Gut Health in New Zealand Vegans: The Relationship Between Dietary Fibre and Gastrointestinal Symptoms.

A thesis presented in partial fulfilment of the requirements for the degree of

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Abstract

Background: Dietary guidelines recommend adequate dietary fibre intake to support normal laxation and gastrointestinal (GI) health. However, excess intake of some fibre types may lead to the onset of gaseous GI symptoms. Internationally, many vegans exceed the dietary fibre recommendations; however, no studies have investigated its link to reports of GI symptoms. Meanwhile, the gut health and dietary fibre intake of NZ vegans have not been investigated; thus, research is needed.

Aim: To investigate the relationship between dietary fibre intake and gastrointestinal symptoms among NZ Vegans.

Methods: As part of the Vegan Health Research Programme, this cross-sectional study recruited adults aged ≥18yrs who had followed a strict vegan diet for at least two years. Health and demographic data were obtained from questionnaires. Participants completed a 4-Day Food Record to investigate dietary fibre intake, which was compared to the NZ median intake and Nutrient Reference Values (NRVs) for the dietary fibre Adequate Intake (AI) and Suggested Dietary Target (SDT) recommendations. A Gastrointestinal Symptom Rating Scale (GSRS) questionnaire was completed by the participants to investigate the prevalence and severity of GI symptoms. A binary logistic regression analysis was conducted to determine whether there was a correlation between GSRS outcomes and dietary fibre intake.

Results: Across the GSRS domains, no correlations were found between dietary fibre intake and reports of GI symptoms due to minimal variance in vegans' GSRS scores. Overall, participants (n= 212) reported minimal GI symptoms, ranging on average from 'no discomfort – minor discomfort' (GSRS scores 1-2) across the GSRS domains. Females reported worse symptoms of abdominal pain ($p=0.02$) and indigestion ($p<0.001$) than males, while younger participants experienced more abdominal pain than older participants ($p=0.03$), as examined through modelling a binary logistic regression analysis inclusive of dietary fibre intake (g/day), sex, age and BMI. Dietary fibre intake exceeded the NZ median intake (20g/day), averaging 45.91g/day (25^{th}, 75^{th} percentile, 36.33 to 54.75g/day); 97% of participants exceeded the NZ NRV Adequate Intake (AI) (25-30g/day), 90% exceeded the Suggested Dietary Target (SDT) (28-38g/day). While males consumed more dietary fibre than females (52.62g/day *versus*. 42.24g/day), females had greater energy-adjusted dietary fibre intakes than males (22.21g/1000kcal *versus*. 20.54g/1000kcal). Finally, the major sources of dietary fibre were legumes, bread, fruit, oats, and vegetables.

Conclusion: NZ vegans experience minimal GI symptoms, while their dietary fibre intake exceeds the NZ NRV recommendations and population median intake. Overall, there were no associations between high dietary fibre intake and reports of GI symptoms among NZ vegans.

Keywords: vegans, GI symptoms, dietary fibre**,** GSRS, gut health.

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List of Abbreviations

AI	Adequate Intake (NRV)
BM	Bowel movement
BMI	Body Mass Index
BSFS/BSS	Bristol Stool Form Scale / Bristol Stool Scale
CD	Coeliac disease
g	Grams
g/1000kcal	Grams per 1000 kilocalories
g/day	Grams per day
GERD	Gastroesophageal reflux disease (AmE)
GI	Gastrointestinal
GIT	Gastrointestinal tract
GSRS	Gastrointestinal Symptom Rating Scale
GORD	Gastro-oesophageal reflux disease (BrE)
DF	Dietary fibre
EI	Energy intake
FC	Functional constipation
FD	Functional dyspepsia
IBD	Inflammatory Bowel Disease
IBS	Irritable Bowel Syndrome
IDF	Insoluble dietary fibre
Kcal	Kilocalorie
Kg	Kilogram
n	Number
NRV	Nutrient Reference Values
NZ	New Zealand
PUD	Peptic ulcer disease
SCFA	Short-chain fatty acids
SD	Standard Deviation
SDF	Soluble dietary fibre
SDT	Suggested Dietary Target
SIBO	Small intestinal bacterial overgrowth

UC	Ulcerative colitis
UL	Upper Limit
yrs	Years old
±	Plus-minus

Chapter 1.0: Introduction

1.1 Background

Dietary fibre, an indigestible carbohydrate of plant origin, is essential for maintaining gut health (FSANZ, 2016; National Health and Medical Research Council et al., 2006). Dietary fibre regulates digestion, absorption, transit time, and stool formation by facilitating the movement of food through the digestive system (Gill et al., 2021). This, in turn, promotes normal bowel function and regular laxation (Cummings, 1984; McRorie & McKeown, 2017), preventing and alleviating constipation and diarrhoea (Stephen & Cummings, 1980; McRorie et al., 1998; Singh, 2007). Meanwhile, through dietary fibres' ability to dilute carcinogens by increasing stool bulk (Weisburger et al., 1993), and modulate gut bacteria (Lim et al., 2005), its preventative role in the pathology of colon cancers (Bingham, 1990; Loius et al., 2014) and gastrointestinal disease (Burkitt et al., 1974; Gasaly et al., 2015) has been well described.

Due to the health benefits of dietary fibre, individuals are recommended to consume a fibre-rich diet through a variety of fruits, vegetables, legumes, nuts, seeds and grains, mostly wholegrain and those naturally high in fibre (Ministry of Health, 2020). In New Zealand (NZ), an Adequate Intake (AI) of 25-30g/day has been established based on population median intakes in healthy populations in Australia and NZ. This provides an estimate of adequate requirements for normal GI function and laxation. A Suggested Dietary Target (SDT) of 28-38g/day has also been set to reduce chronic disease risk (The National Health and Medical Research Council et al., 2006). No Upper Limits (UL) have been established due to the recognition that dietary fibre has no significant adverse effects on human health, even at large doses (Gordon et al., 1995).

While dietary fibre intake should not be limited, certain fibre types may trigger gastrointestinal (GI) symptoms. Large intakes of short-chain, non-viscous soluble, and highly fermentable dietary fibre can lead to imbalances within the GI tract (GIT) due to their slow transit time. This has been associated with an increased risk of rapid fermentation by bacteria and consequent gas production (Chutkan et al., 2012). Such physiological responses may provoke GI symptoms such as abdominal pain and discomfort, bloating, distension and flatulence (Alyousif et al., 2020; Borkoles et al., 2022; Gonlachanvit et al., 2004). For example, high intakes of legumes may increase the onset of flatulence (Othman et al., 2023; Price et al., 1988). Given international studies (Davies et al., 1985; Larsson & Johansson,

2005) have reported that people following a vegan diet have high intakes of these potentially symptom-provoking foods, these outcomes may be problematic within this population. It has also been reported that people adhering to fibre-rich diets may experience greater digestive symptom burden, including flatulence and borborygmus, compared to those on Western-type diets (Barber et al., 2021).

To our knowledge, the link between dietary fibre intake and GI symptoms has not been investigated exclusively among vegans. Nonetheless, studies have found that vegan dieters may experience greater bowel motion frequency compared to meat-eaters (Panigrahi et al., 2013; Sanjoaquin et al., 2004). This may be attributed to the higher dietary fibre intake among vegans than those who eat meat (Sliz et al., 2021). Commonly, vegans consume greater quantities of fruits, vegetables, wholegrains, legumes and nuts than meat-eaters (Davies et al., 1985; Larsson & Johansson, 2005). Thus, while the majority of New Zealanders do not consume enough dietary fibre (Ministry of Health, 2011), it can be hypothesised that vegans among the population do. This aligns with international research, which has shown that vegan populations vastly exceed the suggested dietary fibre recommendations (Neufingerl & Eilander, 2021); however, analyses are yet to be conducted within NZ, thus research specific to the local context is required.

Due to conflicting evidence that some types of fibre may cause GI symptoms, it is of interest to investigate these outcomes among individuals who may adhere to fibre-rich diets. Therefore, the aim of this study is to investigate the relationship between dietary fibre intake and gastrointestinal symptoms among NZ Vegans. In addition, the most common food sources of dietary fibre will be identified and compared to NZ intakes. This study will provide insight into the relationship between dietary fibre intake and GI symptoms in vegans.

1.2 Purpose

The purpose of this study was to investigate gut health among NZ vegans, specifically with regard to GI symptoms and dietary fibre intake. Although there is evidence on the effects of different fibre types on GI symptoms across various population groups, there is limited research among vegans. Furthermore, no previous studies have explored gut health and dietary fibre intake among NZ vegans. This study may provide insight into the benefits or drawbacks of the vegan diet on gut health.

1.3 Aim

To investigate the relationship between dietary fibre intake and gastrointestinal symptoms among NZ Vegans.

1.3.1 Objectives

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1. To explore gastrointestinal symptoms in vegans using the Gastrointestinal Symptom Rating Scale (GSRS) tool.
2. To assess whether dietary fibre intake is associated with gastrointestinal symptoms among vegans.
3. To assess the dietary fibre intake of vegans, from a 4-day food diary, and compare to the NZ Nutrient Reference Values (AI and SDT) and NZ median intake.
4. To identify the major food sources of dietary fibre among NZ vegans.

1.3.2 Hypotheses

1. Vegans exceeding the SDT, and those not meeting the AI, dietary fibre recommendations may experience higher GSRS scores.
2. Vegans will exceed the NZ Nutrient Reference Values for dietary fibre recommendations with respects to both the AI (25-30g) and SDT (28-38g).
3. Vegans dietary fibre intakes will exceed the NZ median intake of 20g/day.

1.4 Thesis Structure

This thesis includes four main chapters. Chapter 1 presents the scope and justification of the study, including its aims, objectives and hypotheses. Chapter 2 reviews the related literature whereby we discuss gut health in vegans, and the role of dietary fibre in gut health and its association with GI symptoms. This chapter also reviews gastrointestinal health- and dietary-assessment tools. Chapter 3 of the thesis is presented as a research manuscript, including an abstract, introduction, methods, results, and discussion. The final chapter includes a brief overview of the study findings and their significance, the strengths and limitations of the research, and further recommendations for future research. This is followed by the studies references and appendices.

1.5 Researcher Contributions

Chelsea Corkindale MSc Human Nutrition & Dietetics Candidate	The primary author of this thesis and responsible for statistical analysis, reviewing literature, and writing and preparing the thesis chapters, manuscript and conclusions. Member of the vegan research team with a role in food dairy data entry.
Prof. Cathryn Conlon Primary Supervisor	Responsible for supervising, participant recruitment, assisting with the research proposal, and editing and preparation of the manuscript.
Prof. Pamela von Hurst Co-Supervisor	Principal Investigator for the vegan study. Responsible for supervising overall study management.
Prof. Kathryn Beck Research Assistant	Co-investigator on the vegan study. Responsible for participant recruitment, study advertisement, data collection and sorting, and FoodWorks data entry, sorting and analysis.
Dr. Karen Mumme Statistician	Responsible for sorting data, assisting with statistical analysis for the vegan study, and review of the data analysis plan.
Rebecca Paul Research Assistant	Responsible for participant recruitment, and FoodWorks data entry, sorting and analysis.
Dr. Hajar Mazahery Project Manager	Responsible for managing all aspects of recruitment, data collection and quality control.

Chapter 2.0: Literature Review

2.1 Introduction

This literature review explores dietary fibre intake and gut health among vegans, including the gastrointestinal-related symptoms and benefits of dietary fibre intake, dietary fibre recommendations, gastrointestinal symptoms assessment tools, and dietary assessment methods. Online databases were searched (Google Scholar, Massey Discover, PubMed, Web of Sciences, Science Direct) to identify relevant literature. Statistics and recommendations within NZ were derived from the National Health and Medical Research Council et al. (2006) and the Ministry of Health (2011, 2020). The search strategy (Figure 1)was based off the study objectives . Keywords and combinations were identified in free text, research titles, and abstracts to search the databases. Reference lists of relevant articles were also examined. Only articles published in English (BrE, AmE) before August 2023 were searched.

Figure 2.1: Search Strategy for Literature Review

Date searched: November 2022 - August 2023

Search criteria:
Vegans OR vegan diet OR veganism
Dietary fibre OR fibre OR indigestible carbohydrates
Soluble fibre OR insoluble fibre OR fermentable fibre
Excess dietary fibre OR inadequate dietary fibre OR optimal dietary fibre
Intake OR diet OR consumption
Gut health OR gastrointestinal health
Gut symptoms OR digestive symptoms OR gastrointestinal symptoms OR abdominal discomfort OR abdominal pain OR bloating OR flatulence OR indigestion OR reflux
Bowel motions OR bowel regularity OR stools OR laxation OR constipation OR diarrhoea (BrE) / diarrhea (AmE)

Filters:
Past 5 years, past 10 years, past 15 years

Electronic databases:
Massey Discover, Google Scholar, PubMed, Web of Sciences.

2.2 Dietary Fibre

2.2.1 Definition

Dietary fibre is an indigestible carbohydrate of plant origin and is considered an essential nutrient for gut health (National Health and Medical Research Council et al., 2006).
Food Standards Australia NZ (FSANZ, 2016) define *dietary fibre* as the portion of plants that resists digestion and absorption in the small intestine, usually undergoing complete or partial fermentation in the large intestine. The main physiological benefits of dietary fibre include promoting laxation, reducing blood cholesterol, and modulating blood glucose (Cummings, 1984; FSANZ, 2016) and gut bacteria (Lim et al., 2005). Meanwhile, the role of dietary fibre in the pathology of gastrointestinal cancers (Bingham, 1990; Loius et al., 2014) and disease (Burkitt et al., 1974; Gasaly et al., 2015) has been well studied.

2.2.2 Types and Characteristics of Dietary Fibre

The primary classes of dietary fibre include celluloses, hemicelluloses, beta-glucans, pectins, gums and mucilages, oligosaccharides, resistant starches and lignins (FSANZ, 2016.). These fibre types behave differently within the GIT due to their structural variability (Williams et al., 2019). Therefore, each dietary fibre class exerts unique health benefits (Chutkan et al., 2012). Due to these structural differences, dietary fibre may be defined by its viscosity, fermentability (fermentable and non-fermentable fibre), or solubility (soluble and insoluble fibre). While dietary fibre is most commonly classified by its solubility- soluble or insoluble, most fibre-rich foods are often a mix of both fibre types rather than one exclusively (Chutkan et al., 2012).

Insoluble Fibre

Insoluble dietary fibre includes cellulose, lignin, waxes, chitins, resistant starch, and some hemicelluloses (Ionita-Mindrican et al., 2022). These portions of dietary fibre do not dissolve in water and are indigestible by enzymes within the GIT; thus, they remain mostly intact throughout the large intestine (Jimenez-Escrig & Sanchex-Muniz, 2000; Tian et al., 2022). Most insoluble dietary fibre is poorly fermented compared to soluble fibre (Chutkan et al., 2012). However, fermentable insoluble fibre may act prebiotically to enhance the growth and activity of beneficial bacteria in the GIT, thus improving host gut health (Eswaran et al., 2013; Gibson & Roberfroid, 1995).

Soluble Fibre

Soluble dietary fibre includes pectin, inulin, gums, mucilage, phytates and some hemicellulose (Ionita-Mindrican et al., 2022). Unlike insoluble fibre, soluble fibre readily dissolves in water. These fibre types may be further subdivided by viscosity, that is, those that are viscous and those that are non-viscous (mostly fermentable). High-viscosity dietary fibre absorbs water to form gel-like substances when hydrated, while non-viscous dietary fibre does not. Many health benefits are attributed to the gel-forming properties of soluble dietary fibre; thus, the term 'viscous' was introduced to emphasise the physiological advantages of these fibre types (Anderson et al., 2009).

Fermentable Fibre

Fermentable fibre includes inulin, beta-glucans, pectins, wheat dextrin and guar gum (Slavin et al., 2009). Although most dietary fibre types ferment within the GIT to some extent, soluble fibre ferments more readily than insoluble fibre (Weickert & Pfeiffer, 2008). The process of fermentability depicts the rate and extent to which dietary fibre is broken down within the large intestine by gut bacteria. During this process, fermentable fibre provides fuel for the bacteria within the gut. As a result, this assists with the production of gases and SCFA's- acetate, propionate and butyrate, creating a prebiotic effect (Blaak et al., 2020; Silva et al., 2020). On the other hand, nonfermentable dietary fibre primarily includes insoluble fibre (e.g. wheat bran and cellulose). However, some soluble viscous fibre (e.g. psyllium) may also resist fermentation (Chutkan et al., 2012; Cockburn & Koropatkin, 2014). Some dietary fibre types may also have insoluble and soluble fibre characteristics, yet behave in the GIT like soluble fibre whereby it is fermented, such as resistant starch (RS) (McRorie & McKeown, 2017). These are categorised into four types (R1-4), with some providing the benefits of insoluble fibre and others of soluble fibre (Rosin et al., 2002).

2.2.3 Sources of Dietary Fibre

According to FSANZ (2016), for a food to be classified as a source of fibre, it must contain no less than 2.0g of fibre per serving of food. Foods with dietary fibre contents above 4.0g and 7.0g per serving are deemed good and excellent sources, respectively. Dietary fibre is found in plant foods, including fruit, vegetables, nuts, seeds and grains (e.g., barley, corn, maize, oats, quinoa, rye, wheat), breakfast cereals, and wholegrain bread, pasta and rice. Dietary fibre is not found naturally in meat, milk, cheese and eggs. However, food

manufacturers may add dietary fibre to meat products, beverages, and bakery products as functional food ingredients due to its health benefits in the human diet (Yegin et al., 2020).

All plant-based foods contain two types of fibre: soluble and insoluble. While insoluble fibre is usually the primary fibre type found in plant foods, some may have slightly soluble properties (Anderson et al., 1994). These soluble fibre-rich foods include dried beans, oats, and certain fruits and vegetables (Anderson et al., 1994). Typically, foods that contain higher quantities of pectins, gums, beta-glucans, and/or oligosaccharides are considered soluble fibre, and foods highest in cellulose and lignin are regarded as insoluble fibre; among these, the latter is most common. As a result, a food may be deemed a good source of soluble fibre, yet classified as an insoluble fibre due to a higher presence of cellulose and/or lignin. For example, legumes are considered to be rich sources of soluble fibre, yet many are classified as insoluble fibre (Khan et al., 2007; Schakel et al., 2001).

