.13 The Rasch measure, standard error (SE) and Outfit MNSQ statistics of UPE-R5 and UPE-R4 models

	UPE-R5		UPE-R4	
Item[1]	Measure±SE	Outfit MNSQ	Measure±SE	Outfit MNSQ
Q1R	0.85±0.05	0.86	1.10±0.08	0.89
Q3	-1.10±0.05	1.01	-1.51±0.07	1.01
Q4R	0.66±0.05	1.11	0.96±0.08	1.21
Q7R	0.76±0.05	1.27	1.23±0.08	1.20
Q15	-0.79±0.05	0.84	-1.09±0.07	0.77
Q16	-0.38±0.05	0.91	-0.70±0.07	0.89

[1] the items with letter R were analysed with the reversed scores.

A Wright Map in Figure 2.7 illustrates the estimates for panellists and items for the UPE-R4 model. The item Q7R, with the highest measure 1.23, was plotted at the highest of the Wright map, followed by Q1R and Q4R, respectively. Panellists rated Q7R with higher categories, and more agree with the statement “I have forbidden foods that I do not allow myself to eat”. They agreed most with item Q3 by rating it using higher categories. It means that they allow themselves to eat any food they are craving without a doubt. The persons at the top of the map could be considered individuals who are ready to eat when they feel hungry and what food is desired at the moment without label certain foods into allowed or forbidden foods than those at the bottom.

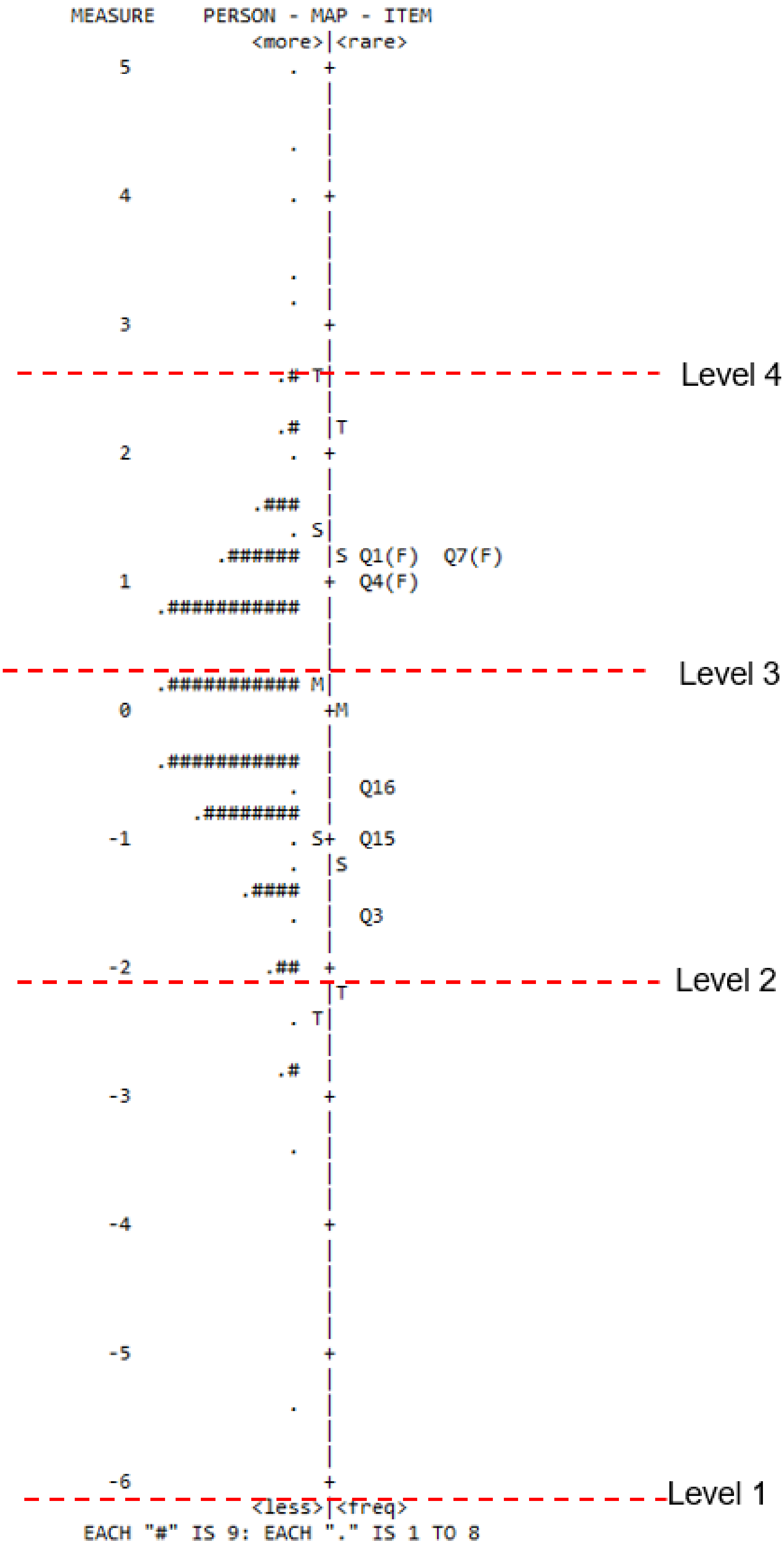

Figure 2.7 Wright map of UPE-R4 model. The red dash lines present the minimum measures for the next upper levels of Rasch statistical levels

2.4.8 Rasch analysis of BFCC original model (BFCC-R5)

The BFCC-R5 model showed acceptable model fit with more than 96.9% of the absolute standardised residuals were below 2. The BFCC-R5 model with 5 categories followed the rating scale's guidelines for proper functioning (Table 2.3). All three items Outfit MNSQ fall in the range of 0.66 to 1.25. All the persons, including the misfit person, remained in the analysis since they were unlikely to impact the BFCC items' fit significantly.

Table 2.14 The Rasch measure, standard error (SE) and outfit MNSQ statistics of items within the BFCC-R5 model

Item	Measure±SE	Outfit MNSQ
Q17	0.04±0.08	1.25
Q18	0.32±0.08	0.66
Q19	-0.36±0.08	0.90

[1] Question: To what extent do you agree or disagree with the statements listed below

The persons and items' distribution on the BFCC-R5 model were visualised using the Wright map in Figure 2.8, where the items' location was in the middle of the map, ranging between -0.36 to 0.32. Item Q18 is located at the top, likely being rated with lower categories than Q17 and Q19. They mostly agree that they eat food for energy and stamina (Q19) followed by eating for body performance (Q17) and take nutritious food most of the time (Q18), respectively. There was a pattern where most person measures skewed towards the top tail on the Wright map. The higher a person on the Wright map, the more agreeable they with the BFCC statement and considered individuals who choose healthy and tasty nutrition in line with bodily needs than those at the bottom.

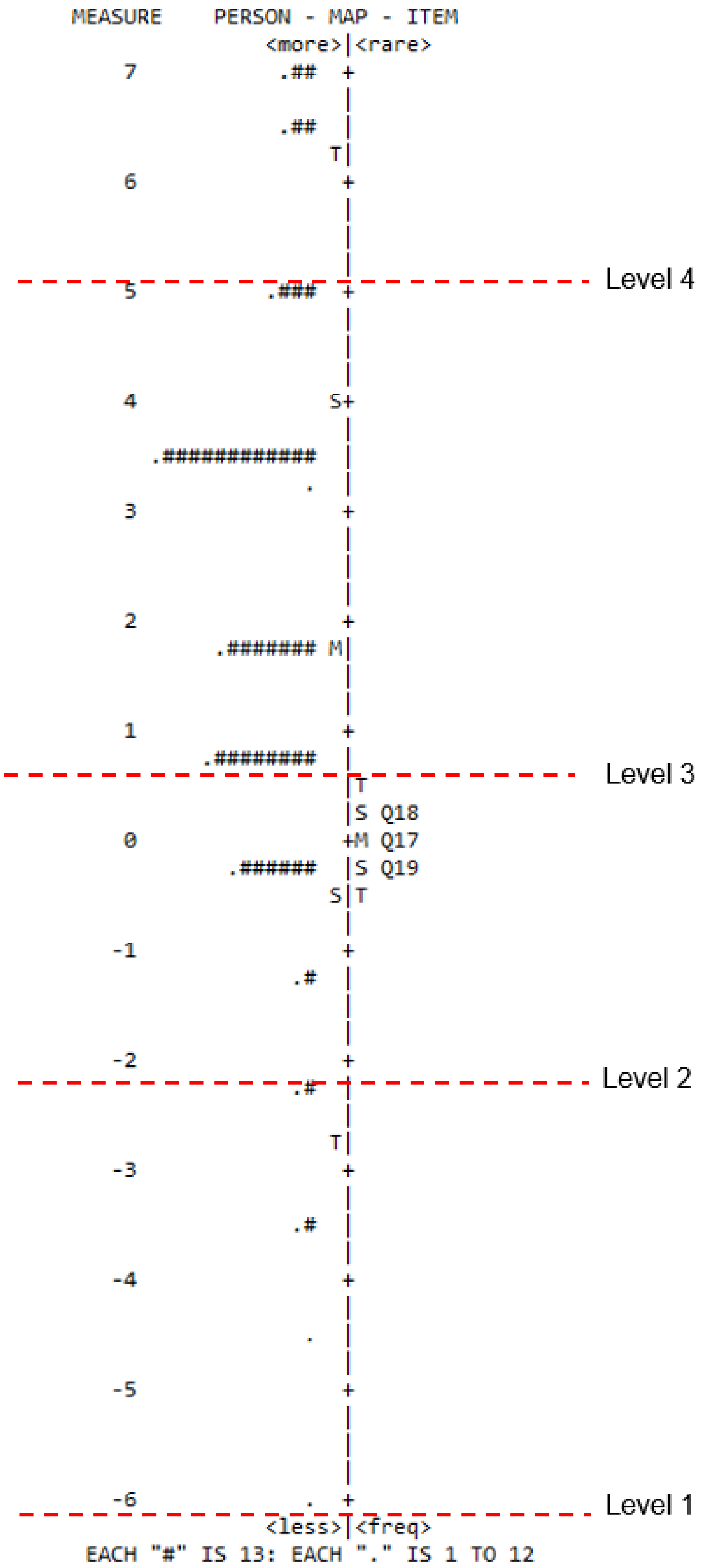

Figure 2.8 Wright map of BFCC-R5 model. The red dash lines present the minimum measures for the next upper levels of Rasch statistical levels

2.4.9 Clustering participants based on person measures

The IES-2 survey's objective was to categorise the respondents into groups towards their intuitive eating behaviours. Individuals in the same groups tend to behave similarly in specific aspects (Charrad, Ghazzali, Boiteau, & Niknafs, 2014; Everitt, Landau, Leese, & Stahl, 2011). Clustering analyses have been applied in many studies, such as to group person skills, diseases and patterns (Anderson, Lee, & Dean, 2014; Dean & Nugent, 2013; Flynt & Daepp, 2015).

Rasch statistical different levels of intuitive eating were determined for each dimension from a table representing the relationship between the lowest and highest possible Rasch measures. Table 2.15 shows the person stratification for each dimension IES-2 based on their Rasch measures. The vertical dash lines on the Wright maps presented the minimum measures for the next upper levels (Figure 2.5 to Figure 2.8). The values at the dash lines were less than Logit measures to start the next level. From the Winstep analysis, there was a maximum of 5 statistical levels suggested for EPRE-R4 and RHSC-R4 dimensions and four levels for UPE-R4 and BFCC-R5 dimensions. The two statistical levels were distinguished approximately at three times standard error (SE) ($p \leq 0.05$) in the normal distribution sample (Linacre, 2019). Strata is used in a set of persons or items with heavy-tailed outliers at low or high extremes because it can represent extreme performance levels (Wright & Masters, 2002). The strata in all four dimensions gave slightly fewer values than statistical levels, but it could be concluded that using strata, the person clusters were still the same.

For Rasch statistical levels analysis, most respondents were in the middle levels in all dimensions except for the BFCC-R5 dimension (Table 2.15). Statistical levels with the least number of persons were not considered for comparison and were merged into the closest level. So that, they were classified into 2 out of 4 levels in the dimension UPE-R4, 3 out of 5 levels in EPRE-R4 and RHSC-R4, and 3 out of 4 levels in BFCC-R5 dimension.

Table 2.15 Stratification of person groups based on Rasch statistical levels and minimum measures

Statistical Level	EPRE-R4		RHSC-R4		UPE-R4		BFCC-R5	
	No. of person	Minimum measure	No. of person	Minimum measure	No. of person	Minimum measure	No. of person	Minimum measure
1	21	0.00	7	0.00	15	0.00	24	0.00
2	153	28.22	116	27.69	253	31.64	126	28.61
3	275	45.35	320	45.93	333	52.50	370	52.10
4	140	59.11	161	64.78	24	69.44	105	73.09
5	36	74.48	21	83.17	-	-	-	-
Strata	4.8		4.5		3.9		3.6	
Max. stat. levels	5		5		4		4	

Table 2.16 NbClust() function: 30 indices for choosing the best number of clusters

No. of cluster[1]	EPRE-R4		RHSC-R4		UPE-R4		BFCC-R5	
	No. of person[2]	Cluster center[3]	No. of person[2]	Cluster center[3]	No. of person[2]	Cluster center[3]	No. of person[2]	Cluster center[3]
1	31	26.13	123	38.33	267	44.42	43	26.70
2	143	39.80	319	55.32	358	59.77	107	44.72
3	107	47.55	183	72.51	-	-	205	56.05
4	168	54.86	-	-	-	-	165	70.41
5	136	64.16	-	-	-	-	73	84.48
6	26	78.78	-	-	-	-	32	99.96
7	14	96.61	-	-	-	-	-	-

[1] Number of clusters were based on optimal number of clusters suggested according to the majority rule in NBClust packages

[2] Number of person in each cluster using K-means analysis

[3] Cluster center is the mean of all the measures belonging to the specified cluster

The clustering done using Rasch analysis was supported by algorithmic method analysis known as k-means. The number of clusters should be decided to perform k-means analysis. One way to find the optimal clusters is by fitting k-means models for a range of consecutive numbers. A few points of desired clusters are then selected at the beginning to set initial centers, and the clustering process is iterated until the centers no longer move (Charrad et al., 2014). A more practical solution for deciding the optimal clusters is applying NbClust packages (Charrad et al., 2014). According to the majority rule, the best number of clusters proposed by NbClust, where thirty clustering validity indices simultaneously involved in a single function call (Charrad et al., 2014).

Moreover, Charrad and colleagues (2014) suggested that the majority rule is more reliable for deciding the optimal number of clusters in IES-2 data, as we use the real data set in this study. Table 2.16 demonstrates that the suggested NbClust optimal clusters for EPRE-R4, RHSC-R4, UPE-R4 and BFCC-R5 dimensions were 7, 3, 2 and 6, correspondingly. After the optimal clusters were decided, the kmeans algorithm analysis was performed to get amount of participants to belong to the clusters. Kmeans analysis groups the participants into the clusters by minimising the overall distance between individual measures and the cluster means (or another name cluster centre) to which they are closest (Flynt & Dean, 2016). In EPRE-R4 kmeans clusters, persons in clusters 1 and 2 were groups as one group, followed with merged clusters 3 and 4, and clusters 5, 6 and 7 as another two groups (Table 2.16). Persons in BFCC-R5 were divided into three groups by combining two clusters next to each other as a single group. For dimensions RHSC-R4 and UPE-R4, the clusters had remained as proposed by NbClust analysis.

Interestingly, by looking at both Rasch statistical levels and kmeans optimal clusters, there were similarities in the pattern the respondents were divided. Taken as a whole, we can see that the number of persons in each group between these methods did not differ significantly. We concluded that persons were stratified into high, medium and low groups in EPRE-R4, RHSC-R4 and BFCC-R5 dimensions and two groups (low and high) in UPE-R4 dimension. One downside regarding these methods is that we might overlook the persons who were located between 2 groups. They might be grouped in the wrong group, either to be positioned in lower or higher groups. Although there was some inconsistency in participant numbers in each group, we believed that person clustering using Rasch and kmeans methods was comparable and practical to be used in further study.

2.5 Conclusion

The Rasch analysis supported that the Intuitive Eating Scale-2 (IES-2) was constructed from four dimensions. However, the Principal Component Analysis of Rasch residuals (PCAR) failed to prove the assumption of unidimensionality in the IES-2 instrument. The study suggested that the IES-2 instrument was built up of four independent unidimensions; which were Physical Rather Than Emotional Reasons (EPRE), Reliance on Hunger and Satiety Cues (RHSC), Unconditional Permission to Eat (UPE) and Body-Food Choice Congruence (BFCC) dimensions. The findings proved that the IES-2 instrument is valid and reliable for larger populations. The segmentation of persons into groups based on their agreement towards IES-2 statements will help the researchers to investigate the effect of intuitive eating levels on satiety in the next Chapter 4.

Chapter 3

Application of Rasch analysis in measuring overall satiety

3.1 Introduction

The interpretation of satiety description is subjective and have been discussed over the years. There is no general agreement on terminology to describe the satiety (Karalus, 2011). The researchers used different descriptors to evaluate satiety. Some researchers only used descriptors hunger or/and fullness (Louis-Sylvestre et al., 1989; Spiegel, 1973; Teghtsoonian, Becker, & Edelman, 1981) and the others have asked the panellist to rate satiety with same descriptors with combination with other descriptors such as thirst, appetite, nausea, desire to eat, prospective consumption, nausea, stomach aches and many more (Bell, Roe, & Rolls, 2003; Brondel et al., 2007; Burton-Freeman, 2005; Cani, Joly, Horsmans, & Delzenne, 2006; Flood, Roe, & Rolls, 2006; Mattes, 2007; Mattes & Campbell, 2009).

With the reason mentioned above, Karalus (2011) developed and validated an instrument to measure satiety called 5-Factor Satiety Questionnaire. The instrument was constructed for measuring hunger and fullness produced by an eating occasion and to be used in developing products that provide greater satiation and satiety with fewer calories (Karalus & Vickers, 2016). It was built from satiety-related descriptors using the results of the focus groups and compressive collection of rating scales from published scientific literatures from the past 40 years. Factor analysis grouped final 41 items into five factors: Mental Hunger, Physical Hunger, Mental Fullness, Physical Fullness and Food Liking. This instrument has been selected to be used in the thesis because it comprised of validated descriptors to define hunger and satiety.

In general, many researchers use satiety-related self-reports include a range of measures intended to capture, over a given period, specific somatic sensations or perceived general state of hunger and fullness feelings, desire to eat, or prospective judgments of the quantity of food or specific foods types that could or would be eaten to evaluate self-assessment of subjective satiety level among healthy subjects (Blundell et al., 2010). The satiety intensity commonly evaluated using a line scale, called a visual analogue scale (VAS), by many researchers (Blundell et al., 2010; Holt et al., 2001; McCrickerd et al., 2020; Merrill et al., 2002; Stubbs et al., 2000). The VAS scales are popular among the researchers because they are easy and quick to use and simple to interpret

(Karalus, 2011). Satiety Labelled Intensity Magnitude (SLIM) scale was constructed to measure satiety perceptions with ratio level responses (Cardello et al., 2005; Zalifah et al., 2008). The study by Karl, Young, and Montain (2011) reported that the SLIM scale was more sensitive and reliable than classic VSA and suitable to access satiation and satiety. Apparent ratio properties of SLIM allow the researchers to evaluate the intensity of satiety perceptions (such as hunger or fullness) in different individuals (Cardello et al., 2005). The SLIM was constructed based on Labelled Magnitude Scale (LMS) measurement tool which was pioneered by Green and colleagues (1993). The LMS measures satiety with nonlinear spacing semantic label of sensation intensities on the label scale (Schifferstein, 2012). The LMS was created based on Borg's (1982) category ratio scale and provide a direct scaling to represent the magnitudes of sensory perceptions simply and straightforwardly (Schifferstein, 2012).

Even though the researchers came out with various scaling methods to measure self-reported satiety, individual rating for each descriptor cannot be considered as an all-inclusive variable to measure overall satiety. It is important to have an instrument built with a set of satiety descriptors that define the latent construct of satiety. The Rasch models are proposed to provide an appropriate measure of overall satiety. They can transform ordinal-level data to interval-data on a logit scale and analyse them as a single latent measure (Bond & Fox, 2015). The details of Rasch models were discussed in Chapter 1.

3.2 Aim of the chapter

The study aimed to explore the applicability of Rasch models in measuring satiety as a single measure.

To achieve this aim, the following objectives were achieved:

3) To examine the unidimensionality of the 5-Factor Satiety Questionnaires (Karalus, 2011) construct using Rasch analysis
4) To compare the dimensions proposed by Rasch analysis with Exploratory Factor Analysis (EFA)

3.3 Materials and Methods

3.3.1 Participant recruitment

Ninety participants in the study were recruited among students and staff of the University of Leeds through emails, posters and flyers placed around the campus. All individuals completed a health checklist to assess their suitability for the study. The participants were thoroughly explained about the whole procedure and provided informed written consent prior to the commencement of the trial.

Participants were generally healthy and more than 18 years old. A health checklist was used to screen the participants to make sure they had no food allergies, no medical condition that restricted their diet in any way that may interfere with the ability to sense, eat, digest, absorb or excrete food, and on any special diet or were taking fibre supplements over the last 3 months. The pregnant or lactating women were excluded from this study. At the end of the study, the participants were reimbursed with 20£ shopping voucher for their participation. The study was approved by the MaPS and Engineering joint Faculty Research Ethics Committee (MEEC FREC) the University of Leeds, dated 4th March, 2019 (Ethics reference: MEEC 16-040 amendment January 2019) 5.4Appendix D).

3.3.2 Satiety trial procedures

A schematic overview of the timeline and trial procedure is summarised in Figure 3.1. On the day before the trial visit, the participants were asked to have their last meal not later than 10 p.m and refrain from consuming any foods or drinks except water until they attend the study centre the following morning. The trial required participants to come to the FSN school to register themselves to the researcher before 8.45 a.m. They verbally confirmed that they had fasted from the night before. They had been seated in individual cubicles and been asked to answer the first set of satiety questionnaires within 15 minutes (hereby known as 'Before Preload'). Then they were given with preload breakfast meal and been asked to consume everything presented within fifteen minutes and followed by answering the same set of satiety questionnaires immediately after they finish their breakfast (After Preload). An individual's time to complete the preload was recorded and time started when they finished the preload. They were then given an option; either to stay in the lab or free to leave the lab. They were reminded not to eat or drink except for water. They were required to be in the FSN Food Technology Lab on time to have their ad libitum lunch meal.

The participants were required to answer the same set of questionnaires, at 1 hour after preload (1H After Preload) and 2.5 hour after preload/before ad libitum lunchtime (Before Lunch). A notification had been sent via their registered emails to remind them to answer them. During lunchtime, they were instructed to consume an ad libitum lunch meal and water presented as much as they preferred until they feel comfortably satisfied and to give a signal to the in-charge researcher after they finished lunch. Afterwards, the participants would be required to answer the same set of questionnaires immediately after they finished the lunch meal (After Lunch) and 1-hour post-lunch (1H After Lunch).

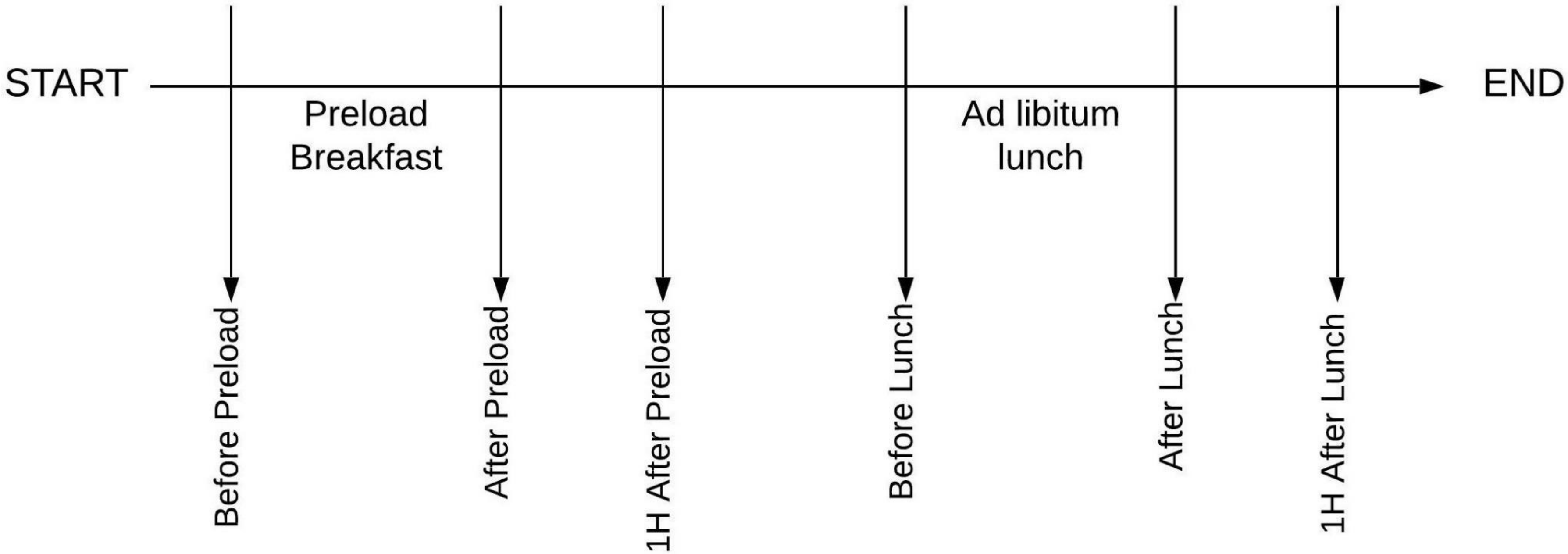

Figure 3.1 General procedure of satiety trial. Participants rated the 41-item of 5-Factor Satiety Questionnaires (Karalus, 2011) at 6-time intervals; before preload breakfast (Before Preload), immediately post-breakfast (After Preload), 1-hour post-breakfast (1H After Preload), 2.5-hour post-breakfast/ pre-lunch (Before Lunch), immediately post-lunch (After Lunch) and 1 hour post-lunch (1H After Lunch). Participants were served with preload breakfast (sandwiches and orange juice) and ad libitum lunch (whole-wheat spaghetti with bolognese sauce meal).

