Habitual sweet food intake and eating behaviour are influenced by sweet taste perception

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Abstract

Background: Sugar consumption creates pleasure, and excessive sugar consumption leads to weight gain and is therefore a key driver of obesity. This study aims to assess sweet food and beverage intake, eating behaviours and how they may be explained by perceived sweet taste intensity and hedonic preference.

Aim: To assess sweet food habits and eating behaviours in 20-40-year-old NZ European women, and understand how measures of sweet taste perception can help explain these sweet food choices and eating behaviours.

Methods: Women (N=45), aged 20-40 years, were recruited for this cross-sectional study. A non-quantitative sweet food-food frequency questionnaire (SF-FFQ) was developed to assess sweet food intake. Liking of sweetened beverages was assessed on a 100 mm visual scale. The Three Factor Eating Questionnaire (TFEQ) was used to assess the eating behaviours. Perceived sweet taste intensity and hedonic preference of glucose concentrations (125 mM, 250 mM, 500 mM, 1000 mM) was rated (0-100) on a modified general Labelled Magnitude Scale (gLMS).

Results: Frequency of daily intake was reported as daily frequency equivalents (DFE). Occasional sweet food DFE was high (4.23±2.29), with intake of baking and sweets especially high (1.20±0.83). Participants with a self-reported "sweet tooth" more frequently consumed baking (*P*=0.04), chocolate (*P*=0.03) and soft lollies (*P*=0.04) compared to participants with no "sweet tooth". Chocolate DFE was higher in participants who experienced regular food cravings compared to those who did not (*P*<0.001). Higher consumption of sweet food was correlated with less sensitivity to 1000 mM glucose (*P*=0.02). A negative correlation was found between intensity rating (1000 mM), fruit juice liking (*P*=0.01) and fruit drink liking (*P*<0.001). Participants who preferred sweet snacks, were less sensitive to 1000 mM glucose than those who preferred savoury (*P*=0.04).

Conclusion: Participants in this study habitually consumed foods high in sugar such as baking, sweets, chocolate and sweetened beverages. The participants' sweet beverage choice was influenced by their liking of sweet beverages. Some participants were found to express certain eating behaviours that influenced their intake of sweet food such as hunger, food cravings and “sweet tooth”. Sensitivity to sweet taste was inversely associated with consumption of sweet tasting food. The data suggest that sweet taste intensity perception plays an important role in habitual sweet food and beverage intake.

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Table of Contents

List of Tables

List of Figures

List of Appendices

Abbreviation List

BF%	Body Fat Percentage
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
CI	Confidence Interval
FFQ	Food Frequency Questionnaire
gLMS	general Labelled Magnitude Scale
MSG	Monosodium Glutamate
MU	Massey University
NZ	New Zealand
OECD	Organisation for Economic Cooperation and Development
P	p-value (statistical analysis)
PROP	6-n-propylthiouracil
PTC	Phenylthiocarbmide
r	Correlation coefficient (statistical analysis)
SD	Standard Deviation
SF-FFQ	Sweet Food- Food Frequency Questionnaire
T2DM	Type 2 Diabetes Mellitus
T2R	Type 2 Receptor
TFEQ	Three Factor Eating Questionnaire
USA	United States of America
VAS	Visual Analogue Scale
VLDL	Very Low Density Lipoprotein
WHO	World Health Organisation

Chapter One Introduction

1.1 Background and Study Justification

Sugar, it's everywhere, we feed it to our children, and it is laced in all of our breakfast cereals, and is consumed in considerable amounts through fizzy drinks and juices. The latest data shows that on average, New Zealanders consume about 150 grams (38 teaspoons) of added sugar per day (Food and Agriculture Organization of the United Nations Statistics Divison, 2015). Also, about 17% of total sugar intake comes from sweetened beverages and 15% from added sugar and sweets (Ministry of Health, 2013). Sugar is a contributing factor to the current obesity epidemic; one of the world's largest health care issues (World Health Organisation, 2014).

1.1.1 The link between excessive sugar consumption and obesity

Obesity is killing New Zealanders; more than 1000 die each year due to an obesity-related disease, which is double the road toll (New Zealand Health Strategy, 2001). Obesity is one of the most significant modifiable risk factors for many key diseases, including; type 2 diabetes mellitus (T2DM), ischaemic heart disease, ischaemic stroke and some cancers (New Zealand Medical Association, 2014). The prevalence of obesity in New Zealand has increased significantly over the past three decades, and currently 28.4% of the population are obese (Ministry of Health, 2013, Statistics New Zealand, 2014). Additionally, New Zealand is ranked the fourth highest country for obesity prevalence among those belonging to the Organisation for Economic Cooperation and Development (OECD) (Ng *et al.*, 2014). This is a major public health issue; the estimated cost to the country is between $722 million and $849 million each year in health care costs and lost productivity (The University of Auckland, 2012). Obesity is a multi-factorial disease that has some genetic basis, but it is also influenced by environmental factors such as dietary intake, physical activity, and culture (Overberg *et al.*, 2012). Dietary intake is one of the main modifiable influences on weight status, with sugar intake proposed as a major contributor.

The Western diet, comprised of highly refined carbohydrates and fat, and reduced complex plant polysaccharides, has been linked to the prevalence of obesity

(Drewnowski, 2007). In particular, dietary sugars and fats have been suggested as an important cause of obesity; they influence biochemical markers of metabolic health, blood pressure and body weight (Te Morenga *et al.*, 2013). Sugar is thought to be a contributor to the obesity epidemic as it is added to many foods and is high in calories. Sweetness has a powerful hedonic appeal, therefore preference for sweet food is an important contributor to increased body weight and metabolic disease risk (Laffitte *et al.*, 2014, Martínez-Ruiza *et al.*, 2014). This was shown in research by Ettinger *et al.* (2012) who reported that overweight women had a lower sweet taste sensitivity than normal weight women. These findings suggest that overweight women may require higher concentrations to detect sweetness, and may thus consume more sugar (Sartor *et al.*, 2011).

1.1.2 The important influence of sensory attributes on food selection

Sensory attributes such as smell, taste, appearance and texture have a strong influence on eating behaviours and dietary intake (Overberg *et al.*, 2012). Taste has however, been found to be the main driver of food acceptance and choice (Cox *et al.*, 2014, Hoppert *et al.*, 2012). Our sensation of taste is influenced by an innate preference for certain foods, specifically sweet tasting food (Bouhlal *et al.*, 2011). A better understanding of sweet taste perception can help explain the reasons behind people's food choices. This can lead to a better understanding of one of the issues behind the multifaceted obesity epidemic.

1.1.2.1 Sweet taste perception

Taste perception is a collective term that is used to describe taste sensitivity and preference. Although humans like and dislike similar tastes, there are individual differences in taste perception (Drewnowski *et al.*, 2012, Mennella *et al.*, 2011). Sensory evaluation, used in psychophysics, is a scientific method used to assess senses of smell, sight, taste and hearing. In taste research, this method has been useful to determine individuals' taste perception (Lawless and Heymann, 1999). Individuals cannot directly share or describe experiences, therefore it can be challenging to measure taste perception (Hayes *et al.*, 2013). Scaling measures have been developed that can help to overcome these issues. Scaling measures have been used in past sensory studies to measure both perceived taste intensity and hedonic taste preference in individuals (Drewnowski *et al.*, 1997, Duffy *et al.*, 2003, Holt *et al.*, 2000, Mahar and Duizer, 2007, Zandstra *et al.*, 1999).

A better understanding of an individual's taste perception can be useful in the food and beverage industry and the health sector, as it can enable and support understanding of consumer behaviour (Bunting *et al.*, 2013, Citterio and Suzuki, 2008). Consequently, there is tremendous potential to use the knowledge gained through sensory research for the design of healthier food options in a food technology context.

1.1.2.2 Linking sweet taste perception and dietary intake

Past research has considered the link between taste perception and food intake; however results have been conflicting. Some research suggests that individuals who prefer higher levels of sugar or sweetness have greater dietary intakes of sugar and sweet food (Drewnowski, 1997, Duffy *et al.*, 2003, Holt *et al.*, 2000, Liem and Mennella, 2002, Mennella *et al.*, 2011, Pepino and Mennella, 2012, Salbe *et al.*, 2004, Stewart *et al.*, 2010, Zandstra *et al.*, 1999). In contrast, other research has found there to be no relationship between taste perception and dietary intake (Cicerale *et al.*, 2012, Lanfer *et al.*, 2012). Some of the differences obtained in these studies stems from differences in the methodologies used in sensory evaluations, as well as dietary assessments. Control over confounding variables that can influence intake such as, restrained eating or dieting behaviours may also be limited (Duffy, 2004). The controversy arising from these opposing results and shortcomings in the published studies calls for new enquiries that can illuminate the relationship between sensory attributes, eating behaviour and dietary intake.

1.1.3 Dietary assessments to define food choices

Dietary assessment refers to the comprehensive evaluation of a person's food intake, which can be achieved through a range of methodologies. Dietary assessments collect information about the types and quality of foods consumed, frequency and time of consumption, and cooking methods, in an attempt to gather sound information about a person's 'typical' diet (Biro *et al.*, 2002). Dietary assessment tools can not only assess actual intake, but can also be used to address an individual's attitudes and beliefs towards food, which may influence their choices. These assessments can be retrospective, such as 24-hour dietary recalls, Food Frequency Questionnaires (FFQ), and diet histories. Alternatively they can be prospective, such as weighed or estimated food records. They can also be short-term dietary assessments; collecting information about an individual's current intake, or long-term; collecting information about intake over the past months or years (Biro *et al.*, 2002).

Dietary assessment methods have some challenges, and each method has strengths and weaknesses. It can be difficult to capture a person's 'typical' diet as it is susceptible to change. Individuals can also display respondent bias due to social pressure. Many dietary methods also rely on memory which can cause reliability issues (Gibson, 2005). Sugar, sugar-rich foods and sweets can be prone to underreporting as they are often discretionary foods, are easily forgotten, or not mentioned (Vucic *et al.*, 2009). Therefore, it is important for this research project to use a dietary assessment method specifically focused on measuring intake of sweet tasting food and beverages. Thus far, few published studies have achieved this (Holt *et al.*, 2000). In the context of sugar intake, dietary assessment methods also need to adequately assess sweetened beverage consumption as they are one of the largest sugar contributors in the NZ diet (Ministry of Health, 2013), and excessive intake has been associated with increased risk of many chronic diseases (Sartor *et al.*, 2011). There is a dearth of published research investigating the potential link between sweet taste preference and the actual consumption of beverages (Kim *et al.*, 2014). If a link could be established between sweet taste perception and the actual consumption of sweet food and beverages, this would lead to better understanding of the impact sweet taste may have on diet quality (Cicerale *et al.*, 2012, Kim *et al.*, 2014), which may open new avenues for obesity prevention strategies.

1.1.4 The link between taste perception and eating behaviour

Although taste has been found to be the most influential factor to affect dietary intake, an individual's attitudes and beliefs can influence perceived taste perceptions and food intake (Lampuré *et al.*, 2015). Eating behaviours such as cognitive restraint, emotional eating and uncontrolled eating have been related to a higher Body Mass Index (BMI) and unhealthy dietary choices (Camilleri *et al.*, 2014, Karlsson *et al.*, 2000, Lauzon *et al.*, 2004). Eating behaviour questionnaires have been developed that assess these dietary behaviours (Stunkard and Messick, 1985, van Strien *et al.*, 1986) and research has demonstrated a link to dietary intake. For example, high preference for sweets is positively associated with uncontrolled eating (Lähteenmäki and Tuorila, 1995), but inversely associated with cognitive restraint (De Castro, 1995, French *et al.*, 1994, Kleifield and Lowe, 1991, Williams *et al.*, 1996). It has also been argued that restrained eaters may avoid sugar and sweet tasting foods for health reasons, and may have trained themselves to dislike sweet foods regardless of their taste preference (Duffy *et al.*, 2003). Emotional eating has also been found to be related to liking of sweet tasting food, and a greater intake of sweet and fatty snacks (Camilleri *et al.*, 2014, Lampuré *et al.*, 2015, Lauzon *et al.*, 2004). This suggests that there is a clear link between eating behaviours and dietary intake related to sweet taste; however limited research has specifically addressed the relationship between these. It is important that we better understand this link as eating behaviours can strongly influence food intake. A better understanding of eating behaviours is also beneficial within dietary counselling as it gives practitioners a better insight into the effects eating behaviours have on clients' dietary intake.

1.1.5 Justification of the current research approach

There are considerable differences between individuals' sensitivity to sweet taste which can influence food choices and eating behaviours (Mennella *et al.*, 2011). It is clear from previous research that an individual's taste perception influences their sweet taste preference. However, methodological differences in the measurement of taste perception and dietary intake have created inconsistencies about the potential link. The current study uses taste perception assessment tools that are well-established and fully validated in our laboratory. This includes a measure of sweet taste intensity and hedonic preference using the general Labelled Magnitude Scale (gLMS). The current study also uses dietary assessment tools that specifically focus on sweet tasting food and beverages to ensure habitual intake is accurately described. This research project includes an assessment of sweetened beverage liking as these are believed to be one of the main sugar contributors in our diet. Furthermore, the current research addresses a gap in knowledge about eating behaviours, preference and intake of sweet tasting foods and beverages. The current study will assess sweet taste perception and dietary intake of females only to ensure study standardisation, as gender difference can exist (Hayes and Duffy, 2008, Laeng *et al.*, 1993, Monneuse *et al.*, 1991, Nakamura *et al.*, 2008, Roininen *et al.*, 1999, Sartor *et al.*, 2011). Few past studies have addressed taste responses and actual intake within the same study population (Drewnowski, 1997). Therefore, The current research study aims to address the gaps in the literature; using a specific study population of New Zealand European women aged 20-40 years, to contribute to a better understanding of the biological and psychological links between sweet taste perception, food choices and eating behaviour. Advances in knowledge in this field will support solutions for important public health issues that address key pathways to obesity and may open new avenues for prevention strategies.

1.2 Aims and Objectives

The aim of the study is to contribute to a better understanding of the biological and psychological links between sweet taste perception, food choices and eating behaviour in 20-40-year-old NZ European women.

Objectives

- To assess frequency of sweet tasting food intake
- To determine liking of sweet tasting beverages
- To assess eating behaviours
- To measure sweet taste intensity
- To measure hedonic preference of sweet taste
- To establish the link between sweet taste perception, sweet tasting food intake and eating behaviours

This study will **test the hypothesis** - that sweet taste sensitivity is associated with hedonic preference for sweet taste and influences sweet food choices.

To test this hypothesis, a mixed methods, cross-sectional study in 45 NZ European women, aged 20-40 years was completed. To understand individuals' sensitivity and preference of sweet taste, participants ranked their perception of sweet taste intensity and their preference of various (low to high) glucose concentrations on a modified gLMS. To enable this to be linked with sweet food and beverage intake, a non-quantitative sweet food-food frequency questionnaire (SF-FFQ) was developed to gain an understanding of habitual intake. A 100 mm visual scale beverage liking questionnaire was also employed to assess the liking of sweet beverages typically consumed by the study participants. The Three Factor Eating Questionnaire (TFEQ), developed by Stunkard and Messick (1985), was also used to better understand the influence that specific eating behaviours have on sweet tasting food and beverage intake.

1.3 Structure of the Thesis

The study has been assembled into six chapters. Chapter one introduces the key research concepts and highlights the significance of the study. Chapter two is a review of the literature and covers sensory methodology, the link between sweet taste perception and diet, dietary assessment methods, and eating behaviour methods. The third chapter outlines the methods and materials the study employed. Chapter four outlines the key results and study findings, followed by chapter five, a discussion of the results. Lastly, chapter 6 concludes the research and includes study strengths, limitations and directions for future research.

1.4 Researchers Contribution

Table 1.1- Researchers Contribution to the Sweet Taste Study

Researchers	Contributions and Support
Stacey Rivers- Masters student	Main researcher, developed SF-FFQ, developed beverage liking questionnaire, participant screening, sensory and dietary data collection, data entry and analysis, statistical analysis, interpretation and discussion of results, author of thesis
Prof Bernhard Breier- supervisor	Main academic supervisor, research strategy and direction, funding, study design, academic mentorship, assistance with analysis and interpretation of results, reviewed thesis
A/Prof Rozanne Kruger- supervisor	Academic mentorship, research direction, development of SF-FFQ and beverage liking questionnaire, assistance with analysis and interpretation of results, reviewed thesis
Shakeela Jayasinghe - PhD student	Primary investigator of the Sweet Taste Study, application for ethics, study design, sensory methodology development, SF-FFQ development, beverage liking questionnaire development, recruitment and screening, sensory and dietary data collection, data entry and analysis, statistical analysis, interpretation and discussion of results, review of methods and results
Sophie Kindleysides-PhD student	Recruitment, sensory and dietary data collection
Maggie Cao- Masters student	Sensory and dietary data collection

Chapter Two Literature Review

2.1 Introduction

Sugar is a term used to describe a sweet tasting simple carbohydrate. Glucose, fructose and sucrose are the most common types of simple sugars found in our diet. The monosaccharides glucose and fructose combine to make the disaccharide sucrose, also known as table or white sugar (New Zealand Nutrition Foundation, 2015). Sugar occurs naturally in a range of foods such as fruit, vegetables, milk and cereals. They can also be added to foods as white, brown or raw sugar, sugar syrups, and other extracts (University of Otago and Ministry of Health, 2011). Added sugar can be found in many processed foods such as cakes, buns, cereals, desserts, pastries, juices and carbonated drinks (Nik Shanita *et al.*, 2012). Historically, sugar was not abundant to our ancestors, however since the 1970's there has been a worldwide increase in sugar consumption; tripling in the past 50 years (Lustig *et al.*, 2012). This was likely to be caused by the introduction of sugar-sweetened beverages and processed foods which are reasonably cheap with high palatability, leading to consumption of more than 500 calories from added sugar around the world (Lustig *et al.*, 2012).

Obesity and chronic disease prevalence has paralleled the increase in sugar consumption; with rates steadily rising over the past 50 years (Boniface, 2013). The United Nations have declared that chronic disease now poses a larger threat to human health than infectious disease (U.S Department of State, n.d). These chronic diseases include T2DM, metabolic syndrome, heart disease and cancer (Lustig *et al.*, 2012). Evidence suggests that sugar contributes to poor health outcomes such as overweight and obesity (Te Morenga *et al.*, 2013), hyperlipidemia (Zhang *et al.*, 2015), insulin resistance, T2DM (Johnson *et al.*, 2009, Malik *et al.*, 2010) and gout (Choi *et al.*, 2010).

2.1.1 Excessive sugar consumption and increased disease risk

The prevalence of obesity in New Zealand (NZ) has increased substantially over the past three decades. Obesity is a high amount of fat mass compared to lean mass, and is defined as a BMI over 30 kg/m^2 (Ministry of Health, 2015). At present, 1.2 million adults (31% of the population) are obese (Ministry of Health, 2013, New Zealand Medical Association, 2014). Each decade, between 1980 and 2008 there has been a worldwide increase in BMI of 0.4 kg/m^2 per decade for men, and 0.5 kg/m^2 per decade for women (Finucane *et al.*, 2011). A meta-analysis by Te Morenga *et al.* (2013) concluded that dietary sugar intake is associated with body weight; those who consumed greater amounts were more likely to be overweight. Frequent consumption of sugar-sweetened beverages such as soft drinks, fruit drinks, and iced tea has been associated with weight gain and risk of obesity (Malik *et al.*, 2010, Malik *et al.*, 2006, Te Morenga *et al.*, 2013). This relationship is likely to exist as foods high in sugar are often highly palatable, high in energy and induce little satiation (Cox *et al.*, 2014). Furthermore, the worldwide increase in sugar intake is in line with increasing prevalence of metabolic syndrome risk factors, T2DM, cardiovascular disease and risk of gout (Choi and Curhan, 2008, Dhurandhar and Thomas, 2015, Johnson *et al.*, 2009). A meta-analysis by Malik *et al.* (2010) found those with the highest intake of sugar-sweetened beverages have a 26% increase in the risk of T2DM development, and a 20% increased risk of metabolic syndrome development. Dhingra *et al.* (2007) also linked metabolic syndrome risk with sweetened beverage consumption; individuals that consumed more than one soft drink each day had an increased risk of impaired fasting glucose, increased blood pressure, and hypertriglyceridemia.

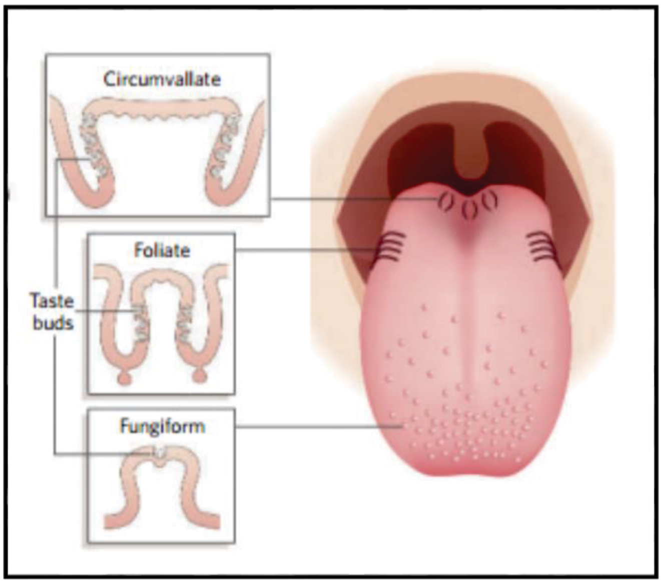
The above research shows that high intakes of dietary sugar can influence diet quality and as a result lead to health implications; increasing the risk of chronic disease. Excessive sugar consumption is therefore a major public health concern.

2.2 Introduction to the Sensory World of Food

When an individual consumes food, many sensory properties are experienced which help to determine enjoyment. This begins before the food is even tasted; the appearance and aroma, and once eaten, the texture and taste of food (Clark, 1998). The sensation of taste is linked with an innate preference for certain foods, specifically sweet tasting food (Bouhlal *et al.*, 2011), which are high in calories and nutrients (Drewnowski *et al.*, 2012). This means humans' sensory systems have evolved to prefer energy rich foods high in sugar (Drewnowski *et al.*, 2012). Through-out a person's lifetime they have personal food experiences, leading to individual attitudes towards food, which influences food choices (Mela, 2001). Individuals are also motivated by their desire to satisfy hunger, own social and cultural beliefs, as well as price, brands, and convenience of foods. Regardless of the many influences, taste has been found to be the main driver of food acceptance and choice (Cox *et al.*, 2014, Hoppert *et al.*, 2012). Therefore, taste is the most important influence on consumption.

2.2.1 Taste receptors

The tongue and soft palate contain specialised sense organs called taste buds, which consist of clusters of 30-50 taste receptor cells embedded in cell membranes (Lawless and Heymann, 1999). The location of the taste buds are shown in Figure 1; circumvallate papillae contain thousands of taste buds and are found at the back of the tongue, folate papillae contain a dozen to hundreds of taste buds and are located at the posterior lateral edge of the tongue and fungiform papillae are found at the front of the tongue and contain one to a few taste buds (Chandrashekar *et al.*, 2006).



Circumvallate papillae, found at the back of the tongue, folate papillae at the posterior lateral edge of the tongue and fungiform papillae are found at the front of the tongue.

Source: Chandrashekar *et al.* (2006).

Figure 2.1- Location of taste buds on the papillae of the tongue

Taste cells can be characterised into four cell types (type I, II, III and IV cells). Each taste cell type is sensitive to the existence, quality and concentration of a taste stimuli, and each has a different function (Dvoryanchikov *et al.*, 2009). Type I cells are important for maintenance of the extracellular environment, which keeps the cells excited for firing (Dvoryanchikov *et al.*, 2009), as well as a supporting and secretory function

(Martin *et al.*, 2009). Type II receptor cells are thought to be the main sensory receptor cells which express the G-coupled receptors; T1R1, T1R2 and T1R3 (Martin *et al.*, 2009). Type III cells have a role in transmitting information to the nervous system (Dvoryanchikov *et al.*, 2009), and are thought to be responsible for sour taste (Martin *et al.*, 2009). Type IV cells are dividing cells which differentiate into type I, II or III cells. This is important as taste cells are constantly being renewed, with a lifespan of around 9-10 days (Martin *et al.*, 2009).

When we consume food, specific molecules interact with the taste receptors on our tongue (Frank and Hettinger, 2005). This electrically excites the cells, which creates an action potential (Dvoryanchikov *et al.*, 2009), sending information to the brain which is interpreted, and causes a sensory perception (Frank and Hettinger, 2005). The sensory perception of food is caused by five key tastes; sweet, salty, bitter, sour and umami (Garcia-Bailo *et al.*, 2009). Evidence suggests that there may also be a sixth taste; fat taste (Garcia-Bailo *et al.*, 2009). Taste is important as it allows humans to evaluate the nutrition of food and prevents consumption of noxious matter (Chandrashekar *et al.*, 2006). Detection of sweet taste allows identification of calorie-dense food, umami is important for amino acid recognition, salt is necessary to keep electrolytes balanced, both sour and bitter help to detect potential noxious substances (Chandrashekar *et al.*, 2006), and fat is proposed to identify calorie-dense food and important fat-soluble nutrients (Garcia-Bailo *et al.*, 2009)

2.2.2 Sweet, umami and bitter taste detection

G protein-coupled receptors which assemble into either homodimeric or heterodimeric complexes are responsible for detection of sweet, umami, and bitter taste (Chandrashekar *et al.*, 2006). These receptors are located within type II cells (Martin *et al.*, 2009). The heterodimer T1R2/T1R3 has many binding sites responsible for recognition of sweet taste from nutritive and non-nutritive sweeteners (Martin *et al.*, 2009, Masuda *et al.*, 2012). Nutritive sugars include; glucose, sucrose, fructose, sugar alcohols, D-amino acids and glycosides. Non-nutritive, artificial substances include; sucralose, aspartame, neotame, saccharin Na, acesulfame K and cyclamate (Masuda *et al.*, 2012). A heterodimer is also responsible for umami taste, however it is the G protein-coupled receptors T1R1/T1R3 (Li *et al.*, 2002). Umami has been described as a meaty or savoury taste/flavour, created by two amino acids; monosodium glutamate (MSG) and aspartate (Chandrashekar *et al.*, 2006).

Evidence suggests that bitter taste is mediated through another group of G protein-coupled taste receptors called type 2 receptor (T2R) (Pronin *et al.*, 2004). Bitter taste is elicited by amides such as denatonium benzoate, and alkaloids such as caffeine and quinine (Martin *et al.*, 2009). It is thought that sensitivity to bitter tasting foods is an evolutionary advantage as bitter can be associated with noxious substances (Garcia-Bailo *et al.*, 2009). The genetic basis of bitter taste was discovered through studies using phenylthiocarbmide (PTC) and 6-n-propylthiouracil (PROP) (Garcia-Bailo *et al.*, 2009). Individuals sensitive to these compounds have been found to be more sensitive to the bitter taste of foods (Garcia-Bailo *et al.*, 2009). Studies have also discovered that there is a link between bitter taste sensitivity and increased sweet taste sensitivity. High sensitivity to bitter taste has been proposed to decrease the intake of bitter tasting vegetables and increase intake of foods that are sweet and fatty, therefore negatively influencing health status (Dinehart *et al.*, 2006, Duffy *et al.*, 2003, Garcia-Bailo *et al.*, 2009, Hayes and Duffy, 2008, Yeomans *et al.*, 2007).

2.2.3 Sour and salty taste detection

Ion channels are responsible for sour and salty taste, with Na^+ and H^+ depolarising the taste cells (Martin *et al.*, 2009). Sour taste perception occurs when an acidic substance stimulates the taste buds (Garcia-Bailo *et al.*, 2009). It has been suggested that perception of sour taste may help to determine if food is spoiled or to indicate ripeness of fruit (Garcia-Bailo *et al.*, 2009). It is also important for maintenance of the acid-base balance in the body (Martin, 2009). The exact mechanism behind this is still controversial with a large range of mechanisms, cell receptors and cell types suggested to cause sour taste (Chandrashekar *et al.*, 2006). Sodium chloride is the substance which creates salty taste, and is important for maintaining the bodies blood pressure and blood volume (Martin *et al.*, 2009).

2.2.4 "Fat" taste detection

It has been proposed that fat taste is important from an evolutionary perspective as it allows for detection of foods high in energy, or containing important essential fatty acids and fat soluble vitamins (Garcia-Bailo *et al.*, 2009). Traditionally it was thought that fat detection was through texture and olfaction. However, when these factors are blocked, fat can still be detected, indicating that there may be a 'fat taste' (Garcia-Bailo *et al.*, 2009).

2.3 Sensory Evaluation

Sensory evaluation plays an important role in food and consumer product industries. It is an integral part of product development and optimisation, ingredient modification, and quality control. It allows products introduced to the market to have more favourable sensory properties (Lawless and Heymann, 1999). Sensory evaluation emerged from physiology and psychology, giving rise to the scientific discipline of psychophysics (Stone and Sidel, 2004). Psychophysics aims to isolate sensory properties from the stimuli itself, to allow a measure of behaviour, which is used as an indirect measure of a sensory experience (Lawless and Heymann, 1999, Leek, 2001). More recently, sensory evaluation has been used to help characterize an individual's taste perception and determine how this can predict food intake (Dinehart et al., 2006, Pepino and Mennella, 2012).