Resistant starch is found in various foods, depending on its structure. Naturally occurring resistant starches (RS1-RS3) are found in starchy foods with seeds or germ (RS1) (e.g. unprocessed wholegrains and legumes), uncooked potato and unripe banana (RS2), and starchy foods that have been cooled following cooking (RS3) (e.g. leftover potato, rice, pasta and oats). Chemically modified resistant starch (RS4) is found in starchy foods that have been synthetically altered (e.g. commercial bread and baked goods) (Bojarczuk et al., 2022).

Table 2.1 (below) illustrates a range of dietary fibre sources indicating the variability in DF content and their predominant fibre type (soluble *versus* insoluble).

Table 2.1: Food Sources of Dietary Fibre

Food source	**Total DF** **(per cup, unless specified)[1]**	**Predominant DF type [2]**
Fruits – fresh		
Apple, unpeeled, raw	2.7g (1 fruit)	Insoluble
Avocado, raw	8g (1 fruit)	Insoluble
Banana, yellow, ripe, raw	2g (1 fruit)	Insoluble
Blueberry, raw	6.1g	Insoluble
Kiwifruit, green, raw	2.2g (1 fruit)	Insoluble
Pear, raw	3.9g (1 fruit)	Insoluble
Fruits – dried		

Apricot, dried	12.5g	Soluble / Insoluble*
Cranberry, dried	7.3g	Insoluble
Date, dried	18.2g	Insoluble
Prune, dried	13.3g	Soluble
Vegetables		
Beetroot, flesh, boiled	4.5g	Soluble / Insoluble*
Broccoli, cooked	2.8g	Soluble / Insoluble*
Brussel sprout, steamed	5.7g	Soluble
Carrot, raw	2.6g	Soluble
Corn, whole kernels, raw	3.5g	Insoluble
Potato, baked	2.9g	Insoluble (with skin); Soluble (skinless)[3]
Legumes & Pulses		
Black beans, boiled	15.8g	Soluble
Chickpeas, cooked	13.1g	Insoluble
Dried peas, spit, boiled	7.6g	Insoluble
Kidney beans, boiled	13g	Soluble / Insoluble*
Lentils, split, boiled	7.4g	Insoluble
Pinto beans, cooked	14.8g [4]	Insoluble
Grains and cereals		
Bread, wheat	2.4g (1 toast slice)	Insoluble
Muesli (mixed varieties)	11.3g – 14.3g	Insoluble
Oat bran	18.4g	Soluble
Rice, brown, boiled	1.8g	Insoluble
Rolled oats, cooked	11.7g	Soluble
Weet-Bix, Sanitarium	2.6g (1 biscuit)	Insoluble
Wheat bran	28.2g	Soluble
Quinoa, cooked	4.1g	Insoluble
Nuts & Seeds		
Almonds, raw	11.8g	Insoluble
Cashews, raw	8.1g	Insoluble
Chia seeds, raw	31.9g (100g)	Soluble
Peanuts, raw	12.3g	Soluble / Insoluble*
Psyllium husk	4.5 (5g)	Soluble

Sesame seeds, raw	11.8g (100g)	Insoluble

[*] Indicates approximately even IDF/SDF ratios.
[1] New Zealand Food Composition Database (2022). [2] Anderson (1990); Khan et al (2007), Schakel et al (2001); New Zealand Nutrition Foundation (2022) [3] Mullin & Smith (1991).

2.2.4 Role of Dietary Fibre in Gut Health

Dietary fibre is an essential nutrient within the metabolic and physiological pathways of the gastrointestinal tract (GIT). It plays a pivotal part in intestinal health, promoting laxation and aiding bowel motion regularity, thus preventing constipation (Cummings, 1984; McRorie & McKeown, 2017; Rijnaarts et al., 2022). Three main mechanisms influence the response of dietary fibre. Firstly, it can act on the regulation of satiety and control of food intake (Howarth et al., 2001; Salleh et al., 2019). This relates to the feedback mechanism at the GIT shortly after digestion, inhibiting proximal gastrointestinal motility and secretion (Capuano, 2017). Secondly, dietary fibre modulates digestive processes, increasing stool bulk by absorbing water, thus reducing gastric transit time and enabling easy-to-pass, soft stools (Burkitt et al., 1972). Through these modulatory effects, dietary fibre may also prolong the period in which contact between toxins and the GIT can be made, thus reducing the risk of colorectal cancers (Bingham, 1990; Bingham et al., 2003). Lastly, dietary fibre acts as an energy source for microbial fermentation by commensal bacteria upon entry into the colon, resulting in the production of gases and short-chain fatty acids (SCFAs) (Chinda et al., 2004).

A fibre-rich diet, particularly one high in fermentable fibre, is required for adequate production, absorption and metabolism of SCFA's, notably butyrate (Cuervo et al., 2013; Leonel & Alvarez-Leite, 2012). SCFAs fuel intestinal epithelial cells by acting as an energy source for the gut (Silva et al., 2020). SCFAs improve gut health through several local effects. This includes maintaining intestinal barrier integrity, regulating mucus production, luminal pH and mucosal immunity, and reducing inflammation (Blaak et al., 2020; Zhang et al., 2015). Through these mechanisms, adequate dietary fibre intake may protect against gastrointestinal disease (Burkitt et al., 1974; Dahl et al., 2017; Gasaly et al., 2015; Loius et al., 2014). Consequently, individuals on low-fibre diets may be more susceptible to gastrointestinal conditions and, thus, unfavourable GI symptoms. The GI benefits of dietary fibre are illustrated in Table 2.2 (below).

Table 2.2: GI Health Benefits of Dietary Fibre

GI health benefit		Systemic/GIT cause of DF
Normalises bowel movements	Prevention and alleviation of constipation	Insoluble, non-fermentable DF aids in stool bulk & softening. [1-2] Formation of viscous fibre binds water, causing loosened stool. [3]
	Alleviation of diarrhoea	Formation of viscous fibre linked to delayed gastric emptying. [4-5]
Maintenance of bowel health	Strengthening of the gut barrier Regulation of gut health and inflammation Protection towards various GI diseases[7]	Increases microbial diversity & abundance, fermentation end-products (e.g. SCFA's- energy for colonocytes, inflammatory and immunity regulation, colonization resistance of pathogens).[6-9]
Anticarcinogenic effects	Reduced risk of colorectal cancers	Increases stool mass, diluting carcinogens - reduced carcinogen interaction with gut mucosa. [10-12]
Appetite regulation	Increased perceived satiety [5, 13]	Slows digestion, particularly of carbohydrates and fats. [7, 14] SCFA's, following dietary fibre ingestion, modulate appetite-regulating hormones. [15]

[1] McRorie & McKeown (2017). [2] Stephen & Cummings (1980). [3] McRorie et al. (1998). [4] Singh (2007). [5] Salleh (2019). [6] Silva et al. (2020). [7] Blaak et al. (2020). [8] Zhang et al. (2015). [9] Dahl et al. (2017). [10] Weisburger et al. (1993). [11] Bingham (1990). [12] Bingham et al. (2003). [13] Howarth et al. (2001). [14] Burton-Freeman (2000). [15] Delzenne et al., (2005).

2.2.5 Dietary Fibre and GI Symptoms

Dietary fibre may relieve digestive symptoms among those with chronic GI conditions and healthy populations. The laxation benefits of dietary fibre have been well described (Cummings, 1984; McRorie et al., 1998; Singh, 2007), while it may also improve GI symptoms of abdominal pain/discomfort, bloating and flatulence in those with IBS (Bijkerk et al., 2009; Chutkan et al., 2012; El-Salhy et al., 2017. In addition to these effects, dietary fibre may reduce symptoms of reflux in healthy populations and those with gastro-oesophageal reflux disease (GORD) (DiSilvestro et al., 2011; Morozov et al., 2018). However, these effects depend on the constituents of a host's food intake, as different fibre types elicit distinct physiological responses (section 2.2.2).

Soluble fibre may soften stools in constipated individuals by enabling an increase in stool water content (McRorie et al., 1998). On the other hand, soluble fibre that is viscous and non-fermentable (e.g. psyllium) can alleviate diarrhoea by improving stool consistency (Singh, 2007). This is because the formation of viscose substances delays gastric emptying, thus assisting with bowel motion regulation (Salleh et al., 2019). However, only soluble fibre with moderate to high viscosity can modulate stool consistency; a reduction in fibre viscosity (i.e. soluble non-viscous fibre) will attenuate these outcomes (Anderson et al., 2009; Chutkan et al., 2012). While soluble fibre may alleviate diarrhoea and constipation, those that are insoluble may only provide benefits of the latter.

Insoluble fibre that is minimally fermentable facilitates the increase in fecal mass, thus assisting with the movement of material through the digestive system (Stephen & Cummings, 1980). Similarly, large/coarse particles of insoluble fibre (e.g., wheat bran, cellulose, lignin) mechanically irritate the mucosa of the large intestine, therefore leading to the secretion of water and mucous, resulting in soft and bulky stools (McRorie & McKeown, 2017). Through these mechanisms, most insoluble fibre promotes regularity and laxative benefits, thus assisting in preventing and treating constipation. However, insoluble fibre that is fine/smooth (e.g., finely ground wheat bran) adds to the dry mass of stools, therefore resulting in a constipating effect with harder stools and increased strain (McRorie & McKeown, 2017).

While large/coarse insoluble fibre and viscous soluble fibre provide laxation benefits, similar to non-fermentable fibre (McRorie & McKeown, 2017), some dietary fibre types may cause gastrointestinal discomfort. Large intakes of short-chain, non-viscous soluble, and highly

fermentable dietary fibre may increase the risk of abdominal pain and discomfort, bloating/distension and flatulence (Alyousif et al., 2020; Burns et al., 2018; Chutkan et al., 2012; Gonlachanvit et al., 2004). The slow transit time of these fibre types may cause imbalances within the GIT, which can result in rapid bacterial fermentation and consequent gas production that cannot be adequately eliminated (Chutkan et al., 2012). Foods rich in fructans, such as onions, garlic, cabbage, broccoli, wheat, couscous and barley (Fedewa & Rao, 2014), are included in those that may trigger gastrointestinal discomfort symptoms in some individuals. These symptoms may arise due to their highly fermentable properties and low digestibility (Mutuyemungu et al., 2023), with humans only absorbing 5-15% of fructans (Donahue et al., 2010). Likewise, legumes and other foods rich in raffinose-type oligosaccharides may cause flatulence and abdominal discomfort in some individuals due to the lack of the alpha-galactosidase enzyme in humans (Othman et al., 2023; Price et al., 1988). As vegans tend to consume large intakes of legumes (Davies et al., 1985; Larsson & Johansson, 2005), it may be hypothesised that these populations experience high burdens of flatulence symptoms. However, no analyses have investigated these outcomes, thus research is required. Other studies analysing dietary fibre's effects on GI symptoms are depicted in Table 2.3 (below).

Table 2.3: Studies Investigating GI Symptoms Following Dietary Fibre Administration

Study design	GI Assessment tools	Participants	Duration of study	Intervention/ Type & Dose of Fibre	Main findings	Reference (Country)
Randomised, double-blind, crossover study	GSRS, BSFS, Daily GI symptom questionnaire (abdominal cramping & noises, bloating, constipation, diarrhoea, flatulence)	Healthy, older adults (>60y), free of GI concerns (n = 31)	10 weeks	10g Pea Hull Fibre (PHF) cookies (2x/d) (9.3g/d DF) (n= 31) ***vs.*** No added fibre cookies (control) (0g DF) (n= 31)	PHF increased daily symptoms of bloating (P =<0.0 5), abdominal noises (P = <0.01) and flatulence (P = <0.05); no changes in GSRS scores, stool form or frequency in older adults with normal bowel habits.	Alyousif et al., 2020. (United States)
Prospective cross-over study	Jejunal gas perfusion	Healthy adults (19 - 46y), free of GI concerns (n = 10)	2 weeks	30g/d psyllium ***vs.*** standard diet	Supplementation with psyllium resulted in increased gas production; high dietary fibre intake may elicit symptoms of gas by promoting gas retention.	Gonlachanvit et al., 2004. (United States)

Randomized, controlled, double-blind, three-intervention crossover study	GSRS, BSFS	Healthy adults (18- 50y), inadequate DF intake, free of GI concerns (n= 51)	18 weeks	25g/d resistant maltodextrin (RMD) (n= 17) ***vs.*** 15g/d resistant maltodextrin & 10g maltodextrin (MD) (n= 18) ***vs***. 0g/d resistant maltodextrin & 25g maltodextrin (n= 16)	High fermentable soluble dietary fibre (25g/d RMD) increased stool wet weight (P= 0.011) and fecal bifidobacteria counts; no change in stool frequency or consistency (as per BSFS). Symptoms of indigestion increased with RMD, compared to MD alone (P <.001); no significant change in other GSRS scores between groups. Mean daily DF intake exceeded recommendations (14g/1000kcal) with 15g/d & 25g/d RMD.	Burns et al., 2018. (United States)
Mixed-method, feasibility randomised control trial	Gastrointestinal response and stool consistency questionnaire	Healthy adults (18- 50y), free of GI concerns (n= 38)	3 weeks	FibreMAX (two/day 25g serve of BARLEYmax) (product: 12.7g/100g DF) (n = 12) ***vs.*** FibreGRAD (two/day serves with gradual DF increase: W1- 8g, W2-	Fibre supplementation increased levels of perceived satiety, however resulted in some minor acute GI symptoms (moderate-severe flatulence and abdominal discomfort.	Borkoles et al., 2022. (Australia)

				16g, W3- 25g) (product:12.7g/100g DF) (n=11) ***vs.*** Control (two/day serves 25g placebo) (wheat flakes: 6.4g/100g DF) (n = 11)	(bloating, cramping)) that resolved following an adaptation period.	
Randomised, controlled, interventional trial	IBS-SSS	IBS (18 - 65y) (n = 275)	12 weeks	10g/d psyllium (SDF) (n = 85) **vs.** 10g/d bran (IDF) (n=97) ***vs.*** 10g/d placebo (rice flour)(n=93)	Psyllium (SDF) offers GI symptom relief in those with IBS after 4 weeks and 12 weeks at a dose of 10g daily ($P<0.05$). No significant GI-effects of bran (insoluble fibre) supplementation vs. placebo (rice flour)- only small changes noticed following 3 months of daily consumption.	Bijkerk et al., 2009. (Netherlands)
Prospective randomized, single-blinded,	GSRS, BSFS, DBHD, IBS-QoL, IBS-SSI (at study entry)	FC (n = 60), IBS-C (n= 61), Controls (n = 63) (18 – 65y)	16 weeks	2/d Zespri green kiwifruit (6g DF) (n= 184) ***vs.*** 7.5g/d psyllium (6g DF) (n= 184)	Green kiwifruit consumption associated with increase of >1.5 CSBM/week (FC: P= <0.00001, IBS-C: P= 0.0003) & greater	Gearry et al., 2023. (New Zealand, Italy, Japan)

crossover, controlled trial					improvement in GSRS scores in constipated subjects, than psyllium (FC & IBS-C- P = <0.01)	
Crossover trial	BSFS, DSSD	Chronic constipation (18 – 75y) (n= 40)	3 weeks	50g/d prunes (6g DF) (n = 40) ***vs.*** 11g/d psyllium (6g DF) (n= 40)	Prune intake associated with increased CSBM/week and improved stool consistency scores over psyllium (P = <0.05); prunes can improve symptoms of mild to moderate constipation and are more effective than psyllium in constipated subjects.	Attaluri et al., 2011. **(**United States)
Clinical trial	GSRS	Inactive UC (20 – 77y) (n = 32)	12 weeks	60g/day oat bran (20g DF) (n= 22) ***vs.*** standard diet (controls) (n= 10)	Oat bran improved symptoms of abdominal pain and gastroesophageal reflux at 12 weeks (P= <0.05), that returned at follow-up- 12 weeks after intervention; no change in GSRS indigestion, diarrhoea or constipation scores.	Hallert et al., 2003 (Sweden)

Prospective longitudinal case study	GI symptom questionnaire (abdominal pain, anal bleeding, bloating, constipation, degree of strain)	Idiopathic constipation (20 – 80y) (n= 63)	6 months	No DF (avoidance of fruit/veg, cereals/bread/rice) (n = 41) ***vs.*** Reduced DF(some fruit/veg, cereals/bread/rice) (n = 16) ***vs.*** High DF (standard diet) (n = 6).	Idiopathic constipation, and its GI-associated symptoms, can be reduced by stopping or lowering total daily DF intake.	Ho et al., 2012. (Singapore)

Abbreviations: BSFS/BSS, Bristol Stool Form Scale/Bristol Stool Scale; **CSBM,** complete spontaneous bowel movement; **DBHD/DSSD,** Daily Bowel Health Diary/ Daily Stool Symptom Diary; **FC,** functional constipation**; IBS-C**, Irritable Bowel Syndrome with Constipation; **IBS-SSS/IBS-SSI,** Irritable Bowel Syndrome Severity Scoring System/Index; **IDF**, insoluble dietary fibre; **MD**, maltodextrin; **RMD**, resistant maltodextrin; **SDF**, soluble dietary fibre; **UC**, Ulcerative Colitis; **W1-W3**, week 1-3.

2.2.6 Recommended Daily Intake of Dietary Fibre

The Nutrient Reference Values (NRVs) are used in NZ as the basis of dietary guidelines for the population. The NRV's are a set of dietary recommendations of the essential nutrients for optimal health, based on currently available scientific knowledge (National Health and Medical Research Council et al., 2006). To provide these guidelines, nutrient recommendations are usually set at the Recommended Dietary Intakes (RDIs) and Estimated Average Requirements (EARs). RDIs represent the "average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in a particular life stage and sex" (National Health and Medical Research Council et al., 2006, p. 1). EARs represent "a daily nutrient level estimated to meet the requirements of 50% of healthy individuals in a particular life stage and sex" (National Health and Medical Research Council et al., 2006, p. 1). When there is a lack of sufficient evidence to determine RDIs or EARs, Adequate Intakes (AIs) are used. These represent "the average daily nutrient intake level, based on observed or experimentally determined approximations, or estimates of nutrient intake by a group/s of supposed healthy people that are assumed to be adequate" (National Health and Medical Research Council et al., 2006, p 1).