3.3.3 Preload and test meals

The preload breakfast and lunch meals were purchased from local commercial retailers. All the participants received the same breakfast preloads a 353 kcal-sandwich pack (hard-boiled egg, mayonnaise, and salad cress in malted bread) and 200 ml of orange juice (89.4kcal).

Bolognese whole wheat spaghetti meals were served to the participants as *ad libitum* lunch meals. The spaghetti was freshly cooked and served warm with Bolognese sauce. The spaghetti meal was served as single-serving at one time and the participants would allow requesting other servings until they felt comfortably satiated. The total energy and nutrient contents of the test meal for each serving were based on manufacturers' labelling as listed in Table 3.1. The leftover pasta was re-weighed and the total amount of pasta and energy consumed at the lunch meal was calculated. Participants were allowed to drink as much, or little water as they wanted throughout the satiety trial took place.

Table 3.1 Energy content and nutrient compositions of lunch test meal (per serving)

Composition*	Spaghetti (90g, uncooked basis)	Pasta sauce (125 g)
Energy, kcal	314	70
Fat, g	1.8	1.8
Of which saturates g	0.2	0.3
Carbohydrate, g	60.4	9.9
Of which sugars, g	3.0	9.0
Fibre, g	7.2	2.5
Protein, g	10.4	2.5
Salt, g	0.02	0.85

* based on manufacturer's nutrition labelling

3.3.4 Satiety questionnaire items

A set of satiety questionnaires known as 5-Factor Satiety Questionnaires (Karalus, 2011) with modification at scales applied, were used for each time interval. The items were randomly arranged in the RedJade online survey (www.redjade.net). The categories for first two questions (items Q1 and Q2) were labelled with "None", "Very small", "Small", "Moderate", "Large", "Very large", "Extremely large" and "Large possible amount you could eat" as Categories 1 to 8, respectively. For questions Q3 until Q36, the categories "None", "Barely detectable", "Slightly", "Moderate", "Strong", "Very strong", "Extremely strong" and "Strongest sensation of any kind ever experienced" had been used for Categories 1 to 8, respectively. The last five questions (Q36 to Q41) were labelled with eleven categories from "Greatest imaginable disliking" to "Greatest imaginable liking".

3.3.5 Data analysis using Rasch measurement

The 5-Factor Satiety Questionnaires data were analysed using the Rasch measurement model using software package Winsteps Version 4.3.3 (Linacre, 2019). All the extreme and non-extreme data points for ninety participants were included in the Rasch analysis. Numbers of steps were examined based on the procedures suggested by Ho (2019). The summary of Rasch measurement analysis steps is presented in Figure 3.2. The brief procedures for dimensionality and classifying 5-Factor Satiety Questionnaires items into different dimensions were similar to that of briefed subsection 2.3.4 in the previous Chapter 2.

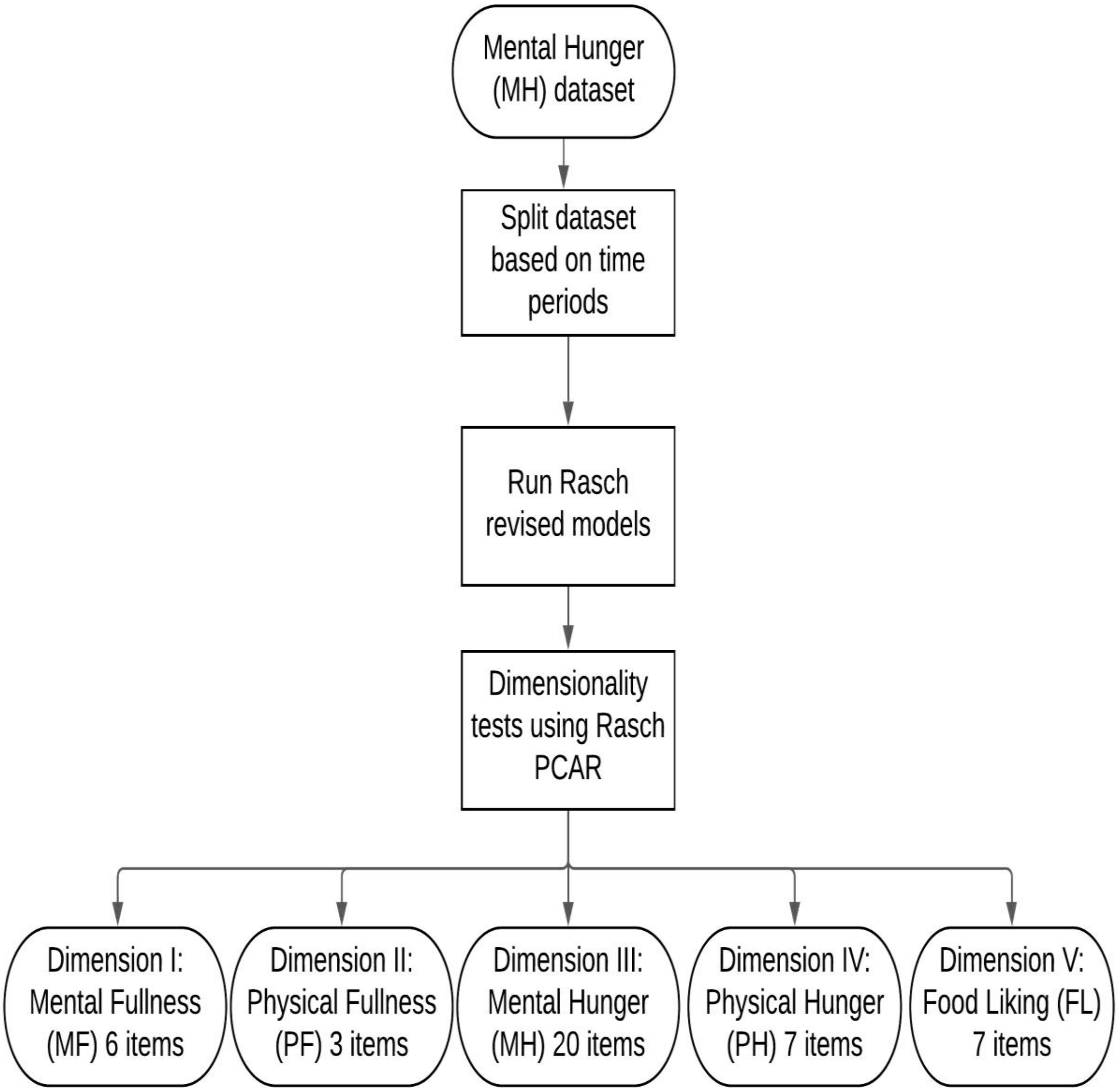

Figure 3.2 Flowchart of procedures used in Rasch Measurement analysis using Winsteps for 5-Factor Satiety Questionnaires models.

3.3.6 Exploratory factor analysis (EFA)

The dimensionality of 5-Factor Satiety Questionnaires items was reconfirmed using an exploratory factor analysis (EFA) which has been practised in Classical Test Theory (CTT). The same dataset used for Rasch Measurement analysis were subjected to principal-axis EFA using the ‘psych’ package (Revelle, 2020). Preliminary tests were conducted to determine whether the dataset used were factorable using Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett’s test of sphericity. The number of dimensions to be extracted was determined the eigenvalues that were derived from the correlation matrix. Multidimensional EFA was performed using ‘nfactors’ argument to specify the number of factors desired. Items with “good” loadings (cutoff loading at 0.30) were retained and that cross-loading items (i.e., items that had loadings of ≥ .30 on more than one factor) would be omitted in primary model (Costello & Osborne, 2005). The instrument's reliability was evaluated by computing Cronbach’s alpha (Cronbach’s α) for each dimension. If an α greater than 0.7, it was considered acceptable (Nunnally and Bernstein, 1994). After the model structure was verified, the participants’ summated score of each dimension was calculated as their total score for each underlying factor.

3.3.7 Statistical analyses

ANOVA, T-test, EFA and Pearson correlations analyses were conducted using R program (RStudio Team, 2017).

3.4 Results

3.4.1 Participant characteristics

Thirty-eight males and 52 females participated in the satiety study with range age from 18 to 64 years (Table 3.2). The had an average body mass index (BMI) of 23.72±4.60 kg/m^2 with a range of 16.13 to 42.51 kg/m^2. They were grouped into underweight (4.4%), healthy weight (48.9%), overweight (20.0%), and obese categories (26.7%) based on the Asian-Pacific cut-off points (Pan & Yeh, 2008).

Table 3.2 Demographic characteristics of participants in the satiety trials

	All participants	Males	Females
Number of participants	90	38	52
Age range	18-64	18-54	18-64
BMI (kg/m^2)	23.72±4.60	22.41±3.70	24.44±3.97
BMI classification*			
Underweight	4 (4.4%)	3 (7.9%)	1 (1.9%)
Healthy weight	44 (48.9%)	14 (36.8%)	30 (57.7%)
Overweight	18 (20.0%)	7 (18.4%)	11 (21.2%)
Obese	24 (26.7%)	14 (36.8%)	10 (19.2%)
Ethnicity*			
Asian	75 (83.3%)	28 (73.7%)	47 (90.4%)
Not Asian	15 (16.7%)	10 (26.3%)	5 (9.6%)

BMI = body mass index (mean±SD)

*The number and percent of participants in each category

3.4.1.1 Changes in satiety measure over time

Satiety study assessed the items at a few time points to measure the changes in satiety levels over times. Table 3.3 shows the person measures and mean of raw scores for 5 items of Mental Hunger model at 4-time points.

Table 3.3 Person measures and raw scores of five Mental Hunger Item Measures at 4 time points.

Time point	person measure*	raw scores[#]
Before preload	-0.83±1.20	2.50±1.24
After Preload	2.08±1.79	4.98±1.27
1H After Preload	1.69±1.33	3.86±1.11
Before lunch	0.1±1.33	2.80±1.15

Data were reported in mean ± SD of 90 participants at four different time points: before preload breakfast (Before Preload), immediately post-breakfast (After Preload), 1-hour post-breakfast (1H After Preload), 2.5-hour post-breakfast/ pre-lunch (Before Lunch),

* Person measures were analysed using Rasch analysis of selected 5 items in Mental Hunger measure

[#] Mean of raw scores were calculated by summarising scores of selected 5 items in Mental Hunger and dividing by five to create an average score

Before having preload, both person measure and raw scores were at the lowest, which explained that their satiety feeling were at the lowest point. It is because they rated Mental Hunger items using higher categories. Then, the MH measure increased drastically after having the meal because they reached their satiation level. The MH values generally decreased over time when they felt hungrier and less satiated. At the pre-ingestion stage (Before Preload), the panellists feel less satiated, so hunger-related items tend to be rated using higher categories and lower categories in fullness-related items. While in post-ingestion stages (Satiety), the ratings were evaluated in opposite directions and change from time to time.

3.4.1.2 Differences in energy intake between gender

Male participants consumed significantly higher (403±126kcal) at the ad libitum lunch than females (303±78kcal) ($p<0.001$). Almost half of the male participants (44%) and 8% female participants ate at least one portion of the provided lunch meal and asked for more before they reached their satiation. Six participants (5 males and 1 female) managed to eat two full portions of lunch meals, which equates to the maximum calorie intakes 628 kcal and 19 participants terminated their eating before they finished their first portion. Our result is in concordance with some studies which reported higher calories intake in males than in females (Davy, Van Walleghen, & Orr, 2007; Ranawana & Henry, 2010).

Our study shows that gender plays an essential role in satiety study. Females tend to have higher satiation and satiety levels than males because, in general, females have lower energy requirements than males (Benelam, 2009). Moreover, the physiological regulation of appetite through sex hormones may lead to gender differences in satiation and satiety levels (Bédard et al., 2015). Specifically, the central and peripheral signals from some satiety hormones (e.g. ghrelin, cholecystokinin, insulin, and leptin) are influenced by female's estrogenic hormones (Asarian & Geary, 2006). Therefore, the hormones implicate in feedback control of eating and may mediate the estrogenic inhibition of eating during the consumption of a meal (Asarian & Geary, 2006). The female hormonal fluctuation during the menstrual cycle may have interfered with their food intake (Benelam, 2009; Bryant, Truesdale, & Dye, 2006), so that this cofounder needs to be taken into account in satiety trial. Besides that, females have higher levels of dietary cognitive restraint than males, which may affect in making dietary decisions (Peng, Cahayadi, Geng, & Eidels, 2020; Provencher et al., 2004). It is interesting to note that the differences in brain activation in integrating multiple hormonal, neural signals and sensory perceptions to satiety and hunger cues suggested that the regulation of food intake by the brain may vary between the genders (Del Parigi et al., 2002; Michon, O'Sullivan, Delahunty, & Kerry, 2009; Smeets et al., 2006). Therefore, females were believed to have a higher satiety level compared to males.

3.4.2 Rasch measures

Two Rasch Partial Credit models (PCM) of 41-items 5-Factor Satiety Questionnaires were evaluated in this study, which were the original model (hereby known as All-PCM) and revised model (All-PCM-R). After PCAR dimensionality analysis, 5-Factor Satiety Questionnaires items were categorised into five dimensions; which were Mental Hunger (MH)(20 items), Physical Hunger (PH)(7 items), Mental Fullness (MF)(6 items), Physical Fullness (PF)(3 items) and Food Liking (FL)(5 items) dimensions. The details of each dimension will be discussed in the next subsections. MH dimension was analysed using PCM while another 4 dimensions were analysed using RSM. All dimensions were analysed using original Rasch and revised models, except for MF dimension that used the original model. The models and the number of categories used in each model are summarised in Table 3.4.

3.4.2.1 Global model fit

The 5-Factor Satiety Questionnaires data fitted the original and revised Rasch models with population standard deviations close to 1. All the models have at least 95% of the absolute standardised residuals less than 2; and less than 5% and 1% were equal or greater than 2 and 3, respectively (see the 3rd and 4th columns of Table 3.5). It explained that the data acceptably fitted the Rasch models and conformed that the data's randomness was normally distributed.

Table 3.4 Original and revised Rasch models used in the Rasch analysis of 5-Factor Satiety Questionnaires

Dataset / Dimension	Number of items	Model code	Rasch model type*	Number of categories
All items				
Original	41	All-PCM	PCM	NA
Revised	41	All-PCM-R	PCM	NA
Mental Hunger (MH)				
Original	20	MH-PCM	PCM	NA
Revised	20	MH-PCM-R	PCM	NA
Physical Hunger (PH)				
Original	7	*PH-RSM-8*	RSM	8
Revised	7	*PH-RSM-7R*	RSM	7
Mental Fullness (MF)				
Original	6	*MF-RSM-8*	RSM	8
Physical Fullness (PF)				
Original	3	*PF-RSM-8*	RSM	8
Revised	3	*PF-RSM-7R*	RSM	7
Food Liking (FL)				
Original	5	*FL-RSM-11*	RSM	11
Revised	5	*FL-RSM-9R*	RSM	9

*Rasch model used in the Rasch analysis; either Partial Credit Model (PCM) or Rating Scale Model (RSM). NA = not available.

Table 3.5 Summary fit statistics for original and revised Rasch models of 5-Factor Satiety Questionnaires data

Model	No of items	Global fit			Items MNSQ OUTFIT[4] (%)	Items Reliability[5]	Items Separation[5]	Person Reliability[5]	Person Separation[5]	Unidimensionality	
		% Stdres[1]	% Stdres[2]	Total[3]						Eigenvalue[6]	Disattenuated correlation[7]
Original scale											
All-PCM	41	2.67(394)	0.75(111)	14760	56.1	0.99	12.26	0.93	3.74	8.3650	0.0759
MH-PCM	20	2.53(182)	0.53(38)	7200	55.0	0.98	6.89	0.95	4.46	3.6393	0.9160
PH-RSM-8	7	0.79(20)	0.04(1)	2520	100.0	0.99	10.73	0.77	1.85	2.1736	0.9408
MF-RSM-8	6	2.27(49)	0.32(7)	2160	100.0	0.87	2.56	0.85	2.43	2.1862	0.7171
PF-RSM-8	3	2.59(28)	0.74(8)	1080	100.0	0.99	9.21	0.57	1.15	1.6341	1.0000
FL-RSM-11	5	2.39(43)	0.61(11)	1800	100.0	0.91	3.12	0.93	3.78	1.4386	0.9171
Revised scale											
All-PCM-R	41	2.60(384)	0.65(96)	14756	65.9	0.98	7.48	0.92	3.46	8.6096	0.4143
MH-PCM-R	20	2.50(176)	0.31(22)	7032	100.0	0.98	6.36	0.97	5.35	2.8362	0.9156
PH-RSM-7R	7	0.83(21)	0.04(1)	2520	100.0	0.99	10.71	0.77	1.84	2.1708	0.9390
PF-RSM-7R	3	2.59(28)	0.74(8)	1080	100.0	0.99	9.29	0.57	1.16	1.6335	1.0000
FL-RSM-9R	5	2.39(43)	0.61(11)	1800	100.0	0.91	3.13	0.93	3.78	1.4216	0.9161

[1] Percentage and number of observations (in brackets) of absolute standardised residuals that were ≥2. It should 5% or less.
[2] Percentage and number of observations (in brackets) of absolute standardised residuals that were ≥3. It should 1% or less.
[3] Total number of observations for the Rasch model used
[4] Percentage of unweighted mean squares for items (MNSQ OUTFIT) that fall in range 0.5 to 1.5
[5] Including measures for extreme scores
[6] Eigenvalues of unexplained variance in first contrast in PCAR analysis
[7] Disattenuated correlations between the highest and lowest loadings

3.4.2.2 Proper functioning of a rating scale of All-PCM and All-PCM-R Models

The original measure of all 41 items of 5-Factor Satiety Questionnaires (Karalus, 2011) (hereby known as All-PCM) was analysed using Rasch Partial Credit Model (PCM) since there were five items with different categories numbers (items Q37 to Q41 had eleven rating categories) and two items (items Q1 and Q2) used eight categories with different meanings from another 34 items. The PCM scales used in the All-PCM model did not function within the specified criteria and guidelines for proper functioning scales for rating scale categories, as suggested by Linacre (2002, 2019). For instance, the rating scale functioning assessment of an 8-point rating scale for item Q1 in the All-PCM measure (Table 3.6) shows that the distances between Rasch-Andrich thresholds for categories 2-3, 6-7 and 7-8 were 0.01, 0.31 and 0.32, respectively. The value was smaller than the recommended value of 0.51 for a rating scale with eight categories and indicated that one of the categories might not be presented as a modal. Moreover, the observed Rasch-Andrich thresholds did not increase monotonically up the scale between categories 6 and 7. Besides that, the observation numbers in categories 1 and 2 were less than 10, affecting the measure's fit accuracy and stability. Therefore, the model was re-analysed by collapsing the 8-point rating scale to a 4-point rating scale. The categories 1, 2 and 3 were collapsed into one category, and categories 6 and 7 were collapsed into another 1 category. As a result, by collapsing those categories, it improved the functioning of the revised rating scale of item Q1, as can be seen in the revised model All-PCM-R measure (Table 3.6). The same steps applied to other models to achieve the proper functioning of rating scale measures.

Table 3.6 Category statistic for the PCM rating scales of item Q1 of original (All-PCM) and revised (All-PCM-R) models

			Average measures			Rasch-Andrich Threshold	
Category	Labels	Counts[1]	Observed[2]	Expected[3]	OUTFIT[4]	Measure[5]	| Difference |[6]
Original All-PCM							
1	None	1 (0.3)	-0.63	-0.41	0.88		
2	Very small	5 (1.4)	-0.49	-0.29	0.83	-1.61	
3	Small	28 (7.8)	-0.40	-0.14	0.64	-1.60	0.01**
4	Moderate	82(22.8)	-0.11	0.03	0.53	-0.79	0.81
5	Large	106(29.4)	0.19	0.23	0.49	0.22	1.01
6	Very large	54(15.0)	0.61	0.46	0.29	1.36	1.14
7	Extremely large	47(13.1)	0.87	0.68	0.41	1.05*	0.31**
8	Large possible amount you could eat	37(10.3)	1.08	0.88	0.63	1.37	0.32**
Revised All-PCM-R							
1	None/	34(9.4)	-2.68	-2.54	0.79		
1	Very small/						
1	Small						
2	Moderate	82(22.8)	-1.39	-1.36	0.82	-2.95	
3	Large	106(29.4)	-0.15	-0.07	1.10	-1.10	1.85
4	Very large/	101(28.1)	1.71	1.53	0.81	0.63	1.73
4	Extremely large						
5	Large possible amount you could eat	37(10.3)	3.45	3.51	0.97	3.42	2.79

[1] Number and percentage (in brackets) of observations used in each category
[2] Modelled average measure in log-odds units (logits)
[3] Expected average measure if data fitted the Rasch model
[4] Unweighted mean square for observations in each category
[5] Location on the latent variable, relative to the centre of the scale, where adjacent categories are equally probable
[6] Absolute difference between Rasch-Andrich threshold values of two adjacent categories
* Measure value that does not increase with a higher rating category
** Difference is smaller than the minimum acceptable threshold value (0.51) for an 8-point rating scale

3.4.2.3 Dimensionality and local dependency of the Rasch models

The eigenvalue of the unexplained variance in the first extracted PCAR contrast in All-PCM data was 8.3650 (Table 3.5). It indicates that with the strength of about 8 to 9 items, a secondary dimension might be presented in the All-PCM model. That value is far above the eigenvalue 2, where the residuals could be considered at the random noise level (John M. Linacre, 2019). At the top of the contrast plot of PCAR, there was a group of 8 items measure hunger-related items while items at the bottom of the plot belonged to food liking-related items. The items located in the highest and lowest loadings might be assumed to measure the different thing because the disattenuated correlation between these Cluster 1 and Cluster 3 was 0.0759. The largest disattenuated correlation was observed between the first and second item clusters, which had a value of 0.9108 (see Figure 3.3). This value was higher than 0.87, above the cut-off point which the persons' measures on the two item clusters measure the same thing (Linacre, 2019). The independent t-test protocol results also supported the assumption that the All-PCM model did not present unidimensionality, as the lower bound of 95% binomial CI was 60.53%, far higher than 5% (Smith, 2002). Besides, the standardized residual correlations between all the food liking-related item pairs and other item pairs were higher than 0.7, which indicated that the assumption of local item independence could hold for those items. The All-PCM and All-PCM-R models failed to support the assumption of unidimensional. Therefore, the items were split into two subsets according to the cluster membership based on their loadings in the PCAR analysis and the item statement's actual meanings. Thirty-six items from Clusters 1 and 2 of All-PCM and All-PCM-R PCAR had the same patterns that measure hunger and fullness attributes (hereby known as Fullness and Hunger-related). In contrast, the items in cluster 3, belonged to the food liking-related group were analysed separately using Rasch RSM as FL-RSM-11 model (Figure 3.3).

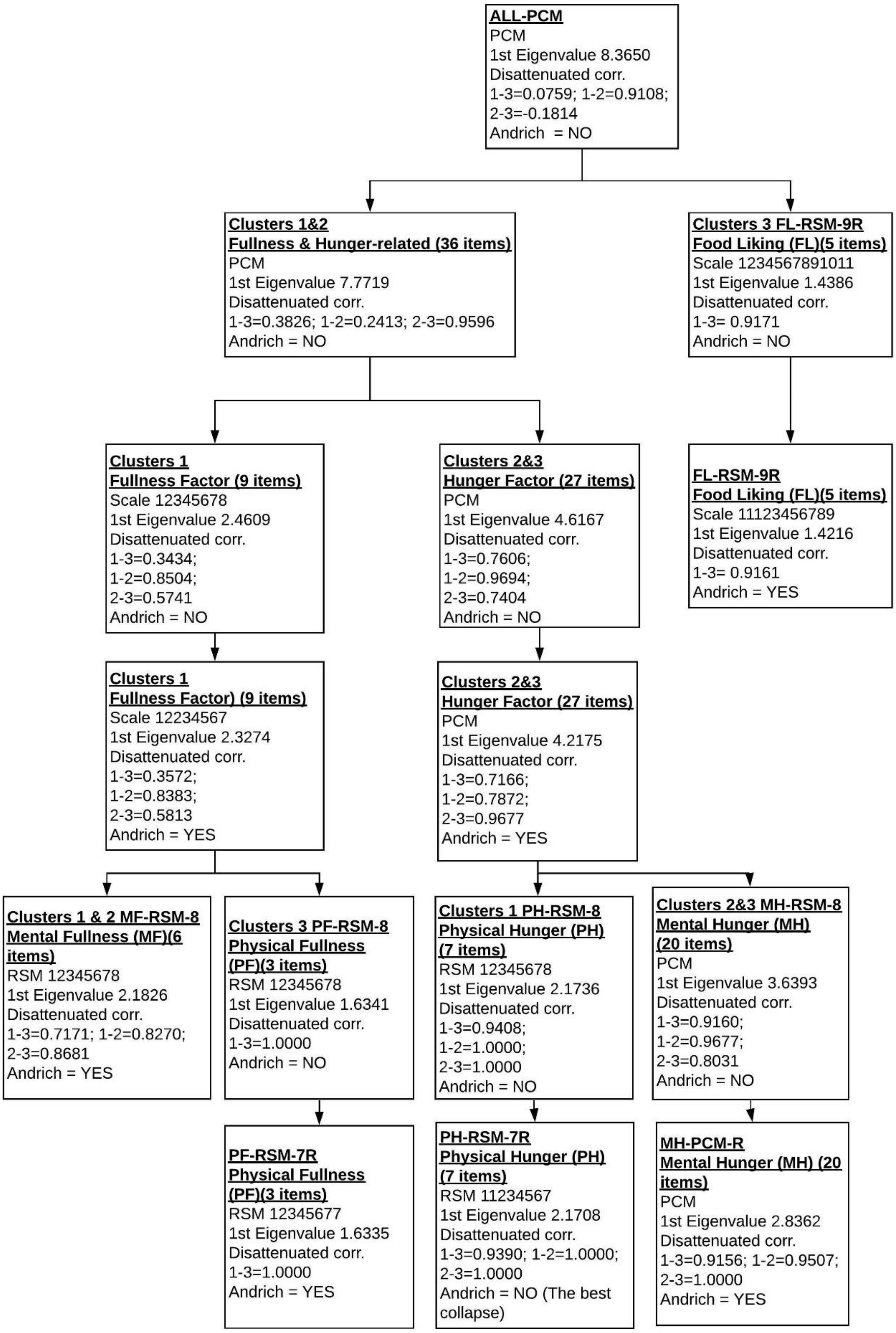

Figure 3.3 Test for unidimensionality of 5-Factor Satiety Questionnaire items

Fullness and Hunger-related items were analysed using Rasch PCM model because two items (Q1 and Q2) applied different labelled categories. The dimensionality tests show that the Fullness and Hunger-related model failed to prove that the measure was unidimensional with eigenvalue in the first contrast PCAR was 7.7719 and explained that at least strength of 7 items to be in a second dimension (Figure 3.3). The disattenuated correlations between Clusters 1-3, 1-2 and 2-3 were 0.3826, 0.2413 and 0.9596, respectively, show that the items in Cluster 1 were not measured same things as in Clusters 2 and 3. Furthermore, the items belonged to Cluster 1 were analysed as Fullness Factor model, while items in Clusters 2 and 3 were analysed as Hunger Factor model.