2.3.1 Taste perception

2.3.1.1 Taste detection and recognition threshold

Threshold measures have been used in psychophysics as they permit individual comparisons of sensitivity to certain stimuli (ASTM, 2008). Detection threshold is defined as the lowest point at which a concentration can be detected; however an individual may not be able to recognize the nature of the substance (Lawless and Heymann, 1999). On the other hand, recognition threshold testing is the lowest concentration a person can detect the substance and the nature of it (Wardwell *et al.*, 2009). The aim of threshold testing is to determine the concentration at which a specific taste is recognised by an individual. Different concentration levels can thus be used to determine specific taste sensitivity (Kennedy *et al.*, 2010). There are many different methods used, with two common methods being the staircase method and the alternative forced choice method (Lawless and Heymann, 1999, Leek, 2001). Although different, the basis for threshold testing is to have participants presented with a range of concentrations of a sweet tasting aqueous solution in an increasing order (Jellinek, 1985).

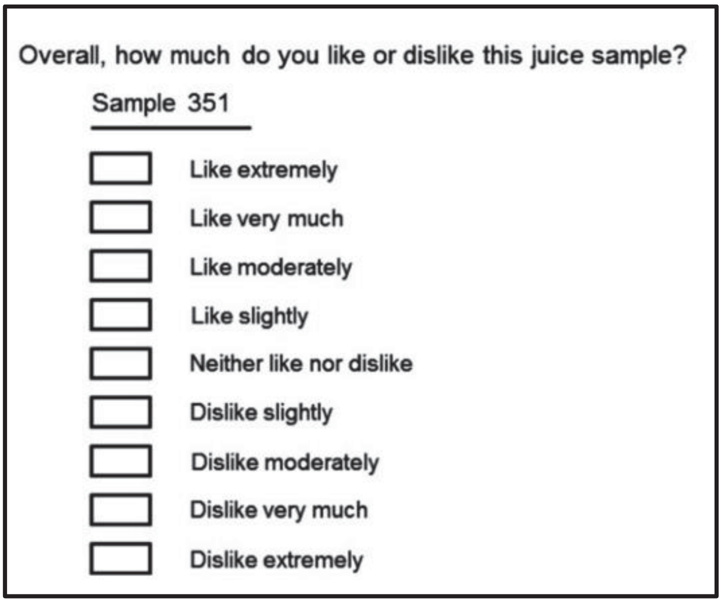
2.3.1.2 Perceived intensity and hedonic preference

It has been argued that thresholds measures are poor predictors of taste experience within the real world (Duffy, 2004; Synder, 2004b as citied in Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006). Sensations often deviate well above threshold levels, therefore measures of this are required (Bartoshuk *et al.*, 2006). Perceived intensity is a measure of the sensation that a taste stimulus creates above threshold level (Keast and Breslin, 2003). Perceived sweet taste intensity is thought to be a measure of "sweet tooth", as it assesses how intense above threshold concentrations of sweet solutions are perceived to be. It measures a person's ability to taste and how well they can determine the quality of sweet taste (Reed, 2006). Hedonic preference is also considered a measure of "sweet tooth"; how much a person likes or dislikes sweet taste (Reed and McDaniel, 2006). It is also an above threshold measure, measuring sweet taste acceptance, and can be affected by attitudes and experiences of individuals (Lim, 2011). Direct comparisons cannot be made across individuals' perceived intensities or hedonic liking as we do not share experiences (Bartoshuk *et al.*, 2003). We can only describe our experiences, therefore, to be able to share our internal experience it needs to be transferred to a number or word (Hayes *et al.*, 2013). This can be achieved through the use of scale measures that use a standard of equal intensity (Bartoshuk *et al.*, 2003).

2.3.2.3 Scale measurements

Scaling involves using numbers as a way to represent a sensory experience (Lawless and Heymann, 1999). This method is frequently used in research as it is a practical way to measure intensity and hedonic preference (Stone and Sidel, 2004). Three of the most common methods used are category scale, magnitude estimation and line marking (Lawless and Heymann, 1999).

Category scales include a choice of responses that increase in intensity or preference, giving the impression that responses are on a continuum (Lawless and Heymann, 1999). The 9 point hedonic scale is the most common measure used in psychophysics to measure hedonic preference (Lim, 2011). The scale is neutral at the middle, positive at one end and negative at the other. The scale consists of equal intervals, labelled with phrases on a continuum from dislike to like (Figure 2.2). The 9-point hedonic scale is a popular method as it is easy to use, and has been found to be reliable and stable (Drewnowski, 1997, Lawless and Heymann, 1999, Lim, 2011, Mahar and Duizer, 2007, Monneuse *et al.*, 1991, Pérez *et al.*, 1994). However, there are some problems with category scales; having a neutral category causes less efficiency and extremes are often avoided. This is because participants may be reluctant to use the endpoints as it indicates a strong response, and a stronger or weaker intensity may be presented later (Lawless and Heymann, 1999). The categories are also not evenly spaced which means meaningful comparisons between groups or individuals are difficult to make (Lim, 2011). A further issue is that this label does not provide ratio data, for example a sweetness rating of 8 is not equivalent to twice the sweetness of 4 (Bartoshuk *et al.*, 2004).


Overall, how much do you like or dislike this juice sample?

Sample 351

- Like extremely
- Like very much
- Like moderately
- Like slightly
- Neither like nor dislike
- Dislike slightly
- Dislike moderately
- Dislike very much
- Dislike extremely

Participants tick how much they like or dislike the juice sample tasted
Source: Lim (2011).

Figure 2.2- Example of a 9 Point Category Scale, showing preference of juice with phrases on a continuum from dislike to like

Line marking scales, such as the Visual Analogue Scale (VAS) removes the labels which enables ratio data to be produced (Bartoshuk *et al.*, 2004). Participants are presented with a horizontal line of 100 mm and asked to indicate, with a mark, the intensity or amount of a sensory characteristic, with the two end points marking the extremes (Bartoshuk *et al.*, 2003, Lawless and Heymann, 1999) (see Figure 2.3). This method has been used in past research as it is easy to administer and easy for participants to use and understand. The removal of numbers is also beneficial as individuals can often have a favourite number which they will mark more frequently (Holt *et al.*, 2000, Salbe *et al.*, 2004). The VAS is useful to provide valid within-subject comparisons, however does not allow for group comparisons as the intensities may mean different things to different groups (Bartoshuk *et al.*, 2006).

How much do you like orange juice?

dislikeStrong ______________________|______________ likeStrong

Participants indicate with a mark, the amount they like or dislike orange juice with the two end points marking the extremes (Lawless and Heymann, 1999).

Figure 2.3- Example of a 100 mm Visual Analogue Scale (VAS) to measure liking of orange juice

Another popular method used in sensory research is magnitude testing, which involves participants allocating numbers to a sensory experience. The participant is free to choose any number to represent the magnitude of an experience; however the ratios need to be the same. For example if the sweetness of a food was indicated as 20, if another is tasted which is twice as sweet, it should be rated 40 (Lawless and Heymann, 1999). A downfall of magnitude testing is that it cannot be used across subjects for comparison, as we are unable to share one another's experiences (Bartoshuk, 2000). It is also more complicated to use in sensory trials, and deeper explanations need to be given to participants, including practice, which is not always possible (Lim, 2011).

A method that has gained popularity is the category-ratio scales. This is a line scale that has verbal descriptions in certain positions on the line (Lim, 2011). This method incorporates both line scales and category scales to allow ratio comparisons to be made (Lim, 2011). An example of a category-ratio scale is the labelled magnitude scale, developed by Green *et al.* (1993) as a way to measure oral sensations specifically. The scale has the description of “no sensation” at the bottom and “strongest imaginable” at the top. Bartoshuk (2000) disputed that the scale could cause a ceiling effect; subjects can only go up to ‘very strong’, but may go higher if the choice was available. For this reason the scale was modified to have “strongest imaginable sensation of any kind” at the top of the scale, and was named the general labelled magnitude scale (gLMS) (Bartoshuk, 2000). As show in Figure 2.4, it is an adjective labelled magnitude scale along a 100 mm log scale. The scale is labelled with; barely detectable (1.4), weak (6), moderate (17), strong (34.7), very strong (52.5), and strongest imaginable sensation of any kind (100) (Duffy *et al.*, 2003). This method has gained popularity as it has been developed as a way that across group comparisons can be made, and it eliminates ceiling effects (Cicerale *et al.*, 2012, Hayes and Duffy, 2008, Sartor *et al.*, 2011, Yeomans *et al.*, 2007).

Figure 2.4A

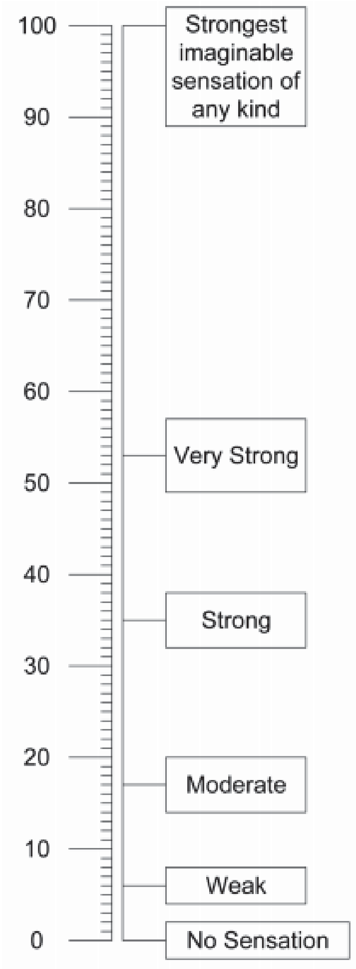
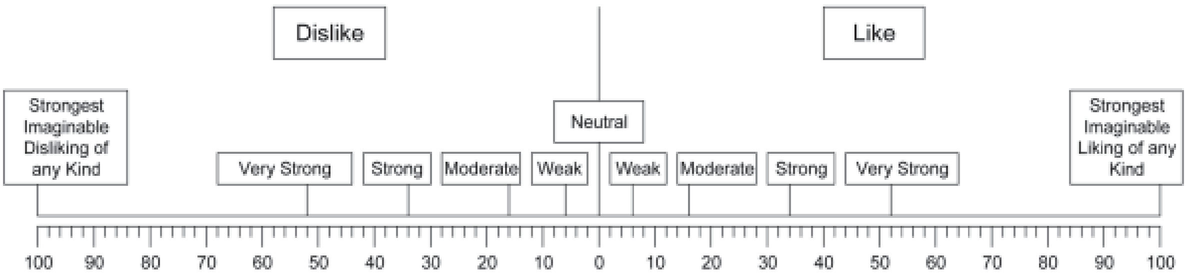


Figure 2.4B



Participants are required to mark with a line how intense a taste is (A) or how much they like a taste (B) Source: Cruickshanks *et al.* (2009).

Figure 2.4- General Labelled Magnitude Scale (gLMS): vertical scale measuring intensity and horizontal scale measuring hedonic liking

2.4 Taste Perception and Dietary Intake

Taste perception and its influence on diet has become of great interest in consumer research, as it allows products to be introduced in the market that have more favourable sensory properties (Lim, 2011). Increasing the palatability of our food is known to lead to an increase in food intake (Yeomans *et al.*, 2007). This highlights that sensory preference can affect our foods likes and eating habits (Drewnowski, 1997). Evolutionarily, liking of sweet taste has played an important role in human nutrition. It causes humans to seek and consume foods higher in calories and nutrients. This has led to humans' sensory systems evolving to prefer energy rich foods (Drewnowski *et al.*, 2012). Therefore, it is unsurprising that as adults we still place high hedonic value on sweetness. The ubiquitous availability and over-consumption of highly palatable, energy-dense and nutrient-poor foods is a key driver of obesity. It has also been hypothesized that people who experience lower intensity sensation when consuming sugar may need an increased amount before liking is achieved, which may also lead to excess energy intake (Duffy *et al.*, 2009).

The study of taste genetics and dietary behaviour can help to solve this theory using psychophysical indicators of oral sensation. This can help to define the interactions between innate and environmental health determinants (Duffy, 2004). The research thus far has however been controversial. Some of this stems from the argument that measuring taste thresholds may not reflect perception and dietary intake. It has also been suggested that the methods used to determine intensity and hedonics are difficult to validate (Duffy, 2004). Some studies also appear to have limited control over confounding variables that may influence intake, such as restrained eating or dieting behaviours (Duffy, 2004). Few studies aiming to link taste with food intake have examined taste response, preference and actual intake within the same study population (Drewnowski *et al.*, 1997). Measuring dietary intake also poses some difficulties as dietary questionnaires have been suggested to be challenging in large study populations (Lanfer *et al.*, 2012). Some of these challenges include; incomplete reporting, modifying foods, inaccurate measures or estimation or portion sizes (Grandjean, 2012).

The research so far has found that preference for sweet taste is widespread, however individual differences exist in preferences, intensity, the ability to detect sweetness at low concentrations (Reed and McDaniel, 2006), and the type of sweet foods and beverages consumed (Drewnowski *et al.*, 2012).

2.4.1 Where it all began; linking taste perception and dietary intake

The majority of the sensory research thus far has focused around the bitter compounds PROP and PTC. Those who can detect the bitterness of PROP and PTC have been classified as either medium tasters; who rate PROP or PTC as moderately bitter, or super-tasters; who rate PROP or PTC as exceptionally bitter. This research has shown that those sensitive to PROP generally dislike some vegetables and eat smaller amounts of these, compared to those not sensitive (Dinehart *et al.*, 2006, Duffy *et al.*, 2003, Hayes and Duffy, 2008, Yeomans *et al.*, 2007). The relationship between those sensitive to the bitter taste of PROP and the influence this has on sweet taste liking, intensity and intake has been addressed. Research has indicated that those sensitive to PROP reported sucrose to be more intense, and had low liking and intake of sugar and sweet tasting foods (Dinehart *et al.*, 2006, Duffy *et al.*, 2003, Hayes and Duffy, 2008, Yeomans *et al.*, 2007). However none of these studies directly assessed dietary intake, therefore we cannot be confident in the dietary results obtained. Research by Drewnowski *et al.* (1997) aimed to address this research gap through the use of a more direct measure of dietary intake. In this study, participants' food preferences were assessed which were hypothesised to predict consumption, along with a three day food record. In agreement with previous research those who were more sensitive to PROP had greater dislike of foods considered bitter, such as cruciferous vegetables and coffee. Also those who rated greater concentrations of sucrose solution as more pleasant had higher preference ratings of sweet tasting desserts and sugar added to tea.

Following the bitter studies, research has aimed to address the gap linking sweet taste sensitivity or hedonic preference to dietary intake. However, limited studies have examined taste response, preference and actual intake within one study population (Drewnowski *et al.*, 1997). Findings thus far have been controversial with some research displaying a relationship between sweet taste perception and dietary intake

(Holt *et al.*, 2000, Liem and Mennella, 2002, Mennella *et al.*, 2011, Pepino and Mennella, 2012, Salbe *et al.*, 2004, Stewart *et al.*, 2010, Zandstra *et al.*, 1999), and others finding none (Cicerale *et al.*, 2012, Lanfer *et al.*, 2012).

2.4.1.1 Heterogeneity of sensory endpoint measures

Studies have used different sensory measures to explore taste preference in individuals with an aim to link this to dietary intake. These sensory measures include; measures of taste threshold, perceived intensity and hedonic preference (Cicerale *et al.*, 2012, Duffy, 2004, Holt *et al.*, 2000, Lanfer *et al.*, 2012, Mattes, 1985). There have however, been equivocal results around the best measure to use, therefore it is important to understand which relates best to dietary habits (Mattes, 1985, Zandstra *et al.*, 1999).

Taste threshold measurements are important research tools to asses an individual's sensitivity to a specific taste. Past studies have used thresholds to determine individuals' sweet taste sensitivity (Mates, 1985; Panek-Scarborough, Dewey & Temple, 2012). This measure only determines a person's lowest concentration of taste. Therefore, taste threshold may not relate well to real life food experiences as taste sensations are often lower than what we would experience from food (Duffy, 2004; Synder, 2004b as cited in Bartoshuk, et al., 2006).

Perceived intensity and hedonic preference are above threshold measures (Keast and Breslin, 2003), and may therefore relate better to dietary intake, however controversy exits between the best method to use. Research by Zandstra *et al.* (1999) suggested that using a measure of perceived intensity is superior as it is more stable compared to hedonic preference. It has also been proposed to be more influenced by a person's current nutritional state and is affected by sensory specific satiety (Degraaf *et al.*, 1993). In direct contrast, an early study by Mattes (1985), found that hedonic preference had the most power in explaining dietary intake. It has also been argued that hedonic preference may be a better indicator of dietary intake as individuals will eat what they like and avoid what they do not (Duffy, 2007). This was also supported by Kim *et al.* (2014), who argued that liking or disliking of sweet tasting food and beverages is not associated with sensitivity to sweet taste, but it is rather about how much an increasing concentration of sweetness is liked. A well-designed study by Holt *et al.* (2000) also identified that sweet taste preference was positively related to dietary intake, but sweet taste intensity was not. Mennella *et al.* (2011) discovered that hedonic preference of sweet taste was significantly correlated with the sweetness of cereal and beverages preferred. However, the measure of cereal beverage and preference used in this study was a limitation, as participants were only asked to name their favourite cereal and beverage. Therefore, future studies should employ exhaustive dietary questionnaires that can be used to determine true intake.

Contrasting these findings there has been some research that has found no association between hedonic preference of sweet taste and dietary intake. Research by Lanfer *et al.* (2012) assessed the relationship between hedonic preference of sweet taste and dietary intake of sweet and fat foods in children; finding no association. Cicerale *et al.* (2012) measured sweet taste intensity and the relationship to dietary intake using female participants. Like Lanfer *et al.* (2012) the research concluded that perceived sweet taste intensity does not play a role in eating behaviours and food choice. This suggests the importance in determining which sensory measure best describes dietary intake so this information can be used confidently in future research, and an agreed methodology can be used in future studies.

2.4.2 Taste perception and sweet beverages

Excessive intake of soft drinks and sugar-sweetened beverages is a public health problem, as it has been associated with increased risk of many chronic diseases (Sartor *et al.*, 2011). Experimental and epidemiological research has shown that high consumption of sugar-sweetened drinks is associated with overweight and obesity (Malik *et al.*, 2010, Malik *et al.*, 2006). Consumption of one or more soft drinks each day is suggested to increase the risk of developing metabolic syndrome (Dhingra *et al.*, 2007), and high intake of sweetened drinks has been associated with increased T2DM (Montonen *et al.*, 2007, Palmer *et al.*, 2008, Schulze *et al.*, 2004). A rise in chronic disease has been paralleled by an increase in the intake of sweetened beverages around the world (Lustig *et al.*, 2012). Approximately half of the calories consumed from added sugar come from sugar-sweetened beverages (Zhang *et al.*, 2015). In NZ non-alcoholic beverages are the second largest source of sugar in our diet, contributing

17% of total sugar intake, with fruit at 18% (Ministry of Health, 2011b). Research in The USA has shown that between 1977 and 2001 there was an increase from 2.8% to 7.0% in energy from soft drinks, and an increase from 1.2% to 2.2% in energy from fruit juice (Nielsen and Popkin, 2004).

Hedonic preference of sweet taste is known to differ between individuals; however, there is limited knowledge of hedonic preference and sweetened beverage consumption at a range of concentration levels among groups. For example, those with different sensitivity to sweet taste, likers and dislikers of sweet taste, or different population groups (Kim *et al.*, 2014). There has not been a lot of effort put into establishing the link between individuals with a preference for sweet tasting food and the actual consumption of beverages (Kim *et al.*, 2014). It would be beneficial to investigate this relationship to better understand the role sweetened beverages have on diet quality.

2.4.2.1 Research linking hedonic perception of sweet taste and sweet beverages

Hedonic preference of sweet taste has been linked to greater liking and intake of sweet tasting food. Research by Kim *et al.* (2014) measured sweet taste intensity and hedonic preference of a sucrose solution and a sweetened strawberry drink. The liking of 15 sweet foods, 24 savoury foods, milk and dark chocolate was also measured. It was discovered that participants with an increased hedonic preference of the sucrose solution also had the highest liking score of the 15 sweet foods and the sweetest milk chocolate. Tepper *et al.* (1996) found there to be a relationship between higher sweet taste preferences of cherry flavoured beverages and dietary intake of sweet food in a population of type 2 diabetics.

Other research that has directly assessed beverage liking and beverage intake has investigated the theory of plasticity; taste perception depends on our usual intake and exposure. It is possible that high intakes of sugar-sweetened beverages may increase our sweet taste threshold, causing changes to intensity and pleasant ratings (Sartor *et al.*, 2011). A study by Sartor *et al.* (2011) found this to be true. Participants' diets were supplemented with a soft drink for one month. Sweet taste intensity and hedonic preference responses were affected; those that disliked sweet taste at baseline had an increase in liking after the intervention. The theory of taste plasticity was also supported by Liem and Mennella (2002); infants exposed to a greater amount of sugar preferred higher sweet concentrations and consumed foods with more added sugar. Mahar and Duizer (2007) also found that high consumption of natural or artificial sugar was related to preference of a higher concentration of sucrose in orange juice.

Although sweetened beverages have been highlighted as a major sugar contributor in individuals' diets, there has been a lack of research relating hedonic preference of sweet taste to actual consumption of sweetened beverage. This gap needs to be addressed with further research.

2.4.3 Methodological differences of sweet taste assessments

2.4.3.1 Sweet taste preference measured with food vehicles

The concentration of sweet taste in food and beverages can be manipulated to measure hedonic preference of sweet taste. This method has been argued to relate well to real life consumption (Liem and Mennella, 2002, Mahar and Duizer, 2007, Mennella *et al.*, 2011). Mahar and Duizer (2007) assessed both natural sugar and artificial sugar preference in 64 women using five concentrations of sweetened orange juice. Results revealed that individuals with a higher intake of sweetened beverages preferred sweeter orange juice, compared to those with lower intake. Research by Liem and Mennella (2002) discovered that children whose mothers regularly added sugar to their diets preferred higher levels of sugar in apple juice, and preferred cereals that had a higher sugar content, compared to those that did not have sugar added to their diet. Early research by Pérez *et al.* (1994) provided male and females participants with yogurt which contained different concentrations of sucrose. Sweet intensity and hedonic preference of the yoghurt was rated on a nine point scale and intake was measured in an ad-libitum test. The research discovered that yoghurt intake increased when it was considered more palatable by participants.

One of the methodological limitations of ad-libitum studies is that the short term behaviours that exist under experimental conditions may not occur in more realistic circumstances (Mela, 1996). Ad-libitum studies may also not display a real world effect, as it is argued that other factors could influence intake such as hunger or energy content of the food. Participants may also feel pressure to finish what they are given (Zandstra *et al.*, 1999). Sweetness liking has also been found to differ within an individual according to the type of food i.e. a level of sucrose that is pleasant in one food, may be unpleasant in another, as the properties are different and sugar can be absorbed differently (Holt *et al.*, 2000). Also using foods that are already considered sweet can be problematic, and may not be sensitive enough to find a true effect.

A further problem with the use of food vehicles is that studies have used foods which contain both fat and sugar (Zandstra *et al.*, 1999). This can be seen in research by Duffy *et al.* (2003) who used cake, chocolate, jelly and marshmallows to assess preference in a group of 38 female and 44 male participants. Chocolate and cake both contain a considerable amount of fat. The same issue arises in research by Bartoshuk *et al.* (2006); measuring sweet taste preference with foods containing fat such as chocolate, cookies, and whipped cream, which is not typically considered sweet. Using foods that contain both fat and sugar can be problematic as it can weaken the perception of water-soluble flavourants like sugar. This is caused by a semi-solid fluid which covers the tongue and may affect the interaction of sugar with the taste buds (Foss, 1981 as cited in Holt, 2000). Therefore a food that contains considerable amounts of fat will taste less sweet compared to one that contains no fat. This was demonstrated in research by Holt *et al.* (2000) with mean sweetness intensity ratings found to be much lower in a sweetened biscuit compared to juice.

2.4.3.2 Taste perception measured with sweet aqueous solutions

To avoid the potential confounding variables that food and drink mediums may introduce, an aqueous solution to determine sweet taste sensitivity and hedonic preference of sweet taste has been used (Alexy *et al.*, 2011, Drewnowski *et al.*, 1997, Duffy *et al.*, 2003, Holt *et al.*, 2000, Sartor *et al.*, 2011). This allows tight experimental control as the exact amount of sugar in the solution is known. However, a challenge of past studies has been the use of different concentration levels of sweet tastants, which may account for some of the differing research findings. These have ranged from using only one sucrose concentration, to eleven different sucrose concentrations (Alexy *et al.*, 2011, Drewnowski, 1997, Duffy *et al.*, 2003, Holt *et al.*, 2000, Mennella *et al.*, 2011, Sartor *et al.*, 2011, Yeomans *et al.*, 2007). Use of a small number of concentrations can reduce reliability and confidence in assessing sweet taste sensitivity and hedonic preference. However, use of a high range of concentrations can prove to be a problem as subject fatigue may occur.

In a genetic study of PROP sensitivity, Duffy *et al.* (2003) used one sucrose solution of 20% to measure sweet taste intensity and hedonic preference using the gLMS. This research found those more sensitive to PROP had greater preference for, and intake of added sugars. More recent research by Cicerale *et al.* (2012) also used only one aqueous solution to determine intensity in participants and found no relationship between sweet taste intensity and dietary intake. Use of only one sucrose solution may have some issues of reliability compared to when a range of concentrations are used. Holt *et al.* (2000) used five aqueous solutions of 2, 4, 8, 16 and 32% sucrose w/v, and four samples of orange juice with sucrose concentrations of 0, 5, 10 and 20% w/v. Findings suggested that those who preferred higher sucrose levels had higher dietary intakes of sugar and sweet food. Similar results were found by Mennella *et al.* (2011) where five sucrose solutions at concentration of 3%, 6%, 12%, 24%, and 36% w/v were used. Preferred sweetness of sucrose was significantly correlated with sweetness of a favourite cereal or beverage. A study by Sartor *et al.* (2011) used a total of 11 sucrose solutions to measure sweet taste intensity and hedonic preference using the gLMS. Using a large number of concentrations such as this may be problematic as it may induce participant fatigue.

It is important that sweet taste studies use a range of sweet concentrations. This is to ensure the test is sensitive enough to be able to find differences among individuals, and also not induce participant fatigue.

2.5 Individual Level Dietary Assessment Methods used in Sensory Research

Individual dietary assessments can be used to better understand the quality of a person's diet, their usual consumption habits, and the amounts and frequency of consumption (Biro *et al.*, 2002). Dietary assessment can not only assess people's actual food intake but can also be used to address individuals' attitudes and beliefs towards food, which may influence their food choices. Using dietary questionnaires is important to gain an understanding about what people are eating and why, which helps to improve nutrition education and counselling (Glanz *et al.*, 1998). Sweet taste studies have used a range of methods to assess dietary intake, each with strengths and weaknesses (Table 2.1) (Appleton and Blundell, 2007, Drewnowski *et al.*, 1997, Duffy *et al.*, 2003, Holt *et al.*, 2000, Lanfer *et al.*, 2012, Mahar and Duizer, 2007). It is vitally important that the dietary assessment method used is reliable and valid, to ensure the dietary patterns in the study population are determined correctly (Vucic *et al.*, 2009). These assessments can be retrospective (24-hour recall, FFQ, and diet histories) or prospective (weighed or estimated food records). They can also be short-term; collect information about an individual's current intake (24 hour recall, food record), or long term; collect information about intake over the past months or years (FFQ, diet history) (Biro *et al.*, 2002).

Valid observational measures of dietary intake can prove to be challenging for a number of reasons; people tend to report an intake that is more socially acceptable, often under-reporting or over-reporting intake, interviewer bias may result (Coulston *et al.*, 2013), and lifestyle and behavioural factors can affect dietary assessment (Segovia-Siapco *et al.*, 2008). Many studies lack the ability to measure absolute consumption frequency when assessing dietary intake, because of the high participant burden and specialised skills required from a Registered Dietitian or Nutritionist (Lanfer *et al.*, 2012). It is important that a comprehensive measure of dietary intake is conducted, and that the method employed is the most appropriate based on time constraints, the research question, and the specific study population. The various methods of individual dietary assessment methods most often used in sweet taste research will be discussed.

Table 2.1- Advantages and disadvantages of dietary intake assessment methods

Method	Characteristics	Description	Strengths	Weaknesses
24 hour recall	-Retrospective -Short term -Quantitative	-Interview style where participants describe intake over last the 24 hours -Includes quantity, brand and preparation methods	-Low participant burden -Short to administer -No literacy requirements -Direct contact with participant (more reliable) -Can be in person or over the phone	-Skilled interviewer required -Relies on participants memory -Difficult to estimate portion sizes -Low reproducibility- only capture one day -Potential interviewer bias
Diet history	-Retrospective -Long or short term -Qualitative and quantitative	- Used to establish habitual intake through questioning of intake over the past week or month -Is a combination method: interview to find usual meal pattern, a 24 hour recall and FFQ -Can include a three-day food record	-Includes preparation and cooking methods -Detailed: captures a 'typical' diet, including seasonal changes -Only a single interview is needed to capture all information	-Requires a highly trained interviewer -Relies on memory -Time consuming -High cognitive burden -Can overestimate intake
Food frequency questionnaire	-Retrospective -Long term -Qualitative or Quantitative	-Self-administered survey format -Participants report frequency of consumption of a list of foods over a given period -Quantitative FFQ's include portion sizes -Non-quantitative do not include portion sizes	-Quick to complete -Low cost -Low participant burden -Easy to administer -Describes usual intake -Can be used in large study populations -Eating patterns not changed	-Relies on memory -Poor use in measuring absolute values caused by portion size inaccuracies -Overestimates food intake -Portion size knowledge required if quantitative
Food record	-Prospective -Short term -Quantitative	-Participants record all the food and drink consumed over a specified period -Estimated food record: household measures and food models used to estimate portion sizes -Weighed food record: food is weighed with scales	-Detailed information about food consumption and patterns -Includes quantity, preparation, brands, cooking methods and time of consumption -Accurate: considered the 'gold standard' -No reliance on memory	-High participant burden: need to be motivated, literate and numerate -Requires training -Dietary patterns can change during recording -Reliability influenced by participant fatigue if too many days are recorded

The table above was assembled using the following references; Biro *et al.* (2002), Black (2001), Coulston *et al.* (2013), Gibson (2005), Lee and Nieman (2007), Mahar *et al.* (2012), Segovia-Siapco *et al.* (2008).