In NZ, establishing EARs for dietary fibre intake is difficult due to difficulties in assessing stool weight that promote laxation and minimise the risk of constipation; therefore, AI recommendations are used (National Health and Medical Research Council et al., 2006). The NZ NRV AIs are derived from median dietary fibre intakes across Australasia, where problems with laxation are not common among the population (National Health and Medical Research Council et al., 2006). The AI values are set at the highest median for all age groups, with an additional allowance of just over 4g/day for men and just under 3g/day for women; this has been used to allow room for error within the food database during the completion of the surveys (National Health and Medical Research Council et al., 2006). However, these AI targets are not based on reducing chronic disease risk; therefore, the NRV's have included a Suggested Dietary Target (SDT) for both women and men, which works towards this.

Recommendations for dietary fibre in NZ vary across age brackets, genders, and stages of life (National Health and Medical Research Council et al., 2006). In the NRVs for those aged 18yrs, the AI is set at 28g/day for males and 22g/day for females. For those aged 19 to 50yrs, the AI is set at 30g/day for males and 25g/day for females. For the prevention of chronic

disease, the SDT recommendations are set at 38g/day for males and 28g/day for females. These NRV guidelines follow similar suit to dietary fibre recommendations globally, with most countries agreeing that 25-30g is adequate for the maintenance of normal laxation and health (McKeown et al., 2022). However, insufficient recent research has examined the Upper Limits (UL) of dietary fibre intake both within NZ and globally.

Setting a UL is challenging as dietary fibre is variable in composition. As different fibre types lead to diverse physiological responses, it is difficult to associate one type with a particular adverse outcome (National Health and Medical Research Council et al., 2006). However, as there is no compelling scientific evidence that dietary fibre has adverse effects on human health, even at high doses, NZ does not have a set UL (Gordon et al., 1995). Individuals should not restrict dietary fibre due to its health benefits, including in laxation and the maintenance of adequate gut function (Cummings, 1984; McRorie & McKeown, 2017). Moreover, dietary fibre may aid in the prevention of obesity and other non-communicable disease (Mayor, 2019; Salleh et al., 2019). This is owing to its low energy density and ability to modulate satiety, blood glucose and cholesterol levels (Salleh et al., 2019; Jenkins et al., 2000). Given that health authorities are increasingly prioritising preventative measures against chronic disease (Ministry of Health, 2000; Ministry of Health, 2023), dietary guidelines have been established to encourage diets rich in fibre.

2.2.7 Intake of Dietary Fibre – Vegans vs. Omnivores

Based on the Adult Nutritional Survey (Ministry of Health, 2011), NZ adults have less than optimal dietary fibre intake with, an average intake of 20g/day. Most adults ate more refined bread (25-30%) than light-grain bread (50%), while Māori, Pasifika and those living in the most socioeconomically deprived areas were likelier to choose white bread. Overall, bread was the greatest contributor to dietary fibre intake (17%), followed by vegetables (16%) – notably kumara, potato and taro, and fruit (12%). However, despite studies undertaken among the general NZ population, there is a lack of research specific to vegans within the local context. Nonetheless, research abroad (Davies et al., 1985) show that the greatest contributors to dietary fibre intake among vegans are fruit, vegetables, bread, legumes and cereal fibre, with the latter two consumed significantly more among vegans than meat-eaters.

While there is limited research on the predominant dietary fibre sources among vegans, their overall fibre intake has been studied internationally. A recent systematic review (n= 141 studies) (Neufingerl & Eilander, 2021), spanning studies across Europe, South/East Asia and North America, analysed the dietary fibre intake of vegans compared to those on omnivorous diets (i.e. meat-eaters). Individuals following a vegan diet exceeded NZ AI recommendations (44g/day) compared to meat-eaters who did not (21g/day). While these findings did not compare to the SDT (females, 28g/day; males, 38g/day), an intake of 44g/day sufficiently surpasses the NZ recommendations (National Health and Medical Research Council et al., 2006). Moreover, individual studies have reported that vegan dietary fibre intakes are vastly above the findings from this systematic review. Sliz et al. (2021) found that dietary fibre intake was 225% greater in vegans than omnivores (61.46g ± 14.26g/day (vegan) *vs*. 27.22g ± 9.13g/day (omnivores)). These results remained significant when the higher energy intake of vegans was considered (2657 kcal ± 618 kcal (vegan) *vs*. 2408 kcal ± 557 kcal (omnivores)), with the ratio of dietary fibre per 1000kcal just above double in vegans than omnivores (23g / 1000kcal *vs.* 11g / 1000kcal). While other studies (Dawczynski et al., 2022; Larsson & Johansson, 2005) have disagreed that energy intake is higher among vegans than omnivores, daily dietary fibre intake and energy-adjusted dietary fibre intake remain significantly greater among individuals following a vegan diet. Despite these studies, there remains a need for research specific to NZ to better understand dietary patterns and fibre intake among vegans within the local context.

2.3 Gut Health

2.3.1 Definition

The term ‘gut health' has no singular definition despite its wide use in medicine and scientific literature (Bischoff, 2011; Cummings et al., 2004). Nonetheless, the concept of gut health encompasses a host of beneficial factors related to the functioning of the gastrointestinal (GI) tract. These include the effective digestion and absorption of food, adequate immune response, a balanced and healthy ecosystem of microbes in the gut- termed the 'gut microbiome' (Thursby & Juge, 2017), and the absence of gastrointestinal illness, symptoms, and a sense of digestive well-being (Bischoff, 2011). Many factors influence gut health, with an individuals’ nutritional intake being key (Choct, 2009).

2.3.2 The Gut and Diet

Individuals' habitual dietary intake is considered one of the main drivers of gut health (Flint et al., 2015; Romano-Keeler et al., 2021). This may be influenced by an individual's micro- and macronutrient intakes, energy intakes, and food group consumption (Schneeman, 2008). Among these, dietary fibre, carbohydrates, protein, and fat have interchangeably integral roles in the maintenance of digestive health. These elicit varying responses within the gut due to their structural variances and, thus, digestibility (Zhang, 2022). The amount and types of nutrients consumed by an individual influence the passage of food through the GIT, thus affecting bowel motion regularity and consistency (Sensoy, 2021). In general, large dietary intakes of fruit, vegetables, grains, nuts and seeds reduce constipation risk, while low consumption of these foods may have the opposite effect (Ionita-Mindrican et al., 2022). High intakes of energy, sugar and sodium, as seen in Westernised diets (Rakhra et al., 2020), may further increase the risk of constipation (Rollet et al., 2022) in addition to functional GI disorders (Buscail et al., 2017; Goyal et al., 2021)

Establishing a healthy balance of good gut bacteria is crucial in preventing GI disorders and, thus, digestive symptoms such as abdominal pain, bloating and diarrhoea (Nishida et al., 2022; Tana et al., 2010). An imbalanced gut, also known as dysbiosis, may be attributed to the increased risk of GI complications such as IBS and IBD (Bull & Plummer, 2014). Diet is implicated as a leading factor in the susceptibility of dysbiosis due to its ability to modulate the gut microbiome (Brown et al., 2012; Martinez et al., 2021), which in turn may influence GI outcomes (Flint et al., 2015; Romano-Keeler et al., 2021).

2.3.3 The Gut and Dietary Supplements/Aids

There is growing availability of a diverse range of gut-supporting supplements and aids targeted at both healthy and GI-diseased individuals. Despite this, summarising the effects of dietary supplementation on gut health and digestive symptoms is complex. This is given that the microbial profile of the gut is variable between individuals and disease states (Hajela et al., 2015; Hills et al., 2019), which is a crucial determinant of the response to supplementation with various nutrients (Baxter et al., 2019; Hills et al., 2019). While supplements with anti-inflammatory properties (omega-3, probiotics, curcumin, butyrate, silymarin) may improve symptoms in those with inflammatory conditions such as IBD (Kiani et al., 2022; Burge et al., 2019), their effects are less studied in healthy populations.

However, some evidence suggests that prebiotics, probiotics and synbiotics may improve GI symptoms in disease states and healthy individuals. Thus, these supplements will be reviewed. Moreover, experimental studies analysing the effects of alternative high-fibre dietary supplements (psyllium, oat bran, wheat bran) have been examined in Table 2.3.

Probiotics and prebiotics have become popular among consumers owing to their health benefits (Jackson et al., 2019). Probiotics (live microorganisms) support GI health by promoting the growth and activity of good bacteria in the GIT, thus enhancing the microbial composition of the gut (Markowiak & Slizewska, 2017). Aside from the capsulated probiotic forms, prebiotics may be added to fermented foods as a functional ingredient (Lin, 2003). On the other hand, prebiotics (a specialised fermentable fibre) may support GI health by serving as a substrate for SCFA's production, thus acting as an energy source for gut bacteria (Baxter et al., 2019). The most common prebiotics include fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS), and trans-galactic-oligosaccharides (TOS) (Davani-Davari et al., 2019), while probiotics commonly include *Bifidobacterium*, *Lactobacillus acidophilus, Lactiplantibacillus plantarum* and *Saccharomyces boulardii* (Tarapatzi et al., 2022). These may be combined with strains of the prebiotic to form synbiotics which improve the viability of the probiotic within the GIT (Markowiak & Slizewska, 2017; Rioux et al., 2005).

Supplementation with prebiotics and synbiotics may support bowel health in middle-aged adults, improving stool frequency, consistency, and SCFA concentrations (Neyrinck et al., 2021; Roberfroid et al., 2010). However, some studies disagree with these findings (Wilson et al., 2019), while other researchers suggest that only specific strains of prebiotics may be beneficial (Ford et al., 2018). Irrespectively, their role in enhancing the efficacy of probiotics has been well described (Pandey et al., 2015; Topping et al., 2003). Probiotics may offer symptom relief to those with GI complications, such as IBD, IBS and gastroenteritis, through improving bowel motion frequency and quantity, abdominal pain and distention (Gionchetti et al., 2000; Roy & Dhaneshwar, 2023; Simon et al., 2021). Probiotics may also reduce stool frequency and the duration of infectious (Allen et al., 2010) and antibiotic-associated diarrhoea (McFarland, 2006). The proposed mechanism for these probiotic effects is that they may modulate immune response and compete for binding sites against enteric pathogens (Alander et al., 1997; Perdigon et al., 1995). Despite these benefits, evidence is lacking with regard to the form (i.e. capsules, powder, probiotic food) and strain of probiotic that supports these benefits best (Allen et al., 2010), while some effects may be dependent on the age of

the host (Sazawal et al., 2006). There is also a lack of evidence confirming the benefits of probiotics in relation to digestive symptom relief among healthy populations.

2.3.4 Gut Health in Vegans vs. Omnivores

In contrast to the omnivorous diet, vegan diets are commonly richer in fruit and vegetables, wholegrains, legumes and nuts, resulting from the exclusion of animal-based products (Davies et al., 1985; Larsson & Johansson, 2005). Due to the high fibre content of plant-based foods, vegans experience greater bowel motion frequency than meat-eaters (Panigrahi et al., 2013; Sanjoaquin et al., 2004). Vegans also experience lower incidences of GORD and general acid refluxes than meat-eaters (Baroni et al., 2023; Rizzo et al., 2023), which may be attributed to the anti-reflux effects of fibre-rich foods (DiSilvestro et al., 2010).
However, limited studies have examined other GI-related symptoms among vegans. Despite this, GI health has been examined among those following similar dietary patterns to the vegan diet. In a two-week experimental study, Barber et al. (2021) compared the effects of a low-fat, high-residue diet (fibre-enriched Mediterranean diet (FMD)) to those on a high-fat, low-residue diet (Western-type diet (WD)), distinguishing differences in gut symptom burden. Overall, those on the fibre-rich diet (FMD) experienced more GI symptoms than those on the Western-type diet (WD), including flatulence and borborygmus, despite greater stool output and softer stool consistency (Barber et al., 2021). These symptoms may be attributed to the slow transit time and highly fermentable nature of some fibre types, which may result in gaseous GI symptoms (Alyousif et al., 2020; Burns et al., 2018; Chutkan et al., 2012; Gonlachanvit et al., 2004), given they are more likely to be consumed on fibre-rich diet. On the other hand, the benefits of dietary fibre in supporting normal gut function and laxation (Cummings, 1984; McRorie & McKeown, 2017) may explain why those on the fibre-rich diet had improved bowel motion regularity and consistency.

While fibre-rich diets may cause some GI symptoms, the prevalence of GI disorders is likely lower in comparison to Western diets (Barber et al., 2021). The *Bacteroides* enterotype- a harmful bacterium, has been associated with Western-style diets high in animal protein and saturated fats while low in dietary fibre (Wu et al., 2011). This bacterium has been linked to gut inflammation, commonly affecting individuals in Western countries (Iljazovic et al., 2020; Mobeen et al., 2018). Similarly, an increase in the *Prevotella* enterotype- a beneficial bacterium, has been associated with plant-rich diets that are high in complex carbohydrates and dietary fibre, such as vegan and vegetarian diets (Losno et al., 2021; Precup & Vodnap.,

2019). Promisingly, a higher abundance of the *Prevotella* enterotypes has also been linked to fewer incidences of IBD (Mobeen et al., 2018). Therefore, plant-based diets may be protective against the susceptibility to GI conditions. However, more studies are required to examine gastrointestinal symptoms among the vegan population.

2.4. Gastrointestinal Health Assessment

2.4.1 GI Symptom Assessment Tools

Various tools have been developed for the assessment of gastrointestinal symptoms. These have been employed in analyses of digestive symptoms and bowel health among healthy populations (Alvarez et al., 2023; Blake et al., 2016) and those with chronic GI illness (Adam et al., 2005; Muller-Lissner et al., 2003; Revicki et al., 2004). Each assessment tool has unique strengths and limitations, with different uses for its application. The choice of the assessment tool depends on the objective of the researcher, individual or health professional, with each tool exploring assessment parameters of varying GI symptoms. Among the available GI symptom assessment tools, the GSRS appears most suitable for examining general GI symptoms within healthy populations (Alyousif et al., 2020), owing to its good reliability and construct validity (Revicki et al., 1998; Svedlund et al., 1988). While the DHSI, GISSI, and SAGIS questionnaires may also be suitable for assessing GI symptoms in healthy individuals, alike the GSRS questionnaire, they are lengthier and place an additional burden on participants to complete. Table 2.4 (below) summarises the GI symptoms assessment tools commonly used in research and healthcare, including their description, assessment parameters, outcome measure, outcomes and limitations.

Table 2.4: GI Symptom Assessment Tools

Tool	Description	Assessment parameters	Outcome measure	Outcomes	Limitations	Reference (Country)
GSRS (Gastrointestinal Symptom Rating Scale)	Evaluates the intensity & frequency of GI-related symptoms experienced during a seven-day period.	15 items: Abdominal pain (3 items), reflux syndrome (2 items), diarrhoea syndrome (3 items), indigestion syndrome (4 items), constipation syndrome (3 items)	Likert-7	Good reliability and construct validity for evaluating general GI symptoms. [1-2] Utilised within the assessment of a wide-range of GI complications:	GSRS abdominal pain syndrome measure may not be reliable in healthy populations; abdominal pain syndrome is inclusive of nausea, stomach & hunger pains, which may not have correlations with one another	Svedlund et al., 1988. (Sweden)

				IBS, IBD, CD, GORD, PUD, FC, FD, SIBO, colorectal cancers and healthy populations.[1-11] Useful for assessing GI-related symptoms in a range of GI conditions following dietary intervention. [3-5, 8] Employed alongside the assessment of HRQOL measures; strong correlation in results between GSRS and PGWB [12]	in healthy individuals.[9] Only specific to the previous seven-day period; does not question how long symptoms have persisted for.[1] Does not assess symptoms of satiety; the GSRS-IBS tool was developed with the inclusion of these questions, as a result, to enable specificity to those with IBS.[13]	
IGQ (International Gas questionnaire)	A two-part, 24hr symptom diary used to assess 7 gas-related GI symptoms and their impact on daily life in IBS and general populations.	17 items: Bloating (6 items), flatulence (3 items), belching (2 items), bad breath (2 items), stomach rumbling (2 items), difficult gas evacuation (2 items).	Likert-5	Ability to capture impact of gas-related symptoms on individuals quality of life among various domains. [14] Assess GI symptoms in those with IBS and the general population. Validated for its good psychometric properties in assessing GI symptoms; strong discriminant	Application limited to gas-related symptoms. [14] Only queries GI symptoms experienced within a 24hr period. [15]	Chassany et al., 2015. (France)

				validity and test-retest reliability. [15]		
GIS (Gastrointestinal Symptom Score)	Applied in clinical practice to assess dyspeptic symptoms in patients with functional dyspepsia.	10 items: nausea, sickness, vomiting, bloating, abdominal cramps, early satiety, acidic eructation/ heartburn, loss of appetite, retrosternal discomfort, epigastric pain/upper abdominal pain.	Likert-5	Valid and reliable instrument to assess the intensity of symptoms in patients with functional dyspepsia. [16]	Application limited to patients with functional dyspepsia. [16] Inability to represent the burden of disease in line with best-worst scaling (BWS) in functional dyspepsia. [17]	Adam et al., 2005. (Germany)
GISSI (Gastrointestinal Symptom Severity Index)	Self-reported tool assessing the frequency, severity, and level of bother of individual GI and female pelvic floor / urogynaecologic symptoms.	39 items: Constipation/ difficult defecation (5 items), abdominal pain/discomfort (4 items), dyspepsia (4 items), diarrhoea/anal incontinence (4 items), GERD/chest symptoms (4 items), nausea/ vomiting (2 items), other upper/lower GI symptoms (9 items) female pelvic floor/	Likert-5	Good evidence for scaling prominent GI symptom clusters. [18] Excellent discrimination between patient symptoms at different intervals. [18] Enables reporting of female pelvic floor/ urogynaecologic symptoms. [18]	Lengthy questionnaire; participant burden. Further validation required for increased efficiency and reliability of patient-reported clinical outcomes. [18]	Crowell et al., 2015. (United States)

		urogynaecologic symptoms (7 items).				
SAGIS (New Structured Assessment of Gastrointestinal Symptoms Scale)	Clinically validated self-administration tool for assessing the intensity and impact of 22 upper and lower gastrointestinal symptoms.	22 items: Epigastric pain (7 items), diarrhoea and discomfort (6 items), reflux (3 items), nausea/vomiting (4 items), constipation (2 items).	Likert-5	Good psychometric properties and symptom-based categorization to support research and clinical assessment of a wide variety of digestive symptoms across GI diseases. [19] Suitable self-administrated instrument for assessing GI symptoms in both adults [20] and children/adolescents. [20] Results consistent with the GSRS. [21] Clinician approved for its ability to discriminate the severity and impact of GI symptoms in a prompt and structured manor. [20]	Does not reduce the patients time required with a clinician in primary care, despite its timely and accurate assessments outcomes. [19] Lack of formal testing on patient satisfaction levels, despite high qualitative patient feedback through the increase in targeted / focused conversations with a clinician. [20] Not intended to replace GI symptom assessment tools applied for use in clinical trials. [20]	Koloski et al., 2017. (Australia)
BSFS/BSS (Bristol Stool Form Scale/	A medical aid used to classify forms of human faeces into seven categories.	1 item: Type 1-2 indicate constipation.	Likert-5	Commonly used to assesses stool form in healthy individuals and those with IBS [23]	Only assesses stool type/consistency; not for application in analysing other	Lewis & Heaton, 1997.