Both Fullness Factor and Hunger Factor models fail to prove the assumption that it was unidimensional, with the eigenvalue values 4.3274 and 4.2175, respectively in PCAR first contrast which revealed that the second dimension might be presented in the models with the strength at least of 4 items. The former model items were then split and reanalysed as Mental Fullness (MF-RSM-8) and Physical Fullness (PF-RSM-8) models. On the other hand, the latter model items were divided into two subsets based on disattenuated correlations and analysed separately. The first model was named PH-RSM-8; consisted of 7 items from Cluster 1 and the second model, MH-PCM was run with 20 items from Clusters 2 and 3.

To sum up, PCAR analysis showed that All-PCM and All-PCM-R models could not be held as unidimensional measures and there were five dimensions derived from these models named as MH-PCM, PH-RSM-8, MF-RSM-8, PF-RSM-8 and FL-RSM-11 models. The five dimensions were reanalysed and refitted to fit the Rasch models. The details of each Rasch model are discussed in the next subsections. Our finding has confirmed previous research done by (Karalus, 2011) that revealed the 5-Factor Satiety Questionnaires constructed from 5 factors; mental hunger (MH), physical hunger (PH), mental fullness (MF), physical fullness (PF) and food liking (FL).

3.4.2.4 Rasch analysis of Mental Fullness (MF-RSM-8) model

The MF-RSM-8 model showed acceptable model fit with more than 97.5% of the absolute standardised residuals were below than 2. The 8-category MF-RSM-8 functioned within the specified criteria for the proper functioning of the rating scale (Figure 3.6). None of the MF items misfit the MF-RSM-8 model with the original 8 categories RSM scales. The Outfit MNSQ for all MF-RSM-8 items ranged from 0.82 to 1.29 (Table 3.8). All the person including misfit person remained in the analysis since they were unlikely to impact the MF items' fit significantly. The eigenvalue 2.1826 in PCAR first contrast supported the assumption that the MF-RSM-8 was unidimensional, and the strength of 2 items could not able to create a second dimension in this model. There was no local dependency between items pairs reported, with the highest standardized residual correlations between items pairs was 0.34.

The items measures in MF-RSM-8 (Table 3.8) and person measures have been illustrated on a Wright map (Figure 3.4). Persons located at the top on the Wright map's left sides rated the MF items using higher categories, while those at the bottom used lower categories numbers. Each "#" symbol represents three participants and symbol "•" represents 1 to 2 persons on the map. Participants mostly were positioned at the middle of the map, with about logits -3 to 3, and a bit of tails towards the top and bottom. All items measures located in the middle of the scale and close to the mean of item measure (0). Items Q28 and Q29 shared the same measure 0.22. It could be due to understanding both sensation contentedness (Q28) and fullness (Q29) definitions. Focus group participants Karalus's (2011) study agreed that content feeling summarised the typical fullness sensation, besides other sensations such as lack of hunger, comfortable and decrease in the desire of food etc.

Table 3.7 Category statistic for the RSM rating scales of MF-RSM-8 model

			Average measures			Rasch-Andrich Threshold	
Category	Labels	Counts[1]	Observed[2]	Expected[3]	OUTFIT[4]	Measure[5]	∣Difference∣[6]
Original MF-RSM-8							
1	None	30 (1.4)	-2.51	-3.01	2.20		
2	Barely detectable	139 (6.4)	-2.08	-2.19	1.29	-4.09	
3	Weak	297(13.8)	-1.67	-1.57	0.84	-2.63	1.46
4	Moderate	688(31.9)	-0.92	-0.85	0.81	-2.06	0.57
5	Strong	575(26.6)	0.14	0.10	0.82	-0.22	1.84
6	Very strong	296(13.7)	1.38	1.25	0.85	1.32	1.54
7	Extremely strong	116(5.4)	2.52	2.52	1.07	2.81	1.49
8	Strongest sensation of any kind ever experienced	19(0.9)	2.96	3.56	1.81	4.87	2.06

[1] Number and percentage (in brackets) of observations used in each category
[2] Modelled average measure in log-odds units (logits)
[3] Expected average measure if data fitted the Rasch model
[4] Unweighted mean square for observations in each category
[5] Location on the latent variable, relative to the centre of the scale, where adjacent categories are equally probable
[6] Absolute difference between Rasch-Andrich threshold values of two adjacent categories

Table 3.8 Measure, standard error (SE) and outfit MNSQ statistics of MF-RSM-8 model.

		MF-RSM-8	
Items	**Statement**	Measure±SE	Outfit MNSQ
Q28	Rate your contentedness with the food you last ate	0.22±0.06	0.85
Q29	Rate your feeling of fullness from the food you last ate	0.22±0.06	1.16
Q30	Rate your appetite satisfaction from the food you last ate	-0.19±0.06	0.97
Q31	Rate your satisfaction with the food you last ate	-0.17±0.06	0.82
Q32	Rate your satisfaction with your feeling of fullness from the food you last ate	0.10±0.06	0.95
Q33	Rate your feeling that the meal or snack was a sufficient size	-0.18±0.06	1.29

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Figure 3.4 Wright map of MF-RSM-8 model

3.4.2.5 Rasch analysis of Physical Fullness original (PF-RSM-8) and revised (PF-RSM-7R) models

Three items from Fullness-related items were analysed as an RSM model known as PF-RSM-8. The PF-RSM-8 model shows that the categories 7 (Extremely strong) and 8 (Strongest sensation of any kind ever experienced) have only 9 and 2 observations, respectively (Figure 3.8).The minimum ten observations are essential to make sure the model stable besides helpful for fit accuracy and sample interference (John M. Linacre, 2002). Therefore, the model was revised by collapsing the categories 7 and 8 into 1 category to create new 7-category RSM model named PF-RSM-7R. After revising, the PF-RSM-7R model failed to meet the criteria for the proper functioning of a rating scale, where the distance between thresholds “Weak” and “Moderate2 was only 0.51. However, we decided to maintain the model since the minimum distance between thresholds is not essential but only helpful for sample inference.

The Outfit MNSQ for items in PF-RSM-8 and PF-RSM-7R models were in the ranges of 0.87 to 1.12 (see Table 3.10) which fall in the recommended range 0.5 to 1.5 (John M. Linacre, 2019; Wright & Linacre, 1994). Therefore, all data in the three items were retained for further analysis. The eigenvalues 1.6341 and 1.6335 in PCAR first contrast supported the assumption that the PF-RSM-8 and PF-RSM-7R, respectively, were unidimensional (Figure 3.3). There was no local dependency between items pairs reported in both models, with negative standardized residual correlations between items pairs.

Table 3.9 Category statistic for the RSM rating scales of original (PF-RSM-8) and revised (PF-RSM-7R) models

			Average measures			Rasch-Andrich Threshold	
Category	Labels	Counts[1]	Observed[2]	Expected[3]	OUTFIT[4]	Measure[5]	| Difference |[6]
Original PF-RSM-8							
1	None	336 (31.1)	-3.03	-3.04	1.14		
2	Barely detectable	298 (27.6)	-2.35	-2.29	0.71	-2.83	
3	Weak	190 (17.6)	-1.51	-1.60	0.87	-1.49	1.34
4	Moderate	141(13.1)	-0.89	-0.96	0.83	-0.98	0.51
5	Strong	74(6.9)	-0.44	-0.36	1.04	-0.02	0.96
6	Very strong	30(2.8)	0.21	0.25	1.32	0.85	0.87
7	Extremely strong	9(0.8)*	1.16	0.88	0.69	1.76	0.91
8	Strongest sensation of any kind ever experienced	2(0.2)*	0.11**	1.60	3.94	2.71	0.95
Revised PF-RSM-7R							
1	None	336 (31.1)	-2.59	-2.60	1.13		
2	Barely detectable	298 (27.6)	-1.90	-1.83	0.72	-2.38	
3	Weak	190 (17.6)	-1.05	-1.14	0.87	-1.03	1.35
4	Moderate	141(13.1)	-0.43	-0.50	0.83	-0.52	0.51***
5	Strong	74(6.9)	0.03	0.12	1.04	0.45	0.97
6	Very strong	30(2.8)	0.72	0.76	1.34	1.33	0.88
7	Extremely strong/	11(1.0)	1.55	1.66	1.49	2.15	0.82
7	Strongest sensation of any kind ever experienced						

[1] Number and percentage (in brackets) of observations used in each category
[2] Modelled average measure in log-odds units (logits)
[3] Expected average measure if data fitted the Rasch model
[4] Unweighted mean square for observations in each category
[5] Location on the latent variable, relative to the centre of the scale, where adjacent categories are equally probable
[6] Absolute difference between Rasch-Andrich threshold values of two adjacent categories
*Observations less than 10 in the category
** Measure value that does not increase with a higher rating category

*** Difference is smaller than the minimum acceptable threshold value (0.57) for a 7-point rating scale

Table 3.10 Measure, standard error (SE) and outfit MNSQ statistics of PF-RSM-8 and PF-RSM-7R models

		PF-RSM-8		PF-RSM-7R	
Items	**Statement**	Measure±SE	Outfit MNSQ	Measure±SE	Outfit MNSQ
Q34	Rate the extent to which your stomach currently feels bloated	0.22±0.06	0.92	0.22±0.06	0.92
Q35	Rate the extent to which your stomach currently feels like it is bursting	0.59±0.07	1.12	0.60±0.07	1.11
Q36	Rate the extent to which your stomach currently feels stuffed	-0.81±0.05	0.87	-0.82±0.06	0.88

The respondents' distributions and items on the PF-RSM-7R model were visualised using the Wright map in Figure 3.5. The higher the item on the scale, the more likely the item described the physical fullness feelings at the most. Besides, the items on the top of the map were highly being rated using low categories. It indicated that item Q35, located at the top with measure 0.60 was too difficult to be endorsed during the survey. In other words, the panellists had fewer physical sensations towards stomach bursting even though they reach their fullness. Item Q36 seems to be more endorsed with higher categories by the panellists compared to items Q34 and Q35, and they more agreed that they felt physically full when their stomach stuffed with the last food or meal they had. The panellists' locations were mapped in the opposite orientation. The panellists with the least feelings towards physical fullness or rated using lower categories located at the bottom of the scales. Those at the top likely to rate the PF items using higher categories or might have higher feelings towards physical fullness. There was a pattern where the PF items with were likely more difficult to be endorsed by the majority of the panellists as the items were at a higher location, while the majority of person measures skewed towards to the bottom tail on the Wright map.

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Figure 3.5 Wright map of PF-RSM-7R model.

3.4.2.6 Rasch analysis of Physical Hunger original (PH-RSM-8) and revised (PH-RSM-7R) models

The fit statistics show that the data used fitted both original (PH-RSM-8) and revised (PH-RSM-7R) models (Table 3.5). However, the 8-category scale used in the model did not function well, with only 2 observations in category 1, and the Rasch-Andrich threshold difference between category 6 and 7 was 0.49 (see Table 3.11). It had been decided to collapse the categories 1 and 2 as one category in the revised model PH-RSM-7R. Even though the Rasch-Andrich threshold between Categories 5 and 6 was slightly below the minimum requirement for acceptable threshold value for a 7-point rating scale model, it was the best compared to other collapsing scales because it just helpful, not essential in sample inferencing step. The eigenvalue of raw unexplained variance on the first PCAR contrast (2.1708) was less than 3.0, clearly indicating that the PH-RSM-7R model was unidimensional. It requires at least 3 items to create a potential another second dimension (John M. Linacre, 2019). The disattenuated correlations between the three item clusters were close to 1.00 (Figure 3.3), which implies that the clusters measured the same things and no local dependency found in item pairs.

Table 3.11 Category statistic for the RSM rating scales of original (PH-RSM-8) and revised (PH-RSM-7R) models

			Average measures			Rasch-Andrich Threshold	
Category	Labels	Counts[1]	Observed[2]	Expected[3]	OUTFIT[4]	Measure[5]	| Difference |[6]
Original PH-RSM-8							
1	None	2(0.1)	-3.20	-2.19	0.31		
2	Barely detectable	11 (0.4)	-0.38	-1.13	2.01	-3.33	
3	Weak	64 (2.5)	-0.09	-0.19	1.20	-2.40	0.93
4	Moderate	147(5.8)	0.51	0.57	1.06	-0.63	1.77
5	Strong	250(9.9)	1.20	1.26	0.88	0.39	1.02
6	Very strong	360(14.3)	1.92	1.96	1.12	1.25	0.86
7	Extremely strong	661(26.2)	2.80	2.76	0.83	1.74	0.49*
8	Strongest sensation of any kind ever experienced	1025(40.7)	3.77	3.77	1.02	2.98	1.24
Revised PH-RSM-7R							
1	None/	13(0.5)	-1.35	-1.73	1.65		
1	Barely detectable						
2	Weak	64 (2.5)	-0.67	-0.78	1.20	-2.82	
3	Moderate	147(5.8)	-0.07	-0.01	1.05	-1.21	1.61
4	Strong	250(9.9)	0.62	0.68	0.88	-0.19	1.02
5	Very strong	360(14.3)	1.34	1.38	1.11	0.67	0.86
6	Extremely strong/	661(26.2)	2.21	2.18	0.83	1.16	0.49**
7	Strongest sensation of any kind ever experienced	1025(40.7)	3.19	3.19	1.01	2.40	1.24

[1]Number and percentage (in brackets) of observations used in each category
[2] Modelled average measure in log-odds units (logits)
[3] Expected average measure if data fitted the Rasch model
[4] Unweighted mean square for observations in each category
[5] Location on the latent variable, relative to the centre of the scale, where adjacent categories are equally probable
[6] Absolute difference between Rasch-Andrich threshold values of two adjacent categories

* Difference is smaller than the minimum acceptable threshold value (0.51) for an 8-point rating scale
** Difference is smaller than the minimum acceptable threshold value (0.57) for a 7-point rating scale

The PHRSM-7R items’ measures are similar to the original PH-RSM-8 model (Table 3.12) and illustrated in the Wright map (Figure 3.6). The Wright map of PH-RSM-7R was interpreted opposite from the MF and PF models Wright map. It is because all the items in PH-7R were reverse-scored before Rasch analysis. The item at the top of the scale has likely been rated using higher categories by the panellists. The panellists at the top were the one who was with the least tendency towards fullness-related feelings. The PH-RSM-7R Wright map shows that the panellists distribution was higher than the items' location and skewed to the top tail. It explained that most of the panellists rated the Physical Hunger items using smaller categories and they believed that stomach cramps (refer to Q25) could be as a leading indicator, while stomach emptiness (Q26) was the least body signals for them to start to feel hungry. The panellists' distributions seemed to follow the normal distribution, with approximately 6% extreme outliers and no flooring and ceiling effects found in the PH-R7 models (Terwee et al., 2007).

Table 3.12 Measure, standard error (SE) and outfit MNSQ statistics of original (PH-RSM-8) and revised (PH-RSM-7R) models

		PH-RSM-8		PHRSM-7R	
Items*	**Statement**	Measure±SE	Outfit MNSQ	Measure±SE	Outfit MNSQ
Q21	Rate the extent to which your stomach currently aches	-0.43±0.07	0.87	-0.43±0.07	0.87
Q22	Rate the extent to which you currently feel stomach pain	-0.69±0.07	0.96	-0.68±0.07	0.96
Q23	Rate the extent to which you currently feel famished	0.75±0.06	1.24	0.74±0.06	1.24
Q24	Rate the extent to which your stomach is currently rumbling	-0.11±0.07	0.84	-0.11±0.07	0.84
Q25	Rate the extent to which you currently have stomach cramps	-0.80±0.08	1.10	-0.80±0.08	1.10
Q26	Rate the extent to which your stomach currently feels empty	1.38±0.06	1.11	1.38±0.06	1.11
Q27	Rate the extent to which your stomach is currently growling	-0.10±0.07	0.82	-0.10±0.07	0.82

*the items were analysed with the reversed scores in Rasch analysis

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             ######  |
    2       ####### M+
              .####  |
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             .#####  |T
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    1          .###  +
                .##  |
             .##### S|S Q23
                 ##  |
                 .#  |
               .###  |
    0             .  +M
                     |  Q24  Q27
                 .#  |
                  # T|  Q21
                     |S Q22
                 .#  |  Q25
   -1             .  +
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   -2                +
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Figure 3.6 Wright map of PH-RSM-7R model

3.4.2.7 Rasch analysis of Mental Hunger original (MH-PCM) and revised (PH-PCM-R) models

After undergoing Rasch analysis steps, the fit statistics demonstrated that the data fitted the revised MH-PCM-R model with only 2.50% of absolute standardized residuals in the data equal to or greater than 2; 0.31% of them were ≥3 (see Table 3.5). The eigenvalue of raw unexplained variance in the PCAR first contrast was 2.8362, suggested that the assumption of unidimensionality could be hold in the MH-PCM-R model. The disattenuated correlation between the three item clusters was close to 1 implies that the items in all clusters measure the same things (Figure 3.3). There were no local item dependencies found in the model, as the maximum item pair residual correlation was 0.35. The value was half of the suggested value (0.7 or more) to be concerned about dependency because they may only share about 12% of their “random” variance (John M. Linacre, 2019).

The Outfit MNSQ for all MH-PCM-R items ranged from 0.57 to 1.50 (Table 3.13). The item Q13, asking about fullness feeling, with the highest measure 0.92, was plotted at the highest of the Wright map (Figure 3.7). It explained that the panellists rated the Q13 with lower categories. In other words, it indicated that panellists hardly defined their feeling of fullness. As previously mentioned, the rest nineteen items were reversed score analysed; so that the interpretations of these item measures were in the opposite direction from Q13. The second-highest item measure in MH-PCM-R was item Q11, with measure 0.88, described that the panellists rated using higher categories on the feeling towards their appetite during the trial period. So that, when they mentally feel hungrier, their appetite towards food would be increased. On the other hand, items Q10 and Q5 located at the bottom might have been rated using low category scales. It explains that desires to eat a snack or fatty foods were least affected by hunger signals. The items spread out in a much narrow range on the scale, with measure ranges between -1.06 to 0.92, compared to the panellists distribution. The panellists located at the top of the scale were the least lenient person, whereas the others at the bottom were the strictest in rating the items with higher categories. The panellists located on the tails presented a tendency to rate the items using extreme-scale categories. However, panellists' distribution could be considered normal because 95% of panellists measures fall within the two standard deviation levels.

Table 3.13 Measure, standard error (SE) and outfit MNSQ statistics of Mental hunger-related items in original (MH-PCM) and collapsed (MH-PCM-R) models

		MH-PCM		MH-PCM-R	
Items	**Statement**	Measure±SE	Outfit MNSQ	Measure±SE	Outfit MNSQ
Q1*	Rate the amount of food you currently desire[a]	-0.28±0.06	0.78	0.12±0.08	0.90
Q2*	Rate the current amount of food you could eat[a]	0.36±0.06	0.70	0.51±0.08	0.90
Q3*	Rate your current desire to eat any food	0.03±0.05	0.46	0.02±0.07	0.59
Q4*	Rate your current desire to eat your next meal	0.16±0.05	0.54	-0.02±0.07	0.66
Q5*	Rate your current desire to eat something fatty	-0.48±0.05	1.25	-0.91±0.09	1.27
Q6*	Rate your current desire to eat something salty	-0.30±0.05	1.90	-0.46±0.10	1.29
Q7*	Rate your current desire to eat something savoury	0.41±0.05	1.15	-0.67±0.08	1.27
Q8*	Rate your current desire to eat something sweet	-0.40±0.05	1.82	0.83±0.08	1.50
Q9*	Rate your current desire to eat your favourite food	0.20±0.05	0.91	0.44±0.06	1.42
Q10*	Rate your current desire to eat a snack	-0.46±0.05	1.40	-1.06±0.07	1.42
Q11*	Rate your current appetite	0.49±0.06	0.50	0.88±0.07	0.61
Q12*	Rate your current appetite for a meal	-0.13±0.05	0.51	-0.09±0.07	0.60
Q13	Rate your current feeling of fullness	1.20±0.06	1.80	0.92±0.07	1.48
Q14*	Rate your current feeling of hunger	-0.47±0.05	0.61	0.13±0.06	0.86
Q15*	Rate your current motivation to eat	-0.01±0.05	0.46	0.09±0.06	0.59
Q16*	Rate the extent to which you are currently thinking of food	-0.02±0.05	0.80	0.13±0.06	1.02
Q17*	Rate your current urge to eat	-0.05±0.05	0.46	-0.42±0.07	0.57
Q18*	Rate your current willingness to eat	0.12±0.05	0.48	-0.03±0.07	0.59
Q19*	Rate your desire for more of the food you last ate	-0.61±0.05	2.78	-0.07±0.09	1.47
Q20*	Rate your current desire for a different food than you last ate	0.24±0.05	1.62	-0.36±0.08	1.26

*the items were analysed with the reversed scores in Rasch analysis

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   6                   +
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   1        .#######   +T Q11  Q13
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           .########   |S Q2   Q9
           .######## M|   Q14  Q16
   0       .########   +M Q1   Q12 Q15  Q18  Q19  Q3  Q4
            ########   |  Q20
         ###########   |S Q17  Q6
             .######   |  Q7
  -1     .##########   +T Q10  Q5
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  -5                   +
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Figure 3.7 Wright map of MH-PCM-R model

3.4.2.8 Rasch analysis of Food Liking original (FL-RSM-11) and revised (FL-RSM-9R) models

The five food-liking-related items in cluster 3 PCAR of the All-PCM-R model were analysed using Rasch RSM models because all the items shared the same number of categories. The summary fit statistics show that the data fit the Rasch original and revised models (hereby known as FL-RSM-11 and FL-RSM-9R, respectively). Both models presented data with more than 95% of absolute standardised residuals below two and items MNSQ OUTFIT in the range of 0.5 to 1.5 (see Table 3.5).

Table 3.14 shows that the original measure FL-RSM-11 with 11 categories did not fulfil proper functioning for the rating scale model. The responses in categories 2 and 3 were less than ten observations and Rasch-Andrich threshold did not increase monotonically up the scale between categories 3 “Dislike very much” and 4 “Dislike moderately”. Moreover, there was no observation found in category 1 “Greatest imaginable disliking”. The eigenvalue in the PCAR first contrast (1.4386) and disattenuated correlation between clusters 1 and 3 (0.9171) (Table 3.5) supported the assumptions that the FL-RSM-11 model was unidimensionality.

The revised collapsing FL-R9 model was analysed with collapsed categories 2 and 3 into one category (Figure 3.3). The nine categories scale used in the FL-RSM-9R functioned adequately (Table 3.14) and followed the guidelines for the proper functioning of a rating scale (Linacre, 2002). Moreover, the FL-R9 model could be assumed as unidimensional with eigenvalue in the PCAR first contrast and disattenuated correlation between clusters 1 and 3 were 1.4216 and 0.9161, respectively (Table 3.5). No local dependencies between items pair found in the model.

Table 3.14 Category statistic for the RSM rating scales of original (FL-RSM-11) and revised (FL-RSM-9R) models

			Average measures			Rasch-Andrich Threshold	
Category	Labels	Counts[1]	Observed[2]	Expected[3]	OUTFIT[4]	Measure[5]	| Difference |[6]
Original FL-R11							
1	Greatest imaginable disliking						
2	Dislike extremely	4 (0.2)	-4.67	-5.53	2.54		
3	Dislike very much	9(0.5)	-4.56	-5.11	1.58	-6.10	
4	Dislike moderately	95(5.3)	-4.52	-4.50	1.10	-7.16*	1.06
5	Dislike slightly	115(6.4)	-3.61	-3.44	0.54	-4.20	2.96
6	Neutral	359(19.9)	-1.67	-1.75	1.20	-3.78	0.42
7	Like slightly	400(22.2)	0.26	0.29	0.94	-0.83	2.95
8	Like moderately	453(25.2)	2.12	2.17	0.88	1.10	1.93
9	Like very much	300(16.7)	4.57	4.55	0.91	3.70	2.60
10	Like extremely	49(2.7)	7.54	7.12	0.61	7.66	3.96
11	Greatest imaginable liking	16(0.9)	8.33	9.07	2.09	9.60	1.94
Revised FL-R9							
1	Dislike extremely/	13(0.7)	-5.29	-6.06	1.87		
1	Dislike very much						
2	Dislike moderately	95(5.3)	--5.41	-5.38	1.13	-7.70	
3	Dislike slightly	115(6.4)	-4.42	-4.26	0.53	-5.05	2.65
4	Neutral	359(19.9)	-2.47	-2.54	1.21	-4.59	0.46
5	Like slightly	400(22.2)	-0.52	-0.49	0.96	-1.61	2.98
6	Like moderately	453(25.2)	1.34	1.39	0.90	0.32	1.93
7	Like very much	300(16.7)	3.80	3.77	0.90	2.92	2.60
8	Like extremely	49(2.7)	6.76	6.34	0.61	6.88	3.96
9	Greatest imaginable liking	16(0.9)	7.56	8.29	2.09	8.82	1.94

[1]Number and percentage (in brackets) of observations used in each category
[2] Modelled average measure in log-odds units (logits)
[3] Expected average measure if data fitted the Rasch model

[4] Unweighted mean square for observations in each category
[5] Location on the latent variable, relative to the centre of the scale, where adjacent categories are equally probable
[6] Absolute difference between Rasch-Andrich threshold values of two adjacent categories
* Measure value that does not increase with a higher rating category

Table 3.15 Measure, standard error (SE) and outfit MNSQ statistics of Food Liking-related items in original (FL-R11) and collapsed (FL-R9) models

		FL-R11		FL-R9	
Items	**Statement**	Measure±SE	Outfit MNSQ	Measure±SE	Outfit MNSQ
Q37	Rate your overall liking of the food you last ate	-0.21±0.08	0.79	-0.22±0.08	0.79
Q38	Rate your liking of the appearance of the food you last ate	-0.22±0.08	0.98	-0.22±0.08	0.98
Q39	Rate your liking of the odour of the food you last ate	0.49±0.08	1.44	0.50±0.08	1.43
Q40	Rate your liking of the flavour of the food you last ate	-0.16±0.08	0.87	-0.17±0.08	0.87
Q41	Rate your liking of the texture of the food you last ate	0.10±0.08	0.84	0.10±0.08	0.84

No misfit issue was found in Food-liking item measures (Table 3.15). The outfit MNSQ statistics range was similar between the estimates based on the original and revised models. Approximately 12% of the panellists were found to have misfitted in the measurements. However, they did not seem to affect the item fit; therefore, all the panellists were kept for further analysis. A Wright Map in Figure 3.8 illustrates the estimates for panellists and items for the FL-RSM-9R model. The items' location was in the middle of the map, ranging between -0.22 to 0.50. The panellists rated their likings on overall and appearance using higher categories while odour was least liked attribute and contributed least to the measure of Food Liking. The panellists tend to describe their liking towards food by looking at overall and appearance attributes first, followed by flavour, texture, and odour. Even though the measures for Overall Liking (item Q37) and Appearance Liking (item Q38) were the same, but they measure different things and did not depend on each other (standardized residual correlation was -0.24). The panellists located at the top of the scale showed that they tend to rate the food liking items with higher rating scale categories. In contrast, the panellists at the bottom were more likely to use the low levels of liking categories.