2.5.1 Twenty four hour food recall

A 24 hour recall of dietary intake involves an interviewer asking a participant to recall their exact intake over the last 24 hours (Biro *et al.*, 2002). This needs to be carried out by a skilled interviewer who has sound nutrition knowledge, and is able to probe to gather sufficient detail (Coulston *et al.*, 2013). The recall should include time and place of consumption, quantity, quality, preparation methods, and brands of foods consumed (Coulston *et al.*, 2013). Advantages of this method include low participant burden, as it is short and literacy skills can be minimal (Biro *et al.*, 2002). A disadvantage of this method is that it relies on the memory of the subject (Coulston *et al.*, 2013). It is also difficult to estimate portion sizes with this approach as respondents may be unaware or unable to explain this adequately (Gibson, 2005). The 24 hour recall only captures one day of many, therefore it does not accurately represent an individual's usual intake and has low reproducibility. For this reason this method is best used to assess actual intake in nutrition counselling, rather than population studies (Gibson, 2005). Repeated 24 hour recalls can however be used to estimate usual intake or intake over a longer period (Coulston *et al.*, 2013). This method is better able to adequately represent intake because it reduces intra-individual variability (Biro *et al.*, 2002). This method was used in sensory research by Duffy *et al.* (2003) who used five non-consecutive 24 hour recalls to measure dietary intake, to find total energy intake from added sugar. This technique was also used by Panek-Scarborough *et al.* (2012) to find participants usual dietary intake, and it was repeated four times on separate days.

2.5.2 Food record

A food record is a dietary assessment method that does not rely on participant memory. Participants record their dietary intake at the time of consumption for a set number of days. This can be either a weighed food record or estimated food record. The weighed food record requires each food item to be weighed prior to and after consumption with scales or measuring cups and spoons (Coulston *et al.*, 2013). This method is accurate, and has been deemed the 'gold standard' of individual dietary assessment methods (Biro *et al.*, 2002). However participant burden is high and it requires training before commencement. An estimated dietary intake may reduce some of this burden, however accuracy is compromised as intake and portion sizes are estimated (Coulston *et al.*, 2013). The reliability of food records reduces over time because of respondent fatigue, and changing of dietary habits to make recording easier (Biro *et al.*, 2002). Collecting non-consecutive days, and including weekdays and weekends is the best way to accurately represent the diet (Biro *et al.*, 2002). Weighed dietary records have been suggested as the best choice for small research projects (Black, 2001). Drewnowski *et al.* (1997) used this method to assess sweet taste and food preference, with participants completing a three day food record, with a weekend day included. Sartor *et al.* (2011) also assessed participants eating habits using a food record; however using an estimated approach. This consisted of seven days of food recording before the experiment, and recording of food intake for 14 days during the experiment. Although thorough, such long recording periods may have led to subject fatigue, influencing the reliability of the results.

2.5.3 Diet history

A diet history is usually conducted by a trained interviewer with the aim to establish habitual intake. This is achieved by open ended questioning of the past intake over a week or month (Black, 2001). The diet history consist of three components; firstly a 24 hour food recall based on foods typically eaten at each meal, and then information about any alternative choices, portion sizes and snacks. The second component is a FFQ which provides detail of the frequency of consumption. Lastly, a three day food record is used to cross check the data, however this part is often omitted (Biro *et al.*, 2002, Gibson, 2005). Strengths of this method include questions around preparation and cooking methods. The recall process may also be easier for the respondent as it is based around meal times, rather than foods (Coulston *et al.*, 2013). The interview can however be time consuming and have high cognitive burden, as it can take 60-90 minutes and requires a lot of concentration from both interviewer and respondent (Black, 2001). A highly skilled interviewer is also required to carry out the diet history (Black, 2001). Diet histories have been found to over report consumption compared to short term methods such as 24 hour food recall. This method has not been popular within a research setting and has limited validation for population studies (Coulston *et al.*, 2013).

2.5.4 Food frequency questionnaire

The food frequency questionnaire (FFQ) is a commonly used retrospective dietary assessment tool (Simon *et al.*, 2001). This tool assess individuals' usual consumption frequency of a list of foods, over a certain time period (such as the previous month or year). This questionnaire is often self-administered; participants are provided with a list of foods and asked to indicate how frequently they consume each, often ranging from never to several times a day (Black, 2001). There is variation in the number of frequency intervals used, often between five and nine choices (Cade *et al.*, 2004). The list of foods may focus on specific groups of foods, foods consumed over a particular season or event, or a large list to cover total food intake (Gibson, 2005). It is important to develop a list that is comprehensive enough to include all of the study populations' choices, however should not be so long that it increases participant burden. The FFQ was originally designed to be qualitative; to obtain usual dietary patterns or intake of special groups of foods (Gibson, 2005). This method allows participants to be ranked based on their usual intake of food groups or particular foods or nutrients, however absolute values cannot be obtained (Coulston *et al.*, 2013). Semi-quantitative FFQ's include a standard portion size and participants are asked to report their frequency of intake (Cade *et al.*, 2004). Alternatively, a quantitative FFQ includes an open question about portion size or provides participants with a choice i.e. small, medium or large (Willet, 1998). Inclusion of portion size allows absolute values of energy and nutrient intake to be assessed (Gibson, 2005). Controversy arises as this is said to increase respondent burden, as it makes the assessment too long (Coulston *et al.*, 2013). Quantification of intake can also be challenging as portion size estimates are difficult to make and can influence accuracy (Biro *et al.*, 2002). Therefore, it has been argued that FFQs are better to be used to categorise participants based on their frequency of intake (less commonly consumed or more commonly consumed), and identify participants at the upper and lower extremes of intake (Coulston *et al.*, 2013, Willet, 1998).

The FFQ is a popular method to assess usual intake in population studies as it can be self-administered, is fast, low cost, has low participant burden, does not require much interviewer input (Segovia-Siapco *et al.*, 2008), and are useful in comparing those with high or low intakes of specific foods or nutrients (Biro *et al.*, 2002). A review paper by Vucic *et al.* (2009) found the FFQ to be preferred by participants because of the ease and speed of use. For these reasons, FFQs have been used in sweet taste studies to enable assessment of long-term dietary intake (Appleton and Blundell, 2007, Holt *et al.*, 2000, Lanfer *et al.*, 2012, Mahar and Duizer, 2007, Mattes, 1985). Holt *et al.* (2000) developed two short semi-quantitative FFQ's to assess participants' intake of sugar, artificial sweeteners, sweet food and beverages. One questionnaire consisted of 78 foods which include staple foods and foods high in sugar that are typically consumed in Australian diets. The second questionnaire was intended to assess the Malaysian diet, and consisted of 77 foods typically consumed. The data from these questionnaires were used to estimate sugar intake based on the Australian and Malaysian food composition tables. Lanfer *et al.* (2012) used a short non-quantitative FFQ (43 foods) to assess dietary habits over the previous 4 weeks. The foods included were those high in sugar and fat, and was used to assess food consumption associated with overweight and obesity, not total food intake. Although a short FFQ such as this would have had low participant fatigue, the food list may not be sufficient to adequately capture sugar intake.

A better way to reduce participant burden is to develop a brief FFQ (Biro *et al.*, 2002). A brief FFQ is one that consists of a shorter food list; only including foods that contain specific nutrients that are intended to be assessed (Biro *et al.*, 2002). Nik Shanita *et al.* (2012) accomplished this by developing and validating a semi-quantitative FFQ that specifically assessed sugar intake in a Malaysian population. It was the first study to develop an FFQ that could be used to assess added sugar consumption from beverages, achieved through the inclusion of sweetened beverages in the FFQ. The FFQ was found to be useful in sugar intake assessment and was found to have good validity (with a weighted Kappa of 0.34, deemed an acceptable level) after comparison with two 24 hour recalls. A review by Cade *et al.* (2004) assessed the results from 227 FFQ validation studies and concluded that FFQ's are useful tools in population studies. However, there is no standard FFQ that can be used and each should be developed based on the specific study objectives and study population (Cade *et al.*, 2004).

2.5.5 Eating behaviours

There are many factors that can influence an individual's dietary intake. These could include; sociodemographic, lifestyle and psychological factors, as well as an individual's attitudes and beliefs (Lampuré *et al.*, 2015). Many people may have weight concerns, or general health and nutrition concerns, which can affect their taste perception, and in turn, their dietary intake (Drewnowski *et al.*, 1997). These individual characteristics should be better understood in relation to sweet taste sensitivity and hedonic liking, to gather a more in-depth understanding of individuals sweet taste perception; yet to date there have been limited studies that have explored this association.

Eating behaviours such as cognitive restraint, emotional eating and uncontrolled eating have been related to a higher BMI and unhealthy dietary choices, including consumption of foods high in sugar, salt and fat (Camilleri *et al.*, 2014, Karlsson *et al.*, 2000, Lauzon *et al.*, 2004). This is concerning as unhealthy eating behaviours can lead to health problems such as obesity (Camilleri *et al.*, 2014). Two questionnaires that have been developed to address these eating behaviours are; The Three-Factor Eating Questionnaire (TFEQ) (Stunkard and Messick, 1985), and the Dutch Eating Behaviour Questionnaire (DEBQ) (van Strien *et al.*, 1986), and have been frequently used in research. The TFEQ was developed by Stunkard and Messick (1985) to assess restrained eating, disinhibition, and perceived hunger. This was then modified by van Strien *et al.* (1986) to include emotional eating and external eating, named the DEBQ.

Individuals differ in the cognitive control they have over their food intake; some unconsciously eat whatever they want, whereas others may consciously restrict their intake (De Castro, 1995). Restraint is a behaviour that is used in an effort to lose or maintain weight, often displayed as dieting behaviours (van Strien *et al.*, 1986). On the other hand, disinhibition is a loss of control of eating, leading to over eating. It has been discovered that those who display some degree of restrained eating experience more disinhibition compared to others (Mela, 2001). This occurs when there is a collapse in restraint; when a situation or event overrides a person's normal restrictive eating, releasing an underlying desire to over-eat (Mela, 2001). Disinhibition has been divided into three subscales. The first is disinhibition caused by emotion, such as anxiousness, loneliness, or boredom. The second is habitual eating; eating at a certain time of day. Lastly, situational; over-eating at social occasions, or when palatable food is available (Lesdéma *et al.*, 2012). Another common eating behaviour is external eating, which is the theory that some individuals are less sensitive to their internal cues of hunger, and are more reactive to external cues such as food availability, time of day, or quality of food (Mela, 2001). This trait is likely to lead to overeating in today's environment, as food is readily available and highly palatable (Mela, 2001). Hunger is another eating behaviour often assessed and reflects how strongly an individual experiences the sensation of hunger, and how intensely this influences eating. Those who display high scores on the hunger scale have been found to eat more than those who score low (Duffy *et al.*, 2003, Lowe and Maycock, 1988).

2.5.5.1 Linking taste perception and diet with eating behaviours

Research has shown that high preference for sweets is positively associated with uncontrolled eating (Lähteenmäki and Tuorila, 1995), but inversely associated with cognitive restraint (De Castro, 1995, French *et al.*, 1994, Kleifield and Lowe, 1991, Williams *et al.*, 1996). Contento *et al.* (2005) used the TFEQ to measure cognitive restraint and disinhibition in Latino women. The study found that women who had higher restraint had lower intake of sugar, whereas those who displayed high levels of disinhibition tended to overeat, and had a higher intake of sugar. Lampuré *et al.* (2015) also used the TFEQ to gain a better understanding of psychological influences on food consumption patterns, but aimed to relate this more specifically to preference of sweet and salty tasting food. The study found those with higher dietary restraint displayed lower liking of sweet tasting food and the opposite was true for those with low dietary restraint. Restrained eaters may avoid sugar and sweet foods for health reasons and may have trained themselves to dislike sweet tasting food regardless of taste preference. It was also uncovered that uncontrolled eating and emotional eating were associated with a greater liking of sweet tasting foods (Lampuré *et al.*, 2015). Emotional eating was related to dietary intake in a study by Camilleri *et al.* (2014). However, this was specifically related to consumption of energy dense foods, particularly those containing large amounts of sugar and fat, for example chocolate, cakes, biscuits, pastries, ice cream, confectionary, and breakfast cereals. A similar study by Lauzon *et al.* (2004) aimed to better define the relationship between eating behaviours and dietary intake using the TFEQ. This research found that those with higher dietary restraint had a higher intake of foods considered healthy such as vegetables and consumed less sugar. Like Camilleri's findings, those who displayed high emotional eating had higher intake of energy dense snacks.

This shows a clear link between eating behaviours and dietary intake particularly foods high in fat, salt and sugar. Yeomans *et al.* (2007) used the TFEQ and restraint scale to measure differences in restraint among sweet taste likers and sweet taste dislikers, but found no difference in restrain between these groups. It is clear that more research is required to further address eating behaviours, sweet taste perception and intakes within one population group. It is important that we better understand this link as eating behaviours can strongly influence food intake. Individuals displaying certain eating behaviours may have trained themselves to dislike sweet taste regardless of taste preference.

2.6 Physiological Influences on Taste Perception, Dietary Intake and Eating Behaviour

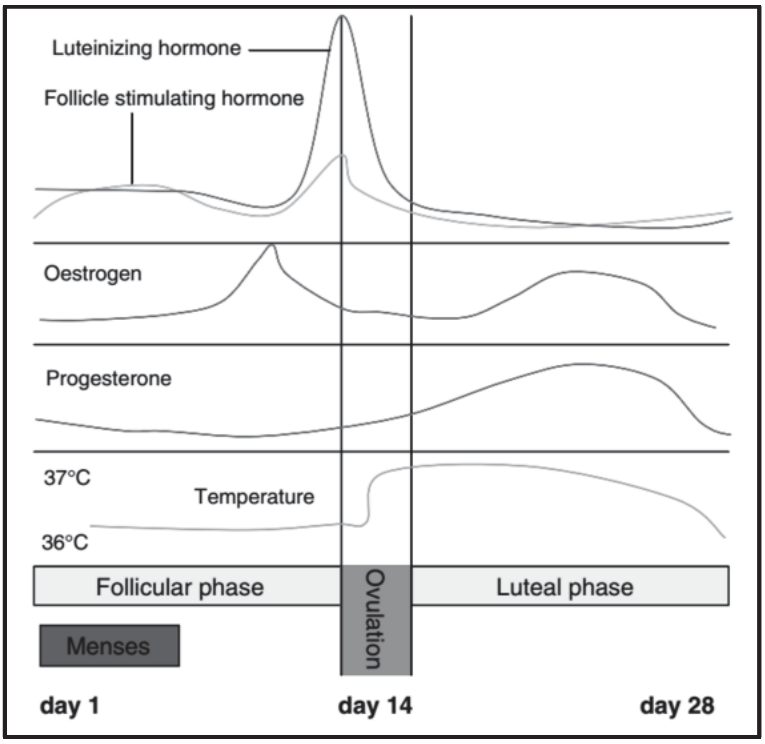
2.6.1 Differences among sexes

Past research has shown gender differences in taste perception. Laeng *et al.* (1993) assessed the sweet taste perception of males and females during hunger and satiety. The study found women to rate a sweet lime drink as more intense compared to male subjects. Research by Sartor *et al.* (2011) found that males rated sucrose solutions as 5-fold more intense compared to females. Hedonic preference of sweet taste has also been found to differ between males and females, with men preferring sweeter intensities compared to women (Hayes and Duffy, 2008, Monneuse *et al.*, 1991). In contrast; females rate sweet solutions as more intense compared to males (Laeng *et al.*, 1993). Differences in eating attitudes and behaviours are also evident between males and females where females have a greater desire to be thin (Nakamura *et al.*, 2008), are more interested in eating nutritiously, and men are more sceptical about the health benefits of certain diet patterns (Roininen *et al.*, 1999).

It is therefore important that sweet taste perception and dietary intake of males and females be assessed separately as strong differences may exist between the two groups.

2.6.2 Menstrual cycle

The gender differences described above may be somewhat influenced by the female menstrual cycle. Research has shown that thresholds for sucrose remain constant for men, whilst for women it changes depending on the phase of their menstrual cycle (Than *et al.*, 1994). A female's menstrual cycle generally averages about 28 days and is divided into four phases; menstruation (day 1-4), follicular phase (day 5-11), ovulation (day 12-15), and luteal phase (day 16-28) (Davidsen *et al.*, 2007). The main hormones involved in menstruation are gonadotropin-releasing hormone (GnRH), follicular stimulation hormone (FSH), luteinizing hormone (LH), progesterone and oestrogen. These hormones are released in different amounts over the course of menstruation (see Figure 2.5).



Source: Davidsen *et al.* (2007)

Figure 2.5- Female menstrual cycle: indicates the menstrual cycle phases and changes in hormones during the cycle and body temperature

Oestrogen levels rise during the late follicular phase and a peak is reached at ovulation, this falls in the luteal phase and reaches its lowest point during menses

(Than *et al.*, 1994). Progesterone levels are also at their lowest during menses, as well as the follicular phase, and the peak is reached at the luteal phase (Than, 1994).

There have been several studies that have addressed taste changes that occur during the menstruation cycle, with inconsistent results. Research by Than *et al.* (1994) measured women's sucrose threshold variation at different phases of the menstrual cycle. These were measured three times to ensure menstruation, pre-ovulation and post-ovulation were included. This research showed that threshold levels were lowest in the pre-ovulation phase and highest during menstruation and post-ovulation. The exact mechanism that ovarian hormones are acting on to influence sensitivity is however still unknown. A study by Pomerleau *et al.* (1991) compared the hedonic preference of sweet taste in 64 female smokers and non-smokers. The research included an assessment of the influence menstruation has on sweet taste in 9 participants, finding no significant difference in sweet taste preference. However, the sample size may have influenced the results found.

Research has also suggested that ovarian hormones influence energy intake and expenditure; however the results are also inconsistent (Davidsen *et al.*, 2007, McVay *et al.*, 2012, Tucci *et al.*, 2010). A review paper by Davidsen *et al.* (2007) found that women's energy intake and expenditure are increased during the luteal phase of menstruation. Women report more cravings for foods high in carbohydrate and fat in the luteal phase compared to the follicular phase. Levels of progesterone are low during the luteal phase which is hypothesized to cause increased food cravings (McVay *et al.*, 2012). Also, high oestrogen levels in the follicular phase have been hypothesised to reduce appetite and therefore energy intake at this time (Davidsen *et al.*, 2007). A study conducted by Tucci *et al.* (2010) concluded that women in the luteal phase of their menstrual cycle had greater caloric intake of sweet food, but no hedonic changes. In contrast to these studies, research by McVay *et al.* (2012) found that there was no change in food cravings, type of macronutrients consumed or the amount of chocolate eaten between cycle phases. These studies do have some limitations; there is an ignorance of individual variability in menstrual cycle, as women have different cycle lengths and often the defining of cycle phase is poor. Therefore, results from these studies (Davidsen *et al.*, 2007, McVay *et al.*, 2012, Tucci *et al.*, 2010) show that it is still unclear exactly how menstrual cycle influences taste perception and dietary intake, and this needs to be considered in future research.

2.6.3 Fasting

Research has suggested that sweet taste intensity and hedonic preference can be influenced by state of hunger (Laeng *et al.*, 1993, Pasquet *et al.*, 2006, Zverev, 2004). A study by Laeng *et al.* (1993) compared hedonic liking of a sucrose sweetened lime drink in subjects hungry or satiated. The research found a significant difference in pleasant ratings in those in the hungry group. Those with a self-reported “sweet tooth” also had an increased pleasant rating of sweet taste after fasting. The difference between the two groups may have been too small; with the hungry group defined as those who had not eaten in the past 2 hours or more, and the satiated group defined as those who had eaten in the past 2 hours. Zverev (2004) fasted participants for a much greater length of time (14-16 hours) and compared this to fasting of only 1 hour. These findings suggest that hunger influences taste perception as the recognition threshold for sucrose was found to be significantly lower after fasting compared to satiated. In contrast, Pasquet *et al.* (2006) analysed recognition thresholds of participants prior to a meal and post meal. This study found no significant difference in taste recognition. Therefore controversy remains about the influence hunger state has on taste perception. Hunger should be standardised in future studies to improve confidence in the results obtained.

2.6.4 Age

Age-related differences in hedonic preference of sweet taste have been found. Young children and adolescents like more intensely sweet solutions compared to adults (Mennella *et al.*, 2011). Taste function has also been found to decrease with age in adults (Ahne *et al.*, 2000, Gudziol and Hummel, 2007). A study by Gudziol and Hummel (2007) found those aged 21-40 years had greater taste sensitivity than those over 60. Therefore future research should focus on a specific age group to minimise the potential influence of aging.

2.6.5 Ethnicity

Some studies have found cultural differences with regard to sweet taste perception (Holt *et al.*, 2000, Liem and Mennella, 2002, Mennella *et al.*, 2011, Salbe *et al.*, 2004). This may be explained by differences in exposure and experiences of ethnic groups, which establish the frequency and intensity of food and flavours that are preferred (Holt *et al.*, 2000). There are also genetic differences in the number of taste buds on the tongue which may explain some of the differences (Bartoshuk *et al.*, 2004). For this reason it is important to address the research questions within one ethnic group to reduce these confounding variables.

2.7 Conclusion

Sugar is added to many foods, which increases both the calorie content of food and its hedonic appeal (Dressler and Smith, 2013). High consumption of sugar has been associated with increased non-communicable disease risk, and is therefore a health issue in NZ (Laffitte *et al.*, 2014, Martínez-Ruiza *et al.*, 2014, Te Morenga *et al.*, 2013, World Health Organisation, 2014). Taste is a significant driver of food acceptance and choice (Cox *et al.*, 2014, Hoppert *et al.*, 2012), therefore strongly influencing eating behaviours and dietary intake (Overberg *et al.*, 2012). A better understanding of the biology and psychology of sweet taste perception can help to explain, in part, some of the reasons behind specific food choices. The results of this study will contribute to a better understanding of the relationships between taste perception, food preferences and eating behaviours, with the general aim to better understand pathways to obesity and help to seek solutions to address this major public health issue. This research also has the potential to contribute to new product development or modifications of existing foods by the food industry to produce healthier food options. This research can also provide a better understanding of clients' sweet food intake and eating behaviours within nutrition consultation.

Chapter Three Methodology

3.1 Study Design

This study, named the “Sweet Taste Study” throughout this thesis, is a cross sectional, mixed-methods, observational study. The study investigated the links between sweet taste perception, sweet food choices and eating behaviour in 20-40-year-old NZ European women. Food intake and dietary behaviour was measured using quantitative and qualitative tools. These included a sweet food - food frequency questionnaire (SF-FFQ), Three Factor Eating Questionnaire (TFEQ) and beverage liking questionnaire. Sweet taste perception was assessed using the sensory measures of perceived sweet taste intensity and hedonic preference of sweet taste. The sensory measures were performed four times to characterise the nature and repeatability of the sensory assessments. Given the labour-intensive nature and the wide range of scientific enquiries of the sweet taste study, it was conducted in collaboration with Shakeela Jayasinghe (a PhD student in our department) and Maggie Chao (a master’s student in our department). Test-re-testability of the sensory measures (glucose recognition threshold, sweet taste intensity and hedonic preference of sweet taste) was measured as an integral part of the research study, however was not part of the present thesis, therefore it will not be discussed.

3.2 Ethics Approval

This project has been recorded on the low risk database of the Massey University Human Ethics Committee.

3.3 Setting

This project was conducted in the Human Nutrition Research Unit at Massey University Albany, Oteha Rohe campus. Sensory testing was completed in the sensory booths in the food laboratory.

3.4 Power Calculation

The power calculation was conducted by Shakeela Jayasinghe under the guidance of statistician Dr Daniel Walsh. Participants were required to be tested four times to assess repeatability of the sensory method used in this study, and to thoroughly assess the nature of the measures of sweet taste perception. This was calculated assuming the true probability of detection at any level is 0.75, and when repeated four times this gives 84% power that the recognition of sweet will be above the chance level of 0.33. A sample size of 45 subjects would provide 95% confidence that the mean sweet recognition threshold would fall within ± 15 mM (Nakamura *et al.*, 2008). Therefore a sample size of 45 women was required for the study.

3.5 Participants

Premenopausal women of New Zealand European ethnicity aged 20-40 years from the Auckland region were recruited to participate in the study. Female participants were recruited to ensure testing was standardized, as gender differences in taste perception, eating attitudes and behaviours exist (Hayes and Duffy, 2008, Laeng *et al.*, 1993, Monneuse *et al.*, 1991, Nakamura *et al.*, 2008, Roininen *et al.*, 1999, Sartor *et al.*, 2011). Also, the results of this study will be used in collaboration with a female only study, which is part of a wider PhD study. Taste function has been found to decrease in aging adults (Ahne *et al.*, 2000, Gudziol and Hummel, 2007). Therefore the research focused on a specific age group to minimise the potential influence of age.

Participants were included in the study if they identified as European ethnicity, were in good health, between the ages of 20-40 years, and had regular menstruation.

Participants were excluded from the study if they were; pregnant, breastfeeding, smoking, had a chronic illness, had been on any type of antibiotic over the past three months, or had a medical history of a condition that could alter gustatory function, for example; chemotherapy, radiation therapy, kidney or liver disease, or any form of oral or nasal disease (Ruo Redda and Allis, 2006, Steinbach *et al.*, 2009). Any participant who was unable to give informed consent was also excluded from the study.

3.6 Study Process

3.6.1 Overview of sweet taste study process

The sweet taste study involved three key study phases, (see Figure 3.1).

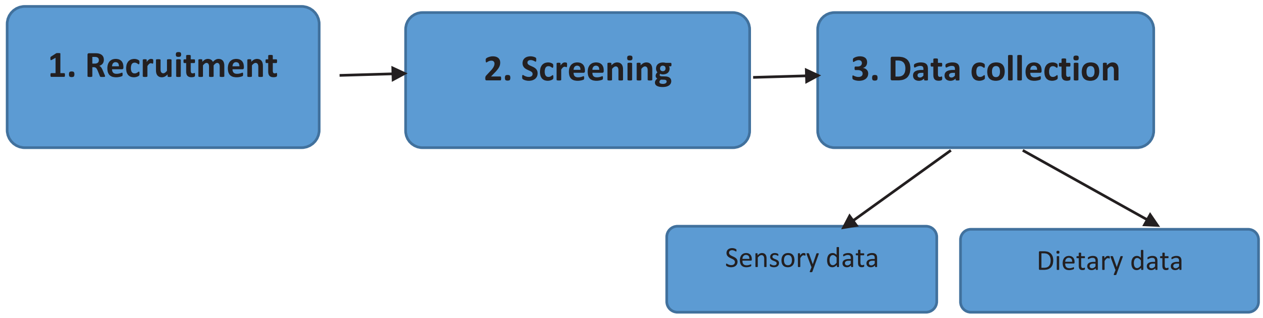


Figure 3.1-Three phases of the sweet taste study

3.6.2 Recruitment

Participant recruitment commenced in January 2014, and was complete in May 2014. A snowball sampling method was employed to recruit participants. This began with emails to Massey University staff and students, and information flyers displayed across the Albany campus. Following this, recruitment was widened to the local community through Facebook advertisements on local Facebook pages. Participation information was also sent to women that were part of another research study previously conducted at the School of Food and Nutrition.

3.6.3 Screening

Women who displayed an interest in the sweet taste study were sent a participant information sheet and a link to the screening questionnaire on SurveyMonkey. They were invited to complete the screening questionnaire to determine if the inclusion criteria was met. The screening questionnaire consisted of 23 questions regarding demographics, health status, medications, menstruation, diet/exercise habits, known glucose allergies and smoking habits (see Appendix A).

3.6.4 Booking visits

If the inclusion criteria was met testing times were emailed for the month ahead, and women were asked to choose four sessions to attend. Testing times were in the morning at 7.30am or 8.30am, as participants were fasted overnight. To ensure a range of tasting sessions were available for attendance, they ran on Tuesday, Thursday and Saturday. As recruitment continued, Saturdays became increasingly popular; therefore testing sessions were extended to Sundays. Once testing was booked each participant was issued with a four digit study number for identification. Three days prior to a testing session participants received an email as a reminder of the time of testing and testing expectations.

3.6.5 Data collection for the sweet taste study

Participants were involved in four testing sessions, each taking approximately 1.5 hours (Table 3.1). Participants arrived after an overnight fast from 10pm onwards. They were also asked not to brush their teeth an hour prior to testing (Nakamura *et al.*, 2008). On day one of testing, written consent to participate was obtained (Appendix B). Participants were also provided with an information sheet that outlined the details of the study (Appendix C), and were informed of their right to withdraw from the study at any stage, without reason. Participants also completed the health and demographic questionnaire (Appendix D). Anthropometric measures were also taken at the first testing session. Height was measured three times using a stadiometer to ensure measures were accurate (Webber *et al.*, 2015). Weight, muscle mass and body fat percentage were measured using a bioelectrical impedance analyser (BIA) (InBody 230, Biospace, Cerritos, CA), which has been validated for accuracy against other body composition methods (Kyle *et al.*, 2004). Following this, participants moved to the sensory booths to begin sensory trials. The sensory trials completed at each testing session included; glucose recognition threshold, perceived intensity of sweet taste and hedonic preference of sweet. Each sensory trial took approximately 45 minutes. Following this, participants had one dietary questionnaire to complete at each trial; electronically, or on paper. Electronic questionnaire results were stored on the Massey University SurveyMonkey server. Instructions on how to complete each questionnaire was provided and a researcher was available at all times to assist if necessary. Breakfast was provided at the end of each testing session. At the last testing session participants were given petrol vouchers to compensate for their travel to Massey University and were provided with their BIA results.

