Exploring the relationship between dietary patterns, eating behaviour and fat taste detection thresholds

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Abstract

Background: Dietary pattern analysis provides a unique opportunity to explore combinations of food intake in conjunction with factors known to affect dietary intake. Fat taste sensitivity is an emerging correlate of dietary intake and, when impaired, has a proposed role in the dysregulation of dietary intake and eating behaviours.

Aim: To investigate dietary patterns, eating behaviours and fat taste detection thresholds in a group of New Zealand European women aged 19-45 years and identify associations between these factors.

Methods: Fifty post-menarche, pre-menopausal New Zealand European (NZE) women, (18-40 years) completed a partially validated, semi-quantiative 220-item food frequency questionnaire and a validated Three-factor eating questionnaire. Height and weight were measured to calculate body mass index (BMI) (kg/m^2) and a bioeletrical impedence analysis (BIA) was completed to measure body fat percentage (BF%). During sensory testing protocol participants were exposed to increasing concentrations of ultra-heat treatment (UHT) milk/oleic acid (OA) solutions using the three alternative forced choice method (3-AFC). A naïve OA detection threshold was determined at the point where the participant identified the OA solution correctly three times at the same concentration. Dietary patterns were determined using principal component factor analysis. Associations between dietary pattern scores, taste sensitivity, eating behaviour and baseline characteristics were investigated.

Results: Three dietary patterns were identified: 'unhealthy', 'healthy' and 'snacking'. Most women had low eating behaviour scores for cognitive restraint (90%) and disinhibition (74%). Hunger scores were comparatively higher, only 40% had low scores. Twenty-three participants (46%) were classified as hypersensitive and 54% were hyposensitive to OA taste. 'Unhealthy' pattern scores were inversely associated with cognitive restraint (r=.391, P=.005) and positively associated with age (r=.297, P=.036). 'Healthy' pattern scores were positively associated with cognitive restraint (r=.418, P=.003), OA taste detection thresholds (r=0.446, P=.001) and BMI (r=.325, P=.021). Women with low 'snacking' pattern scores were significantly older (31.7 years (24.7, 40.4)) than those with moderate scores (24.0 years (22.0, 28.1)) (P=.037). No relationship was found between OA taste detection thresholds and eating behaviour.

Conclusion: Participants in this study showed a significant link between habitual dietary intake and measures for eating behaviour and fat taste sensitivity. Both ‘healthy’ and ‘unhealthy’ dietary patterns were associated with one, or both, of these factors. An unexpected positive association between the ‘healthy’ dietary pattern and fat taste sensitivity indicates a need for further investigation to better understand this relationship. Findings from the current study support the use of dietary patterns to better represent habitual intake in future research investigating fat taste sensitivity or eating behaviour.

Key words: Habitual intake, dietary intake, fat taste sensitivity, cognitive restraint, disinhibition, hunger

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Abbreviation List

3-AFC	Three Alternative Forced Choice
5-HT	5-hydroxytryptamine
AMDR	Acceptable Macronutrient Distribution Range
AMPM	Automated Multiple Pass Method
ATP	Adenosine Triphosphate
BF%	Body Fat Percentage
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
CVD	Cardiovascular Disease
DASH	Dietary Approaches to Stop Hypertension
DEBQ	Dutch Eating Behaviour Questionnaire
DFE	Daily Frequency Equivalent
EDTA	Ethylenediaminetetraacetic acid
EXPLORE	Examining The Predictors Linking Obesity Related Elements
FFA	Free Fatty Acid
FFQ	Food Frequency Questionnaire
GPCR	G-Protein-Coupled Receptor
GPR120	G-Protein Receptor 120
ICC	Intra-class Correlation
LCFA	Long Chain Fatty Acid
MOH	Ministry of Health
NZE	New Zealand European
NZW-FFQ	New Zealand Women's Food Frequency Questionnaire

OA	Oleic acid
TEI	Total Energy Intake
TFEQ	Three-factor Eating Questionnaire
TRC	Taste Receptor Cell
UHT	Ultra Heat Treatment
WHO	World Health Organisation

Chapter 1 – Introduction

1.1 Background and study justification

Like a finger print, dietary intake is unique for every individual, however when investigating habitual food intake distinct patterns of consumption are evident (Kant, 2004). Dietary patterns provide a necessary alternative to traditional measures of dietary intake (i.e. nutrients or foods items) by considering multiple food components and combinations at once (Moeller et al., 2007). Relationships between dietary patterns and health outcomes have become a popular area of research, resulting in publicly recognised diets, including the Mediterranean diet and the 'Dietary approaches to stop hypertension' (DASH) diet (Moeller et al., 2007). Adherence to recommended 'healthy' dietary patterns is often suboptimal (Kant, 2004; Ministry of Health, 2011a). Therefore, it is necessary to identify the factors which are associated with both favourable, and unfavourable patterns of dietary intake. Determinants of dietary intake form an extensive and complex web, including genetic, environmental, social, cultural, economic, physiological and psychological influences (Kant, 2004). Understanding these influences and establishing how they interact can produce significant opportunities for health intervention.

Taste is known to play a significant role in food choice and eating behaviour (Gibson, 2006). There are five recognised primary tastes (sweet, salty, bitter, sour and umami), however fat has recently been proposed as the sixth taste quality (Liu, Archer, Duesing, Hannan, & Keast, 2016). Furthermore, evidence suggests that sensitivity to fat taste may be associated with dietary intake, and dietary intake-related behaviours such as overconsumption of foods (Keast, Azzopardi, Newman, & Haryono, 2014). Given the newness of fat taste sensitivity, research is limited. Associations with dietary intake and behaviour have been inconsistent and need further investigation (Stewart, Newman, & Keast, 2011).

1.1.2 Defining dietary patterns

Traditionally nutrition research has focussed on how specific nutrients, or foods, played a role in creating potentially beneficial or harmful effects on health (Tucker, Tucker, Bailey, & LeCheminant, 2015). However, foods and nutrients are rarely consumed in isolation. Additionally, by studying the components of food independently it is possible, and even likely, that we may overlook the synergistic effects of dietary combinations consumed in a normal diet (Moeller et al., 2007). A review by Kant (2004) has suggested that dietary patterns are also appropriate for investigating determinants of dietary intake. The patterns are thought to more accurately reflect social, cultural, genetic, health and lifestyle determinants (Kant, 2004).

The four most commonly used methods for assessing dietary patterns are score-based methods, factor analysis, cluster analysis and reduced rank regression analysis (Hu, 2002). Both score-based methods and reduced rank regression analysis require adequate existing research to make decisions regarding predictor variables and patterns (Ocke, 2013). Factor analysis and cluster analysis are data-driven methods which identify combinations of dietary variables commonly consumed in a specified population (Hu, 2002). Factor analysis produces a continuous dietary pattern measure and cluster analysis is categorical (Moeller et al., 2007). Factor and cluster analysis are the best methods to use when limited research has been conducted (Moeller et al., 2007).

When comparing research that investigates dietary patterns, ideally it is better to use studies which have been conducted in participant groups from populations with similar demographics. New Zealand women of a reproductive age are a key population in which statistically derived dietary patterns have been assessed in New Zealand. This group of women also have the highest rates of overweight and obesity, which is concerning due to the potential health repercussions for future offspring (Ministry of Health, 2016).

Four studies of dietary patterns have been conducted in the New Zealand adult female population. (Beck et al., 2013; Schrijvers, McNaughton, Beck, & Kruger, 2016; Thompson et al., 2010; Wall et al., 2016). Each study was able to identify specific demographic characteristics which were associated with one or more dietary patterns. Additionally, those who studied health outcomes also found associations between dietary patterns and markers of health. For example, Beck et al. (2013) found that a dietary pattern high in milk and yoghurt was positively associated with a risk of suboptimal iron status.

Additionally, several of the New Zealand studies identified dietary patterns that were consistent with well-established patterns found in research from other countries. This was particularly true for the 'junk' dietary patterns identified by Thompson et al. (2010) and Wall et al. (2016) which consisted of foods high in sugar, fat and salt, including takeaways, chips, ice cream, cakes and biscuits. These dietary components are consistent with those found in a 'western' dietary pattern (Hu, 2002; Rodriguez-Monforte, Flores-Mateo, & Sanchez, 2015). The 'western' dietary pattern has been associated with increased risk of type II diabetes, colon cancer, coronary heart disease (Kant, 2004; Rodriguez-Monforte et al., 2015) and liver disease

(Oddy et al., 2013). Therefore, identifying factors which may reduce adherence to similar patterns is beneficial.

1.1.2 Linking eating behaviour and dietary intake

Eating behaviour encompasses the patterns of behaviour and habits people commonly adhere to around food (Provencher, Drapeau, Tremblay, Després, & Lemieux, 2003). There have been themes established, particularly around behaviours for cognitively restrained eating, disinhibited eating and hunger (Gibson, 2006; Stunkard & Messick, 1985). Questionnaires have been developed which provide scores for different eating behaviours (van Strien, Frijters, Bergers, & Defares, 1986). Scores for restrained eating have been found to be inversely significantly correlated to body mass index (BMI), while scores for uncontrolled or disinhibited eating have been found to positively correlate to BMI (Keskitalo et al., 2008).

Specific eating behaviours have also been found to have a significant impact on the way food is consumed. Studies show that non-obese people are more likely to slow their rate of eating toward the end of a meal (Chambers & Yeomans, 2011). Conversely, people who are obese are more likely to eat at the same rate from start to finish. This behaviour is attributed to disinhibited eating, but may also reflect a physiological dysfunction of impaired satiety (Chambers & Yeomans, 2011). It is reasonable to suggest that some aspects of eating behaviour linked to appetite regulation, have a neuroendocrinological basis (Chambers & Yeomans, 2011; Keast et al., 2014).

1.1.3 The role of fat taste sensitivity

Increasingly, taste is being investigated for its role in the signalling pathways which govern the body's response to incoming food (Cvijanovic, Feinle-Bisset, Young, & Little, 2015). The physiological mechanisms of taste have multiple functions which include: signalling appeal or safety of items in the oral cavity, providing feedback to the digestive system about incoming food, and assisting in the regulation of satiety (Liu et al., 2016).

To date, fat has largely been recognised for its contribution to the aroma and texture (or mouth-feel) of a food (Besnard, Passilly-Degrace, & Khan, 2016). However, recent evidence has indicated that fat may also meet the key requirements of a primary taste quality. Previous review studies have indicated that a key challenge for achieving a consensus on sensory thresholds for fat taste, is the wide range of methodologies used to test this variable (Cox, Hendrie, & Carty, 2016). A standardised procedure for assessing fatty acid taste thresholds has now been published (Haryono, Sprajcer, & Keast, 2014). However, there is limited research where this methodology has been carried out at the same time as a full dietary assessment.

Recent research has proposed that individuals with higher thresholds of fat taste sensitivity are also more likely to consume a diet higher in fat, and therefore, are more likely to suffer from poor health outcomes such as obesity (Keast et al., 2014; Stewart et al., 2010). However, the existing evidence is inconclusive, as Tucker et al. (2014) found no relationship between intake of dietary fat and fat taste sensitivity. Although it may be possible to demonstrate this relationship in a controlled environment, the relative effects on complete dietary intake may be negligible (Keast et al., 2014). Therefore, it is important to compare these newly established measures of fat taste sensitivity to whole dietary patterns in order to better understand any relationships which may exist. Knowledge of such relationships may contribute to the development of screening tools, based on sensory perception, which could be used to identify members of the population for targeted dietary intervention (Stevenson, 2017). Additionally, the ongoing investigation of potential links between habitual dietary intake and sensory perception of foods is an integral part of promoting product reformulation within the food industry for better health.

1.2 Aims and Objectives

The aim of this study is firstly to investigate dietary patterns, eating behaviours and fat taste detection thresholds in a group of New Zealand European women aged 19-45 years; and secondly to identify associations between these factors.

1.2.1 Specific objectives

1. To describe the dietary patterns, eating behaviours and fat taste detection thresholds in a group of New Zealand European women aged 19-45 years.
2. To establish associations between dietary patterns and eating behaviours described as cognitive restriction, disinhibition and hunger.
3. To establish associations between dietary patterns and fat taste detection thresholds in female adults.
4. To determine the association between fat taste detection thresholds and eating behaviours.

1.2.2 Hypothesis

It is hypothesized that adherence to dietary patterns will be associated with eating behaviour scores and OA detection thresholds in 50 New Zealand European women, aged 19-45. A secondary hypothesis is that eating behaviour scores will be associated with OA taste detection thresholds for these women.

1.3 Structure of the thesis

This thesis consists of five chapters. Chapter 1 provides the introduction to key concepts and the significance of the study. Chapter 2 reviews the relevant literature outlining the role of dietary patterns, the impact of eating behaviours on dietary intake, and explains sensory methodology. Chapter 3 describes the methods and materials utilised in this study. Chapter 4 presents the key findings and results from the data which are then discussed in Chapter 5, along with strengths and limitations of the present study, recommendations for future research and conclusions.

1.4 Researcher's Contribution to the study

Table 1.1 Researchers contributions to the Dessert taste study

Researchers	Contributions to the thesis
Lisa Henderson	Main researcher; involved in study design; participant recruitment and testing; data entry and analysis; statistical analysis; interpretation and discussion of results; author of the thesis
Prof Bernhard Breier	Main academic supervisor; study design; research strategy and direction; application for ethics; provided funding through the Massey University Research Fund; development of sensory aspects of study design; supervision of statistical analysis and interpretation of results; thesis revision and approval.
Dr Kathryn Beck	Academic co-supervisor; research strategy and direction; development of dietary component of study design; supervision of statistical analysis and interpretation of results; thesis revision and approval.
Sophie Kindleysides	Primary investigator and research coordinator for the Dessert taste study; research strategy and direction; application for ethics; study design and sensory methodology development; coordinated recruitment and screening, data collection, data entry and analysis; statistical analysis; interpretation and discussion of the results; review of the methods, results and discussion.

Chapter 2 – Literature Review

Dietary intake has been measured on multiple levels, from micronutrients to foods and food groups (Thompson & Subar, 2013). Research suggests that habitual dietary intake over time has a greater impact on health than the consumption of single nutrients or food (Freeland-Graves & Nitzke, 2013). This has led to the development of statistical methods which identify dietary patterns. Dietary patterns provide a better reflection of combinations and patterns of food consumption (Ocke, 2013). The link between dietary patterns and consequent health outcomes has been increasingly supported by a growing body of evidence (Ocke, 2013). The profiles of certain dietary patterns are well known within the public arena for their health benefits. For example, the "Dietary Approaches to Stop Hypertension" (DASH) dietary pattern has been associated with reduced hypertension; the "Mediterranean" dietary pattern has been associated with improved cardiac health; and more recently, the "Blue Zone" dietary pattern has been linked to an increased life span (Department of Agriculture, 2014; Rodriguez-Monforte et al., 2015).

Alternatively, research has also identified patterns which are associated with poorer health outcomes. The most regularly identified by research is the "western" dietary pattern which is considered to be of poorer nutritional quality (Hu, 2002). A western dietary pattern is characterised by high intakes of salt, sugar, trans and saturated fats and processed and convenience foods (Hu, 2002). It also has lower intakes of wholegrains, fruit, vegetables, nuts and legumes. People who closely adhered to such a pattern were at greater risk of weight gain, hypertension, cancer and cardiovascular disease (CVD) (Kant, 2004; Rodriguez-Monforte et al., 2015). Evidence suggested that this dietary pattern could also have a significant impact on the brain and behaviour, adversely affecting learning and memory and increasing the risk of cognitive disorders (Stevenson, 2017).

The role of dietary patterns as a basis for guiding healthy dietary intake has been well defined (Moeller et al., 2007). This is because dietary patterns provide a better representation of the subtle and complex interactions resulting from exposure to multiple dietary components (Teucher et al., 2007). Stevenson (2017) agreed that dietary patterns would provide a better understanding of the characteristics that contributed to more healthful, or less healthful, patterns of dietary intake.

2.1 Determinants of dietary intake

Although specific dietary patterns have been associated with improved health outcomes (e.g. the DASH diet), nationally and globally it has been found that adherence to healthful patterns is frequently suboptimal (Ministry of Health, 2011a). The increasing prevalence of non-communicable diseases, with known associations to dietary intake (e.g. diabetes, CVD, cancer and respiratory disease), is testament to this (Ministry of Health, 2016). Promoting eating for improved health outcomes is a priority for the health and nutrition industries, but there are many other factors at play which affected dietary intake on both the levels of the individual, and the population.

Determinants of dietary intake are extensive and complex; involving genetic, environmental (social, cultural, economic etc.), physiological and psychological influences (Kant, 2004). There have been many attempts to explain how these factors interact. One explanation was modelled on the theory of planned behaviour (Figure 1) (Shepherd, 1985). This model divided factors affecting dietary intake into three key domains: the physical and chemical properties of food; psychological and physiological personal factors; and economic and social factors which affect attitude.

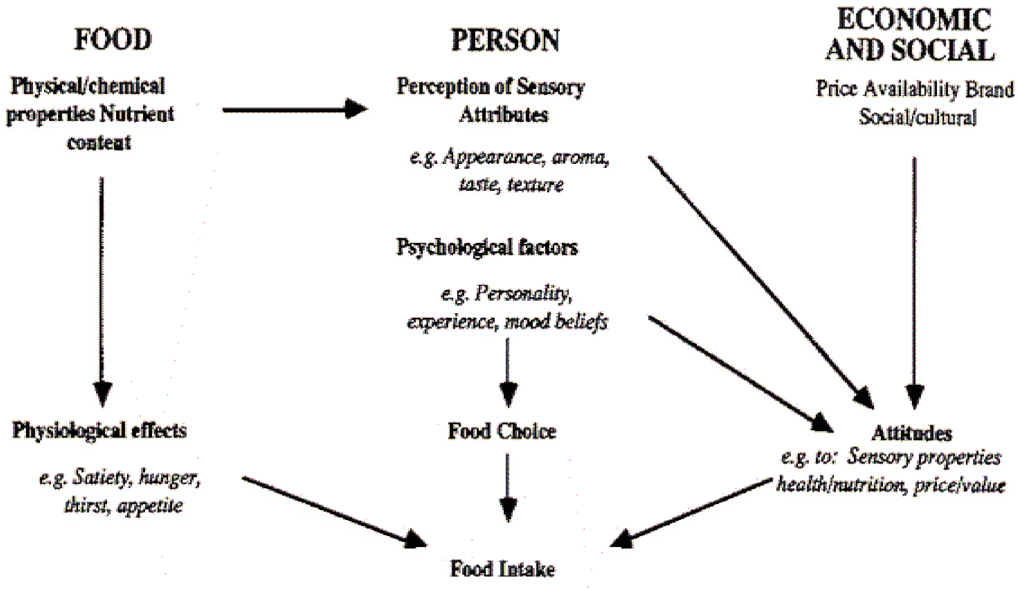


Figure 2.1 – Theory of planned behaviour model for factors influencing dietary intake (Shepherd, 1985)

An example of the interaction between determinants of dietary intake is the relationship between foods high in salt (chemical determinant) and salt taste preference (physiological determinant) (Liem, Miremadi, & Keast, 2011; Shepherd, 1985). A number of early studies showed that preference for salty foods may be reduced by a long-term reduction in dietary salt intake (Bertino, Beauchamp, & Engelman, 1982; Mary Bertino, Beauchamp, & Engelman, 1986; Blais et al., 1986). Research identified opportunities for altering food composition to reduce the volume of salt used, without affecting palatability (Bolhuis et al., 2011; Mitchell, Brunton, & Wilkinson, 2013). Several countries initiated government or industry led programmes for product reformulation to progressively reduce the volume of sodium chloride added to foods (Monro, Mhurchu, Jiang, Gorton, & Eyles, 2015). In the United Kingdom, a government-led programme resulted in an estimated 7% reduction of salt found in processed foods over ten years (Monro et al., 2015). To date, New Zealand based research reported limited success in our own industry-led initiative, however support remains for a government-led programme to be developed (Monro et al., 2015).

Salt taste sensitivity is one example of how improved understanding of individual sensory attributes serve to inform knowledge around the properties of food, physiological factors, attitudes and food choice, all of which contribute to food intake (Figure 1.1). Fat taste is one of the most recent sensory attributes to come to light in research and there have been several proposed benefits for improving the understanding of how fat taste may relate to dietary intake (Stewart et al., 2010). In New Zealand, the obesogenic environment has often been associated with an excess consumption of dietary fat (Ministry of Health, 2011a). Greater intakes of energy-dense high-fat foods have been associated with an increased risk of overweight and obesity and are also directly linked to an increased risk of cardiovascular disease, diabetes and cancer (Liu et al., 2016; Tucker et al., 2014).

Evidence supporting a relationship between fat taste, fat intake and total dietary intake is inconsistent (Keast et al., 2014). Typically, fat taste has been investigated in relation to total dietary intake of fats or it’s saturated and unsaturated forms (Stevenson, 2017). However, fat also contributes textural and olfactory sensory attributes to food and may be perceived or tasted differently depending on other components of the food or meal (Liu et al., 2016). Additionally, fat has known roles in the regulation of satiety, which may influence behaviours of food consumption (Keast et al., 2014). As fat is rarely consumed in isolation, it is useful to understand how fat taste might be associated with patterns of dietary intake (Teucher et al., 2007).

2.2 Dietary patterns in research

The traditional approach to dietary analysis has been to isolate specific dietary components, such as foods or nutrients, and compare these to other variables (Ocke, 2013). It has been recognised that this method overlooks the complex nature of interactions which occur during normal intake of food (Teucher et al., 2007). The key advantage of dietary patterns is the ability to offer an alternative to nutrient-related nutrition assessment by considering the whole diet and identifying combinations of food consumption (Beck & Heath, 2013).

2.2.1 Establishing dietary patterns

Statistical analysis is required for assessing dietary patterns as they cannot be measured directly (Hu, 2002). Four statistical approaches have been established: diet indices scores, factor analysis, cluster analysis and reduced-rank regression analysis (Moeller et al., 2007; Ocke, 2013). The strengths and limitations of the four approaches are outlined in Table 2.1.

Diet index scores were designed to assess the extent to which a participant "meets", or "does not meet", a set of pre-determined dietary criteria (Ocke, 2013). Diet indices primarily assess the "healthfulness" of a diet and are focused on specific aspects of dietary quality including nutrient adequacy, density, variety or diversity (Moeller et al., 2007). One of the most well recognised examples is the Mediterranean diet score which was developed by Trichopoulou et al. (1995). It is composed of eight dietary components including the ratio of monounsaturated to saturated fat and the consumption of seven specific food groups (i.e. legumes, cereals, fruits and nuts, vegetables, meat and meat products, milk and dairy products and alcohol) (Ocke, 2013; Trichopoulou et al., 1995). The key benefit of the diet index method is that the same index can be used in different studies of similar populations, allowing for more opportunities to compare between studies (Hu, 2002; Ocke, 2013).

Factor analysis, cluster analysis and reduced rank regression analysis are similar in that they are all data-driven methods, and therefore do not require a pre-conditioned theory of expected dietary patterns (Moeller et al., 2007; Ocke, 2013). Instead, dietary data is collected from participants using food frequency questionnaires (FFQ), 24-hour recalls, diet histories or diet records (Thompson & Subar, 2013). The components of dietary intake are grouped into variables, usually by nutritional similarity, and then analysed statistically (Hu, 2002).

Table 2.1 Strengths and limitations of methods used to assess dietary patterns

Method	Strengths	Limitations
Score-based methods for: • Nutrient adequacy or density • Variety or diversity • Index-based summaries.	- Characterise total diet - Simple to compute - Easy to reproduce and compare - Results can be meaningful and associated with health outcomes	- Scores based on meeting dietary criteria ('met', 'not met') do not quantify amounts of foods consumed - Dependent on dietary guidelines underlying score - Subjectivity occurs through selection and interpretation of guidelines, and in the construction of scores
Data-driven methods including: • Factor analysis • Cluster analysis	- Characterise total diet - Allows for interactions between nutrients - Results can be meaningful and associated with health outcomes -Shown to have reproducibility across some populations - Factor analysis (continuous variable) describes variation in food intake based on correlations between food items - Cluster analysis (categorical variable) creates mutually exclusive groups based upon similar dietary intakes	- Limited data assessing reproducibility and validity - Multiple points of subjectivity within the analysis, including: grouping of dietary items; treatment of input variables; analytic choices and selecting of final pattern
Hybrid methods using predictor variables: • Reduced rank regression analysis	- Characterise total diet - Allows for interactions between nutrients in relation to prespecified predictor variable - Identifies dietary combinations relevant to a health outcome	- Require a clear picture of biological mechanism underlying predictor variables - Subjectivity occurs through selection of predictor variable and interpretation of dietary pattern analysis

Table above was assembled using the following references; Ocke (2013), Hu (2002) and Moeller et al. (2007)

The factor analysis method most commonly used is principal component analysis (Varraso et al., 2012). This method is most useful for the ability to express interactions between foods or food groups as a continuous measure. In a process described by Ocke (2013), foods are grouped into dietary variables based on nutritional similarities (e.g. sesame oil, olive oil, canola oil). Combinations of associated dietary variables are identified using a correlation or covariance matrix to produce factors. Loadings are calculated which indicate how strongly a dietary variable is associated with the factor. Participants then receive a score for each derived factor, or dietary pattern, which indicates their level of adherence to that pattern. There are limitations to this method as the determination of how many factors to extract is subjective in nature (Beck & Heath, 2013; Ocke, 2013). Statistical assumptions and criteria are often used, along with observing the interpretability of each factor.