Bristol Stool Scale)		Type 3 – 4 indicate easy to pass stools. Type 5 – 7 may indicate diarrhoea and urgency.		Excellent reliability and agreement, from adult users of the tool, towards differentiating one stool type from another. [24] Assists with approximating stool transit time through the appearance of stools alone, thus is non-invasive. [25]	GI symptom measures unless incorporated in a DBHD.[24] Does not reveal clustering between dietary triggers. [26] Poor ability to differentiate abnormal from normal stool forms (i.e. constipation *versus* diarrhoea) from Rome III criteria. [24]	(England)
SGA (Subjects Global Assessment of Relief)	Global measure to assess overall wellbeing, abdominal pain/discomfort, and bowel function in those with IBS.	5 items: Pain/discomfort, distension/ bloating, urgency, number of bowel movements, feeling of incomplete evacuation	Likert-7	Wide application across clinical trials analysing treatment options on IBS-related symptoms; Consistent results analysing tegaserod in IBS subjects. [28-29] Ability to measure symptoms that are both relevant and representative of numerous conditions; is responsive to detecting changes among clinical symptoms; outcome measures reflect genuine	Application limited to patients with IBS. [27] Lack of validated outcome measures. [27] Potential positive bias in users responses; symptom assessment scale contains three items for improvement, only one for neutral, only one for worsening. [27]	Muller-Lissner et al., 2001. (Switzerland)

				change in generalised health status of user. [27]		
PAGI-SYM **(**Patient assessment of Upper Gastrointestinal Symptom Severity Index)	Self-administrated symptom severity tool for application in those with GORD, dyspepsia and gastroparesis.	20 items: Heartburn/regurgitation (7 items), postprandial fullness/early satiety (4 items), nausea/vomiting (3 items), bloating (2 items) upper abdominal pain (2 items), lower abdominal pain (2 items).	Likert-6	Good reliability and construct validity in subjects with GORD, FD and gastroparesis. [30] Significant association between PAGI-SYM symptom scores (heartburn/ regurgitation, nausea/vomiting, bloating, lower abdominal pain) with gastric emptying and hypersensitivity in those with FD; may be useful in assessing GI symptom responsiveness to gastric prokinetics. [31]	Application limited to patients with GORD, FD and gastroparesis. [32] Does not assess bowel function/ movement due to its application in assessing upper GI symptoms, irrespective of lower abdominal pain. [30] Lack of clear differentiation for symptom scores between those with normal and abnormal gastric physiology. [31]	Rentz et al., 2004. (Netherlands)
DHSI (Digestive Health Status Instrument)	Self-reported survey for patients in primary care to evaluate GI complaints of heartburn and	34 items: Bowel dysfunction (11 items), reflux (9 items), upper tract dysmotility complex (6 items),	Undefined	Good to excellent internal consistency, high validity by comparison of the SF-36 assessing QOL measures. [33]	Lengthy questionnaire; participant burden. Trailed within a relatively homogenous population; no assessment conducted among	Shaw et al., 1998. (United States)

	abdominal pain or discomfort.	pain (8 items).	Incorporates the Rome criteria for IBS and dyspepsia subgroups, and the Manning criteria for IBS; is the only disease-specific health measure to do so. [33] Responsive to change within the treatment of GORD. [34]	different racial groups or subjects of lower socioeconomic status during development of the questionnaire. [33] Test-retest reliability suggested when used in application to assess outcomes of disease treatment.. [33]

Abbreviations: ADL's, activities of daily living; **CD**, coeliac disease; **DBHD**, Daily Bowel Health Diary; **FC**, functional constipation; **FD**, functional dyspepsia; **GORD**, Gastroesophageal Reflux Disease; **IBD**, inflammatory bowel disease; **IBS**, irritable bowel syndrome; **PUD**, peptic ulcer disease; **SIBO**, small intestinal bacterial overgrowth

REF: [1] Svedlund et al. (1988). [2] Revicki et al. (1998). [3] Bayer et al. (2022). [4] Nyman et al. (2020). [5] Lohiniemi et al. (2000). [6] Pacini et al. (2005). [7] Matsuzaki et al. (2012). [8] Ouyang et al. (2023). [9] Alvarez et al. (2023). [10] Hogberg et al. (2020). [11] Alyousif et al. (2020). [12] Canestaro et al. (2016).[13] Wiklund et al. (2003). [14] Chassany et al. (2015). [15] Duracinsky et al. (2022). [16] Adam et al. (2005). [17] Mühlbacher & Kaczynski (2021). [18] Crowell et al. (2015). [19] Koloski et al. (2017). [20] Hammer et al. (2023). [21] Chan et al. (2021). [22] Lewis & Heaton (1997). [23] Blake et al. (2016). [24] Chumpitazi et al. (2015). [25] Harvey et al. (2022). [26] Rijnaarts et al. (2021). [27] Muller-Lissner et al. (2003).[28] Novick et al. (2002). [29] Muller-Lissner et al. (2001). [30] Rentz et al. (2004). [31] Kindt et al. (2009). [32] Revicki et al. (2004). [33] Shaw et al. (1998). [34] Shaw et al. (2001).

2.4.2 Gastrointestinal Symptom Rating Scale [GSRS]

What is the GSRS

The Gastrointestinal Symptom Rating Scale [GSRS] questionnaire is a validated tool, implemented in 1988, to evaluate the intensity and frequency of GI-related symptoms (Svedlund et al., 1988). The GSRS comprises fifteen items, split into five domains: 1. Abdominal pain (abdominal pain, hunger pains and nausea), 2. Reflux syndrome (heartburn and acid regurgitation], 3. Diarrhoea syndrome (diarrhoea, loose stools and urgent need to defecate), 4. Indigestion syndrome (borborygmus, abdominal distension, eructation and increased flatus), and 5. Constipation syndrome (constipation, hard stools, and feeling of incomplete evacuation). From each area, subjects are required to rank their level of concern utilising a 7-level Likert scale, from 1- no discomfort to 7- very severe discomfort, to give a total range-value between 15 – 105. These results are merged to obtain a median score indicating the severity of discomfort specific to each GI issue. The results may be collated to determine an overall GSRS score (an average of all five sub-scores) or analysed individually (average score within that domain) to determine the primary symptoms of concern. A higher score within a domain represents the main symptoms complained about by the questionnaire user. However, it is noteworthy that the questionnaire regards symptoms experienced only within the previous seven days. Thus, specificity is limited to only the duration of this period. The constituents of the GSRS have remained stable throughout the utilisation of the tool. However, minor modifications have been implemented through the years with further research.

Changes to the GSRS

The original GSRS tool was developed as an interview-based rating scale to examine GI symptoms among those with IBS and peptic ulcer disease (Svedlund et al., 1988). This tool assessed four domains: 1. Abdominal pain syndrome (epigastric pain, colicky pain, dull pain, undefined pain), 2. Dyspeptic syndrome (epigastric pain, heartburn, acid regurgitation, sucking sensations in the epigastrium, nausea and vomiting), 3. Indigestion syndrome (borborygmus, abdominal distension, eructation, increased flatus), and 4. Bowel function syndrome (decreased/increased passage of stools, loose stools, hard stools, urgent need for defecation, feeling of incomplete evacuation). However, the questionnaire was modified in 1993 to become self-administrable (Dimenas et al., 1993), thus allowing physicians and

researchers to enable individuals to complete the questionnaire independently. Within the modified GSRS, syndrome assessment measures were simplified and rearranged. 'Bowel function syndrome' was broken into two separate domains- 1. Constipation syndrome, and 2. Diarrhoea syndrome. Meanwhile, 'dyspeptic syndrome' was removed from the questionnaire in place of 'Reflux syndrome'. This may be owed to the significant heterogeneity between the diagnostic criteria for GERD and FD or IBS, thus placing a degree of subjectiveness on their analysis (de Bortoli et al., 2018). These modifications also gave the tool purpose in the symptom assessment of other GI-related complications and general GI health.

Validity and Application of the GSRS

Since the modifications to the original GSRS, the tool has been widely used in research and healthcare to evaluate gastrointestinal symptoms in individuals and populations. This includes those in good health (Alyousif et al., 2020) and those with GI conditions such as IBD (Nyman et al., 2020), IBS (Bayer et al., 2022; Svedlund et al., 1988), GORD (Pacini et al., 2005; Revicki et al., 1998), CD (Canestaro et al., 2016; Lohiniemi et al., 2000), PUD (Svedlund et al., 1988), SIBO (Ouyang et al., 2023), functional dyspepsia (Matsuzaki et al., 2012), and colorectal carcinomas (Hogberg et al., 2020) (Table 3). Researchers have utilised the GSRS among these populations to assess GI-related outcomes following lifestyle, medical and dietary interventions, while it has been widely used alongside measures of health-related quality of life (HRQOL).

Cronbach's alpha (α) and McDonald's omega (ω) have been employed to evaluate the internal consistency reliability of the GSRS. Several studies (Kulich et al., 2008; Revicki et al., 1998; Wiklund et al., 2003) have denoted the GSRS's good psychometric properties in the assessment of GI symptoms when compared to other GI assessment tools. For example, the reliability and validity of the GSRS have been compared to a GI symptom daily questionnaire to assess the GI tolerance of nondigestible carbohydrates in healthy adults (Alvarez et al., 2023). In this study, the GSRS exhibited acceptable reliability within the overall GSRS scale (α = 0.76; ω = 0.87) and syndromes of constipation (α = 0.73; ω = 0.74) and diarrhoea (α = 0.76; ω = 0.77). However, poor reliability was indicated in the assessment of abdominal pain (α = 0.54; ω = 0.54), reflux (α = 0.69; ω = 0.67), and indigestion (α = 0.64; ω = 0.67). Nonetheless, several of the GSRS symptom items (stomach pain, nausea, flatus, constipation, diarrhoea) were moderately correlated (Spearman's correlation= 0.55-0.64; P=

<0.001) with similar constituents of the DQ. Meanwhile, the GSRS constipation syndrome predicted slow transit tools in line with BSFS types 1 – 2, thus supporting the tools' reliability in assessing stool form. Therefore, the GSRS, with its good psychometric properties, is a valid tool for assessing digestive outcomes among healthy populations following dietary interventions.

2.5 Dietary Assessment Methods

Dietary assessment methods are used to obtain an accurate record of food and drink consumption for an individual or population over a specific period. These analyses are undertaken to understand group dietary patterns and nutrient intakes. The most commonly used forms of dietary assessment methods in research include food records, 24-hour recalls and food frequency questionnaires (FFQ) (Burrows et al., 2019). Given these methods are subjective, they rely on the individual to provide fair and accurate dietary information. Each has its own strengths and limitations, thus making different methods more suitable for specific studies. The choice of dietary assessment method depends on the study design, time frame, research question, sample size, and participant characteristics (Bailey, 2021).

Different dietary assessments may be used to investigate the dietary fibre intakes of individuals, groups, or populations. While there is no gold standard for dietary fibre assessment (Hudson et al., 2006), various methods for collecting dietary information have been developed. The 4-day food record (4DFR) and FFQs are popular assessment methods used in investigations into dietary fibre intakes (Hudson et al., 2006; Yu et al., 2022). In addition to these assessment methods, some dietary fibre-specific assessment questionnaires have been developed; these include 'The Fat and Fibre Barometer' (Wright & Scott, 2000), a 'short food questionnaire for the assessment of dietary habits' (Svilaas et al., 2002), and the 'DFI-FFQ' (dietary fibre intake short food frequency questionnaire) (Healey et al., 2016). While these assessment methods are shorter and thus reduce participant burden, they lack accuracy in generating detailed information regarding individuals' exact daily dietary fibre intakes and rather focus on general dietary habits, patterns and behaviours.

2.5.1 Food Record

Food records require subjects to document their food and fluid intake over a given period, usually three to five days. These records may be either estimated or weighed. In a weighed

food record, all food and drink must be accurately measured using household measures (kitchen scales, measuring spoons and cups) or a to-scale pictorial representation. In an estimated food record, the participants must roughly calculate how much they consumed at each meal/drink. For both methods, subjects are advised to record their meals immediately following consumption to minimise recall bias of oral intake.

Advantages

Weighed food records are the most quantitative method, providing accurate dietary assessment in determining one's habitual food intake (Tucker, 2007; Gariballa & Forster, 2008). Advantages of this method include the ability to accurately measure all food and beverages consumed by the participant, helping to determine portion sizes (Green et al., 1998; Tucker, 2007). The weighed food record provides detailed dietary intake information for individuals and populations (Tucker, 2007), with a low risk of recall and interpretation bias (Green et al., 1998; Shim, 2014). These are advantages over the FFQ, which is susceptible to recall and interviewer bias (Shim, 2014). Studies comparing their effectiveness in dietary fibre assessments have denoted the weighed food record as the most accurate method over the FFQ (Green et al., 1998). An alternative method is the estimated food record, allowing users to document their dietary intake without the burden of weighing and measuring their food. However, it may not be as accurate as the weighed food record (Tucker, 2007).

Limitations

One limitation of food records is that under-reporting of dietary intake may arise (Livingstone, 1990). In the weighed food record, individuals may find it challenging to weigh and measure all food and drink consumed accurately, leading to under-reporting (Shim, 2014). Similarly, in the estimated food record, this may occur due to the reliance on participant memory and difficulty in accurately estimating portion sizes. Poor participant motivation, inadequate training, and literacy, as well as reluctance from individuals to report unhealthy meals, can also contribute to under-reporting in both forms of dietary assessments (Livingstone, 1990; Cook et al., 2000). Some participants may avoid consuming certain meals or takeaways and restaurant food due to difficulty reporting it (Tucker, 2007). These concerns may be more problematic in large-population studies and, therefore, may be more suitable for analysing dietary patterns in smaller cohorts (Tucker, 2007).

2.5.2 Food Frequency Questionnaires (FFQ)

Food Frequency Questionnaires (FFQs) require participants to recall their frequency of consumption of various foods over a specific period, typically ranging from weeks to months. FFQs consist of a select list of foods and fluids, with usually around 80 to 120 items (National Cancer Institute, n.d.), which may be rich in dietary fibre and/or other nutrients, thus allowing researchers to estimate an individual's dietary fibre intake.

Advantages

The FFQ is a widely used population-based dietary assessment tool, owing to its ease of administration, and thus reducing participant burden (Shim, 2014). The FFQ is affordable and can assess individuals, groups and populations dietary intake over a prolonged period (Molag et al., 2007). The tool can estimate energy and nutrient intakes, such as dietary fibre, through calculating the frequency that each food item on the FFQ is consumed, with portion sizes taken into account (Cade et al., 2002).

Limitations

Despite the advantages of the FFQ in estimating dietary intakes, the accuracy and reliability of the FFQ in measuring exact dietary intakes are debated (Hebden et al., 2013). The FFQ may not be as accurate as the Food Record in assessing dietary fibre intakes of individuals and populations (Green et al., 1998). For example, studies have suggested that large food item FFQs can overestimate participants' fruit and vegetable intake, thus providing inaccurate dietary fibre intakes (Krebs-Smith et al., 1995). A common feature of the FFQ is its high rate of misreporting dietary intake (Molag et al., 2007); therefore, the tool may not provide the most accurate results within dietary fibre intake analyses.

2.6 Summary

International studies have shown that plant-based eaters have high dietary fibre intakes, vastly above that of meat-eaters (Neufingerl & Eilander, 2021). Dietary fibre has a crucial role in GI health, supporting normal gut function and laxation (Cummings, 1984; McRorie & McKeown, 2017). This has led to recommendations encouraging a fibre-rich diet (Ministry of Health, 2020; National Health and Medical Research Council et al., 2006). Due to the digestive benefits of dietary fibre, it is no surprise that vegans internationally experience

optimal bowel motion frequency and consistency (Panigrahi et al., 2013; Sanjoaquin et al., 2004) and low incidences of GORD and general acid refluxes (DiSilvestro et al., 2010; Rizzo et al., 2023). However, there is a lack of research investigating other GI symptoms among vegans, both internationally and within NZ. As it is thought that high intakes of some fibre types may increase the risk of gaseous GI symptoms, such as abdominal pain/discomfort, bloating/distension and flatulence (Alyousif et al., 2020; Burns et al., 2018; Chutkan et al., 2012; Gonlachanvit et al., 2004) it is worth exploring these outcomes among vegans who are believed to consume fibre-rich diets.