Table 3.1- Overview of the sweet taste study testing sessions

Visit One	Information sheet Health and demographic questionnaire Anthropometric measures Sensory tests- perceived sweet taste intensity, hedonic preference
Visit Two	Sensory tests- perceived sweet taste intensity, hedonic preference Eating behaviour questionnaire
Visit Three	Sensory tests- perceived sweet taste intensity, hedonic preference Beverage liking questionnaire
Visit Four	Sensory tests- perceived sweet taste intensity, hedonic preference Sweet Food- Food Frequency Questionnaire

3.7 Questionnaires

3.7.1 Health and demographic questionnaire

The health and demographic questionnaire consisted of 10 questions (see Appendix D). The purpose of the questionnaire was to gather demographic information and to obtain information about the participant's current diet, medication and supplement use, their level of exercise/ activity, and the date of their last menstrual period. The effect that menstrual cycle has on taste perception and diet is inconclusive (Bryant *et al.*, 2006, Pomerleau *et al.*, 1991, Tucci *et al.*, 2010), therefore it was important that the menstrual cycle phase of each participant was recorded at the time of testing. The health and demographic questionnaire included questions about participants' current diet, as strict diets could have influenced the SF-FFQ results. It was also important to assess medication and supplement use as many medications can influence taste and may cause changes in food intake (Douglass and Heckman, 2010).

3.7.2 Sweet Food- Food Frequency Questionnaire

A non-quantitative SF-FFQ was developed to specifically assess the frequency of sweet foods and sweet beverages consumed by NZ European women aged 20-40 years over the past month, prior to commencement of sensory testing. The SF-FFQ was piloted to a small group of dietetic students prior to study commencement. The purpose of the FFQ was to assess habitual intake of sweet tasting food, rather than quantify individual consumption (Ling *et al.*, 1998). As the SF-FFQ was not intended to assess overall nutrient intake, it did not include all individuals foods and food categories consumed as part of a normal diet. The sweet foods and beverages included in the SF-FFQ were based on data from the 1997/98 National Nutrition survey food list, and foods frequently eaten by New Zealanders (Ministry of Health, 1999). Sweet foods currently consumed by the study population were identified using the National Nutrition Survey 2008/09 results (Ministry of Health, 2011b). A range of validated food frequency questionnaires were also reviewed to help with development of the SF-FFQ (Boniface, 2013, Houston, 2014, National Health and Nutrition Examination Survey, 2008). Supermarket visits were conducted to ensure sweet food and beverages included in the SF-FFQ were freely available. Discussions with family, friends and colleagues within the demographic group provided further insight about the sweet foods they typically consumed.

A total of 69 foods were included in the SF-FFQ and were classified into the following 8 categories; fruit, sweet vegetables, dairy, cereals, spreads/sweeteners, baking/sweets, desserts and beverages.

Frequency of intake was assessed using eight categories including; never, less than once a month, 2-3 times per month, once per week, 2-4 times per week, 4-6 times per week, once a day, and twice or more a day. Participants were asked to choose one option that best describes their intake of each food over the past month (Cade *et al.*, 2004).

Supplementary questions were also included in the SF-FFQ to gain better understanding of participants' sweet food habits. These questions included assessment of participants' favourite foods, snacking habits, food cravings, and sugar additions to food and drink. This provided an understanding of participants' enjoyment of sweet food, if they had a sweet or savoury preference, and an understanding of a "sweet tooth" presence. "Sweet tooth" is defined as a strong liking for sweet taste, preference of a more intense sweetness, a persistent need to consume sweet foods and preference of sweet over savoury (Conner *et al.*, 1988, Thai *et al.*, 2011, Wansink *et al.*, 2006). Participants provided a self-report of sweet tooth presence, and an explanation for the reason they believe this, which included the aspects provided in the definition of sweet tooth. The supplementary questions provided verbatim comments which were used to enrich the data obtained from the food list tables.

The finalised version of the SF-FFQ was uploaded onto SurveyMonkey; an online survey development programme. Participants were provided with instructions on how to complete the survey and a supervisor was available to answer questions. Participants' results were stored on the Massey University SurveyMonkey server.

The final SF-FFQ (See Appendix E) consisted of 8 categories, with a total of 69 foods and 15 supplementary questions. It took participants approximately 10 minutes to complete the survey online.

3.7.3 Beverage liking questionnaire

The beverage liking questionnaire was developed to measure hedonic preference of sweet beverages typically consumed as part of the study populations' diet. The beverage liking questionnaire was piloted to a small group of dietetic students prior to study commencement. The sweet beverages included in the beverage liking questionnaire were the same as those included in the SF-FFQ, based on data from the 1997/98 National Nutrition survey food list, and foods frequently eaten by New Zealanders (Ministry of Health, 1999). Current sweet beverages consumed by the study population were identified using the National Nutrition Survey 2008/09 results (Ministry of Health, 2011b). Supermarkets visits also occurred to ensure beverages included in the beverage liking questionnaire were freely available. Discussions with family, friends and colleagues within the demographic group also provided insight about the sweet beverages consumed as part of their diet. Within the questionnaire beverages with similar properties were grouped together as one category. For example, all soft drinks available in the market were collectively assessed as 'soft drinks' to reduce repetition and participant fatigue.

A 100 mm visual scale was used to measure hedonic preference. Extremes of the scale were marked with 'strong dislike' and 'strong like'. Participants were asked to mark on a predetermined line how much they liked/disliked each beverage (Asao *et al.*, 2015, Goldfield *et al.*, 2011, Kim *et al.*, 2014). A total of 16 sweet beverages/ beverage categories were included in the beverage liking questionnaire (see Appendix F). It took participants approximately 10 minutes to complete the questionnaire.

3.7.4 Three Factor Eating Questionnaire

The TFEQ developed by Stunkard and Messick (1985) consisted of 51 questions used to assess participants' eating behaviour traits of restraint, disinhibition and hunger. It took participants approximately 10 minutes to complete the survey online.

3.8 Sensory Methodology

Perceived sweet taste intensity and hedonic preference of sweet was measured at each visit to establish test-retest repeatability (part of PhD project), and to thoroughly characterise the sensory test procedures for sweet taste perception. The sensory tests were piloted to a small group of dietetic students prior to study commencement. The sensory testing was completed in a laboratory at the Human Nutrition Research Unit, at a room temperature of 20^{o}C (Smutzer *et al.*, 2008). Past research has shown that recognition of sweet taste displays a diurnal difference which is correlated with leptin levels (Nakamura et al., 2008). Therefore to ensure hunger levels of participants were standardized, subjects were asked to avoid consumption of food and drink from 10pm the previous evening, and not to brush their teeth within one hour of the test procedure (Nakamura et al., 2008).

3.8.1 Perceived sweet taste intensity and hedonic preference of sweet

The type of sweet taste stimulus used in the study was glucose (dextrose monohydrate), dissolved in distilled water (Gonzalez *et al.*, 2007). Glucose was used as the test solution as it is a simple sugar, has clearly defined metabolic processes, and is strongly linked to insulin sensitivity measures (Schaefer *et al.*, 2009).

Table 3.2 displays the concentration range used for the sensory measures. The concentrations chosen ensured the lowest concentration was recognised by participants, but would not produce a reasonable perception. The highest concentration was intended to be recognised by all participants and should provoke an extremely sweet response (Pepino and Mennella, 2012).

Table 3.2- Concentration levels of glucose solutions

Concentration level	1	2	3	4
Concentration (mM)	125	250	500	1000

The general labelled magnitude scale (gLMS) was used to assess sweet taste intensity and hedonic preference of sweet (Sartor *et al.*, 2011). The gLMS is a labelled scale that requires individuals to rate the sweet taste sensation of each different glucose concentration along a vertical axis (shown in Appendix G). The scale to rate intensity contains adjectives from "no sensation" to "strongest imaginable sensation of any kind" (Bartoshuk *et al.*, 2004). Similarly, the scale to rate hedonic liking contains adjectives from "strongest imaginable dislike of any kind" to "strongest imaginable like of any kind" (Appendix G).

Ten millilitre aliquots of each concentration (shown in Table 3.2) were presented one at a time at room temperature, in a randomised order (Sartor *et al.*, 2011). Each sample was coded with a random three digit number. Participants were asked to take the whole sample into their mouth, swirl it around for 3 seconds, and then to expectorate into a waste cup. Subjects were then asked to rate the sweetness of each sample by appropriately marking their experience level on the gLMS scale and writing the three digit sample number. Participants were then asked to rate how much they like the sweetness of the sample tasted on a separate gLMS scale, and write the sample number.

3.9 Data Handling and Statistical Analysis

3.9.1 Data handling

Sweet Food- Food Frequency Questionnaire

The SF-FFQ data was downloaded from the server to an excel spreadsheet (Excel, Microsoft Office) and checked for completion. The SF-FFQ provided a report of the frequency of intake of 69 sweet foods. For each food item, participants had to choose one of eight frequencies of consumption (see Table 3.3). These frequencies were converted to a daily frequency equivalent (DFE) of each food item (Daly *et al.*, 2011, Ireland *et al.*, 1994, Sauvageot *et al.*, 2013, Stephens *et al.*, 2011). This was achieved by allocating proportional values to the frequency of consumption options calculated with reference to a base value of 1.0 ("once a day"). For example, the value 0.71 was assigned to the "four to six times a week" option. This was calculated the following way: [(4+ 6)/2] divided by seven (the number of days in a week) = 0.71 (Silva *et al.*, 2013). Similar to other research, DFE scores were reported as mean ± standard deviation (SD) (Di Noia and Contento, 2009, Ling *et al.*, 1998). Food category scores were calculated as a mean DFE score (Daly *et al.*, 2011, Di Noia and Contento, 2009). All sweet food types were grouped into either every-day (20 food items) or occasional (49 food items) food categories. Everyday foods are those that should be eaten daily as part of a healthy and balanced diet as they are high in nutrients, low in sugar, salt and saturated fat (e.g. fruit, vegetables, dairy). Occasional foods included those high in sugar, fat, and sodium, and/or low in micronutrients, and/or pre-packaged, processed or sold in takeaway food outlets (e.g. chocolate, cake, soft drink) (Ministry of Health, 2011a).

Table 3.3- Original frequency of the SF-FFQ and conversion to daily frequency equivalents

Original frequency	Daily frequency equivalent (DFE)
Never	0
Less than once a month	0.03
2-3 times per month	0.08
Once per week	0.14
2-4 times per week	0.3
4-6 times per week	0.71
Once per day	1
Twice a day or more	2

The supplementary questions in the SF-FFQ (see Appendix E) were treated as qualitative data, therefore the participants' responses were organised into similar themes and then categorized (displayed in section 4.2.4).

Beverage liking questionnaire

Beverage liking was marked on a visual scale (line of 100 mm); the neutral or zero point on the line scale was in the centre of the line, resulting in a scores ranging between -50 to 50. Participants' scores were measured in millimetres with a ruler from the zero point on the scale (Zdilla et al., 2015). These results were entered into an excel spreadsheet (Excel, Microsoft Office) which was then checked by another member of the sweet taste study team. Participants' beverage liking scores were categorised as strong liking (score of 25 to 50), liking (score of -24.99 to 24.99) and strong dislike (score of -25 to -50), of each individual beverage. This categorization was used to distinguish between those that really like and dislike the beverage. Similar to other research, results were presented as mean ±SD (Kranzler et al., 2001).

Three Factor Eating Questionnaire

The TFEQ data was downloaded to an excel spreadsheet (Excel, Microsoft Office) and checked for completeness. The data were scored and divided into the three eating behaviour factors (namely cognitive restraint, disinhibition and hunger) according to Stunkard and Messick (1985) (see Table 3.4).

Table 3.4- Score ranges for each factor on the Three Factor Eating Questionnaire

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

Low, medium and high range is based on Stunkard, 1984

Perceived sweet taste intensity and hedonic preference

The marked line on the gLMS that corresponded to the intensity or preference value of the sweet taste participants experienced was measured in millimetres (Holt et al., 2000) with a ruler and manually entered into an excel spreadsheet (Excel, Microsoft Office) along with the ranking of each concentration. All measurements and entered data were checked by another member of the sweet taste study team.

Test-re-testability was assessed by Shakeela Jayasinghe (PhD student) and Dr Daniel Walsh (Statistician) and was considered to be highly significant for both perceived sweet intensity and hedonic preference of sweet taste. For this reason the present study used a mean score of participants' rating of intensity and preference over the four trials. Similar to other research, the sensory results are presented as mean ± SD (Cicerale *et al.*, 2012).

The frequency of participants' ability to rank the intensity of glucose concentrations in the correct order was assessed, by finding how frequently they correctly ranked the samples for increasing sweetness. For example, participants who correctly gave increasing sweetness intensity ratings as the concentration increased over all trials were given a 5/5 score. Participants who scored two concentrations correctly but rated the last two incorrectly were given a 3/5 score (Holt *et al.*, 2000).

3.9.2 Statistical analysis

All data was entered into Statistical Package for Social Sciences (SPSS) for Windows software, (version 22.0, Armonk, NY: IBM Corp) for analysis. The data was tested for normality using Shapiro-Wilk tests, and Kolmogorov-Smirnov tests. Normality was assessed using the following; superimposed normal curves on a histogram, box plots, de-trended plots and Q-Q normality plots. Where data were not normally distributed, the data were log transformed and then tested again for normality. The descriptive statistics of continuous variables were reported as means and standard deviations (SD) for normally distributed data, and geometric means and 95% confidence intervals (CI) for log transformed data. Variables that were unable to be normalised were reported as medians with 25^{th} and 75^{th} percentiles. Categorical variables were reported as frequency summary statistics. A significance level of $P<0.05$ was considered significant (Field, 2013), however where many comparisons were made a significance level of $P<0.001$ was used.

To assess the relationship between variables, Pearson's correlation coefficients were used for parametric data and Spearman's Correlations Coefficients for non-parametric data (Cicerale *et al.*, 2012). Statistically significant differences between groups were measured using Mann-Whitney t-tests (parametric data) and Kruskal Wallis tests (non-parametric data). Where a significant difference was found with Kruskal Wallis tests, post hoc Mann-Whitney t-tests were applied to identify where the significant difference was (Field, 2013). A Bonferroni correction was used to ensure the chance of a type 1 error was reduced. Group differences for parametric data were measured using independent t-tests and one way ANOVA. Where one way ANOVA found significant differences a post hoc Tukey was performed to find where the difference was. For variables that showed statistically significant differences between groups, effect size was measured, which enabled an objective measure of the importance of the effect using the following formulas; Mann-Whitney U test, effect size= $Z/\sqrt{n}$; for the independent t-test, $\sqrt{t^2/(t^2+df)}$; One way ANOVA, $\sqrt{SS_m/SS_r}$. An effect size of 0.10 indicates a small effect, 0.30 a medium effect and ≥0.50 indicates a large effect (Field, 2013).

Chapter Four Results

The results of this study are presented in order of the objectives outlined in Chapter 1 (page 6). The characteristics of the participants are presented first, followed by the results from the SF-FFQ, the beverage liking questionnaire and the TFEQ findings. Sweet taste perception data is then presented, followed by the correlations between sweet taste perception, sweet food and beverage intake and eating behaviours. The results highlighted as the most important findings of the study are presented as figures and tables. Data which is considered to be of secondary importance is presented as tables. Results considered to be background data as it generates the scene or background is found within the text, or alternatively within Appendix H.

4.1 Participant Characteristics

A total of 45 women took part in the sweet taste study. All women included in the study were of New Zealand European ethnicity, and between the ages of 20-40 years. Table 4.1 provides a summary of the demographic characteristics of the women that participated. The median (25, 75 percentile) age of women in the study was 29 (23, 32.5) years. The mean BMI (95% CI) was 24.07 [23.10, 25.07] kg/m^2. The majority of participants were in the normal BMI category (67.4%) and half of the participants (50.0%) had a high body fat percentage.

Table 4.1- Anthropometric characteristics of the sweet taste study participants (n=45)

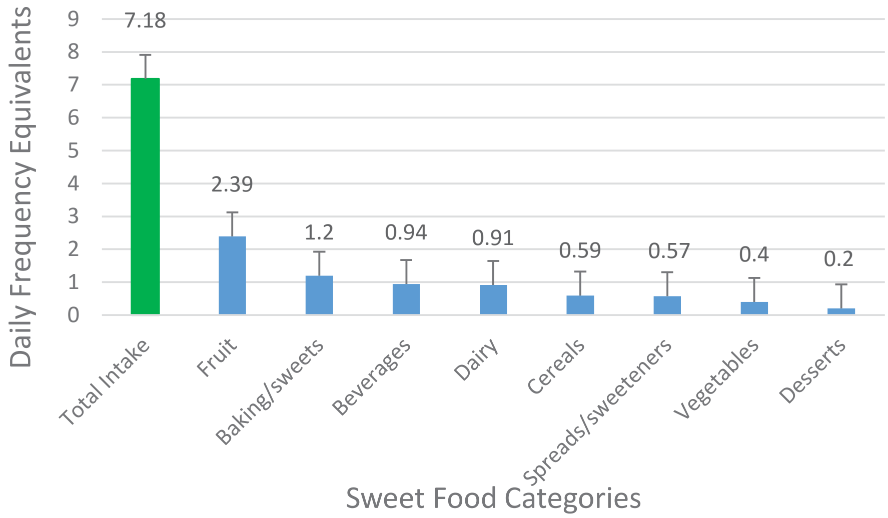
Characteristics	N (%)
Age (years)	29.0 (23.0, 32.5)*
Height (cm)	167 ±5.98+
Weight (kg)	64.4 (60.4, 74.6)*
BMI (kg/m^2)	24.1 [23.1, 25.1] §
BMI category (% of n)	
Normal (18.5-24.9kg/m^2)	31.0 (67.4%)
Overweight (25.0- 29.9kg/m^2)	10.0 (21.7%)
Obese (>30.0kg/m^2)	4.00 (8.70%)
Body fat % (% of total body weight)	31.1 ±7.13+
Body fat % category (% of total body weight) **	
Low (<21.9%)	4.00 (8.7%)
Normal (22-29.9%)	18.0 (39.1%)
High (>30%)	23.0 (50.0%)
Muscle mass (kg)	25.3 ±2.87+
Muscle mass (%)	37.9±4.00+

BMI, body mass index
+Mean ± SD used for normally distributed data
*Median (25, 75 percentiles) used for data not normally distributed
§Geometric mean [95% CI]
**Body fat % cut offs (Kruger *et al.*, 2015)
#BMI cuts offs (Ministry of Health, 2015).

4.2 Sweet Food- Food Frequency Questionnaire

4.2.1 Daily frequency equivalents of sweet food categories

The total sweet food DFE, and DFE of each sweet food category is presented in Figure4.1. The total intake of sweet food (7.18±2.98) indicates that a sweet food was consumed seven times a day by participants. The highest total sweet food DFE score was 13.54 sweet items, the lowest daily sweet food intake score was 2.3 sweet foods. Total DFE of the fruit category was 2.39±1.74, and 48.9% of participants were found to consume two or more pieces of fruit a day. The daily intake of the baking/ sweets category was moderately high (1.20±0.83), with 53.3% of participants found to consume bakery/sweets once a day or more.

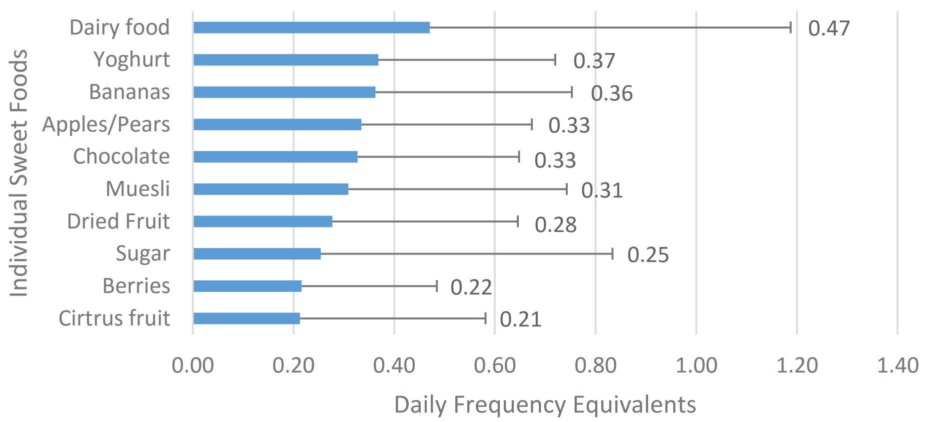


Data displayed as mean DFE
Positive error bars represent positive SD

Figure 4.1- Overall summary of daily frequency equivalents consumed from different sweet food categories and total sweet food

4.2.2 Daily frequency equivalents of individual sweet foods.

The individual sweet food items most frequently consumed, indicated by DFE scores, are presented in Figure 4.2. Dairy food had the highest daily consumption (0.471 ± 0.717), equivalent to about half a serve a day.



Data displayed as mean DFE
Positive error bars represent positive SD

Figure 4.2- Most frequently consumed foods based on highest daily frequency equivalents

The most frequently consumed individual foods within each food category from the SF-FFQ are presented below.

Fruit category

Bananas were on average the most frequently consumed fruit (0.36±0.39 DFE), with 10 participants reporting daily consumption. The fruits that were consumed least frequently included apricots (0.05±0.09 DFE), mango (0.04±0.07 DFE), melon (0.07±0.14 DFE), canned fruit in syrup (0.05±0.16 DFE) and canned fruit in juice (0.04±0.07 DFE) (see Table 4.2).

Table 4.2- Total mean daily frequency equivalents of sweet fruit, and frequency of participants' consumption responses (N=45)

Fruit	Total DFE (mean ± SD)	Daily		Weekly		Once per month or less	
		Mean ± SD	*Frequency n (%)*	*Mean ± SD*	*Frequency n (%)*	*Mean ± SD*	*Frequency n (%)*
Bananas*⁺	**0.36±0.39**	**0.93±0.40**	**10 (22.2)**	**0.28±0.16**	**25 (55.6)**	**0.01±0.02**	**10 (22.2)**
Apples/Pears*	**0.33±0.34**	**0.89±0.15**	**16 (35.6)**	**0.03±0.16**	**24 (55.3)**	**0.02±0.02**	**11 (24.4)**
Dried Fruit*	**0.28±0.37**	**0.91±0.43**	**10 (22.2)**	**0.18±0.14**	**17 (37.8)**	**0.01±0.2**	**18 (40.0)**
Berries*⁺	**0.22±0.27**	**0.81±0.15**	**6 (13.3)**	**0.17±0.13**	**27 (60.0)**	**0.01±0.02**	**12 (26.7)**
Citrus Fruit*	0.21±0.37	1.09±0.53	5 (11.1)	0.16±0.13	24 (53.3)	0.01±0.02	16 (35.6)
Feijoa*	0.18±0.36	0.97±0.58	5 (11.1)	0.23±0.17	13 (28.9)	0.02±0.02	27 (60.0)
Grapes⁺	0.12±0.15	-	0	0.21±0.16	**25 (55.6)**	0.02±0.02	20 (44.4)
Stone fruit	0.12±0.34	1.14±0.74	3 (6.67)	0.26±0.16	20 (44.4)	0.01±0.02	22 (48.9)
Kiwifruit	0.10±0.18	0.71±0.00	2 (4.44)	0.22±0.16	12 (26.7)	0.01±0.02	31 (68.9)
Melon	0.07±0.14	0.71±0.00	1 (2.22)	0.16±0.12	13 (28.9)	0.01±0.02	31 (68.9)
Pineapple	0.05±0.09	-	0	0.02±0.14	10 (22.2)	0.02±0.02	35 (77.8)
Apricots	0.05±0.09	-	0	0.16±0.13	12 (26.7)	0.01±0.02	33 (73.3)
Canned fruit in syrup	0.05±0.16	1.00±0.00	1 (2.22)	0.20±0.12	3 (6.67)	0.01±0.02	41 (91.1)
Canned fruit in juice	0.04±0.07	-	0	0.12±0.14	13 (28.9)	0.01±0.02	32 (71.1)
Mango	0.04±0.07	-	0	0.15±0.13	7 (15.6)	0.01±0.02	38 (84.4)

Numbers in the table show the daily frequency of sweet food intake, number and percentage of individuals consuming each food daily, weekly or monthly.
*Greatest number of participants reporting daily consumption
⁺ Greatest number of participants reporting consumption once a week
Bold text indicates highest consumption based on mean DFE
DFE: daily frequency equivalents

Vegetable category

Few participants reported daily consumption of sweet vegetables. Kumara was the most frequently consumed sweet vegetable (0.12±0.18 DFE) (see Table 4.3).

Table 4.3- Mean daily frequency equivalents of sweet vegetables, and frequency of participants' consumption responses (N=45)

Vegetables	**Total DFE**	**Daily**		**Weekly**		**Once per month or less**	
	(Mean ± SD)	***Mean ± SD***	***Frequency n (%)***	***Mean ± SD***	***Frequency n (%)***	***Mean ± SD***	***Frequency n (%)***
Kumara^{+}	**0.12±0.18**	**1.00±0.00**	**1 (2.22)**	**0.16±0.12**	**26 (57.8)**	**0.02±0.02**	**18 (40.0)**
Corn	0.10±0.14	-	0	0.19±0.15	22 (48.9)	0.02±0.02	23 (51.1)
Beetroot	0.09±0.15	0.71±0.00	1 (2.22)	0.17±0.15	17 (37.8)	0.01±0.02	27 (60.0)
Pumpkin^{+}	0.09 ±0.10	-	0	0.14±0.11	25 (55.6)	0.02±0.02	20 (44.4)

Numbers in the table show the daily frequency of sweet food intake, number and percentage of individuals consuming each food daily, weekly or monthly.
*Greatest number of participants reporting daily consumption
$^{+}$ Greatest number of participants reporting consumption once a week
Bold text indicates highest consumption based on mean DFE
DFE: daily frequency equivalents

Dairy category

Similar mean DFE scores were found for dairy food (0.47±0.72) and yoghurt (0.37±0.35), which is less than half a serving a day (Table 4.4).

Table 4.4-Mean daily frequency equivalents of sweet dairy, and frequency of participants' consumption responses (N=45)

Dairy	**Total DFE (Mean ± SD)**	**Daily**		**Weekly**		**Once per month or less**	
		Mean ± SD	***Frequency n (%)***	***Mean ± SD***	***Frequency n (%)***	***Mean ± SD***	***Frequency n (%)***
Dairy Food*⁺	**0.47±0.72**	**1.61±0.55**	**11 (24.4)**	**0.22±0.16**	**15 (33.3)**	**0.01±0.02**	**19 (42.2)**
Yoghurt*⁺	**0.37±0.35**	**0.85±0.15**	**13 (28.9)**	**0.27±0.16**	**20 (44.4)**	**0.01±0.02**	**12 (26.7)**
Flavoured milk & milkshakes	0.05±0.12	0.71±0.00	1 (2.22)	0.13±0.10	11 (24.4)	0.01±0.02	33 (73.3)
Yoghurt Drinks	0.02±0.03	-	0	0.09±0.02	6 (13.3)	0.00±0.01	39 (86.7)

Numbers in the table show the daily frequency of sweet food intake, number and percentage of individuals consuming each food daily, weekly or monthly.
*Greatest number of participants reporting daily consumption
⁺ Greatest number of participants reporting consumption once a week
Bold text indicates highest consumption based on mean DFE
DFE: daily frequency equivalents

Cereals category

Muesli was the most frequently consumed cereal (0.31±0.43 DFE), with consumption by 11 participants daily and 15 once a week. Chocolate cereal was the least popular cereal, 41 participants never had this in the past month, and mean DFE of 0.04±0.15 (see Table 4.5).

Table 4.5- Mean daily frequency equivalents of sweet cereals and frequency of participants' consumption responses (N=45)

Cereals	Total DFE (Mean ± SD)	Daily		Weekly		Once per month or less	
		Mean ± SD	*Frequency n (%)*	*Mean ± SD*	*Frequency n (%)*	*Mean ± SD*	*Frequency n (%)*
Muesli*⁺	**0.31±0.43**	**0.96±0.38**	**11 (24.4)**	**0.21±0.16**	**15 (33.3)**	**0.01±0.02**	**19 (42.2)**
Natural Cereal	0.12±0.29	1.00±0.00	4 (8.89)	0.20±0.16	7 (15.6)	0.01±0.01	34 (75.6)
Fruity Cereal	0.08±0.33	1.50±0.71	2 (4.44)	0.10±0.03	5 (11.1)	0.00±0.01	38 (84.4)
Liquid Breakfast	0.04±0.11	-	0	0.24±0.18	7 (15.6)	0.00±0.01	38 (84.4)
Chocolate Cereal	0.04±0.15	0.71±0.00	2 (4.44)	0.08±0.00	2 (4.4)	0.00±0.01	41 (91.1)

Numbers in the table show the daily frequency of sweet food intake, number and percentage of individuals consuming each food daily, weekly or monthly.
*Greatest number of participants reporting daily consumption
⁺ Greatest number of participants reporting consumption once a week
Bold text indicates highest consumption based on mean DFE
DFE: daily frequency equivalents

Spreads/Sweetener category

The most frequently consumed sweetener was sugar (0.25±0.58 DFE), however only 5 participants consumed sugar daily and 13 once a week. Jam was the most frequently consumed sweet spread (0.12±0.20 DFE) (see Table 4.6).