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Figure 3.8 Wright map of FL-RSM-9R model

3.4.3 Exploratory factor analysis (EFA)

The KMO test results for sampling adequacy and Bartlett's test of sphericity in Table 3.16 indicated large relationships within 5-Factor Satiety Questionnaires data set to perform EFA. The KMO Measure of Sampling Adequacy (MSA) must be 0.60 before performing the EFA and range 0.90 to 1.0 was considered ‘Marvelous’ or ‘Great’ (Kaiser, 1970). The Bartlett’s test of sphericity was significant (p-value<0.05) indicated that the data used were not an identity matrix and appropriate for EFA (Howard, 2016).

Table 3.16 Results of KMO test and Bartlett’s test of sphericity on raw scores of 5-Factor Satiety Questionnaire

Scale	KMO[1]	Bartlett's test of sphericity		
		χ^2	*df*	p-value
5-Factor Satiety Questionnaire item	0.95	13694.52	820	0.000
Criteria	0.6			<0.05

[1] Kaiser–Meyer–Olkin overall measure of sampling adequacy

The parallel analysis with principal axis factoring implied that the 5-Factor Satiety Questionnaires items could be grouped into five factors; with all factors with eigenvalues greater than 1.0 were retained for rotation and scree plot in Figure 3.9 visualised representation of eigenvalues.

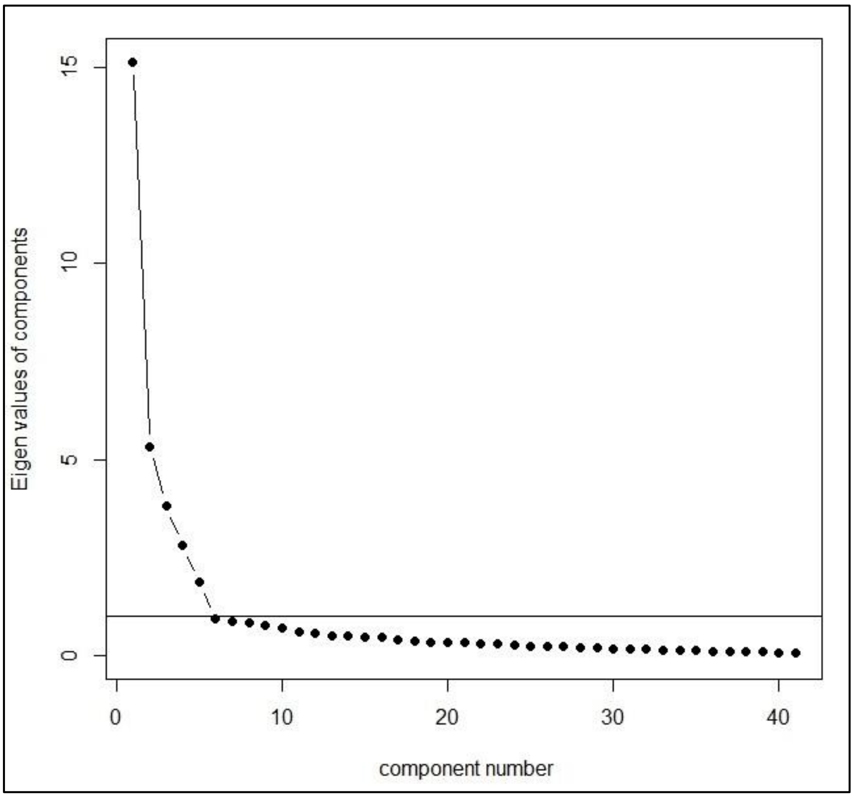

Figure 3.9 Scree plot of 5-Factor Satiety Questionnaires parallel analysis. The number of components (factors) above the horizontal line were retained.

Table 3.17 tabulates the factor loadings of 5-Factor Satiety Questionnaires items with the 5-factor solution. In general, the extracted loadings revealed an underlying structure that was almost consistent with the proposed five factors by Karalus (2011). Three items (Q13, Q23 and Q36) showed cross-loadings at cut-off point >0.3, which indicates item redundancy and considered to be eliminated from the model. All 20 Mental Hunger (MH) were loaded onto the first factor (F1) included two Physical Hunger items (Q23 and Q26) and 1 Physical Fullness item (Q36). However, considering the meaning of 'famish' and 'empty' of items Q23 and Q26, both items appeared more relevant to measuring physical hunger than mental hunger. Item Q36 loadings in F1 and F5 was very close (0.41 and 0.43, respectively). Because of the Q36 asking about the stuffed stomach, we decided to remain Q36 in F5 together with Q34 and Q35 items. Items loaded onto the second factor (F2) comprised five items from Food Liking factor (Items Q37 to Q41). The third to fifth factors (F3, F4 and F5) consists of Mental Fullness (MF), Physical Hunger (PH) and Physical Fullness (PF) items, respectively (Table 3.17).

Table 3.17 Item-Factor Loadings for 5-Factor Satiety Questionnaires dataset

Item	Factor*	F1	F2	F3	F4	F5
Q1	MH	**0.83**	0.03	0.04	-0.01	0.07
Q2	MH	**0.75**	-0.03	0.14	0.05	0.16
Q3	MH	**0.91**	0.03	-0.02	0.00	0.06
Q4	MH	**0.88**	0.03	-0.05	0.01	0.11
Q5	MH	**0.76**	-0.04	0.10	-0.04	-0.21
Q6	MH	**0.56**	0.07	0.12	0.14	-0.31
Q7	MH	**0.85**	0.04	-0.01	0.04	-0.26
Q8	MH	**0.70**	-0.06	-0.15	-0.14	-0.22
Q9	MH	**0.89**	-0.04	0.13	-0.06	-0.22
Q10	MH	**0.77**	-0.03	-0.09	-0.06	-0.20
Q11	MH	**0.93**	0.02	-0.02	-0.01	0.03
Q12	MH	**0.83**	-0.01	0.02	0.08	0.15
Q13	MH	**0.41**	-0.03	0.29	0.01	**0.47**
Q14	MH	**0.74**	-0.01	0.07	0.19	0.21
Q15	MH	**0.88**	0.01	0.00	0.07	0.07
Q16	MH	**0.82**	-0.01	-0.01	0.08	0.05
Q17	MH	**0.89**	-0.02	-0.03	0.03	0.10
Q18	MH	**0.90**	0.05	-0.05	0.04	0.07
Q19	MH	**0.39**	-0.10	-0.32	0.16	0.21
Q20	MH	**0.71**	-0.03	0.07	-0.05	-0.22
Q21	PH	0.01	0.07	-0.03	**0.84**	-0.01
Q22	PH	-0.01	0.02	-0.03	**0.76**	-0.03
Q23	PH	**0.48**	-0.03	-0.07	**0.32**	0.11
Q24	PH	0.25	-0.06	0.01	**0.62**	0.01
Q25	PH	-0.02	-0.01	0.07	**0.77**	-0.06
Q26	PH	**0.63**	-0.07	0.00	0.26	0.27
Q27	PH	0.12	-0.06	0.03	**0.72**	0.08
Q28	MF	0.01	0.07	**0.75**	-0.07	0.00
Q29	MF	0.13	-0.09	**0.67**	0.06	0.23
Q30	MF	-0.04	0.10	**0.81**	-0.02	-0.16
Q31	MF	-0.07	0.06	**0.84**	0.00	-0.18
Q32	MF	0.07	-0.07	**0.71**	0.01	0.27
Q33	MF	-0.03	-0.04	**0.59**	0.06	0.12
Q34	PF	0.19	0.04	0.08	-0.45	**0.41**
Q35	PF	0.13	0.05	0.09	-0.52	**0.30**
Q36	PF	**0.41**	-0.02	0.24	-0.12	**0.43**
Q37	FL	0.04	**0.91**	0.01	-0.03	-0.01
Q38	FL	0.07	**0.90**	-0.05	0.03	0.02
Q39	FL	-0.06	**0.77**	0.05	-0.04	0.03
Q40	FL	-0.03	**0.89**	0.03	0.00	-0.02
Q41	FL	0.00	**0.92**	0.00	0.03	0.03

*Factors that were proposed by Karalus (2011).

MH= Mental Hunger, PH= Physical Hunger, MF= Mental Fullness, PF= Physical Fullness, and FL=Food Liking

Items in bold indicate items associated with each factor at cut-off point 0.3

The Cronbach's alpha coefficient of each subscale and its 95% CI were computed in Table 3.18. The MH and FL factors Cronbach's alpha revealed that these factors might shorten the scale (DeVellis, 2017). The multicollinearity may present among the items within the factor and suggest redundancy and unnecessary duplication across items (Streiner, 2003). The internal consistency reliability of MF and PH factors were interpreted as very good (0.80 to 0.90) while PF factor was categorised as undesirable (0.60 to 0.65) (DeVellis, 2017).

Table 3.18 The Cronbach's alpha and 95% confidence intervals (CI) of five factors of 5-Factor Satiety Questionnaire

Factor	Cronbach's alpha	95%CI Lower bound	95%CI Upper bound
MH	0.97	0.97	0.97
MF	0.88	0.86	0.90
PH	0.88	0.86	0.89
PF	0.63	0.56	0.70
FL	0.94	0.93	0.95

MH= Mental Hunger, PH= Physical Hunger, MF= Mental Fullness, PF= Physical Fullness, and FL=Food Liking

3.4.4 Correlations of satiety to food liking

All the ‘satisfaction’ and fullness attributes had positive correlations with food liking factor, but they negatively affected hunger attributes (Table 3.19). It was supported by the result of higher food liking scores after consuming preload breakfast and an ad libitum lunch meal, and then the ratings started to decrease over time. These Pearson correlations explain that food liking has positive associations with satiety because of the higher satiety ratings (higher fullness; lower hunger ratings), the higher food liking. Flavour plays a key role in describing overall liking, with the highest correlations (≥0.90) between overall and flavour likings. The correlations among the attributes were generally higher when the panellists just finished their ad libitum lunch meal compared to those at 1 hour after that. The satisfactions and food likings start to decrease when the panellists feel more hunger and less full, or in other words, the satisfactions and food liking decreased when the satiety decreased. Food liking could cause an increase hunger sensations due to a rise in the desire to eat (Karalus, 2011). Moreover, food liking positively correlates with satiety because higher food liking led to greater satisfaction (Mattes & Vickers, 2018). Sensory-specific satiety may reduce food liking of the food. The higher next-meal intake can explain the pattern of decrement of food liking due to sensory-specific satiety. Low liking rating also may be due to unfamiliarity with the type of food served. Some Chinese participants in this study discontinued eating because they did not familiar with Bolognese pasta as their lunch meal. It explains that they terminated their eating not because they reached the satiation, but because they could not tolerate the meal served to them.

Table 3.19 Pearson correlation matrix between satisfaction, food liking, fullness and hunger ratings (changes between T5 and T6)

Attributes	1	2	3	4	5	6	7	8	9	10
1- appetite satisfaction	-	**0.50**	**0.64**	**0.62**	**0.55**	**0.66**	**0.54**	**0.55**	0.34	-0.38
2- satisfaction	**0.75**	-	0.40	**0.56**	0.48	**0.52**	**0.53**	0.47	0.33	-0.17
3- fullness satisfaction	**0.67**	**0.69**	-	0.36	0.45	**0.50**	0.24	0.42	**0.53**	-0.31
4- overall liking	**0.71**	**0.78**	**0.59**	-	**0.67**	**0.70**	**0.91**	**0.66**	0.16	-0.25
5- appearance liking	**0.63**	**0.58**	**0.58**	**0.65**	-	**0.75**	**0.69**	**0.83**	0.28	-0.34
6- odour liking	**0.64**	**0.62**	**0.57**	**0.76**	**0.68**	-	**0.68**	**0.70**	0.21	-0.34
7- flavour liking	**0.72**	**0.76**	**0.55**	**0.90**	**0.58**	**0.76**	-	**0.66**	0.09	-0.32
8- texture liking	**0.62**	**0.65**	**0.54**	**0.69**	**0.75**	**0.63**	**0.68**	-	0.34	-0.35
9- fullness	**0.61**	**0.67**	**0.74**	**0.55**	**0.55**	**0.56**	**0.52**	**0.50**	-	-0.27
10- hunger	-0.40	-0.31	-0.52	-0.30	-0.38	-0.33	-0.33	-0.37	-0.34	-

Notes: Correlation between attributes at +30 (immediately after ad libitum lunch) are presented below the diagonal, whereas correlations at +90 (1 hour after ad libitum lunch) are presented above the diagonal.
Correlations above 0.5 between attributes are bolded, and negative correlations are in red fonts

3.5 Conclusion

The Rasch analysis is practical to be used in selecting items to measure satiety. The Principal Component Analysis of Rasch residuals (PCAR) failed to prove the assumption of unidimensionality in 5-Factor Satiety Questionnaire instrument. There were five unidimensional measures could be derived; which were MH-PCM-R (20 items), MF-RSM-8 (7items), PH-RSM-7R (6 items), PF-RSM-7R (3 items) and FL-R9 (5 items). The original Rasch models, except for MF-RSM-8, were suggested to collapse into small categories to achieve the rating scale's proper functioning. The models constructed using Rasch analysis would be useful to measure the satiety levels in different sets of people and other foods because the items' reliability was high. The understanding of satiety levels could be explored with person and items measures.

Chapter 4

Effect of oat fibre and capsaicin enrichment on the satiety response to a noodle soup dish and relationship to intuitive eating in human volunteers

4.1 Introduction

Noodles have been consumed in Asian countries since ancient times (Fu, 2008), and have gained popularity worldwide becoming components of staple dishes (Zhang & Ma, 2016). Therefore, noodles and pasta are excellent vehicles to deliver nutrients to consumers by introducing nutrients and other components to their formulation. Several nutrients including dietary fibre (DF) have been added with various effects on their physicochemical and sensory properties of the pasta and noodles (see Table 4.1)

DF has been highlighted in promoting various health benefits, including potential roles in reducing the risk of colorectal and other cancers and coronary heart disease by lowering plasma cholesterol, improving lipid metabolism, reducing glycaemic index and preventing of obesity (Izydorczyk & Dexter, 2008; Rebello, O'Neil, & Greenway, 2016; Slavin, 2013). The effect of DF consumption on satiety and satiation has been extensively documented. Aside from these advantages, the role of DFs in improving satiety and satiation could not be doubted, with much extensive evidence have been proved in the literature (refer 1.2.3.2). The variation in structures and physiological functions of DF (Slavin & Jacobs, 2010) is thought to affect satiety in many ways such as hydration, solubility and viscosity and fermentability. Mastication of high fibre foods requires more time and efforts, which prolong oral exposure and reduce rate of ingestion (Slavin & Green, 2007), thus allows signals that mediate satiety sensations to the brain (Blundell & Halford, 1994). Viscous DF are proposed to increase satiety by absorbing more water and inducing thickening which lead to increase stomach distension thus trigger the vagal signals of fullness (De Graaf et al., 2004). The DF also increases the viscosity of the digesta in the small intestine therefore prolong small intestine transit time and absorption rates of nutrients (Kristensen & Jensen, 2011; Rebello et al., 2016). The prolonged nutrients availability in the small intestine would release satiety-related hormones such as cholecystokinin (CCK), glucagon-like peptide 1 (GLP-1) and peptide YY (PYY) (Chaudhri, Small, & Bloom, 2006) thus inhibit food intake (Perry & Wang, 2012). Colonic fermentation of insoluble DF resulting in increased production of short-chain fatty acids (SCFA) that could stimulate colonic L-cells to secrete metabolically active peptides involved in food intake, lipid storage, and energy homeostasis (Nicholson et al., 2012).

People add herbs and spices into food products to improve acceptability and organoleptic properties, as well as for preservative and medicinal purposes (El-Sayed & Youssef, 2019; Tapsell et al., 2006). One of the most commonly consumed spices globally is chilli, as it has been integrated into many culinary cultures such as Korean, Chinese, Middle Eastern, Indian, Southeast Asian and Mexican (Lv et al., 2015; Mongkolporn & Taylor, 2011; Mózsik, 2016; Sativa, Harianto, & Suryana, 2017; Shi, Riley, Brown, & Page, 2018). The chilli peppers' pungent sensation comes from an active component known as capsaicin (CAP). The studies suggest that CAP significant increases energy expenditure and lipid oxidation (Balaji et al., 2016; Lejeune, Kovacs, & Westerterp-Plantenga, 2003; Ludy & Mattes, 2011; Matsumoto et al., 2000). CAP causes increases in catecholamine secretion and subsequent sympathetic nervous system activation (Ludy & Mattes, 2011) thus increases fat oxidation. Fat oxidation would take place earlier before other substrate oxidation (protein and carbohydrate) before the start of the next meal (Westerterp-Plantenga et al., 2005) and lead to suppressed energy intake and body weight, and regulating appetite and increasing satiety (Golzarand, Toolabi, & Aghasi, 2018; Ludy & Mattes, 2011; Westerterp-Plantenga et al., 2005; Whiting, Derbyshire, & Tiwari, 2012; Yoshioka et al., 2004).

Despite the evidence suggesting that of the consumption of DFs and CAP influence satiety, there is not, to the best of our knowledge, any study reporting the effect of the combination of DF and CAP on satiety in individuals with different in intuitive eating levels.

Table 4.1 Effect of enrichments of fibres on the physicochemical qualities of noodles and pasta

Added fibres	Amount of fibre incorporated in the formulation	Findings	References
Oat bran	50% w/w substitution of durum wheat	increased the TDF content of 61% than control increased the antioxidant activity by ≈46% decreased the caloric content and digestibility of starch component	Espinosa-Solis et al., 2019
β-glucan enriched barley flour (BF)	40% w/w substitution of durum wheat	Comparable optimal cooking time (OCT), swelling index (SI), starch-protein texture to the control durum ditalini Higher phenol content and antioxidant capacity Higher cooking loss Cooked BF-ditalini soup delayed the hydrolysis of starch without affected viscosity	Montalbano et al., 2016
Coarse wheat bran (CB), fine wheat bran (FB), and purified wheat fibre (fine-FWF or coarse CWF)	Fortification of wheat flour with CB, FB, CWF or FWF at 4, 8 and 12% (w/w)	Increasing wheat fibre levels increase cutting force of raw and cooked noodles, decrease breaking force (dried noodles) and extensibility (raw and cooked noodles) Raw, dried and cooked fiber-enriched noodles with small fibre size had higher breaking force and extensibility and lower cutting force than that with large particle size	Shiau, Wu, & Liu, 2012
Apple flour (50% w/w substitution)	50% w/w substitution of durum wheat	Decreased protein content increased the antioxidant activity by ≈97%	Espinosa-Solis et al., 2019
long-chain inulin (HPX), short-chain inulin (GR), psyllium (P), Glucagel	Individually 15% w/w substitution semolina flour or combinations	Increased OCT (HPX- the highest) Increased cooking loss (P, GR, and HPX-P pasta- the highest)	Foschia, Peressini, Sensidoni,

(15% w/w substitution) or combinations with oat bran (O)	with oat bran OB (semolina:fibre:O 85:7.5:7.5)	Higher swelling index (SI) and water absorption index (WAI) (GR, P and HPX-P pasta- the highest value) Higher CL, SI and WAI (P, GR, and HPX-P pasta- the highest value) Decreased firmness significantly in GR-P and GR pasta Decreased maximal breaking strength in all fibre pasta formulations except for GG, HPX and HPX-O pasta Lower lightness in all uncooked fibre pasta, and higher lightness in all cooked inulin-added pasta (except for GR-P) than control	Brennan, & Brennan, 2015
Mango peel powder (MPP)	2.5, 5.0 and 7.5% w/w substitution of semolina flour	Increased TDF content significantly (13.8 to 17.8%) Increased polyphenols (1.47 to 1.80 mg/g), carotenoids contents (26 to 84µg/g) and decreased scavenging activities in all MPP pasta Increased cooking loss in 5.0% and 7.5% MPP pasta and firmness Decreased cooked weight in all MPP pasta Acceptable sensory quality at 5% MPP incorporation (colour, taste and texture attributes)	Ajila, Aalami, Leelavathi, & Rao, 2010
Cassava pulp (CP) and Pomelo pulp (PP) powders	1-20% CP and 1-10% PP (w/w) substitution of rice flour	TDF content in PP powder (98.7%) and CP powder (33.9%) Higher OCT and CL in 10% PP, 20% Mixed fibre (CP:PP; 10:10) and 20% Mixed fibre (CP:PP; 15:5) pasta Increased cooking weight in all fibre pasta (the highest in 20% Mixed fibre (CP:PP; 10:10) pasta) Increased TDF content (the highest TDF in 20% Mixed fibre (CP:PP; 10:10) pasta) Reduced tensile stresses (the lowest value in 10% PP pasta)	Wandee et al., 2014

Matured green banana flour (BF) and oat β-glucan (OB)	30% BF, 10% OB and BF-OB (30:10% w/w) substitution of wheat flour	Significant higher crude fibre and protein in 30% BF and BF-OB noodles than control Significant higher resistant starch in all fibre noodles Carbohydrate digestibility increased with time; significant higher in BF, OB and BF-OB noodles Categorised as low glycaemic index (GI) food for all 4 noodles (GI <55), with the highest GI in OB noodles (53), followed by BF-OB (40), control (35) and BF noodles (31) Improved antioxidant properties (total phenolic content and inhibition of peroxidation) in all fibre noodles compared to control The highest sensory firmness in BF-OB noodles, and the lowest in control noodles. Comparable sensory overall acceptance for BF noodles with the control	Choo & Aziz, 2010
Anthocyanin-rich fractions of debranned purple wheat	Flours from debranning fraction levels 3.7% (F1), 6.0% (F2) and bran from conventional milling (CB)	No differences in OCT compared to control pasta Lower water absorption in CB and F1 pasta higher ferric reducing-antioxidant power in F1, F2 and CB pasta (2.3 to 2.6 µmol Fe(II)/g) Highest anthocyanin content in F1 and F2 pasta (60-67.9 µg/g) higher cooking loss in F1 and F2 pasta	Zanoletti et al., 2017
Ripened pumpkin powder (PP)	2.5, 5.0 and 10.0% w/w substitution of wheat flour	β-carotene content (0.72-5.52 mg/100g instant fried noodles) Increased significantly cooked weight and volume gain in 2.5% PP and 5% PP noodles Lowest gumminess and hardness in 5% and 10% PP noodles Most acceptable by the panellists at 5% PP noodles	Lee et al., 2002

4.2 Aim of the chapter

This chapter aimed to examine the effect of DF and CAP enrichment on the satiety response to a noodle soup dish in human volunteers and the relationship of satiety responses with intuitive eating scores.

To achieve this aim, the following objectives were achieved:

1) Production of noodles enriched with DF and/or CAP including the optimisation of fibre level to achieve optimal cooking and textural characteristics.
2) To undertake a randomised controlled trial to test the effect of DF and CAP on satiety response in human volunteers with various levels of intuitive eating both after consumption of the noodle soup and a following ad libitum meal.

The chapter builds on chapter 2 by utilising the Rasch model for intuitive eating, and chapter 3 by utilising the optimised instrument for measuring satiety.

4.3 Materials and methods

4.3.1 Raw Materials

Oat fibre flour (BG 14, BG 22 and BG28) were supplied by Swedish Oat Fiber (Naturex, Sweden). Commercial high protein wheat flour and other food ingredients were purchased from a local supermarket in Leeds (Tesco, England). Breakfast preloads for satiety trial were purchased from local commercial retailers (Tesco and Sainsbury's supermarkets) and freshly bought in the morning on the same day of satiety trial. The details about the foods were explained in subsection 4.3.8.4.

4.3.2 General chemical reagents

Heat stable α-amylase (3000 Ceraplha U/ml), purified protease (350 Tyrosine U/ml), purified amyloglucosidase (3300 U/ml), 2(N-morpholino) ethanesulfonic acid (MES) and tris(hydroxymethyl)aminomethane (TRIS) were purchased from Megazyme (Megazyme, Bray, Co., Wicklow, Ireland). CAP and dihydrocapsaicin standards, sulphuric acid (H_2SO4), sodium hydroxide (NaOH), ethanol (EtOH), hydrochloric acid (HCl), acetone, boric acid, and Celite® were obtained from Sigma-Aldrich (Merck KGaA, United Kingdom). The other chemicals and solvents were of analytical grade and were purchased from Fisher Scientific (United Kingdom) unless otherwise stated.

4.3.3 Preparation of oat fibre-enriched noodles

The noodles were prepared with high protein wheat flour and different oat fibre flour (BG14, BG 22 and BG 28) (Table 4.2). Control wheat noodles (hereby known as Control) were made from a blend of 100% high protein wheat flour and 40% of water (w/w). For oat fibre-enriched noodles, high protein wheat flour was substituted by 25% (w/w) of different oat fibre flour (hereby known as BG14, BG22 or BG28 noodles). The wheat flour and oat fibre flour were mixed thoroughly in the Kenwood KMC Chef stand mixer (Kenwood Ltd., England) prior to the water's slow addition. They then mixed thoroughly at high speed (Level 4) for 10 minutes until the dough was adequately and evenly formed. Then the dough balls were rolled into 1-mm thick sheet and cut into 4-mm wide strands using Kenwood pasta roller (Level 7) and tagliolini pasta cutter attachments

(Kenwood Ltd. England), respectively. The noodle strands were lightly flour-dusted and oven-dried at 40°C overnight (16 hours) until the moisture content reached below 10%. The dried noodles were kept in the airtight aluminium zipper bags and stored in a dried and ambient room until further analyses were needed. Three batches of each noodle formulation were made.