Cluster analysis assesses individual intake and separates participants into mutually exclusive, nonoverlapping groups (Newby & Tucker, 2004). There are two common methods of cluster analysis, the first is K-means which is an optimization technique where the number of clusters are predetermined by the researcher (Newby & Tucker, 2004). The other is Ward's method which is hierarchical and produced groupings based on the best statistical solution. Like principal component analysis, determining the appropriate number of clusters is based on interpretability and statistical criteria which has the potential for bias due to subjectivity (Beck & Heath, 2013).

Reduced rank regression analysis is the most recently developed dietary pattern methodology. This hybrid approach to assessing dietary patterns combines the use of predictor variables, as in dietary index scores, with multivariate analysis of the study data to identify dietary patterns specific to the study population (Ocke, 2013). Predictor variables are generally indicators of nutrition related-health status such as biomarkers, disease state, or specific nutrient intakes (i.e. iron intake as an indicator of iron deficiency) (Ocke, 2013). The reduced rank regression analysis method identifies combinations of food intake that best explain the variance of predetermined predictor variables. Like factor analysis, the number of patterns are decided upon and each participant receives a score indicating their level of adherence to the patterns. This method is most appropriate for studies where there is a clear understanding of the biological mechanism underlying a disease or state of health and the associated markers and influencing factors (Ocke, 2013).

Dietary index scores and reduced rank regression analysis have primarily been used where there was already a substantial field of knowledge linking nutrition and consequent health outcomes (Ocke, 2013). Data-derived methods, such as factor and cluster analysis, were beneficial when the aim was to investigate a potential relationship between dietary intake and other variables and there was limited or contradictory evidence. An important consideration for data-derived dietary pattern analysis, is accuracy and reliability of the dietary data being used (Beck & Heath, 2013). Therefore, it is important that the data collection methodology be appropriate for the participant group being studied (Beck & Heath, 2013).

2.2.2 Assessing individual dietary intake for dietary patterns

A range of assessment methods have been developed for measuring dietary intake. Table 2.2 summarises the most common dietary assessment methods used in research including diet records, diet history, 24-hour food recalls and food frequency questionnaires (FFQ). One of the greatest challenges of nutrition-based research is achieving accurate records of dietary intake (Thompson & Subar, 2013).

Weighed or estimated diet records are considered an imperfect gold standard due to several limitations. It has been found that the effect of participant burden is higher with food records and studies have shown that recording accuracy is significantly reduced after the fourth day of the record (Thompson & Subar, 2013). Additionally, participant selection bias is more likely to occur due to the higher food literacy and commitment required for this method. A limitation of the weighed food record is that it captures only specific periods of dietary intake, which may result in some foods being misrepresented if they were not consumed within the specified reporting period.

Twenty-four-hour food recalls are more reliant on memory than weighed food records and have the same potential for food items to be misrepresented. However, the participant burden is reduced as it does not require a written record to be kept (Thompson & Subar, 2013). Food literacy is also less of a concern as protocol requires the interviewer to be nutritionally trained and able to question the respondent appropriately to identify food items and volumes consumed. It is recognised that the research budget must allow for the expense of trained interviewers to ensure quality of data is achieved (Moeller et al., 2007).

Table 2.2 Comparison of strengths and weaknesses of the five main dietary assessment methods

Dietary Assessment Method	Procedure	Strengths	Weaknesses
Dietary record (weighed/estimated)	Respondent records type and volume of all food and beverages consumed over a specified period of time, preferably at the time the item is eaten. Volumes can either be measured (weighed) or estimated by the respondent.	- Gold standard of dietary assessment - Provides detailed information of volumes and which foods are eaten together - Reduced reliance on memory and estimation	- Only captures a limited time period - High level of participant burden, may affect participant selection - Potential for bias in self-reporting and altered eating patterns - Careful training of respondent is required to improve record accuracy
24-hour food recall	Interviewer asks respondent to recall all foods and beverages consumed in the previous 24 hours, and estimate the volumes of these. Typically uses a triple pass system, known as the automated multiple-pass method (AMPM)	- Low respondent burden - Can capture adequate detail to identify and analyse new foods - Administration by interviewer reduces literacy barriers	- Portion size estimation can be challenging due to memory decay - Requires well-trained interviewer - Requires multiple 24 hour recalls to determine usual intake
Diet history	Often conducted by an interviewer, respondent reports on frequency and amount of foods usually	- Assesses usual intake and meal patterns in more detail than frequency assessment methods. Details can be obtained for meal	- Subjective nature of reporting - Reliant on memory - Nutrient intakes should be considered

Dietary Assessment Method	Procedure	Strengths	Weaknesses
	consumed, as well as food characteristics (i.e. preparation methods). Report of diet history is often done by meal.	preparation etc. - Duration of food intake is generally longer than that considered in food records - Respondent may find it easier to report quantity of item consumed per meal than over a set time period (day, week etc.)	relative, not absolute values - Meal-based assessment may not identify snacking patterns - Difficult to standardise due to use of interviewer - Expense of interviewer training
Food Frequency Questionnaire (FFQ)	Respondent reports usual frequency of intake for each food or food group listed. Usually administered as a questionnaire	- Reduced burden on participants - Economical for researchers - Less impacted by temporary dietary changes as it captures dietary intake over an extended period of time, usually twelve months	- Relies upon self-reporting and ability of participant to make a generic quantification of recent intake. This can be difficult if diet is unstable - Balance required between food list specificity and length of questionnaire - Difficult to quantify seasonal changes to dietary intake - Doesn't usually assess preparation or combinations of foods - Highest rate of reporting inaccuracies

Table above was assembled using the following references; Lee and Nieman (1996); Thompson and Subar (2013)

Diet histories are also reliant on the interviewer questioning the respondent on their usual intake. The benefit of this method is that it is possible to gain an understanding of food combinations and preparation methods (Thompson & Subar, 2013). Diet histories are also able to capture regular variation in the diet dependent on the time period being targeted (i.e. between weekdays and weekends, work and holiday or seasonal variations). The diet history method is reliant on respondent memory which increases the likelihood of reporting inaccuracies (Thompson et al., 2010). Recall is usually meal based which can be particularly difficult for those people who have a highly variable dietary intake, or are regular grazers.

Food frequency questionnaires (FFQ) capture a person's habitual dietary intake and allow for inclusion of foods which are consumed irregularly. Food frequency questionnaires assess dietary intake over a specified extended period of time. For example, a respondent may have been asked to report their usual intake from the past 12 months. This method is useful when comparing dietary intake to variables thought to be stable, regardless of short term dietary fluctuations. Earlier studies have indicated that a FFQ should be designed or validated in the country of its intended use for it to significantly correlate with weighed food records (Silva, Sichieri, Pereira, Silva, & Ferreira, 2013; Thompson & Subar, 2013). The FFQ method is largely regarded as appropriate for qualitative descriptions of dietary intake. A well-designed FFQ is deemed an appropriate measure of dietary intake when establishing dietary patterns due to the ability to measure habitual intake over longer periods of time (Hu et al., 1999).

Across all dietary assessment methods, the most well documented challenge was misreporting of dietary intake. Estimations of underreporting ranged from 2-85%, dependent on the participant group being studied (Maurer et al., 2006). Several factors have been identified which were significantly associated with misreporting of dietary data including age, gender, weight status, physical activity and cognitive factors (Gemming, Jiang, Swinburn, Utter, & Mhurchu, 2014). In those methods where actual intake was recorded; under-eating may have occurred to reduce burden. Social desirability bias may also have resulted in the under-reporting of foods perceived to be "unhealthy". Under-reporting was most commonly seen in overweight and obese participants (Stevenson, 2017). A significant benefit of using dietary pattern analysis is that it has been found to be less affected by underreporting (Bailey, Mitchell, Miller, & Smiciklas-Wright, 2007).

Due to the limitations associated with achieving inaccurate assessment of dietary intake, there has been a greater focus on developing new tools and methods. The incorporation of technology into dietary assessment produced positive results for accuracy and reducing participant burden (Thompson, Subar, Loria, Reedy, & Baranowski, 2010). For example, a "food meter" combined a barcode reader with scales to reduce measuring error and reduce the specificity required when recording types of food eaten (Thompson et al., 2010). It has been suggested that ongoing developments in this area will also benefit the accuracy and validity of dietary patterns (Beck & Heath, 2013).

2.2.3 Dietary patterns in the New Zealand population

Within similar populations, commonalities have often been found in the types of patterns derived from dietary data (Kant, 2004). By comparing the commonalities of these patterns, it has been possible to develop an understanding of the trends in nutrient and food intake, as well as identify common characteristics of the participants who strongly adhered to them (Bailey et al., 2006; Department of Agriculture, 2014). To date, New Zealand women of a reproductive age are the primary group in which statistically derived dietary patterns have been assessed. This is pertinent as the most recently released New Zealand obesity statistics indicate that women of reproductive age (15-45 years) are most likely to be overweight or obese (Ministry of Health, 2016). This poses a serious concern for future generations given the known associations between overweight and obese mothers and the future health outcomes for their offspring including increased pregnancy risk and risk of overweight, obesity, type II diabetes and other cardiometabolic diseases (Drake & Reynolds, 2010). A summary of the studies assessing dietary patterns of women living in New Zealand can be found in Table 2.3.

Of the four studies which identified dietary patterns of New Zealand women, all were conducted in premenopausal women, and two studies included pregnant women only (Beck et al, 2013; Schrijvers et al, 2016; Thompson et al, 2010; Wall et al, 2016). All four studies used FFQs to collect the dietary data used in dietary pattern analysis. The number of dietary patterns identified for each participant group ranged from three to seven.

A study by Schrijvers et al. (2016) found, in a population of 231 women, it was possible to derive four dietary patterns. The patterns were 'snacking', 'energy-dense meat', 'fruit and vegetable' and 'healthy'. When compared to New Zealand acceptable macronutrient distribution ranges (AMDR), all four patterns had average carbohydrate intakes below the recommended guideline of 45-65% (Ministry of Health, 2006). Saturated fat was above the recommended guideline of less than 10% for each pattern. When comparing baseline characteristics of the women to dietary pattern scores it was found that both the 'snacking' and 'energy-dense meat' patterns were positively correlated with age. The 'energy-dense meat' pattern also correlated positively with BMI and BF%.

Table 2.3 Summary of dietary patterns derived by factor analysis observed in New Zealand women

Author, study design	Purpose	Participants (sample size)	Methods	Dietary patterns identified	Findings and conclusions
Schrijvers et al. (2016), cross-sectional study	Investigate dietary patterns and body composition profiles	Post menarche, pre-menopausal NZE women (N=231)	- 220-item FFQ - Body composition (Bodpod) - Height, weight and BMI	- Snacking - Energy-dense meat - Fruit and vegetable - Healthy	- 'Snacking' and 'energy-dense meat' patterns were positively associated with age. - 'Energy-dense meat' pattern was positively associated to BMI and BF%. - All patterns had carbohydrate intakes below AMDR and saturated fat intakes above recommendations of less than 10%.
Beck et al. (2013), cross-sectional study	Investigate associations between dietary patterns and suboptimal iron status	Pre-menopausal women, aged 18-44 years (N=375)	- 144-item iron FFQ - Dietary practices questionnaire - Haemoglobin, SF and CRP	- Refined carbohydrate and fat - Asian - Healthy snacks - Meat and vegetable - High tea and coffee - Bread and crackers - Milk and yoghurt	- Participants with greater adherence to the 'Asian', 'tea and coffee' and 'healthy snack' patterns were significantly older. - Participants with high adherence to the 'milk and yoghurt' pattern were significantly younger than those with low adherence. - No relationship was found between BMI and level of adherence to any of the six dietary patterns.

Author, study design	Purpose	Participants (sample size)	Methods	Dietary patterns identified	Findings and conclusions
Wall et al. (2016), longitudinal cohort study	Describe dietary patterns of pregnant women and investigate associations with sociodemographic, birth place, health and lifestyle factors	Pregnant women, living in New Zealand, aged 15-47 years (N=5664)	- 44-item FFQ - Antenatal enrolment interview for measures of socio-demographic, health and lifestyle factors	- Junk - Traditional/white bread - Health conscious - Fusion/protein	- Increased adherence to ‘junk’ and ‘traditional/white bread’ patterns were associated with younger age, lower level of education. Adherence to these patterns was higher in Pacific and Maori. - Those with increased adherence to ‘health conscious’ and ‘protein/fusion’ patterns were more likely to be older, have better self-rated health and have a lower BMI
Thompson et al. (2010), case-control study	Describe dietary patterns in pregnant women and assess associated risk of having SGA baby	Pregnant women, living in New Zealand (N=1714)	- 71-item FFQ administered in the first and last month of gestation - Maternal interview for sociodemographic factors	- Junk - Traditional - Fusion	- Strong correlations were found between early and late pregnancy indicating the women had minimal change in dietary pattern throughout pregnancy. - The ‘junk’ pattern was inversely associated with socio-economic status and age, and positively associated with weight. - Adherence to the ‘traditional’ pattern was associated with higher education and socio

Author, study design	Purpose	Participants (sample size)	Methods	Dietary patterns identified	Findings and conclusions
					economic status, being of European descent, older and of average weight and height. - The ‘fusion’ pattern was associated with women who were younger, had lower socioeconomic status and were non-European.

AMDR = Acceptable macronutrient distribution range; BF% = Body fat percentage; BMI = Body mass index; CRP = C-reactive protein; FFQ = Food frequency questionnaire; SF = Serum ferritin; SGA = Small-for-gestational age

Seven dietary patterns were found in a study aimed at identifying dietary patterns associated with iron status (Beck et al., 2013). The study used a food frequency questionnaire (FFQ) which was developed specifically to assess foods related to iron status. The dietary patterns found in this study were 'refined carbohydrate and fat', 'Asian', 'healthy snacks', 'meat and vegetable', 'high tea and coffee', 'bread and crackers' and 'milk and yoghurt'. Participants who had a greater adherence to the 'Asian', 'high tea and coffee' and 'healthy snack' patterns were found to be significantly older. Those who adhered to the 'milk and yoghurt' pattern were younger.

A large longitudinal study of 5664 pregnant women found four dietary patterns (Wall et al., 2016). These were 'junk', 'traditional/white bread', 'health conscious' and 'fusion protein'. Younger age and lower education levels were found to be associated with increased adherence to the 'junk' and 'traditional/white bread' patterns. Characteristics of those who adhered to a 'health conscious' or 'fusion protein' pattern were women who were older, had better self-rated health and a lower BMI.

Thompson et al. (2010) found similar patterns to the study above. 'Junk', 'traditional' and 'fusion' patterns were derived from the dietary intake of 1714 pregnant New Zealand women. These dietary patterns were consistent from the first to the final trimester. Both the 'junk' and fusion patterns were associated with lower socio-economic status. 'Junk' was also associated with younger age and increased weight. In contrast to the associations found by Wall et al. (2016), women who adhered to a 'traditional' pattern in this study were more likely to have a higher education level and socio-economic status. They were also more commonly of European descent and of average weight.

Although 'traditional' patterns identified by both Thompson et al. (2010) and Wall et al. (2016) shared similar names, they were substantially different. The 'traditional/white bread' pattern found by Wall et al. (2016) included whole or standard milk, white bread, margarine, jam honey marmalade, peanut butter, Nutella and low fibre and/or high sugar cereals. Comparatively, the other 'traditional' pattern was identified based on having similar components to a traditional British diet including fruit, green and root vegetables, dairy foods and water (Jacka et al., 2010; Thompson et al., 2010). The variation between these patterns and corresponding variation in associations with baseline characteristics, demonstrated one of the challenges of comparing dietary patterns.

Both studies conducted in pregnant women identified a 'junk' dietary pattern (Thompson et al., 2010; Wall et al., 2016). The common food items which characterised this diet were foods high in sugar, fat and salt. Included were confectionary, takeaways, chips, ice cream, cakes and biscuits. In both studies the 'junk' pattern was inversely associated with age and level of education (Thompson et al., 2010; Wall et al., 2016). A review by Kant (2004) found that other populations showed a similar dietary pattern of the foods listed above and this was frequently referred to as a 'junk' or 'western' pattern.

A 'snacking' pattern was identified in two studies, however the food groups which contributed to these patterns varied slightly between the studies (Beck et al., 2013; Schrijvers et al., 2016). In the EXPLORE study (Examining the predictors linking obesity related elements) the 'snacking' pattern was characterised by greater consumption of sweet and savoury snack foods, dairy, crackers, brown bread, spreads, cakes and biscuits and hot beverages (Schrijvers et al., 2016). The 'healthy snacks' pattern identified by Beck et al. (2013) had fewer components and included only yoghurt, brown bread, fruits and hot beverages. Irrespective of the differences, both studies found that participants adhering to a 'snacking' pattern were significantly older.

2.2.4 Dietary patterns and metabolic and health outcomes

Dietary patterns associated with favourable health outcomes have received increased attention in both the world of research and on the public stage. The benefit of this popularity is the growing body of evidence supporting the concept that habitual intake can be expressed as a single dietary pattern variable to be compared to health outcomes and characteristics which may contribute to dietary intake (Hu, 2002). The Dietary Approaches to Stop Hypertension (DASH) diet is one example of this. The DASH diet was established through a clinical trial looking at the effect of dietary patterns on blood pressure. It found that a dietary pattern that is low in fat and high in fruits, vegetables and low-fat dairy foods was effective in reducing blood pressure (Sacks et al., 2001).

The 'healthy' or 'prudent' pattern was also found to be associated with improved health outcomes, including reduced BMI, lower waist circumference, and a reduced risk of chronic disease (Rodriguez-Monforte et al., 2015). This pattern was consistently higher in intakes of fruit, vegetables, whole-grain breads and cereals, lean unprocessed meats, poultry, fish and low fat dairy products (Schulze, Fung, Manson, Willett, & Hu, 2006; van den Bree, Eaves, & Dwyer, 1999). In a study of 281 females, it was found that intake of dietary fat was inversely associated with a 'prudent' dietary pattern, which in turn, was associated with lower BMI and body fat percentage (BF%). A validation study also found that those who adhered closely to the prudent pattern had higher intakes of fibre, potassium, magnesium, Vitamin B6, folate and carotenes, and lower intakes of saturated and total fat (Hu et al., 1999).

The investigation of dietary patterns has also been employed to identify factors which may be associated with a pattern of less favourable dietary intake. Recent studies have further evidenced associations between specific dietary patterns and chronic disease (Kant, 2004). The most common of these is thought to reflect a typical 'western' dietary pattern containing regular intake of refined grains, breads and cereals, red and processed meats, fast foods, sugar sweetened-beverages, alcohol, sweets and desserts (Rodriguez-Monforte et al., 2015). Based on a review of 30 studies, Kant (2004) further simplified the dietary components of the 'western' dietary pattern into higher intakes of fat, meat and refined grains. The 'western' pattern is similar to the 'junk' dietary pattern identified in New Zealand women, and has been correlated with a higher fat intake and reduced micronutrient intake (Kant, 2004; Thompson et al., 2010; Wall et al., 2016). The negative outcomes associated with the 'western' dietary pattern were found to be weight gain and an increased risk of chronic diseases such as cardiovascular disease, type II diabetes and cancer (Rodriguez-Monforte et al., 2015; van den Bree et al., 1999).

One of the largest studies found to demonstrate the relationship between dietary patterns, factors related to health and health outcomes was the Nurses' Health study (Schulze et al., 2006). Those women with a low score for adherence to the prudent dietary pattern were younger, less physically active, and more likely to smoke. They also had a macronutrient distribution higher in fat and lower in carbohydrates. Women with a consistently high score for the western dietary pattern throughout the study, were more likely to have a higher body weight and BMI and be less physically active (Schulze et al., 2006).

2.3 The role of eating behaviour

Eating behaviour has been given many operational definitions. Elsner (2002) defined it as "the thoughts, actions, and intents that an organism enacts in order to ingest solids or liquids". Thus it follows that eating behaviours are well recognised factors associated with dietary intake (Keskitalo et al., 2008). It is theorised that this relationship is complex in causality. How habitual diet may affect, and be affected by, eating behaviour is not well understood (Stevenson, 2017). Studies have suggested that there may be a neuroendocrinological component which includes the reward, satiety and sensory pathways (Gibson, 2006; Passilly-Degrace et al., 2014).

2.3.1 Assessing eating behaviour

Eating behaviour encompasses a wide range of behaviours and habits which people engage in, both when preparing to eat, and in the act of eating (de Lauzon et al., 2004). Several studies have attempted to measure and categorize these behaviours. Two of the most commonly used measures of eating behaviour are the Three-factor eating questionnaire (TFEQ) and the Dutch Eating Behaviour Questionnaire (DEBQ) (Stunkard & Messick, 1985; van Strien et al., 1986). Both questionnaires were developed using factor analysis to identify closely correlated patterns of behaviour related to eating.

The TFEQ is a 51-item questionnaire. It was developed to assess three dimensions of eating behaviour named cognitive restraint, disinhibition and hunger (Stunkard & Messick, 1985). Cognitive restraint pertained to the conscious mechanisms used by people to restrict dietary intake. Disinhibition related to uncontrolled periods of eating. Hunger indicated the perceived susceptibility to hunger cues both internally and through external sensory and environmental stimulus (de Lauzon et al., 2004; Rivers, 2015; Stunkard & Messick, 1985). Since its inception, the questionnaire has been validated and revised, however the concepts of cognitive restraint, disinhibition and hunger remain key themes for the analysis of eating behaviour in current research. The original TFEQ was appropriate for use in both normal and overweight participants (Keränen, Strengell, Savolainen, & Laitinen, 2011).

A more recent version of the TFEQ was designed and validated for use in overweight and obese populations (de Lauzon et al., 2004). It is an 18-item questionnaire which measures cognitive restraint, uncontrolled eating and emotional eating. There has been limited research conducted to assess the validity of using the shorter TFEQ-18 questionnaire to assess participants of normal weight.

The DEBQ is a 46-item questionnaire. It was developed to assess the behavioural constructs of restrained eating, external eating and two dimensions of emotional eating (Elfhag & Morey, 2008; van Strien et al., 1986). In this questionnaire, restrained eating had a similar definition to cognitive restraint in the TFEQ (de Lauzon et al., 2004; Elfhag & Morey, 2008). External eating was used to described the responsiveness to all external cues which may influence eating (e.g. environment, sensory, timing). Emotional eating was divided into subsets of behaviour as it was observed that a diffuse emotional state had a greater effect on eating behaviour than clearly identified emotions (van Strien et al., 1986).

2.3.2 Eating behaviour and dietary intake

Research investigating the relationship between eating behaviour and dietary intake has been predominantly conducted using traditional methods of dietary assessment. Thus, there has been a focus on total energy intake (TEI) and macronutrient contributions to energy. Studies investigating these relationships in adults are outlined in Table 2.4.