Table 4.6-Mean daily frequency equivalents of spreads/sweeteners, and frequency of participants' consumption responses (N=45)

Spreads/sweeteners	Total DFE (mean ± SD)	Daily		Weekly		Once per month or less	
		Mean ± SD	***Frequency n (%)***	***Mean ± SD***	***Frequency n (%)***	***Mean ± SD***	***Frequency n (%)***
Sugar*+	**0.25±0.58**	**1.80±0.45**	**5 (11.1)**	**0.18±0.14**	**13 (28.9)**	**0.00±0.01**	**27 (60.0)**
Jam*	**0.12±0.20**	**0.86±0.20**	**2 (4.44)**	**0.18±0.14**	**18 (40.0)**	**0.02±0.02**	**25 (55.6)**
Honey/Golden syrup	0.10±0.21	1.00±0.00	2 (4.44)	0.13±0.08	17 (37.8)	0.01±0.02	26 (57.8)
Alternative sweetener	0.07±0.20	0.86±0.20	2 (4.44)	0.26±0.12	4 (8.89)	0.01±0.01	39 (86.7)
Nutella	0.02±0.03	-	0	0.10±0.03	5 (11.11)	0.01±0.01	40 (88.9)
Marmalade	0.01±0.03	-	0	0.10±0.03	5 (11.11)	0.00±0.01	40 (88.9)

Numbers in the table show the daily frequency of sweet food intake, number and percentage of individuals consuming each food daily, weekly or monthly.
*Greatest number of participants reporting daily consumption
+ Greatest number of participants reporting consumption once a week
Bold text indicates highest consumption based on mean DFE
DFE: daily frequency equivalents

Baking/Sweets category

The most regularly consumed food in this category was chocolate (0.33±0.32 DFE). Cake was consumed once a week by 34 participants (see Table 4.7).

Table 4.7- Mean daily frequency equivalents of baking/sweets, and frequency of participants' consumption responses (N=45)

Baking/sweets	Total DFE	Daily		Weekly		Once per month or less	
	(Mean ± SD)	Mean ± SD	Frequency n (%)	Mean ± SD	Frequency n (%)	Mean ± SD	Frequency n (%)
Chocolate*+	**0.33±0.32**	**0.81±0.14**	**12 (26.6)**	**0.17±0.12**	**29 (64.4)**	**0.01±0.02**	**4 (8.89)**
Muesli bars*	**0.15±0.24**	**0.79±0.14**	**4 (8.89)**	**0.22±0.15**	**15 (33.3)**	**0.01±0.02**	**26 (57.8)**
Plain biscuits	0.10±0.23	1.00±0.00	2 (4.44)	0.21±0.16	18 (40.0)	0.02±0.02	25 (55.6)
Choc/ cream biscuits	0.10±0.16	0.71±0.00	1 (2.22)	0.19±0.15	22 (48.9)	0.02±0.02	22 (48.9)
Cake+	0.10±0.11	0.71±0.00	1 (2.22)	0.11±0.06	34 (75.6)	0.02±0.02	10 (22.2)
Soft lollies+	0.10±0.13	-	0	0.17±0.14	25 (55.6)	0.02±0.02	20 (44.4)
Loaves	0.10±0.33	1.50±0.71	2 (4.44)	0.10±0.03	7 (15.6)	0.02±0.02	36 (80.0)
Hard boiled lollies	0.06±0.11	-	0	0.19±0.15	12 (26.7)	0.01±0.02	33 (73.3)
Pancakes/Waffles	0.03±0.03	-	0	0.08±0.00	9 (20.0)	0.02±0.02	36 (80.0)
Pastries	0.03±0.04	-	0	0.10±0.03	8 (17.8)	0.01±0.02	37 (82.2)
Scone	0.02±0.02	-	0	0.03±0.00	2 (4.44)	0.02±0.02	43 (95.6)
Cheesecake	0.02±0.02	-	0	0.08±0.00	1 (2.22)	0.02±0.02	44 (97.8)
Tarts	0.02±0.03	-	0	0.08±0.00	4 (8.89)	0.01±0.02	41 (91.1)
Iced Buns	0.01±0.01	-	0	-	0	0.01±0.01	45 (100)

Numbers in the table show the daily frequency of sweet food intake, number and percentage of individuals consuming each food daily, weekly or monthly.
*Greatest number of participants reporting daily consumption
+ Greatest number of participants reporting consumption once a week
Bold text indicates highest consumption based on mean DFE
DFE: daily frequency equivalents

Dessert category

Consumption of desserts was infrequent as DFE scores were low and most participants reported consumption of once per week or less for all desserts. Ice-cream was the most popular dessert with 27 participants reporting consumption once a week and a DFE score of 0.09±0.10 (see Table 4.8).

Table 4.8- Mean daily frequency equivalents of desserts, and frequency of participants' consumption responses (N=45)

Dessert	Total DFE (Mean ± SD)	Daily		Weekly		Once per month or less	
		Mean ± SD	*Frequency n (%)*	*Mean ± SD*	*Frequency n (%)*	*Mean ± SD*	*Frequency n (%)*
Ice-cream[+]	**0.09±0.10**	**-**	**0**	**0.13±0.11**	**27 (60.0)**	**0.02±0.02**	**18 (40.0)**
Ice-blocks	0.05±0.09	-	0	0.14±0.14	12 (26.7)	0.01±0.02	33 (73.3)
Sorbet	0.02±0.03	-	0	0.08±0.00	7 (15.5)	0.01±0.02	38 (84.4)
Custard	0.02±0.07	-	0	0.26±0.25	2 (4.44)	0.01±0.02	43 (95.6)
Jelly	0.01±0.02	-	0	-	0	0.01±0.02	45 (100)
Dairy Desserts	0.01±0.01	-	0	-	0	0.01±0.01	45 (100)

Numbers in the table show the daily frequency of sweet food intake, number and percentage of individuals consuming each food daily, weekly or monthly.
*Greatest number of participants reporting daily consumption
[+] Greatest number of participants reporting consumption once a week
Bold text indicates highest consumption based on mean DFE
DFE: daily frequency equivalents

Beverages category

Fruit juice (0.18±0.33 DFE), regular soft drink (0.16±0.37 DFE), sugar free soft drink (0.15±0.36 DFE) and fruit smoothies (0.10±0.21 DFE) were the most frequently consumed beverages. Overall, few participants consumed any of the beverages daily (see Table 4.9).

Table 4.9- Mean daily frequency equivalents of beverages, and frequency of participants' consumption responses (N=45)

Beverage	Total DFE (mean ± SD)	Daily		Weekly		Once per month or less	
		Mean ± SD	*Frequency n (%)*	*Mean ± SD*	*Frequency n (%)*	*Mean ± SD*	*Frequency n (%)*
Fruit Juice[+]	**0.18±0.33**	**1.14±0.74**	**3 (6.67)**	**0.18±0.14**	**23 (51.1)**	**0.02±0.02**	**19 (42.2)**
Soft drink regular	**0.16±0.37**	**1.18±0.56**	**4 (8.89)**	**0.19±0.15**	**12 (26.7)**	**0.01±0.02**	**29 (64.4)**
Soft drink sugar free	**0.15±0.36**	**1.33±0.56**	**4 (8.89)**	**0.15±0.09**	**13 (28.9)**	**0.01±0.02**	**28 (62.2)**
Fruit smoothie[+]	**0.10±0.21**	**1.00±0.00**	**2 (4.44)**	**0.12±0.08**	**18 (40.0)**	**0.02±0.02**	**25 (55.6)**
Beer/Cider[+]	0.09±0.11	-	0	0.15±0.11	26 (57.8)	0.01±0.02	19 (42.2)
Fruit Drink	0.05±0.11		0	0.12±0.16	10 (22.2)	0.01±0.01	35 (77.8)
Flavoured water	0.04±0.11	0.71±0.00	1 (2.22)	0.10±0.03	6 (13.3)	0.01±0.01	38 (84.4)
Spirit with mixer	0.03±0.04	-	0	0.09±0.02	10 (22.2)	0.02±0.02	35 (77.8)
Dessert wine	0.03±0.07	-	0	0.22±0.14	4 (8.89)	0.01±0.02	41 (91.1)
Milk mixer	0.03±0.09	-	0	0.33±0.16	3 (6.67)	0.01±0.01	42 (93.3)
Cordial	0.03±0.07		0	0.15±0.14	6 (13.3)	0.01±0.01	39 (86.7)
Cocktail	0.02±0.02	-	0	0.08±0.00	3 (6.67)	0.02±0.02	42 (93.3)
Iced Tea	0.01±0.03	-	0	0.08±0.00	5 (11.1)	0.01±0.01	40 (88.9)
Iced coffee	0.01±0.03	-	0	0.12±0.04	3 (6.67)	0.01±0.01	42 (93.3)
Yoghurt drink	0.01±0.02	-	0	0.08±0.00	3 (6.67)	0.00±0.01	42 (93.3)

Numbers in the table show the daily frequency of sweet food intake, number and percentage of individuals consuming each food daily, weekly or monthly.
*Greatest number of participants reporting daily consumption
[+] Greatest number of participants reporting consumption once a week
Bold text indicates highest consumption based on mean DFE
DFE: daily frequency equivalent

4.2.3 Daily frequency equivalents of everyday and occasional food categories

Table 4.10 displays the sweet food category of 'everyday' and 'occasional' foods. These groups were based on the Ministry of Health guidelines (Ministry of Health, 2011a) (refer to section 3.9.1). Food category intake totals were calculated by summing intake of 20 everyday food items and 49 occasional food items.

Table 4.10- Daily frequency equivalents of everyday and occasional food

Sweet food category	Daily Frequency Equivalents
Everyday (n= 20)	2.95±1.91+
Occasional (n=49)	4.23±2.29+

+Mean ± SD

4.2.4 Sweet food related eating behaviours

The SF-FFQ consisted of supplementary questions to gain more understanding of participants' eating habits, favourite foods and sweet food related eating behaviours. Table 4.11 displays some of the additional questions and participants' frequency of yes/no response.

Table 4.11- Sweet food related eating behaviours (n=45)

Supplementary Questions	Yes n (%)	No n (%)
Do you like sweet food?	44 (95.7)	1 (2.22)
Do you snack during the day?	35 (76.1)	10 (22.2)
Do you have a sweet tooth?	27 (58.7)	18 (40.0)
Do you regularly experience food cravings?	26 (56.5)	19 (42.2)
Prefer a sweet snack over a savoury snack?	20 (43.5)	25 (55.6)
Do you have sugar in your hot drinks?	11 (23.9)	34 (75.6)
Do you have sugar on your cereal?	4 (8.89)	41 (91.1)

Sweet tooth

Many of the participants (n= 27, 58.7%) believed they had a "sweet tooth" and gave a variety of reasons for why they believed this to be so. Responses were then organised into themes shown in Table 4.12.

Table 4.12- Participants' reasons for why they believed they had a "sweet tooth" (n=27)

Reason for sweet tooth	Frequency n (%)
Enjoyment or preference	**14 (51.9)**
'enjoy sweet foods'	10 (37.0)
'pick sweet over savoury'	3(11.1)
'love lollies'	3(11.1)
'love chocolate'	5(18.5)
Addiction or craving	**11 (40.7)**
'crave sweet food'	7 (25.9)
'crave chocolate'	3 (11.1)
'addicted to sweet food'	1 (3.70)
Habit or high consumption	**5 (18.5)**
'because I consume a lot of sugar/sweet food'	2 (7.4)
'it has become a habit'	3 (11.1)

Some of the participants' verbatim responses to having a "sweet tooth":

"I really like to eat chocolate, it tastes really good! I also have gotten into the habit of eating sweet foods whilst studying because it gives me a sugar rush and therefore more energy when studying. It is also cheaper to buy than some savoury foods so I get the sweet items, so I have caused myself to prefer sweet stuff".

With reference to chocolate cravings: "the sweet taste makes you crave more".

Favourite foods

The top three favourite sweet foods reported by participants were categorised into foods that were considered 'everyday' foods (n=22, 16.3%) and 'occasional' foods (n=113, 83.7%) (Table 4.13) (See section 3.9.1 for grouping criteria). Bakery foods were the most popular sub-category, and included foods such as cakes, biscuits, muffins, scones, and slices.

Table 4.13 –Participants' favourite sweet foods

Favourite sweet foods (n=135)	Frequency n (%)
Everyday foods	**22 (16.3)**
Fruit	14 (10.4)
Yoghurt	4 (2.96)
Other	5 (3.7)
Occasional foods	**113 (83.7)**
Bakery foods	40 (29.6)
Chocolate	36 (26.7)
Lollies/candy	14 (10.4)
Desserts	19 (14.1)
Other	4 (2.96)

The participants in the study named their favourite food; 17 (37.8%) had a sweet favourite food, while 28 (62.2%) had a non-sweet favourite food. (Table 4.14).

Table 4.14 – Participants' favourite foods and frequency of response

Favourite foods	Frequency n (%)
Sweet	**17 (37.8)**
Fruit	6 (13.3)
Chocolate	5 (11.1)
Yoghurt	3 (6.67)
Ice-cream	1 (2.22)
Biscuits	1 (2.22)
Lollies/candy	1 (2.22)
Non-sweet	**28 (62.2)**
Takeaways	7 (15.6)
Main meals	6 (13.3)
Pasta	5 (11.1)
Vegetables	4 (8.89)
Meat	4 (8.89)
Other	2 (4.44)

Participants also indicated what their three favourite foods to eat away from home were. These included foods that are considered non-sweet (92, 68.1%) and sweet (26, 19.3%) (Table 4.15).

Table 4.15- Participants' favourite foods consumed outside of the home and frequency of response

Favourite food (n=135)	Frequency n (%)
Non- sweet	**110 (81.5)**
'Unhealthy' takeaways	39 (28.9)
'Healthy' takeaways	25 (18.5)
Snack food	13 (9.63)
Coffee	11 (8.15)
Sandwiches/salads	11 (8.15)
Other	11 (8.15)
Sweet	**25 (18.5)**
Sweet bakery items	9 (6.670
Sweets and desserts	8 (5.93)
Fruit	4 (2.96)
Sweet drinks	4 (2.96)

Favourite snacks

Participants' three favourite snack foods were categorised into groups (see Table 4.16); with 64 (47.4%) sweet snacks and 71 (52.6%) non-sweet snacks. Chocolate (n=15, 11.1%) and chips (potato crisps and corn chips) (n=15, 11.1%) were the most popular individual foods.

Table 4.16- Categories of favourite snack food and frequency of response by participants

Favourite snack foods (n=135)	Frequency n (%)
Sweet	**64 (47.4)**
Baking/sweets	25 (18.5)
Fruit	24 (17.8)
Chocolate	15 (11.1)
Non-sweet	**71 (52.6)**
Chips/popcorn	20 (14.8)
Crackers	17 (12.6)
Nuts	15 (11.1)
Cheese	7 (5.19)
Vegetables	5 (3.70)
Bread	3 (2.22)
Other	4 (2.96)

Food cravings

Over half of the participants (n=26, 56.5%) reported that they experienced regular food cravings. There was a variety of foods that were craved and these were categorised into sweet food and non-sweet food (see Table 4.17). Chocolate was the most craved sweet food (n=14, 26.92%), and the most craved non-sweet food was hot chips (n=8, 15.4%).

Table 4.17- Frequency of participants craving sweet food and the type of food craved

Craved food (n=52)	Frequency n (%)
Sweet food	**28 (53.9)**
Chocolate	14 (26.9)
Baking	4 (7.69)
Lollies	3 (5.77)
Ice-cream	2 (3.85)
Coke	2 (3.85)
Fruit	2 (3.85)
Non-sweet food	**24 (46.2)**
Hot chips	8 (15.4)
Bread	4 (7.69)
Takeaways	3 (5.77)
Cheese	2 (3.85)
Mince pie/sausage roll	2(3.85)
Other	5 (9.62)

4.2.5 Relationship between frequency of sweet food intake and sweet food related eating behaviours

The influence that "sweet tooth" (as defined by participants in Table 4.12) had on the intake of various sweet foods within different sweet food categories was investigated (see Table 4.18). All items from the SF-FFQ (Appendix E) were investigated, however only significant findings or data of interest are presented. The total sweet food DFE score was not different for those with or without a "sweet tooth" (*P*=0.54). However, participants with a "sweet tooth" had a higher baking/sweets category DFE score (1.41± 0.93) compared to those without (0.86±0.56) (*P*=0.04). Participants with a "sweet tooth" also consumed significantly more chocolate (*P*=0.03), and were more likely to prefer a sweet snack ($\chi2$= 9.38, *P*< 0.001) compared to those without a "sweet tooth".

Table 4.18- Differences in frequency of sweet food consumption caused by presence of a "sweet tooth"

	"Sweet tooth"- yes⁺ (n= 27)	**"Sweet tooth"- no⁺ (n= 18)**	***P*-value**
Sweet food category			
Total sweet food DFE	7.41±2.81	6.85±3.28	0.54
Everyday food DFE	2.75±1.83	3.25±2.04	0.40
Occasional food DFE	4.66±2.36	3.58±2.08	0.13
Sweet food item			
Chocolate DFE	**0.40±0.34**	**0.21±0.27**	**0.03***
Baking/sweets DFE	1.41± 0.93	0.86±0.56	**0.04***
Soft lollies DFE	**0.14 ±0.15**	**0.05±0.05**	**0.04***

⁺ Mean ± SD
DFE=daily frequency equivalent
Independent t-test for parametric data
Mann-Whitney U test for non-parametric data
*Significant finding *P*<0.05 in bold

The influence that food cravings had on sweet food intake was also investigated (see Table 4.19). All items from the SF-FFQ (Appendix E) were investigated however only significant findings or data of interest are presented.

Table 4.19- Differences in sweet food consumption caused by presence of food craving

	Food cravings- yes+ (n=26)	**Food cravings- no**+ (n=19)	***P*-value**
Sweet food category			
Overall sweet food DFE	6.87±2.73	7.61±3.33	0.42
Occasional food DFE	4.07±1.93	4.45±2.75	0.58
Everyday food DFE	2.80±1.79	3.16±2.11	0.53
Sweet food item			
Chocolate DFE	**0.44±0.35**	**0.17±0.19**	**<0.00***

+ Mean ± SD
DFE=daily frequency equivalent
Independent t-test for parametric data
Mann-Whitney U test for non-parametric data
*Significant finding *P*<0.05 in bold

Participants with food cravings had a greater intake of chocolate compared to those who did not have food cravings (*P*=0.00). The difference in frequency of sweet food intake and snacking preference was also investigated (see Table 4.20). All items from the SF-FFQ (Appendix E) were investigated, however only significant findings or data of interest are presented. Participants that liked sweet snacks consumed sweet foods and occasional foods more than those who preferred savoury snacks (*P*=0.01).

Table 4.20- Differences in frequency of sweet food consumption and snacking preference

Sweet FFQ category	**Sweet snack preference**+ **(n= 20)**	**Savoury snack preference**+ **(n= 25)**	***P*-value**
Overall sweet food DFE	8.44±2.89	6.18±2.71	**0.01***
Occasional food DFE	5.30±2.16	3.37±2.05	**0.01***

+Mean ± SD
DFE=daily frequency equivalent
Independent t-test for parametric data
Mann-Whitney U test for non-parametric data
*Significant finding *P*<0.05 in bold

4.3 Beverage Liking Questionnaire

The beverage liking questionnaire is a 100 mm visual scale that was used to determine participants' liking of sweet beverages, with scores ranging from -50 to 50 (see section 3.9.1). Table 4.21 reports the liking of each beverage as mean ± SD.

Table 4.21- Liking scores of the sweet beverages (n=45)

Sweet Beverage	Overall score (mm)
Fruit Smoothie	24.73±19.3
Cocktail	13.7±26.8
Dessert wine/Cider	10.4±29.2
Milk mixer	9.84±22.4
Fruit Juice	9.22 ±23.3
Iced coffee	1.04±36.9
Flavoured milk/Milkshakes	0.14±30.7
Iced tea	-2.47±29.6
Soft drink regular	-3.89±28.6
Flavoured water	-5.78±25.0
Spirits	-6.67±28.5
Soft drink sugar free	-7.33±32.0
Yoghurt drink	-8.07±28.9
Fruit drink	-8.29±27.9
Cordial	-18.72±22.2
Energy drink	-23.8±26.4
Total mean score	**-0.10±12.3**

Results presented as mean ±SD

Overall fruit smoothie had the greatest mean liking score (24.73±19.3), followed by cocktails (13.7±26.8), and dessert wine/ cider (10.4±29.2). Energy drink had the lowest liking score (-23.8±26.4), with 26 participants strongly disliking this beverage. The participants' responses were categorised into tertiles; 'strong liking' (score of 25 to 50), 'neutral liking' (score of -24.99 to 24.99) and 'strong dislike' (score of -50 to -25), of each individual beverage (see Table 4.22).

Table 4.22- Frequency of participants liking of each sweet beverage, including mean score of each category (n=45)

Drink	**Strong liking score* (mm)**	**Strong liking frequency n (%)**	**Neutral liking score* (mm)**	**Neutral liking frequency n (%)**	**Strong dislike score* (mm)**	**Strong dislike frequency n (%)**
Soft drink sugar free	38.9±12.4	9 (20.0)	-0.11±16.7	19 (42.2)	-39.9±16.3	17 (37.8)
Dessert wine/Cider	38.5±9.22	15 (33.3)	8.57±13.3	23 (51.1)	-43.9±19.7	7 (15.6)
Iced coffee	37.4±8.99	17 (37.8)	12.6±11.2	11 (24.4)	-42.8±16.0	17 (37.8)
Fruit Smoothie	37.2±6.79	27(60.0)	7.88±14.8	17 (37.8)	-26.0±19.1	1 (2.22)
Yoghurt drink	37.1±11.4	8 (18.2)	-3.43±13.7	21 (47.8)	-38.7±16.4	15 (34.1)
Soft drink regular	37.0±13.1	8 (17.8)	-2.30±17.5	27 (60.0)	-40.9±17.5	10 (22.2)
Cocktail	36.7±9.65	17 (37.8)	10.9±10.7	22 (48.9)	-41.5±20.3	6 (13.3)
Flavoured water	35.8±16.4	4 (8.89)	2.82±14.2	28 (62.2)	-37.1±15.0	13 (28.9)
Flavoured milk/Milkshakes	35.8±9.36	13 (29.5)	0.84±14.5	19 (43.1)	-39.6±16.5	12 (27.3)
Spirits	34.4±12.0	7 (15.6)	1.08±15.6	24 (53.3)	-40.4±16.4	14 (31.3)
Fruit Juice	34.1±8.95	12 (26.7)	5.31±15.7	29 (64.4)	-37.0±20.5	4 (8.89)
Milk mixer	33.8±8.84	12 (26.7)	6.83±12.8	29 (64.4)	-40.3±20.1	4 (8.89)
Iced tea	33.2±9.03	10 (22.2)	1.63±16.2	24 (53.3)	-43.8±17.3	11 (24.4)
Cordial	31.5±17.0	2(4.44)	-4.57±14.3	21 (46.7)	-36.8±14.7	22 (48.9)
Fruit drink	31.0±10.9	5 (11.1)	1.24±13.2	25 (55.6)	-37.3±15.2	15 (33.3)
Energy drink	30.0±13.7	3 (6.67)	-2.19±14.8	16 (35.6)	-43.2±15.3	26 (57.8)
Total mean score	**35.1±2.70**		**2.95±5.21**		**-39.3±4.29**	

*Results presented as mean ± SD

4.4 Relationship between Beverage Liking and Beverage Intake

The relationship between intake of sweet beverages and liking of sweet beverages was investigated (Table 4.23). The strongest correlation was found with sugar free soft drink (r=.80, n=45, *P*<0.001).

Table 4.23- Relationship between beverage liking and beverage intake (n=45)

Beverage	Correlation co-efficient	*P*-value
Soft drink (Sugar Free)	.80	<0.001*
Soft drink (regular)	.69	<0.001*
Flavoured water	.67	<0.001*
Fruit juice	.66	<0.001*
Iced tea	.51	<0.001*
Milkshake/flavoured milk	.51	<0.001*
Spirits	.48	<0.001*
Fruit drink	.46	<0.001*
Iced coffee	.44	<0.001^{+}
Fruit smoothie	.40	0.01^{+}

*Pearson's correlation for normally distributed data (2-tailed)
$^{+}$Spearman's correlation for non-normal data (2-tailed)
Significant finding at P<0.01

4.5 Three Factor Eating Questionnaire

The TFEQ assessed three eating behaviours; cognitive restraint, disinhibition and hunger. Table 4.24 shows the participants' mean scores of each of these eating behaviours. Participants' scores on each eating behaviour factor was split into tertiles of 'low', 'medium' and 'high' according to Stunkard, 1984 (see Table 3.4). Participants mean score was in the low range for both cognitive restraint (7.84±4.04) and disinhibition (5.33 [4.32, 6.58]), and a mean score in the medium range for hunger (5.27±2.90). The frequency of participants that scored in each factor is shown in Table 4.11. Most participants scored low on cognitive restraint (n=42, 91.3%) and disinhibition (n=30, 65.25%). Forty four percent of participants scored in the medium category and 28.3% in the high category for hunger.

Table 4.24- Descriptive statistics of the Three Factor Eating Questionnaire (n=45)

Eating behaviour	Mean	Range	Theoretical range	Low n (%)	Medium n (%)	High n (%)
Cognitive restraint *(Factor 1)*	7.84±4.04+	1-17	0-21	42 (91.3)	3 (6.5)	0
Disinhibition *(Factor II)*	5.33 [4.32, 6.58]§	1-15	0-16	30 (65.2)	11 (23.9)	4 (8.7)
Hunger *(Factor III)*	5.27±2.90+	0-12	0-14	12 (26.7)	20 (44.4)	13 (28.3)

+Mean ± SD used for normally distributed data
*Median (25, 75 percentiles) used for data not normally distributed
§Geometric mean [95% CI]
Low, medium and high range is based on Stunkard, 1984 (Table 3.4).

The relationship between each eating behaviour factor was investigated, shown in Table 4.25. A positive correlation was observed between cognitive restraint and disinhibition (r_s=.43, n= 45, *P*=0.00). Hunger and disinhibition were also found to be positively correlated (r_s=.52, n=45, *P*=0.00).

Table 4.25- Relationship between eating behaviour factors from the TFEQ

Eating Behaviours	Correlation co-efficient	*P*-value
Cognitive restraint and disinhibition	**.43**	**<0.001***
Restrictive eating and hunger	.04	0.81*
Hunger and disinhibition	**.52**	**<0.001***

Significant finding *P*<0.05 in bold (2-tailed)
*Pearson's correlation for normally distributed data

BMI and/or body fat percentage were not significantly correlated with any of the eating behaviour factors. No significant difference in BMI was found amongst those in the low (1.38±0.06) and medium (1.35±0.03) restraint groups, (F=1.05, (1, 43), df, *P*=0.31). There was also no difference in BMI amongst those in the low (1.33±0.05), medium (1.41±0.07) or high (1.42±0.07) disinhibition groups, (F=2.97, *P*=0.63). No difference was found in scores of the low (1.40±0.06), medium (1.37±0.06) or high (1.40±0.06) hunger groups (F= 1.36, (2, 42) df, *P*=0.27). No difference in body fat percentage was found amongst those in the low (1.33±0.05, medium (1.41±0.07) or high (1.42±0.07) disinhibition groups, (F= 0.22, (2, 42) df, *P*=0.81). There was also no difference in body fat percentage among those in the low (2.73±0.47), medium (2.62±0.50) or high (2.69±0.48) hunger groups, (F= 0.21, (2, 42) df, *P*=0.82). No difference in body fat percentage among those in the low (2.67±0.48), and medium (2.67±0.58) cognitive restriction groups (F= 0.00, (1, 43) df*, P*=1.00) was indicated.

4.6 Relationship between Eating Behaviours, Sweet Food and Beverage Consumption and Beverage Liking

The relationship between TFEQ eating behaviours and frequency of sweet food and beverage consumption was investigated. This included all items in the food list tables of the SF-FFQ (Appendix E). No association was found; therefore data can be found in Appendix H. The association between sweet food related eating behaviours (supplementary questions from the SF-FFQ, Table 4.11) and TFEQ eating behaviours was also investigated (Table 4.26). Participants who snacked during the day had a higher score on the hunger eating behaviour factor than those who did not snack (t=3.40, df= 43, *P*<0.001).

Table 4.26- Association between TFEQ eating behaviours and snacking behaviours

Eating behaviour	Snacking yes (n= 35)	Snacking no (n=10)	*P*-value	Effect size
Cognitive restraint	8.03±3.7⁺	7.20±5.07⁺	0.50	-
Disinhibition	5.83 [4.62, 7.35] §	3.92 [2.32, 6.63] §	0.12	-
Hunger	**5.97±2.71⁺**	**2.80±2.15+**	**<0.001**	**0.46**

⁺Mean ± SD used for normally distributed data
§Geometric mean [95% CI]
Bold indicates a significant difference, *P*<0.05
One way ANOVA for parametric data

Participants who experienced food cravings had a higher hunger (t=3.08, df=43, *P*=0.00), and disinhibition score (t= 2.98, df 43, *P*<0.001), compared to participants who did not experience food cravings (see Table 4.27). No relationship was found between those who self-identified as having a “sweet tooth” and TEFQ eating behaviours, therefore data is presented in Appendix H.

Table 4.27- Association between eating behaviours and food cravings

Eating behaviour	Food cravings yes (n=26)	Food cravings no (n= 19)	*P*-value	Effect Size
Cognitive restraint	8.15 ±3.89⁺	7.42±4.31⁺	0.55	-
Disinhibition	**6.81 [5.51, 8.42] §**	**1.69 [1.16, 2.46] §**	**<0.001**	**0.42**
Hunger	**6.31±2.84⁺**	**3.84 ±2.36⁺**	**<0.001**	**0.43**

⁺Mean ± SD used for normally distributed data
§Geometric mean [95% CI]
Bold indicates a significant difference, *P*<0.05
One way ANOVA for parametric data

Next, the relationship between TFEQ eating behaviours and liking of all sweet beverages was investigated. A significant positive correlation existed between disinhibition and beverage liking score (r=.52, n=45, *P*=0.00), however no other significant relationships were found (Appendix H).