To investigate these outcomes, the GSRS questionnaire and 4-day food diary will be employed. The GSRS questionnaire is a validated GI symptoms assessment tool with good reliability and construct validity (Revicki et al., 1998; Svedlund et al., 1988) for assessing GI discomfort symptoms among healthy populations (Alyousif et al., 2020). Meanwhile, the 4-day food record is a widely implemented dietary assessment method for assessing nutrient intakes of individuals, groups and populations (Tucker, 2007; Gariballa & Forster, 2008). These tools will be used to investigate GI discomfort symptoms and dietary fibre intake of NZ vegans. This research will provide new insights into vegans in the local context, given no previous studies have investigated this group in NZ. This study may also enhance individuals' understanding of the relationship between dietary fibre intake and GI symptoms in vegans.

Chapter 3.0: Research Manuscript: Gut Health in New Zealand Vegans: The Relationship Between Dietary Fibre and Gastrointestinal Symptoms.

3.1 Abstract

Background: Dietary guidelines recommend adequate dietary fibre intake to support normal laxation and gastrointestinal (GI) health. However, excess intake of some fibre types may lead to the onset of gaseous GI symptoms. Internationally, many vegans exceed the dietary fibre recommendations; however, no studies have investigated its link to reports of symptoms. Meanwhile, the gut health and dietary fibre intake of NZ vegans have not been investigated; thus, research is needed.

Aim: To investigate the relationship between dietary fibre intake and gastrointestinal symptoms among NZ Vegans.

Methods: This cross-sectional study recruited adults (≥18yrs) who had followed a strict vegan diet for ≥two years. Health and demographic data were obtained from questionnaires. Participants completed a 4-Day Food Record to investigate dietary fibre intake, which was compared to the NZ median intakes and dietary guidelines. A Gastrointestinal Symptom Rating Scale (GSRS) questionnaire was employed to investigate GI symptoms. Binary logistic regression analysis was conducted to determine whether dietary fibre intake predicted the odds of GI symptoms in vegans.

Results: Across the GSRS domains, no correlations were found between dietary fibre intake and reports of GI symptoms due to minimal variance in vegans' GSRS scores. Overall, participants (n= 212) reported minimal GI symptoms, ranging on average from 'no discomfort – minor discomfort' (GSRS scores 1-2) across the GSRS domains. Females reported worse symptoms of abdominal pain ($p=0.02$) and indigestion ($p<0.001$) than males, while younger participants experienced more abdominal pain than older participants ($p=0.03$), as examined through modelling a binary logistic regression analysis inclusive of dietary fibre intake (g/day), sex, age and BMI. Meanwhile, dietary fibre intake exceeded the NZ median intake (20g/day), averaging 45.91g/day (25^{th}, 75^{th} percentile, 36.33 to 54.75g/day); 97% of participants exceeded the NZ NRV Adequate Intake (AI) (25-30g/day), 90% exceeded the Suggested Dietary Target (SDT) (28-38g/day). While males consumed more dietary fibre than females (52.62g/day *vs*. 42.24g/day), females had greater energy-adjusted dietary fibre intakes than males (22.21g/1000kcal *vs*. 20.54g/1000kcal). Finally, the major sources of dietary fibre were legumes, bread, fruit, oats, and vegetables.

Conclusion: NZ vegans experience minimal GI symptoms, while their dietary fibre intake exceeds the NZ NRV recommendations and population median intake. Overall, there were no associations between high dietary fibre intake and reports of GI symptoms among NZ vegans.

Keywords: vegans, GI symptoms, dietary fibre**,** GSRS, gut health.

3.2 Introduction

Dietary fibre, an indigestible carbohydrate of plant origin, is considered an essential nutrient for gut health (FSANZ, 2016; National Health and Medical Research Council et al., 2006). Dietary fibre regulates digestion and absorption, transit time, and stool formation by aiding with the movement of food through the digestive system (Gill et al., 2021). Through these mechanisms, dietary fibre supports normal bowel function and regular laxation (Cummings, 1984; McRorie & McKeown, 2017), thus assisting in the prevention and alleviation of constipation and diarrhoea (Stephen & Cummings, 1980; McRorie et al., 1998; Singh, 2007). In addition, through dietary fibres' ability to dilute carcinogens (Weisburger et al., 1993) and modulate gut bacteria (Lim et al., 2005), its preventative role in the pathology of colon cancers (Bingham, 1990; Loius et al., 2014) and gastrointestinal disease (Burkitt et al., 1974; Gasaly et al., 2015) has been well described.

The benefits of dietary fibre have led to recommendations encouraging a fibre-rich diet inclusive of fruits and vegetables, grains, legumes, nuts, and seeds (Ministry of Health, 2020). The National Health and Medical Research Council et al. (2006) advise an Adequate Intake (AI) level of 25-30g/day, based on population median intakes in Australia and New Zealand (NZ). A Suggested Dietary Target (SDT) of 28-38g/day has also been set for the prevention of chronic disease (National Health and Medical Research Council et al., 2006). As there is no convincing evidence that dietary fibre has adverse effects on human health, even at large doses, there is no set Upper Limit (UL) (Gordon et al., 1995).

While individuals should not restrict dietary fibre, some fibre types may lead to the onset of gastrointestinal (GI) symptoms. This is dependent on the solubility, viscosity and fermentability of fibre, as different types elicit varying responses within the gastrointestinal tract (GIT) (Chutkan et al., 2012). High consumption of short-chain, non-viscous soluble, and highly fermentable dietary fibre types can lead to imbalances within the GI tract due to their slow transit time. This has been associated with an increased risk of rapid fermentation by bacteria and consequent gas production (Chutkan et al., 2012). Such physiological responses may provoke GI symptoms such as abdominal pain and discomfort, bloating, distension and flatulence (Alyousif et al., 2020; Borkoles et al., 2022; Gonlachanvit et al., 2004; Price et al., 1988). Thus, it can be hypothesised that individuals on a markedly high-fibre diet (above

recommendations) are likely to consume these fibre types and may experience gastrointestinal symptoms.

International studies indicate that the vegan diet is high in dietary fibre. Vegans consume more fibre than meat-eaters (Sliz et al., 2021), exceeding the NZ Nutrient Reference Values (NRVs) in relation to Adequate Intake (AI) and Suggested Dietary Target (SDT) recommendations (Neufingerl & Eilander, 2021). This can be attributed to their higher intake of fruits, vegetables, wholegrains, legumes and nuts compared to meat-eaters (Davies et al., 1985; Larsson & Johansson, 2005). Given vegans reliance on fibre-rich plant-based foods, they may experience greater bowel motion frequency compared to those who eat meat (Panigrahi et al., 2013; Sanjoaquin et al., 2004). However, some research has found that those adhering to fibre-rich diets experience greater digestive symptom burden, including flatulence and borborygmus, compared to those on Western-type diets (Barber et al., 2021). Among these fibre-rich foods, legume consumption is believed to contribute to symptoms of flatulence (Othman et al., 2023; Price et al., 1988). Given international studies (Davies et al., 1985; Larsson & Johansson, 2005) reporting vegans' high intake of these potentially symptom-provoking foods, these symptoms may be problematic. However, to our knowledge, these effects have not been analysed exclusively among vegans, thus further research is required.

While the majority of New Zealanders do not consume enough dietary fibre (Ministry of Health, 2011), no research has been undertaken to analyse vegan diets within the population. Despite international analyses, there remains a need for research specific to NZ to better understand fibre intake and gut health among vegans within the local context. Due to conflicting evidence that some dietary fibre types may result in GI symptoms, it is of interest to investigate these outcomes among individuals who may adhere to fibre-rich diets. Therefore, the aim of this study is to investigate the relationship between dietary fibre intake and gastrointestinal symptoms among NZ Vegans. Meanwhile, the most common food sources of dietary fibre will be identified and compared to NZ intakes. This study will provide insight into the relationship between dietary fibre intake and GI symptoms in vegan populations.

3.3 Methods

3.3.1 Study Design

This cross-sectional study investigates gut health among NZ vegans and is a research question as part of a wider research study within the Vegan Health Research Programme. Ethical approval was granted by the Health and Disability Ethics Committees (HDEC 2022 EXP 12312). The study was funded by the Lottery Health Project Grant (LHR-2022-185693).

3.3.2 Participants and Recruitment

Recruitment took place between July 2022 to March 2023 in Auckland, NZ. Participants were recruited via advertisements on social media, flyers on community noticeboards and distributed to vegan cafes/restaurants, and by word-of-mouth. The study aimed to recruit a total of 220 participants based on a recent study of NZ adults suggesting that less than 1% of the population are vegan (Greenwell et al., 2024). The inclusion criteria for participants were females and males aged 18 years and over, who had followed a vegan diet (i.e. no animal products) for at least two years, and were not pregnant nor planning to be during the study. All participants were provided with a Participant Information Sheet (Appendix A) and were required to complete a written consent form (Appendix B) prior to enrolment in the study for data collection.

3.3.3 Data Collection

All participants were screened for eligibility through an online screening questionnaire, which was collected via Qualtrics™, or via phone call. Once eligibility was confirmed, the participants were invited to the Massey University Human Nutrition Research Unit for anthropometric measures. A trained researcher measured the participants' height at standing via a stadiometer, while weight was measured on a hard floor surface using electronic scales. The participants received a $20 petrol voucher to reimburse for travel costs and time spent during data collection protocols.

All participants completed a Health and Demographic Questionnaire (Appendix C) to collect data on age, sex, ethnicity, medical history/conditions and supplement use. Individuals were classified into a single ethnic group: European, Māori, Pasifika, Asian, Middle Eastern/Latin American/African (MELAA), via priority ethnicity (Education Counts, 2021). All chronic gastrointestinal (GI) conditions were recorded and grouped accordingly, while participants

who reported no GI complications or other medical conditions were categorised as ‘no GI condition’. Information on participants' supplement use was obtained from the Dietary Practices and Supplement Use Questionnaire (Appendix D); only participants' use of prebiotics, probiotics, and synbiotics was analysed and reported.

For the analysis of dietary fibre, fibre sources and energy intake, participants were required to complete a 4-Day Food Record via a provided template (Appendix E). Participants were instructed to detail all food and drink consumed across the four days. This included measuring and/or weighing each component of the meal/beverage at the time of consumption and photographing supplements (prebiotics, probiotics, synbiotics) taken during this period. The diaries were to be completed on consecutive days (one weekend, three weekdays), while the participants were asked to adhere to their regular diet so that it was representative of their usual nutrient intake. Once the 4-day food diaries were complete, they were emailed through to the research team for analysis. Returned food diaries were checked for completeness, and for any queries, participants were contacted for a follow-up.

Finally, to assess GI symptoms, each participant completed a Gastrointestinal Symptom Rating Scale (GSRS) questionnaire (Appendix F). Participants answered 15 questions relating to the severity of GI discomfort symptoms among the five GSRS domains: abdominal pain syndrome (abdominal pain, hunger pains, nausea), reflux syndrome (heartburn, acid regurgitation), diarrhoea syndrome (diarrhoea, loose stools, urgent need to defecate), indigestion syndrome (borborygmus, abdominal distension, eructation, increased flatus), and constipation syndrome (constipation, hard stools, feeling of incomplete evacuation). For each symptom, participants were asked to indicate the level of severity they had experienced within the past seven days, as per the GSRS Likert-7 scale: 1= ‘no discomfort at all’, 2= ‘minor discomfort’, 3 = ‘mild discomfort’, 4 = ‘moderate discomfort’, 5 = ‘moderately severe discomfort’, 6 = ‘severe discomfort’, 7 = ‘very severe discomfort’.

3.3.4 Gastrointestinal Symptom (GSRS) Analysis

All GSRS symptom severity scores, as based on the GSRS Likert-7 scale, were merged with the respective symptoms across the five GSRS domains. For further analysis, GSRS results were collated into binary response outcomes (yes/no). Occurrence of gastrointestinal symptoms was assumed if subjects indicated ‘2’ or greater (‘minor discomfort’ – ‘very severe

discomfort') (GSRS, yes = 2-7) and not assumed with reported scores below 1.99 (GSRS, no = 1 – 1.99). Binary logistic regression analyses were carried out using GSRS binary response outcomes (yes/no) to establish predictors of GSRS scores; these were analysed alongside participant characteristics (age, sex, BMI) and dietary fibre intakes (g/day and g/1000kcal) to assess whether they predicted GSRS outcomes.

3.3.5 Dietary Analysis

4-day food records were analysed using Foodworks 10 version 10.0.4266 (Xyris Software Pty Ltd., Brisbane, Queensland, Australia) based on the NZ food composition database FoodFiles 2018 version 1. Vegan foods not included in the database were manually created using Nutrition Information Panels (NIPs) from supermarkets (Countdown, PAK'nSAVE, New World) and similar sources from FoodFiles 2018. These were adjusted according to yield and retention factors (Bognár, 2002) and collated into a new database for standardisation across food diaries. Intake of dietary fibre, source of dietary fibre, and energy intake were used for statistical analysis.

Dietary fibre (g/day) intakes were reported as both mean and median for comparison to NZ statistics, whose NRVs are based on median dietary fibre intakes across Australasia (National Health and Medical Research Council et al., 2006). Intake of dietary fibre was compared to the NZ median dietary fibre intake and the NRVs for Adequate Intake (AI) and Suggested Dietary Targets (SDTs). Our results showed the percentage of only those who met and exceeded these targets. For the NZ median intake, this was those who met and exceeded 20g/day dietary fibre intake. For the AI, this was set at ≥25g/day for females and ≥30g/day for males, and for the SDT, this was set at ≥28g/day for females and ≥38g/day for males. Energy-adjusted dietary fibre intakes (g/1000kcal) were also calculated to determine whether the density of dietary fibre from energy intake (per 1000kcal) influenced the odds of GI symptoms. This was achieved by using participants' mean dietary fibre intakes (g/day) divided by mean daily energy intake (1000kcal); an energy intake of 1000kcal was used for standardisation across participants' diets.

To identify the major sources of dietary fibre among vegans, each food diary was analysed using the 'dietary fibre sources' key, subcategorised under 'dietary fibre' on FoodWorks 10. The top three contributors to dietary fibre intake were taken from each participant's food

diaries, collated into a spreadsheet and entered into SPSS Statistics® for analysis and graphing. Individual foods were grouped into either legumes, bread, cereals, grains, fruit, vegetables, pasta, oats, alternative milk, nuts, and seeds, while any remaining foods were collated into 'other'.

3.3.6 Statistical Analysis

All statistical analyses were carried out using IBM SPSS Statistics® (version 29.0; SPSS Inc., Chicago, IL) with a significance level of $p < 0.05$. The data set was large enough for the Central Limits Theorem to apply. Continuous data with a symmetric distribution was described with a mean ± SD. Where necessary, skewed data was described with a median (25^{th}, 75^{th} percentile) (Tukey's Hinges). Categorical data was described as a number (%). An independent t-test was used to assess differences between groups for continuous data. Mann-Whitney U Test was used to compare differences between non-parametric, ordinal data. A chi-square test (or Fishers Exact test where conditions were not met) was used for differences between categorical groups. Kolmogorov-Smirnov, Shapiro-Wilk test and histograms were used to assess the normality of data. Levene's test for homogeneity was used to assess equality of variances. Binary logistic regression using the enter method was conducted to determine predictors of GSRS scores inclusive of dietary fibre intake (g/day and g/1000kcal, sex, age, and BMI). Finally, the Hosmer and Lemeshow Test assessed the models' fit, with a significance $p > 0.05$ illustrating suitability, while variation in the dependent variable (GSRS scores) was determined using Nagelkere R^2.

3.4 Results

3.4.1 Participant Characteristics

Two hundred and twelve vegan participants were recruited to the study with their characteristics shown in Table 3.1. Participants were aged between 19 – 75yrs (39.49 ± 12.3 yrs), mostly of a healthy BMI (23.92 ± 3.11 kg/m^2), and mostly NZ European (85%). The majority of participants had no underlying chronic GI conditions (95.3%), and most did not take probiotics, prebiotics or synbiotics (95.3%). More females (73%) took part in the study than males (27%), although there were no differences in BMI, age, presence of chronic GI condition, or supplement use between sexes. However, GSRS scores for abdominal pain, indigestion, constipation and overall were significantly higher in females compared to males. Moreover, of the two hundred and twelve participants, nineteen failed to complete the 4-day food diaries. Among those with completed food diaries, dietary fibre and energy intake was significantly higher among males ($p<0.01$) than females. However, this difference was attenuated when fibre intakes were considered in relation to energy, with females consuming more dietary fibre per 1000kcal of energy than males ($p=0.048$).