Table 4.2 Formulation of noodles prepared using wheat flour and three different oat fibre flour

Ingredients (% w/w)[1]	Noodle type[2]			
	Control	BG14	BG22	BG28
High protein wheat flour	100	75	75	75
BG14 Oat fibre flour	0	25	0	0
BG22 Oat fibre flour	0	0	25	0
BG28 Oat fibre flour	0	0	0	25

[1] Ingredients are expressed on a dry weight basis (w/w)

[2] Control= control noodles made with 100% wheat flour, BG14= Noodles made with substitution of 25% of wheat flour with BG14 oat fibre flour, BG22= Noodles made with substitution of 25% of wheat flour with BG22 oat fibre flour, BG28= Noodles made with substitution of 25% of wheat flour with BG28 oat fibre flour

4.3.3.1 Infusion of CAP into noodles

1000 ppm (1mg/L) CAP stock solution was prepared by dissolving 1 g of CAP powder in 20 g of food-grade polysorbate-80. Then, the mixture was made up to 1000 ml with deionised water. The stock solution was freshly prepared and kept chilled up to 3 months. CAP and oat fibre-CAP (BG28CAP) noodles were prepared by replacing 10 ml water in the Control and BG28 noodles formulations, respectively, with 10 ml of CAP stock solution (Table 4.3).

4.3.4 Proximate analysis

4.3.4.1 Determination of total protein content using the Kjeldahl method

The determination of total protein content was using the Kjeldahl method. A gram of grounded noodle flour was accurately weighed and transferred into a digestion flask. The samples were digested in boiling 25 ml concentrated sulphuric acid with the addition of one catalyst tablet (5g K_2SO_4 + 0.5g $CuSO_4$ x $5H_2O$) for 1 hour until complete dissolution and oxidation in the Gerhardt digestion apparatus set (Gerhardt, UK). The mixture was allowed to cool and then transferred into 800 ml distillation flask. The distilled water was used to rinse the digestion flask and transferred to the distillation flask until the volume reaches approximately 400 ml. Ten drops of phenolphthalein indicator, 1 g of anti-bumping granules (VWR Chemicals, UK) and 1 ml of the anti-foam agent (Xiameter, UK) were added into the distillation flask. The condenser delivery tube dipping into 500mL conical flask containing 100mL of 4% boric acid solution with three drops of screened methyl red indicator (Scientific Laboratory Surplus, UK) was set up, with the outlet of the delivery tube was wholly submerged in the boric acid. Next, 50% sodium hydroxide was added via the dropping funnel until the test solution became alkaline (pink in colour). The distillation flask was heated with a Bunsen burner until a minimum of 250 mL distillate had been collected in a boric acid solution. Finally, the ammonia contained in the boric acid solution was titrated with 0.25M sulphuric acid. The protein content was determined by multiplying the nitrogen content with protein factor 5.83 for wheat and oat (Merrill & Watt, 1973) and been expressed as % total protein.

Equation 4.1 Nitrogen (N) (%)

$$\%\, nitrogen\ (N) = \frac{(ml\ H2SO4 - ml\ blank)\ X\ N\ of\ H2SO4\ x\ 14.007\ X\ 100}{weight\ of\ sample\ in\ grams\ X\ 1000}$$

Equation 4.2 Total Protein (%)

$$\%\, total\ protein = \%\, nitrogen\ \ X\ 5.83$$

4.3.4.2 Determination of total lipid content using AOAC Method 922.06

The total fat content of noodles was determined using Soxhlet method (AOAC Method 922.06) (AOAC, 2012). Ten grams of grounded noodles flour was weighed into a beaker, followed by 50 mL of 4 M HCL. The mixture was boiled for 3 minutes over a Bunsen flame until completely hydrolysed. Then the mixture was filtered through a No.1 fluted filter paper while it was still hot. The filter paper contained the residues were washed twice with hot water and air-dried in the fume cupboard overnight. The round bottom flask was dried at 105°C and cooled in a desiccator until constant weight. Then the flask had been weighed accurately on a microbalance to the nearest 0.001g.

The filter paper followed by a cotton wool plug was inserted into a Soxhlet extraction thimble, and then the thimble was placed in Soxhlet extractor. The weighed round bottom flasks were filled in with approximately 150-200 ml of petroleum spirit. The solvent extraction was carried out for about 10 hours. The petroleum spirit was distilled off from the flask using a pressure equalising funnel until only about 10 ml of solvent remained. The solvent residue was removed by placing the flask on a steam bath before it was oven-dried at 80°C. The flask was accurately weighed after it was cooled in a desiccator for at least 30 minutes until it reached a constant weight. Total lipid content in the noodles was calculated using the formula as below;

Equation 4.3 Total lipid content %

$$Total\ lipid\ content\ (\%) = \frac{(flask\ with\ residue\ (after\ extraction)) - (empty\ flask\ (before\ extraction))}{initial\ sample\ weight}\ X\ 100\%$$

4.3.4.3 Determination of total, soluble and insoluble dietary fibres using Megazyme kit (AOAC Method 991.43)

The total, soluble and insoluble dietary fibres were determined using the modified Megazyme method (Megazyme International Ireland, 2016). This method was based on AOAC Method 991.43 “Total, Soluble, and Insoluble Dietary Fibre in Foods” (First Action 1991) and AACC Method 32-07.01 “Total, Soluble, and Insoluble Dietary Fibre in Foods and Food Products” (Final Approval 10-16-91).

4.3.4.3.1 Sample and Blanks Preparation

A gram of grounded samples (± 0.005 g) (<250 µm) were weighed accurately into 400 ml beaker. A blank was run along with samples to measure any contributions from reagents to a residue with each assay. 40 ml of 0.05 M MES-TRIS blend buffer solution (pH 8.2) was added to each beaker and stirred on a magnetic stirrer until the sample was dispersed entirely in solution.

4.3.4.3.2 Incubation with Heat-stable α-amylase

50 µl heat-stable α-amylase solution (3000 Ceraplha U/ml, Megazyme International Ireland) was added into the beaker while stirring at low speed. Aluminium foil-covered beakers were placed in a shaking bath at 98 – 100°C and incubated for 30 minutes with continuous agitation. The beakers then were removed from the hot water bath and cooled to 60°C. The sidewall of the beaker and spatula were rinsed with 10 ml distilled water.

4.3.4.3.3 Incubation with protease

100 µl of protease solution (50 mg/ml, 350 Tyrosine U/ml, Megazyme International Ireland) was added to each sample. The incubation process was continued in agitation 60°C water bath for 30 minutes. 5 ml of 0.561 N HCl solution was dispensed into the beaker while stirring, and then the pH was adjusted to range 4.1 to 4.8 by adding 5% NaOH solution or 5% HCl solution depending on solution pH.

4.3.4.3.4 Incubation with amyloglucosidase

The process was continued with the addition of 200 µl amylogucosidase solution (200 pNP β-maltoside U/ml, Megazyme International Ireland) while stirring on a magnetic stirrer and incubated in constant agitation 60°C water bath for 30 minutes.

4.3.4.3.5 Filtration Steps for Insoluble Dietary Fibre (IDF)

Crucibles containing Celite® were wet and redistributed bed of Celite® with approximately 3 ml distilled water, and suction was applied to the crucibles to draw Celite® onto fritted glass mat. Enzyme mixture from previous steps was filtered through crucible into a filtration flask. Residues in enzyme mixture beaker were washed twice with 10 ml of 70°C pre-heated distilled water before washing residue in a crucible. Filtrate and water washings were kept for further determination of SDF. The residue was washed twice with 10 ml of ethanol and acetone. The crucible containing residue was dried at 103°C overnight then been cooled in a desiccator for 1 hour. Residue weight was obtained by differencing of weight crucible containing IDF and Celite® with the weight of dried crucible and Celite®.

4.3.4.3.6 Precipitation of Soluble Dietary Fibre (SDF) Filtrate

In the previous step, solution filtrate and water washings were weighed. 4 volumes 95% EtOH pre-heated to 60°C was added into the filtrate mixture and been allowed to precipitate at room temperature for 60 minutes.

4.3.4.3.7 Filtration Steps for Soluble Dietary Fibre (SDF)

Crucibles containing Celite® were wet and redistributed bed of Celite® with 15 ml of 78% EtOH from wash bottle, and suction was applied to the crucibles to draw Celite® onto fritted glass mat. Precipitated enzyme digest was filtered through crucible into a filtration flask. Residues in enzyme mixture beaker were washed twice with two portions of 15 ml of 78% EtOH, 95% EtOH and acetone. Weight of SDF residues was proceeded with steps as for the IDF method. The crucible containing residue was dried at 103°C overnight then been cooled in a desiccator for 1 hour. Residue weight was obtained by differencing of weight crucible containing SDF and Celite® with the weight of dried crucible and Celite®.

The calculation for determining IDF, SDF and TDF using the formulas below (Equation 4.4Equation 4.6);

Equation 4.4 Insoluble Dietary Fibre (IDF) (%)

$$\boldsymbol{Insoluble\ Dietary\ Fibre\ (IDF)\ (\%) = \frac{IDF\ Residue - blank}{sample\ weight}\ X\ 100}$$

Equation 4.5 Soluble Dietary Fibre (SDF) (%)

$$Soluble\ Dietary\ Fibre\ (SDF)\ \ (\%) = \frac{SDF\ Residue - blank}{sample\ weight}\ X\ 100$$

Equation 4.6 Total Dietary Fibre (TDF) (%)

$$Total\ Dietary\ Fibre\ (TDF)\ (\%) = IDF\ (\%) + SDF\ (\%)$$

4.3.4.4 Determination of starch content

4.3.4.4.1 Preparation of Dinitrosalicylic acid assay (DNS) solution

Five grams of 3,5 dinitrosalicyclic acid were dissolved in 250 ml of pre-heated distilled water (80°C). The solution was then cooled to room temperature before adding 100 ml of 2 N NaOH and 150 g of potassium sodium tartrate-4-hydrate. The mixture was stirred until completely dissolved and then made up with deionised water to 500 ml.

4.3.4.4.2 Protocol

Ten milligrams of glucose powder were dissolved in 1 mL of Milli-Q water to make 10 mg/mL D-glucose standard stock solution. Serial dilution of glucose standards ranges from 0.1 mg/mL to 1.2 mg/mL were prepared from the stock solution, and 2 mL of the standard solution was transferred into 15-mL centrifuge tubes. It was followed by pipetting 1 mL of DNS into the tube. Two ml of supernatant from fibre analysis from subsection 4.3.4.3 was pipetted in other centrifuge tubes, followed by 1 mL DNS. The centrifuge tubes containing glucose standards and samples were incubated in a boiling water bath for 15 minutes and then cooled in an ice bath. Later, nine mL of Milli-Q water was added into the centrifuge tubes and mixed well. The absorbance was measured at 540 nm using Jenway Multi-cell changer spectrophotometer (Cole-Parmer, England). A standard curve was plotted using glucose standard absorbance readings to calculate the amount of glucose in the samples. The glucose amount was converted to starch content by multiplying by a factor of 0.9.

4.3.4.5 Determination of ash content

Accurately 1.000 g sample was placed in a ceramic crucible. The ceramic crucible was heated and cooled until a constant weight was obtained prior to ashing analysis. The samples were subjected to ashing in a Phoenix microwave furnace maintained at 650°C until a constant final weight for ash was achieved (approximately 30 minutes). Then, the crucibles carefully transferred to the desiccator and cooled down until constant weight was achieved before been weighed. The ash content was calculated as follow;

Equation 4.7 Ash content (%)

$$Ash\ content\ (\%) = \frac{(crucibles + sample\ (before\ ashing\ )) - (crucibles + sample\ (after\ ashing))}{initial\ sample\ weight}\ X\ 100$$

4.3.4.6 Determination of moisture content using AOAC Method 925.10

The moisture content of noodles was determined using the air oven drying method (AOAC Method 925.10) (AOAC, 2012). Flour samples were weighed accurately 1 gram and placed in constant weighed dried crucibles. These were dried at 105 °C overnight (16 hours) until a constant weight was reached and cooled in a desiccator for 3 hours. Subsequently, the moisture content was calculated as the weight of water removed during drying divided by the initial weight of the sample Equation 4.8.

Equation 4.8 Moisture content (%)

$$Moisture\ content\ (\%) = \frac{(crucibles + sample\ (before)) - (crucibles + sample\ (after))}{initial\ sample\ weight}\ X\ 100\%$$

4.3.5 Determination of available carbohydrate by differences

The available carbohydrate was calculated by difference (Menezes, de Melo, Lima, & Lajolo, 2004). The differences were estimated by subtracting the amount of protein, fat, TDF, moisture and ash in 100 g of food (Equation 4.9)

Equation 4.9 Available carbohydrate (%)

$$Available\ carbohydrates\ (\%) = 100 - [weight\ in\ gram\ (protein + lipid + TDF + moisture + ash)\ in\ 100\ g\ of\ sample]$$

4.3.6 Determination of noodles cooking properties

4.3.6.1 Determination of Optimal cooking time

The optimum cooking time was measured, as suggested by Li and Vasanthan (2003). 5.0 g of noodles were cut into 3 – 5 cm lengths and cooked in 200 ml of boiling distilled water. The beaker was covered with aluminium foil to minimise evaporation losses. The optimum cooking time was determined by squeezing cooked noodles strands between 2 glass plates in an interval of 30 seconds. The white hard core's disappearance in the noodle strand indicated that starch in the centre of noodles strands was cooked/hydrated (as seen in Figure 4.1). The optimum cooking time was recorded when the noodles were cooked entirely.

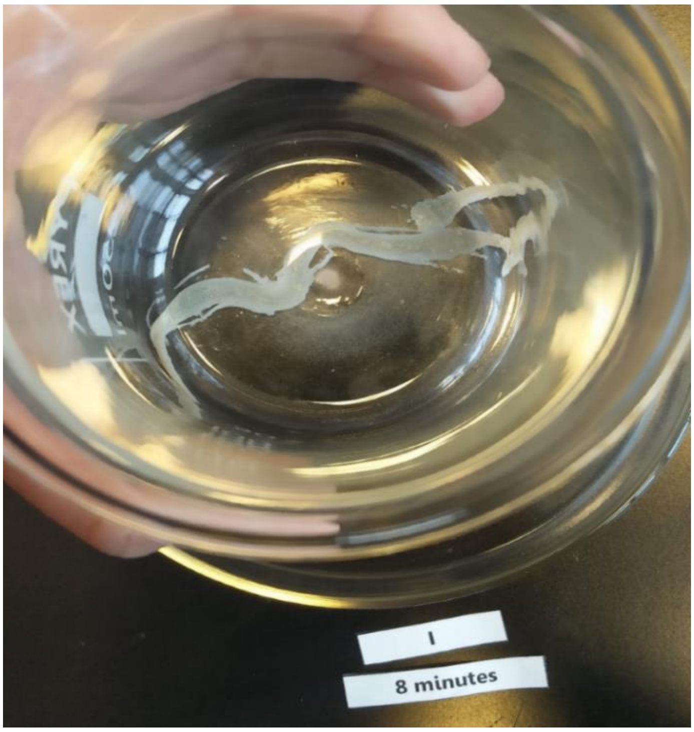

Figure 4.1 Cooked noodle strand crushed between 2 glass plates

4.3.6.2 Determination of Cooking Loss, Cooked Weight and Swelling Index

The cooking loss and cooked weight were measured by cooking the noodles strands, as mentioned in the previous procedure, for 1 minute more than the optimum cooking time (Li & Vasanthan, 2003). The cooked noodles were then filtered through a nylon screen, rinsed with distilled water, and drained for 5 minutes. The cooking loss was determined by evaporating the combined cooking water and rinse water at 110°C till constant weight was obtained and cooled in a desiccator. The solid residues remained in the cooking and rinsed water after drying were calculated. The cooking loss was expressed as the percentage of solids loss during cooking and cooked weight was calculated as the weight of cooked noodles as a percentage of dry noodle weight before cooking. The swelling index calculation was based on a calculation by Inglett et al. (2005). The cooking loss, cooked weight, and swelling index of noodles equations are as follows:

Equation 4.10 Cooking Loss (%)

$$cooking\ loss\ (\%) = \frac{weight\ of\ solid\ residue\ after\ drying}{weight\ of\ uncooked\ noodles}\ x\ 100$$

Equation 4.11 Cooked Weight (%)

$$cooked\ weight\ (\%) = \frac{weight\ of\ cooked\ noodles}{weight\ of\ uncooked\ noodles} x\ 100$$

Equation 4.12 Swelling Index

$$swelling\ index = \frac{weight\ of\ cooked\ noodles - weight\ of\ cooked\ noodles\ after\ drying}{weight\ of\ cooked\ noodles\ after\ drying}$$

4.3.7 Instrumental textural analysis

The elasticity, stickiness and firmness of cooked noodles were determined using TA-XT2 Texture Analyser (Stable Micro System Ltd., Godalming, England). The noodle strands were cooked at optimum cooking time and drained 5 minutes before the measurement (Brennan & Tudorica, 2007).

Elasticity was determined using the A/SPR Spaghetti/Noodle Test Rig with settings pre-test speed, test speed, and post-test speed at 1 mm/s, 3 mm/s and 10 mm/s respectively and distance 100 mm at a rate for data acquisition of 200 pps. A cooked noodle strand was be wound two or three times around the grips. The upper arm was set at a 3 mm/s to travel apart from the lower arm and been stretched until the noodle strand start to breakdown. The force (g) and the distance readings (in mm) to break the noodle strand indicated that the sample resistance to the breakdown and extensibility, respectively.

The stickiness of cooked starch noodles was determined using HDP/PFS Pasta Firmness/Stickiness Rig with the following settings: pre-test speed 1 mm/s, test speed 0.5 mm/s, post-test speed 10 mm/s with distance 100 mm, compression time 2 seconds with auto-trigger at 20 g and data acquisition rate of 500 pps. Five noodle strands were placed adjacent to one another centrally under the knife blade, with the product's axis at right angles to the blade.

Firmness was analysed using the A/LKB-F Light Knife Blade - Cooked Pasta Quality/Firmness Rig with test speed 0.17 mm/s, post-test speed 10.0 mm/s, distance 4.5 mm settings and data acquisition rate of 400 pps. The rig was positioned in the Heavy Duty Platform, and the rectangular probe was attached to the load cell and lowered into the platform's retaining plate.

The stickiness and firmness were determined based on the force-time curves of the TPA. At least five readings from the same formulation were evaluated, and the results were expressed as an average value. Repetitions have been done using fresh samples at each time.

4.3.8 Satiety Trial

4.3.8.1 Ethical review approval

This satiety trial was part of the ethical approval number MEEC 16-040 (amendment January 2019). The details of the procedures were explained in subsequent subsections below.

4.3.8.2 Participants

Twenty-three participants were recruited to take part in the satiety trial. Eligibility to participate in the satiety trial has been detailed in the previous Chapter 4.

4.3.8.3 Study design and procedure of the satiety trial

The trial was designed as a single-blinded randomised, cross-over study, where the participants were randomised to consumed four different ad libitum noodle meals across four non-consecutive test days. Unfortunately, due to the Covid19 pandemic outbreak, all the participants only completed the first trial day. The details about four different noodle meal formulations have been summarised in Table 4.3 below.

Table 4.3 Formulation of noodles prepared with BG28 oat fibre flour and capsaicin for satiety trial

Ingredients (% w/w)[1]	Noodle type[2]			
	Control	BG28	CAP	BG28CAP
High protein wheat flour	100	75	100	75
BG28 Oat fibre flour	0	25	0	25
Capsaicin stock solution (ml)[3]	0	0	10	10

[1] Ingredients are expressed on a dry weight basis (w/w)

[2] Control= control noodles made with 100% wheat flour, BG28= Noodles made with substitution of 25% of wheat flour with BG28 oat fibre flour, CAP= Noodles made with 100% of wheat flour and added with 10ml capsaicin stock solution, and BG28CAP= Noodles made with substitution of 25% of wheat flour with BG28 oat fibre flour and added with 10ml capsaicin stock solution.

[3] Concentration of capsaicin stock solution is 1000ppm

The satiety trial procedure on the test day was similar to those discussed in subsection Material and Methods in Chapter 4. The participants had been asked to answer a set of 20 Mental Hunger (MH) items at 5-time points; as follow:

1. before ad-libitum lunch meal
2. Immediately after ad libitum lunch meal
3. 1-hour after ad libitum lunch meal
4. 2-hour after ad libitum lunch meal
5. 3-hour after ad libitum lunch meal

The period from time point before the participants having ad libitum meals and immediately after they terminated their meal know as pre-ingestive period. From the time point after the participants terminated the meal until 3 hours after meal are known as post-ingestive period. All the food leftovers were re-weighed, and the amount of energy was calculated. The summary of the satiety trial was illustrated in Figure 4.2.

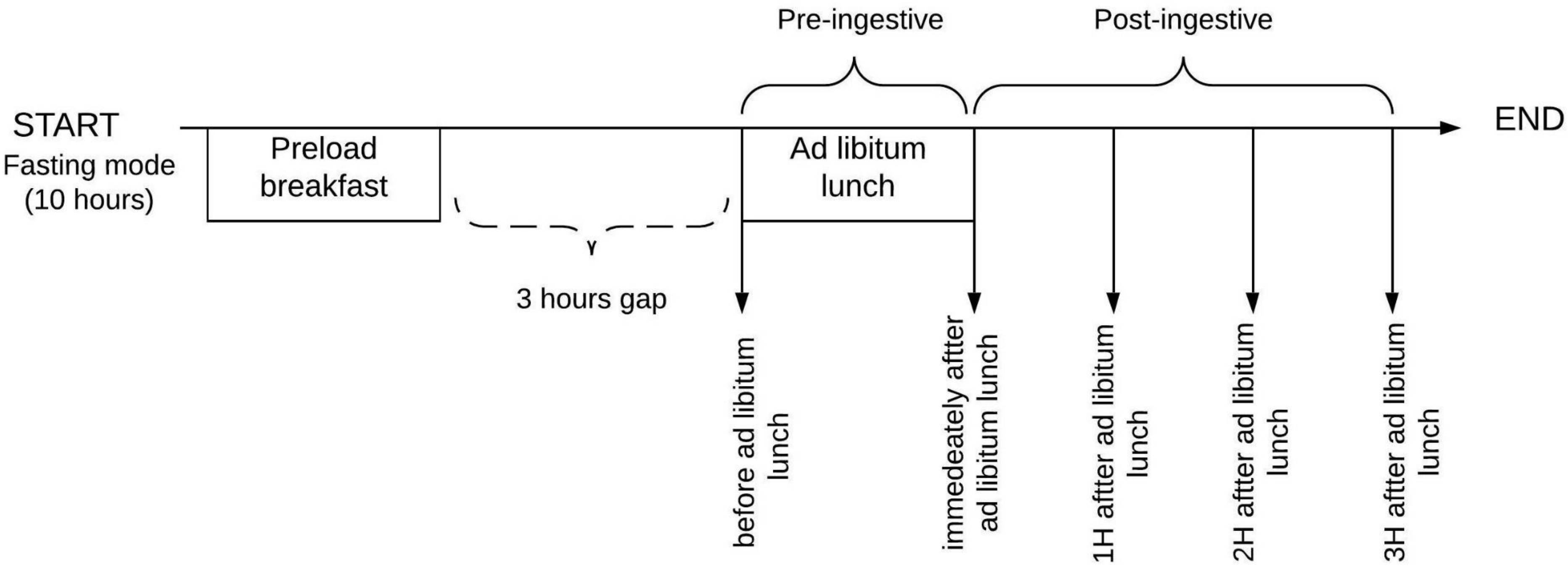

Figure 4.2 General procedure of satiety trial. Participants rated satiety levels using 20-item Mental Hunger (MH) items at 5-time intervals; before lunch, immediately after lunch, 1-hour, 2-hour, and 3-hour after lunch.

4.3.8.4 Preload breakfast and ad libitum lunch

All the participants received the same breakfast preloads, as in Chapter 4.

For ad-libitum lunch, there were four different noodle meals had been served to the participants. They were wheat (Control), oat fibre-enriched (BG28), capsaicin-enriched (CAP), and fibre-capsaicin-enriched noodle (BG28CAP) noodle meals (see Table 4.3). One hundred grams of dried noodles were cooked at the optimal cooking time and served warmed with 200 ml of vegetable-flavoured broth. A jug of water was served together with a noodle meal. The participants were allowed to drink as much or little as they wanted throughout the satiety trial.

4.3.9 Rasch repeated measure analysis

The satiety trial data has been analysed using Rasch repeated measure analysis. The data has been divided into two parts and run separately; pre-ingestive and post-ingestive periods. The same participants have tendencies to rate the same items differently at different time points. For example, a participant would rate a hunger-related item with higher categories at a time point before he/she ate the meal, and then rated the same item with lower categories after he/she finished the meal because they felt less hunger than before. So that, the Rasch repeated measures analysis was used to control the invariances between individuals. The item measures (item difficulties) remained constant and only the person measures (abilities) changed in the Rasch repeated measures.

The Rasch repeated measures analysis underwent a few steps, as summarised in Figure 4.3. Firstly, the Rasch models with all participants were analysed (Step 1), as discussed in subsection 2.3.4. Then, each participant was randomly selected across four-time points (Before Preload, After Preload, 1H After Preload and Before Lunch), so that one participant was only presented in the data set once and all time-points were equally represented. The Rasch models with random data set were analysed and item difficulties and Rasch-Andrich thresholds were estimated (Step 2). The MH item difficulties and Rasch-Andrich thresholds derived from 'Random' Rasch models were known as 'anchored' files where they became the definitive set of item difficulties and thresholds in defining the measurement framework of the latent variable. Next, the 'anchored' files were applied in control file with person abilities at all time-point stacked in one dataset (control file from Step 1) (Step 3). The Rasch analysis was run with all the data stacked and person measures were estimated. The MH items were modelled to maintain their difficulties across the time points. The person measures were rescored to range 0 to 100 (Step 4). Changes in satiety MH measures were illustrated by plotting the rescored person measures across time points from the stacked models.