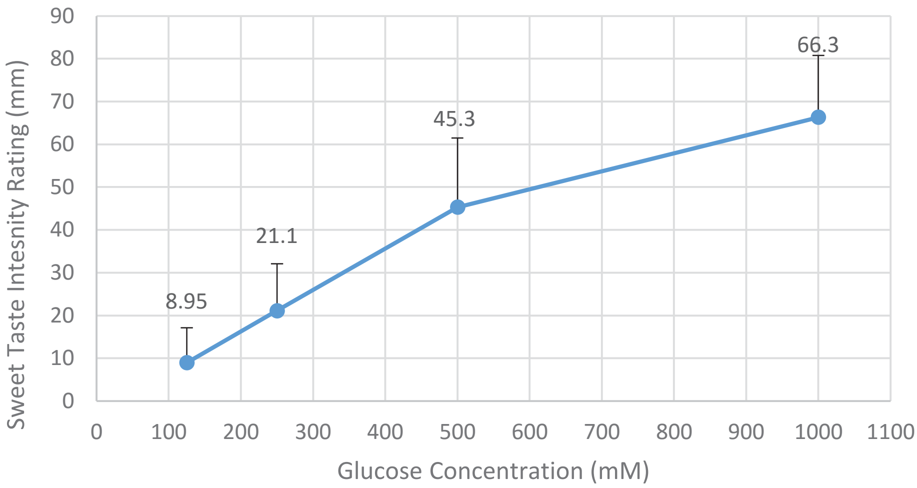
4.7 P**erceived Sweet Taste Intensity and Hedonic Preference of Sweet Taste**

Perceived sweet taste intensity and hedonic preference of sweet taste was measured in millimetres on a modified gLMS scale that ranged from 0 mm to 100 mm, using four glucose concentrations (125 mM, 250 mM, 500 mM and 1000 mM) (see section 3.8.2). Hedonic preference and perceived intensity were not found to be correlated with age, BMI, or body fat percentage.

4.7.1 Perceived sweet taste intensity

As described in the method section (section 3.9.1) the frequency of participants’ ability to rank the intensity of glucose concentrations in the correct order was assessed. Participants were consistently able to correctly rank the glucose concentrations an average of 80.7% of the time over the four trials.

The mean ± SD intensity rating of each glucose concentration is shown in Figure 4.3, which shows an increase in perceived sweetness as glucose concentration increases.

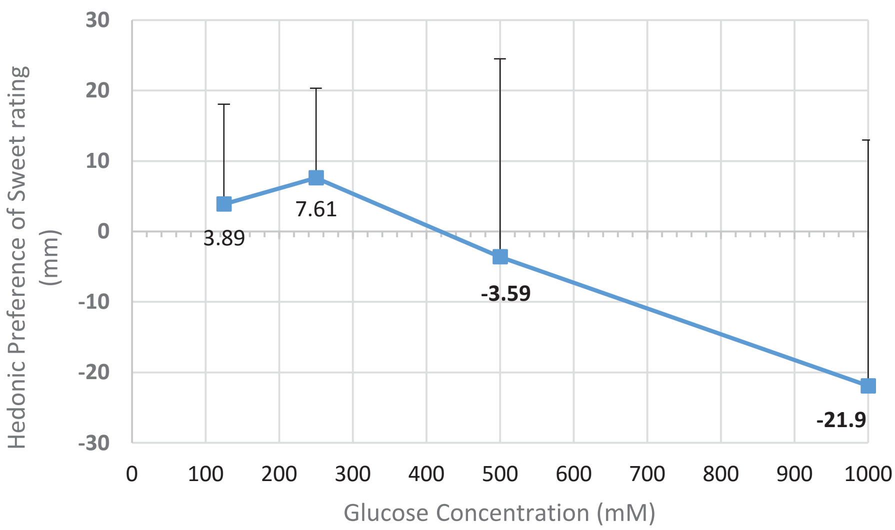


Mean sweet taste intensity rating score on the gLMS
Error bars display SD.

Figure 4.3- Mean gLMS score of percieved sweet taste intensity (mm) with increasing glucose concentration (mM)

4.7.2 Hedonic preference of sweet taste

The mean hedonic preference ratings of each glucose concentration are shown in Figure 4.4. Perceived hedonic preference of the glucose solution peaks at 250 mM (7.61±12.7 mm) and decreases as the glucose concentration increases.

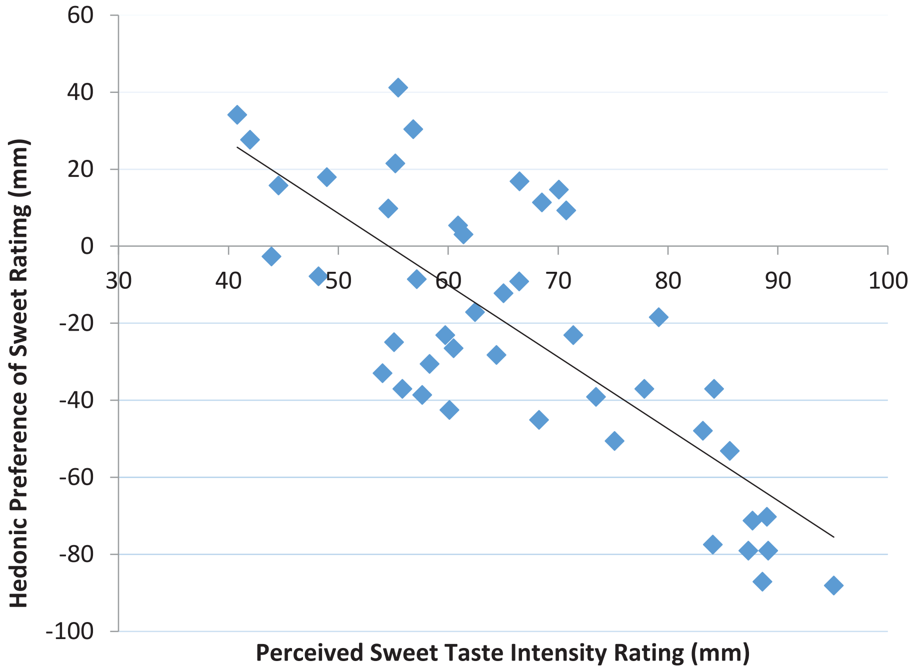


Mean sweet taste intensity rating score on the gLMS
Error bars display SD.

Figure 4.4- Mean hedonic preference of sweet taste according to score on the gLMS at each glucose concentration

4.7.3 Relationship between perceived sweet taste intensity and hedonic preference of sweet taste

The relationship between perceived sweet taste intensity and hedonic preference of sweet taste was investigated, and the strongest correlation was found at 1000 mM glucose concentration (r=-.77, n=45, *P*<0.001) (see Figure 4.5). This indicates that at 1000 mM glucose concentration a strong sensory signal was elicited. The sensory methodology was also found to be highly repeatable at this concentration (based on PhD research); therefore it is a strong reliable measure. For these reasons 1000 mM glucose solution was used for analysis of comparison with the SF-FFQ, beverage liking and TFEQ.

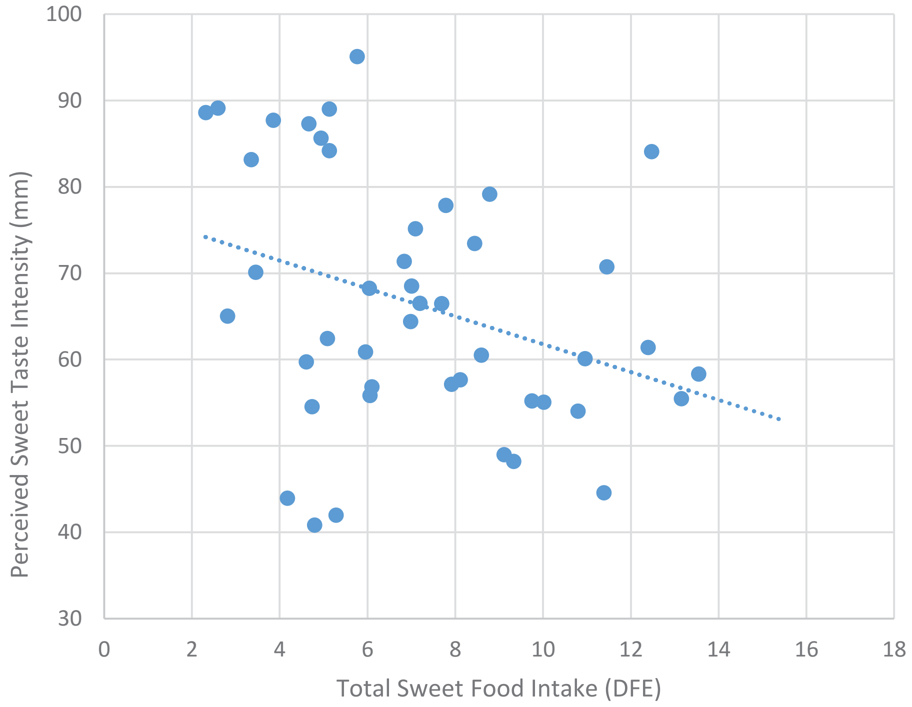


Pearson's correlation co-efficient for normally distributed data

Figure 4.5- Correlation between perceived sweet taste intensity and hedonic preference sweet taste of 1000 mM glucose

4.8 Relationship between Perceived Sweet Taste Intensity, Sweet Food Intake and Sweet Food Related Eating Behaviours

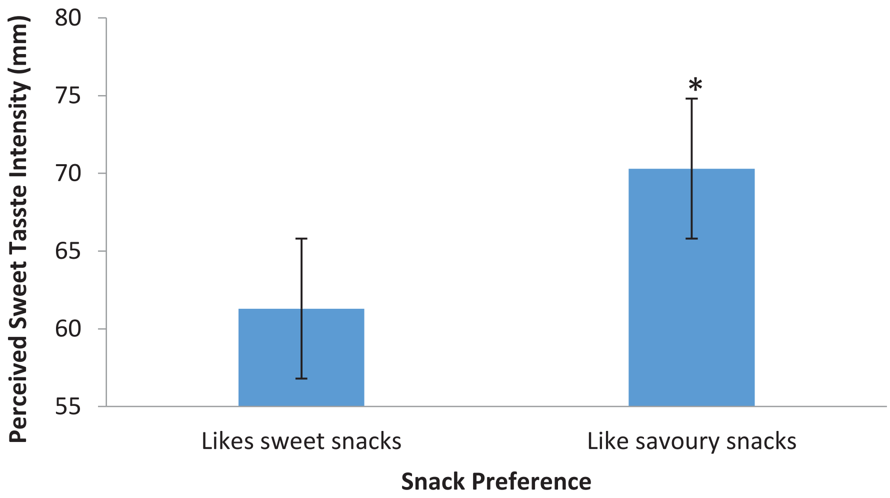
The relationship between intensity rating (1000 mM), DFE of each sweet food category and individual sweet food items from the SF-FFQ (Appendix E) was investigated. Total sweet food DFE was negatively correlated with sweet taste intensity rating (r_s=-.35, *P*=0.02) (see Figure 4.6). However, no other category or sweet food item from the SF-FFQ was found to be significantly related to perceived sweet taste intensity, therefore results are not presented here (see Appendix H).



Pearson's correlation for normally distributed data
DFE: Daily frequency equivalents

Figure 4.6- Relationship between total sweet food intake and perceived sweet taste intensity of 1000 mM glucose

The relationship between perceived intensity score and sweet food related eating behaviours was investigated. Participants who liked sweet snacks had a lower mean sweet taste intensity rating (61.3±13.0 mm) compared to those that liked savoury snacks (70.3±14.5 mm) (t=-2.2, df= 43*,* *P*= 0.04) (see Figure 4.7). No difference was found in sweet taste intensity rating between those with a "sweet tooth" (*P*=0.95), those with food cravings (*P*=0.72), or with high snacking behaviour (*P*=0.65), compared to those without.



*Significant difference between groups tested by independent t-test (p<0.05)
Like sweet snacks (n=20), like savoury snacks (n=25)
Error bars displaying SD

Figure 4.7- Difference of mean scores in perceived sweet taste intensity between those who like sweet snacks and those who like savoury snacks

4.9 Relationship between Perceived Sweet Taste Intensity and Beverage Liking

As shown in Table 4.28 the relationship between perceived sweet taste intensity and liking of sweet beverages was investigated. A negative correlation was found between sweet taste intensity rating (of 1000 mM glucose), fruit juice liking (r_s=-0.37, P=0.01) and fruit drink liking (r=-0.45, P=0.00). All other relationships were not significant (see Appendix H).

Table 4.28- Relationship between perceived sweet taste intensity (of 1000 mm glucose) and beverage liking

Beverage	Correlation co-efficient	Significance
Fruit drink	**-.45**	**<0.001***
Fruit juice	**-.43**	**<0.001***
Cocktail	-.09	0.55*
Milk mixer	.01	0.93⁺
Iced coffee	.01	0.95⁺
Fruit smoothie	-.01	0.94⁺
Dessert wine/cider	-.01	0.97*
Mean beverage liking score	-.10	0.50*

*Significant finding *P*<0.01 in bold
*Pearson's correlation is used for normally distributed data
⁺Spearman's correlation is used for non-normal data

4.10 Relationship between Hedonic Preference of Sweet Taste, Sweet Food Intake and Beverage Liking

The relationship between hedonic preference rating of 1000 mM glucose, total sweet food DFE, sweet food category DFE and sweet food related eating behaviours was investigated, no relationships existed, therefore results are not presented here (see Appendix H). The relationship between liking of sweet beverages, and hedonic preference was also investigated. A positive correlation was found between fruit juice liking and hedonic preference (r=.35, *P*= 0.02).

The relationship between eating behaviours, perceived sweet taste intensity and hedonic preference of sweet taste was investigated, however no relationships were found therefore results are not presented here (see Appendix H).

Chapter Five Discussion

The main aims of this thesis were; to explore and describe the sweet food intake and eating behaviours of a female NZ European sample of the New Zealand population, and to better understand how sweet food intake and eating behaviours may relate to sweet taste perception. Previous research has clearly shown that taste perception influences our sweet taste preference; however, methodological differences in the literature have created inconsistencies about the potential relationship between sweet food intake and sweet taste perception. There have been few past studies that have studied taste perception, preference and dietary intake within one study population (Drewnowski, 1997). The current study aimed to address this gap. It used thorough dietary assessment tools that specifically focused on sweet food to ensure their intake was accurately described. This research project also included an in-depth assessment of sweetened beverages as they are one of the main sugar contributors in our diet. The current research used reliable clinical sensory measures to better understand sweet taste sensitivity and preference of the sample population. Furthermore, the current research addressed a gap in knowledge about eating behaviours, and the relationship with sweet taste preference and intake.

5.1 Participant Characteristics

A total of 45 women who identified as NZ European ethnicity were included in the sample population. As highlighted in the results, most of the participants (67.4%) had a BMI that fell within what is considered a normal range (18.5-24.9 kg/m^2). The sample population may not be representative of the New Zealand population as the average portion of NZ European women with a normal BMI is only 39.6%, with 33.0% overweight and 27.5% obese (Ministry of Health, 2014). Fifty percent of participants in the study had a body fat percentage considered high (over 30%), which indicates some of the women may have a hidden body fat profile (Kruger *et al.*, 2015).

5.2 Sweet Food-Food Frequency Questionnaire

5.2.1 Habitual intake of sweet food categories, everyday and occasional foods

The study objective to assess frequency of sweet tasting food intake was met using results from the SF-FFQ. The procedure used was similar to other validated FFQs

(Boniface, 2013, Houston, 2014, National Health and Nutrition Examination Survey, 2008). This tool included all the major sweet tasting foods in the NZ diet, and intakes were similar to those published in the NZ National Nutrition Survey 2008/09 (Ministry of Health, 2011b).

As highlighted in the results section, mean consumption of sweet foods was moderately high, with participants consuming sweet foods over 7 times a day (7.18±2.98 DFE). Part of this intake comes from foods considered to be everyday sweet food (3.72±2.45 DFE), and the remaining from occasional sweet food consumption (4.2±2.29 DFE). Duchaine *et al.* (2014) found premenopausal women consumed 2.4 sweet foods per day. The sweet foods included in Duchaine *et al.* (2014) were similar to those included in the occasional food category in the present study. These results may indicate that some women in the current study have somewhat unhealthy dietary patterns compared to other populations. The fruit category in the SF-FFQ included fruit typically eaten by New Zealanders. On average the participants in the present study consumed fruit at a frequency of twice a day (2.39±1.74 DFE). Similar consumption frequency was found in other research; Wansink *et al.* (2006) found participants consumed 2.11 servings of fruit a day, and Daly *et al.* (2011) found fruit was consumed 2.3 times a day. The Ministry of Health suggests that at least 2 servings of fruit should be consumed daily as part of a healthy diet (Ministry of Health, 2011a). On average, 48.9% of participants in the current study were meeting this recommendation. This is less than the average intake of the New Zealand population based on the 2008/09 New Zealand Nutrition Survey, with 64% of NZ European women consuming at least 2 servings of fruit daily. Consuming adequate fruit is an important part of a balanced and healthy diet, and provides further evidence that women may require further support to meet recommendations.

Consumption of the baking/sweets category of the SF-FFQ was moderately high, with 53% of participants consuming baking/sweets once or more daily (1.20±0.832 DFE). A similar consumption pattern was shown in research by Ames *et al.* (2014); the mean servings of sweet snacks was 1.33±1.54 a day. This finding is interesting as the study population were adolescent females, and research shows that adolescents typically have more unhealthy dietary habits compared to adults (Chand *et al.*, 2014).

Overall the frequency of consumption of occasional foods, especially baking/sweets appears to be higher in this group of women than NZ recommendations (Ministry of Health, 2011a). The Ministry of Health suggests foods high in sugar and fat such as cakes, biscuits, and chocolate bars should only be consumed occasionally. This indicates nutrition information may not be reaching some women in the study, or it may be unclear what ‘occasionally’ means. The Ministry of Health may need to consider the creation of a guideline that is better understood by the general public, as the term “occasionally” may be open to interpretation. Occasional foods provide high amounts of sugar, fat and salt, and offer little in the way of nutrients (Ministry of Health, 2011a). Therefore, better guidelines to reduce and replace these with nutrient rich foods could be a small step in helping to lessen the obesity epidemic.

The moderately high intake of sweet foods displayed in the present study is also somewhat concerning from a metabolic health perspective. Fifty percent of participants in the current study had a high body fat percentage. This may be somewhat influenced by the high intake of sweet foods, especially those considered to be occasional foods, which are energy dense. This may indicate that some participants in the current study may be metabolically unhealthy. This can become a problem not only for their own health as they become older, but also for their offspring. Many women in the study are of childbearing age, and research shows there is an increase in the risk of future development of cardiovascular disease and T2DM in offspring of obese/unhealthy mothers (Eriksson *et al.*, 2014).

Future sweet taste research should consider assessing sweet food intake in a population group that consists of a greater number of individuals who are overweight or obese. This will not only ensure the body weight of the sample population is more representative of the NZ population, but would also be important to highlight the impact sweet tasting food may have on weight status. Sweet food intake in those who are overweight/obese can then be compared to that of healthy weight individuals.

5.2.2 Habitual intake of individual sweet foods

To further assess the frequency of sweet food intake, habitual intake of individual sweet food items were captured in detail. Dairy food was found to be the most regularly consumed sweet food overall (0.47±0.72 DFE). It is likely that participants may have misinterpreted what dairy food was, as the question was framed unclearly and dairy food is unlikely to be consumed regularly by adults. Participants may have believed the question was regarding overall dairy (the food group) such as the combined intake of milk, yoghurt, ice cream etc. However this was to describe chocolate/strawberry flavoured dairy food which is similar to yoghurt (e.g. Calci-Yum).

The most frequently consumed fruit included apples/pears (0.33±0.33 DFE), bananas (0.36±0.39 DFE), and dried fruit (0.28±0.37 DFE). These fruit are relatively cheap, less influenced by season and available all year. Seasonal fruits such as mango (0.04±0.07 DFE), melon (0.07±0.14 DFE), and apricots (0.05±0.09 DFE) were less frequently consumed, which may have been affected by the time of year the study was conducted.

Chocolate was a popular individual sweet food in the SF-FFQ (0.33±0.32 DFE), with 26.6% of participants consuming chocolate daily and 64.4% consuming chocolate once a week. Chocolate was also found to be one of the most popular snacks (n=15, 11.1%), most craved food (n=14, 26.9%) and the most popular favourite sweet food (n=36, 26.7%). Chocolate is a significant food stimulus (Geiselman *et al.*, 1998), and research has shown that chocolate is more enjoyed, and eaten more frequently by females compared to men (Rozin *et al.*, 1991). This may offer some explanation for the high frequency of chocolate consumption and liking in the current study population.

5.2.3 Sweet food related eating behaviours and the relationship with habitual sweet food intake

5.2.3.1 Sweet tooth

As shown in the results section, 59% of participants in the current study had a self-reported "sweet tooth". These participants believed they had a "sweet tooth" for various reasons including; enjoyment or preference for sweet food, an addiction or craving for sweet food, or because of habitual or high consumption. Results indicated that participants who considered themselves to have a "sweet tooth" were more likely to prefer sweet snacks over savoury snacks, compared to those without a "sweet tooth" (P= 0.00). These findings demonstrate that participants in the current study were able to correctly identify as having a “sweet tooth”. This is indicated as past research has described individuals with a “sweet tooth” have some of the following traits; a strong liking for sweet taste, prefer more intense sweetness, have a persistent need to consume sweet foods and preference of sweet over savoury foods (Conner *et al.*, 1988, Thai *et al.*, 2011, Wansink *et al.*, 2006).

Based on the above definition of a “sweet tooth” individuals with a “sweet tooth” would be expected to have higher consumption of sweet food. However, the current study found no difference in total sweet food consumption between those with or without a “sweet tooth” (*P*=0.54). There was however, a higher habitual intake of the baking/sweets category by those with a “sweet tooth” (*P*=0.04). Participants with a “sweet tooth” also had a greater habitual intake of soft lollies (*P*=0.04) and chocolate (*P*=0.03), compared to those with no “sweet tooth”. These foods may be consumed in greater amounts by those with a “sweet tooth” as they may be perceived to have a more intense sweet taste. Together, these findings may suggest that women with a “sweet tooth” could be at greater risk of unhealthy eating behaviours. Women with a “sweet tooth” may require advice about more healthful sweet alternatives or practical tips on behaviour modification.

5.2.3.2 Food cravings

Food cravings are defined as a powerful urge or desire for a particular food (Christensen, 2007). The results highlighted that self-reported food cravings were experienced by 56.5% of participants in the current study. Fifty nine percent of the foods craved were sweet, and chocolate was the most popular craved food (n=14, 26.92%). The fairly high percentage of reported food cravings is expected in this study population as women have been found to experience more food cravings compared to men. Research also shows the most commonly craved foods are sweet carbohydrates and high fat foods (Christensen, 2007). Similar research by Chao *et al.* (2014) found foods craved by participants were; pizza, chocolate, and ice cream, and cravings for sweet food was significantly associated with intake of sweet food (*P*<0.001). The current study found food cravings to be significantly associated with chocolate intake; those with food cravings consumed significantly more chocolate than those without (*P*<0.001). Chocolate has been found to be the most craved food in the Western world, with many people feeling ‘addicted’ to chocolate (Van Gucht *et al.*, 2014). More specifically, chocolate has also been found to be the most craved food by women (Rozin *et al.*, 1991). The strong appeal of chocolate is suggested to arise from the high amount of both sugar and fat which gives it pleasing sensory characteristics (Rozin *et al.*, 1991). If women frequently experience food cravings and this leads to consumption of foods high in sugar and fat, there may be a significant impact on overall diet quality.

5.3 Frequency of Beverage Consumption and How this Relates To Beverage Liking

Few individual sweetened beverages were consumed daily by participants in the study. However, the frequency of intake of total sweetened beverages was found to be just under once per day (0.94±0.86 DFE). The consumption frequency was similar to research by Ames *et al.* (2014), showing that adolescent females consumed beverages 0.96±0.89 times a day. Duchaine *et al.* (2014) found premenopausal women consume 2.1±4.4 servings of sugar-sweetened beverages per week, which is a lot less than the current study population. These results are somewhat concerning from a public health perspective, as consumption of one sweetened beverage or more a day can put an individual at greater risk of metabolic syndrome development (Dhingra *et al.*, 2007). Sweetened beverages are high in sugar, contributing excess calories and little in the way of nutrients, and may contribute to overweight and obesity. Therefore, more effort is needed to help New Zealanders reduce their intake of sweetened beverages. The Ministry of Health guidelines (Ministry of Health, 2011a) could be a starting point, as currently the recommendation is to reduce sweetened beverage intake, which may be an unclear guideline to the NZ population.

The liking of sweet tasting beverages was determined using the beverage liking questionnaire. The relationship between beverage liking and beverage intake was also investigated. A positive correlation between the frequency of beverage consumption and liking of most sweet beverages was found, indicating that participants’ sweet beverage choices are influenced by their liking. This is to be expected based on the principle that individuals will eat what is liked and avoid what is not (Duffy, 2009).

There were however some exceptions including; cordial (*P*=0.30), milk mixer (*P*=0.23), wine (*P*=0.60) and yoghurt drinks (*P*=0.35). This shows that influences other than liking can influence intake, and past research has shown this to be true (Dressler and Smith, 2013). For example, some sweetened beverages may not be readily available, women may have a negative perception of some sweetened beverages, or they may be influenced by cost, all of which would influence intake. Participants in the current study may also be displaying a degree of restrictive behaviour, by restricting the intake of beverages they like. Research has suggested that a discrepancy between a person's liking and intake may be an indirect measure of dietary restraint (Ledikwe *et al.*, 2007).

5.4 Eating Behaviours of the Sample Population

The cognitive restraint scale of the TFEQ measures a person's conscious intent to restrict food, often with the aim of changing weight status (Contento *et al.*, 2005). Results highlighted that participants in the current study had low cognitive restraint (7.87±4.03). This shows that on average, the study population do not restrict their intake. Disinhibition was also found to be low (5.33 [4.32, 6.58]), which shows participants in the current study do not have a tendency to experience loss of control over eating once they begin, or overeat, due to certain situations or emotional states (Contento *et al.*, 2005). Similar scores of cognitive restraint (6.3±0.1) and disinhibition (6.0±0.1) was discovered in a young French population, with a mean age of 29.5±0.2 years (Aurélie *et al.*, 2012). However, other research had found cognitive restraint and disinhibition scores in women to be higher compared to the current study (Contento *et al.*, 2005, Lähteenmäki and Tuorila, 1995, Stunkard and Messick, 1985). This discrepancy is likely to arise from the difference in population groups which may affect eating behaviours as past research has included dieters, and overweight populations.

The current study found participants' mean hunger score to be in the medium range (5.31±2.89), which shows this population of women find it somewhat challenging to cope with sensations of hunger (Lähteenmäki and Tuorila, 1995). The mean hunger score of the current study population was similar to that seen in an obese, Swedish population (6.0±2.6) (Bjorvell *et al.*, 1986). It was also similar to a young French population with a mean BMI score in the healthy range (23.7±0.1 kg/m^2) (Aurélie *et al.*, 2012). This indicates participants in the present study may have a greater tendency to overeat, caused by the experience of hunger, which can lead to excess calorie consumption and may influence weight status late in life.

The current study found cognitive restraint score to be positively correlated with disinhibition (r=.48, *P*=0.00). This may indicate that when women become more restrictive, they are more likely to lose control of eating. This relationship has been proposed when situations or events override a person's normal restrictive eating, releasing an underlying desire to overeat (Mela, 2001). These situations include emotional distress, or when palatable food or alcohol is available (Contento *et al.*, 2005). Research by Aurélie *et al.* (2012) also found cognitive restraint to be positively correlated with disinhibition, however this relationship was less pronounced (r=.16). This difference may be influenced by the weight status of the study population as all participants were of normal BMI. Contrasting this, an inverse association has been found in other research; higher scores of cognitive restraint was connected with less tendencies to have uncontrolled eating (Karlsson *et al.*, 2000, Lähteenmäki and Tuorila, 1995). The discrepancy may arise from differences in population groups; obese or dieting individuals have often been recruited in past research, whereas the current study recruited 'normal' everyday women. No participant in the current study scored high on the cognitive restraint scale, which will largely account for the discrepancy in results. Participants in the current study did not exercise high cognitive restraint, therefore the inverse relationship cannot occur.

Hunger and disinhibition were also found to be significantly positively correlated (r=.55, *P*= 0.00). This correlation has been repeated in other research, with a stronger relationship found among free eaters (r=.73) compared to dieters (r=.36) (Stunkard and Messick, 1985). Research by Aurélie *et al.* (2012) also found a positive correlation between hunger and disinhibition (r=.52) among women with a normal BMI. These findings may suggest that the current population group may be considered 'normal' eaters.

These observations are important as they show that eating behaviours can influence populations groups differently. Also the association between eating behaviours can be different depending on the population group studied. It was important to understand the eating behaviours that may have influenced the current study population as this can influence their dietary intake of sweet food.