Table 3.1: Participant Characteristics (n= 212) [1]

	Participants			
	Female	**Male**	**Total**	**P value**
Characteristics	**n = 155 (73%)**	**n = 57 (27%)**	**n = 212**	
Age (years) [2]	39.26 ± 12.51 [19.70 – 75.60]	40.12 ± 12.11 [21.40 – 69.30]	39.49 ± 12.38 [19.70 – 75.60]	0.66 [b]
BMI (kg/m^2) [2]	23.71 ± 3.15 [16.35 – 36.06]	24.48 ± 2.97 [18.50 – 33.24]	23.92 ± 3.11 [16.35 – 36.06]	0.11 [b]
Ethnicity				0.11[a]
European	129 (84%)	49 (88%)	178 (85%)	
Māori	8 (5.2%)	0 (0%)	8 (3.8%)	
Pacifika	0 (0%)	1 (1.8%)	1 (0.5%)	
Asian	13 (8.4%)	3 (5.4%)	16 (7.6%)	
MELAA	4 (2.6%)	3 (5.4%)	7 (3.3%)	
(Missing data)	1	1	2	
GI condition				0.46 [a]
IBS	5 (3.2%)	1 (1.72%)	6 (2.8%)	
IBD (CD)	2 (1.3%)	0 (0%)	2 (0.9%)	
Hirschsprung disease	0 (0%)	1 (1.7%)	1 (0.5%)	
Chronic Gastritis	0 (0%)	1 (1.7%)	1 (0.5%)	

Coeliac disease	0 (0%)	0 (0%)	0 (0%)	
No GI condition	148 (95.5%)	54 (94.7%%)	202 (95.3%)	
Supplementation				0.065 [a]
Probiotics	9 (5.80%)	0 (0%)	9 (4.2%)	
Prebiotics	0 (0%)	0 (0%)	0 (0%)	
Synbiotics	1 (0.65%)	0 (0%)	1 (0.5%)	
No supplementation[3]	145 (93.5%)	57 (100%)	202 (95.3%)	
Dietary intakes	**n = 141**	**n = 52**	**n = 193**	[b]
Dietary fibre intake (g/day)	43.44 ± 12.72 42.24 (34.60 – 51.30)	55.02 ± 17.79 52.62 (44.91 – 61.58)	46.56 ± 15.12 45.91 (36.33 – 54.75)	<0.01*
Energy intake (kcal/day)	1,975 ± 455	2,704 ± 635	2,172 ± 603	<0.01*
DF/EI (g/1000kcal)	22.21 ± 5.32	20.54 ± 4.79	21.76 ± 5.22	0.048*
(missing data)	14	5	19	
GSRS scores [4]	**n = 155**	**n = 57**	**n = 212**	[c]
GSRS overall	1.33 (1.20 – 1.73) [1.00 – 3.87]	1.13 (1.07 – 1.33) [1.00 – 2.53]	1.30 (1.13 - 1.67) [1.00 – 3.87]	<0.001*
Abdominal pain	1.33 (1.00 – 1.67) [1.00 – 5.67]	1.00 (1.00 – 1.33) [1.00 – 3.33]	1.33 (1.00 - 1.67) [1.00 – 5.67]	0.001*
Reflux	1.00 (1.00 – 1.00) [1.00 – 5.50]	1.00 (1.00 – 1.00) [1.00 – 3.00]	1.00 (1.00 - 1.00) [1.00 – 5.50]	0.30
Indigestion	1.50 (1.25 – 2.50) [1.00 – 5.00]	1.00 (1.00 – 1.75) [1.00 – 3.75]	1.50 (1.12 - 2.00) [1.00 – 5.00]	<0.001*
Constipation	1.00 (1.00 – 1.67) [1.00 – 5.00]	1.00 (1.00 – 1.00) [1.00 – 3.00]	1.00 (1.00 - 1.67) [1.00 – 5.00]	0.006*
Diarrhoea	1.00 (1.00 – 1.67) [1.00 – 5.00]	1.00 (1.00 – 1.33) [1.00 – 3.67]	1.00 (1.00 - 1.67) [1.00 – 5.00]	0.06

Abbreviations: BMI, body mass index; **CD**, Crohn's disease; **DF/EI**, dietary fibre (g/day) from energy intake (1000kcal); **GSRS**, gastrointestinal symptom rating scale; **IBD**, Inflammatory Bowel Disease, **IBS**, Irritable Bowel Syndrome; **MELAA**, Middle Eastern, Latin, American, African.

[1] Data expressed as mean ± standard deviation (SD) for continuous variables and n (%) for nominal variables, unless otherwise specified.

[2] [Range].

[3] Represents no supplementation with prebiotics, probiotics or synbiotics only.

[4] Data expressed as median (25^{th}, 27^{th} percentile), [range].

* P=<0.05, significant difference.

[a] Pearson's Chi-squared test; Fishers exact test.
[b] Independent t-test.
[c] Mann-Whitney U Test.

3.4.2 Intake of Dietary Fibre Compared to the NZ Median and NRVs

Table 3.2 summarises those meeting/exceeding the NZ median dietary fibre intake (20g/day) and the Nutrient Reference Value (NRVs) (Adequate Intake (AI) and Suggested Dietary Target (SDT)) dietary fibre recommendations. Overall, the majority of study participants exceeded the NZ median, AI and SDT, while there were no significant differences between females and males in meeting these targets ($p>0.05$).

Table 3.2: Percentage of Participants Exceeding NZ Median Dietary Fibre Intake and NRVs (AI and SDT) [1] (n = 193)

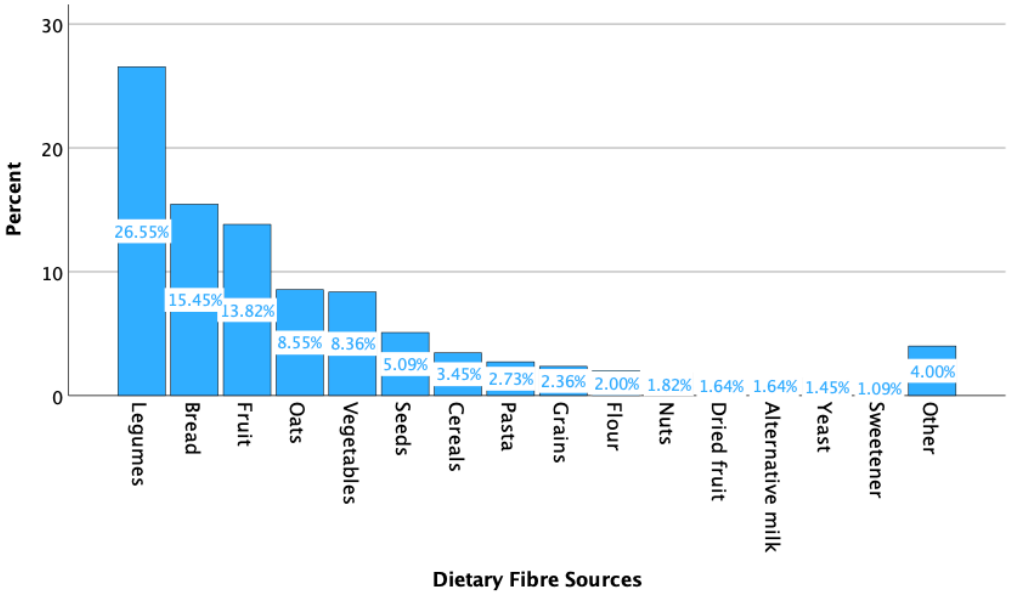
	Females (n= 141)	Males (n= 52)	Total (n= 193)	P value [a]
NZ median intake	**20g/day**			
	139 (99%)	52 (100%)	191 (99%)	1.00
Adequate Intake	**25g/day**	**30g/day**		
	135 (96%)	52 (100%)	197 (97%)	0.19
Suggested Dietary Target	**28g/day**	**38g/day**		
	129 (91.5%)	44 (85%)	173 (90%)	0.16

Data presented as n (%).
[1] Nutrient Reference Values (Adequate Intake and Suggested Dietary Target).
* P=<0.05, significant difference.
[a] Pearson's Chi-Squared Test; Fishers exact test.

3.4.3 Vegans Major Sources of Dietary Fibre

Figure 3.1 (below) illustrates the major sources of dietary fibre among vegans. These are presented as the percentage of participants whose top three dietary fibre sources included the food group. Of the 193 participants who completed the 4-day food diaries, only 183 participants' FoodWorks analyses provided the summarised results due to FoodWorks software error. The greatest source of daily dietary fibre intake among study participants was legumes, making up 26.55% of all participants' top three dietary fibre sources. This was followed by bread, fruit, oats, and vegetables.

Figure 3.1: The Major Sources of Dietary Fibre Among Vegan Diets (n= 183)



3.4.4 Gastrointestinal Symptoms (GSRS) and Dietary Fibre Intake

For the first logistic regression, all models showed good fit ($p>0.05$) as per Hosmer and Lemeshow Tests (X^2): GSRS, $X^2(8) = 10.64$ ($p= 0.22$); abdominal pain, $X^2(8) = 9.14$ ($p= 0.33$); reflux, $X^2(8) = 7.52$ ($p= 0.48$); diarrhoea: $X^2(8) = 3.05$ ($p= 0.93$); constipation, $X^2(8) = 6.69$ ($p= 0.57$); indigestion, $X^2(8) = 9.63$, ($p= 0.29$). Nagelkerke R^2 was low among all models (4 – 15%), thus the majority of variation between GSRS outcomes was not explained by the predictors.

Of the models, none showed statistically significant associations between GSRS scores and dietary fibre intake (g/day). However, a significant association was found between participants' characteristics, including abdominal pain and indigestion with sex and abdominal pain with age. Firstly, females were approximately five times more likely than males to experience abdominal pain (OR, 5.01 (95%CI, 1.37 to 18.26), p=0.02) and indigestion (OR, 5.61 (95%CI, 2.19 to 14.35), p<0.001). Meanwhile, increasing age was associated with a decreased odds of 0.96 (95%CI, 0.93 to 1.00), p=0.03) of abdominal pain. Lastly, no associations were found between participants' characteristics and the remaining GSRS scores: GSRS overall, reflux, diarrhoea, or constipation.

Table 3.3: Predictors of GSRS Scores[1] – Dietary Fibre (g/day), Sex, Age, BMI. [a]

	Coefficient B	S.E.	Wald	df	P value	Odds ratio	95% C.I odds ratio
GSRS overall							
DF/day	-0.04	0.02	3.64	1	0.056	0.97	0.93, 1.00
Sex [2]	0.88	0.67	1.74	1	0.19	2.41	0.65, 8.89
Age	-0.03	0.02	2.25	1	0.13	0.97	0.94, 1.01
BMI	-0.02	0.07	0.05	1	0.82	0.98	0.86, 1.13
Constant	-0.29	2.45	0.01	1	0.90	0.76	
Abdominal pain							
DF/day	- 0.004	0.02	0.06	1	0.81	1.00	0.97, 1.03
Sex [2]	1.61	0.66	5.96	1	0.02*	5.01	1.37, 18.26
Age	-0.04	0.02	4.97	1	0.03*	0.96	0.93, 1.00
BMI	0.01	0.06	0.02	1	0.88	1.01	0.89, 1.14
Constant	-2.90	2.28	1.62	1	0.20	0.06	
Reflux							
DF/day	-0.01	0.02	0.09	1	0.76	0.99	0.96, 1.03
Sex [2]	0.30	0.58	0.27	1	0.60	0.74	0.24, 2.29
Age	0.01	0.02	0.17	1	0.68	1.01	0.97, 1.05
BMI	0.14	0.08	3.41	1	0.06	1.15	0.99, 1.33
Constant	-5.24	2.62	4.00	1	0.05	0.01	
Diarrhoea							
DF/day	0.00	0.02	0.00	1	0.99	1.00	0.97, 1.03
Sex [2]	0.66	0.52	1.60	1	0.20	1.94	0.70, 5.41
Age	-0.01	0.02	0.75	1	0.39	0.99	0.95, 1.02
BMI	0.10	0.06	2.50	1	0.11	1.10	0.98, 1.24
Constant	-4.51	2.14	4.42	1	0.04	0.01	
Constipation							
DF/day	-0.02	0.02	1.45	1	0.23	0.98	0.95, 1.01
Sex [2]	0.68	0.54	1.55	1	0.21	1.97	0.68, 5.72
Age	-0.02	0.02	1.33	1	0.25	0.98	0.95, 1.01
BMI	-0.02	0.06	0.11	1	0.74	0.98	0.87, 1.11
Constant	-0.62	2.15	0.08	1	0.77	0.54	
Indigestion							
DF/day	-0.05	0.03	1.72	1	0.19	0.96	0.89, 1.02
Sex [2]	1.72	0.48	12.91	1	<0.001*	5.61	2.19, 14.35
Age	-0.02	0.01	2.03	1	0.16	0.98	0.95, 1.01
BMI	0.06	0.05	1.32	1	0.25	1.06	0.96, 1.18
Constant	-3.59	1.79	4.04	1	0.04	0.03	

Abbreviations: DF/day, dietary fibre (g/day) per day; **BMI**, body mass index

[1] OR >1 favouring: GSRS 'yes' (GSRS score: 2-7 (minor – very severe discomfort)); OR <1 favouring: GSRS, 'no' (GSRS score: <1.99 (no issues)).

[2] Males coded 0, females coded 1.

* P=<0.05, significant difference.

[a] Binary logistic regression.

Table 3.4 (below) illustrates the second binary logistic regression analysis. This was employed to determine predictors of GSRS outcomes with dietary fibre (g/day) exchanged for dietary fibre (g/1000kcal). Energy-adjusted dietary fibre (g/1000kcal) was employed to consider the amount of fibre eaten from total daily food intake between participants. As individuals with energy-dense diets may consume more dietary fibre, energy-adjusted intakes (g/1000kcal) were also included to reduce the risk of confounding results. Six models were built for each of the GSRS scores, with uniform binary format to GSRS outcomes and a sample size (n= 193. All models showed good fit ($p>0.05$) as per Hosmer and Lemeshow Tests (X^2): GSRS, $X^2(8) = 7.53$ ($p= 0.48$); abdominal pain, $X^2(8) = 11.24$ ($p= 0.19$); reflux, $X^2(8) = 9.46$ ($p= 0.31$); diarrhoea: $X^2(8) = 11.17$ ($p= 0.19$); constipation, $X^2(8) = 6.30$ ($p= 0.61$); indigestion, $X^2(8) = 4.04$, ($p= 0.85$). Nagelkerke R^2 was low among all models (5 – 15%), thus the majority of variation between GSRS scores was not explained by the predictors.

No models showed statistically significant associations between GSRS scores and dietary fibre intake (g/1000kcal). However, the associations remained between GSRS outcomes and participants characteristics: abdominal pain and indigestion with sex, and abdominal pain with age. Females were approximately five times more likely than males to experience abdominal pain (OR, 5.61 (95%CI, 2.19 to 14.35), p=0.009) and indigestion (OR, 5.61 (95%CI, 2.19 to 14.35), p<0.001). Similarly, increasing age was associated with a decreased odds of 0.96 (95%CI, 0.93 to 1.00), p=0.03) of abdominal pain. Meanwhile, a new association appeared between sex and GSRS overall with the addition of dietary fibre (g/1000kcal) in the model. Females were approximately four times more likely than males to experience GI symptoms overall (OR, 3.95 (95%CI, 1.11 to 13.99), p=0.03). Finally, no correlations were found between participants' characteristics and the remaining GSRS domains: reflux, diarrhoea, constipation.

Table 3.4: Predictors of GSRS Scores[1] – Dietary Fibre (g/1000kcal), Sex, Age, BMI. [a]

	Coefficient B	S.E.	Wald	df	P value	Odds ratio	95% C.I odds ratio
GSRS overall							
DF//1000kcal	-0.07	0.05	2.10	1	0.15	0.94	0.86, 1.02
Sex [2]	1.37	0.65	4.53	1	0.03*	3.95	1.11, 13.99
Age	-0.03	0.02	2.07	1	0.15	0.97	0.94, 1.01
BMI	-0.02	0.07	0.05	1	0.82	0.99	0.86, 1.13
Constant	-1.38	2.30	0.36	1	0.55	0.25	
Abdominal pain							

DF/1000kcal	- 0.002	0.04	0.002	1	0.97	1.00	0.93, 1.08
Sex [2]	1.66	0.64	6.83	1	0.009*	5.26	1.51, 18.28
Age	-0.04	0.02	5.02	1	0.03*	0.96	0.93, 1.00
BMI	0.01	0.06	0.03	1	0.86	1.01	0.90, 1.14
Constant	-3.15	2.16	2.13	1	0.14	0.04	
Reflux							
DF/1000kcal	-0.11	0.06	3.15	1	0.08	0.90	0.80, 1.01
Sex [2]	0.10	0.55	0.04	1	0.85	0.90	0.31, 2.64
Age	0.02	0.02	0.77	1	0.38	1.02	0.98, 1.06
BMI	0.12	0.08	2.37	1	0.12	1.12	0.97, 1.30
Constant	-3.47	2.47	1.98	1	0.16	0.03	
Diarrhoea							
DF/1000kcal	-0.04	0.04	0.92	1	0.34	0.96	0.89, 1.04
Sex [2]	0.72	0.50	2.13	1	0.15	2.06	0.78, 5.42
Age	-0.01	0.02	0.34	1	0.56	0.99	0.96, 1.02
BMI	0.08	0.06	1.89	1	0.17	1.09	0.97, 1.23
Constant	-3.64	2.01	3.27	1	0.07	0.03	
Constipation							
DF/1000kcal	-0.07	0.04	2.87	1	0.09	0.93	0.86, 1.01
Sex [2]	1.01	0.53	3.70	1	0.054	2.75	0.98, 7.70
Age	-0.02	0.02	0.79	1	0.38	0.99	0.95, 1.02
BMI	-0.03	0.06	0.25	1	0.62	0.97	0.85, 1.10
Constant	-0.43	2.05	0.04	1	0.83	0.65	
Indigestion							
DF/1000kcal	-0.05	0.03	1.72	1	0.19	0.96	0.89, 1.02
Sex [2]	1.72	0.48	12.91	1	<0.001*	5.61	2.19, 14.35
Age	-0.02	0.01	2.03	1	0.16	0.98	0.95, 1.01
BMI	0.06	0.05	1.32	1	0.25	1.06	0.96, 1.18
Constant	-3.59	1.79	4.04	1	0.04	0.03	

Abbreviations: DF/1000kcal, dietary fibre (g/day) per 1000kcal; **BMI**, body mass index

[1] OR >1 favouring: GSRS 'yes' (GSRS score: 2-7 (minor – very severe discomfort)); OR <1 favouring: GSRS, 'no' (GSRS score: <1.99 (no issues)).

[2] Males coded 0, females coded 1.

* P=<0.05, significant difference.

[a] Binary logistic regression.

A statistically significant difference was observed between dietary fibre intake (g/day) and two GSRS outcomes: overall and indigestion. Mean dietary fibre intake was significantly greater by 7.95g/day (95%CI, 3.00 - 13.86) (p=0.009) in those with no GI symptoms (47.75 ± 15.12g/day) (S.E., 1.18) compared to those with GI symptoms (39.81 ± 13.47g/day) (S.E., 2.50), as per GSRS overall. Similarly, dietary fibre intake was significantly greater by 6.36g/day (95%CI, 1.81 to 10.90) (p=0.006) in those with no symptoms of indigestion (48.57 ± 15.66g/day) (S.E., 1.36) compared to those with indigestion (42.21 ± 12.94g/day) (S.E., 1.66). However, no statistically significant differences were observed between dietary fibre

intake (g/1000kcal) and GSRS binary response outcomes. Across all GSRS domains, standard error (S.E.) of mean dietary fibre intakes (g/day) were high, notably among groups with symptoms ("yes"), indicating large variability in average dietary fibre (g/day) intakes.