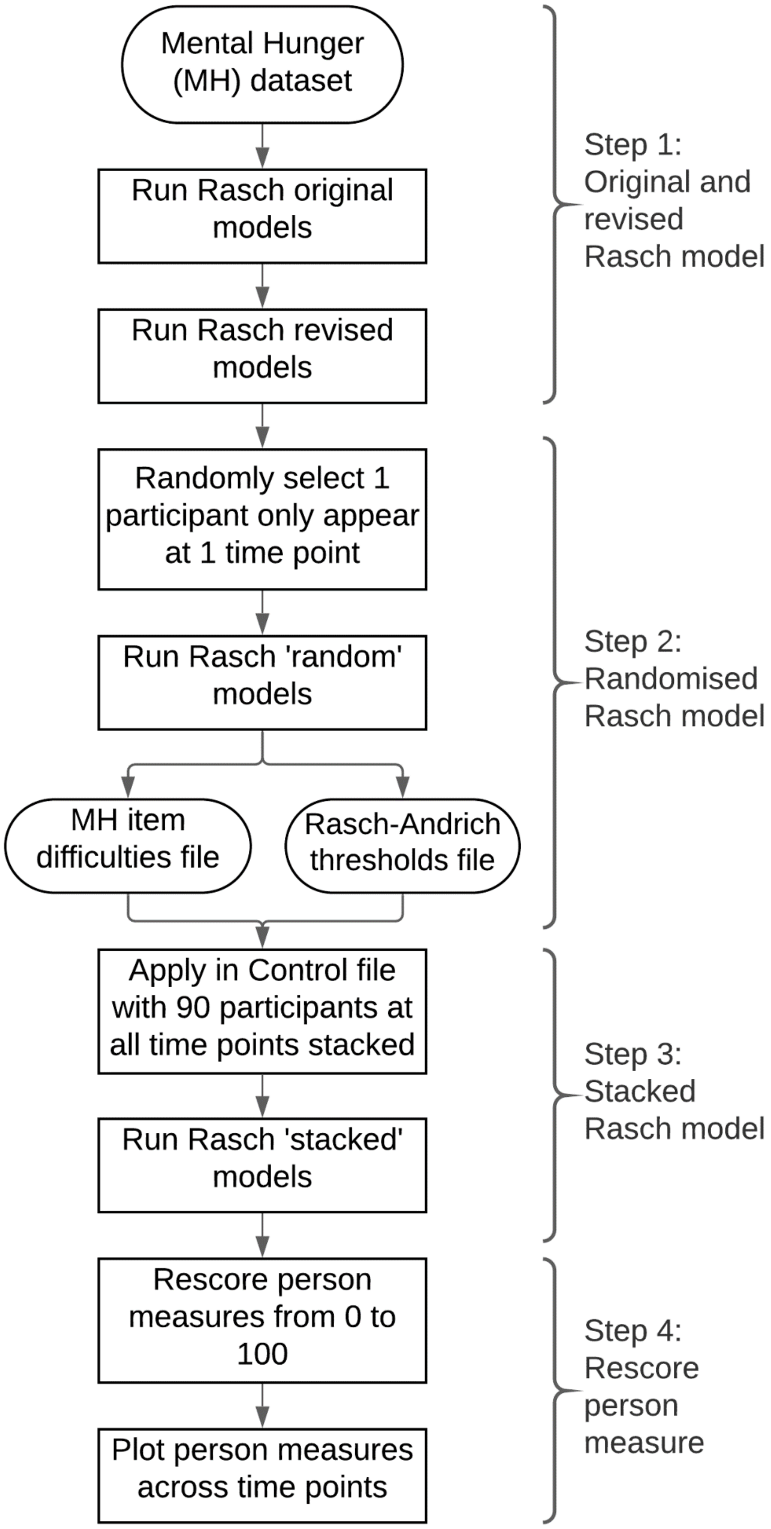

Figure 4.3 Rasch repeated measures procedure flowchart

4.3.10 Statistical analysis

All chemical and instrumental texture analyses of noodles were performed in triplicates for each batch of noodles unless otherwise stated individually in each subsection. The results were reported as the mean ± standard deviation (SD). All statistical analyses were conducted using R Studio (R Core Team, 2019). One-way analysis of variance (ANOVA) was used to determine if there was a significant difference between samples. Multiple comparisons were analysed using the Tukey HSD test. The statistics for the participant responses in the satiety trial were run as in previous Chapters 2 and 3.

4.4 Results and discussion

4.4.1 Proximate compositions of control noodles and three different oat fibre-enriched noodles

The proximate compositions of four noodle flour formulations are presented in Table 4.4. The available carbohydrate content of Control noodle is significantly higher than that of in fibre-enriched noodles (BG14, BG22 and BG28 noodles). As expected, the carbohydrate contents of all raw noodle treatments were similar to the theoretical calculation from manufacturer's labels (see Table 4.5). The total starch content of the noodles was significantly lower ($p<0.05$) in the noodles enriched with 25% BG22 and BG28. This resulted from the replacement of wheat flour with oat fibre. All raw noodle starch values were about 50% below than of the finding by Kaletunc and Breslauer (2003) where wheat starch content of about 60 to 73%, while starch content in oat is only 39-55%. A possible explanation for the differences between those values may be because the method used in this study was based on enzymatic digestion of starch, and it is possible that starch in the raw noodles was not fully digested, which may suggest the presence of resistant starch.

Crude protein and fat contents in fibre-enriched noodles (BG14, BG22 and BG28) were significantly higher than in Control noodles. These findings are in agreement with the study done by Aydin and Gocmen (2011), which observed higher protein and fat contents when the noodles supplemented with oat flour. Those findings explained that oat fibre flour contributed a certain amount of fat and protein to the noodles. Unlike other cereal grains, which are usually low in fat content, oats are relatively high in fat content (3 to 11%) (Zhou, Robards, Glennie-Holmes, & Helliwell, 1999). They could be accumulated up to 18% (Peterson & Wood, 1997). The fat content is predominantly in the endosperm tissues (Banaś et al., 2007; Heneen et al., 2009). Therefore, higher protein and fat contents observed in oat fibre-enriched noodles could be due to higher concentrations of macronutrients in the outer layer of oat groat (Grundy, Fardet, Tosh, Rich, & Wilde, 2018; Miller & Fulcher, 2011).

Table 4.4 Proximate composition of control noodles and three different oat fibre-enriched noodles

Noodle	g per 100 g of uncooked sample (dry basis)					
	Available carbohydrates	Starch	Protein	Fat	Ash	Moisture
Control	$74.11^{a}±1.50$	$36.57^{a}±2.90$	$10.43^{b}±0.25$	$1.11^{b}±0.05$	$2.03^{a}±1.61$	$6.62^{a}±0.18$
BG14	$60.54^{b}±2.30$	$31.77^{ab}±1.49$	$13.13^{a}±0.79$	$1.99^{a}±0.05$	$3.25^{a}±1.63$	$6.09^{b}±0.06$
BG22	$56.21^{c}±0.62$	$31.34^{b}±1.37$	$13.26^{a}±0.41$	$1.99^{a}±0.06$	$2.25^{a}±0.55$	$5.66^{c}±0.17$
BG28	$53.07^{c}±0.73$	$27.52^{b}±1.49$	$13.68^{a}±0.23$	$2.04^{a}±0.06$	$3.56^{a}±0.50$	$5.58^{c}±0.03$

Data were reported in mean ± SD of three independent observations. The values with different small letter superscripts in a column differ significantly ($p < 0.05$).

Table 4.5 Composition of raw materials used in the noodle making

Flour	g per 100 g of sample (dry basis) *			
	Carbohydrate	Protein	Fat	Total Fibre
High protein wheat	68.5	12.6	1.4	3.1
BG14 Oat fibre flour	34.0	21.0	5.0	30.0
BG22 Oat fibre flour	22.0	20.0	5.0	44.0
BG28 Oat fibre flour	9.0	23.0	5.0	52.0

*based on the manufacturer's labelling

The ash content of noodle formulations ranged between 2.03 to 3.56 g/100g. The addition of oat fibre flour into noodle formulations did not give significant effect in ash content of noodles. The higher ash content in oat fibre-enriched noodles is consistent with Aydin and Gocmen's (2011) finding, as the primary minerals magnesium, manganese, zinc and iron contributed to the higher ash content in oats. Moisture contents of BG28 and BG22 noodles significantly higher than that in BG14 and Control noodles. Moisture contents of noodles samples varied between 5.58 and 6.62 g/100g. Increasing the amount of DF cause a reduction in the moisture content of the noodles. The moisture content result is consistent with Levent and colleagues' (2020) finding, which negatively correlated the moisture content with the amount of fibre content in noodles.

4.4.2 Total, soluble and insoluble dietary fibre contents of control noodles and three different oat fibre-enriched noodles

Total dietary fibre (TDF) content of control noodles was 5.7%, and the TDF significantly increased to 15%, 21% and 22% after substituting wheat flour with 25% of BG14, BG22 and BG28 oat fibre flour, respectively (Table 4.6). A higher dietary fibre content observed in all three fibre-enriched noodles formulations than theoretical calculation based on manufacturer labelling could be due to the method used for fibre analysis which could also include resistant starch (RS), The protein and starch might be incompletely hydrolysed in this enzymatic-gravimetric method; therefore likely some of these were recovered as IDF. The SDF and IDF ratio almost similar in all the formulations (SDF:IDF 0.9:1), with the IDF was slightly higher than SDF. As reported by the manufacturer, the oat fibre flour used in this study was mainly oat bran. Our findings are in line with previous literature that found that half of the oat bran TDF consists of IDF, and another half is SDF (Chiemela Enyinnaya, Yogeshini, Muna, Mat, & Kharidah, 2015; Cui, Wu, & Ding, 2013; Dreher, 1987). In oat bran, β-glucan is the main component of SDF, while the oat bran IDF could be larger β-glucan, cellulose, arabinoxylans, lignin and some associated hemicellulose (Cui et al., 2013; Drzikova, Dongowski, & Gebhardt, 2005). Insoluble β-glucans have more cellotriose units than soluble β-glucans (Khan et al., 2016). The oat RS contributed about 0.4 to 12.8% to the oat DF content (Drzikova et al., 2005) ,is not digested in small intestine and be found as good substrate for fermentation to increase short-chain fatty acids (Upadhyaya et al., 2016)..

Table 4.6 Dietary fibres contents of dried raw noodles

Raw noodles	g per 100 g of sample (dry basis)			Theoretical calculation[1]
	SDF	IDF	TDF	
Control	$2.54^{c}\pm0.36$	$3.15^{d}\pm0.23$	$5.70^{d}\pm0.25$	3.10
BG14	$7.10^{b}\pm0.18$	$7.89^{c}\pm0.44$	$14.99^{c}\pm0.47$	9.83
BG22	$9.99^{a}\pm0.61$	$10.64^{b}\pm0.27$	$20.62^{b}\pm0.68$	13.33
BG28	$10.57^{a}\pm0.36$	$11.50^{a}\pm0.24$	$22.07^{a}\pm0.42$	15.33

Data were reported in mean ± SD of three independent observations. The values with different small letter superscripts in a column differ significantly ($p < 0.05$).

[1]Theoretical calculation for TDF in noodle formulations based on the manufacturer's labeling

4.4.3 Cooking quality properties of fibre-enriched noodles

Cooking qualities of control and oat fibre-enriched noodles are summarised in Table 4.7. The optimum cooking time (OCT) for the noodles ranged between 6 and 9.5 minutes. The OCT inversely corresponded to the amount of dietary fibre contents, with BG28 noodles required the shortest time while the control noodles took the longest to be fully cooked. This result is in good agreement with previous findings where the fortification of non-wheat ingredients into noodle/pasta formulations decreased the OCT of the final products (Petitot, Boyer, Minier, & Micard, 2010; Torres, Frias, Granito, Guerra, & Vidal-Valverde, 2007; Zhao, Manthey, Chang, Hou, & Yuan, 2005). The presence of dietary fibres likely contributed to the differences in the OCT, where the physical disruption of the gluten matrix by fibres might have occurred. It is suggested that the addition of fibre weakens the gluten network and assists water migration to the core of noodle strands (Chillo, Laverse, Falcone, Protopapa, & Del Nobile, 2008; Petitot et al., 2010; Sozer & Kaya, 2008). As consequence, fibre addition resulted in higher cooking loss, as more solids leached out from the noodle strands. However, there were no significant differences in cooking loss among the noodles reported. The control and fibre-enriched noodles were considered good quality noodles since the cooking losses were below 12% (Fu, 2008).

Table 4.7 Optimum cooking time (OCT), cooking loss, cooked weight and swelling index of control noodles and three different oat fibre-enriched noodles.

Noodles	OCT (minute)	Cooking loss (%)	Cooked weight (%)	Swelling index
Control	9.5	8.29^{a}±0.33	301.58^{d}±2.86	2.51^{b}±0.03
BG14	7.5	8.26^{a}±0.26	316.09^{c}±2.24	2.51^{b}±0.06
BG22	6.5	8.86^{a}±0.28	330.77^{b}±2.13	2.86^{a}±0.02
BG28	6.0	8.08^{a}±0.22	340.17^{a}±1.42	2.94^{a}±0.02

Data were reported in mean ± SE of three independent observations. The values with different superscripts in a column differ significantly ($p < 0.05$).

Noodle cooked weight increased about three times from the uncooked dried noodles in all formulations. The cooked weight significantly increased in parallel with the amount of fibre. Our findings corroborate with the previous study that has demonstrated that water hydration increased in proportional to the amount of fibre incorporation into wheat flour (Sosulski & Wu, 1988). Increasing fibre contents resulted in a high swelling index of the noodles. The highest swelling index was obtained for BG28 noodles, followed by BG22 noodles, while BG14 noodles were similar to that of control noodles. The capability of SDF in retaining a high amount of water may explain the trends (Foschia et al., 2015). The differences in water absorption by different fibre are mainly caused by the greater number of hydroxyl groups in fibre structure that allow more water interaction through hydrogen bonding (Rosell, Rojas, & Benedito de Barber, 2001). Chemical structure of β-glucans responsible to the solubility, water retention properties viscosity of the food product (Kaur et al., 2020). In details, the abundance of hydroxyl groups in β-glucans that form in hydrogen bonding with water allows the β-glucans to hold water in both soluble and insoluble forms (Ahmad & Kaleem, 2018; Tejinder et al., 2000). Moreover, hydration could also be explained by the swelling power of starch granules. Under specific conditions such as temperature and water content, starch granules that can hydrate more have greater swelling capacity (Punia et al., 2020). Oat starch has a greater swelling index than barley, corn and wheat starches (Doublier, Paton, & Llamas, 1987; Šubarić, Babić, Lalić, Aćkar, & Kopjar, 2011). A few factors affecting swelling included the amylose content, starch structure and morphology(Srichuwong & Jane, 2007; Vamadevan & Bertoft, 2015). Moreover, protein coagulation can also be a factor, as the water penetrates the protein matrix through the fissures during cooking process allow the protein hydrate and expand in volume (Bustos, Perez, & Leon, 2015). The process gives tensions that lead to the formation of additional fractures and generates a mobile diffusion gradient from the noodles surface to the core while starch gelatinisation takes place (Fardet et al., 1998).

4.4.4 Instrumental textural properties of fibre-enriched noodles

The texture is a key attribute in determining consumer acceptance and becomes the predominant criteria for evaluating pasta or noodle quality (Fu, 2008). Increasing fibre concentration significantly impacted oat fibre-enriched noodles' instrumental textural properties in terms of firmness, stickiness, and elasticity (Figure 4.4). Enrichment of oat fibre flour significantly decreased noodle firmness with the lowest firmness in BG28, followed by BG22, BG14 and control noodles, respectively. Our results contradict the study by Song et al. (2013) that found that noodles' firmness showed up trends with increased bran amount. However, ours are consistent with those of findings that showed decreased firmness in wholegrain and pasta enriched with fibre (Aravind, Sissons, Egan, & Fellows, 2012; Basman, Koksel, & Atli, 2006; Brennan & Tudorica, 2007; Makhlouf et al., 2019; West, Seetharaman, & Duizer, 2013). The elasticity of cooked noodles was significantly reduced with an increased amount of oat fibre. The result is in line with previous studies by Shiau et al. (2012) and Fogliano and Vitaglione (2005). The opposite direction could be seen in noodle stickiness. The stickiness increased by 23%, 29% and 49% for BG14, BG22 and BG28 noodles, respectively, compared to control noodles.

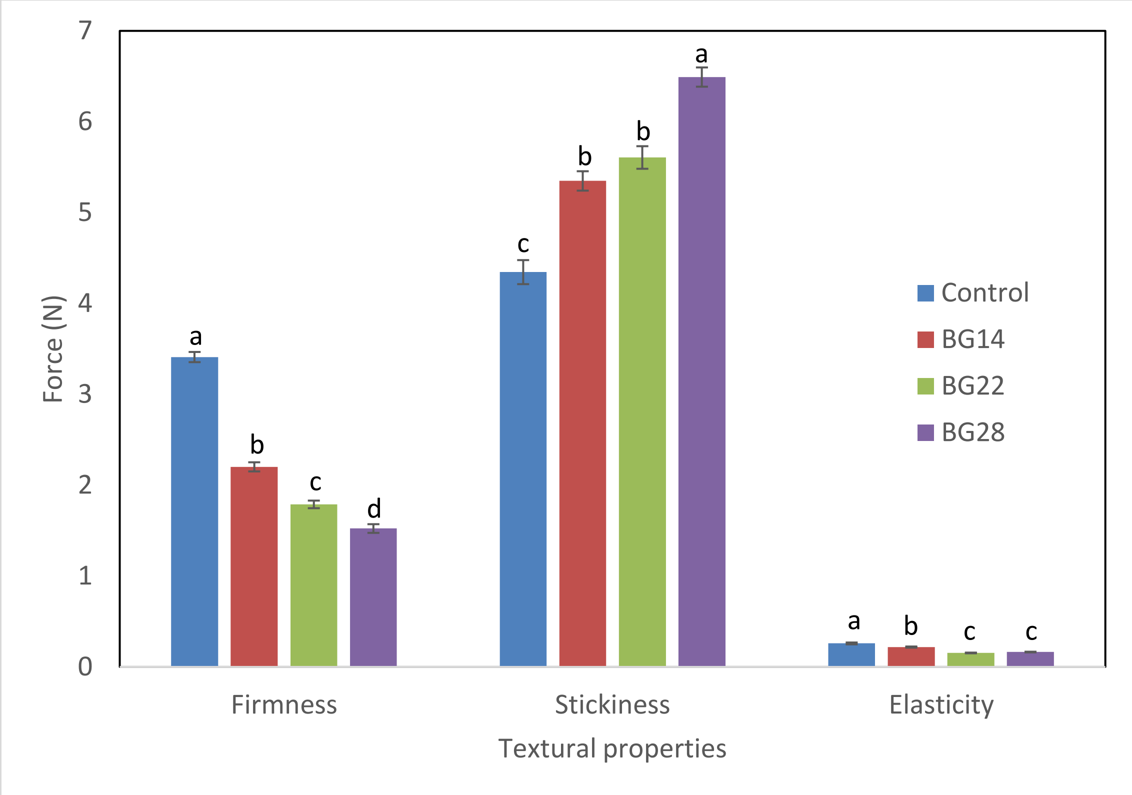

Figure 4.4 Instrumental textural properties (firmness, stickiness and elasticity) of control and three different oat fibre-enriched noodles. Different letters above the bars within each textural property indicate a significant difference (P<0.05).

These trends may be explained by the fact that competition between the starch swelling and protein coagulation occurred during the cooking process leads to significant structural changes and hence affected the final texture (Brennan, 2013; Bruneel, Pareyt, Brijs, & Delcour, 2010; Delcour et al., 2000; Resmini & Pagani, 1983). Strong protein network caused the starch granules entrapped in the gluten network produced the firmer and more elastic noodles, and on the other hand, if starch swelling wins, the final products became stickier and softer (Delcour et al., 2000). Moreover, the presence of fibre distorted the gluten network and allowed the water diffusion to the starch granules, hence increased the water absorption and starch swelling; thus reduced the firmness and increased the stickiness of the final products (Brennan & Tudorica, 2007; Foschia et al., 2015). The differences in amylose-amylopectin ratio, molecular size and chain structure of the leached amylopectin from the surface cooked products are likely to be a significant determinant of the stickiness of the cooked starchy products (Li, Fitzgerald, Prakash, Nicholson, & Gilbert, 2017).

Taken together, BG28 noodles were selected for the next satiety trial, based on the cooking and instrumental texture properties besides its higher dietary fibre content. BG28 noodles exhibit shortest optimal cooking time, comparable cooking loss without degraded the cooked noodles' texture quality. All the analyses that had been done in selecting fibre-enriched noodles to be used in satiety trial would be not repeated for the CAP-enriched noodles.

4.4.5 Effect of DF and CAP noddle enrichment on satiety in human volunteers

Satiety trial has been done to evaluate the effect of DF and CAP on the satiety in 23 individuals with different intuitive eating levels. The participants had been asked to eat one of ad libitum meals, which either Control, BG28, CAP or BG28CAP noodle meals. Satiety was measured using 20-item Mental Hunger and the energy intake was calculated. The satiety was analysed using Rasch repeated measure at satiation and satiety periods.

4.4.5.1 Participants characteristics

The 23 participants, 8 males and 15 females, ranged in age from 18-44 years took part in the saiety trial (Table 4.8). The had an average body mass index (BMI) of 23.61±4.44 kg/m^2 with a range of 17.36 to 36.81 kg/m^2. They were randomly selected from three levels of intuitive eating (low, medium or high) based on RHSC measure from the previous analysis in Chapter 2.

Table 4.8 Participant characteristics counts or means for four test meal groups.

	Control	BG28	CAP	BG28CAP
Number of participants (Male/Female)	7(4/3)	5(1/4)	5(0/5)	6(3/3)
Age range (years)	18-44	18-44	18-44	18-44
BMI (kg/m^2)	23.50±3.79	22.41±3.70	24.44±3.97	24.05±6.61
RHSC Group (low/medium/high)	2/1/4	2/2/1	0/1/4	4/2/0

4.4.5.2 Changes in Mental Hunger (MH) measures

The satiation and satiety changes in response of Mental Hunger (MH) measures in four different noodle meals are presented in Figure 4.5 A-C and Table 4.9. The satiety changes at pre-ingestive due to ad libitum noodle meal consumption was calculated by the differences in MH measures between before having the meal (Before lunch) and after the termination of eating (After lunch). The post-ingestive period's satiety changes were the differences of MH measures at 1H, 2H and 3H after having meal from the MH measure at 'After lunch' time point. In general, the MH measures decreased significantly ($p<0.05$) in the pre-ingestive period between before and after ad libitum lunch meal, while the opposite pattern was seen in the post-ingestive period in all 4 different meals (Figure 4.5A-C). After having ad libitum lunch meals, all the participants reached their satiation with the lowest MH measures at time point 'after lunch'. After 1 hour of having the meals (1H after), the MH measures increased significantly compared to that of at 'after lunch' point. MH measures at 1H after meal for Control noodles (42.74±9.24) did not significantly differ from BG28 (51.26±7.42) and CAP noodles (40.10±7.06), while the MH measure for BG28CAP noodles was significantly lower (28.82±8.02). The MH measures in BG28 and CAP noodle meals did not significantly differ from that in Control noodle meal throughout 5 time points (Figure 4.5A-B). The BG28CAP noodle meal produced a significant drop in the MH measures than did the Control noodle before having the meal (Before lunch) and after 1H after meal (1H after) (Figure 4.5c).

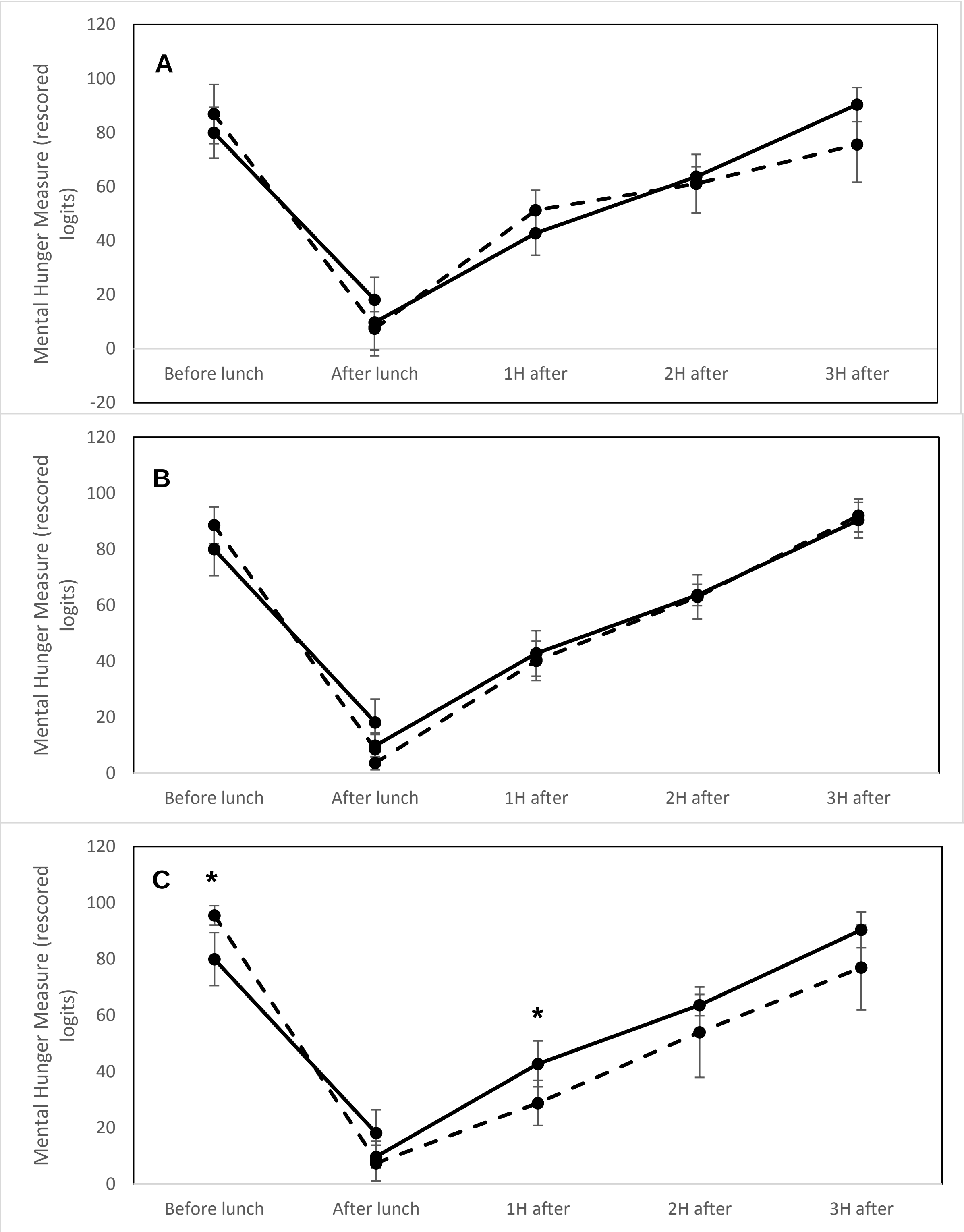

Figure 4.5 Plots of the mean ± SD of Mental Hunger (MH) measures at pre-ingestive period (before lunch to after lunch) and post-ingestive period (from after lunch to 3H after) in Control noodle meal (black lines) and treatment noodles (dashed lines); A = BG28 noodle, B= CAP noodle and C= BG28CAP noodle. The MH measures (in logits value) were rescored from 0 to 100. The * superscript represents MH measure differ significantly at specified time point ($p < 0.05$).