5.4.1 Relationship between eating behaviours, sweet food and beverage consumption and beverage liking

To better understand the influence eating behaviours may have on sweet food intake, the relationship between the TFEQ, SF-FFQ, and the beverage liking questionnaire was investigated. The current study did not find intake of sweet food to be influenced by eating behaviours of the TFEQ. Past research has however, found eating behaviours such as cognitive restraint, uncontrolled eating, and emotional eating to be strongly associated with an unhealthy dietary pattern (Lampuré *et al.*, 2015). Research by Camilleri *et al.* (2014) found that emotional eating behaviours influenced intake of sweet and fatty foods. Cognitive restriction has also been associated with a higher intake of fruit and vegetables, which is indicative of a more healthful dietary pattern (Elfhag *et al.*, 2008). The reason for the lack of relationship in the current study may be explained by the fairly low scores of emotional eating. Further research using a population group with higher emotional eating scores would be needed to better understand this relationship.

TFEQ eating behaviours were however, related to sweet food related eating behaviours from the SF-FFQ. Participants who snacked more, scored higher on the hunger scale compared to those who did not snack (P=0.00), which suggests feelings of hunger may lead to more snacking. Research by Lauzon, 2004 also found snacking was influenced by eating behaviours; girls that were emotional eaters consumed significantly more snacks such as cakes, pastries and biscuits. Participants in the current study who experienced food cravings also had significantly higher scores of hunger (P=0.01) and disinhibition (P=0.00). The association between hunger and food cravings is expected as the hunger scale includes a measure of food cravings (Karlsson *et al.*, 2000). The relationship between disinhibition and food cravings may suggest that food cravings can cause women to have loss of control and overeat. The current study also found disinhibition to be positively correlated with beverage liking (P=0.00); as the liking of sweet beverage increased, women were more likely to be disinhibited. This provides some evidence for the theory that disinhibition is influenced by hedonic factors; the expected pleasure that food gives may override the cognitive control one has (Lähteenmäki and Tuorila, 1995).

Together, these results may suggest that certain eating behaviour traits may have a negative impact on health, making women are more susceptible to overconsumption. If maintained over long periods this can lead to an increase in the risk of overweight and obesity, and negative health outcomes later in life.

5.5 Perceived Sweet Taste Intensity and Hedonic Preference of Sweet

5.5.1 Perceived sweet taste intensity

The current study measured perceived sweet taste intensity of glucose to better understand women's sensitivity to sweet taste. This is a measure of a person's ability to taste sweetness, and how well they can determine the quality of the taste (Reed, 2006). The data revealed that participants in the current study were able to effectively discriminate between different concentrations of glucose, with correct intensity ranking achieved 80.7% of the time in all four trials. Participants also generated an appropriate concentration–response curve; intensity scores increased with increasing concentration. This trajectory shows that participants in the current study are able to perceive clear differences in sweetness of different concentrations (Mahar and Duizer, 2007).

5.5.2 Hedonic preference of sweet taste

Hedonic preference is a measure of "sweet tooth"; how much a person likes or dislikes sweet taste. Hedonic preference has also been proposed to measure an individual's likelihood of consumption of sweet food (Reed and McDaniel, 2006). Therefore hedonic preference was measured in the present study to better understand preference of sweet taste and relate this to the likelihood of sweet food consumption. Research has shown differences in adults' hedonic response to sweet tastes, including sucrose, glucose and fructose. Most adults have greater liking as sweet concentration increases, while few display reduced liking as sweet concentration increases, and some, a peak at low sweet concentration (Drewnowski *et al.*, 1997, Looy and Weingarten, 1992, Yeomans *et al.*, 2007). The latter was shown in the current study; a peak in preference at low concentration, followed by a decrease in preference as the sweet taste concentration increased. As highlighted in the results, the current study showed hedonic preference for glucose to be low, with the highest mean score to be just above 'weakly like' (7.61±12.7 mm at 250 mM glucose concentration), and the lowest mean score between moderately dislike and strongly dislike (-21.9 ± 34.9 at 1000 mM glucose concentration). This trend was also shown in research by Holt *et al.* (2000), Mahar and Duizer (2007), Thai *et al.* (2011), Zandstra *et al.* (1999); however the mean preference ratings were varied. These difference are likely to be affected by the difference in test solutions used; sucrose is most often used in preference research, and has been described as being sweeter than glucose (Moskowitz, 1970). Past research also employed different concentrations of sweet solutions and different scale methods, which can further influence results. Thai *et al.* (2011) suggests that low hedonic preference results are unsurprising for sweet solutions in water as few people would like and choose to drink sweetened water. This may provide some explanation for the low preference ratings found in the current study. Past research has shown pleasantness ratings to be higher for mediums such as lemonade or coke, compared to sucrose in water (De Graaf and Zandstra, 1999, Thai *et al.*, 2011). Tepper *et al.* (1996) assessed hedonic liking in individuals with diabetes and matched controls. Sucrose sweetened cool aid was used as the test solution, and liking was found to increase as sweetness did. Cool aid is similar to cordial in NZ, and may be a good medium to use in future research as it is may be better accepted than sugar in water. Like sugar in water, the level of sweetness can be well controlled, and it would be possible to begin at very low concentrations. This would allow a robust measure of sweet taste preference to still be obtained.

5.5.3 Relationship between perceived sweet taste intensity and hedonic preference of sweet taste

The results of the current study found an inverse relationship between perceived sweet taste intensity and hedonic preference of 1000 mM glucose solution ($r=-.77$, $P=0.00$). This may suggest that women who perceive 1000 mM glucose solution as highly sweet are more likely to have a stronger dislike of the sweet taste. Past research exploring sweet taste intensity and preference of oral nutrition supplements also found an inverse relationship between intensity of sweet taste and hedonic preference. Participants' had greater dislike of the nutrition supplements as the sweetness increased (Kennedy *et al.*, 2010). This trend was also shown in research by Yeomans *et al.* (2007); preference ratings of sweet 'dislikers' decreased as perceived intensity increased. Collectively, this may indicate that above a certain perceived sweet intensity level a sweet taste may become too sweet in taste, and as a result the product will be disliked. Product manufacturers should consider this when creating food and beverages to ensure the sweet taste is not above the preferred level of sweetness.

5.5.4 Relationship between perceived intensity, sweet food intake and sweet food related eating behaviours

To establish the relationship between sweet taste perception and sweet tasting food intake, the relationship between perceived sweet taste intensity and the SF-FFQ was investigated. The current study found an inverse relationship between sensitivity to sweet taste and consumption of sweet food (r=-.35, *P*=0.03). Lower sensitivity to sweet taste may increase consumption of sweet food. On the other hand, high consumption of sweet food may lower a person's sweet taste sensitivity. Further research is therefore required to investigate the cause of the relationship between these two factors. The findings provides some support to the theory that sensory perceptions influence not only food preferences, but also our food consumption and habits (Drewnowski, 1997). Adding to this, participants who preferred sweet snacks rated sweet intensity as significantly lower than those who like savoury snacks (*P*= 0.04) and consumed sweet tasting foods more frequently (*P*=0.01). Duffy *et al.* (2003) found individuals with lower sweet sensitivity to sucrose consumed more added sugar in their diets. These findings may give support to the theory that individuals who experience lower intensity of sweet taste may need higher concentrations of sweetness before liking is attained, and therefore consume more sweet foods (Duffy *et al.*, 2009). If sweet foods are over-consumed as a result of low sensitivity, this could potentially lead to an increase in risk of obesity prevalence and related chronic conditions.

5.6 Relationship between Perceived Intensity, Beverage Intake and Beverage Liking

Results revealed that participants sweet taste intensity ratings were related to liking of fruit juice ($r=-.43$, $P<0.001$), and fruit drink ($r=-.45$, $P<0.001$). Liking of fruit juice and fruit drink was also positively correlated with habitual intake of these beverages ($P<0.001$). This may provide further support to the theory that low sweet taste intensity may cause individuals to need higher concentrations to achieve liking, which may lead to greater consumption of sweet food (Duffy *et al.*, 2009). Alternatively, it could be hypothesised that liking of fruit juice and fruit drink increases intake and exposure to sweet taste, which leads to reduced sensitivity. Sartor *et al.* (2011) supports this theory; participants were supplemented with sweetened beverages for one month and were found to have reduced sweet taste sensitivity upon retest. Together, these results suggest that perceived sweet taste intensity, sweet liking and intake are related, however further research is required to determine the cause of the relationship.

5.7 Relationship between Hedonic Preference of Sweet Taste, Sweet Food Intake and Beverage Liking

To establish the link between sweet taste perception and sweet tasting food intake, the relationship between hedonic preference of sweet taste, the SF-FFQ and beverage liking was investigated. The current study found hedonic preference of 1000 mM glucose was not related to sweet food intake. This lack of relationship could have been influenced by a multitude of factors. Sweetness preference may depend on nutritional state and sensory specific satiety (Degraaf *et al.*, 1993). It may also be influenced by social psychological factors, such as the idea of sugar being unhealthy. Which may cause women to report dislike of a sweet taste, when they actually like it, because they believe they should be consuming less sugar in their diet (Clark, 1998). Use of a sip and spit technique may have also influenced findings; ratings may be influenced by the unpleasantness of spitting out, or the interaction with taste receptors may have been inadequate to create an appropriate response (Zandstra *et al.*, 1999). Hedonic preference is also argued to better correlate with intake when an ad libitum test is performed, rather than a sip and spit test. This is thought to be more like real life as the person is consuming food, and therefore the relationship is likely to be stronger (Zandstra *et al.*, 1999). Research by Duffy *et al.* (2003) supports this; preference was measured using a range of sampled foods and found preference for sweet food caused a notable increase in consumption. Many factors also influence dietary intake, including weight and health concerns, cost (Dressler and Smith, 2013), food availability (Mattes, 1985), preference for convenience foods (Glanz *et al.*, 1998), psycho-social factors (Baranowski *et al.*, 1999), and eating behaviours (Garcia-Bailo *et al.*, 2009).

There have however, been studies that have found a relationship between sweet taste preference and dietary intake (Duffy *et al.*, 2003, Holt *et al.*, 2000, Kim *et al.*, 2014). Sweet likers have been identified in past research and are defined as those who have a higher sweet taste preference. Research has shown liking and consumption to be higher in this group (Holt *et al.*, 2000, Kim *et al.*, 2014). Research by Duffy *et al.* (2003) observed the mean intake of sweet foods to be greater by 1-2 servings per day in those that had higher sweet taste preference.

The current study found a significant positive relationship between fruit juice liking and hedonic preference of sweet taste ($r= .35$, $P=0.02$). However, liking of no other sweetened beverage was related to hedonic preference. There was also no significant association between hedonic preference of sweet taste and habitual consumption of sweetened beverages. Research by Mahar and Duizer (2007) discovered that high consumption of sweetened beverages correlated with a higher sweetness preference level of orange juice compared to those who have low beverage intake. Tepper *et al.* (1996) also found a relationship between higher sweet preference of cherry flavoured beverages and dietary intake of sweet food in a population of individuals with T2DM. The variance in results could arise from the use of different mediums used to measure preference of sweet taste.

Chapter Six Conclusion

6.1 Aim of the Research

Research has proven that differences exist between individuals' sensitivity to sweet taste, and these differences can influence food choices and eating behaviours (Mennella *et al.*, 2011). Methodological differences in the measurement of taste perception and dietary intake have created inconsistencies about the potential relationship between the two. Using a specific study population of NZ European women aged 20-40, this research study aimed to describe women's sweet food and beverage intake, and eating behaviours, and to understand how this may be influenced by sweet taste perception. This study tested the hypothesis that sweet taste sensitivity is associated with hedonic preference for sweet taste, and influences sweet food choices.

6.2 Main Findings of the Research

The results of this research study indicated that sweet food and beverage consumption in this group of participants may be higher than recommendations for a healthy diet (Ministry of Health, 2011a). Baking, sweets and sweetened beverage consumption was particularly high; baking and sweets being consumed on average one or more times a day, and sweetened beverages being consumed almost once per day by participants. In this study participants' sweet beverage intake was influenced by their liking, showing they will most often consume what they like. Habitual intake of sweet foods was also influenced by food cravings and "sweet tooth" presence by some participants in the study. Chocolate was a popular sweet food; with high habitual intake, and some reports of chocolate cravings. Eating behaviours of the participants in the current study were not strongly influenced by cognitive restraint or disinhibition. Participants were however, influenced somewhat by hunger; finding it challenging to cope with sensations of hunger. Together, these findings suggest that intervention strategies are required to help educate or create change in women to have more healthful dietary behaviours. The research also highlighted that women may require practical advice to help deal with feelings of hunger, food cravings and presence of a "sweet tooth". Additionally, education should be provided about better sweet food choices. This support will help women to avoid indulging in foods high in sugar, such as chocolate and baking.

The study results revealed that sweet taste sensitivity was associated with hedonic preference for sweet taste, and dietary intake of sweet tasting food. However, there was no relationship found between hedonic preference of sweet taste and intake of sweet tasting food. Further research is required to ascertain the direction of the relationship between sweet taste sensitivity and sweet food preference. Lower sensitivity to sweet taste may have caused participants to consume more sweet food. Alternatively, women who consumed more sweet food may have reduced their sweet taste sensitivity due to exposure. Participants who preferred sweet snacks also had lower sweet sensitivity compared to those who preferred savoury snacks. Furthermore, participants sweet taste sensitivity was related to liking of fruit juice and fruit drink.

6.3 Strengths of the Research

A key strength of the present study is the use of a specific study population of NZ European women aged 20-40 years. This is important as gender differences in taste perception, eating attitudes and behaviours exist (Hayes and Duffy, 2008, Laeng *et al.*, 1993, Nakamura *et al.*, 2008, Roininen *et al.*, 1999, Sartor *et al.*, 2011). Age-related differences in sweet taste preference have also been discovered; with children and adolescents liking more intensely sweet solutions than adults (Mennella *et al.*, 2011), and taste function has been found to decrease with age (Ahne *et al.*, 2000, Gudziol and Hummel, 2007). Furthermore, studies have found cultural differences in sweet taste perception (Holt *et al.*, 2000, Liem and Mennella, 2002, Mennella *et al.*, 2011, Salbe *et al.*, 2004). Use of a specific study population ensures these potential confounding variables are reduced and allows more confidence in the study results obtained.

The SF-FFQ is a brief, focused FFQ that allows frequency of sweet food intake to be described in detail, as it focuses on foods consumed that are considered to have a sweet taste. This improves compliance and prevents underreporting caused by forgetfulness. Other dietary assessment methods can be used to assess sweet food consumption, however many have downfalls. Firstly, sugar and sweets can be prone to underreporting as they are often discretionary foods and easily forgotten (Vucic *et al.*, 2009). Some dietary assessment methods require a highly skilled interviewer, are time consuming, expensive to conduct, have high participant burden, require literacy skills and highly motivated respondents (Black, 2001, Gibson, 2005). The SF-FFQ on the other hand is quick and easy to use, does not require an interviewer, and is low cost (Segovia-Siapco *et al.*, 2008). Validation studies have also found FFQ's to be a valid measure of dietary intake (Cade *et al.*, 2004, Kiwanuka *et al.*, 2006, Nik Shanita *et al.*, 2012), therefore FFQ's can be used with confidence.

Although the SF-FFQ does not account for portion sizes, this was not seen as a problem as the aim of the current study was to analyse habitual consumption, not absolute nutrient intake. The exclusion of portion sizes enabled the SF-FFQ to be fast and easy to use for participants. However, future studies that investigate the relationship between sweet taste perception and dietary intake could consider the quantitative assessment of sweet tasting food. This could be achieved using a semi- quantitative or quantitative FFQ. This would have the advantage of accurately quantifying sweet food and sugar intake, to enable comparison with NZ guidelines.

A specific measure of participants' sweet beverage intake and liking was included as part of the current study. This was important to help establish the relationship between preference and the actual consumption of sweetened beverages, and the impact this may have on diet quality (Kim & Prescott, 2014). A visual scale was used to measure participants' liking, which is easy for participants to use and understand, therefore reducing participant burden.

Psychological factors have been known to influence dietary intake, however limited research has specifically addressed the relationship between psychological behaviours, sweet taste perception and dietary intake. The present research addressed this gap by including the TFEQ which measures the following eating behaviours; cognitive restraint, disinhibition and hunger. This tool has also been validated in both obese and normal population groups, therefore we can be confident in the results produced (Hyland et al., 1989 as cited in Kavazidou et al., 2012; Karlsson et al., 2000).

Many of the questionnaires included in the sweet taste study were completed electronically on SurveyMonkey. This programme is beneficial as the computerised format ensures complete data is collected as participants cannot move on unless all questions are answered. It also minimises issues of human error with data processing, as the results can be directly downloaded to Excel, Microsoft Office.

The test-re-test-repeatability of the sensory methods employed in the sweet taste study was assessed as part of a PhD research project. Measures of perceived sweet taste intensity and hedonic preference were found to have strong repeatability and can therefore be used confidently in the present study. The taste-and-spit test also occurred under well controlled standardised conditions. All participants were fasted overnight as research suggests that sweet taste intensity and preference can be influenced by state of hunger (Laeng *et al.*, 1993, Zverev, 2004). A modified gLMS was used to measure both perceived sweet taste intensity and hedonic preference of sweet taste. This method has been found to be a valid measure of sensory perception and has been used in many past studies (Bartoshuk *et al.*, 2004, Cicerale *et al.*, 2012, Hayes and Duffy, 2008, Sartor *et al.*, 2011, Yeomans *et al.*, 2007).

6.4 Limitations of the Research

The validity of dietary assessment methods is the degree that the method actually assesses usual intake of participants and is of importance in dietary research (Willet, 1998). The SF-FFQ and beverage liking questionnaire were created for this study, as validated tools were not available that specifically assessed sweet tasting food and beverage intake, and liking of sweetened beverages. Future studies could carry out an in-depth validation against weighed food records or 24 hour recalls to enable validity of these tools. This would have allowed some condensing of the questionnaires and exclusion of those items that made minimal contribution to sugar intake.

Dietary habits can vary with changes in seasons (Gibson, 2005). Collection of dietary data for the current study occurred from January-May 2014. This period was not sufficient to cover dietary patterns over a range of seasons, as it only reflected one or two seasons. Future research could assess whether results during other seasons may differ if repeated later in the year.

After completion of the SF-FFQ it became apparent that a few key food items were missing, or some food items should have been named differently for clarification. For example, a specific muffins/slices food item should have been included in the baking/sweets category. Also dairy food should have been named by its brand to ensure participants' understood what food was being referred to i.e. Calci-Yum dairy food.

Under or over reporting can be an issue with dietary assessments and can be challenging to avoid. Because of the nature of the questionnaire it is unknown if under or over reporting occurred in the population group. However, overestimation of intake has been found to be a problem with FFQs (Coulston *et al.*, 2013), and therefore could have been an issue in the present study.

The body composition of the study population was not representative of the general NZ population. The proportion of study participants with a normal BMI (18 - 24.99 kg/m^2) was higher than the NZ population, 67.4% and 35% respectively (Ministry of Health, 2012). A convenience sample was recruited in the present study from the general NZ European population in Auckland, using email distribution, local online and paper advertisements. The women who volunteered in this study may have had a greater interest in nutrition and be more health conscious than the general NZ population. Individuals who volunteer for studies have been found to have more healthful diets compared to those who do not volunteer (Kim, Kim, & Hyun, 2004). Therefore, the sample of women in this study may not be representative of the rest of the NZ population. This may explain some of the difference in BMI of the study population and the NZ population.

The sweet taste study was piloted in dietetic students to assess fatigue, instruction understanding, ease of use, and time of completion of the sensory measures and dietary questionnaires. This group however, is not representative of all NZ European women as they would have higher nutrition knowledge and understanding.

The current study was only powered to be exploratory, discover relationships, and assess the repeatability of the sensory methods, therefore the sample size was kept fairly small (45 women). If a larger study population was recruited participants could be classified into sweet taste groups similar to past studies. This would allow participants to be classified into sweet taste likers or sweet taste dislikers. This would be beneficial to further our understanding of the eating habits of people that have a strong liking for sweet taste.

It is argued that sugar in water may not be the best test solution for sweet taste preference studies aiming to understand the link to dietary intake. This is because few people would like and choose to drink sweetened water (Thai *et al.*, 2011). Use of a more accepted food or beverage such as cordial, coke, yoghurt etcetera may have more dietary relevance, and a strong relationship with intake may be revealed.

6.5 Use of the Research Findings

This research is relevant in dietetics as results show that NZ European women are frequently consuming sweet tasting foods high in sugar. High intakes of sugar can compromise dietary quality and increase energy intake, which may lead to health complications, including obesity (Duffy *et al.*, 2003). It is argued that nutrition education and interventions focus on nutritional quality of food, rather than taste acceptance (Drewnowski, 1997). Dietetics professionals can assist clients/patients by assessing taste preferences and providing practical advice on how to include sweet tasting foods that are enjoyable, healthful, that meet individual needs. Also, women with a “sweet tooth” may require diet strategies to reduce sugar intake. This could include the use of non-caloric sweeteners to reduce calorie intake, the slow reduction of sugar added to food and beverages to increase sensitivity to sweet taste, education on nutrition label reading, and behaviour change strategies such as distraction when something sweet is craved.

There has been a recent increase in the demand for a ‘healthy alternative’ by consumers which has left many food manufacturers in a predicament (Clark, 1988). Manufacturers need to find ways to reduce the amounts of sugar (or fat), without unfavourably affecting a foods sensory properties. The present study allows food manufacturers to gain a better understanding of sweet food consumption patterns and preferred sweetness level, which can be useful in development of foods that have acceptable taste qualities.

6.6 Recommendations for Future Sweet Taste Studies

- Ensure the food item 'dairy food' in the SF-FFQ is understood by study participants by providing an example of what this is.
- Inclusion of a food item called 'muffins/slices' in the SF-FFQ.
- Removal of foods such as fruit and vegetables to leave only those considered to be discretionary foods. Discretionary foods contain added sugar and can have negative health effects, therefore should be the focus.
- Assessment of the validity and reproducibility of the SF-FFQ and beverage liking questionnaire in the study population and other NZ population groups.
- Addition of portion sizes to create a quantitative SF-FFQ. This would allow sugar intake to be quantified, which would provide an understanding of how sugar intake in the study population compares to NZ guidelines.
- Consider the use of real food to assess preference, as this is closer to real life consumption. This raises the prospect that testing with actual foods, especially those varying is sweetness, might reveal associations between sweet liking and dietary preferences.
- Future studies could explore different sweet tastants including fructose, disaccharides, polysaccharides and artificial sweeteners and investigate how these relate to sweet food intake.
- Ensure a large study population is recruited so research has the power to categorize participants into sweet likers or sweet dislikers, to allow the dietary habits between the two groups to be assessed.
- Further research to determine the cause of the relationship between perceived intensity, sweet beverage liking and beverage intake. A better understanding of this relationship would be beneficial from a dietetic perspective as it would provide support to the practical advice given to patients/clients about slowly reducing sweet foods and drinks to reduce sensitivity and liking.

6.7 Conclusion

The aim of the present research was to assess the sweet food habits and eating behaviours in 20-40-year-old NZ European women, and how measures of sweet taste perception can help explain these sweet food choices and eating behaviours. The study found participants in this study habitually consumed foods high in sugar such as baking, sweets, chocolate and sweetened beverages and that participants' sweet beverage choice was influenced by their liking. Some participants were found to express eating behaviours that influenced their intake of sweet tasting food. The current research also found that an inverse association between sweet food consumption and sweet taste perception exists. These findings may provide some support to the theory that individuals that experience lower intensity of sweet taste may need higher concentrations of sweetness before liking is attained, and therefore consume more sweet tasting foods (Duffy *et al.*, 2009). The current research has therefore added to our understanding of the links between sweet taste perception, dietary intake and eating behaviours.

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Appendices

Appendix A: Screening Questionnaire

Sweet Taste Study Screening Questionnaire

Please fill in the following screening questionnaire that will be used to determine whether you fit the inclusion criteria as a study participant. All information will be kept confidential.

Why is your gender?

Personal Details

First name:

Family name:

Home address:

Suburb:

City/town:

Post code:

E-mail address:

Home phone:

Mobile phone

Date of birth:

Your age:

Years:

Months:

Ethnicity you most identify yourself with:

New European

Maori

Pacific Island

Asian

Indian

Middle Eastern/Latin American/African

Other (Specify)

General Health Status

- Are you currently on a specific diet or exercise programme aimed at weight loss? Yes/no

- If yes, please provide details of your diet or exercise programme

- Are you pregnant or breastfeeding? Yes/no

- Do you currently have regular menstrual periods? Yes/no

- Please provide the date of your last menstrual period

- Over the last 12 months how often did your menstrual period occur?

Once every 3-5 weeks

Once every 6-8 weeks

Interval of > 2 months (irregular)

None

- Are you currently using any form of hormonal contraception (e.g. pill, mirena, depoprovera)? Yes/no

- Do you suffer from any chronic diseases (e.g. diabetes, cardiovascular)? Yes/no

- Do you have any clinical causes of dry mouth (e.g. Xerostomia or Sjogren's syndrome)? Yes/no

- Have you been on any type of antibiotics over the last 3 months? Yes/no

- Are there any other medical conditions you would like to inform us about? (e.g. surgery, cancer) Yes/no

- Are you currently smoking or in the process of quitting?

Assessing allergy

To assess where you are allergic to any of the tasting solutions please answer the following questions.

Are you allergic to glucose? Yes/No

Please tell us how you found out about the sweet taste study:

Questionnaire complete

Thank you very much for taking your time to complete the questionnaire, we will be in touch with you shortly. In the mean time, if you have any further queries please do not hesitate to contact us on sweettastestudy@gmail.com

Appendix B: Participants Consent Form

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

Institute of Food, Nutrition and Human Health
Massey University
Private Bag 102-904
North Shore Mail Centre
Albany, Auckland
New Zealand
T 09 414 0800

SWEET TASTE STUDY

Participant Consent Form

I have read the Information Sheet and have had the details of the study explained to me.

My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: .... **Date:** ....

Full Name ....

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

SWEET TASTE STUDY PARTICIPANT INFORMATION SHEET

We are researchers of Human Nutrition and Food Technology at Massey University and are looking for women to take part in the research on sweet taste.

Description of the project

Over the past few decades there has been an increased availability and consumption of low cost, readily available food and beverage products that are high in added sugar. Taste sensitivity to sweet varies considerably between individuals. As variations in taste sensitivity influences food choice, and thereby affects quality of life, there is much interest to understand the role of taste perception in the way people select food and how much they consume. Therefore the main aim of the project is to understand the relationship between sweet taste perception and food intake and behaviour.

Who can take part?

We are looking for women of

- New Zealand European ethnicity
- 20-40 years of age
- Not be pregnant or breastfeeding
- Who are non-smokers
- Have had regular menstrual periods for a year
- Not have any chronic illnesses or clinical cause for a dry mouth

Project Procedures

Prior to taking part in this study you will need to complete a screening questionnaire to assess your health status and medical conditions that may influence the results of the study.

The study requires you to attend **four sessions** each approximately 1.5 hours long at the sensory unit at Massey University Albany. You will be required to come for each session after an overnight fast and refrained from brushing your teeth at least an hour prior to the appointment. These appointments will be conducted between **7.30-8.30am on weekday**s and **selected weekends**. At each session you will undertake a **sensory test** and complete **one dietary questionnaire**. You will also maintain a **four-day weighed food record**. In addition, height, weight, and body fat % will be measured at the first session.

Sensory testing

Taste testing involves tasting sweet samples to determine your sensitivity to sweet taste. The 3 - Alternative Forced Choice (3-AFC) test will be used to determine sensitivity to sweet taste. You will be asked to take the whole cup of one sample (5-10mls), swirl it in your mouth for 3 seconds and then spit it out to a waste cup (swallowing may affect the results). Two of the three samples will be identical and one is different. You will pick the sample with the sweet taste and write the number down when you have finished all the samples. After recording the number, you will be asked to return the tray with the form and empty cups. You will rinse your mouth with distilled water and wait 20 seconds before you move to the next sample. In addition you will also rate 'intensity' and 'preference' of four sweet solutions on a scale.

Dietary analysis

You will be asked to keep a weighed food record of all food and beverages consumed over four days. At the first session you will watch a video that explains the procedure of a food record. At each of the next three visits you will complete one dietary questionnaire relating to your diet history, food choice and eating habits.

What will you receive?

You will be reimbursed for travel expenses with a $100 petrol voucher following the completion of testing (voucher received at the end of the fourth session). You will also receive a written report containing the main findings of the study once data analysis and interpretation is completed.

Confidentiality

All data collected will be used solely for research purposes and will be prepared for publication in a professional journal. All personal information will be kept confidential by assigning number codes to each participant. No names will be visible on any papers on which you provide information. If you are a student of one of the research teams please note that your academic grades will not be affected whether you decide to complete the study or withdraw at a later time. All data/information will be handled in confidence and will be stored in a secure location for five years on the Massey University Albany campus. After this time it will be disposed of by an appropriate staff member from the Food Technology department.

Participant's rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any particular question;
- Withdraw from the study at any time;
- Ask any questions about the study at any time during participation;
- Provide information on the understanding that your name will not be used unless you give permission to the researcher

Contact information

If you have any further questions or concerns about the project, either now or in the future, please contact the sweet taste study team on sweettastestudy@gmail.com

Specific contacts:
Professor Bernhard Breier B.Breier@massey.ac.nz
Shakeela Jayasinghe (PhD student) s.n.jayasinghe@massey.ac.nz

Human ethic committee Approval Statement
"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.
If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email humanethics@massey.ac.nz".

Appendix D: Health and Demographic Questionnaire

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

SWEET TASTE STUDY - Personal information, health and demographic questionnaire

First name: ____

Family name: ____

When did your last period start? (Day / month / year) ____________________

Are you pregnant or breastfeeding? Yes □ No □

Are you taking any form of medication, including traditional or homeopathic medicine and contraception?
Yes □ No □

Please specify the condition, the medication and the dosage in the table provided.