Table 2.4 Studies investigating eating behaviour and dietary intake

Author, study design	Purpose	Participants (sample size)	Method	Findings and conclusions
Keranen, Strengell, Savolainen, and Laitinen (2011), randomized follow up study	To investigate associations between eating behaviour and dietary intake at baseline and an 18-month follow up.	Adults aged 18-65 years with a BMI >27 kg/m^2 (N=82)	- 5d food records - TFEQ-18 - Weight - Blood pressure	- At baseline, cognitive restraint was inversely associated with TEI - At the 18-month follow up, cognitive restraint was inversely associated with TEI and fat and positively associated with carbohydrate, sucrose and fibre. - At baseline, no associations were found between the uncontrolled eating or emotional eating and energy, macronutrients, fibre or alcohol. - Uncontrolled eating was found to be inversely correlated to sucrose intake at the 18-month follow up.
de Lauzon et al. (2004), cross-sectional study	To determine associations between eating behaviours and eating patterns in a general population	French participants aged ≥14 years (N=854)	- TFEQ-18 - 124-item, semi quantitative FFQ	- Females were found to have higher scores for cognitive restraint and emotional eating. - Cognitive restraint was positively associated with healthy food groups in adults, including low-fat foods, green vegetables, fish and yoghurt. Inverse associations were found for cognitive restraint and French fries, sugar and confectionary. - Uncontrolled eating was positively associated with energy-dense foods such as fats and potatoes. Fat as a percentage of total energy

Author, study design	Purpose	Participants (sample size)	Method	Findings and conclusions
				was also positively associated with scores for uncontrolled eating. - Emotional eating was positively associated with increased consumption of cakes, biscuits and pastries.
Elfhag, Tholin, and Rasmussen (2008), cross-sectional study	To investigate associations between consumption of fruits, vegetables, sweets and soft drink and eating behaviours in children and parents	Swedish families with 12-year-old children (N=1795 mothers, 1471 fathers and 1441 children)	- DEBQ - 11-item FFQ - Harter self-perception scale - Weight, height, BMI	- In adults, cognitive restraint was positively associated with consumption of fruits and vegetables. - External eating was found to be positively associated to consumption of sweets for both adults and children. - Both women and girls were found to have a positive association between scores for emotional eating and consumption of sweet foods and soft drinks. - Regression analysis determined that adults who had frequent intakes of healthy foods had greater cognitive restraint and self-worth. Older age and a higher education also fitted into this predictor model.
Provencher et al. (2003), cross-sectional study	To identify relationships between dietary and anthropometric profiles of men and	Canadian males and females (N=596)	- TFEQ - 3d estimated food diary - Weight, height, BMI, RMR, body	- Women were found to have higher scores for cognitive restraint and disinhibition than men. - Cognitive restraint was inversely associated with total energy intake and consumption of fat (%TE). - For both male and female participants, hunger was positively

Author, study design	Purpose	Participants (sample size)	Method	Findings and conclusions
	women and assess the influence of gender and obesity status		composition	associated with increased energy intake.
Anschutz, Van Strien, Van De Ven, and Engels (2009), cross-sectional study	Examine relations between restrained, emotional and external intake and measure of dietary intake	Dutch female students from Radboud University (N=475)	- DEBQ - 145-item FFQ - Physical activity record - Height, weight and BMI	- Cognitive restraint was inversely associated to energy intake and fat and carbohydrate intake. - Emotional eating was not related to intake of energy, carbohydrate or fat. - External eaters had a lower body weight but a higher energy intake than restrained eaters

BMI = Body mass index; d = Day; DEBQ = Dutch eating behaviour questionnaire; FFQ = Food frequency questionnaire; RMR = Resting metabolic rate; TEI = Total energy intake; TFEQ = Three-factor eating questionnaire; TFEQ-18 = Three-factor eating questionnaire

Cognitive restraint was assessed in all five studies and was the only measure of eating behaviour to demonstrate consistent relationships with total energy and macronutrient intakes (Anschutz et al., 2009; de Lauzon et al., 2004; Elfhag et al., 2008; Keränen et al., 2011; Provencher et al., 2003). Higher cognitive restraint scores were found to be associated with a lower intake of total energy, especially energy consumed from sweet or fatty foods (Keränen et al., 2011; Provencher et al., 2003; Stevenson, 2017). Higher cognitive restraint scores were also linked to a long-term reduction in fat intake, increased fibre consumption and sustained weight loss. In two studies, cognitive restraint was positively associated with intake of fruits and vegetables (de Lauzon et al., 2004; Elfhag et al., 2008). de Lauzon et al. (2004) also found that intake of fish, fat-reduced foods and milk was higher for participants with higher scores of cognitive restraint.

Disinhibition and uncontrolled eating measure the same behavioural construct within the TFEQ. Both uncontrolled eating and disinhibition have been found to be positively associated with increased intakes of fat and energy (Stevenson, 2017). This is consistent with the findings from de Lauzon et al. (2004) which found that participants with high scores for uncontrolled eating consumed more energy-dense high-fat foods. Stevenson (2017) suggested a possible explanation was that uncontrolled eating behaviour may have been a result of impaired regulation pathway.

Of the five studies, three measured emotional eating (Anschutz et al., 2009; Elfhag et al., 2008; Keränen et al., 2011). Only two of these studies found there was a relationship between dietary intake and emotional eating (de Lauzon et al., 2004; Elfhag et al., 2008). Both studies had consistent findings, where higher emotional eating scores were associated with increased intakes of sweet foods including biscuits, pastries and cakes. Of interest, Elfhag et al. (2008) found the relationship existed for women and girls only.

2.3.3 The sensory component of eating behaviour

Eating behaviour has been shown to be consistently associated with taste preference in the literature (Stevenson, 2017). Taste preference is defined as a measure of hedonic liking for specific taste qualities, flavours, foods or food combinations (Tepper et al., 2009). Less well understood, is whether similar relationships exist between eating behaviour and chemosensory ability (Stevenson, 2017). Studies investigating associations specifically between eating behaviour and taste sensitivity have been largely focussed on sweet, salty and bitter taste qualities.

Research suggests that overconsumption of energy-dense, highly palatable foods may lead to an anhedonic state, where sensitivity to the reward response is reduced (Chambers & Yeomans, 2011; Keskitalo et al., 2008). Overconsumption may also cause dysregulation of the signals responsible for ending a period of eating (i.e. satiety and taste fatigue), leading to further disinhibited eating behaviour (Keskitalo et al., 2008; Passilly-Degrace et al., 2014). A study, which supported this theory, found that obese children consumed more of a meal following a preload (extra food given prior to test meal) than normal weight children (Carnell & Wardle, 2007). This finding suggested the obese children were more responsive to sensory cues for a meal which stimulated hunger, and less able to regulate intake based on satiety (Wardle, 2007).

In some people, it has been suggested that weight maintenance is a greater motivator than palatability or flavour preference (Keranen et al., 2011; Tepper & Ullrich, 2001). For example, cognitively restrained eaters may have a significantly higher preference for sweet or fatty foods but override this preference with restrained eating behaviour (Chambers & Yeomans, 2011). It was found that cognitively restrained eaters were also more likely to consume greater amounts of a food, when they did choose to eat it, in comparison to unrestrained eaters (Chambers & Yeomans, 2011; Stunkard & Messick, 1985).

Many studies have investigated the relationship between eating behaviour and fat taste preference, but few studies have compared established eating behaviour methodology to measures of fat taste sensitivity (Ahrens, 2015; Lähteenmäki & Tuorila, 1995).

2.4 Developments in the physiology of taste

Taste is one of three senses which make up the combined effect of flavour. Also included are olfaction and somatosensation (Keast, Dalton, & Breslin, 2008). Individual perception of flavour is known to play a significant role in determining the palatability of foods (Prescott, 2012). Indications are that taste also plays several other roles in the process of eating, digestion and absorption. Liu et al. (2016) has identified that taste buds provide the important detection system for the presence of favourable nutrients or potentially harmful toxins. Additionally, taste signalling activates other regulatory mechanisms to help prepare the digestive tract for nutrients consumed (Liu et al., 2016).

2.4.1 Gustatory Anatomy

Literature investigating the mechanisms of taste found gustatory papillae are located on the tongue and throughout the oral cavity (Chaudhari & Roper, 2010; Liu et al., 2016). Gustatory papillae contain taste receptor cells (TRCs), which are bundled into groups of 50-100, known as taste buds (Liu et al., 2016). Taste buds transfer the gustatory signals to the afferent fibres of chorda tympani and glossopharyngeal nerves via synaptic contacts (Passilly-Degrace et al., 2014). Papillae are categorised into fungiform, foliate or circumvallate papillae based on the topographical structure (Liu et al., 2016). TRCs are also divided into four types based on function. These functions are complex and have been described in detail by Chaudhari and Roper (2010), however a simplified explanation is as follows:

- Type I receptor cells maintain the extracellular environment through neurotransmitter clearance and ion transport and redistribution.
- Type II receptor cells produce G-coupled protein receptors and are thought to be mainly responsible for taste transduction.
- Type III receptor cells are associated with sour taste and have a proposed role in transmitting sensory information to the central nervous system through synthesis and release of neurotransmitters.
- Type IV receptor cell function is not as well understood, but are thought to have a role in TRC renewal, dividing into new Type I, II and III receptor cells on a 9-day cyclical basis.

2.4.2 Primary tastes and taste criteria

There are five recognised primary tastes – sweet, bitter, umami, salty and sour (Liu et al., 2016). Research suggests that three key neurotransmitters are responsible for the signalling of these different tastes within the gustatory pathway. The neurotransmitters are 5-hydroxytryptamine (5-HT), norepinephrine and adenosine triphosphate (ATP) (Chaudhari & Roper, 2010).

It has been theorised that the detection of specific tastes is related to the way taste stimuli are sensed by afferent fibres. Some afferent fibres only respond to a specific taste stimuli, while others react more broadly to more than one taste stimuli (Liu et al., 2016). The ability for a stimulus to generate a specific reception and signalling pathway is one of the five criteria used to determine a primary taste quality (Passilly-Degrace et al., 2014). The criteria are as follows:

1) Have an effective stimulus
2) Have specific reception and signalling for that stimulus
3) Involve the gustatory pathway
4) Have a physiological impact
5) Create an identifiable sensation

Humans have the ability to detect taste qualities from a wide range of food and non-food items, however, sensitivity to these qualities varies greatly between individuals (Liu et al., 2016). The level of sensitivity (sensitivity threshold) is often used to indicate the degree of taste function (Liu et al., 2016).

2.4.3 Defining taste thresholds

There are three common definitions used when discussing taste sensitivity thresholds (Table 2.5). Research has found that no one definition adequately represents taste function on its own. One of the most commonly used is a detection threshold which is defined as the lowest point at which an individual is able to detect stimulus, but may be unable to identify what the taste quality is (Liu et al., 2016). A recognition threshold is the lowest concentration at which an individual can associate a stimulus with it's appropriate taste quality (i.e. sucrose = sweet) (Wise, Hansen, Reed, & Breslin, 2007). As recognition thresholds require the participant to be familiar with a taste quality, this threshold is not used for investigating new or unusual taste stimuli (Stewart et al., 2010). One of the least commonly utilised threshold definitions is supra-thresholds, which indicate that a stimulus is present in sufficient strength or quantity to produce a physiological effect (Liu et al., 2016). The challenge for determining a supra-threshold is understanding the specific mechanism which produces a physiological response to a taste stimuli (Liu et al., 2016).

Table 2.5 Sensory threshold definitions

Threshold	Definition
Absolute / detection	The minimum concentration at which a specific stimulus can be perceived by taste only
Recognition	The minimum concentration required of a specific stimulus to allow it to be identified by taste only.
Supra-threshold	The minimum concentration at which a stimulus is sufficient to produce an action potential in taste receptor cells

This table was assembled from the following references (Bartoshuk, 1978; Liu et al., 2016)

2.4.4 Fat as a primary taste

The appeal of high-fat foods has been well recognised and exploited (Martinez-Ruiz, Lopez-Diaz, Wall-Medrano, Jimenez-Castro, & Angulo, 2014). Using fat to improve the chemical and physical properties of a food item is a common practice within the food industry. The contribution of fat to increasing the palatability of a food item has thought to have been related to improving texture and olfaction (Martinez-Ruiz et al., 2014). However, fat is yet to be fully recognised for its taste qualities (Liu et al., 2016). Increasingly, studies have come to show that when all other sensory cues are obscured, a chemosensory response to fat taste is detectable (Haryono et al., 2014). Research conducted on oral nutrient receptors found that sensitivity for free fatty acids (FFA) differed between individuals, and FFA taste sensitivity may have the potential to impact on food acceptance, preference, liking and intake (Mattes, 2009; Stewart et al., 2010).

The supporting evidence for fat as a true taste in humans has been inconclusive. It is suggested that taste reception for fatty acids maybe only be for a detection threshold, and not a supra-threshold (i.e. one which would produce a physiological response) (Stewart et al., 2010). One of the current debates, regarding the acceptance of fat as a taste, is whether the taste quality can be reliably recognised or if it is limited to simple detection thresholds (Liu et al., 2016).

2.4.4.1 Mechanisms of fat taste

Two possible pathways for FFA detection have been suggested, the first is similar to bitter taste, where multiple transduction pathways use different receptors. Alternately, similar to sweet taste, there may be one receptor type showing differing levels of affinity to the FFAs (Liu et al., 2016). There are several receptors which have shown responsiveness to FFAs, with responsiveness varying depending on chain length and degree of saturation (Liu et al., 2016). In food, there are commonly three types of FFAs, saturated, monounsaturated and polyunsaturated (Mattes, 2009). A weak correlation has been found between detection thresholds for each of these FFAs (Mattes, 2009).

Investigations into the mechanisms of fat taste are ongoing, however animal studies support the existence of at least two receptors which are involved in detecting and signalling the presence of fat in the oral cavity (Martin et al., 2011). For fat to be detectable by taste receptor cells (TRC), it must be soluble in saliva (Liu et al., 2016). However, triglycerides are predominantly insoluble. In rodent studies, it was proposed that FFAs were freed from the glycerol backbone by lingual lipase, to interact with TRCs (Cvijanovic et al., 2015). Humans have comparatively low levels of lingual lipase, thus it has been suggested that release of FFAs may be achieved though food preparation, cooking and mastication (Mattes, 2009).

A glycoprotein (CD36) has been identified in rodents, and more recently in humans (Galindo et al., 2011; Martin et al., 2011). CD36 was found to bind to long chain fatty acids (LCFA), a form of FFA. The binding created a signal conveyed to the central nervous system using the gustatory pathway, which played a role in preparing the body for incoming fat and upregulating secretion of digestive enzymes (e.g. lipases) and hormones (e.g. cholecystokinin) (Martin et al., 2011). An additional receptor type, known as G-protein-coupled receptors (GPCR), is also thought to play a role in fat preference, as rodent studies found that mice without the GPR-120 receptor were unable to detect a fatty substance (Passilly-Degrace et al., 2014). Research suggests that different taste receptor mechanisms may be employed dependent on the length and saturation of the fatty acid chain. GPCRs are one such mechanism thought to selectively bind to fatty acids (Stewart et al., 2010).

2.4.4.2 Measuring fat taste sensitivity

There have been several research projects undertaken in recent years with the objective to produce a robust protocol for establishing fat taste sensitivity thresholds in a participant group (Haryono et al., 2014).

Adding to the challenge of establishing fat taste sensitivity thresholds, has been the potential for a learned response. Several studies have found over a series of consecutive testing sessions that participants have learnt to detect fat taste more efficiently (Mattes, 2009; Newman & Keast, 2013; Tucker et al., 2014). As fat is not a taste people are regularly taught to identify, it was suggested that some people may adapt or 'learn' more quickly than others, suggesting more visits would be required to allow for 'learning' (Tucker et al., 2014). Supporting this theory is a study which found that lean and overweight participants showed significantly greater sensitivity to fat taste over seven visits, compared to their obese counterparts (Tucker et al., 2014). Obese participants showed no increased sensitivity across the seven visits.

However, it was also hypothesized that the detection threshold determined at the first testing session may be a more relevant measure when comparing fat taste sensitivity to dietary intake. It was thought that a naïve untrained response best reflected natural human exposure and perception of food (Running, Mattes, & Tucker, 2013).

Investigations into the relationship between fat taste sensitivity and associated factors have primarily been cross-sectional studies. A useful outcome of these observational study designs is the ability to determine prevalence of specific characteristics or qualities. In the case of fat taste sensitivity, prevalence of hypersensitivity and hyposensitivity to fat taste has often been expressed by dividing participants into groups using pre-established cut-off points (Keast et al., 2014).

2.4.4.3 Sensory testing methodologies

There are three well established methods for testing sensory thresholds (ATSM, 2011). These are the staircase method, the three alternative forced choice (3-AFC) method and triangle triplicates.

The most commonly used methodology for testing sensory thresholds is the 3-AFC (Haryono et al., 2014). For this method, participants have to identify the 'odd' sample out of three samples, starting with the lowest concentration or intensity. The threshold is ascertained at the level where the participant is able to correctly identify the 'odd' sample three times. The main concern with using 3-AFC, is that it could result in participant fatigue (Tucker & Mattes, 2013). This is particularly true when the stimulus is perceived as unpleasant (Tucker & Mattes, 2013).

The triangle triplicate method is a condensed version of the 3-AFC method which categorises participants based on their performance at a pre-determined measure of concentration or intensity (Stewart et al., 2010). It is only used in studies where adequate research has been conducted to identify a cut-off concentration or intensity level. The triangle triplicate method requires participants to identify the 'odd sample' out of three and the process is repeated three times (Stewart et al., 2010; Stewart, Newman, et al., 2011). Participants who get all three correct are considered hypersensitive to the stimulus and those who get one or more incorrect are considered hyposensitive.

The staircase method starts with a median concentration and progresses up, or down, in concentration dependent on whether the participant correctly identifies the stimulus out of three samples (Tucker et al., 2014). Correctly identifying the solution moves the participant to a lower concentration, an incorrect response would move the participant to higher one. The benefit of this method is that it does not require the participant to progress through all concentrations, starting from the lowest, until they are correctly able to identify the stimulus (ATSM, 2011; Tucker et al., 2014). Therefore, the staircase method is better for reducing participant fatigue (Bi & Ennis, 1998).

There are two main limitations to the staircase method, firstly there is a risk that those who are more sensitive to the stimulus may learn from the higher concentration (Bi & Ennis, 1998). As the concentrations step down, they may be able to identify the stimulus at a lower threshold than they would otherwise have been able to achieve. The second limitation is that there is a relatively high probability of making a correct guess; 11.1%, compared to the 3-AFC method which is only 3.3% (Tucker & Mattes, 2013).

2.5 Fat taste sensitivity, dietary intake, eating behaviour and body composition

Methodological differences in research has produced inconsistent findings about the relationship between fat taste and dietary intake. Six studies were found with methodologies that included laboratory measured fat taste sensitivity thresholds and at least one form of dietary assessment (Keast et al., 2014; Newman, Bolhuis, Torres, & Keast, 2016; Stewart et al., 2010; Stewart & Keast, 2012; Stewart, Newman, et al., 2011; Tucker et al., 2014). Of these, two were intervention studies (Newman et al., 2016; Stewart & Keast, 2012). All six studies included measures of total energy and macronutrient intake and body composition, three also measured hedonic liking. Three studies measured aspects related to eating behaviour (Keast et al., 2014; Stewart, Newman, et al., 2011; Tucker et al., 2014) A summary of these studies is presented in Table 2.6.

Fat taste sensitivity

In studies where participants were categorised into groups based on fat taste sensitivity, the prevalence of hypersensitive participants ranged from 22-58%. The effect of sex was assessed in a reliability study which took seven measures of fat taste sensitivity and found no significant difference between males and females (Tucker et al., 2014).

Dietary intake

A range of dietary intake assessment methods were used across the studies, with the most common being a weighed or estimated food diary reported for 2-5 days. Two studies used an FFQ and one study used the 24-hour recall method. All six studies reported measures of total energy and fat intake. No statistical analysis for dietary patterns was conducted for any of the six studies.

Table 2.6 Summary of studies investigating fat taste sensitivity, dietary intake and metabolic outcomes

Author, study design	Purpose	Participants (sample size)	Method	Findings and conclusions
Stewart et al. (2010), cross-sectional study	Investigate oral fatty acid sensitivity, food selection and BMI in humans	Australian males and females (N=54)	- Triplicate triangle oral fatty acid sensitivity tests - 2d food diary - Height, weight and BMI - Fat ranking task (Custard)	- 22% of participants were categorised as hypersensitive - Hypersensitivity to fat taste was associated with lower intakes of energy and total fat and a lower BMI. They also performed better in the fat ranking task. - Hypersensitive participants consumed significantly less carbohydrate and polyunsaturated fats.
Keast et al. (2014), blinded crossover study	Determine if altered oral fatty acid chemoreception affects energy intake and perceived satiety	Australian males and females from Deakin University (N=24)	- Fat taste detection thresholds determined by 3-AFC method - Test meal observations - Satiety questionnaire and hedonic liking scale - 4d food diary - 107-item FFQ - Height, weight and BMI	- 58% of participants were hypersensitive to fat taste. - No significant difference was found between hypersensitive and hyposensitive groups for energy or macronutrient intake. - Following a high fat breakfast, hyposensitive participants were significantly more likely to report increased hunger than their hypersensitive counterparts. They were also more likely to consume more energy at their lunchtime meal.
Stewart, Newman, et	Extend knowledge around fatty acid	Australian males and females	- Triplicate triangle oral fatty acid sensitivity tests	- 25% of participants were found to be hypersensitive. - Hypersensitive participants were significantly better at

Author, study design	Purpose	Participants (sample size)	Method	Findings and conclusions
al. (2011), cross-sectional study	taste, particularly types of foods consumed and dietary behaviours associated	(N=51)	- Fat ranking task (Custard) - PROP chemoreceptor taste sensitivity - 4d food diary - Food attitudes and behaviours questionnaire - Weight, height, BMI	completing the fat ranking task - Hyposensitive participants reported a significantly higher intake of energy, total fat, saturated and polyunsaturated fats - They also had higher intakes of full-fat dairy, meat, eggs and spreads. - Hyposensitive participants had a higher BMI.
Tucker et al. (2014), cross-sectional study	Examine reliability of associations between fat taste, hunger, dietary fat intake and BMI	American males and females (N=48)	- Fat taste detection thresholds determined by the staircase method over seven visits - Hunger visual analogue scale - Habitual dietary fat intake (Block rapid fat screener) - Height, weight and BMI	- Participants who were lean or over weight reduced their taste thresholds significantly more study duration than obese participants. - Trending changes in taste detection threshold were not different between males and females. - Saturated fat intake positively correlated to baseline fat taste sensitivity - In lean and overweight participants, total fat correlated to baseline fat taste sensitivity. - Mean fat taste sensitivity was positively associated with total fat intake, saturated fat intake and fat as %TE

Author, study design	Purpose	Participants (sample size)	Method	Findings and conclusions
Stewart and Keast (2012), randomized cross-over trial	Evaluate influence of a high-fat and low-fat diet on taste sensitivity to oleic acid in lean and OW/OB participants	Australian males and females (N=31)	- 4 week high-fat (>45%) and low-fat (<20%) intervention diet - Fat taste detection thresholds determined by 3-AFC method - Fat ranking task - 24-hour food recall (baseline) - 1d food diary (weekly) - 9-point hedonic liking scale - Weight, height and BMI	- No difference was found in fat taste thresholds between lean and OW/OB participants prior to commencing the intervention. - The low-fat diet intervention significantly decreased OA taste thresholds in both lean and OW/OB participants and significantly improved performance in the fat ranking task.
Newman et al. (2016)	Assess effects of a 6-week low-fat or potion control diet on fat taste thresholds, perception and	Australian males and females, aged 18-75 with a BMI >25 kg/m^2 (N=53)	- 6-week low-fat (>25% energy from fat) diet or a portion control diet (<33% energy from fat and 25% reduction in total energy) - Fat taste detection	- There was no significant difference for OA taste detection thresholds at baseline between the intervention groups - At week six OA taste detection thresholds had significantly decreased in the low-fat diet group compared to the portion control group. The low-fat group has also significantly improved in the fat ranking task.

Author, study design	Purpose	Participants (sample size)	Method	Findings and conclusions
	preference in OW/OB people.		thresholds determined by 3-AFC method - Fat ranking task (Custard) - 1d food diary (BL and weeks 2. 3. 4 and 6) - 120-item FFQ - 9-point hedonic liking scale - Weight, height and BMI	- No relationship was found at baseline between OA taste detection thresholds and BMI. At the end of the intervention OA taste detection thresholds and BMI were positively associated.

%TE = percentage of total energy; 3-AFC = Three Alternative Forced Choice; BL = Baseline; BMI = Body Mass Index; d = Day; FFQ = Food frequency questionnaire; OA = Oleic acid; OW/OB = Overweight and obesity

Fifty-four Australian adults were divided into hypersensitive and hyposensitive groups for fat taste (Stewart et al., 2010). It was found that those participants who were hypersensitive to fat taste had lower intakes of total energy, total fat, polyunsaturated fat and carbohydrate. The findings for reduced total energy and fat intake were consistent with two other studies. Stewart, Newman, et al. (2011) found that hyposensitive participants had significantly higher intakes of energy, total fat, saturated fat and polyunsaturated fats. Tucker et al. (2014) found that total energy, total fat and saturated fat intake was positively associated with mean fat taste sensitivity thresholds over seven repeated measures. Keast et al. (2014) had a contradictory result, finding no significant difference in energy or macronutrient intake between participants who were hypersensitive or hyposensitive to fat taste.