Table 4.9 Pre-ingestive and post-ingestive (1H-, 2H- and 3H- after) satiety changes for Mental Hunger (MH) measures for Control and 3 treatment noodles.

Noodles	Pre-ingestive	Post-ingestive		
		1H -after	2H-after	3H-after
Control	$-61.86^{b}\pm17.58$	$33.00^{ab}\pm10.70$	$53.88^{a}\pm7.82$	$80.64^{a}\pm11.65$
BG28	$-78.62^{ab}\pm11.18$	$43.81^{a}\pm5.62$	$53.63^{a}\pm15.37$	$68.15^{a}\pm16.92$
CAP	$-80.00^{ab}\pm9.54$	$36.56^{ab}\pm5.99$	$59.41^{a}\pm7.27$	$88.46^{a}\pm7.13$
BG28CAP	$-87.24^{a}\pm8.46$	$21.38^{b}\pm13.07$	$46.56^{a}\pm22.02$	$69.57^{a}\pm19.97$

Data were reported in mean ± SD of satiation and satiety changes (in logits) at each time point. The values with different superscripts in a column differ significantly ($p < 0.05$).

BG28CAP noodle meal produced the greatest satiation effect (Table 4.9), followed by CAP, BG28 and Control noodle meals, respectively. This finding explained that the participants felt satiated at the most when they had BG28CAP meal with the largest drop in MH measures. Satiety changes did not significantly differ after having different noodle meals except for satiety at 1H after the meal where BG28CAP noodle meal produced significant greater satiety (with lower MH measure changes) than BG28 noodle meal. It is plausible that a number of limitations could have influenced the satiation and satiety changes in different meals. It could be due to the experimental design. A small number of participants took part in the trial and only managed to try one meal each. For those reasons, it produced larger standard errors and challenging to make a distinct comparison in satiety using subjective ratings. Even though the MH measures did not give the results as expected, our findings were still supported by the results based on energy intake and food consumed, as discussed in the next subsection.

4.4.5.3 Energy intake and amount of food consumed at ad libitum lunch

Energy intake (kcal) and amount of food consumed (in grams) at ad libitum lunch test meals are presented in Figure 4.6 and Table 4.10, respectively. In overall, there was a significant effect of enrichment of DF and CAP on lunch ad libitum intake ($F (3,19) = 10.64$, p value <0.001), with participants consuming significantly more at Control noodle meal (736.09±126.41kcal). The infusion of CAP did not significantly reduce the energy intake of CAP noodle meal (674.09±35.85kcal) compared to the Control noodle meal. Enrichment of oat fibre BG28 (543.30±23.40kcal), or combination of both fibre and CAP (532.82±33.26kcal) into the noodle formulations (BG28 and BG28CAP noodle meals, respectively) seemed able to reduce the energy intake in ad libitum meal compared to control noodles meal. The amount of the meal consumed were not significant in Control, BG28 and CAP noodle meals. However, the enrichment of BG28 flour and CAP significantly decreased the amount of food consumed in BG28CAP noodle meal.

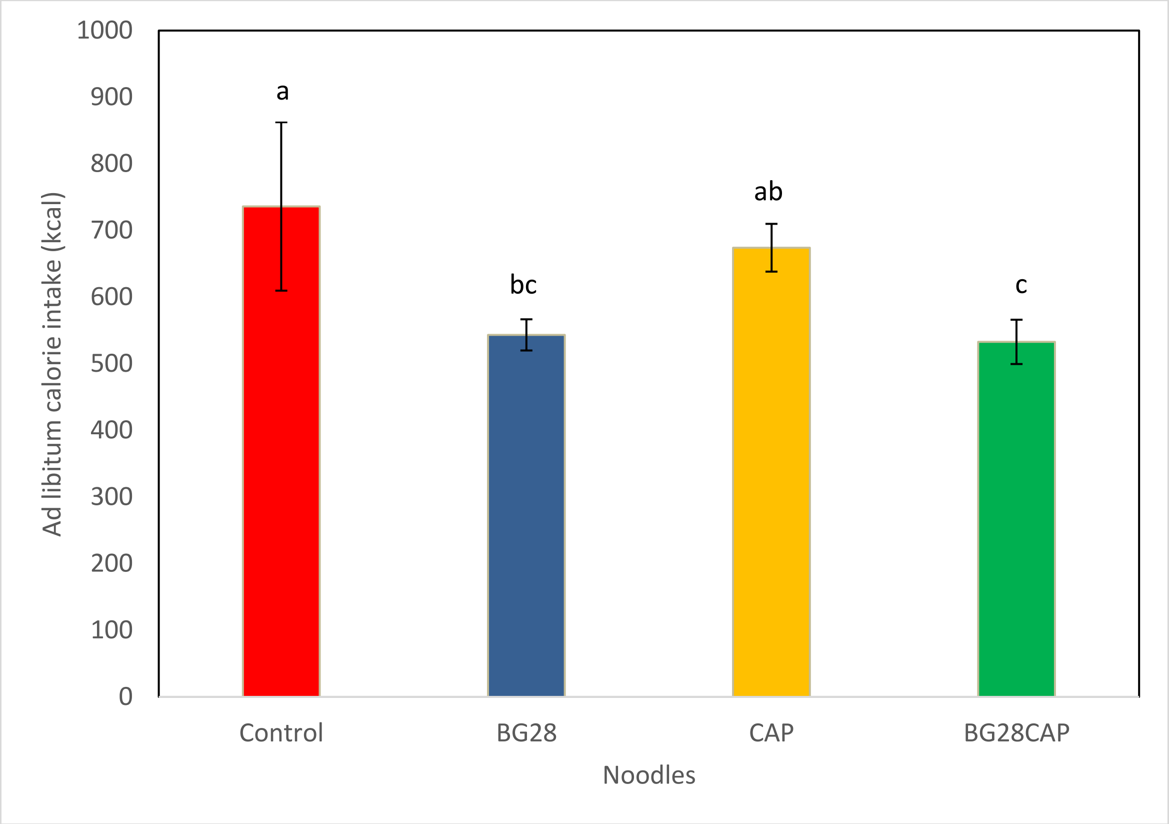

Figure 4.6 Ad libitum calorie intake (kcal) for 4 different noodles formulations. Values are means, with standard deviations represented by vertical bars. The bars with same small letters on did not differ significantly ($p < 0.05$).

Table 4.10 Energy per one portion meal and amount of food consumed in ad libitum lunch meal

Noodles	Energy (kcal)*	Food consumed (in grams) #
Control	359.6	662.23^{a}±111.67
BG28	329.5	552.62^{ab}±26.15
CAP	359.6	604.68^{ab}±31.08
BG28CAP	329.5	536.95^{b}±37.23

*Data are expressed as kcal per 100g of noodles (raw) and served with vegetable-flavoured broth

#Data were reported in mean ± SD of amount of food (in gram) consumed for individual noodles at ad libitum lunch meal. The values with different superscripts in a column differ significantly ($p < 0.05$).

The reduction in meal size (energy intake and amount of food consumed) was associated with the effect of DF on satiation. As satiation controls meal size (Forde, 2018), the results explained that BG28CAP noodles have the highest satiation, followed by BG28, CAP and Control noodles, respectively. It is supported with the satiation changes, as shown in the second column of Table 4.9. When an individual reaches his or her satiation, they will terminate the meal and inhibit further eating. Reduction in energy intake in fibre-enriched noodle meals is in line with previous studies that show the DF able to increase satiety by reducing energy intake in the subsequent meal (Archer, Johnson, Devereux, & Baxter, 2004; Jensen, Kristensen, Belza, Knudsen, & Astrup, 2012; Martini et al., 2018; Perrigue, Monsivais, & Drewnowski, 2009; Vitaglione, Lumaga, Stanzione, Scalfi, & Fogliano, 2009a).

The ability to absorb more water besides increasing viscosity, gelling in the stomach and ferment in the gut makes the dietary fibre a food ingredient that promotes satiety (Clark & Slavin, 2013; Slavin & Green, 2007). Oat soluble fibre viscosity increased gastric retention and reduced satiety hormones responses (Juvonen et al., 2009; Lyly et al., 2010). Viscosity, resistance to breakdown in the stomach, and ability to form gels within gastrointestinal tract delay gastric emptying and increasing bulks, made the DFs as good diet sources with a more prolonged feeling of satiety (Bellissimo & Akhavan, 2015; Campbell, Wagoner, & Foegeding, 2017; Dikeman, Murphy, & Fahey, 2006; Grundy et al., 2016; Hoad et al., 2004; Slavin, 2013). Delay in gastric emptying causes increased gastric volume and gastric distension, inhibiting the hunger-stimulating hormone ghrelin and prolonging satiety (Marciani et al., 2001; Mion et al., 2005).

Contrary to expectations, we did not find a significant effect of CAP in reduction of energy intake or amount of food consumed in CAP noodles. Even though our results differ from some published studies (Janssens et al., 2014; Westerterp-Plantenga et al., 2005; Yoshioka et al., 2004), they are still consistent with Rigamonti et al. (2018) and Smeets and Westerterp-Plantenga (2009) who found that CAP failed to reduce energy intake after CAP meals. Despite the fact that there was some inconsistency between our findings and some of previous literature on the effect of CAP on energy intake, there is interesting to note that CAP able to produce greater satiety with the presence of oat DF, as the energy intake and amount of food consumed decreased in BG28CAP noodle meal. It seems likely that synergy effect of DF and CAP may helpful in increasing satiety by considerable reduction in energy intakes and lower MH measures at '1H after' time point. This concurs well with Yoshioka et al. (2001) that found synergy effect between CAP and caffeine in decreasing cumulative energy and macronutrient intakes and a study by Reinbach and colleagues (2009) combination of CAP and green tea able to reduce energy intake during positive energy balance. The finding from this trial and other literature points towards the idea that to add CAP into high-satiated food formulations to boost the satiety effects of the products.

4.4.5.4 Correlations between RHSC measures, gender and BMI on Satiation and Satiety measures and food intakes

Results of the correlations between intuitive eating measures and satiety changes are shown in Table 4.11. Intuitive eating measures used in this trial were based on Reliance on Hunger and Satiety Cues (RHSC) measures that has been analysed in the previous Chapter 2. No significant interaction between RHSC measures and type of noodle meals on satiation and satiety (p>0.05) (Second column Table 4.11). Overall, Pearson's correlations show that RHSC measures did not affect satiety and satiation changes differently in Control and treatment noodle meals (p>0.05). We also found that participants in RHSC group 'High' consumed significantly more food than in 'Low' RHSC participants Table 4.12). Unexpectedly, these findings unable to demonstrate that individuals with high intuitive eating would eat in response to hunger and satiety cues. It is suggested that participants with high RHSC could not solely rely on their internal hunger or fullness perceptions to reach satiety but also need to consider other confounding factors such as psychological healths, ethnicity, BMI, physical activities and socio-economic status that could be affected their intuitive eating behaviours (Madden et al., 2012; Van Dyke & Drinkwater, 2014).

Table 4.11 Correlation between RHSC scores and Satiety ratings for Control and treatment noodle meals at pre-ingestive and post-ingestive period

	Noodles X RHSC*	All (n=23)		Control (n=7)		BG28 (n=5)		CAP(n=5)		BG28CAP (n=6)	
	P	r	P	*r*	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Pre-ingestive	0.132	-0.280	0.195	-0.572	0.180	0.342	0.573	0.590	0.295	0.192	0.716
Post-ingestive (1H)	0.895	0.216	0.322	-0.326	0.476	0.248	0.687	-0.870	0.055	0.540	0.269
Post-ingestive (2H)	0.628	0.398	0.059	-0.245	0.597	0.321	0.599	-0.870	0.056	0.748	0.087
Post-ingestive 3H	0.961	0.297	0.169	-0.634	0.126	0.246	0.689	-0.011	0.986	0.367	0.475

Associations between RHSC measures and satiation and satiety rating measures for individual noodle meals were conducted using Pearson correlations

*ANOVA analysis for RHSC groups and type of noodle meals interaction

r= Pearson correlation; *P*= probability value

Table 4.12 Relationship between RHSC, gender and BMI categories with energy intake and amount of food consumed at ad libitum lunch meal.

Category	Energy intake (Kcal)	Amount food (gram)
RHSC		
High (n=9)	698.91^{a}±101.65	633.75^{a}±82.19
Medium (n=6)	609.37^{ab}±150.75	584.83^{a}±112.96
Low (n=8)	561.26^{b}±41.57	553.88^{a}±24.35
Gender		
Male (n=7)	699.34^{a}±167.74	653.34^{a}±124.46
Female (n=16)	596.32^{b}±68.73	566.90^{b}±36.75
BMI		
Underweight (n=1)	491.42^{a}	483.89^{a}
Healthy weight (n=13)	611.64^{a}±99.59	584.84^{a}±69.52
Overweight (n=4)	712.90^{a}±184.09	650.96^{a}±143.29
Obese (n=5)	628.42^{a}±70.18	590.63^{a}±30.61

Data were reported in mean ± SD of amount of energy intake (kcal) and food consumed (in gram). The values with different superscripts in a column for each category differ significantly ($p < 0.05$)

Male participants significantly consumed higher amount (energy intake and weight) of food consumed than females ($p<0.05$). All males in the trial at least consumed the second portion of noodle meals and 3 of them asked for the third portion. Even though Pearson's correlations do not show any significant differences ($p>0.05$) between RHSC measures and the satiation and satiety changes in noodle meals, regardless the gender; but the energy intake and amount of foods show that gender plays an essential role in satiety study. This matches well with previous findings (Bédard et al., 2015; Vicky Drapeau et al., 2007; Ranawana & Henry, 2010) that found males consumed more energy than females. In general, females have lower energy requirements than males (Benelam, 2009), plus, the physiological regulation of appetite through sex hormones may partly lead to gender differences in satiation and satiety levels (Bédard et al., 2015). Specifically, the central and peripheral signals from some satiety hormones (e.g. ghrelin, cholecystokinin, insulin, and leptin) are influenced by female's estrogenic hormones (Asarian & Geary, 2006). Therefore, the hormones implicate in feedback control of eating and may mediate the estrogenic inhibition of eating during the consumption of a meal (Asarian & Geary, 2006). It is interesting to note that the differences in brain activation in integrating multiple hormonal, neural signals and sensory perceptions to satiety and hunger cues suggested that the regulation of food intake by the brain may vary between the genders (Del Parigi et al., 2002; Michon et al., 2009; Smeets et al., 2006).

BMI groups did not significantly affect amount of food consumed in ad libitum meals. There were no interactions between BMI groups with calories intake ($F(3,19)=1.343$, $p=0.29$) and food consumed (in grams) ($F(3,19)=1.347$, $p=0.29$). Our finding unsuccessful in proving that overweight and obese participants would consume more food than healthy and underweight participants. It can thus be reasonably assumed that external factors contributed to the differences in food intake such as cultural (Herman, Roth, & Polivy, 2003), social (Higgs & Thomas, 2016), eating disorder (Dalton, Blundell, & Finlayson, 2013) and environmental factors (Stroebele & de Castro, 2006; Wansink, 2004). As anticipated, some discrepancies in the correlation results due to the number of participants to test individual noodle meal were too small and only managed to complete 1 meal each. The differences in satiation and satiety measures and food intakes could be due to large inter-individual variations, rather than between noodle treatments.

4.5 Conclusion

In summary, the nutritional, cooking and textural properties of the noodle development revealed that enrichment of 25% of oat fibre flour improved the quality of wheat noodles. The BG28 noodles was found to contain the highest content of total, insoluble and soluble dietary fibres, followed by BG22, BG14 and Control noodles, respectively. Besides dietary fibre, the carbohydrates and protein contents also assist migration of water into the noodle texture network that led to softer noodle strands without significantly affect the cooking loss. Composition of these nutrients in fibre-enriched noodles also play important roles in prolonging satiety. Subjective satiety ratings using Mental Hunger items in different RHSC intuitive eaters failed to show any significant differences in satiation and satiety changes by four different noodle meals. However, the satiety trial demonstrated that BG28 fibre and capsaicin play a synergy effect in modulating satiety by reduced energy intake in ad libitum noodle meals consumption. The limited number of participants took part in the satiety trial, curtailed by Covid19, may led to the null findings in determining the effect of intuitive eating on satiety changes of different noodle meals. Therefore, further investigations with sufficient data collection are needed to evaluate the effect of dietary fibre and capsaicin on satiety responses in different intuitive eaters.

Chapter 5
GENERAL DISCUSSION

5.1 Summary of the research

The PhD project has advanced the knowledge by evaluating the satiety levels in different intuitive eaters using Rasch measurement analysis. Based on the literature, the Rasch Measurement Theory (RMT) application was tested as an alternative to Classical Test Theory in measuring intuitive eating and satiety instruments. The Intuitive Eating Scale-2 (IES-2) (Tylka & Kroon Van Diest, 2013) and 5-Factor Satiety Questionnaire (Karalus, 2011) were analysed using Rasch analyses (**Chapters 2** and **3**). It was hypothesised that the IES-2 measure was constructed from 4 dimensions. The dimensions were; Eating for Physical Rather Than Emotional Reasons (EPRE), Unconditional Permission to Eat (UPE), Reliance on Hunger and Satiety Cues dimension (RHSC), and Body-Food Choice Congruence (BFCC) dimensions. The latter scale, the 5-Factor Satiety Questionnaire measure, was hypothesised to build from five dimensions: Mental Hunger (MH), Physical Hunger (PH), Mental Fullness (MF), Physical Fullness (PF) and Food Liking (FL). The strategy to test these hypotheses involved a few Rasch procedures, including inspection of the data used fitted the Rasch models, items and person fits, model dimensionality test of Rasch PCAR and person separation using statistical levels. The hypothesis was supported, and person separation (grouping) was confirmed with Kmeans Clustering analysis using RStudio. The dimensionality of the Rasch models was reconfirmed with Exploratory Factor Analysis (EFA). The selection of fibre-enriched noodles for the satiety trial was decided based on the final product's cooking properties and textural attributes (**Chapter 4**). Finally, using different intuitive eaters from Chapter 2 and Mental Hunger items from Chapter 3, the effect of fibre-enriched and capsaicin noodle meals on satiety and food intake were measured (**Chapter 4**). New insights were generated on the prolonged satiety and reduction of ad libitum intake by the fibre-capsaicin noodles meals compared to control wheat noodle meals.

An overview of the thesis chapters and their outcomes are shown in Figure 5.1. Firstly, participants' responses were analysed and participants grouped into intuitive eating levels. The Rasch analysis analysis allowed the selection of and satiety items. Research then focused on the development of fibre-enriched noodles. In the final stage, the satiety perception in response to the noodles was evaluated in participants with different intuitive eating levels in a short-term satiety trial. The discussion chapter reflects the critical findings obtained in each working chapter of the thesis and considers the major study parameters. The implications of the results are discussed and recommendations for future directions are made.

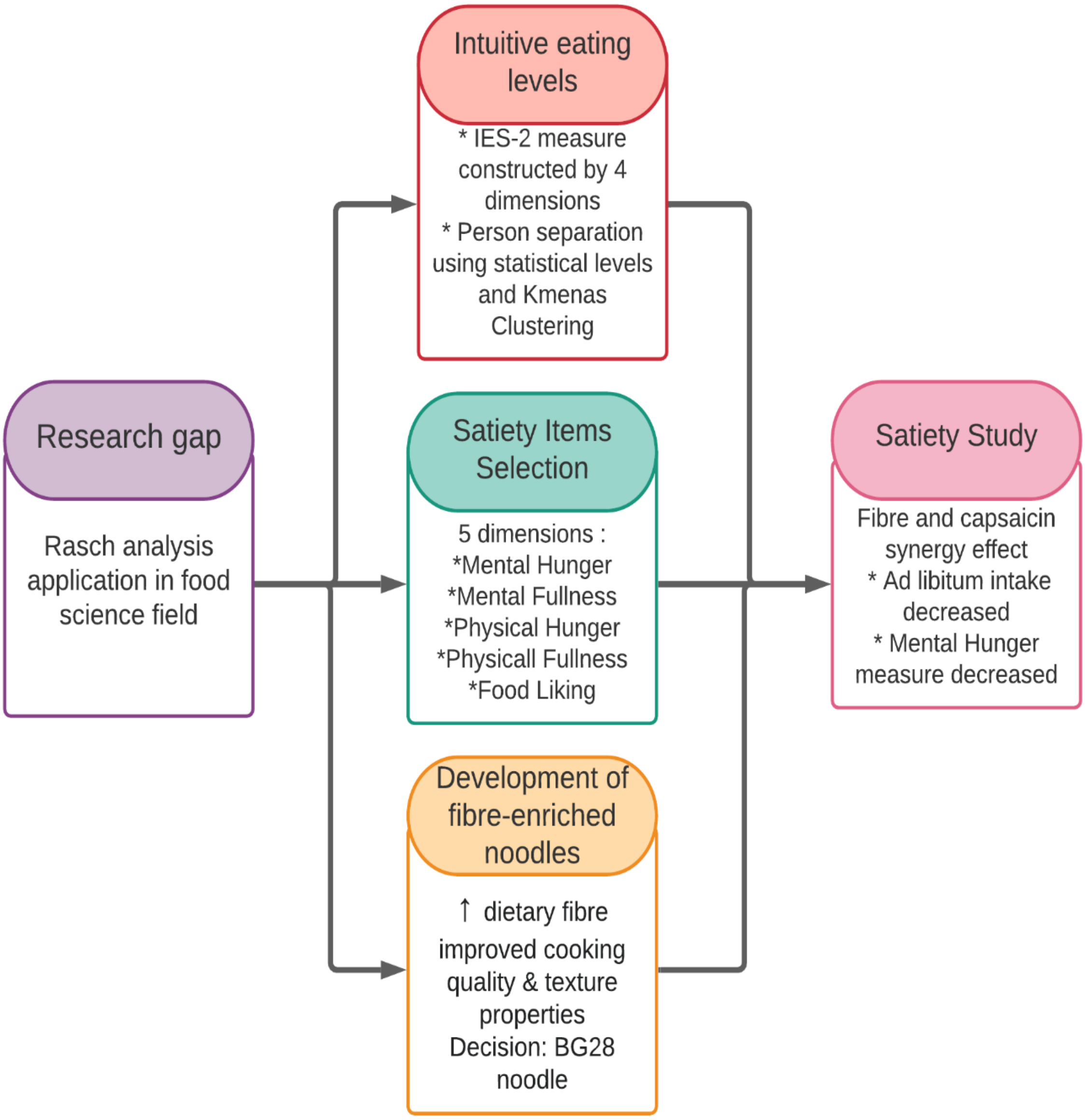

Figure 5.1 Thesis summary: association between intuitive eating and satiety items selection using Rasch analysis and fibre-enriched noodles development to the satiety measures and energy intakes.

5.2 Discussion points and contribution of the thesis

5.2.1 Improvement of an instrument using Rasch analysis application

Rasch analyses have been applied in working Chapters 2 to 4. As discussed in the subsection Material and Methods, the first step for Rasch analysis was examining the Global model fit of the data. The Global fit statistics show the data used fitted all the Rasch models; with less than 5% and 1% of absolute standardised residuals were ≥2 and ≥3, respectively. This statistic highlights the data fit the Rasch models, not the models fit the data as suggested by CTT models. When the data fit the model, the estimation procedure would recover the values of the parameters used to generate those values (Linacre, 2004). The invariance of items is independent and sample-free of its results and invariant when computed in groups with different abilities (Magno, 2009). Plus, the same individuals or groups can behave in a similar manner using another set of items, appropriate to their ability levels and the measure will be directly comparable.

The original Rasch Rating Scale Models (RSM), except for BFCC-R5 model, failed to meet some of the essential criteria for the proper functioning of a rating scale, as suggested by Linacre (2002). A rating scale's proper functioning is necessary because it helps eliminate noise and improve variable clarity of an instrument with improving the presentation and interpretation of the measure (Bond & Fox, 2015; Linacre, 2002). As a suggestion, the original models were revised by collapsing a few categories into appropriate categories. After the categories-collapsing, the revised models achieved the proper functioning of a rating scale. The collapsing categories should not from adjacent categories that qualitatively different meanings and resulting in a uniform frequency distribution (Bond & Fox, 2015; Linacre, 2002). Selection of optimal categories numbers in constructing a new instrument is important to achieve satisfactory scale reliability and appropriate research conclusions (Grondin & Blais, 2010). The usage of more categories tends to have the potential to convey more useful information and allow the researchers to discriminate between the responses in details (Weng, 2004). Still, it may reduce the clarity of meaning (Grondin & Blais, 2010) and enables the respondents to fail to distinguish reliably between adjacent categories (Weng, 2004) and increases inconsistency within and between respondents regarding the meaning they interpret to each response option (Wright & Linacre, 1992).