Condition	Medication	Dosage	Frequency

Are you taking any form of supplements, including tablets or drinks? Yes □ __ No □

If yes, what are the name, brand and dosage of the supplements you are taking? _____

(Will send details by email Yes □ No □)

Supplement	Brand	Dosage	Frequency

Do you follow a specific diet for health reasons? Yes □ No □

Please explain

Do you follow a specific diet aimed at weight loss? Yes □ No □

Please explain

Do you follow any diet for cultural or religious reasons? Yes □ No □

Please explain

Are you happy with your current body weight? Yes □ No □

Questions regarding physical activity

1. What is your occupation?

2. What is the main activity that your occupation requires?

____
____

____
____

3. Do you do a sport or other organised physical activity in addition to your job?
   Yes □ No □

   If yes, please describe the activity ______________________________

   ____

   a. How many times a week? ______________________________

   ____

   ____

   b. How many minutes at a time? ___________________________

   ____

   ____

I would like to receive a brief report summarizing the main findings of the project:

Yes □ No □

I am willing to be contacted in future research projects within the Institute of Food, Nutrition and Human Health:

Yes □ No □

Appendix E: Sweet Taste Study Food Frequency Questionnaire

SWEET TASTE STUDY FOOD FREQUENCY QUESTIONNAIRE

This questionnaire is designed to obtain information about your usual intake of sweet tasting food in the past month. Please answer by ticking HOW OFTEN you ate a particular food over the LAST MONTH. If you did not consume a type of food over the last month please choose NEVER. Please answer the questionnaire as accurately as possible. Refer to the examples sheet provided if any of the foods are unclear.

	Never	**Less than once per month**	**2-3 times per month**	**Once a week**	**2-4 times per week**	**4-6 times per week**	**Once a day**	**Twice a day or more**
Fruit								
Apricots								
Apples/Pears								
Bananas								
Berries								
Grapes								
Kiwifruit								
Mango								
Citrus fruit								
Pineapple								
Feijoa								
Stone fruit								
Pears								
Melon (water melon or rock melon), paw-paw								
Dried Fruit								
Canned fruit in syrup								
Canned fruit in juice								
Vegetables								
Beetroot								
Corn								
Pumpkin								
Kumara (yellow or orange)								
Dairy Based Food								
Yoghurt / frozen yoghurt								
Dairy food								
Yoghurt drinks								
Flavoured								

milk/milkshakes								
Cereals								
Muesli								
Natural cereals (All bran, Special K)								
Light and fruity cereals (Just Right, Light and Tasty)								
Chocolate based cereals (Coco Pops, Milo cereal)								
Liquid breakfast (Up and Go)								
Cakes, biscuits and other sweet food								
Cake								
Cheesecake								
Loaves								
Pastries/Pinwheels (sweet)								
Scone (sweet)								
Iced buns/twist								
Tarts								
Plain biscuits								
Chocolate or cream biscuits								
Waffles, pancakes or pikelets								
Muesli bars, breakfast bars or energy bars								
Chocolate								
Hard boiled lollies								
Soft lollies								
Desserts								
Jelly								
Ice-cream								
Ice blocks								
Sorbet								
Custard								
Dairy desserts (instant pudding)								
Spreads/Sweeteners								
Nutella								
Jam								
Marmalade								
Honey/ Golden syrup								
Sugar, white								
Alternative sweetener								

Beverages								
Fruit juice								
Fruit drink								
Cordial								
Soft drink, regular								
Soft drink, sugar free or diet								
Iced Coffee								
Milk mixer								
Ice tea								
Fruit Smoothie								
Yoghurt drink								
Flavoured water								
Beer, lager or cider								
Dessert wine								
Spirit with mixer								
Cocktails								

Please tick the appropriate answer or write in the blank space.

1. What is your most favourite food to eat and how often do you have it?

2. What are the three most popular foods you would buy when away from home? Name 3 in order of preference

3. Do you usually eat snack during the day?
   Yes
   No

4. Name your three favourite snacks (e.g. chips, cake, cheese)?
   - __
   - __
   - __

5. If you are having a snack to eat would you prefer something sweet or savoury?

6. Do you like/enjoy sweet food?
   Yes
   No

7. Do you believe you have a ‘sweet tooth’
   Yes
   No

8. If yes, why do you think you have a sweet tooth?

9. Do you regularly experience food cravings?

10. If yes, what type of food do you crave, give two examples

- __
- __

11. What are your three favourite sweet foods (not drinks) and how often do you have them?

12. Do you have sugar in your hot drinks?

Yes

No

13. If so, how many teaspoons per cup of hot beverage?

14. Do you have sugar on your cereal?

Yes

No

15. If so, how many teaspoons?

Appendix F: Sweet Taste Study Beverage Liking Questionnaire

Sweet Taste Study Beverage Liking Questionnaire

Subject ID: _________ Date: __________ Session #: __________

This questionnaire will be used to assess your liking of different beverages. Please indicate with a vertical line how much you like each on the scale provided. If you are unsure about what the drink is, please see separate examples sheet provided.

For example, how much do you like going to the movies

Strong ______________________________|______________ Strong

This shows that you enjoy going to the movies

1. **Fruit Juice (e.g. just juice, ribena)**

Strong dislike ____ Strong like

2. **Fruit drink (e.g. golden circle)**

Strong dislike ____ Strong like

3. **Cordial (e.g. Vitafresh)**

Strong dislike ____ Strong like

4. **Soft drink regular (e.g. Coke)**

Strong dislike ____ Strong like

5. **Soft drink- sugar free or diet varieties (e.g. Coke Zero)**

Strong dislike ____ Strong like

6. **Energy drink (e.g. V)**

Strong dislike ____ Strong like

7. **Flavoured milk/milk alternatives (e.g. Primo)**

Strong dislike ____ Strong like

8. **Iced coffee**

Strong dislike ____ Strong like

9. **Milk Mixer (e.g. Milo)**

Strong dislike ____ Strong like

10. **Iced Tea**

Strong dislike ____ Strong like

11. **Fruit smoothie**

Strong dislike ____ Strong like

12. <u>Yoghurt drinks (e.g. Yakult)</u>

Strong dislike ____ Strong like

13. <u>Flavoured water</u>

Strong dislike ____ Strong like

14. <u>Dessert Wine or Cider</u>

Strong dislike ____ Strong like

15. <u>Spirits with mixer (e.g. RTDs)</u>

Strong dislike ____ Strong like

16. <u>Cocktails (e.g. cosmopolitan)</u>

Strong dislike ____ Strong like

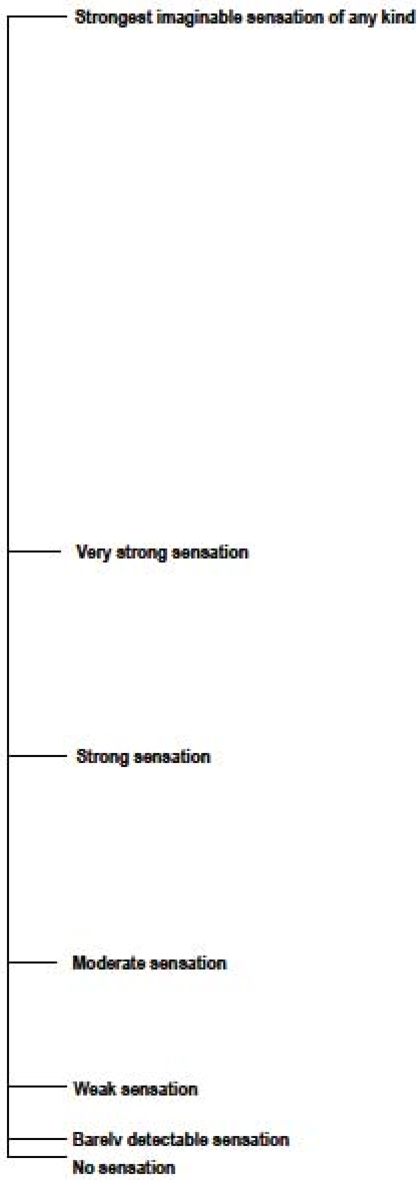
Appendix G: Sweet Taste Intensity and Hedonic Preference of Sweet Taste

Sweet taste study rating

Subject ID .... Date.................. Session # ....

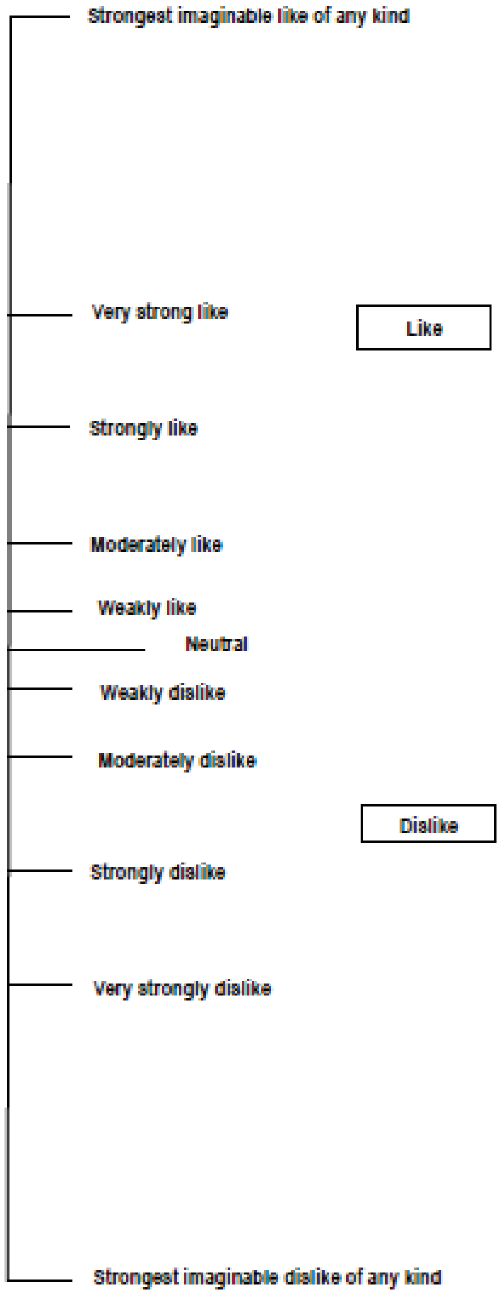
You will be given one sweet solution at a time. Please take the whole sample in your mouth and swirl it around for 3 seconds. Then spit the sample in to the waste cup and rate the following attributes of the sample you tasted by marking **anywhere** on the line. Please do not swallow any of the samples. Write the sample number next to the marking. You will taste 4 samples in total and rate attributes on the same scale.

Please rate the **sweetness** of the sample you tasted. Write the sample number next to the marking.



Please turn page

How much do you like the sweetness of the sample you tasted? Write the sample number next to the marking.



Please pass the tray to the lab and rinse your mouth with water before moving on to the next sample.

Appendix H: Sweet Taste Study Additional Results

Table H1- Association between TFEQ eating behaviours and SF-FFQ categories

FFQ category	**Cognitive restraint***		**Disinhibition***		**Hunger***	
	Correlation	*Significance*	*Correlation*	*Significance*	*Correlation*	*Significance*
Fruit DFE#	0.15	0.31	-0.01	0.94	0.18	0.24
Vegetables DFE*	0.29	0.06	0.14	0.36	0.29	0.06
Dairy DFE*	-0.09	0.58	-0.13	0.41	0.13	0.42
Cereals DFE*	0.06	0.73	-0.30	0.07	-0.00	0.99
Spreads/sweeteners DFE*	-0.07	0.69	0.08	0.62	-0.08	0.60
Baking/sweets DFE*	-0.03	0.84	0.21	0.16	0.25	0.09
Desserts DFE#	-0.19	0.22	-0.05	0.75	0.14	0.36
Beverages DFE*	-0.19	0.22	0.36	0.81	-0.01	0.96
Everyday food DFE*	0.86	0.58	-0.01	0.95	0.25	0.10
Occasional food DFE*	-0.25	0.11	0.12	0.45	0.06	0.71
Total sweet food DFE*	-0.06	0.71	-0.09	0.57	0.19	0.22

*Significant finding $P<0.05$ in bold

*Pearson's correlation used for data normally distributed

#Spearman's correlation used for data non-normally distributed

DFE= daily frequency equivalents

Table H2- Association between TFEQ eating behaviours and SF-FFQ food items

Food Items	Cognitive restraint		Disinhibition		Hunger	
	Correlation	*Significance*	*Correlation*	*Significance*	*Correlation*	*Significance*
Apricots DFE	0.23	0.13	0.12	0.43	0.18	0.24
Apples/Pears DFE	0.24	0.12	0.18	0.23	0.32	0.03
Bananas DFE	0.14	0.35	-0.01	0.97	-0.07	0.65
Berries DFE	-0.09	0.55	-0.34	0.02	-0.10	0.53
Grapes DFE	-0.04	0.78	-0.15	0.32	0.10	0.51
Kiwifruit DFE	0.05	0.75	-0.01	0.97	0.07	0.63
Mango DFE	0.00	0.99	0.02	0.92	0.29	0.05
Citrus fruit DFE	-0.13	0.40	0.04	0.80	0.17	0.26
Pineapple DFE	0.00	0.98	0.05	0.76	0.07	0.63
Feijoa DFE	0.01	0.97	-0.23	0.13	-0.16	0.29
Stone fruit DFE	0.17	0.25	0.12	0.49	0.08	0.60
Pears DFE	0.00	0.99	-0.11	0.46	-0.06	0.70
Melon DFE	-0.13	0.41	-0.20	0.20	-0.01	0.97
Dried Fruit DFE	-0.04	0.78	-0.10	0.50	0.19	0.21
Canned fruit in syrup DFE	-0.03	0.87	0.19	0.21	0.14	0.35
Canned fruit in juice DFE	0.05	0.76	0.25	0.10	0.29	0.05
Beetroot DFE	0.28	0.06	0.15	0.33	0.32	0.03
Corn DFE	-0.14	0.36	-0.02	0.88	0.09	0.57
Pumpkin DFE	0.34	0.02	0.15	0.34	0.24	0.11
Kumara DFE	0.13	0.41	0.10	0.54	0.18	0.25
Yoghurt DFE	-0.02	0.89	-0.05	0.75	0.13	0.39
Dairy food DFE	-0.10	0.50	-0.10	0.51	0.06	0.71
Yoghurt drinks DFE	0.19	0.20	0.15	0.33	-0.09	0.54
Flavoured milk & milkshakes DFE	-0.07	0.66	0.09	0.58	-0.17	0.26
Muesli DFE	-0.10	0.52	-0.12	0.45	0.26	0.08
Natural cereal DFE	0.17	0.26	0.03	0.86	0.09	0.55
Fruity cereal DFE	0.17	-0.17	-0.17	0.28	0.10	0.52
Chocolate Cereal DFE	-0.28	0.06	-0.06	0.69	-0.06	0.69
Liquid Breakfast DFE	0.32	0.03	-0.11	0.48	-0.09	0.55
Nutella DFE	0.36	0.83	0.03	0.83	-0.03	0.83

Food Items	**Cognitive restraint**		**Disinhibition**		**Hunger**	
	Correlation	*Significance*	*Correlation*	*Significance*	*Correlation*	*Significance*
Jam DFE	0.08	0.58	0.09	0.58	0.18	0.25
Marmalade DFE	0.18	0.25	0.18	0.25	0.26	0.09
Honey/Golden syrup DFE	-0.04	0.79	-0.04	0.79	0.53	0.73
Sugar DFE	0.03	0.86	0.03	0.86	-0.18	0.23
Alternative sweetener DFE	0.08	0.59	0.06	0.70	-0.14	0.37
Cake DFE	-0.24	0.12	0.09	0.54	0.05	0.74
Cheesecake DFE	0.04	0.80	-0.07	0.67	-0.30	0.04
Loaves DFE	-0.13	0.40	-0.15	0.33	-0.19	0.21
Pastries DFE	0.01	0.93	0.21	0.18	0.31	0.04
Scone DFE	0.04	0.81	0.18	0.23	0.14	0.35
Iced Buns DFE	-0.08	0.59	0.12	0.42	0.02	0.96
Tarts DFE	-0.03	0.86	0.35	0.02	0.24	0.10
Plain biscuits DFE	-0.05	0.76	0.14	0.93	0.23	0.12
Choc or cream biscuits DFE	-0.10	0.51	0.00	0.99	0.10	0.52
Pancakes/Waffles DFE	0.06	0.72	-0.05	0.73	-0.12	0.49
Muesli bars DFE	-0.03	0.86	0.06	0.68	0.20	0.18
Chocolate DFE	-0.03	0.82	0.19	0.20	0.04	0.82
Hard boiled lollies DFE	0.01	0.95	0.06	0.70	-0.07	0.64
Soft lollies DFE	-0.14	0.37	0.09	0.56	0.09	0.54
Jelly DFE	-0.02	0.88	-0.13	0.41	-0.20	0.19
Ice-cream DFE	-0.26	0.08	0.05	0.77	0.20	0.19
Ice-blocks DFE	-0.18	0.23	0.07	0.65	0.22	0.14
Sorbet DFE	0.14	0.01	0.01	0.94	0.03	0.82
Custard DFE	0.26	0.05	0.05	0.77	0.00	0.98
Dairy Desserts	-0.10	0.51	0.01	0.96	0.01	0.93
Fruit Juice DFE	-0.30	0.05	-0.04	0.79	0.19	0.23
Fruit Drink DFE	-0.16	0.29	-0.10	0.53	-0.04	0.80
Cordial DFE	-0.09	0.55	-0.05	0.77	-0.08	0.59
Soft drink regular DFE	-0.03	0.87	0.03	0.86	-0.03	0.86
Soft drink sugar free DFE	0.15	0.33	0.17	0.26	-0.07	0.65
Iced coffee DFE	-0.00	0.98	-0.04	0.77	-0.13	0.40
Milk mixer DFE	0.03	0.84	-0.06	0.69	-0.32	0.03

Food Items	Cognitive restraint		Disinhibition		Hunger	
	Correlation	*Significance*	*Correlation*	*Significance*	*Correlation*	*Significance*
Iced Tea DFE	0.13	0.40	0.07	0.65	-0.11	0.45
Fruit smoothie DFE	-0.08	0.60	-0.09	0.57	0.00	0.99
Yoghurt drink DFE	0.15	0.33	0.15	0.33	-0.09	0.57
Flavoured water DFE	0.01	0.97	-0.11	0.45	-0.14	0.37
Beer/Cider DFE	0.21	0.16	0.22	0.14	0.05	0.75
Dessert wine DFE	0.13	0.40	0.21	0.17	0.01	0.97
Spirit with mixer DFE	0.01	0.95	0.33	0.03	0.00	0.48
Cocktail DFE	-0.19	0.21	-0.18	0.25	0.02	0.88

Significant finding *P*<0.01 in bold
Spearman's correlation used for non-normal data
DFE= daily frequency equivalents

Table H3- Relationship between TFEQ eating behaviours and "sweet tooth"

Eating behaviour	Sweet tooth yes (n=27)	Sweet tooth no (n=18)	Significance
Cognitive restraint	7.33±4.17^{+}	8.61±3.82^{+}	0.30
Disinhibition	5.65 [4.29, 7.44] §	4.90 [4.44, 6.98] §	0.51
Hunger	5.59±2.72^{+}	4.78±3.15^{+}	0.36

$^{+}$Mean ± SD used for normally distributed data
§Geometric mean [95% CI]
Bold indicates a significant difference, *P*<0.05
One way ANOVA for parametric data

Table H4- Association between TFEQ eating behaviours and beverage liking

Beverage liking	**Cognitive restraint***		**Disinhibition***		**Hunger***	
	Correlation	*Significance*	*Correlation*	*Significance*	*Correlation*	*Significance*
Fruit juice*	-0.20	0.18	0.27	0.07	0.20	0.19
Fruit drink*	-0.06	0.69	0.29	0.05	0.16	0.28
Cordial*	0.09	0.58	0.31	0.04	0.04	0.81
Soft drink regular*	-0.09	0.57	0.10	0.50	0.12	0.42
Soft drink sugar free*	0.11	0.47	0.23	0.12	0.01	0.93
Energy drink[#]	0.00	0.98	0.24	0.12	0.15	0.33
Flavoured milk/milkshakes*	-0.02	0.90	0.16	0.30	-0.16	0.31
Iced coffee[#]	0.17	0.27	0.26	0.08	-0.02	0.86
Iced tea*	0.22	0.14	0.14	0.36	0.16	0.28
Fruit smoothie[#]	0.02	0.91	0.12	0.43	0.22	0.15
Yoghurt drink*	-0.10	0.51	0.05	0.78	0.12	0.45
Flavoured water*	0.10	0.51	-0.01	0.95	-0.05	0.77
Dessert wine/cider*	0.07	0.67	0.23	0.14	0.24	0.12
Spirits*	0.44	0.78	0.34	0.24	0.08	0.61
Mean beverage liking score*	0.10	0.53	**0.44**	**0.00**	0.23	0.12

*Significant finding $P<0.01$ in bold

*Pearson's correlation used for data normally distributed

[#]Spearman's correlation used for data non-normally distributed

Table H5- Relationship between SF-FFQ categories, perceived sweet taste intensity and hedonic preference of sweet taste

FFQ Category	**Perceived sweet taste intensity**		**Hedonic preference of sweet taste**	
	Correlation co-efficient	*Significance*	*Correlation co-efficient*	*Significance*
Total sweet food DFE*	-0.35	0.03	0.26	0.08
Every-day food DFE*	-0.20	0.20	0.19	0.21
Occasional food DFE*	-0.27	0.07	0.18	0.23
Fruit DFE⁺	-0.18	0.24	0.14	0.35
Vegetables DFE*	-0.03	0.86	-0.05	0.76
Dairy DFE*	-0.07	0.68	0.17	0.27
Cereals DFE*	0.07	0.97	0.05	0.75
Spreads/sweeteners DFE*	-0.08	0.62	0.14	0.38
Baking/sweets DFE*	-0.22	0.16	0.15	0.33
Desserts DFE⁺	-0.05	0.76	-0.06	0.69
Beverages DFE*	-0.28	0.68	0.21	0.17

Significant finding *P*<0.05 in bold

Pearson's correlation for normally distributed data

⁺Spearman's correlation used for non-normal data

DFE= daily frequency equivalents

Table H6- Relationship between SF-FFQ food items, perceived sweet taste intensity and hedonic preference of sweet taste

Food Item	**Perceived sweet taste intensity**		**Hedonic preference of sweet taste**	
	Correlation co-efficient	*Significance*	*Correlation co-efficient*	*Significance*
Apricots DFE	-0.01	0.95	0.14	0.37
Apples/Pears DFE	-0.03	0.87	-0.07	0.67
Bananas DFE	-0.37	0.02	0.31	0.04
Berries DFE	0.11	0.46	-0.01	0.96
Grapes DFE	0.01	0.95	-0.15	0.34
Kiwifruit DFE	-0.17	0.27	0.32	0.03
Mango DFE	-0.12	0.42	0.12	0.45
Citrus Fruit DFE	-0.05	0.75	-0.11	0.48
Pineapple DFE	0.06	0.70	-0.11	0.46
Feijoa DFE	0.02	0.89	0.02	0.90
Stone fruit DFE	-0.03	0.86	0.05	0.73
Pears DFE	-0.08	0.60	-0.03	0.84
Melon DFE	-0.12	0.45	0.01	0.96
Dried Fruit DFE	-0.33	0.03	0.16	0.30
Canned fruit in syrup DFE	-0.16	0.29	0.16	0.31
Canned fruit in juice DFE	-0.10	0.53	-0.04	0.81
Beetroot DFE	0.27	0.07	-0.14	0.37
Corn DFE	-0.25	0.10	0.13	0.41
Pumpkin DFE	0.03	0.86	-0.05	0.76
Kumara DFE	-0.03	0.82	0.05	0.75
Yoghurt DFE	0.06	0.72	0.12	0.43
Dairy Food DFE	-0.03	0.86	-0.02	0.91
Yoghurt Drinks DFE	0.10	0.51	0.02	0.89
Flavoured milk & milkshakes DFE	0.05	0.72	-0.10	0.51
Muesli DFE	0.06	0.70	-0.00	0.98
Natural Cereal DFE	0.12	0.45	0.19	0.20
Fruity Cereal DFE	0.37	0.02	-0.20	0.19
Chocolate Cereal DFE	-0.02	0.18	0.14	0.37
Liquid Breakfast DFE	-0.12	0.50	0.30	0.05
Nutella DFE	0.12	0.42	-0.02	0.89

Food Item	**Perceived sweet taste intensity**		**Hedonic preference of sweet taste**	
	Correlation co-efficient	*Significance*	*Correlation co-efficient*	*Significance*
Jam DFE	0.19	0.22	-0.09	0.56
Marmalade DFE	-0.05	0.76	-0.04	0.78
Honey/Golden syrup DFE	0.05	0.73	0.04	0.81
Sugar DFE	-0.27	0.07	0.21	0.17
Alternative sweetener DFE	-0.04	0.79	0.15	0.31
Cake DFE	-0.10	0.53	0.02	0.90
Cheesecake DFE	0.01	0.94	0.19	0.21
Loaves DFE	-0.02	0.26	-0.10	0.51
Pastries DFE	-0.02	0.89	-0.01	0.94
Scone DFE	0.15	0.33	0.02	0.91
Iced Buns DFE	-0.16	0.30	0.21	0.17
Tarts DFE	-0.04	0.82	0.05	0.73
Plain biscuits DFE	-0.01	0.93	-0.18	0.25
Choc or cream biscuits DFE	0.03	0.83	-0.08	0.60
Pancakes/Waffles DFE	-0.04	0.08	0.12	0.44
Muesli bars DFE	-0.31	0.04	0.31	0.04
Chocolate DFE	-0.03	0.84	0.17	0.29
Hard boiled lollies DFE	-0.19	0.21	-0.04	0.77
Soft lollies DFE	0.14	0.36	-0.00	0.98
Jelly DFE	0.08	0.62	-0.08	0.62
Ice-cream DFE	0.01	0.94	-0.11	0.46
Ice-blocks DFE	-0.06	0.69	-0.10	0.52
Sorbet DFE	0.03	0.82	0.02	0.87
Custard DFE	-0.03	0.86	0.02	0.89
Dairy Desserts	0.02	0.91	0.03	0.86
Fruit Juice DFE	-0.14	0.36	0.15	0.07
Fruit Drink DFE	-0.2	0.18	0.07	0.63
Cordial DFE	0.01	0.96	-0.02	0.89
Soft drink regular DFE	-0.09	0.55	-0.09	0.55
Soft drink sugar free DFE	0.04	0.78	-0.01	0.94
Iced coffee DFE	0.24	0.12	-0.06	0.72
Milk mixer DFE	-0.02	0.92	-0.16	0.29

Food Item	**Perceived sweet taste intensity**		**Hedonic preference of sweet taste**	
	Correlation co-efficient	*Significance*	*Correlation co-efficient*	*Significance*
Iced Tea DFE	0.23	0.12	-0.23	0.14
Fruit smoothie DFE	-0.06	0.72	0.19	0.21
Yoghurt drink DFE	0.15	0.33	-0.10	0.53
Flavoured water DFE	0.31	0.04	-0.27	0.08
Beer/Cider DFE	-0.02	0.93	-0.01	0.96
Dessert wine DFE	0.05	0.75	-0.01	0.93
Spirit with mixer DFE	-0.10	0.51	0.09	0.58
Cocktail DFE	-0.07	0.64	0.11	0.47

Significant finding $P<0.01$ in bold

Spearman's correlation used for non-normal data

DFE= daily frequency equivalents

Table H7- Relationship between beverage liking, perceived sweet taste intensity and hedonic preference of sweet taste

Beverage liking	**Perceived sweet taste intensity**		**Hedonic preference of sweet taste**	
	Correlation co-efficient	*Significance*	*Correlation co-efficient*	*Significance*
Mean beverage liking score*	-0.10	0.50	0.16	0.31
Fruit juice*	**-0.43**	**0.00**	**0.35**	**0.02**
Fruit drink*	**-0.45**	**0.00**	0.25	0.10
Cordial*	-0.09	0.54	-0.07	0.66
Soft drink regular*	-0.26	0.08	0.12	0.43
Soft drink sugar free*	0.02	0.90	0.10	0.52
Energy drink#	-0.09	0.55	0.16	0.29
Flavoured milk/milkshakes*	-0.06	0.68	0.22	0.15
Iced coffee#	0.01	0.95	0.14	0.35
Iced tea*	0.26	0.09	-0.22	0.15
Fruit smoothie#	-0.01	0.94	0.20	0.18
Yoghurt drink*	0.21	0.17	0.05	0.76
Flavoured water*	0.18	0.25	-0.21	0.16
Dessert wine/cider*	-0.01	0.97	-0.05	0.74
Spirits*	-0.15	0.32	0.04	0.08

*Significant finding $P<0.05$ in bold

*Pearson's correlation used for data normally distributed

#Spearman's correlation used for data non-normally distributed

Table H8- Differences in hedonic preference of sweet taste score based on sweet food related eating behaviours

Sweet food related eating behaviour	***P* value**
"Sweet tooth"	0.92
Food cravings	0.74
Sweet snack preference	0.12
Snacks during the day	0.42

Independent t-test for parametric data
*Significant finding $P<0.05$ in bold

Table H9- Relationship between perceived sweet taste intensity, hedonic preference of sweet taste and TFEQ eating behaviours

TFEQ eating behaviours	**Perceived sweet taste intensity**		**Hedonic preference of sweet taste**	
	Correlation co-efficient	*Significance*	*Correlation co-efficient*	*Significance*
Cognitive restraint	0.12	0.48*	0.01	0.97*
Disinhibition	-0.20	0.19*	0.20	0.20*
Hunger	-0.07	0.67*	0.10	0.52*

Significant finding $P<0.05$ in bold
*Pearson's correlation used for data normally distributed
#Spearman's correlation used for data non-normally distributed