Stewart, Newman, et al. (2011) was the only study to investigate associations between fat taste sensitivity and food groups. The study found that participants with higher thresholds of fat taste detection were more likely to consume full-fat dairy, meat, eggs and spreads. It was suggested that these foods were typical of a traditional western-style diet (Stewart, Newman, et al., 2011). However, these components were not consistent with 'traditional' diet patterns identified in New Zealand women or the 'western' patterns described in a review of dietary patterns by Kant (2004). Stewart et al. (2010) identified a need for fat taste sensitivity to be studied in conjunction with habitual dietary intake to better understand how combinations of food may relate to fat taste.

Eating Behaviour

Perceived hunger was measured in two of the six studies (Keast et al., 2014; Tucker et al., 2014). It was also one of the aspects measured for hunger-related eating behaviours in the Three-factor eating questionnaire (Chambers & Yeomans, 2011). Keast et al. (2014) found that participants who were hyposensitive to fat taste were more likely to report higher sensations of hunger following a high-fat breakfast. Additionally, they were also more likely to consume more energy at the following meal. Of interest, Tucker et al. (2014) found that hypersensitive participants rated their hunger sensations more intensely while in a fasted state prior to fat taste sensitivity testing than their hyposensitive counterparts.

Stewart, Newman, et al. (2011) identified several dietary habits associated with fat taste sensitivity. They found hypersensitive participants were more likely to perceive fried foods as unhealthy and hyposensitive participants were less likely to substitute red meat for white meat and avoid eating saturated fat.

Body composition

Five of the studies found associations between fat taste sensitivity and BMI. Both Stewart et al. (2010) and Stewart, Newman, et al. (2011) found that hypersensitivity to fat taste was associated with a lower BMI. An intervention study by Stewart and Keast (2012) assessed the effect of low-fat and high-fat diets on taste sensitivity in lean and overweight/obese participants. They found that a high-fat diet significantly reduced fat taste sensitivity in lean participants. Additionally, the low-fat diet improved fat taste sensitivity irrespective of BMI. This was a similar finding to Newman et al. (2016), where fat taste sensitivity was positively associated with BMI irrespective of being in the low-fat or portion-control diet group. Interestingly, both intervention studies found that BMI was not significantly associated with fat taste sensitivity at the baseline measure (Newman et al., 2016; Stewart & Keast, 2012).

A study by Tucker et al. (2014) assessed repeatability of fat taste detection thresholds. The study found that participants who were of lean (18.5-24.9 kg/m^2) or overweight (25-29.9 kg/m^2) body composition improved their fat taste detection thresholds significantly more that their obese counterparts. No significant improvement was seen in fat taste detection thresholds for the obese participants.

2.6 Summary

The current global food environment is one dominated by energy-dense processed foods, with very little nutritional benefit. However, investigating energy and macronutrient intake alone provides an inadequate measure of habitual intake of such foods and how they fit into an individual's overall diet. The use of statistically derived dietary patterns may better serve to highlight the consequences of consuming habitual diets high in energy-dense processed foods. It may also be possible to gain a better understanding of how to change a person's dietary intake by investigating what drives them to adhere to a healthy or unhealthy dietary pattern.

Taste remains one of the key aspects of palatability, an important driver of food selection. Fat is increasingly being recognised, in research, as having a detectable taste. However, inconclusive results for the associations between fat taste and dietary intake indicate that a new approach is required to better understand the role that fat taste may play. As fat is rarely consumed in isolation, dietary patterns provide an opportunity to investigate associations between habitual dietary intake and fat taste sensitivity. Furthermore, the knowledge of pathways linking specific behavioural responses to sensory perception of fat in foods could create significant opportunities for individual and population-based intervention.

Chapter 3 - Method

3.1 Study design

This study was an integral part of the “Dessert taste study”, a cross-sectional, mixed-methods observational study. The Dessert taste study primarily aimed to investigate fat taste detection thresholds, olfaction detection thresholds and hedonic liking for fat. Additional investigations were made into the relationships between these measures and dietary intake, eating behaviour and anthropometric measures. Questionnaires were used to assess eating behaviour and dietary intake. The questionnaires included the New Zealand women’s food frequency questionnaire (NZW-FFQ) and the Three-factor eating questionnaire (TFEQ) (Houston, 2014; Stunkard & Messick, 1985). The sensory methodology was similar to that used in previous studies by Keast et al. (2014) and Haryono et al. (2014).

This study utilised dietary data obtained from the NZW-FFQ, to establish the dietary patterns of the participant group for comparison against sensory measures for fat taste detection thresholds, and eating behaviour scores.

3.2 Ethical approval

The study protocol was peer reviewed and judged to be low-risk by Massey University, New Zealand. Participants were provided with information sheets and written informed consent was obtained prior to commencing data collection.

3.3 Study Population

3.3.1 Participants

New Zealand European (NZE) females, aged 19-45 years of good health and menstruating regularly, were recruited from the Auckland area. Participants were female only to ensure testing was standardized in this sample size. This was due to the known differences between genders in taste function, perception and eating behaviour and to guide the development of a protocol for a larger research project in females only (Feeney, O'Brien, Scannell, Markey, & Gibney, 2011). As taste function deteriorates with age and may alter during menopause, participants were under the age of 45 and premenopausal (Methven, Allen, Withers, & Gosney, 2012). Research suggests that taste function, and more specifically, taste preference varies between ethnicities (Ahrens, 2015). To eliminate this potentially confounding variable, all recruited participants self-identified as New Zealand European.

Screening was achieved by an online questionnaire to reduce potential inhibitors of normal gustatory function. Exclusion criteria included individuals who were pregnant or breastfeeding, smokers, those with allergies, intolerances, a medical history of gastrointestinal dysfunction or recent antibiotic use in the past three months (Kruger et al., 2015). Participants with a medical condition which could affect gustatory function, for example; chemotherapy, radiation therapy or any form of oral or nasal disease were also excluded (Steinbach et al., 2009). Participants were asked to reschedule if they were experiencing cold or flu symptoms on test days.

3.3.2 Recruitment

Recruitment for this study commenced in May 2015, and ran in parallel with data collection until completion in August 2015. Sampling was via convenience and snowball methods through online advertising, information flyers around the Massey University campus and previous research participant databases.

3.3.3 Screening

All women who registered interest were provided with an information sheet and invited to complete an online screening questionnaire, hosted by SurveyMonkey (Appendix A). This questionnaire established participant demographics, health status, medications, menstruation, diet and exercise habits and smoking habits. Participants who met the inclusion criteria for the "Dessert taste" study were contacted via email to be booked in for three data collection visits.

3.4 Procedures

3.4.1 Data collection

Participants attended three, one and a half hour, sessions in the sensory laboratory at the Massey University Albany campus, in the Human Nutrition Research Unit. All sensory testing was conducted in the sensory booths.

Visits were on non-consecutive days and completed within one month of the initial visit (Figure 3.1). Anthropometry measures were taken at the initial session to determine height, weight, body mass index (BMI) and body fat % (BF%). Height was measured using a stadiometer (SECA, Germany). Weight and BF% were determined using Bioelectrical Impedance Analysis (BIA) (Biospace, InBody 230, Cerritos, CA), which also functioned as electrical scales. BMI was calculated using the equation weight (kg) / height (m)^2. Dietary assessment and eating behaviour questionnaires were sent to the participants electronically after the first test session and took approximately 60 minutes to complete. These were undertaken online in the participants own home.

Visit 1

- Information sheet and consent
- Anthropometric measures (BIA and stadiometre)
- Sensory tests - taste, olfaction and hedonic liking[1]
- Protocol for online NZW-FFQ and TFEQ explained

Visit 2

- Sensory tests - taste, olfaction and hedonic liking[1]

Visit 3

- Sensory tests - taste, olfaction and hedonic liking[1]
- Final date to complete NZW-FFQ and TFEQ

[1] Testing for fat olfactory sensitivity and hedonic liking were included in the wider Dessert taste study.
NZW-FFQ = New Zealand women's food frequency questionnaire; TFEQ = Three-factor eating questionnaire

Figure 3.1 Summary of the Dessert taste study testing sessions

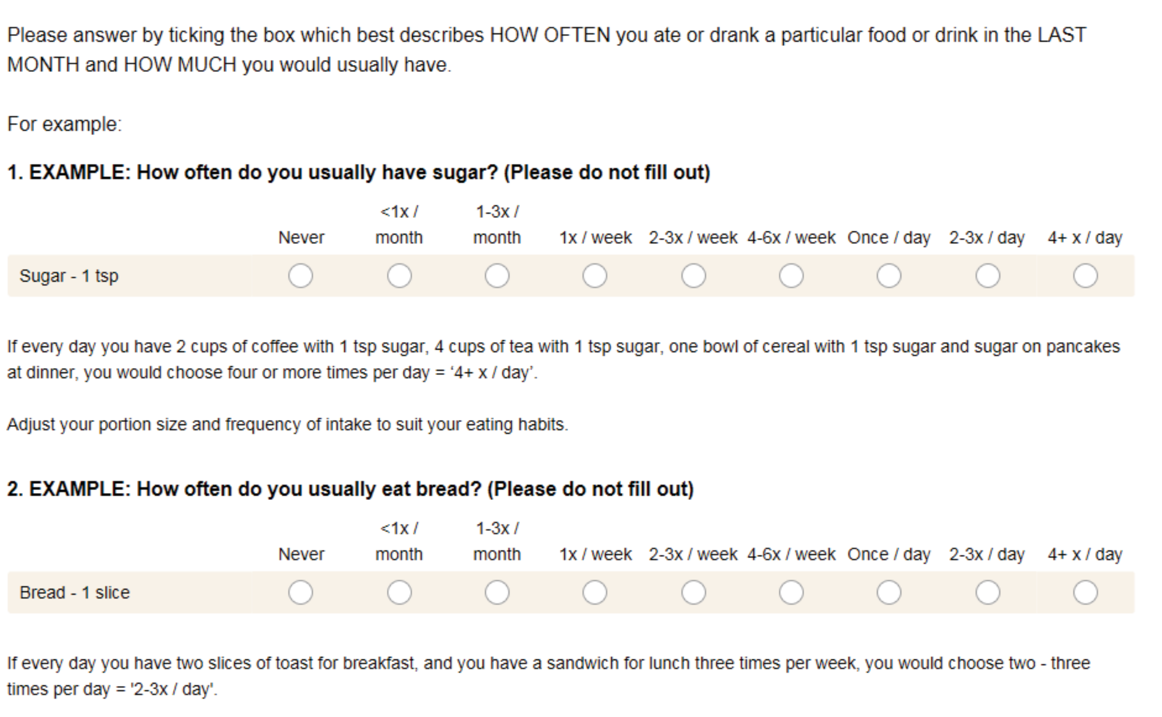
3.5 Dietary and eating behaviour questionnaires

3.5.1 Food frequency questionnaire

The New Zealand Women's Food Frequency Questionnaire (NZW-FFQ) is a partially validated, self-administered 220-item food frequency questionnaire which provides information on overall diet and fat related eating behaviour (i.e. trimming fat off meats) for the previous 12 months (Houston, 2014; Kruger et al., 2015) (Appendix B). The NZW-FFQ is organised by common food groups (e.g. dairy; breads and cereals; meat, fish and poultry; fats and oils; fruit and vegetables; drinks; takeaways and miscellaneous (baking, spreads etc.)). Food items were measured using standard, natural portion sizes (i.e. one egg; one slice of bread). Frequency was reported by selecting one option which best described that participant's regular intake. The nine frequency options were: never; less than once per month; 2-3 times per month; once per week; 2-4 times per week; 4-6 times per week; once a day; 2-3 times per day; or more than four times per day. Questions were also included which investigated food preparation methods (e.g. removal of skin or fat from meat) and cooking methods (e.g. use of oils or sprays when frying).

The questionnaire was adapted from the “2007/08 New Zealand Adult Nutrition Survey” and is currently in the process of being validated for nutrient intake by the EXPLORE study (Kruger et al., 2015; Ministry of Health, 2011b). Although a weighed food record is the widely accepted ‘gold standard’ for dietary assessment, the method requires a significant contribution from the participant (Keast et al., 2014; Kruger et al., 2015). To limit participant burden, the NZW-FFQ was considered the most appropriate dietary assessment tool for capturing dietary intake in this participant group.

Prior to receiving the NZW-FFQ, participants were given verbal directions for completing the questionnaire. Key instructions included completing the questionnaire in a quiet, uninterrupted period and basing responses on participant’s own intake rather than household or others. The online questionnaire format provided additional guidance, with examples to demonstrate how to answer frequency questions (Figure 3.2).


Please answer by ticking the box which best describes HOW OFTEN you ate or drank a particular food or drink in the LAST MONTH and HOW MUCH you would usually have.

For example:

1. EXAMPLE: How often do you usually have sugar? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Sugar - 1 tsp									

If every day you have 2 cups of coffee with 1 tsp sugar, 4 cups of tea with 1 tsp sugar, one bowl of cereal with 1 tsp sugar and sugar on pancakes at dinner, you would choose four or more times per day = ‘4+ x / day’.

Adjust your portion size and frequency of intake to suit your eating habits.

2. EXAMPLE: How often do you usually eat bread? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Bread - 1 slice									

If every day you have two slices of toast for breakfast, and you have a sandwich for lunch three times per week, you would choose two - three times per day = '2-3x / day'.

Figure 3.2 Example questions used to demonstrate correct procedure for completing the New Zealand Women’s Food Frequency Questionnaire

3.5.2 Data analysis of FFQ

Responses to the NZW-FFQ and TFEQ were downloaded from the online host, SurveyMonkey, to Excel spreadsheets (Microsoft Office, 2007).

Data obtained from the NZW-FFQ were operationalised as Daily Frequency Equivalent's (DFE's) for the purposes of statistical analysis. A DFE value was calculated for each of the nine possible frequency responses (Table 3.1). For example, '4-6 x/week' was calculated as 5 days / 7 days = 0.71 DFE's (F. Hu et al., 1999; Silva et al., 2013).

Table 3.1 Daily frequency equivalent response conversions

Response	Numerical frequency	Daily Frequency Equivalent (DFE)
Never	0 m	0.0
<1 x/month	0.25 m	0.01
1-3 x/month	2 m	0.07
1 x/week	1 w	0.14
2-3 x/week	2.5 w	0.36
4-6 x/week	5 w	0.71
Once/day	1 d	1.0
2-3 x/day	2.5 d	2.5
4+ x/day	4 d	4.0

m = month; w = week; d = day

3.5.3.2 Food groupings

All food items included in the NZW-FFQ were categorised into 29 independent food groups that were based on foods with similar nutritional composition and functional characteristics (Table 3.2). Where the serving sizes differed significantly within a food group, DFEs were recalculated, based on a standard serving size. For example, 'low fat milk' included low fat milk with hot drinks (50 mL), milk as a drink (200 mL) and milk on cereal (125 mL), and the DFE was recalculated based on the number of 200 mL serves.

Table 3.2 Twenty-nine food groups used in principal component factor analysis

Food Group	Food Items Included
Full fat milk	Full fat milk (silver, purple, dark blue top)
Low fat milk	Lite milk (light blue top), trim milk (green top), calcium enriched (yellow top), non-dairy (soy, nut milk)
Yoghurt and other milk products	Breakfast drinks, flavoured milk, evaporated milk, fermented milk products, yoghurt (plain, fruity, greek, unsweetened)
Cheese	Cheddar, processed cheese, cream cheese, blue vein, brie, edam, cottage cheese, ricotta, camembert, feta
Fruit	All fruit including fresh, canned, frozen, dried
Non-starchy vegetables	Capsicum, onion, mushrooms, frozen mixed vegetables, beetroot, tomatoes, lettuce, spinach, cabbage, broccoli, watercress, green beans, sprouts, courgette
Starchy vegetables	Kumara, yam, parsnip, turnip, swedes, taro, green banana, sweet corn kernels, potato (excluding chips)
Refined grains, crackers and bread	White bread, wraps, fruit bread, focaccia, bagel, pita, paraoa bread, rewena bread, doughboys; discretionary breads including: crumpets, scones, savoury muffin, pancakes/waffles; crackers including: cream, cruskit, corn, rice, vitawheat; white rice; pasta including: penne, spaghetti, vermicelli; noodles including: instant, egg, rice; canned spaghetti
Wholegrains and Wholegrain bread	Bread (high fibre, wholemeal, wholegrain), brown rice, quinoa, couscous, bulgur wheat
Sweetened cereals	Milo cereal, coco pops, nutrigrain, honey puffs, fruit loops, special K, light and tasty, sultana bran
Unsweetened cereals	Weetbix, cornflakes, rice bubbles, all bran, branflakes, porridge, rolled oats, oat bran, oat meal
Red meats	Beef (mince dishes, casseroles, stew, stir-fry, roast, steak), lamb (stew, casserole, stir-fry), venison, hogget (roast, chop, steak, casserole, stew, stir-fry), offal (liver, kidney, pate), veal
White meat	All chicken (breast, leg, wing, casserole, stir-fry), turkey/quail, pork (roast, chop, steak), mutton bird/duck
Processed meat	Sausages, frankfurters, saveloys, cherrios, bacon, ham, luncheon meats, salami, chorizo, meatloaf, corned beef, patties
Fish and seafood	Canned salmon, canned tuna, canned mackerel, snapper/hoki, gurnard, shark, tuna, salmon, shrimp/prawn, crab, mussels, pipi, whitebait, kina, squid
Egg and egg dishes	Egg, egg mixed dishes (omelette, quiche, frittata, other baked egg

	dishes)
Legumes and Soybean products	Canned/dried (lentils, chickpeas, peas, beans, baked beans), hummus, dahl, soybeans, tofu
Nuts and seeds	Nuts (brazil, walnut, almond, cashew, pistachio), seeds (pumpkin, sunflower), peanut butter, peanuts
Fats (Animal and coconut)	Butter, lard, dripping, ghee, coconut milk, cream, oil
Oil and oil-based dressings	Canola, sunflower, olive, vegetable oil, cooking spray, salad dressing (French, Italian), avocado, margarine – all types
Savoury Condiments	Mayonnaise, creamy dressings, white/cheese sauce, sour cream, sauces including: tomato, barbeque, chilli, mint, soy; gravy, mustard, chutney, instant soup, vegemite, marmite
Sweeteners and sweet condiments	Jam, honey, marmalade, white sugar
Sweet snack food, cakes and biscuits	Cakes, loaves, muffins, croissant, sweet pies, pastries, tarts, doughnuts, iced bun, biscuits (plain, chocolate covered), chocolate, lollies, muesli bars
Puddings	Ice cream, custard, milk puddings (semolina, instant), other non-dairy based puddings (pavlova, sticky date pudding), jelly, ice blocks
Savoury snack foods	Potato chips, corn chips, twisties
Fast-food	Meat pie, sausage roll, savouries, burgers, kebab, Chinese, Indian, Thai, pizza, crumbed chicken/fish, battered fish, potato fries, chicken nuggets
Cold beverages (excl. water and milk)	Fruit drink, sparkling grape juice, cordial, iced tea, energy drinks, sports drinks, flavoured water, soft drinks, fruit and vegetable juice, diet energy drinks, diet soft drinks, diet cordial
Hot beverages	Black tea, herbal tea, instant coffee, brewed water-based coffee, espresso, Milo, hot chocolate, soy drinks
Alcohol	Standard beer, low alcohol beer, white wine, red wine, wine cooler, cider, spirits, sherry, port, ready-to-drink, kava

Table above was assembled from the following references; Ministry of Health (2011b); Schrijvers et al. (2016)

3.5.3 Eating Behaviour questionnaire

The three-factor eating questionnaire (TFEQ) is a 51-item, validated questionnaire that provided information on eating behaviour regarding cognitive restriction, disinhibition and hunger (Stunkard & Messick, 1985) (Appendix C). Previous studies have found scores for cognitive restriction were inversely correlated to the occurrence of obesity, and disinhibition scores were positively correlated (Keskitalo et al., 2008; Kruger, De Bray, Beck, Conlon, & Stonehouse, 2016; Stunkard & Messick, 1985). The TFEQ was completed during the same period of time as the NZW-FFQ.

3.5.4 Data analysis of TFEQ

Reponses to the Three-factor eating questionnaire were separated into the three behavioural categories: cognitive restraint, disinhibition and hunger. Scores for each behaviour category were calculated and compared to reference ranges as determined by Stunkard and Messink (1985). Reference ranges were also used to determine low, medium and high scores for each eating behaviour (Stunkard & Messick, 1985) (Table 3.3).

Table 3.3 – Reference ranges for scoring the Three-factor eating questionnaire (TFEQ)

Eating behaviour factor	Low range	Medium range	High range
Cognitive restraint	4-14	15-17	18-21
Disinhibition	1-8	9-12	13-16
Hunger	0-3	4-6	7-14

Table above assembled from Stunkard and Messick (1985)

3.6 Sensory methodology

Several earlier studies (Haryono et al., 2014; Stewart & Keast, 2012) established key procedures for the testing of oral fat taste detection thresholds. These studies identified UHT milk as the best vehicle for fatty acids as it provided better stability; ensuring solutions were homogenized for the duration of the testing session (Stewart et al., 2010).

Testing took place in the Massey University food laboratory sensory booths under red light to obscure any visual cues. Prior to beginning each sensory session, it was confirmed that participants had been in a fasted state for the previous 12 hours. Nose clips were worn throughout sensory testing for fat taste thresholds to prevent olfactory interference. Participants followed the sip-and-spit procedure and rinsed their mouth with water between sample triplicates (Haryono et al., 2014).

The base solution was prepared using non-fat UHT milk. For every 2L of non-fat UHT milk, 100g of gum Arabic and 200 mg of 0.01% EDTA (Ethylenediaminetetraacetic acid) was added. The base solution was then divided in half. For the blank solution, 5% liquid paraffin was added (35 mL 5% liquid paraffin per 750 mL of blank solution) in a sufficient quantity to ensure there were no textural inconsistencies between solutions containing oleic acid (OA) and those without. OA solutions were prepared in a 250 mL beaker with 5ml liquid paraffin per 100 mL of base solution. Solutions were made in increasing concentrations of OA as outlined in Table 3.4. All solutions were homogenized (Silverson L4RT) starting with the blank solution, followed by OA solutions in ascending order of concentration.

Table 3.4 Ascending concentrations of oleic acid (OA) solutions used to measure OA taste detection thresholds

Oleic acid concentration (mM)[1]	µl/100 ml
0.02	0.56
0.06	1.90
1.0	31.5
1.4	44.1
2.0	63.1
2.8	88.4
3.8	119.9
5.0	157.8
6.4	202
8.0	250
9.8	309
12.0	380
20.0	631.2

[1] Concentrations determined from previous methodologies as follows; Haryono et al. (2014); Keast et al. (2014); Stewart et al. (2010); Stewart and Keast (2012)

3.6.1 Use of oleic acid in testing fat detection thresholds

OA is the most commonly used long chain fatty acid for testing fat taste detection thresholds. The main reasons for this include:

1) Ease of use, where OA is a liquid at room temperature
2) More stable in solution compared to linoleic, lauric and capric acids (Stewart, Seimon, et al., 2011)
3) Greater opportunities for comparison to other research
4) OA is widely found in foods including safflower and olive oil, peanuts, red meat, pork and margarine.
5) OA is rarely found in foods at greater than 5%, unless the food is rancid (Tucker, 2014).
6) Low concentrations of OA were not expected to cause oral irritation

For this study, OA was sourced from Sigma Aldrich (MO, USA), and refrigerated below 4^{o}C under nitrogen. In previous studies using OA to achieve detection thresholds, participants have described the taste as “plastic”, “woody” or “dirty”. One study found that 33% of participants reported OA taste as unpleasant (Mattes, 2009). Therefore, it is important to conduct fat taste sensitivity methodology in a way that reduces the effects of participant fatigue at higher concentrations.