Table 3.5: Mean Dietary Fibre Intake (g/day & g/1000kcal), as per GSRS Outcomes (yes/no) (n=193)

GSRS Syndrome		Binary response outcome		Mean difference (95%CI)	P value [a]
		Yes [1]	No [2]		
		n = 29 (15%)	**n** = 164 (85%)		
GSRS (overall)	**g/day**	39.81 ± 13.47 (2.50) [19.93 – 82.03]	47.75 ± 15.12 (1.18) [10.93 – 133.90]	7.95 (3.00 – 13.86)	0.009*
	g/1000 kcal	20.42 ± 4.49 (0.83) [10.81 – 27.91]	22.00 ± 5.31 (0.42) [12.27 – 39.47]	1.57 (-0.49 – 3.64)	0.13
		n = 38 (20%)	**n** = 155(80%)		
Abdominal pain	**g/day**	43.06 ± 13.38 (2.17) [24.06 – 82.03]	47.42 ± 15.43 (1.24) [10.93 – 133.90]	4.35 (-1.02 – 9.73)	0.11
	g/1000 kcal	21.62 ± 5.64g (0.92) [10.81 – 39.40]	21.79 ± 5.13 (0.41) [12.27 – 39.47]	0.17 (-1.84 – 2.18)	0.86
		n = 18 (9%)	**n** = 175 (91%)		
Reflux	**g/day**	45.64 ± 25.29 (5.96) [24.07 – 133.90]	46.66 ± 13.77 (1.04) [10.93 – 90.31]	1.02 (-6.37 – 8.42)	0.87
	g/1000 kcal	19.54 ± 4.75 (1.12) [10.81 – 26.60]	21.99 ± 5.23 (0.40) [12.27 – 39.47]	2.45 (0.08 – 4.98)	0.06
		n = 61 (32%)	**n** = 132 (68%)		
Indigestion	**g/day**	42.21 ± 12.94 (1.66) [19.93 – 82.03]	48.57 ± 15.66 (1.36) [10.93 – 133.90]	6.36 (1.81 – 10.90)	0.006*
	g/1000 kcal	21.04 ± 4.44 (0.57) [11.72 – 32.81]	22.10 ± 5.53 (0.48) [10.81 – 39.47]	1.06 (-0.53 – 2.65)	0.19
		n = 35 (18%)	**n** = 158 (82%)		
Constipation	**g/day**	42. 29 ± 14.39 (2.43) [19.93 – 82.03]	47.51 ± 15.16 (1.20) [10.93 – 133.90]	5.22 (-0.32 – 10.75)	0.06
	g/1000 kcal	20. 45 ± 4.93 (0.83) [10.81 – 32.80]	22.05 ± 5.25 (0.42) [12.27 – 39.47]	1.60 (-0.32 – 3.51)	0.10
		n = 33 (17%)	**n** = 160 (83%)		
Diarrhoea	**g/day**	44.74 ± 14.74 (2.57) [19.93 – 82.00]	46.93 ± 15.21 (1.20) [10.93 – 133.90]	2.19 (-3.52 – 7.90)	0.45
	g/1000 kcal	20.80 ± 4.35 (0.76) [11.72 – 32.81]	21.96 ± 5.37 (0.42) [10.81 – 39.47]	1.16 (-0.81 – 3.12)	0.25

Data expressed as means ± SD (S.E.), above; [Range], below.
[1] GSRS scores: 2-7 (minor – very severe discomfort).
[2] GSRS scores: <1.99 (no issues).
* P=<0.05, significant difference.
[a] Independent t-test.

3.5 Discussion

To our knowledge, this is the first study in NZ investigating dietary fibre intake and gut health among vegans in the local context. This study showed that NZ vegans have high dietary fibre intakes and minimal GI symptoms, while there was no relationship between the two. It is worth noting that the majority of participants were female and NZ European, while the majority of participants did not have any diagnosed chronic GI conditions.

3.5.1 Gastrointestinal Symptoms

Our study analysed participants' GSRS results and found that NZ vegans experience few GI symptoms. On average, participants reported no - minor GI discomfort symptoms across the GSRS domains. Overall, only 15% experienced minor to moderate GI discomfort symptoms collectively (GSRS overall). Specifically, 20% of participants experienced abdominal pain, 9% with reflux, 32% with indigestion, 18% with constipation, and 17% with diarrhoea at or above the level of minor discomfort.

Despite the low prevalence of GI symptoms among the study population, females reported significantly higher symptom severities than males. This included concerns of abdominal pain, indigestion, constipation, and overall GI symptoms, thus contributing to the majority of GI symptom complaints among the vegan population. However, upon further analysis, only abdominal pain and indigestion appeared significant after adjusting for dietary fibre (g/day), age and BMI. Overall, females were 5.18 times (p=0.009) more likely to experience abdominal pain than males and 5.13 times (p<0.001) more likely to report symptoms of indigestion. Moreover, when energy-adjusted dietary fibre intakes (g/1000kcal) were considered, females had an increased odds of 3.91 (p=0.03) of GI symptoms on average (GSRS overall) than males. Interestingly, these outcomes were not observed upon analyses inclusive of daily dietary fibre intakes (g/day). Nonetheless, these findings may illustrate a weak association resulting from the variance in dietary fibre intake (g/day) (10.93 – 133.90g/day) among study participants.

While females within our study reported more GI symptoms than males, this may not be specific to vegans. Among the general populations, females tend to experience abdominal distension and flatulence, rumbling (Choghakhori et al., 2017), indigestion (Milner et al., 1999), constipation (Kim & Kim, 2018; McCrea et al., 2009; Verkuijl et al., 2020), and reflux (Kim et al., 2016) more frequently than males. Similarly, females report higher pain severities than males (Lombana & Vidal, 2012). Thus, this may provide the rationale for the higher symptom severities of abdominal pain among females. While the potential mechanisms behind these findings have not been examined within the vegan study population, physiological influences may explain them. These factors may be attributed to slower GI transit timing in females (Lampe et al., 1993) and hormonal differences during menstruation (Judkins et al., 2020; Moore et al., 1998). Overall, due to the greater number of female participants in the study, there was enough power to determine significance. Irrespectively, despite higher reports of symptoms among females, the majority of GI complaints were no more severe than moderate discomfort; therefore, it cannot be concluded that female vegans experience significant GI issues.

Further analysis found that older participants had fewer reported abdominal pain severities than younger participants. For every one-year increase in the age of our study participants, the risk of abdominal pain symptoms increased by 4% ($p=0.03$). These outcomes may be attributed to the gradual decline in pain perception with age (Beckers et al., 2021; Lautenbacher et al., 2017). Irrespectively, age was not associated with other GSRS outcomes (indigestion, reflux, diarrhoea, constipation, and overall). Thus, there was little variability across age groups regarding GI symptom severities.

To our knowledge, no other studies have employed the GSRS to investigate GI symptoms among vegans. Nor has the tool been used in analyses specific to healthy New Zealanders without chronic GI conditions. Consequently, our study cannot compare GSRS scores to other studies. Nonetheless, the GSRS has been validated by Alverez et al. (2023) for its reliability and validity in assessing GI tolerance of nondigestible carbohydrates among healthy adults. In this study, the GSRS exhibited acceptable reliability within the overall GSRS scale, diarrhoea and constipation; the later sub-scale domain was able to predict slow transit tools in line with BSFS types 1 – 2, thus supporting the tools' accuracy in the assessment of stool form. Therefore, given these findings, the tool appears to be suited to our study population within the assessment of dietary fibre intake on stool-related GI symptoms.

While the GSRS has been shown to accurately assess overall GI discomfort and symptoms relating to stool form, poor reliability has been indicated for evaluating reflux, abdominal pain and indigestion (Alvarez et al., 2023). Despite this, our findings agree with other studies (Rizzo et al., 2023), which report a low incidence of acid reflux in vegan populations. With regard to abdominal pain, it is thought that adequate bowel motion frequency may reduce these symptoms (Wong et al., 2020). Given the low symptom severities of constipation and diarrhoea, and thus frequent bowel movements in line with other reports (Davies et al., 1986; Panigrahi et al., 2013; Sanjoaquin et al., 2004), this may support the accuracy of our findings in relation to low reports of abdominal pain. Finally, while symptoms of indigestion have not been investigated among vegans, as previously indicated, these manifestations are common among females (Milner et al., 1999) and thus validate our findings.

3.5.2 Association Between Dietary Fibre and Gastrointestinal Symptoms

Our study found that those with indigestion and general GI symptoms (GSRS overall) consumed significantly less dietary fibre (g/day) than those without symptoms. Mean dietary fibre intakes for those with symptoms of indigestion were 42.21g/day, compared to 48.57g/day among those without symptoms. For those with general GI symptoms (GSRS overall), mean dietary fibre intakes were 39.81g/day, compared to 47.75g/day for those without symptoms. Therefore, all individuals, whether experiencing GI symptoms or not, exceeded the NZ NRVs for both the AI and SDT recommendations; thus, it cannot be concluded that vegans exceeding the NRV SDT and those not meeting the AI dietary fibre recommendations experienced worse GI symptoms. Moreover, upon further examination with logistic regression analysis, there were no significant associations between dietary fibre intake and the odds of GI symptoms. Therefore, despite the differences in dietary fibre intake, we cannot conclude that dietary fibre intake predicted these symptoms after accounting for participants' demographics (sex, age, and BMI).

Overall, among the GSRS domains, no correlations were found between dietary fibre intake and reports of GI symptoms. These results may be attributed to the low variance in GSRS scores between participants (averaging GSRS 1 to 2 across the domains); thus, no association could be established. Among the study participants, reports of GI symptoms were minimal, while 97% of participants exceeded the NZ NRVs for the dietary fibre AI recommendations

and 90% met the SDT. Therefore, our findings support that exceeding the NZ NRV dietary fibre recommendations does not increase the occurrence of GI discomfort symptoms among vegans. On the other hand, as few participants (3%) did not meet the AI dietary fibre recommendations, our study could not find any associations between low dietary fibre intake and GI symptoms.

While some studies (Alyousif et al., 2020; Chutkan et al., 2012; Gonlachanvit et al., 2004) have linked high intakes of certain fibre types to the onset of GI symptoms (abdominal pain, bloating and flatulence), the results of our study show that this is not a concern among vegans who consume fibre-rich diets. These findings may be supported by adaptation mechanisms from the intestinal microbiota. According to a study conducted by Mego et al. (2017), regular consumption of galacto-oligosaccharides, a type of fermentable dietary fibre, may lead to an increase in intestinal gas production, causing GI symptoms initially. However, this effect declines over time as the intestinal microbiota adapts to the regular consumption of GI symptom-provoking galacto-oligosaccharides (Mego et al., 2017). Given that all vegan study participants had adhered to a strict vegan diet for a minimum of two years, these adaptation mechanisms may support our findings in which reports of GI symptoms were low.

3.5.3 Dietary Fibre Intake

Our study found that NZ vegans consume a significantly higher amount of dietary fibre than the general population, with 99% of participants exceeding the NZ median. While the median dietary fibre intake for the NZ population is 20g/day (Ministry of Health, 2011), vegans consume an median intake of 45.91g/day. Therefore, the dietary fibre intake of vegans is 2.3 times greater than the general NZ public. These findings are consistent with international studies analysing dietary fibre intakes among vegans. A systematic review, which included 141 vegan studies conducted by Neufingerl & Eilander (2021), found that vegans consume an average of 44g of dietary fibre daily. Therefore, this may indicate that vegans adopt comparable dietary habits globally, with the outcomes of our study closely resembling international evidence.

Among the studies analysed by Neufingerl & Eilander (2021), dietary fibre intakes among meat-eaters averaged only 21g/day, respectively, thus aligning closely to the NZ median intake. While statistics on the dietary fibre intakes among New Zealanders do not

differentiate based on an individual's diet classifications (i.e. vegans, vegetarians, meat-eaters, pescatarians), the majority of the population eat meat (Greenwell et al., 2023); it is estimated that less than 1% of New Zealanders follow a vegan diet (Milfont et al., 2021). Therefore, there is sufficient evidence to support that the NZ median is mostly representative of meat-eaters; thus, these findings provide valuable insight into the fibre intakes of NZ vegans compared to omnivores.

In addition to the vegan population exceeding the NZ median dietary fibre intake, dietary fibre intake surpassed the NZ NRV recommendations. This includes the AI of 25g/day for females and 30g/day for males, and the SDT of 28g/day for females and 38g/day for males (National Health and Medical Research Council et al., 2006). Overall, 97% of participants met the AI and 90% met the SDT. Due to these findings, it is not surprising that the prevalence of chronic GI conditions was low (4.7%) among the vegan study population. This is given dietary fibres' preventative role in the susceptibility to GI disease (Burkitt et al., 1974; Gasaly et al., 2015), and more specifically, the majority of participants exceeding the SDT- a set dietary fibre recommendation for the prevention of chronic disease (National Health and Medical Research Council et al., 2006).

While there were no significant differences in achieving the AI or SDT recommendations between sexes, males consumed significantly more dietary fibre than females. Median dietary fibre intake among males averaged 52.62g/day compared to 42.24g/day among females. Despite this, males consumed less fibre-dense diets than females following the consideration of differences in energy intake. Overall, males averaged 20.54g/1000kcal of energy-adjusted dietary fibre compared to 22.21g/1000kcal among females. Other studies (Fernstrand et al., 2017; Seljak et al., 2021) have agreed with these findings, whereby females commonly consume more dietary fibre per 1000kcal than males, despite lower average daily fibre intakes. Regardless, among both females and males, energy-adjusted dietary fibre intakes were greater than recommendations outside of NZ, which suggests an AI of 14g/1000kcal to protect against chronic disease (Dahl & Stewart, 2015). Finally, energy-adjusted fibre intakes were consistent with findings from other vegan analyses reporting dietary fibre ranges from 20-23g/1000kcal, respectively (Dawczynski et al., 2022; Sliz et al., 2021).

3.5.4 Dietary Fibre Sources

The most common contributor to daily dietary fibre intake among vegans was legumes (i.e. soy foods, beans, chickpeas, lentils, peas, peanuts). Legumes were included in the top three contributors of dietary fibre in 26% of all participants. This was followed by bread (15.45%), fruit (13.82%), oats (8.55%) and vegetables (8.36%). These food intakes align with recommendations from the Ministry of Health (2020), which encourage eating a variety of nutrient-dense, fibre-rich foods for the prevention of disease. To compare, findings from the NZ Adult Nutrition Survey (Ministry of Health, 2011) showed that bread (17%) makes up the greatest source of dietary fibre among NZ diets, just ahead of vegetables (16%) and fruit (12%). While the survey did not report legume consumption among the general NZ population, international studies have found higher intakes of legumes among vegans than meat-eaters (Davies et al., 1985; Larsson & Johansson, 2005). These differences may account for the variation in dietary fibre intake between our vegan study participants and the general NZ population.

Although our study did not investigate the ratio of soluble to insoluble fibre consumed by the participants, it is evident that N*Z* vegans eat a diet rich in both fibre types. This is given their high dietary intakes, variety of fibre-dense foods, and common consumption of legumes – a dietary source rich in both soluble and insoluble fibre. While previous studies have linked foods with highly fermentable dietary fibre, such as legumes (Othman et al., 2023; Price et al., 1988), to abdominal discomfort, bloating and flatulence (Alyousif et al., 2020; Gonlachanvit et al., 2004), our study shows that this may not be a concern to those on a long-term vegan diet. These outcomes may result from the variability in dietary fibre types consumed by the participants, which may modulate fermentable fibres' gas-provoking side effects (Azpiroz et al., 2014).

3.5.5 Strengths

To our knowledge, there is no research exploring dietary fibre intake and gut health of NZ vegans. Meanwhile, little research has investigated the impact of high-fibre diets on GI symptoms among healthy populations. This is despite analyses among individuals with GI disorders and short-term high-fibre dietary interventions. Therefore, the outcomes of this study may provide researchers, healthcare professionals, and individuals with detailed insights into vegans' dietary fibre intake and gut health, and the implications of high-fibre

diets on GI symptoms. Moreover, these findings may provide guidance to the NZ population regarding dietary fibre intakes to improve gut health.

The relatively large sample size of 212 adult vegans was another strength of the study, which included a wide age demographic, from 19 – 75 years, with a healthy BMI. Few participants presented with chronic GI conditions (4.7%); therefore, the GI outcomes were representative of healthy vegan individuals. Furthermore, all participants had followed a strict vegan diet for at least two years before the commencement of the study; thus, all findings were representative of a strict vegan population.

Another strength of this study was the thorough dietary data collection and entry protocols, as led by trained researchers. During data collection, all participants were provided with an information sheet (Appendix C) explaining how to complete their 4-day food diaries. To ensure that the food records were representative of the participant's usual diets, they were asked to complete their food diaries on consecutive days of the week (one weekend, three weekdays) while maintaining their regular diet. The participants were also asked to take photos of their meals/food and supplements. The vegan team used these photos to research unknown foods not already in the FoodWorks database, to find their Nutrition Information Panels (NIPs). This was used to create manual entries of foods/recipes that were then adjusted with retention/yield factors from Bognar. (2002). All manually created items were used across all applicable food diaries to ensure new foods/recipes were consistent across all participant food records. The entry of all food diaries into FoodWorks was collectively carried out by a team of student dietitians. Prior to data analysis, food diaries with queries from the research team were re-checked with the participants and updated. All participants' food records were also checked for correctness at least three times in FoodWorks.

3.5.6 Limitations

The study has the following limitations: (1) the GSRS is specific to gastrointestinal symptoms experienced only within the seven-day period prior to the study. Data is also only taken at only one point in time. Therefore, if the participants completed the questionnaire on a day when they were either experiencing improved or worsened GI symptoms, this may introduce bias; (2) the participants were not questioned whether their responses to the GSRS questionnaire were reflective of their usual gut health; (3) the GSRS lacks specificity with

regards to the frequency of GI symptoms; (4) the GSRS is subjective, thus ones definition of discomfort severity may not compare to another participants' perception; (5) the 4-day food diaries were self-reported by participants, thus under-reporting of dietary intake cannot be ruled out; (6) while there are many strengths of our study population, all participants resided in Auckland, NZ, while the majority were female and NZ European. Thus, our results may primarily reflect individuals only of these demographics; (7) no research has employed the GSRS to compare GI symptoms among vegan populations, therefore limiting comparisons to current evidence.