In order for the Rasch model to measure overall measurement, the instrument itself should be unidimensional, where the items relate to the same latent variable and in the same direction along with it (Bond & Fox, 2015). Rasch principal components analysis of residuals (PCAR) suggested that IES-2 could not function as a single total unidimensional Rasch measure, however, was built in of four unidimensional Rasch measures: EPRE, RHSC, UPE and BFCC measures (Chapter 2). For example, EPRE measure consists of 8 items that ask people about their agreement on statement about eating because of physical cues over emotional reasons. Whenever we closely look at all four latent variables, we may find similarities in which they measured intuitive eating, as suggested by Tylka and Kroon Van Diest (2013). Each Rasch measure can act as a unidimensional measure to precisely measure items related and require interpretation in specified contexts. PCAR in Chapter 3 failed to suggest that 5-Factor Satiety Questionnaire instrument was unidimensional. PCAR of All-PCM model showed that eigenvalue in first contrast is 8.3650 and disattenuated correlation between loadings 1 and 3 only 0.0759. There were five items related to food-liking towards foods that belonged to Cluster 3. We agree with Karalus (2011) that the food liking (FL) may potentially influence hunger and satiety feelings; however, FL items are not on the same latent as another 36 items. We decided to use Mental Hunger items for the satiety trial in Chapter 5. There were five Mental Hunger measure items widely used to measure satiety (Blundell et al., 2010). They may be useful to compare our findings with studies done by other researchers in the future.

5.2.2 Food materials as a factor in improving satiety

An increasing number of studies have indicated that dietary fibres (DF) positively impact noodles or pasta quality. Besides improving the DF content of the final product and prolong satiety, it also has positive effects on glycaemic, insulin and cholesterol responses, increases antioxidant properties, cooking quality and physical characteristics, etc. In Chapter 4, DF-enriched noodles were developed by substituting 25% (w/w) of wheat flour with three commercial oat fibre flour types. These oat fibre flours were processed mainly from oat bran and differ in DF content and rich in high molecular weight beta-glucan (β-glucan) (14-28g of β-glucan/100 g flour). β-glucan is well evidenced for positive health effects (European Food Safety Authority (EFSA), 2011). The cooking quality and texture properties of the control and treatment noodles were examined, as these two play high potentials for consumer acceptance.

The optimal cooking time (OCT) could be shortened with the increasing DF content, as the BG28 noodles exhibited the shortest OCT, followed by BG22, BG14 and Control noodles, respectively. The distortion of the gluten network by DF and other components allows water to penetrate the core of the noodle strand. Consequently, it increased the cooked weight of the noodles without affected the cooking loss significantly. It explains the DF's ability to absorb water and form viscous gels that may promote satiety by a number of mechanisms. Regardless of DF levels, our noodle formulations were considered good quality, with the cooking losses were less than 12% (Fu, 2008) and comparable to the Control noodles. The cooking loss occurred due to the substitution of the DF with the starch-protein network, allowing more gelatinised starch to leach out from the noodle during cooking and decrease cooking quality (Makhlouf et al., 2019).

The noodles' texture was influenced by DF content, where the higher DF content, the softer, and the stickier of cooked noodles. As mentioned earlier, the presence of DF distorted the gluten network. β-glucan, which is highly hydratable, allowed the water to diffuse to the starch granules, increasing the water absorption and starch swelling, thus reducing the noodle firmness (Brennan & Tudorica, 2007). The relationship between texture and satiety is explained as follows. Mastication of firmer or viscous food increases the 'oro-sensory exposure time' (time spent in the oral cavity) (Bolhuis et al., 2014; Chambers, 2016; De Graaf, 2011). This stimulates sensory signalling related to increased satiation and reduced intake within the meal (see Figure 4.6 and Table 4.10 in Chapter 4). The findings aligned with the satiety cascade model proposed by Blundell (1987) that highlighted the importance of sensory signalling (food texture) in satiety. Besides the texture of the food that enters the stomach, the viscous characteristics of DF-enriched foods also reported being more satiating, perhaps because they slow the gastric emptying rate (Juvonen et al., 2009).

In our study, the amount of fibre used was fixed (25% w/w) in all formulations for DF-enriched noodles. Plus, we did not focus on the effect of ranges of DF concentration. The amount of DF added into formulations can create the alteration and deterioration to pasta and noodles that face challenges of limited consumer acceptability (Makhlouf et al., 2019). Thus, to provide a better understanding, the optimum amount of substitution needs to be explored. It will help the researchers to find the optimal food product conditions that affect the satiety without neglecting the physicochemical and nutritional properties.

To date, there is still no study on the combination of DF and capsaicin (CAP) in improving satiety has been done. The previous studies extensively look at the effects of DF or CAP on its own or associated with other food materials on the food intake, biochemical responses and subjective satiety ratings. The findings on the reduction of Mental Hunger (MH) measures and ad libitum intake in BG28CAP noodle meal explained that both ingredients work synergically in improving satiety. The BG28 fibre which originally from oat grain, is rich in β-glucan. The insoluble and soluble fibre properties of β-glucan and other DF in BG28 fibre help modulate satiety and energy intake through its physicochemical properties including viscosity, water-holding capacity, fermentability and physical structure effects (Hervik & Svihus, 2019). The differences in proximate compositions between Control and BG28 noodles, as presented in Table 4.4, could also affect the satiety measurement. The different satiating effects of the macronutrients protein, carbohydrate, fat and fibres explain why not all calories will have the same impact on satiety and hugely influential in the development of enhanced satiety foods (Chambers et al., 2015).

Simultaneously, the CAP may affect satiety by increasing the thermogenesis, lipid oxidation and reducing fat tissue (Whiting et al., 2012). The CAP's effect on appetite and energy intake is influenced by the dosage or concentration given. Previous studies apply different CAP concentrations to investigate the impact on appetite (Ludy & Mattes, 2011; Westerterp-Plantenga et al., 2005; Yoshioka et al., 2004). Further investigation in this area would be very informative in defining the optimum level of ingredients to provide significant outcomes. However, the DF-CAP synergistic mechanism remains unclear, and more evidence is needed to understand them completely.

All this clearly points out that it is essential to focus on the field of mechanisms of the different ingredients that affect the quality of food products in terms of technological and nutritional aspects that could improve satiety in order to reduce the risk of obesity.

5.2.3 Advantages of Rasch Measurement application in Food Science and Nutrition field

Rasch measurement theory offers an alternative approach in developing and measuring instruments besides Classical Test Theory. It has been widely applied in other disciplines such as education, medicine and psychology, but there were little to no literature was found have been done in food-related fields. There are four advantages of using Rasch analysis in sensory measurement.

1. Overall measure
   In sensory evaluation, scaling is used to describe the perceived intensity of a sensory experience of the degree of liking or disliking for individual's experience or product (Lawless & Heymann, 2010). Various scaling methods have been widely used, including category scales, line marking and magnitude estimation. Rasch model can be applied to produce interval-scaled estimates of a single measure constructed with unidimensional latent sensory attributes representing the overall measure (Ho, 2019).

2. Reducing biases in sensory judgment
   People tend to bias in judging a sensation or a product that could be influenced by factors such as gender, focus group and interest over time and space etc. It may lead to an inaccurate reflection of the actual sensory experience. For example, an item's statement is somehow more easily understood by the adult group than the adolescent group. With Rasch Differential Item Functioning (DIF) analysis, the bias measurement could be detected and allow the researcher to revise the instrument or interpret an item's measure differently for the two or more compared groups.

3. A straightforward interpretation of findings
   Wright maps have been illustrated to represent the relationship between the distributions of person and item measures plotted along a vertical logit scale. Plotting the Wright map allows the researchers to evaluate an instrument's strengths and weaknesses and how well the test items define a variable by comparing the predicted order of items difficulty with the actual one. Moreover, it will enable the researchers to determine how well the test items are distributed regarding the respondents' ability level or vice versa. For example, the respondents rate a hedonic scale to measure their

liking towards new food products. The Wright map provides the idea that the attributes located at the top of the map are less preferred and rated using low category numbers, and opposite with those at the bottom. It is essential to take them into consideration in decision making.

4. Suitable analysis for a time-dependent study
   Repeated measures using Rasch analysis are suitable for analysing the studies that required the panellists to evaluate an instrument for specific periods or time series; e.g. at every 30-minute, hour or day. The analysis prevents the dependency from distorting the estimated measures since the items difficulties and Rasch-Andrich thresholds are anchored and stacked at their values.

5.2.4 Limitation

We acknowledge the following limitations of the thesis. Due to pandemic Covid-19, our final study was partially completed. The 23 participants only managed to complete Day 1 satiety trial. It means that about 5 to 6 persons tested only one out of 4 noodle meals. Besides, the effect of intuitive eating levels on the different noodle meals could not be assessed. The number of participants presented at each level was minimal and may not be represented enough. Secondly, the satiety trials in Chapters 3 and 4 were recruiting individuals who stay in Leeds, and the majority of them were students and staff of the University of Leeds. They may share some commons and may not represent the whole population. It tends to lead the challenges regarding representativeness, generalisability and comparability of the findings. In new product development (NPD), raw materials' cost plays a crucial role because it will affect in final price. Even though the fibre-enriched noodle made from oat fibre BG28 exhibited the best quality compared to BG14 and BG22, however, the price of BG28 was the most expensive. So, we should consider the cost of raw material in the future.

5.3 Future directions

Based on this study findings, there is an excellent opportunity for further research and development in this area. There are also some suggestions to expand the scope of the study. Some of these suggestions are addressed as follows:

5.3.1 Revision of categories numbers and labels used in rating scales

Rasch analyses show that proposed categories of Intuitive Eating Scale-2 (IES-2) (Tylka & Kroon Van Diest, 2013) and 5-Factor Satiety Questionnaire (Karalus, 2011) in **Chapter 2** and **Chapter 3**, respectively, did not function properly. The Rasch-Andrich thresholds in all models, except for the MH-R-8 model, were suggested to collapse into fewer categories to improve the scale category effectiveness. The collapsing step allows at least two categories to share the same scale in the revised model. It is recommended to re-examine and rename the collapsing categories with the appropriate new labels and easily understood by other researchers to use the instruments with revised categories. The revision is essential to allow the participants to rate the instruments using the right categories.

5.3.2 The long-term effectiveness of fibre-capsaicin meals on satiety

The study in **Chapter 4** successfully proved that high fibre and capsaicin can prolong satiety at acute energy intake in ad libitum meal and reduce in Mental Hunger measures. Nevertheless, the findings did not reflect the long-term effect, as the satiety study was done only for a one-day trial. Therefore, further work is proposed to prolong the trials over longer periods, such as weeks or months using larger targets (adolescents, adults or the elders). It is useful to integrate physiological measures by measuring changes in satiety biomarkers (peptide hormones, blood serum etc.) and gastric emptying rate in the pre- and post-ingestion periods to understand the different physiological mechanisms that underpin eating behaviour. Apart from that, it is suggested to measure ‘expected satiety’ as guidelines and motivations in selecting food (amount of food, types, energy intakes) and portion size that play a crucial key to satisfy hunger and achieve satiation and extend the satiety. Finally, to extrapolate the effects to the longer-term satiety effects, it is suggested to quantify satiety by calculating the calories intakes and food variety intakes between the trial and next meals periods, e.g. using food diaries.

5.3.3 Sensory and tribology attributes of noodle texture.

Texture properties of fibre-enriched noodles in **Chapter 4** were analysed using a texture analyser. It is useful to apply sensory evaluation techniques (intrinsic subjective test) to support instrumental measurements (objective test) to evaluate the quality of final products and predict consumer responses towards the products, as the degree of liking and the overall acceptance. It would also be useful to assess tribology or microstructural eating patterns; such as by measuring bite-size, bite rate, number of bites, chews per bite, and average eating rate associated with different treatment noodles. It is because texture attributes play essential roles in the control of satiation, satiety and caloric intake.

5.3.4 Exploration of Rasch analysis software

Analysing of Rasch models in the thesis using Winsteps software (Linacre, 2019). The Rasch analysis is not limited for Winsteps users only, as it can be analysed using other statistical analysis software such as RUMM, RStudio, SPSS and Microsoft Excel. Variety of software that are available to be used assist the researchers to explore the application of Rasch models in many fields. It is recommended to introduce Rasch analysis in Food Science-related modules such as Sensory Evaluation and NPD, as the models are good to be applied in those fields.

5.4 Conclusion

Despite these reflections highlighting limitations and future works, this thesis's overall outcome has been demonstrated by applying Rasch analysis in consumer research and sensory sciences. The exploration of Rasch analysis could be introduced to the broader aspects, especially new product development (NPD) areas. The present instruments that have been developed could be revised and improved with Rasch models. The Wright map illustrated that each item and individual represent specified difficulty and ability, respectively. The BG28 oat fibre and capsaicin synergically played essential roles in improving satiety in people with different intuitive eating levels. Thus, these two ingredients could be potential sources for producing healthy satiated food products to combat obesity.

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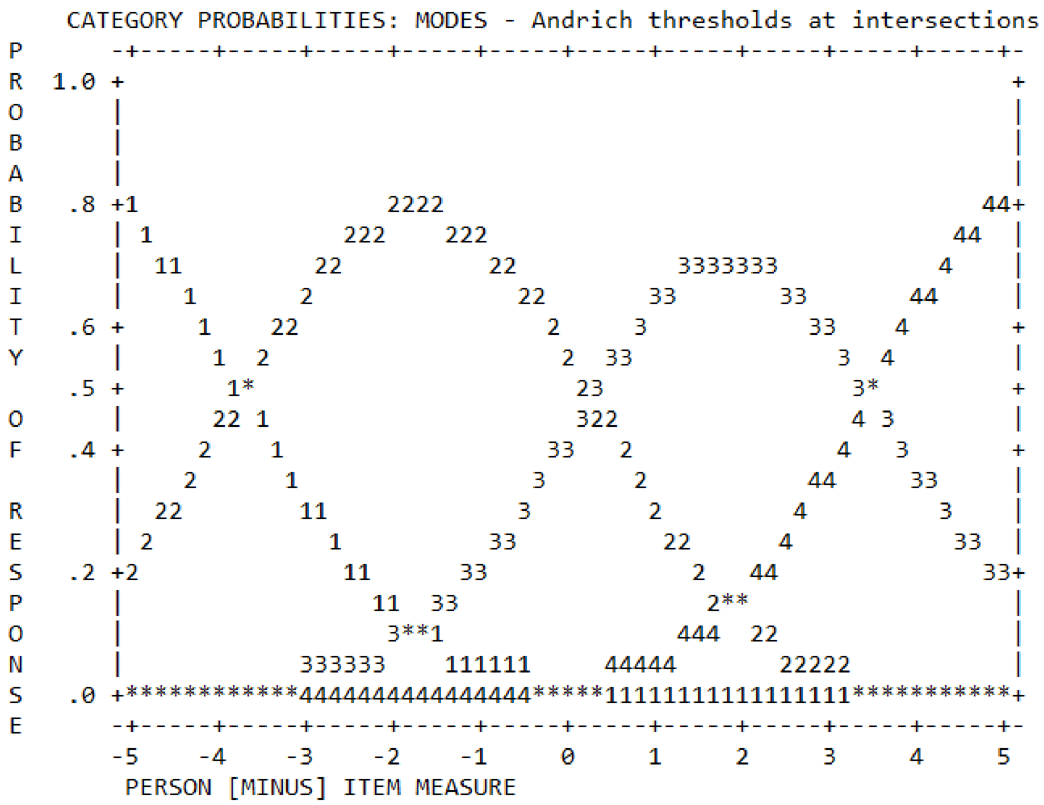
Appendices

Appendix A

A.1 Response category probability curves for the initial Rasch Rating Scale Model (RSM) for EPRE-R5

```
  CATEGORY PROBABILITIES: MODES - Andrich thresholds at intersections
P      -+-----+-----+-----+-----+-----+-----+-----+-----+-----+-
R  1.0 +                                                       +
O      |                                                       |
B      |                                                       |
A      |                                                    555|
B   .8 +1                                                  5   +
I      | 11                                              55    |
L      |   1                           444444           5      |
I      |    1                        44      44        55      |
T   .6 +     1      22222           4          44    5         +
Y      |      1   22     22        4             4  5          |
    .5 +       1*2         2      4               45           +
O      |       2 1          2    4                544          |
F   .4 +      2   1          2  4               55   4         +
       |    22     1          24               5      4        |
R      |   2        1       33**333           5        44      |
E      | 22          1     33 4  2  33       55           4     |
S   .2 +2             1133  4    2   33    5              44   +
P      |              3311 4      22   33*5                 444|
O      |           333   4*1        22555 33                   |
N      |       3333   444   1111  5555222   333333             |
S   .0 +**************5555555555**1111111**********************+
E      -+-----+-----+-----+-----+-----+-----+-----+-----+-----+-
       -4    -3    -2    -1     0     1     2     3     4     5
        PERSON [MINUS] ITEM MEASURE
```

A.2 Response category probability curves for the revised Rasch Rating Scale Model (RSM) for EPRE-R4 after collapsing to 12234 scales



A.3 Comparison between original category (Category 12345) with collapsing categories (Category 12234 and 12334) for EPRE models

Categorisation	Rasch-Andrich Threshold	Fit	Category measures	Separation		Reliability	
				Person	Item	Person	Item
12345	Disordered	<2.0	Ordered	2.28	11.34	0.84	0.99
12234	Ordered	<2.0	Ordered	2.17	10.01	0.82	0.99
12334	Ordered	<2.0	Ordered	2.03	10.33	0.80	0.99

Appendix B

B.1 Response category probability curves for the initial Rasch Rating Scale Model (RSM) for RHSC-R5

```
   CATEGORY PROBABILITIES: MODES - Andrich thresholds at intersections
P      -+---------+---------+---------+---------+---------+---------+-
R  1.0 +                                                             +
O      |                                                           55|
B      |                                                        555  |
A      |                                                      55     |
B   .8 +1                                 4444              55       +
I      | 11                             44    44           5         |
L      |   1         2222              4         44         5          |
I      |    1      22    2           44           4      5           |
T   .6 +     1    2       22        4              4    5            +
Y      |      1 22          2       4               4  5             |
    .5 +       *            2      4                 45              +
O      |      2 1            2    4                  54              |
F   .4 +     2   1            2334                  5  4             +
       |    2     1          3324333              55    44           |
R      |   2       1       33   *   3            5        4          |
E      | 22         1     3    4 2   33         5          4         |
S   .2 +2            1  33    4   2    33      5            44       +
P      |              1*     4     2     33  55               44     |
O      |            333 11 44       22    5**                   444  |
N      |        3333    44*111        ***5   33333                 44|
S   .0 +****************555555********111****************************+
E      -+---------+---------+---------+---------+---------+---------+-
       -5        -3        -1         1         3         5         7
        PERSON [MINUS] ITEM MEASURE
```

B.2 Response category probability curves for the revised Rasch Rating Scale Model (RSM) for RHSC-R4 after collapsing to 12234 scales

```
  CATEGORY PROBABILITIES: MODES - Andrich thresholds at intersections
P      -+---------+---------+---------+---------+---------+---------+-
R  1.0 +                                                             +
O      |                                                             |
B      |                                                             |
A      |               22222222                                      |
B   .8 +             22        22               33333              44+
I      |11          2            22           33     33           4  |
L      |  1        22              2        33         33        4   |
I      |   1     2                  2      3             3    44     |
T   .6 +    1   2                    2    3               3   4      +
Y      |     1 2                      2  3                 3 4       |
    .5 +      *                        23                   *        +
O      |     2 1                       32                  4 3       |
F   .4 +    2   1                     3  22               4   3      +
       |   2     1                   3     2             4     3     |
R      |  2       1                33       2           4       33   |
E      |22         11             3          2         4          3  |
S   .2 +             1          33            22     44            33+
P      |              11       3                2   4                |
O      |                111 333                  ***                 |
N      |               3333*1111            44444   22222            |
S   .0 +***************444444444************1111111111111************+
E      -+---------+---------+---------+---------+---------+---------+-
       -6        -4        -2         0         2         4         6
        PERSON [MINUS] ITEM MEASURE
```

B.3 Comparison between original category (Category 12345) with collapsing categories (Category 12234 and 12334) for RHSC models

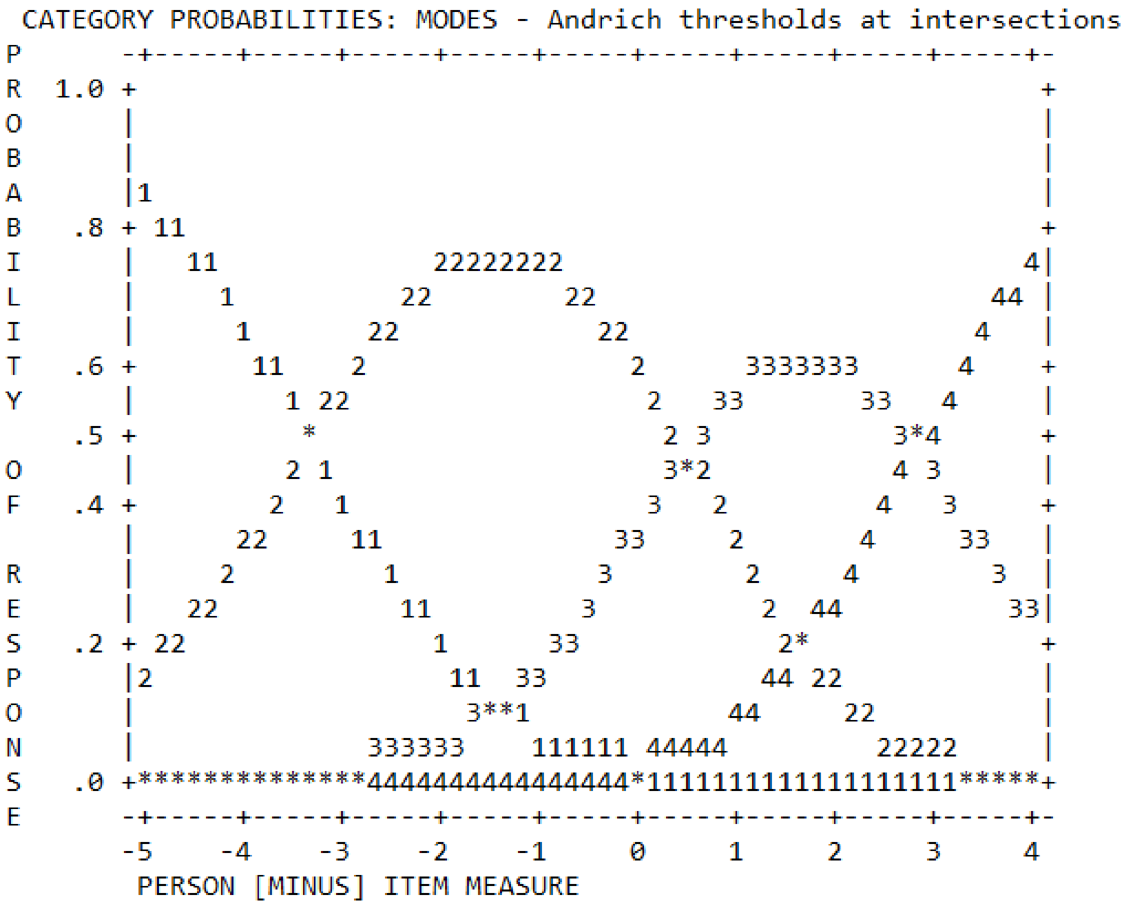
Categorisation	Rasch-Andrich Threshold	Fit	Category measures	Separation		Reliability	
				Person	Item	Person	Item
12345	Disordered	<2.0	Ordered	1.82	3.34	0.77	0.92
12234	Ordered	<2.0	Ordered	1.73	3.42	0.75	0.92
12334	Ordered	<2.0	Ordered	1.25	2.76	0.61	0.88

Appendix C

C.1 Response category probability curves for the initial Rasch Rating Scale Model (RSM) for UPE-R5

```
  CATEGORY PROBABILITIES: MODES - Andrich thresholds at intersections
P      -+------+------+------+------+------+------+------+------+-
R  1.0 +                                                         +
O      |                                                         |
B      |                                                         |
A      |11                                                      5|
B   .8 +  11                                                  55 +
I      |    11                                              55   |
L      |      11                                          55     |
I      |        1                                        5       |
T   .6 +         1                          4444        5        +
Y      |          11    22222             44    444   55         |
    .5 +            1222     22         44         445           +
O      |            21         22      4            544          |
F   .4 +          22  1          2    4           55   4         +
       |        22     11         *33*3          5      44       |
R      |      22         1     333 **  33       5         44     |
E      |    22            1  33   4  2   33   55            44   |
S   .2 +  22               **    4    2    335                44 +
P      |22               33  1144      22  55333                4|
O      |              333    4411       5**     333              |
N      |         33333   4444    111*555   2222    33333         |
S   .0 +*****************55555555555 1111111111******************+
E      -+------+------+------+------+------+------+------+------+-
       -4     -3     -2     -1      0      1      2      3      4
        PERSON [MINUS] ITEM MEASURE
```

C.2 Response category probability curves for the revised Rasch Rating Scale Model (RSM) for UPE-R4 after collapsing to 12234 scales



C.3 Comparison between original category (Category 12345) with collapsing categories (Category 12234 and 12334) for UPE models

Categorisation	Rasch-Andrich Threshold	Fit	Category measures	Separation		Reliability	
				Person	Item	Person	Item
12345	Disordered	<2.0	Ordered	1.18	15.37	0.58	1.00
12234	Ordered	<2.0	Ordered	1.63	9.25	0.73	0.99
12334	Ordered	<2.0	Ordered	1.02	13.76	0.51	0.99

Appendix D

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UNIVERSITY OF LEEDS

Hanis Binti Mat Gani
School of Food Science and Nutrition
University of Leeds
Leeds, LS2 9JT

MEEC Faculty Research Ethics Committee
University of Leeds

19 November 2021

Dear Hanis

Research title	**The effects of fibre-enriched starch noodles on sensory and satiety responses in consumers categorised by their attitude to food.**
Ethics reference	**MEEC 16-040**
Amendment date:	**11 January 2019**

I am pleased to inform you that the amendment to the application listed above has been reviewed by the Deputy Chair of the MaPS and Engineering joint Faculty Research Ethics Committee (MEEC FREC) and I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	*Version*	*Date*
MEEC 16-040 amendment Jan 2019 Amendment_form_V2	1	11/01/19
MEEC 16-040 amendment Jan 2019 AN ETHICS REVIEW FORM Hanis Gani (Amendment V2)	1	11/01/19
MEEC 16-040 amendment Jan 2019 APPENDIX 2_Participant Information sheet_participant V3	1	11/01/19
MEEC 16-040 amendment Jan 2019 APPENDIX 12_Satiety_Protocols	1	11/01/19

Please notify the committee if you intend to make any further amendments to the original research as submitted at date of this approval, including changes to recruitment methodology. All changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, Research & Innovation Service
On behalf of Dr Dawn Groves, Chair, MEEC FREC