3.6.2 Three alternative forced choice (3-AFC) method

All solutions were made fresh on each day of testing to prevent oxidation of OA (Tucker et al., 2014). Using the ascending three alternative forced choice method (3-AFC) (ATSM, 2011) participants were given three 10 mL milk solutions and asked to determine the one that tasted different. The concentration of the OA sample continued to increase until the correct solution was identified. The participant was then provided with two additional triplicates, each containing an OA solution at the same concentration. The fat taste detection threshold was measured as the point at which the participant had correctly identified the solution containing OA three times, at the same concentration (Keast et al., 2014). This method gives a 3.7% probability of guessing all three triplicates correctly at the same concentration which is a lower than other common sensory testing methods (i.e. the staircase method, 11.1%) (ATSM, 2011; Keast et al., 2014).

3.6.3 Establishing fat detection thresholds

The fat detection threshold was determined, at each visit, by the concentration at which a participant could correctly identify the solution containing OA three times consecutively (Haryono et al., 2014). Fat detection thresholds determined at the initial visit were used for further analysis in this study, as they were thought to better reflect the untrained, or 'naïve', sensory experience of consuming triacylglycerol containing foods (Running et al., 2013). Therefore, it is an appropriate threshold for comparison against observational data for dietary intake and eating behaviour. Initial fat detection thresholds were then treated as a grouping variable, using previously established cut-offs by Stewart, Newman, et al. (2011) and Keast et al. (2014). Participants were categorised as hypersensitive (≤3.8 mM) or hyposensitive (>3.8 mM). Threshold data for fat taste detection was entered twice into an excel spreadsheet, using a double verification method, to minimise human error.

3.7 Statistical analysis

Statistical analysis of participant baseline characteristics, dietary, eating behaviour and fat taste detection threshold variables was conducted using SPSS software for Windows (Statistical package for the social sciences, Version 23.0; SPSS Inc, Chicago IL). All data was tested for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. Normality was also confirmed visually with histograms. Data that was not normally distributed was log transformed and retested to check for possible improvements to normality. Descriptive statistics for continuous normally distributed data was expressed as mean and standard deviation (SD) and log transformed data was reported as geometric means and 95% confidence intervals. Where data was not normal, irrespective of log transforming, medians with 25^{th} and 75^{th} percentiles were reported. Categorical data was reported as numbers, frequencies and percentages.

Relationships between continuous variables were investigated using Pearson's correlation coefficients for parametric data and Spearman's Correlation coefficients for non-parametric data. Where a significant relationship was found, the strength of the relationship was determined by the *r* value as follows: 0.1-0.3 weak correlation, 0.3-0.5 moderate correlation, >0.5 strong correlation (Cohen, 1988; Field, 2009). When comparing two participant groups for significant differences, parametric data was tested using Mann-Whitney t-tests. Kruskal-Wallis tests were used to compare groups with non-parametric data. Where a significant difference was identified between groups, Mann-Whitney post hoc tests and a Bonferroni correction were applied to identify the significant difference and reduce the chance of a type 1 error. A chi-square test was conducted to investigate relationships between categorical variables.

3.7.1 Sample size

Statistical power for the Dessert taste study, was calculated, to be 0.8, requiring a sample size of 50 (Kindleysides et al., 2016, December). To assess repeatability of the fat taste detection threshold and olfactory measures, participants were required to attend three visits for testing. This sample size also ensures that the minimum requirements are met for conducting a factor analysis of dietary data (de Winter, Dodou, & Wieringa, 2009).

3.7.2 Assessing dietary patterns

Exploratory factor analysis was used to extract dietary patterns from the food group DFE scores. Factor loadings were extracted using principal component analysis, eigenvalues (greater than one) and varimax rotation. Eigenvalues provide an indication that the factor is loaded with a greater number of values or explains more of the variation. As the variables are not thought to be highly related to each other, it was appropriate to use orthogonal rotation (Bro & Smilde, 2014; Field, 2009). Although misreporting is a significant concern when conducting dietary assessments, it is thought to have a reduced impact on factor analysis as it does not quantify volumes of intake (Bailey et al., 2007).

To determine the number of dietary patterns defined by the principal factor analysis, factor loadings for each food group were closely scrutinised. Previous dietary pattern analysis studies conducted in a similar population group were also considered (Schrijvers et al., 2016). Extracted factors were described based on the food groups which had higher loadings (>0.3), indicating a large contribution to the pattern (Bro & Smilde, 2014; Newby & Tucker, 2004). A negative loading (<-0.3) indicated a stronger inverse relationship between that food group and the dietary pattern being described. Based on analysis of the factor loadings, the number of factors which best described the data was determined. These factors were then named based on the nutritional characteristics of the food groups most highly loaded onto them.

Inter-item reliability of each dietary pattern was assessed using Cronbach's α, to ensure each food grouping was an appropriate measure of the dietary pattern it was associated with. Each pattern was assessed independently using those food groups which were highly associated with the factor (factor loading >0.3). Cronbach's α was improved, where possible, by removing a food group and thus increasing inter-item reliability. The principal component factor analysis was conducted again, following testing for inter-item reliability, to ensure that removal of food groups had not significantly affected the nutritional characteristics of each dietary pattern (Field, 2009).

3.7.3 Validation of oleic acid taste detection thresholds

Intra-participant variability of oleic acid taste detection thresholds was assessed using Intra-class correlation (ICC). In previous studies, it was found that significantly lower detection thresholds were obtained by some participants, during repeated testing, potentially due to a learned recognition of OA taste (Tucker et al., 2014). ICC was conducted for oleic acid taste detection thresholds across all three visits to ascertain the effect of familiarization and learning (Newman & Keast, 2013).

Chapter 4 – Results

The findings presented in the results chapter are a subset of results from the Dessert taste study. The order of presentation corresponds to the order of objectives outlined in Chapter 1, section 1.2. The first section relates to baseline characteristics of the participant group, followed by an analysis of the dietary patterns. Eating behaviours are described and compared to the baseline characteristics and dietary patterns. Oleic acid taste detection thresholds of the participant group are then described and compared to baseline characteristics and dietary patterns. The final section of the results investigates the relationship between OA detection thresholds and eating behaviour. Significant findings are presented as figures or in tables, highlighted in bold.

4.1 Participant characteristics

Fifty-One New Zealand European (NZE) females, aged 19-45 years, were recruited. Of these, 50 women completed all three required visitations. A summary of the baseline characteristics of this group are outlined in Table 4.1. The median (25, 75 percentile) age of the participants was 25.5 (22.4, 32.0) years, with the majority (66%) being under the age of 30. The median BMI (25, 75 percentile) was 23.7 (21.3, 28.3) kg/m^2, and most participants (62.0%) fell within the normal to underweight range of less than 24.9 kg/m^2. Almost half the participants (44%) had a high percentage of body fat. The mean (± SD) for body fat percentage was 30.3 ± 8.4%.

Table 4.1 Age, height and body composition characteristics of study participants (N=50)

Characteristics	N (%)	NZE Women
Age (years)		25.49 (22.39, 32.04)[a]
<30 years	33 (66.0)	23.85 ± 2.88[b]
≥30 years	17 (34.0)	37.08 ± 5.26[b]
Height (cm)		166 ± 6[b]
Weight (kg)		67.4 (57.2, 74.9)[a]
BMI (kg/m^2)[c]		23.7 (21.3, 28.3)[a]
Normal/Underweight (≤ 24.9 kg/m^2)	31 (62.0)	21.9 ± 1.7[b]
Overweight (25.0-29.9 kg/m^2)	11 (22.0)	27.6 ±1.5[b]
Obese (≥ 30.0 kg/m^2)	8 (16.0)	33.2 ± 2.8[b]
Body fat percentage (%)[d]		30.3 ± 8.4[a]
Low (< 22%)	8 (16.0)	19.3 ± 1.8[b]
Normal (22-29.9%)	20 (40.0)	26.0 ± 2.0[b]
High (≥ 30%)	22 (44.0)	38.2 ± 5.5[b]

[a] Median (25th – 75th percentile)

[b] Mean ± Standard deviation

[c] BMI categories as established in (Ministry of Health, 2015)

[d] Body fat percentage (Kruger et al., 2015)

BMI = Body Mass Index

4.2 Dietary Analysis

4.2.1 Dietary Pattern analysis

Dietary patterns were identified using principal component factor analysis of Daily Frequency Equivalents (DFE) obtained from the food frequency questionnaire (FFQ) data. Three distinct patterns were established for the participant group. These are outlined in Table 4.2. The three patterns identified are named and described below:

- **Unhealthy Pattern (Pattern 1)** – This pattern was represented by higher loadings for 11 of the 29 food groups. These included foods typically considered energy dense, and high in fats, sugar and salt. Positive loadings for this pattern include cheeses; alcohol; savoury condiments, savoury snack foods; sweeteners and sweet condiments, fats (animal and coconut); processed meat; red meats; fast food; refined grains, crackers and bread; and puddings. It was also characterised by lower loadings of unsweetened cereals.

- **Healthy Pattern (Pattern 2)** – This pattern was characterised by higher loadings in seven of the 29 food groups, including hot beverages; wholegrains and wholegrain bread; fish and seafood; low-fat milk; nuts, nut spreads and seeds; legumes and soybeans; and egg and egg dishes. This pattern also had negative loadings in some traditionally 'unhealthy' foods including cold beverages; sweet snack foods, cakes and biscuits; and fast food.

- **Snacking Pattern (Pattern 3)** – This pattern was found to have higher loadings in eight of the 29 food groups. The pattern was characterized by foods often consumed as a part of a snack or light meal, including refined grains, crackers and bread; sweetened cereals; puddings; fruit; low-fat milk; yoghurt and other milk products; savoury snack foods; nuts, nut spreads and seeds. Lower loadings were found for full-fat milk; egg and egg dishes; and starchy vegetables.

Table 4.2 Factor analysis matrix for three dietary patterns identified (N=50)

	Dietary Patterns		
	Pattern 1 – Unhealthy	Pattern 2 – Healthy	Pattern 3 – Snacking
Cheeses	**.748**	-	-
Alcohol	**.637**	-	-
Savoury condiments	**.554**	-	-
Unsweetened cereals	**-486**	-	-
Savoury snack foods	**.461**	-	.443
Sweeteners and sweet condiments	**.449**	-	-
Fats (High saturated fat)	.342	-	-
Processed Meat	**.336**	-	-
Red meats	.309	-	-
Cold beverages	-	-.674	-
Hot beverages	-	**.620**	-
Sweet snack food, cakes and biscuits	-	-.615	-
Wholegrains and wholegrain bread	-	**.521**	-
Fish and seafood	-	**.517**	-
Low fat milk	-	**.487**	.482
Nuts, nut spreads and seeds	-	**.470**	.441
Fast food	.407	**-.469**	-
Legumes and soybeans	-	**.423**	-
Refined grains, crackers and bread	.465	**-**	**.634**
Sweetened cereals	-	-	**.595**
Puddings	.342	**-**	**.502**
Fruit	-	-	.498
Full fat milk	-	-	**-469**
Yoghurt and other milk products	-		**.467**
Egg and egg dishes	-	**.386**	-.436
Starchy vegetables	-	-	-.346
White meat	-	-	-

Dietary patterns were determined from a 220-item NZW-FFQ (Houston, 2014);
Factors identified based of loadings >0.3;
Food items with no loadings had loadings <0.2;
Theoretical range -1.00 to 1.00

Inter-item reliability was determined using Cronbach's α (Table 4.3). Reliability was found to be moderate, but improved for each dietary pattern after the removal of non-starchy vegetables from pattern 2, and oils, oil-based dressings and margarine from pattern 3.

Following the removal of these food groups, it was found that fats (animal and coconut) positively loaded onto pattern 1. New Cronbach's α values for the three dietary patterns were found to be 0.654, 0.520 and 0.562 respectively.

Table 4.3 Inter-item reliability of three dietary patterns

Pattern	Original Cronbach's α	Items added or removed	New Cronbach's α
P1: Unhealthy	0.651	Fats (animal and coconut) added	0.654
P2: Healthy	0.450	Non-starchy vegetables	0.520
P3: Snacking pattern	0.551	Oils, oil-based dressings and margarine	0.562

These patterns explained 13.7%, 11.4% and 9.9% of variation in food intakes respectively.

4.2.2 Baseline characteristics of three dietary patterns

The three dietary pattern factor scores were divided into low (N=16), moderate (N=17) or high (N=17) adherence to each pattern for further analysis (i.e. those who scored in the top third for each pattern had higher consumption of foods positively loaded onto the pattern, and reduced consumption of foods negatively loaded).

No significant difference was found in age, BMI or BF%, between tertiles, for the Unhealthy pattern and the Healthy pattern (Table 4.4). There was a significant difference, for age, across the Snacking dietary pattern. Those with low adherence to the snacking dietary pattern were significantly older (31.7 (24.7, 40.4) years) than those with moderate adherence (24.0 (21.8, 30.1) years; P=.037). No significant association was found, between tertiles, for BMI or BF% in any of the three dietary patterns.

Table 4.4 Comparison of age and body composition between low, medium and high adherence to three dietary patterns (N=50)

	Age (years)	p-value	BMI (kg/m^2)	p-value	BF%	p-value
Pattern 1: Unhealthy						
T1: Low	24.8 (21.9, 29.5)		23.5 (21.9, 26.4)		28.3 [25.1, 31.9]	
T2: Moderate	24.8 (23.0, 30.1)		24.4 (21.7, 29.5)		30.9 [26.6, 35.8]	
T3: High	29.7 (23.4, 40.6)	.151	23.8 (20.5, 26.9)	.701	28.3 [24.1, 33.3]	.580
Pattern 2: Healthy						
T1: Low	26.4 (22.3, 31.6)		23.3 (21.0, 26.3)		28.5 [24.4, 33.4]	
T2: Moderate	24.8 (22.5, 31.3)		23.1 (21.8, 24.4)		27.2 [24.5, 30.1]	
T3: High	27.4 (23.0, 35.1)	.853	26.9 (21.9, 30.8)	.108	31.9 [27.2, 37.6]	.221
Pattern 3: Snacking						
T1: Low	31.7 (24.7, 40.4)*		26.3 (22.5, 30.2)		32.2 [28.0, 36.9]	
T2: Moderate	24.0 (22.0, 28.1)*	**.037**	21.9 (21.3, 26.5)		26.8 [22.8, 31.3]	
T3: High	27.4 (21.8, 30.1)		23.5 (21.2, 24.2)	.108	29.0 [25.5, 32.9]	.161

[a] Values are median (25th percentile, 75th percentile);

[b] Values are mean [95% Confidence Interval];

* = statistically significant (*P*<0.05), in bold, analysed using Kruskal-wallis analysis (Mann-Whitney post hoc test and Bonferroni correction)

Overall dietary pattern factor scores were also correlated to age, BMI and BF% to determine whether any further associations existed (Table 4.5). Age was found to be significantly correlated to the Unhealthy dietary pattern (*r*=.297, *P*=.036). The Snacking pattern also trended towards an association with age (*r*=.-.254, *P*=.075), however, this was an inverse relationship, age increased as adherence to the pattern decreased. A positive significant relationship was found between factor scores for the Healthy pattern and BMI (*r*=.325, *P*=.021). No other relationships were established between dietary pattern factor scores and baseline characteristics.

Table 4.5 Correlation between three dietary patterns, age and body composition (N=50)

	Unhealthy		Healthy		Snacking	
	Correlation co-efficient	P-value	Correlation co-efficient	P-value	Correlation co-efficient	P-value
Age[a]	.297	**.036***	.130	.370	-.254	.075
BMI[a]	-.038	.795	.325	**.021***	-.223	.119
BF %[b]	-.021	.887	.176	.222	-.237	.098

[a] Data are not normally distributed, analysed using Spearman's rho;

[b] Data are normally distributed, analysed using Pearson's correlation;

* = statistically significant (*P*<0.05), in bold

4.3 Eating behaviour determined by the Three-factor eating questionnaire

4.3.1 Analysis of the Three-factor eating questionnaire

The three behaviours assessed by the TFEQ were cognitive restraint, disinhibition and hunger. Results from the questionnaire were analysed based on scoring criteria established by Stunkard and Messick (1985) which divides the group into 'low', 'medium' and 'high' for each of the behaviours (Table 4.6). For cognitive restraint, the majority of participants (90%) reported low scores. Participants also reported mostly 'low' scores for disinhibition (37%). For hunger, 40% of participants scored low, 36% medium and 24% high.

Table 4.6 Descriptive characteristics of the Three-factor eating questionnaire (n = 50)

Eating behaviour	Average behaviour score	Range	Theoretical Range	Low N (%)	Medium N (%)	High N (%)
Cognitive restraint (Factor I)	8 ± 5[a]	0-18	0-21	45 (90%)	4 (8%)	1 (2%)
Disinhibition (Factor II)	10.3 [8.89, 12.0][c]	1-15	0-16	37 (74%)	9 (18%)	4 (8%)
Hunger (Factor III)	7.93 [6.62, 9.50]	0-13	0-14	20 (40%)	18 (36%)	12 (24%)

[a] Mean ± SD;

[b] Median (25, 75 percentiles), data are not normally distributed;

[c] Geometric mean [95% CI], data are log transformed;

Range for low, medium and high is taken from Stunkard and Messick (1985)

4.3.2 Associations between eating behaviour, baseline characteristics and dietary patterns

Eating behaviour scores were further analysed for associations with age, BMI and BF%, as well as dietary patterns (Table 4.7). Age was found to significantly, inversely correlate to cognitive restraint (r=-.324, P=.022), disinhibition (r=-.437, P=.002) and hunger (r=-.342, P=.016). No significant associations were found between cognitive restraint, disinhibition or hunger and BMI or BF%

Several correlations were found between the eating behaviours and dietary patterns. Cognitive restraint was found to have a significant inverse relationship with Unhealthy dietary pattern scores (r=-.391, P=.005) and a significant positive relationship with the Healthy pattern (r=.418, P=.003). No other significant relationships with dietary patterns were found.

Table 4.7 Correlations between eating behaviours, baseline characteristics and dietary patterns (N=50)

	Cognitive restraint		Disinhibition		Hunger	
	Correlation co-efficient	P-value	Correlation co-efficient	P-value	Correlation co-efficient	P-value
Baseline characteristics						
Age[a]	-.324	**.022***	-.437	**.002***	-.342	**.016***
BMI[a]	.240	.093	.083	.567	-.085	.561
PBF[b]	.158	.274	.098	.497	.059	.686
Dietary Patterns						
Unhealthy[b]	-.391	**.005***	-.073	.614	-.040	.783
Healthy[b]	.418	**.003***	.050	.731	-.045	.757
Snacking[b]	-.052	.719	.065	.654	.241	.095

[a] Data was not normally distributed, analysed using Spearman's Rho;

[b] Normally distributed data, analysed using Pearson's correlation;

* = statistically significant (P<0.05), in bold

4.4 Establishing oleic acid (OA) taste detection thresholds

4.4.1 Naïve OA taste detection thresholds and intra-class correlations (ICC)

Oleic acid taste detection thresholds were defined at the point where a participant had correctly identified a solution containing oleic acid three times, at the same specific concentration. The oleic acid taste detection threshold, obtained by each person at their initial visit, was used as the naive response for further comparisons to dietary intake and eating behaviour. Research suggests that the naïve response may be a useful measure as it mirrors the response a person may have when they experience the same stimuli in a food (Running et al., 2013).

Of the 50 participants, 86% achieved a naïve OA detection threshold (Figure 4.1). The remaining 14% were unable to detect OA in solution at the highest available concentration and so were assigned a threshold of ≥26.0 mM.

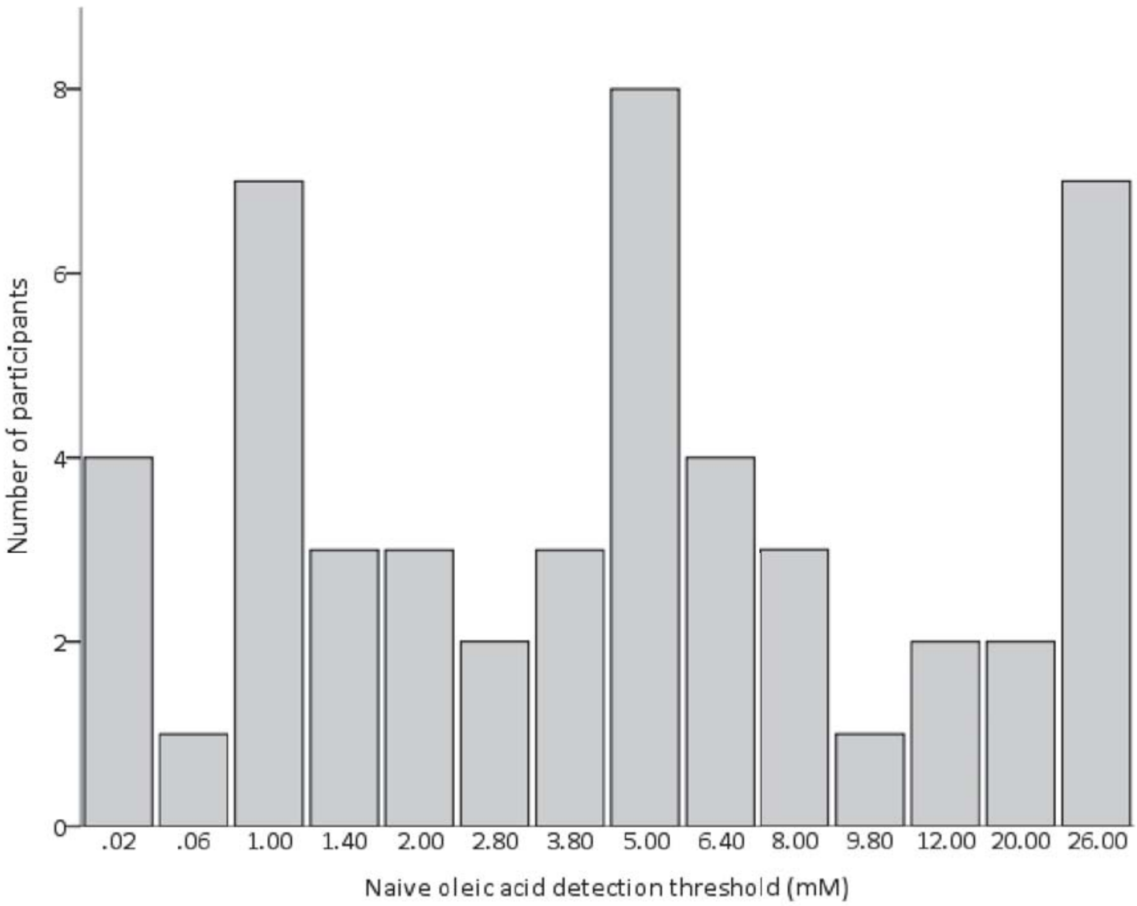


Figure 4.1 – Distribution of naïve oleic acid taste detection thresholds

To ensure that the naïve response did not deviate significantly from the thresholds determined at subsequent visits, intra-class correlations were calculated to assess within participant variability. Moderate intra-class correlations (ICCs) were found for the oleic acid taste thresholds assessed at the three visits, for fat taste detection threshold measurements. The average measure ICC was 0.258 with a 95% confidence interval from .082 to .447 ($F_{(48,96)} = 2.031$, $P<.002$).

Participants with a threshold equal to or below 3.8 mM were categorised as hypersensitive for oral fat taste detection, and those with a threshold above this cut-off were considered hyposensitive (Stewart et al., 2010). At the initial visit, over half of the participants (54%) were categorised as hyposensitive (>3.8 mM), with a median concentration of 8.00 mM (5.00, 26.00) (Table 4.8).

Table 4.8 Median[a] oleic acid taste detection thresholds for hyposensitive and hypersensitive groups

	N (%)	Oleic acid taste detection threshold (mM)[a]
Hypersensitive (≤3.8 mM)	23 (46.0)	1.00 (1.00, 2.00)
Hyposensitive (>3.8 mM)	27 (54.0)	8.00 (5.00, 26.00)

[a] Median (25, 75 percentiles), data are not normally distributed;

OA detection threshold defined in Stewart et al. (2010)

4.4.2 Oleic acid taste detection thresholds and baseline characteristics

When baseline characteristics of age, BMI and body fat % were compared between hypersensitive and hyposensitive participants, no significant differences were found (Table 4.9).

Table 4.9 Comparison of age and body composition for participants hypersensitive (≤3.8 mM) and hyposensitive (>3.8 mM) to oleic acid taste

	Oleic acid detection		P-value
	Hypersensitive[a] (N=23)	Hyposensitive[a] (N=27)	
Age (years)	24.8 (21.8, 32.2)	27.4 (23.0, 32.0)	.592
BMI (kg/m^2)	23.5 (21.3, 27.2)	23.8 (21.7, 29.6)	.419
Body fat %	27.4 (24.0, 35.5)	29.1 (24.1, 38.2)	.892

[a] Values are median (25th, 75th percentile)

[c] Data was not normally distributed, analysed using Spearman's Rho

4.5 Food groups, dietary patterns and OA taste detection thresholds

4.5.1 Oleic acid taste detection thresholds and food groups

Variation in types of food consumed by hypersensitive and hyposensitive participants was determined by comparing the 29 food groups used in the dietary pattern analysis, shown in Table 4.10. Hyposensitive participants were significantly more likely to consume fish and seafood (U=161.5, N=50, P=.004) and eggs and egg dishes (U=201.5, N=50, P=.033). The hypersensitive participants reported consuming fast food significantly more frequently than their hyposensitive counterparts (U=197.0, N=50, P=.027). No other significant differences in food group intake were found between the groups.

Table 4.10 Comparison food group daily frequency equivalents for participants hypersensitive and hyposensitive to oleic acid

Food group	Average DFE by food group		P-value[b]
	Hypersensitive[a] (N=23)	Hyposensitive[a] (N=27)	
Cheeses	0.59 (0.30, 0.93)	0.67 (0.37, 0.87)	.846
Alcohol	0.23 (0.03, 0.73)	0.23 (0.05, 0.37)	.697
Savoury condiments	1.04 (0.50, 1.36)	1.12 (0.71, 1.97)	.386
Unsweetened cereals	0.09 (0.00, 0.43)	0.16 (0.01, 0.88)	.240
Savoury snack foods	0.07 (0.04, 0.14)	0.07 (0.04, 0.14)	.772
Sweeteners and sweet condiments	0.14 (0.07, 0.79)	0.14 (0.07, 0.29)	.589
Fats (animal and coconut)	0.21 (0.11, 0.50)	0.46 (0.11, 1.00)	.088
Processed Meat	0.21 (0.04, 0.57)	0.18 (0.07, 0.30)	.527
Red meats	0.36 (0.16, 0.71)	0.36 (0.24, 0.58)	.977
Cold beverages	0.14 (0.03, 1.11)	0.16 (0.03, 0.46)	.946
Hot beverages	1.79 (0.51, 3.43)	3.00 (1.57, 4.31)	.083
Sweet snack food, cakes and biscuits	0.86 (0.57, 1.18)	0.58 (0.29, 0.96)	.081
Wholegrains and wholegrain bread	0.50 (0.14, 1.15)	0.79 (0.44, 1.29)	.164
Fish and seafood	0.11 (0.04, 0.32)	0.38 (0.21, 0.62)	**.004**
Low fat milk	0.00 (0.00, 0.71)	0.64 (0.00, 1.20)	.085
Nuts, nut spreads and seeds	0.54 (0.21, 1.07)	0.93 (0.43, 1.57)	.083
Fast food	0.50 (0.32, 0.61)	0.32 (0.25, 0.44)	**.027**
Legumes and soybeans	0.08 (0.02, 0.37)	0.22 (0.02, 0.50)	.364
Refined grains, crackers and bread	1.07 (0.40, 1.62)	0.87 (0.60, 1.14)	.915
Sweetened cereals	0.14 (0.02, 0.37)	0.09 (0.00, 0.36)	.505
Puddings	0.15 (0.09, 0.21)	0.16 (0.12, 0.22)	.606
Fruit	2.44 (1.26, 3.24)	2.23 (1.15, 3.46)	.755
Full fat milk	0.12 (0.00, 0.51)	0.00 (0.00, 0.50)	.171
Yoghurt and other milk products	0.22 (0.07, 0.71)	0.36 (0.09, 0.73)	.436
Egg and egg dishes	0.15 (0.14, 0.43)	0.50 (0.21, 0.71)	**.033**
Starchy vegetables	0.36 (0.22, 0.52)	0.46 (0.22, 0.87)	.243
White meat	0.50 (0.17, 0.72)	0.36 (0.22, 0.64)	.442
Non-starchy vegetables	4.09 (2.33, 5.15)	3.80 (2.54, 5.38)	.778
Oils and oil based dressings	1.64 (0.94, 2.57)	1.64 (1.00, 2.14)	.907
Total reported daily DFE intake	22.8 (20.5, 25.2)	26.3 (19.6, 30.8)	.280

[a] Values are median (25th, 75th percentile)
[b] Data was not normally distributed, analysed using Kruskal-Wallis
* = statistically significant (*P*<0.05), in bold
DFE = Daily frequency equivalent

4.5.2 Oleic acid taste detection thresholds and dietary patterns

Scores for each of the three dietary patterns were compared between participants who were either hypersensitive or hyposensitive to oleic acid (Table 4.11). It was found that participants who were hyposensitive to oleic acid taste had a significantly higher adherence to a Healthy dietary pattern than those who were hyposensitive.

Table 4.11 Comparison of dietary pattern factor loadings for hypersensitive and hyposensitive participants

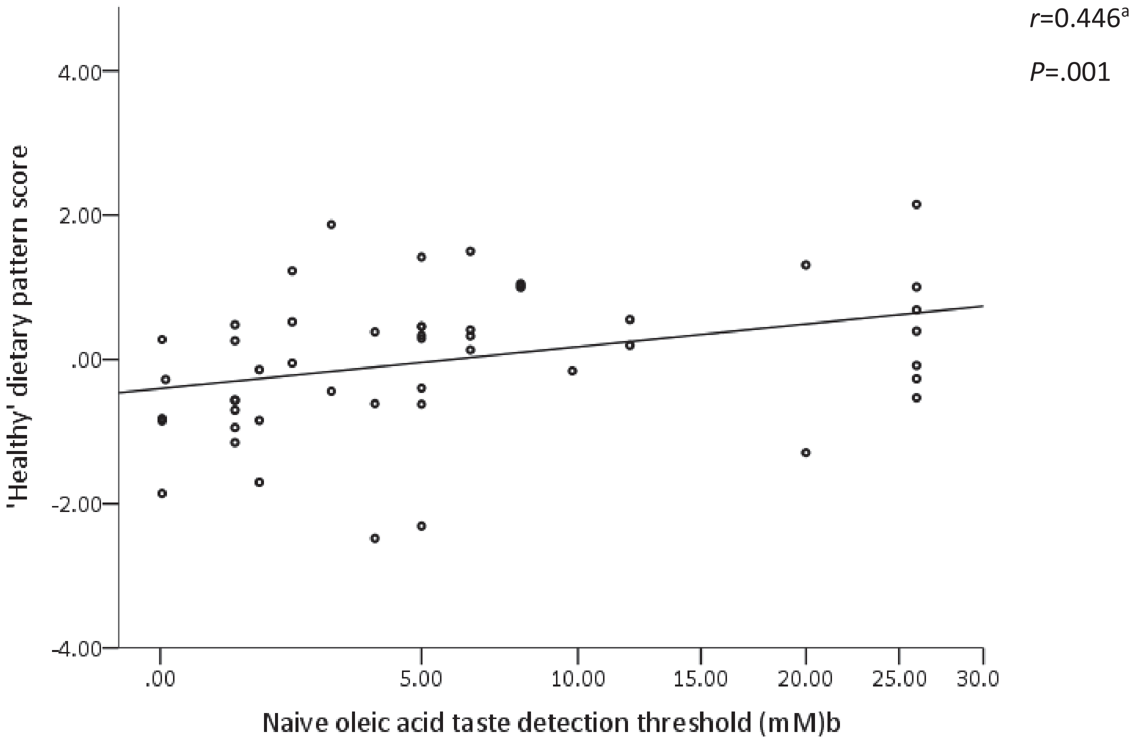
Dietary Pattern	Average factor loading		P-value[b]
	Hypersensitive[a] (N=23)	Hyposensitive[a] (N=27)	
Unhealthy	0.05 (-0.64,0.46)	-0.16 (-0.88, 0.33)	.566
Healthy	-0.57 (-0.85, 0.27)	0.39 (-0.16, 1.00)	**.004***
Snacking	-0.01 (-0.44, 0.53)	-0.08 (-0.73, 0.67)	.553

Values are median (25th, 75th percentile)

[b] Data were not normally distributed, analysed using Spearman's Rho

* = statistically significant (*P*<0.05), in bold

To further investigate the significant relationship factor scores for each of the three dietary patterns were compared to initial oleic acid detection thresholds (Figure 4.2). The Healthy pattern was found to significantly correlate to oleic acid taste detection thresholds for the 50 women (*P*=.001), with the correlation co-efficient (*r*=.446) indicating a moderate relationship (Figure 1). It was found that the Unhealthy pattern and the Snacking pattern had no significant association.



[a] Data was not normally distributed, Spearman's Rho calculated
[b] Threshold data powerscaled on axis to improve data spread

Figure 4.2 – Correlation between 'Healthy' dietary pattern factor scores and naïve oleic acid detection threshold (mM)

4.5.3 Description of oleic acid taste detection thresholds and eating behaviours

When eating behaviour scores for cognitive restraint, disinhibition and hunger were compared to oleic acid taste detection thresholds, no significant associations were found (Table 4.12). No significant difference was found between the number of hypersensitive and hyposensitive participants rating 'low', 'medium' or 'high' for cognitive restraint. However, 29.6% of hyposensitive participants reported 'medium' or 'high' scores for disinhibition, compared to 21.8% of those who had a hypersensitive fat taste detection threshold. Hyposensitive participants also trended towards having 'low' to 'medium' hunger scores (40.7% and 44.4% respectively). Participants with hypersensitive oleic acid taste detection thresholds were more evenly spread across the three levels (low=39.1%, medium = 26.1%, high=34.8%).

Table 4.12 Comparison of hyposensitive and hypersensitive oleic acid detection thresholds to eating behaviour

Eating behaviour	Initial oleic acid detection threshold		*P*-value[a]
	Hypersensitive (≤3.8 mM) (N=23) N (%)	Hyposensitive (>3.8 mM) (N=27) N (%)	
Cognitive restraint			
Low	20 (87.0)	25 (92.6)	.537
Medium	2 (8.70)	2 (7.41)	
High	1 (4.35)	0 (0.00)	
Disinhibition[b]			
Low	18 (78.3)	19 (70.4)	.663
Medium	4 (17.4)	5 (18.5)	
High	1 (4.35)	3 (11.1)	
Hunger[b]			
Low	9 (39.1)	11 (40.7)	.198
Medium	6 (26.1)	12 (44.4)	
High	8 (34.8)	4 (14.8)	

[a] Data was not normally distributed, analysed using Chi-square

Statistically significant = ($P<0.05$)

Chapter 5 – Discussion

Determinants of habitual dietary intake are multifaceted and complex. The analysis of dietary patterns provides an opportunity to compare usual intake of multiple foods with factors thought to have an impact on food preference and choice. Fat is well recognised for its contribution to the textural and olfactory appeal of foods (Fushiki, 2014). The theory that fat may evoke a sensory response through taste is also gaining momentum (Besnard et al., 2016). To date, methodological differences in research have produced inconsistent findings about the relationship between fat taste and dietary intake (Keast et al., 2014). This study has contributed to the growing body of evidence regarding factors related to dietary intake, as organisations from the health and food industries seek to improve health outcomes related to poor diet.

This study sought to identify dietary patterns, eating behaviours and fat taste detection thresholds for New Zealand European (NZE) women participating in the Dessert taste study, and to explore associations between these factors. The objectives of the study were to identify dietary patterns, eating behaviour scores and oleic acid (OA) detection thresholds; establish associations between dietary patterns and eating behaviours (cognitive, restraint and disinhibition) and dietary patterns and OA taste detection thresholds; and to explore possible relationships between eating behaviours and OA taste detection thresholds. The findings demonstrate three dietary patterns could be established within the participant group. Further, relationships between dietary patterns and aspects of eating behaviour and OA taste detection thresholds were established in this participant group. This is the first study to demonstrate such relationships between dietary patterns and fat taste sensitivity.

5.1 Participant characteristics

The 50 NZE women who were included in the participant group had a mean body mass index (BMI) (23.7 kg/m^2) which was within the normal range (18.5-24.9 kg/m^2) (Ministry of Health, 2015). The mean body fat percentage (BF%) (30.3%) fell into the high range (≥30%), suggesting that some of the women have a hidden body fat profile (Kruger et al., 2015). The number of women from the Dessert taste study who were overweight (22%) (25.0-29.9 kg/m^2) or obese (16%) (≥30 kg/m^2), was substantially less than the total NZE female population (31.6% and 30.5% respectively) (Ministry of Health, 2016). Unsurprisingly, the mean BMI of the study participants was also less (27.9 kg/m^2). Therefore, the Dessert taste study participant group was not representative of NZE females living in New Zealand. This was likely due to the convenience sampling method used in the Dessert taste study, which may have oversampled women affiliated with Massey University and the School of Food and Nutrition. It is possible that these women may be more inclined to maintain a healthy weight and overall wellbeing than the general population.

5.2 Dietary pattern analysis

In order to express multiple components of dietary intake as a single exposure, dietary patterns were identified. Three dietary patterns were derived from the food frequency questionnaire (FFQ) data using factor analysis. These were an 'unhealthy' pattern, a 'healthy' pattern, and a 'snacking' pattern. Participants were scored on their adherence to each of the three patterns. A high score indicated the person closely followed the relevant dietary pattern, a low score indicated limited adherence.

Dietary pattern characteristics

The three dietary patterns identified have distinct characteristics, and all three are similar to those found in earlier studies (Schrijvers et al., 2016; Thompson et al., 2010; Wall et al., 2016). The 'unhealthy' pattern was found to describe a high consumption of cheeses, alcohol, savoury condiments and snack foods, sweeteners and sweet condiments, fats (high in animal and coconut fats), processed and red meats, fast food, refined grains, bread and puddings. Unsweetened cereals scored negatively on this dietary pattern. The characteristics of the 'unhealthy' pattern were similar to a 'junk' pattern identified in two studies investigating the intake of pregnant women living in New Zealand (Thompson et al., 2010; Wall et al., 2016). The 'junk' pattern was also high in sweet and fatty foods including confectionary, ice cream, cakes, biscuits and takeaways. However, there were key differences mostly related to the savoury aspects of the pattern. This is likely due to the pregnant women adhering to pregnancy diet guidelines of avoidance of alcohol, cheese and processed (deli) meats.

The 'healthy' pattern consisted of foods commonly associated with a healthier dietary intake including wholegrains, seafood, low-fat dairy, nuts and seeds, legumes, soybean products, eggs and hot beverages. Participants following this dietary pattern were also less likely to consume cold beverages, sweet snack foods, cakes and biscuits, and fast food. A nearly identical 'healthy' dietary pattern was found in a similar population group by Schrijvers et al. (2016), however the pattern did not include hot beverages. A possible reason for this is the dietary variable of hot beverages had been separated into independent variables for tea, coffee and other drinks. A review study showed that fruits, vegetables and wholegrains were the most common components of a 'healthy' or 'prudent' dietary pattern (Kant, 2004). Comparatively, the dietary components of the Dessert taste study 'healthy' dietary pattern are more energy-dense than those identified by Kant (2004).

The 'snacking' pattern was the third pattern, consisting of foods typically consumed during a light meal or snack. Those who adhered to this pattern consumed greater amounts of refined grains, crackers and bread, sweetened cereals, puddings, fruit, low-fat dairy, savoury snack foods and nuts and seeds. These participants also consumed lesser amounts of full-fat dairy, eggs and starchy vegetables. This pattern is consistent with elements of a 'snacking' pattern found in NZE women by Schrijvers et al. (2016) which included sweet and savoury snack foods, dairy, crackers, brown bread, spreads, cakes and biscuits and hot beverages. Fruit was the only dietary component consistent with a 'healthy snacking' pattern identified by Beck et al. (2013)

Two food groups were excluded from the dietary pattern analysis to improve inter-item reliability (Field, 2009). It was found that non-starchy vegetables and oils, oil-based dressings and margarine were associated with more than one of the dietary patterns and consequently reduced reliability. This suggests that irrespective of their dietary pattern, many participants had a high intake of non-starchy vegetables and oils, oil-based dressings and margarines. Other studies have also found that the food group for oil, and oil based dressings reduced reliability (Schrijvers et al., 2016). The high consumption of vegetables by the participant group is consistent with the 2015/16 New Zealand Health Survey, which found 70.9% of NZE women consumed at least the three recommended servings of vegetables per day (Ministry of Health, 2016).

Dietary patterns and participant characteristics

The 'unhealthy' dietary pattern was found to be positively correlated with age in this study (P=.036). However, the relationship was relatively weak (r=.297) and disappeared when dietary pattern scores were broken down into tertiles for low, moderate and high adherence. Tertiles for low and moderate adherence to the 'unhealthy' pattern had the same median age (24.8 years (21.9, 29.5) and 24.8 (23.0, 30.1)) respectively). Women with high adherence (tertile 3) were comparatively older (29.7 years (23.4, 40.6)). The positive correlation between a 'unhealthy' pattern and age was unexpected, as two previous studies in New Zealand women had found an inverse association between similar patterns and age (Thompson et al., 2010; Wall et al., 2016). It is possible that the education level and attitudes of the participants may confound the relationship between age and dietary patterns (Franco et al., 2009). This is because the convenience sampling method may have increased the likelihood of the younger student participants having an established interest in health and nutrition.

Median age was also found to be significantly different between women with low adherence (tertile 1) (31.7 years (24.7, 40.4)) and women with moderate adherence (tertile 2) (24.0 years (22.0, 28.1)) to the ‘snacking’ pattern (*P*=0.037). This finding is also inconsistent with previous studies which found age increased with adherence to a ‘snacking’ pattern (Beck et al., 2013; Schrijvers et al., 2016). It could be of interest to investigate the reasons for younger people having a greater adherence to the snacking pattern in this population group, as it may be education or lifestyle based.

The ‘healthy’ dietary pattern scores were found to have a weak positive association with BMI (*r*=.325, *P*=.021). Again, the relationship disappeared when dietary pattern scores were broken down into tertiles. Tertiles for low (tertile 1) and moderate (tertile 2) adherence to the ‘healthy’ pattern had a similar median BMI (23.3 kg/m^2 (21.0, 226.3) and 23.1 kg/m^2 (21.8, 24.4) respectively). Women with high adherence (tertile 3) had a higher median BMI of 26.9 kg/m^2. This association is inconsistent with findings in a New Zealand based study where a ‘health conscious’ pattern was associated with reduced BMI (Wall et al., 2016). An international review of dietary patterns also suggests that a ‘healthy’ dietary pattern is more commonly associated with a lower BMI (Kant, 2004).

There is more than one possible explanation for the positive association between ‘healthy’ dietary pattern scores and BMI found in women from the Dessert taste study. Firstly, women of a higher BMI have been shown to be susceptible to a social desirability bias and are more likely to underreport consumption of foods which they perceive as being less healthy (Stevenson, 2017). Underreporting of ‘unhealthy’ foods could result in dietary variables for healthy foods appearing comparatively high, which would influence the outcomes of dietary pattern analysis and the resulting dietary patterns scores. Alternatively, the association may be a true reflection of the types of foods consumed by women with a higher BMI, in this participant group. Dietary patterns derived in this study did not aim to quantitate volumes of food eaten or total energy intake (Hu et al., 1999). Instead, they are a measure of the patterns of food consumption. Therefore, a person may show a strong adherence to the ‘Healthy’ dietary pattern, but also be exceeding their energy requirements resulting in a higher BMI. No participant reported actively dieting at the time of data collection, therefore it may be that this participant group includes intentionally “healthy eaters”, irrespective of BMI (McDermott et al., 2015).

5.3 Cognitive restraint, disinhibition and hunger

In the literature, eating behaviours measured by the TFEQ have been found to be associated with dietary intake and body composition (de Lauzon et al., 2004; Kruger et al., 2016). Levels of cognitive restraint, disinhibition and hunger were assessed in the Dessert taste study to identify eating behaviours within the participant group and explore the relationships these behaviours may have with dietary patterns.

Compared to the established ranges, most of the participant group exhibited low scores for cognitive restraint (90%) and disinhibited eating (74%) (Stunkard & Messick, 1985). Eating behaviour scores for hunger were more evenly distributed, with 40% reporting low hunger related behaviours, 36% reported moderate and 24% reported high. This is similar to the findings of Rivers (2015) in a study assessing habitual sweet intake, perception and preference in NZE women. A recent study found that individuals who had a normal BMI (18.5-24.9 kg/m^2) were less likely to report high scores in restrictive and disinhibited eating (Chamoun et al., 2016). The findings in the Dessert taste study support the current literature, as the majority of participants (62%) had a normal BMI.

Cognitive restraint, disinhibition and hunger were all found to be significantly inversely associated with age (r=-.324, P=.022; r=-.437, P=.002 and r=-.342, P=.016 respectively). There is limited literature which has investigated eating behaviour and total dietary intake that has also measured associations between eating behaviour and age in the same population. A study specifically aimed at investigating the effects of age on eating behaviour in men found that behaviour scores for hunger were positively associated with age (Harden, Corfe, Richardson, Dettmar, & Paxman, 2009).

No significant relationships were found between eating behaviour and BMI or BF%. This is of interest as body composition has often been found to be significantly associated to both cognitive restraint and disinhibition (Kruger et al., 2016). A possible cause of this is the generally low scores reported by the Dessert taste study participants for disinhibition and cognitive restraint. Additionally, the participant group for the present study was not representative of the general population and fell within a relatively small range for both BMI and BF%. Therefore, a possible relationship between eating behaviour and body composition may have been underestimated.

Relationship between dietary patterns and eating behaviours

It was found that ‘healthy’ dietary pattern scores were positively associated with scores for cognitive restraint (r=.418, P=.003). This is consistent with findings from de Lauzon et al. (2004)

who reported that cognitive restraint correlated positively with higher intake of healthy food groups. Interestingly, de Lauzon et al. (2004) also found that intake of fish, fat-reduced foods and milk was greater in participants with higher scores of cognitive restraint. These food groups are all included within the 'healthy' dietary pattern in the present study. Supporting these associations is a larger eating behaviour review study, which also found that higher cognitive restraint scores were associated with reduced energy intake from sweet or fatty foods (Stevenson, 2017).

Cognitive restraint was also found to be inversely associated with adherence to the 'unhealthy' dietary pattern (r=-.391, P=.005). This is logical and appropriate, given the previous finding that 'healthy' dietary pattern scores were associated with increased cognitive restraint. The literature found that cognitive restraint scores were also linked to a long-term reduction in fat intake, increased fibre consumption and sustained weight loss. The findings of the present study suggest that it may be possible to improve adherence to a 'healthy' dietary pattern, or reduce adherence to an 'unhealthy' dietary pattern by increasing cognitive restraint.

5.4 Hypersensitivity and hyposensitivity to fat taste

The Dessert taste study determined the lowest concentration at which oleic acid (OA) could be detected in an ultra-heat treated (UHT) low-fat milk solution. For the women in this study, the average naïve OA detection threshold was 5.00 mM (1.40, 8.00). Based on their naïve detection threshold, the women were classified as either hypersensitive to OA fat taste (≤3.8 mM) or hyposensitive (>3.8 mM). Of the 50 NZE women in the study, 46% were found to be hypersensitive and 54% were hyposensitive. In other studies, which have classified participants by fat taste detection thresholds, the prevalence of hypersensitivity has ranged from 22-58% (Keast et al., 2014; Stewart et al., 2010; Stewart, Newman, et al., 2011). Of these studies, the most similar methodology was Keast et al. (2014), who classified 58% of participants as hyposensitive to OA taste.

Relationship between fat taste sensitivity and dietary patterns

A comparison was made between hypersensitive and hyposensitive participants for the number of daily frequency equivalents consumed from each of 29 food groups. It was found that participants, who were hyposensitive to OA taste, ate more fish and seafood (P=.004) and egg and egg dishes (P=.033). Hypersensitive participants had a higher consumption of fast food (P=.027). Stewart, Newman, et al. (2011) also found that higher OA taste detection thresholds were associated with increased intakes of eggs and meat. A possible explanation for this association is that fish, seafood and eggs are sources of dietary fat which may contribute to greater total fat intake which is associated with reduced taste sensitivity (Stewart, Newman, et al., 2011). An alternate explanation could be that eggs are a source of OA, therefore frequent consumption of eggs may alter the sensitivity of taste receptors cells to OA (Caston & Leeson, 1990). Further research is required to understand the impact of foods, with specific free fatty acid profiles, on fat taste sensitivity.

It appears counter-intuitive that fast food is consumed more frequently by hypersensitive participants. However, one possible explanation is that OA is a monounsaturated fat, and may be detected differently to saturated fats, which are commonly a major component of fast foods (Mattes, 2009). Another possible reason is that the total dietary intake of fat is higher in the hyposensitive participants, irrespective of them having a lower intake of fast food. However, this was not investigated and in future research it would be useful to combine qualitative dietary patterns with a quantitative analysis of macronutrient intake to determine the contribution of fat to the diet.

A significant relationship of moderate strength was found between hyposensitivity to oleic acid taste and a higher adherence score to the 'Healthy' dietary pattern (r=.446, P=.001). Food groups which are consumed more frequently in this pattern included fish and seafood, low-fat dairy, nuts and seeds, and eggs, all of which contribute fat to the diet. As previously discussed Stewart, Newman, et al. (2011) did find that meat and eggs were associated with poorer sensitivity to fat taste, both of which are included in the 'healthy' dietary pattern. There have been no other studies investigating associations between dietary patterns and fat taste sensitivity, therefore it is difficult to explain this association. It is possible that those participants who adhere to the 'healthy' dietary pattern still had a higher intake of total fat compared to those adhering to the 'unhealthy' or 'snacking' patterns. This relationship is also somewhat supported by the positive association between the 'healthy' dietary pattern and BMI. Increased BMI could be a result of overconsumption of the foods in this pattern, including foods which are high in energy-dense fat. Further research is necessary to understand this interaction.

No other relationships were found between dietary patterns and OA taste detection thresholds. This is inconsistent with findings from another study where an increased intake of foods similar to the 'Unhealthy' dietary pattern was positively associated with fat taste sensitivity thresholds (Stewart, Newman, et al., 2011). A key aspect of the study by Stewart et al. (2011) was the higher proportion of overweight and obese included in the participant group. It is possible that the present study has underestimated relationships between dietary intake, dietary patterns, fat taste sensitivity and body composition as a result of the comparatively narrow range of participants recruited.

Fat taste sensitivity and eating behaviour

No relationships were found between any measure of eating behaviour and OA taste detection thresholds. Research has not directly addressed possible associations between these measures. To date, the majority of studies evaluating the relationship between taste and eating behaviour have only considered measures of taste preferences, such as hedonic liking of fat (Deglaire et al., 2015; Keskitalo et al., 2008). Recent studies have consistently found no association between hedonic liking of high fat foods and laboratory conducted measures of fat taste sensitivity (Keast et al., 2014; L. P. Newman et al., 2016; Stewart & Keast, 2012).

5.5 Study strengths and limitations

5.5.1 Study strengths

There are several strengths to this study which further support the key findings. They include the specificity of the participant group, use of a New Zealand designed and validated food frequency questionnaire, use of dietary pattern analysis and reliability, and a robust sensory testing methodology with good test-retest repeatability.

Participant group

The participant group for this study was NZE females aged 19-45 years. Age, gender and culture are all evidenced as impacting on dietary patterns, eating behaviour and taste sensitivity. Age-related deterioration of taste sensitivity has also been evidenced in older adults (Methven et al., 2012). It is well supported that culture plays a significant role in defining dietary patterns and eating behaviour (Ahrens, 2015; Franco et al., 2009). There is limited evidence suggesting a relationship between culture and taste sensitivity, particularly fat taste. By using a specific participant group, it was possible to improve control of these factors and reduce potentially confounding variables. This allows for a greater confidence in the key findings of the study.

Validated food frequency questionnaire

The FFQ used in this study was validated in New Zealand as a tool to determine the relationship between dietary intake and nutrition-related risk factors in a New Zealand population (Houston, 2014). Portion sizes and specific foods, appropriate to New Zealand women, were included in the questionnaire. It has been reported that the validity of dietary data obtained from an FFQ is greater when the FFQ has been designed and validated in the country in which it is being used (Thompson & Subar, 2013). Furthermore, this would improve the validity of dietary patterns derived from FFQ data (Nanri et al., 2012)

Additionally, other studies investigating fat taste sensitivity have used questionnaires specifically designed to assess fat intake (Tucker et al., 2014). Fat is generally perceived by the Western population to be a less favourable aspect of dietary intake, so may be underreported (Thompson & Subar, 2013). By using a FFQ inclusive of all food groups, there is less emphasis on dietary fat intake as a key focus.

Dietary pattern analysis and reliability

The use of principal component factor analysis to determine patterns of dietary intake is a strength of this study. Patterns of food intake can more accurately represent habitual consumption, with nutrients and foods being presented in combinations instead of isolated events (Hu, 2002). These habitually consumed combinations have been shown to have strong links to body composition and health outcomes (Kant, 2004). Furthermore, underreporting has been found to have a reduced effect in dietary pattern analysis (Bailey et al., 2007).

Sensory methodology

The sensory component of this study took place under well controlled test conditions in the Massey University sensory booths. The methodology has been used in previous studies, where adequate test re-test reliability has been established (Haryono et al., 2014; Keast et al., 2014). Participants attended each sensory testing session in a fasted state, as research suggests altered states of hunger may affect taste sensitivity (Pepino, Finkbeiner, Beauchamp, & Mennella, 2010).

In this study, the intra-participant variability of fat taste detection thresholds across three visits was assessed as a part of a PhD research project. A moderate intra-class correlation was found between detection thresholds achieved by each participant at the three visits. These factors suggest that the naïve detection thresholds established for each participant can be used confidently within the present study.

5.5.2 Study limitations

This study has several key limitations which may affect the application and generalisability of the results for future research. These include the sampling methods and sample size, the potential for underreporting using an FFQ and the subjective nature of dietary pattern analysis.

Study design

A limitation of the cross-sectional study design is that it does not allow for conclusions to be made about cause-and-effect. However, as this is the first study of its kind to be conducted on a New Zealand participant group, it is useful to first establish the existence of potential associations between dietary intake, eating behaviour and fat taste detection thresholds, prior to determining causation.

This study was powered to ensure reliable testing of the sensory methodology. A higher participant number would be required to ensure reliability of associations found between dietary intake and body composition measures and outcomes. The limited statistical power due to a modest sample size (N=50) may have resulted in associations being under, or over, estimated. A post-hoc power calculation, based on the correlation coefficients observed in the present study and an α of 0.05, found that the correlations between dietary patterns and BMI and BF% were powered to 44% and 53% respectively (Cohen, 1988). Therefore, a sample size of 93 women would be needed to obtain statistical power at the recommended level (Field, 2009). Additionally, research suggests that 50 participants is the minimum sample size on which factor analysis can be conducted (de Winter et al., 2009). Although the present study meets this requirement, it is possible that the small number of participants has affected the ability to determine accurate dietary patterns through factor analysis.

Participant group

Participants for this study were recruited from within the Auckland area using a convenience sampling method. Recruitment was via email, social media and word-of-mouth. Women who responded may have been part of previous research at Massey University, or had an association with the Massey University School of Food and Nutrition. Therefore, they may have had an interest in health and wellbeing. This could also account for the underrepresentation of overweight and obese participants. The lack of diversity in ethnicity and body composition does mean that the findings of this study cannot be generalised to the New Zealand female population.

When investigating dietary intake, and eating behaviour, social desirability may play a role in biasing responses, particularly in those who are health conscious (Stevenson, 2017). Research suggests that participants may respond in a way they believe will 'please' the researcher, or reflects how they would like to eat (Thompson & Subar, 2013). Fat taste detection is a key focus of this study; however, fat is also widely considered a less desirable part of the diet. Although every effort was made to blind participants to the purpose of this study, it is possible that women under-reported their intake of high-fat foods as a consequence of the focus on fat taste, olfaction and mouth feel during the sensory data collection.

Dietary analysis

This study had several limitations in the methodology used for collecting and analysing dietary data. Although the NZW-FFQ was the most appropriate FFQ available to assess dietary intake for the participant group in this study, it has only been validated for nutrient intake, not food groups or dietary patterns (Houston, 2014). Furthermore, the use of an FFQ as a method for dietary assessment may have a greater potential for random error due to inaccuracies and under-reporting compared to other methods (i.e. weighed food record, 24-hour recall) (Thompson & Subar, 2013). However, random error in dietary in assessment is more likely to account for a lack of association than the reverse (Thompson & Subar, 2013).

Dietary pattern analysis, specifically factor analysis relies on a subjective decision by the researcher to determine the number of factors or patterns to extract (Moeller et al., 2007). Although these decisions are supported by confirmatory statistical measures such as Cronbach's α and referencing previous literature, there is still potential for interpretation bias (Field, 2009). This study established three dietary patterns based on what was believed to be the best fit for the participant group.

5.6 Recommendations for future research

- Conduct a study of repeated measures to identify whether adherence to dietary patterns can be intentionally altered. For example, can adherence to a 'healthy' dietary pattern be improved by increasing cognitive restraint?
- Validate an FFQ for dietary patterns, to be used in New Zealand populations.
- Have a sufficient sample size to allow for adequate representation of overweight and obese participants, particularly when investigating fat taste sensitivity. This would also help to reduce the likelihood of underestimating significant associations. The present study potentially underestimated relationships between dietary patterns, eating behaviour and OA taste detection thresholds due to being conducted in a participant group with predominantly normal BMI and only a small range of BF%. It was calculated that a minimum participant group of 136 women would be required to achieve 80% power in future studies using fat taste sensitivity as a screening tool (Cohen, 1988).
- An opportunity for future research could be to investigate whether being of normal weight with hyposensitivity to fat would predispose a person to poorer diet or future weight gain.
- Include dietary pattern analysis in future studies investigating dietary intake and fat taste sensitivity. Establishing the nutrient profiles of each dietary pattern may help to provide a better understanding of the relationship between fat intake, dietary patterns and fat taste sensitivity.
- To date, several long chain fatty acids (LCFAs) have been used in fat taste threshold testing. In both animal and human studies, literature suggests that the different LCFAs may be experienced differently. Future research could investigate whether taste sensitivity to different LCFAs is associated with differing dietary patterns

5.7 Conclusion

This is the first study to investigate dietary patterns, eating behaviours and fat taste detection thresholds in a single participant group, and identify associations between these factors. Knowledge of such relationships may help to identify opportunities for the implementation of screening tools based on sensory sensitivity and continue the progress towards more specialized and individualised methods dietary treatment, particularly for those who are suffering from nutrition-related health issues.

Despite limitations, the snapshot of dietary patterns, eating behaviour and fat taste detection thresholds identified in a group of New Zealand European women aged 19-45 years were found to have several significant associations. Firstly, the women in this study had three patterns of habitual intake identified as ‘healthy’, ‘unhealthy’ and ‘snacking’ patterns. It was found that those who adhered closely to an ‘unhealthy’ dietary pattern were significantly older and were also more likely to have poor cognitive restraint. The women who had higher intakes from the ‘healthy’ pattern were more likely to be insensitive to fat taste and have greater levels of cognitive restraint. These women were also more likely have a higher BMI. Lastly, lower intake from a snacking pattern was more common in the older women.

These findings provide some support that eating behaviour and fat taste sensitivity are related to the habitual intake of food in this group of women. Furthermore, there was an unexpected association found between the ‘healthy’ dietary pattern and reduced fat taste sensitivity. This association contributes to existing literature which suggests the nature of the relationship between fat taste and dietary intake is still unclear. The findings of the current study also support the inclusion of dietary patterns in future studies which investigate fat taste sensitivity or eating behaviour.

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Appendices

Appendix A. Dessert taste study screening questionnaire

(Kindleysides et al., 2016, December)

Dessert Taste Study - Screening Questionnaire

This study is now closed. Thank you for your interest and we hope to see you at one of our future studies! :)

* 1. What is your gender?

- ◯ Male
- ◯ Female

Dessert Taste Study - Screening Questionnaire

* 2. Contact details

Name (first and last): ______

City/Town: ______

Email Address: ______

Phone Number: ______

* 3. Date of birth

	DD		MM		YYYY
Date of birth		/		/	

Dessert Taste Study - Screening Questionnaire

* 4. Ethnicity you most identify with:

- ◯ European (NZ European or any European descent)
- ◯ Maori
- ◯ Pasifika
- ◯ Asian
- ◯ Indian
- ◯ Other

Dessert Taste Study - Screening Questionnaire

* 5. Are you pregnant or breastfeeding?

- ◯ Yes
- ◯ No

Dessert Taste Study - Screening Questionnaire

* 6. Over the last 12 months, how often did your menstrual period occur?

- ◯ Once every 3-6 weeks (regular)
- ◯ Once every 7-8 weeks (irregular)
- ◯ Interval of >2 months (irregular)
- ◯ Not applicable (i.e. currently taking a hormonal contraceptive)
- ◯ None of the above

Dessert Taste Study - Screening Questionnaire

* 7. Are you currently using any form of hormonal contraceptive (e.g. the pill, mirena, depo-provera)?

- ◯ Yes
- ◯ No

Dessert Taste Study - Screening Questionnaire

* 8. Do you suffer from any chronic diseases (e.g. diabetes, cardiovascular)?

- ◯ Yes
- ◯ No

Dessert Taste Study - Screening Questionnaire

* 9. Do you have any clinical causes for a dry mouth (e.g. Xerostomia or Sjogren's syndrome)?

◯ Yes

◯ No

Dessert Taste Study - Screening Questionnaire

* 10. Have you been on any type of antibiotics over the last month?

◯ Yes

◯ No

Dessert Taste Study - Screening Questionnaire

* 11. Are there any other medical conditions you would like to inform us about? (e.g. gastrointestinal surgery, cancer)

- ◯ Yes
- ◯ No

Dessert Taste Study - Screening Questionnaire

* 12. Please provide more details on your medical condition including duration and medication

Dessert Taste Study - Screening Questionnaire

* 13. Are you on any other medication(s) we should be aware of?

- ◯ Yes
- ◯ No

Dessert Taste Study - Screening Questionnaire

* 14. If yes, please specify which medication(s) in the comment box

Dessert Taste Study - Screening Questionnaire

* 15. Are you currently smoking or in the process of quitting?

◯ Yes

◯ No

Dessert Taste Study - Screening Questionnaire

Allergy assessment

Please answer the following questions with care...

* 16. Are you **allergic, intolerant or strongly dislike any of the following foods or products?**

- Milk or dairy products
- Sugar
- Custard
- Coconut
- Vanilla flavour
- Hand creams or moisturising lotions

◯ Yes

◯ No

Dessert Taste Study - Screening Questionnaire

* 17. Do you have any other allergies or food intolerance(s)?

◯ Yes

◯ No

Dessert Taste Study - Screening Questionnaire

* 18. Please specify what allergies or food intolerance(s) you have in the comment box

Dessert Taste Study - Screening Questionnaire

* 19. In this study you will taste milk (low fat milk) and vanilla custard samples.

If you have any aversion to such products please consider opting out of the study as you will taste a number of these products. Please confirm that you are happy to continue:

- ◯ Yes, I am willing to try a variety of milk and vanilla custard products
- ◯ No, I do not wish to participate

Dessert Taste Study - Screening Questionnaire

QUESTIONNAIRE COMPLETE

Thank you very much for taking the time to complete the questionnaire.

We will be in touch with you by email shortly. We will evaluate your survey response to see if you qualify and if you do we will book you in for one of our upcoming tasting sessions.

If you have any further questions please do not hesitate to contact us on desserttastestudy@gmail.com

Thanks again for your time. We really appreciate it.

Regards,

Dessert Taste study team

Appendix B. New Zealand Women's Food Frequency Questionnaire

(Houston, 2014; Kruger et al., 2015)

New Zealand Women's Food Frequency Questionnaire

Please make sure when filling out this questionnaire that you:

- Tell us what YOU usually eat (not someone else in your household!).
- Fill in the form YOURSELF.
- Are correct, but don't spend too much time on each food.
- Answer EVERY question; the asterisk symbol (*) at the beginning of each question means that you must answer before moving onto the next question.

This will help us to get the most accurate information about your usual food intake.

Please answer by ticking the box which best describes HOW OFTEN you ate or drank a particular food or drink in the LAST MONTH and HOW MUCH you would usually have.

For example:

1. EXAMPLE: How often do you usually have sugar? (Please do not fill out

	Never	<1x / month	1-3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4x + / day
Bread • 1 slice									

If every day you have 2 cups of coffee with 1 tsp sugar, 4 cups of tea with 1 tsp sugar, one bowl of cereal with 1 tsp sugar and sugar on pancakes at dinner, you would choose four or more times per day = '4+ x / day'.

Adjust your portion size and frequency of intake to suit your eating habits.

2. EXAMPLE: How often do you usually eat bread? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4x + / day
Bread • 1 slice									

If every day you have two slices of toast for breakfast, and you have a sandwich for lunch three times per week, you would choose two • three times per day = '2•3x / day'.

Adjust your portion size and frequency of intake to suit your eating habits.

EXPLORE Food Frequency Questionnaire

2. EXPLORE Study Food Frequency Questionnaire

*1. Please enter your study ID (if you are unsure or don't know please ask the researcher)

EXPLORE Food Frequency Questionnaire

3. Eating Pattern

*1. How would you describe your eating pattern? (Please choose one only)

- Eat a variety of all foods, including animal products
- Eat eggs, dairy products, fish and chicken but avoid other meats
- Eat eggs, dairy products and fish, but avoid chicken and other red meats
- Eat eggs and dairy products, but avoid all meats, chicken and fish
- Eat eggs, but avoid dairy products, all meats and fish
- Eat dairy products, but avoid eggs, all meats and fish
- Eat no animal products
- None of the above

4. Dairy

*1. Do you use milk? (e.g. fresh, UHT, powdered)

- Yes
- No

2. What type(s) of milk do you have most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- Not applicable
- Full cream milk (purple top)
- Standard milk (blue top)
- Skim milk (light blue top)
- Trim milk (green top)
- Super trim milk (light green top)
- Calcium enriched milk (yellow top) e.g. Xtra, Calci•Trim
- Calcium and vitamin enriched milk e.g. Mega, Anlene
- Calcium and protein enriched milk e.g. Sun Latte
- Standard soy milk (blue)
- Light soy milk (light blue)
- Calcium enriched soy milk (purple) e.g. Calci•Forte, Calci•Plus
- Calcium, vitamin and omega 3 enriched soy milk e.g. Essential
- Calcium and high fibre enriched soy milk e.g. Calci•Plus High Fibre
- Rice milk

*3. On average, how many servings of milk do you have per day? (Please choose one only)

(A ‘serving’ = 250 mL or 1 cup/glass)

e.g. 5 cups of coffee/tea using 50 mL of milk + ½ cup of milk on cereal = 1 ½ servings per day

- Not applicable
- Less than 1 serving
- 1•2 servings
- 3•4 servings
- 5 or more servings

* 4. How often do you usually have milk?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Flavoured milk (milkshake, iced coffee, Primo, Nesquik) • 250 mL/ 1 cup									
Milk as a drink • 250 mL / 1 cup									
Milk on breakfast cereals or porridge • 125 mL/ 1/2 cup									
Milk added to water•based hot drinks (coffee, tea) • 50 mL / 1/5 cup									
Milk•based hot drinks (Latte, Milo) • 250 mL / 1 cup									

* 5. How often do you usually eat cheese?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Cheddar (tasty, mild, colby) • 2 heaped Tbsp / matchbox cube									
Edam, Gouda, Swiss • 2 heaped Tbsp / matchbox cube									
Feta, Mozarella, Camembert • 1 heaped Tbsp / 1 med wedge									
Brie, blue and other specialty cheese • 1 heaped Tbsp / 1 med wedge									
Processed cheese slices • 1 slice									
Cream cheese • 2 heaped Tbsp									
Cottage or ricotta cheese • 2 heaped Tbsp									

* 6. How often do you usually eat these dairy based foods?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Ice cream • 2 scoops									
Custard or dairy food • 1 pottle / ½ cup									
Yoghurt, plain or flavour • 1 pottle / ½ cup									
Milk puddings (semolina, instant) • ½ cup									
Fermented or evaporated milk (buttermilk) • ½ cup									

EXPLORE Food Frequency Questionnaire

5. Bread

* 1. Do you eat bread?

- No
- Yes

* 2. What type(s) of bread, rolls or toast do you eat most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- Not applicable
- White
- White – high fibre
- Wholemeal or wheat meat
- Wholegrain

Other (please state)

* 3. What type of bread slice do you usually have? (Please choose one only)

- Not applicable
- Sandwich slice
- Toast slice
- Mixture of both sandwich and toast slices

EXPLORE Food Frequency Questionnaire

*4. On average, how many servings of bread do eat per day? (Please choose one only)

(A 'serving' = 1 slice of bread or 1 small roll)

- Not applicable
- Less than 1 serving
- 1–2 servings
- 3–4 servings
- 5–6 servings
- 7 or more servings

* 5. How often do you usually eat these bread based foods?

	Never	<1x /	1•3x /	1x /	2•3x /	4•6x /	Once /	2•3x /	4+ x /
Plain white bread • 1 slice									
High fibre white bread • 1 slice									
Wholemeal or wheat meal • 1 slice									
Wholegrain bread • 1 slice									
Fruit bread or fruit bun • 1 slice									
Wrap • 1 medium									
Focaccia, bagel, pita, panini or other speciality breads • 1 medium									
Paraoa Parai (fry bread) • 1 slice									
Rewena bread • 1 slice									
Doughboys or Maori bread • 1 slice									

* 6. How often do you usually eat these other bread based foods?

	Never	<1x /	1•3x /	1x /	2•3x /	4•6x /	Once /	2•3x /	4+ x /
Crumpet or muffin split • 1 crumpet / 1 whole muffin split									
Scone • 1 medium									
Bran muffin or savoury muffin • 1 medium									
Croissant • 1 medium									
Waffle, pancakes or pikelets • 1 medium / 2 small									
Iced buns • 1 medium									
Crackers (cream crackers, cruskits, corn / rice crackers, vitawheat) • 2 medium									

* 7. Do you have butter, margarine or spreads on bread or crackers?

No

Yes

EXPLORE Food Frequency Questionnaire

* 8. What type(s) do you have most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- Not applicable
- Butter (all varieties)
- Monounsaturated fat margarine e.g. Olive, Rice Bran, Canola Oil Spreads
- Polyunsaturated fat margarine e.g. Sunflower Oil Spreads
- Light monounsaturated fat margarine e.g. Olivio Spread Light
- Light polyunsaturated fat margarine e.g. Flora Spread Light
- Plant sterol enriched margarine e.g. Pro Active, Logical Spreads
- Light plant sterol enriched margarine e.g. Pro Active Spread Light
- Butter and margarine blend e.g. Country Soft, Butter Lea

Other (please state)

* 9. On average, how many servings of butter, margarine or spreads do you have per day? (Please choose one only)

(A ‘serving’ = 1 level teaspoon or 5 mL)

e.g. 1 sandwich with butter thinly spread on two pieces of bread = 2 servings

- Not applicable
- Less than 1 serving
- 1–2 servings
- 3–4 servings
- 5–6 servings
- 7 or more servings

EXPLORE Food Frequency Questionnaire

6. Breakfast Cereals

*1. Do you usually eat breakfast cereal and/or porridge?

- No
- Yes

*2. What breakfast cereal(s) do you eat most often? (You can choose up to 3 options, please only choose the ones you usually have)

- Not applicable
- Weetbix
- Refined cereals e.g. Cornflakes or Rice Bubbles
- Bran based cereals including fruity varieties e.g. Special K, Muesli, All Bran
- Sweetened e.g. Nutrigrain, Cocoa Pops
- Porridge

Other (please state)

*3. On average, how many servings of breakfast cereal or porridge do you have per week? (Please choose one only)

(A ‘serving’ = ½ cup porridge, muesli, cornflakes or 2 weetbix)

e.g. ½ cup of porridge 3 times per week + 2 weetbix 4 times a week = 7 servings per week

- Not applicable
- Less than 4 servings
- 4–6 servings
- 7–9 servings
- 10–12 servings
- 13–15 servings
- 16 or more servings

EXPLORE Food Frequency Questionnaire

* 4. How often do you usually eat porridge or these cereal foods?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Porridge, rolled oats, oat bran, oat meal • ½ cup									
Muesli (all varieties) • ½ cup									
Weetbix (all varieties) • 2 weetbix									
Cornflakes or rice bubbles • ½ cup									
Bran cereals (All Bran, Bran Flakes) • ½ cup									
Bran based cereals (Sultana Bran, Sultana Bran Extra) • ½ cup									
Light and fruity cereals (Special K, Light and Tasty) • ½ cup									
Chocolate based cereals (Milo cereal, Coco Pops) • ½ cup									
Sweetened cereals (Nutrigrain, Fruit Loops, Honey Puffs, Frosties) • ½ cup									
Breakfast drinks (Up and Go) • Small carton / 250 mL									

7. Starchy Foods

* 1. Do you eat any type of starchy foods such as rice, pasta, noodles and couscous?

- No
- Yes

* 2. On average, how many servings of starchy foods such as rice, pasta, noodles and couscous do you eat per week? (Please choose one only)

(A 'serving' = 1 cup cooked rice/pasta)

e.g. 1 cup of rice + ½ cup of pasta included in a lasagne pasta dish + 1 cup of spaghetti

= 2.5 servings

- Not applicable
- Less than 4 servings
- 4–6 servings
- 7–9 servings
- 10–12 servings
- 13–15 servings
- 16 or more servings

* 3. How often do you usually eat these starchy food

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Rice, white • 1 cup									
Rice, brown or wild • 1 cup									
Pasta, white or wholegrain (spaghetti, vermicelli) • 1 cup									
Canned spaghetti (Watties) • 1 cup									
Instant noodles (2 minute noodles) • 1 packet									
Egg and rice noodles (hokkien noodles, udon) • 1 cup									
Other grain (quinoa, couscous, bulgar wheat) • 1 cup									

8. Meat

*1. Do you eat beef, mutton, hogget, lamb, or pork

- No
- Yes

*2. Do you trim any excess fat (fat you can see) off these meats? (Please choose one only)

- Not applicable
- Always
- Often
- Occasionally
- Never cut the fat off meat

*3. On average, how many servings of meat e.g. beef, mutton, hogget, lamb or pork do you eat per week? (Please choose one only)

(A 'serving' = palm size or ½ a cup of meat without bone)

e.g. ½ cup of savoury mince + 2 small lamb chops = 2 servings

- Not applicable
- Less than 1 serving
- 1•3 servings
- 4•6 servings
- 7 or more servings

* 4. How often do you usually eat meat?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Beef mince dishes (rissoles, meatloaf, hamburger pattie) • 1 slice / patty / ½ cup									
Beef or veal mixed dishes (casserole, stir•fry) • ½ cup									
Beef or veal (roast, chop, steak, schnitzel, corned beef) • palm size / ½ cup									
Lamb, hogget or mutton mixed dishes (stews, casserole, stir•fry) • ½ cup									
Lamb, hogget or mutton (roast, chops, steak) • palm size / ½ cup									
Pork (roast, chop, steak) • palm size / ½ cup									
Canned corned beef • 1 medium slice									

EXPLORE Food Frequency Questionnaire

*** 5. How often do you usually eat these other meats?**

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Sausage, frankfurter or saveloy • 1 sausage / frankfurter/ 2 saveloys									
Bacon • 2 rashers									
Ham • 1 medium slice									
Luncheon meats or brawn • 1 slice									
Salami or chorizo • 1 slice / cube									
Offal (liver, kidneys, pate) • palm size / ½ cup									
Venison/game • palm size / ½ cup									

9. Poultry

*1. Do you eat poultry e.g. chicken, turkey or duck?

- No
- Yes

*2. Do you remove the skin from chicken? (Please choose one only)

- Not applicable
- Always
- Often
- Occasionally
- Never remove the skin from chicken

*3. On average, how many servings of chicken do you eat per week? (Please choose one only)

(A 'serving' = palm size of chicken or ½ cup)

e.g. 1 chicken breast + 2 chicken drumsticks + 1 chicken thigh = 4 servings per week

- Not applicable
- Less than1 serving
- 1•3 servings
- 4•6 servings
- 7 or more servin

EXPLORE Food Frequency Questionnaire

*** 4. How often do you usually eat poultry?**

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Chicken legs or wings • palm size / ½ cup / 1 unit (wing, drumstick)									
Chicken breast • palm size / ½ cup / ½ breast									
Chicken mixed dishes (casserole, stir•fry) • palm size / ½ cup									
Crumbed chicken (nuggets, patties, schnitzel) • 1 medium / 4 nuggets									
Turkey or quail • palm size / ½ cup									
Mutton bird or duck • palm size / ½ cup									

10. Fish and Seafood

*1. Do you eat any type of fish or seafood?

- No
- Yes

*2. On average, how many servings of fish and seafood (all types; fresh, frozen, tinned) do you eat per week? (Please choose one only)

(A 'serving' = 80 • 120g or palm size or small tin (85g))

e.g. 1 fish fillet and 1 small tin of tuna = 2 servings per week.

- Not applicable
- Less than 1 serving
- 1•3 servings
- 4•6 servings
- 7 or more servings

*3. How do you normally cook/eat fish? (You can choose up to 3 options, but please only choose the ones you usually have)

- Not applicable
- Raw / I don't cook it
- Oven baked / Grilled
- Deep fried
- Shallow fry
- Micro waved
- Steamed
- Poached

* 4. How often do you usually eat seafood?

/	Never	<1 x/month	1•3x /month	1x/ week	2-3x/ week	4-6x/ week	Once/ day	2-3x/ day	4+x/ day
Canned Salmon • 1 small can (85•95g)									
Canned Tuna • 1 small can (85•95g)									
Canned Mackerel, sardines, anchovies, herring • 1 small can (85•95g)									
Frozen crumbed fish (patties, fillets, cakes, fingers, nuggets) • 1 medium / 4 nuggets									
Snapper, Tarakihi, Hoki, Cod, Flounder • palm size / ½ cup									
Gurnard, Kahawai or Trevally • palm size / ½ cup									
Lemon fish or Shark • palm size / ½ cup									
Tuna • palm size / ½ cup									

* 5. How often do you usually eat seafood?

Salmon, trout or eel • palm size / ½ cup

	Never	<1x / month	1•3x / month	1x / wee k	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Shrimp, prawn, lobster or crayfish • ½ cup									
Crab or surumi • ½ cup									
Scallops, mussels, oysters, paua or clams • ½ cup									
Pipi or cockle • ½ cup									
Kina • ½ cup									
Whitebait • ¼ cup									
Roe • ¼ cup									
Squid, octopus, calamari, cuttlefish • ½ cup									

EXPLORE Food Frequency Questionnaire

*1. Do you cook meat, chicken, fish, eggs and/or vegetables with fat or oil?

- No
- Yes

*2. What type(s) do you use most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- Not applicable
- Butter (all varieties)
- Margarines (all varieties)
- Cooking oils (all varieties)
- Lard, Dripping, Coconut oil, Ghee (clarified butter)
- Cooking spray

Other (please state)

*3. When you use fat or oil to cook, how many servings of fat or oil do you use per dish? (Please choose one only)

(A 'serving' = 1 level teaspoon or 5 mL)

- Not applicable
- Less than 1 serving
- 1 serving
- 2 servings
- 3 servings
- 4 servings
- 5 or more servings

. Fats and Oils

*4. On average, how many servings of fat or oil do you use to cook per week? (Please choose one only)

- Not applicable
- Less than 1 serving
- 1•3 servings
- 4•7 servings
- 8•10 servings
- 11•14 servings
- 15 or more servings

13. Eggs

*1. Do you eat eggs?

- No
- Yes

*2. On average, not counting eggs used in baking/cooking, how many eggs do you usually eat per week? (Please choose one only)

- Not applicable
- Less than 1 egg
- 1 egg
- 2 eggs
- 3 eggs
- 4 eggs
- 5 or more eggs

*3. How often do you usually eat eggs?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Whole eggs (hard•boiled, poached, fried, mashed, omelette, scrambled) • 1 egg									
Mixed egg dish (quiche, frittata, other baked egg) • 1 slice									

14. Legumes

* 1. Do you eat legumes e.g. chickpeas/dried peas, soybeans, dried/canned beans, baked beans, lentils or Dahl?

- No
- Yes

* 2. On average, how many servings of legumes (fresh, frozen, canned, dried) do you eat per week? (Please choose one only)

(A 'serving' = ½ cup or 125g of cooked legumes)

- Not applicable
- Less than 1 serving
- 1 serving
- 2 servings
- 3 servings
- 4•5 servings
- 6•7 servings
- 8 or more servings

* 3. How often do you usually eat these legumes?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Soybeans • ½ cup									
Tofu • ½ cup									
Dahl • ½ cup									
Canned or dried legumes, beans (baked beans, chickpeas, lentils, peas, beans) • ½ cup									
Hummus • 2 Tbsp									

15. Vegetables

*1. Do you eat vegetables?

- No
- Yes

*2. On average, how many servings of vegetables (fresh, frozen, canned) do you eat per day? Do NOT include vegetable juices. (Please choose one only)

(A 'serving' = 1 medium potato / kumara or ½ cup cooked vegetables or 1/2 cup of lettuce)

e.g. 2 medium potatoes + ½ cup of peas = 3 servings

- Not applicable
- Less than 1 serving
- 1 serving
- 2 servings
- 3 servings
- 4 or more servings

*3. How often do you usually eat these vegetables?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Potato (boiled, mashed, baked, roasted) • 1 medium / ½ cup									
Pumpkin (boiled, mashed, baked, roasted) • ½ cup									
Kumara (boiled, mashed, baked, roasted) • 1 medium / ½ cup									
Mixed frozen vegetables • ½ cup									
Green beans • ½ cup									
Silver beet, spinach • ½ cup									
Carrots • 1 medium / ½ cup									
Sweet corn • 1 medium cob / ½ cup									
Mushrooms • ½ cup									
Tomatoes • 1 medium / ½ cup									
Beetroot • 1 medium / ½ cup									
Taro, cassava or breadfruit • 1 medium / ½ cup									

* 4. How often do you usually eat these vegetables?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Green bananas (plantain) • 1 medium / ½ cup									
Sprouts (alfalfa, mung) • ½ cup									
Pacific Island yams • 1 medium / ½ cup									
Turnips, swedes, parsnip or yams • ½ cup									
Onions, celery or leeks • ¼ cup									
Cauliflower, broccoli or broccoflower • ½ cup									
Brussel sprouts, cabbage, red cabbage or kale • ½ cup									
Courgette/zucchini, marrow, eggplant, squash, kamo kamo, asparagus, cucumber • ½ cup									
Capsicum (peppers) • ½ medium / ¼ cup									
Avocado • ¼ avocado									
Lettuce greens (mesculin, cos, iceberg) • ½ cup									
Other green leafy vegetables (whitloof, watercress, taro leaves, puha) • ½ cup									

EXPLORE Food Frequency Questionnaire

16. Fruit

*1. Do you eat fruit?

- No
- Yes

*2. On average, how many servings of fruit (fresh, frozen, canned or stewed) do you eat per day? Do NOT include fruit juice. (Please choose one only)

(A 'serving' = 1 medium or 2 small pieces of fruit or 1/2 cup of chopped fruit)

e.g. 1 apple + 2 small apricots = 2 servings)

- Not applicable
- Less than one serving
- 1 serving
- 2 servings
- 3 or more serving

*3. How often do you usually eat these fruits?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Apple • 1 medium / ½ cup									
Pear • 1 medium / ½ cup									
Banana • 1 medium / ½ cup									
Orange, mandarin, tangelo, grapefruit • 1 medium / 2 small									
Peach, nectarine, plum or apricot • 1 medium / ½ cup / 2 small									
Mango, paw•paw or persimmons / ½ cup									
Pineapple • ½ cup									
Grapes • ½ cup / 8•10 grapes									
Strawberries, other berries, cherries • ½ cup									
Melon (watermelon, rockmelon) • ½ cup									
Kiwifruit • 1 medium / 2 small									
Feijoas • 1 medium / 2 small									
Tamarillos • 1 medium / ½ cup									
Sultanas, raisins or currants • 1 small box									
Other dried fruit (apricots, prunes, dates) • 4 pieces									

17. Drinks

*1. On average, how many drinks do you have per day? (Please choose one only) (A 'serving' = 250 mL or one cup/glass)

- Less than 1 serving
- 1•3 servings
- 4•5 servings
- 6•8 servings
- 9•10 servings
- 11 or more servings

EXPLORE Food Frequency Questionnaire

* 2. How often do you usually have these drinks?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Instant soup (Cup of soup) • 250 mL / 1 cup									
Fruit juice (Just Juice, Fresh•up, Charlie's, Rio Gold) • 250 mL / 1 cup/glass									
Fruit drink (Choice, Rio Splice) • 250 mL / 1 cup/glass									
Vegetable juice (tomato juice, V8 juice) • 250 mL / 1 cup/glass									
Iced Tea (Lipton ice tea) • 250 mL / 1 cup/glass									
Cordial or Powdered drinks (Thriftee, Raro, Vita•fresh) • 250 mL / 1 cup/glass									
Low•calorie cordial • 250 mL / 1 cup/glass									
Energy drinks small•medium can (V, Red Bull) • 250•350 mL									
Energy drinks large can (Monster, Mother, Demon, large V) • 450•550 mL									
Sugar•free Energy drinks (sugar•free V, Monster, Red Bull) • 1 small can									
Diet soft/fizzy/carbonated drink (diet sprite) • 250 mL / 1 cup/glass									
Soft/fizzy/carbonated drinks (Coke, Sprite) • 250 mL / 1 cup/glass									
Sport's drinks (Gatorade, Powerade) • 1 bottle									
Flavoured water (Mizone, H2Go flavoured) • 1 bottle									
Water (unflavoured mineral water, soda water, tap water) • 250 mL / 1 cup/glass									

EXPLORE Food Frequency Questionnaire

* 3. How often do you usually have these drinks?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Coffee instant or brewed with or without milk (Nescafe, expresso) • 1 cup									
Specialty coffees (flat white, cappuccino, lattes) • 1 small cup									
Coffee decaffeinated or substitute (Inka) • 1 cup									
Hot chocolate drinks (drinking chocolate, hot chocolate, Koko) • 1 cup									
Milo • 1 tsp									
Tea (English breakfast tea, Earl Grey) • 1 cup									
Herbal tea or Green tea • 1 cup									
Soy drinks • 1 cup									

* 4. How often do you usually have these alcoholic drinks?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Beer – low alcohol • 1 can or bottle									
Beer – ordinary • 1 can or bottle									
Red wine • 1 small glass									
White wine, champagne, sparkling wine • 1 small glass									
Wine cooler • 1 small glass / bottle									
Sparkling grape juice • 1 glass / cup									
Sherry or port • 100 mL									
Spirits, liqueurs • 1 shot or 30 mL									
RTD (KGB, Vodka Cruiser, Woodstock bourbon) • 1 bottle / can									
Cider • 1 glass / cup / bottle									
Kava • 1 glass / cup									

18. Dressings and Sauces

* 1. How often do you usually have these dressings or sauces?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Butter (all varieties) • 1 tsp									
Margarine (all varieties) • 1 tsp									
Oil (all varieties) • 1 tsp									
Cream or sour cream • 1 Tbsp									
Mayonnaise or creamy dressings (aioli, tartae sauce) • 1 Tbsp									
Low fat/calorie dressing (reduced fat mayonnaise) • 1 Tbsp									
Salad dressing (french, italian) • 1 Tbsp									
Sauces (tomato, BBQ, sweet chilli, mint) • 1 Tbsp									
Mustard • 1 Tbsp									
Soy sauce • 1 Tbsp									
Chutney or relish • 1 Tbsp									
Gravy homemade • ¼ cup									
Instant Gravy (e.g. Maggi) • ¼ cup									
White sauce/cheese sauce • ¼ cup									

19. Miscellaneous • Cakes, Biscuits and Puddings

*** 1. How often do you usually eat these baked products?**

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Cakes, loaves, sweet muffins • 1 slice / 1 muffin									
Sweet pies or pastries, tarts, doughnuts • 1 medium									
Other puddings or desserts • not including milk•based puddings (sticky date pudding, pavlova) • ½ cup									
Plain biscuits, cookies (Round wine, Ginger nut) • 2 biscuits									
Fancy biscuits (chocolate, cream) • 2 biscuits									

EXPLORE Food Frequency Questionnaire

* 1. How often do you usually eat these other foods?

	Never	<1x / month	1•3x / month	1x / week	2•3x / week	4•6x / week	Once / day	2•3x / day	4+ x / day
Jelly • ½ cup									
Ice blocks • 1 ice block									
Lollies • 2 lollies									
Chocolate • including chocolate bars (Moro bars) • 1 small bar									
Sugar added to food and drinks • 1 level tsp									
Jam, honey, marmalade or syrup • 1 level tsp									
Vegemite or marmite • 1 level tsp									
Peanut butter or other nut spreads • 1 level Tbsp									
Brazil nuts or walnuts • 2									
Peanuts • 10									
Other nuts (almonds, cashew, pistachio, macadamia) • 10									
Seeds (pumpkin, sunflower)									
Muesli bars • 1 bar									
Coconut cream • ¼ cup									
Coconut milk • ¼ cup									
Lite coconut milk • ¼ cup									
Potato crisps, corn chips, Twisties • ½ cup / handful									

* 2. Do you use salt in cooking?

- Never
- Rarely
- Sometimes
- Usually

*3. Do you use salt at the table?

- Never
- Rarely
- Sometimes
- Usually
- Always

EXPLORE Food Frequency Questionnaire

20. Miscellaneous • Takeaways

*1. On average, how often do you eat takeaways per week? (Please choose one only)

- Never
- Less than 1 times
- 1•2 times
- 3•4 time
- 4•6 times
- More than 7 times

*2. How often do you usually eat these takeaway foods?

	/ month	<1x / month	1•3x / Once / week	1x / 2•3x / week	2•3x / 4+ x / week	4•6x Never day	d
Meat pie, sausage roll, other savouries • 1 pie / 2 small sausage rolls or savouries							
Hot potato chips, kumara chips, french fries, wedges • ½ cup							
Chinese • 1 serve							
Indian • 1 serve							
Thai • 1 serve							
Pizza • 1 medium slice							
Burgers • 1 medium burger							
Battered fish • 1 piece							
Fried chicken (KFC, Country fried chicken) • 1 medium piece							
Bread based (Kebab, sandwiches, wraps, Pita Pit, Subway) • 1 medium							

Appendix C. Three-factor eating questionnaire

(Stunkard & Messick, 1985)

Dessert Taste study - Eating Behaviour Questionnaire

Dessert Taste study - Eating Behaviour Questionnaire

* 1. Please enter your full name

Dessert Taste study - Eating Behaviour Questionnaire

Dessert Taste study - Eating Behaviour Questionnaire

Please answer each question by choosing the the appropriate answer (True or False)

2. When I smell a sizzling steak or see a juicy piece of meat, I find it very difficult to keep from eating, even if I have just finished a meal

◯ True

◯ False

3. I usually eat too much at social occasions, like parties and picnics

◯ True

◯ False

4. I am usually so hungry that I eat more than three times a day

◯ True

◯ False

5. When I have eaten my quota of calories, I am usually good about not eating any more

◯ True

◯ False

6. Dieting is so hard for me because I just get too hungry

◯ True

◯ False

7. I deliberately take small helpings as a means of controlling my weight

◯ True

◯ False

8. Sometimes things just taste so good that I keep on eating even when I am no longer hungry

◯ True

◯ False

9. Since I am often hungry, I sometimes wish that while eating, an expert would tell me that I have had enough or that I can have something more to eat

◯ True

◯ False

10. When I feel anxious, I find myself eating

◯ True

◯ False

11. Life is too short to worry about dieting

◯ True

◯ False

12. Since my weight goes up and down, I have gone on reducing diets more than once

◯ True

◯ False

13. I often feel so hungry that I just have to eat someting

◯ True

◯ False

14. When I am with someone who is overeating, I usually overeat too

◯ True

◯ False

15. I have a pretty good idea of the number of calories in common food

◯ True

◯ False

16. Sometimes when I start eating, I just can't seem to stop

◯ True

◯ False

17. It is not difficult for me to leave something on my plate

◯ True

◯ False

18. At certain times of the day, I get hungry because I have gotten used to eating someting then

◯ True

◯ False

19. While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it

◯ True

◯ False

20. Being with someone who is eating often makes me hungry enough to eat also

◯ True

◯ False

21. When I feel blue, I often overeat

◯ True

◯ False

22. I enjoy eating too much to spoil it by counting calories or watching my weight

◯ True

◯ False

23. When I see a real delicacy, I often get so hungry that I have to eat right away

◯ True

◯ False

24. I often stop eating when I am not really full as a conscious means of limiting the amount that I eat

◯ True

◯ False

17. It is not difficult for me to leave something on my plate

◯ True

◯ False

18. At certain times of the day, I get hungry because I have gotten used to eating someting then

◯ True

◯ False

19. While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it

◯ True

◯ False

20. Being with someone who is eating often makes me hungry enough to eat also

◯ True

◯ False

21. When I feel blue, I often overeat

◯ True

◯ False

22. I enjoy eating too much to spoil it by counting calories or watching my weight

◯ True

◯ False

23. When I see a real delicacy, I often get so hungry that I have to eat right away

◯ True

◯ False

24. I often stop eating when I am not really full as a conscious means of limiting the amount that I eat

◯ True

◯ False

33. I count calories as a conscious means of controlling my weight

- ◯ True
- ◯ False

34. I do not eat some foods because they make me fat

- ◯ True
- ◯ False

35. I am always hungry enough to eat at any time

- ◯ True
- ◯ False

36. I pay a great deal of attention to changes in my figure

- ◯ True
- ◯ False

37. While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high calorie foods

- ◯ True
- ◯ False

Dessert Taste study - Eating Behaviour Questionnaire

Dessert Taste study - Eating Behaviour Questionnaire

Please answer the following questions by choosing the response that is appropriate to you.

38. How often are you dieting in a conscious effort to control your weight?

- ◯ Rarely
- ◯ Sometimes
- ◯ Usually
- ◯ Always

39. Would a weight fluctuation of 2.5 kg (5 lbs) affect the way you live your life?

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Very much

40. How often do you feel hungry?

- ◯ Only at mealtimes
- ◯ Sometimes between meals
- ◯ Often between meals
- ◯ Almost always

41. Do your feelings of guilt about overeating help you to control your food intake?

- ◯ Never
- ◯ Rarely
- ◯ Often
- ◯ Always

42. How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours?

- ◯ Easy
- ◯ Slightly difficult
- ◯ Moderately difficult
- ◯ Very difficult

43. How conscious are you of what you are eating?

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Exremely

44. How frequently do you avoid 'stocking up' on tempting foods?

- ◯ Almost never
- ◯ Seldom
- ◯ Usually
- ◯ Almost always

45. How likely are you to shop for low calorie foods?

- ◯ Unlikely
- ◯ Slightly likely
- ◯ Moderately likely
- ◯ Very likely

46. Do you eat sensibly in front of others and splurge alone?

- ◯ Never
- ◯ Rarely
- ◯ Often
- ◯ Always

47. How likely are you to consciously eat slowly in order to cut down on how much you eat?

- ◯ Unlikely
- ◯ Slightly likely
- ◯ Moderately likely
- ◯ Very Likely

48. How frequently do you skip dessert because you are no longer hungry?

- ◯ Almost never
- ◯ Seldom
- ◯ At least once a week
- ◯ Almost every day

49. How likely are you to consciously eat less than you want?

- ◯ Unlikely
- ◯ Slightly likely
- ◯ Moderately likely
- ◯ Very likely

50. Do you go on eating binges though you are not hungry?

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ At least once a week

51. On a scale of 0 to 5, where 0 means no restraint in eating (eating whatever you want, whenever you want it) and 5 means total restraint (constantly limiting food intake and never 'giving in'), what number would you give yourself?. Choose the answer which best describes you.

- ◯ 0. Eat whatever you want, whenever you want it
- ◯ 1. Usually eat whatever you want, whenever you want it
- ◯ 2. Often eat whatever you want, whenever you want it
- ◯ 3. Often limit food intake, but often 'give in'
- ◯ 4. Usually limit food intake, rarely 'give in'
- ◯ 5. Constantly limiting food intake, never 'giving in'

52. To what extent does this statement describe your eating behaviour ?
'I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow.'

- Not like me
- A little like me
- Pretty good description of me
- Describes me perfectly

Dessert Taste study - Eating Behaviour Questionnaire

For the following questions, please determine whether the statement applies to you or not...

53. I mostly use reduced fat dairy products

- ◯ Yes
- ◯ No

54. I fry food no more than once a week

- ◯ Yes
- ◯ No

55. I eat high fat snack food such as potato chips, chocolate and french fries no more than once a week

- ◯ Yes
- ◯ No

56. I avoid salad dressings or I use 'no-oil' varieties

- ◯ Yes
- ◯ No

57. I snack on bread, fruit and cereals in preference to biscuits and cake

- ◯ Yes
- ◯ No

58. I avoid cream

- ◯ Yes
- ◯ No

59. I avoid using butter, margarine or sour cream on vegetables

- ◯ Yes
- ◯ No