3.6 Conclusion

The results of this study found that reports of GI symptoms were low among NZ vegans. On average, participants reported no – minor GI discomfort across the GSRS domains. Among those with symptoms, female participants and younger individuals reported worse symptoms of abdominal pain, while females also experienced higher rates of indigestion symptoms. Nonetheless, our study found that there were no associations between dietary fibre intake and the risk of GI symptoms. This was despite dietary fibre intake surpassing the NZ NRV recommendations and the NZ median intake. Finally, our study identified the major food sources of dietary fibre among NZ vegans were legumes, bread, fruit, oats and vegetables, with the former consumed the most. Therefore, given the low incidence of GI symptoms, vegans' high consumption of both dietary fibre and legumes- a gaseous fibre-rich food, does appear to provoke GI discomfort. Overall, the results of our study support that high-fibre diets (above the dietary recommendations) do not contribute to increased reports of GI symptoms. This study offers new insights into the health outcomes of NZ vegans, specifically regarding dietary fibre intake and GI health, which no prior research has explored. These outcomes may incentivise healthcare professionals to promote plant-based dietary approaches to support New Zealanders in meeting the recommended fibre intake and to aid gut health.

3.7 Acknowledgements

The authors would like to thank all the participants who took the time to participate in this study.

3.8 Conflicts of Interest

The authors have no conflict of interest to declare.

Chapter 4.0: Conclusions and Recommendations

4.1 Overview of study findings

This cross-sectional study was designed to investigate the relationship between gastrointestinal symptoms and dietary fibre intake in NZ vegans. Eligibility for the study was that participants (n = 212) had to have followed a strict vegan diet (i.e. no animal products) for at least two years prior to the study, over 18 years of age, and not pregnant. Participant characteristics (sex, age, BMI, ethnicity, supplement use and medical history/presence of GI conditions) were collected via a health and demographics questionnaire. Dietary fibre intakes and the major sources of dietary fibre among vegans was collected via 4-day food diaries. Data on participants' gastrointestinal discomfort symptoms was collected via responses to the Likert-7 scale GSRS questionnaire; these were collated into five sub-scales: abdominal pain, indigestion, reflux, constipation, diarrhoea and an overall score.

The primary objective of this study was to explore gastrointestinal symptoms in vegans using the Gastrointestinal Symptom Rating Scale (GSRS). On average, participants reported no - minor GI discomfort symptoms across the GSRS domains. Overall, only 15% experienced minor to moderate GI discomfort symptoms collectively (GSRS overall). Specifically, 20% of participants experienced abdominal pain, 9% with reflux, 32% with indigestion, 18% with constipation, and 17% with diarrhoea at or above the level of minor discomfort. Among those with symptoms, females reported worse symptoms of abdominal pain, indigestion, constipation, and overall GI symptoms.. However, upon further analysis, only abdominal pain and indigestion appeared significant after adjusting for dietary fibre (g/day), age and BMI. Finally, older participants had fewer reported abdominal pain severities than younger participants.

The second objective was to assess whether dietary fibre intake is associated with gastrointestinal symptoms among vegans. Overall, our study revealed no associations between NZ vegans' dietary fibre intake and the occurrence of digestive symptoms. This may be given the low variability in GSRS scores among participants. Therefore, high-fibre diets, above the AI and SDT recommendations, do not contribute to increased reports of GI symptoms. Meanwhile, vegans' high consumption of legumes- a gaseous fibre-rich food, does appear to be problematic with regards to the occurrence of GI symptoms, given their low overall report of GI discomfort severity.

The third objective was to assess the dietary fibre intake of vegans', from a 4-day food diary, and compare to the NZ Nutrient Reference Values and the NZ median intake. Overall, the majority of vegan participants exceeded the dietary fibre recommendations: 97% of participants achieved the Adequate Intake (AI), and 90% met the Suggested Dietary Targets (SDT), while there were no significant differences between females and males with regard to achieving these recommendations. The average dietary fibre intake was 45.91g/day, thus exceeding the NZ median intake of 20g/day. While males consumed more dietary fibre than females, with a median intake of (42.24g/day *versus*. 52.62g/day), females had more fibre-dense diets once the difference in energy intake was considered (22.21g/1000kcal *versus*. 20.54g/1000kcal). The outcomes of this study highlight that NZ vegans have similar dietary fibre intakes to those reported overseas.

The final objective was to identify the major food sources of dietary fibre among NZ vegans. The most common contributor to daily dietary fibre intake among vegans was legumes (i.e. soy foods, beans, chickpeas, lentils, peas, peanuts). Legumes were included in the top three contributors of dietary fibre in 26% of all participants. This was followed by bread (15.45%), fruit (13.82%), oats (8.55%) and vegetables (8.36%). Comparatively, findings from the NZ Adult Nutrition Survey (Ministry of Health, 2011), show that bread (17%) makes up the greatest source of dietary fibre among New Zealanders, just ahead of vegetables (16%) and fruit (12%). Therefore, these results suggest that vegans may have higher dietary fibre intakes due to their large intakes of legumes, which are not commonly consumed by the general NZ population.

4.2 Significance of Findings

This study offers new insights into the health outcomes of NZ vegans, specifically regarding dietary fibre intake and GI health, as no prior research has been conducted on this population. Overall, we found that NZ vegans exceed the NRV recommended dietary fibre intakes and population medians while reporting few digestive symptoms and low incidences of GI disorders. Therefore, these outcomes may incentivise healthcare officials to promote plant-based dietary approaches to support New Zealanders in meeting the recommended fibre intake and to aid gut health. Our identification of vegans' key sources of dietary fibre intake may assist in formulating dietary fibre guidelines to support these incentives. Furthermore, as

our study showed that high fibre consumption does not provoke the onset of digestive symptoms, these outcomes may encourage individuals to obtain fibre-rich intakes without a need for caution on the fibre types one may consume. Finally, the study findings could serve as preliminary data, laying the foundation for further research to ascertain at what intake of dietary fibre GI symptoms may be minimised.

4.3 Strengths and Limitations

A strength of this study was the relatively large sample size of 212 adult vegans, recruited from across Auckland, NZ. However, the study may have benefited from a more evenly distributed ratio of men (27%) to females (73%). Irrespectively, the sample included a wide age demographic from 19 – 75 years, who were of a healthy BMI. Few participants presented with chronic GI conditions (4.7%); therefore, the GI outcomes were representative of healthy vegan individuals. Further, all participants had followed a strict vegan diet for at least two years prior to the commencement of the study, thus all findings were representative of a strict vegan population.

Gastrointestinal Symptom Analysis

The GSRS has been widely validated for its reliability in assessing GI symptoms (Svedlund et al., 1988) in both healthy populations and those with GI disease (Alyousif et al., 2020; Bayer et al., 2022; Lohiniemi et al., 2000), thus enhancing the credibility of our results. The GSRS tool proved valuable for analysing GI symptoms, offering insights into abdominal pain, reflux, indigestion, diarrhoea, constipation, and overall symptoms. The Likert-7 scale design (1 indicating no symptoms, 2-7 signifying minor to very severe discomfort) enabled us to transform the scores into binary response outcomes (yes and no) to establish predictors of GI symptoms.

While the GSRS tool offered valuable insights, the questionnaire lacks specificity with regards to the frequency of these symptoms. Similarly, the questionnaire is only specific to a seven-day period, prior to the commencement of the study, while digestive symptoms are only recorded collectively at one point in time. Consequently, this may have introduced bias if a participant experienced a good day, or a poor day, with their gut health at the time of completion. The participants were also not questioned as to whether their responses to the GSRS questionnaire were reflective of their usual gut health. For example, participants may have been experiencing an acute bout of abdominal pain, indigestion, reflux, constipation or

diarrhoea during the time of study completion, however, no queries were made. Finally, the study participants were not asked whether they may be experiencing an undiagnosed food intolerance, allergy or GI condition that may impact digestive symptom outcomes.

Dietary Analysis

This study employed the 4-day weighed food record for dietary assessment protocols. This is considered one of the more accurate dietary assessment methods for quantifying food intake (Gariballa & Forster, 2008), enabling insight into meal portion sizes. However, as food diaries are self-reported by participants, under-reporting of dietary intake may arise (Livingstone, 1990).

A strength of this study was the thorough data collection protocols for dietary analysis, as led by trained researchers. As part of this process, participants were provided an information sheet (Appendix C) detailing how to complete their 4-day weighed food diaries. To ensure that the participants' dietary data was representative of their usual intake, it was asked that they complete the diaries on consecutive days (one weekend, three weekdays) while maintaining their regular diet. The participants were also asked to take photos of their meals/food and supplements. The vegan team used these photos to research unknown foods not already in the FoodWorks to find their Nutrition Information Panels (NIPs). Finally, prior to data analysis, any food diaries with queries from the research team were re-checked with the participants and updated.

The research team manually entered the food diaries into FoodWorks with each participants' record checked at a minimum of three times. Items that were not already in the database were manually created using the foods NIP and adjusted with retention/yield factors from Bognar. (2002). These were used across all applicable food diaries to ensure new foods were consistent across all participant food records.

4.4 Recommendations for Future Research

While our study provided practical analysis into the gastrointestinal health and dietary fibre intake of vegans, it may be worthwhile conducting the same research in those following an omnivorous diet. These analyses could help to generate further detailed guidance to the NZ population regarding dietary fibre intakes to improve digestive health. Conducting a

comparative analysis may also help confirm the true meaningfulness of our study results. Finally, further recommendations for research include the addition of a more detailed analysis of other variables that may influence gut health among vegans. While dietary fibre and participants' characteristics were analysed, the study could benefit from investigations into physical activity levels, water and alcohol intake, and sugar and saturated fat consumption among the vegan diet.

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Appendices

Appendix A: Participant Information Sheet

Participant Information Sheet

Health and Vegan Diet

A clinical investigation project included in Phase 2 of The Vegan Health Research Programme

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

Lead Researcher: Professor Pamela von Hurst

Study Site: Human Nutrition Research Unit, Massey University, Albany

Contact phone number: 09 414 0800 ext 43657

Ethics committee ref.: 2022 EXP 12312

You are invited to take part in a study investigating the impact of a vegan diet on your health**.** Whether or not you take part is your choice. If you want to take part now, but change your mind later, you can pull out of the study at any time.

This Participant Information Sheet will help you decide if you'd like to take part. It sets out why we are doing the study, what your participation would involve, what the benefits and risks to you might be, and what would happen after the study ends. We will go through this information with you and answer any questions you may have. You do not have to decide today whether or not you will participate in this study. Before you decide you may want to talk about the study with other people, such as family, whānau, friends, or healthcare providers. Feel free to do this.

This form is 8 pages. Please make sure you have read and understood all the pages.

VOLUNTARY PARTICIPATION AND WITHDRAWAL FROM THIS STUDY

Participation in this study is completely voluntary. You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any particular questions
- 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
- Be given access to a summary of the study findings when it is concluded

Withdrawing from the study, should you choose to, will not result in any disadvantage to you.

What is the purpose of the study?

Interest in the vegan lifestyle is growing, and NZ ranks the fifth most vegan country in the world. A vegan diet tends to have some health benefits, but at the same time it might be associated with nutrient deficiencies.

These deficiencies could have significant health consequences if they occur during critical period of life (for example, pregnancy or the rapid growth and developmental stages). Therefore, dietary guidelines stress that those who follow strict vegetarian or vegan diets may need extra information and/or support to ensure that they meet their nutrient needs. Our search has not found any studies to date that have investigated nutritional status, nutrient/food intake, motivations and nutritional knowledge and their sources of NZ vegans.

The aims of this study are to investigate nutritional status, nutrient/food intake, reasons for becoming vegan, nutrition knowledge and sources of nutrition information, and gastrointestinal discomfort symptoms among NZ vegans.

How is the study designed?

This study will involve 220 individuals aged 18 years or older, who have been on a vegan diet for at least two years. Participants will take part in online or telephone screening to check eligibility. If eligible they will visit the Human Nutrition Unit at Massey University, once for approximately 90 minutes,

Participants will be required to have bone density, body composition, and blood pressure measurements, complete online questionnaires regarding health, demographics, lifestyle, physical activity, motivations for following a vegan diet, dietary intake, nutrition knowledge, and sources of nutrition knowledge, and complete a 4-day diet record. In addition, participants will be asked to provide a non-fasted blood sample.

Who can take part in the study?

Individuals aged 18 years or older, who have been following a vegan diet for at least two years will be included in this study. Women who are pregnant or have any likelihood of being pregnant will be excluded from this study. Participants will complete a short screening questionnaire to ensure they meet inclusion criteria.

What will my participation in the study involve?

If you decide to take part in this study, after you have read and had time to consider the information in this information sheet, you will be required to complete the screening questionnaire. Screening involves answering a few inclusion criteria questions, this can be done at home either online or on the phone, and takes approximately five minutes. Your answers to this questionnaire will help us to see if you are eligible to take part in this study or not.

If you are eligible to take part in this study, you will be required to visit Human Nutrition Unit at Massey University in Albany on one occasion for data collection. Prior to your visit to Massey University, we will send you a consent form, some questionnaires that need to be completed online, and a diet diary. For the online questionnaires, we will ask you to:

- Complete demographic, health, lifestyle, and physical activity questionnaires.
- Complete a questionnaire to assess motivations for following a vegan diet

- Complete a questionnaire to assess dietary intake
- Complete a questionnaire to assess nutritional information and their sources
- Complete a questionnaire to assess gastrointestinal discomfort symptoms

For the diet diary, we request that for 4 days you record everything you eat and drink. Instructions will be provided in more detail at your visit.

A researcher will make an appointment with you at your convenience You will be required to not have caffeinated drinks and not exercise for 2hrs prior to the visit. This visit will take approximately 90 minutes and you will be reimbursed for your travel.

At this appointment you will first be asked to hand in the signed consent form for participating in the study and you will have the opportunity to ask any questions you may have about the study. During this visit, we will ask you to

- Have weight, height, and waist and hip circumferences measured by a trained researcher.
- Have bone density and body composition measured using dual-energy X-ray absorptiometry (DXA). This machine uses very low dose X-rays to measure the bone density of your hip and spine, and also measures your body composition (fat mass, lean mass, and bone mass of your body).
- Have blood pressure measured using electronic blood pressure monitor by a trained researcher
- Provide a small venous blood sample (about 20ml which is equivalent to 4 teaspoons). This will be taken by a qualified phlebotomist. It will be used to measure levels of various nutrients in your blood, such as iron and vitamin D.

WHAT WILL HAPPEN TO MY BLOOD SAMPLES?

All samples will be labelled with the participant's unique identity code/number and not by the participant's name.

The blood samples will be stored in a minus 80 degree freezer until the study is completed after which time the biochemical analysis will be conducted. While waiting for data and bloods to be collected from all participants and analysed in one batch, samples will be kept in the freezer at the Nutrition laboratory at Massey University, Building 27, Oteha Rohe campus, Albany.

On completion of the study, samples will be sent to the Canterbury Health Labs to assess vitamins D, B_{12}, folate, iron, lipids, calcium and albumin.

One drop of whole blood sample will be analysed on site at Massey University to assess haemoglobin, and another drop will be applied to a special paper to be sent to CSIRO laboratory in Adelaide to assess polyunsaturated fatty acids.

Participants may ask to withdraw their samples at any time during the study up to the time the samples are analysed. The analysis results in the destruction of the sample.

There may be participants who identify as Māori and if specific concerns develop, the support of Dr Bevan Erueti (Taranaki, Te Ati Haunui-ā-Papārangi, Ngāti Tūwharetoa), Associate Dean Māori, will be afforded. Dr Erueti has expressed that he is happy to act in the capacity of advisor and if required will assist and facilitate the projects Māori agenda and ensure that relational aspects of trust and appreciation are upheld with Māori participants. We are also

aware that a diversity of beliefs and cultural concerns regarding the removal, storage and transport of tissue samples and these should be discussed with your whānau (family) or take advisement from hapū and iwi leaders. Nonetheless, the right to decline or withdraw from the study can be done at any stage of the project.

What are the possible risks of this study?

The DXA has X-ray beams of different energies and, while no dose of radiation is harmless, this dose is very low and unlikely to cause harm. The total effective dose of radiation to which you will be exposed to is 10.8 microsieverts (μSv), which is much lower than the range normally used in medical diagnostics. To place this in perspective, the amount of radiation an individual would receive from flying in an aircraft to the United Kingdom equates to an effective dose about six times that received from the study. The effective dose received by the participants from the study is also equivalent to about 2 days of background radiation to which all New Zealanders are exposed. This procedure is quick, non-invasive and completely painless. The room is private, and the staff are experienced and certified.

Some people may have a fear of having a blood sample taken or experience discomfort when blood samples are taken. Occasionally a slight bruising will result. The bruising usually disappears within a day or two. Blood samples will be taken by a trained phlebotomist. There may be social or cultural discomfort from having a blood sample, bone density, body composition, and blood pressure measurements taken, however, you will be treated with respect, and privacy will be ensured. We will explain all measurements being taken and ask for your permission prior to undertaking these measurements. You may also be accompanied by a support person if you wish. Every effort will be made to ensure your comfort and respect your participation.

WHAT ARE THE POSSIBLE BENEFITS OF THIS STUDY?

- You will be contributing to a greater understanding of the health implications of a vegan diet.
- You will not be charged for any of the measurements conducted for the study
- You will be provided with your body composition results, blood test results and a nutrient analysis of your diet from your 4-day diet diary.
- You will get a summary of the study results.

Will any costs be reimbursed?

Participants will not incur any costs as part of being involved in the study and will receive reimbursement for travel ($20 in vouchers).

What if something goes wrong?

If you were injured in this study, you would be eligible to apply for compensation from ACC just as you would be if you were injured in an accident at work or at home. This does not mean that your claim will automatically be accepted. You will have to lodge a claim with ACC, which may take some time to assess. If your claim is accepted, you will receive funding to assist in your recovery.

If you have private health or life insurance, you may wish to check with your insurer that taking part in this study won't affect your cover.

What will happen to my information?

During this study the researchers will record information about you and your study participation. This includes the results of any study assessments. You cannot take part in this study if you do not consent to the collection of this information.

Identifiable Information

Identifiable information is any data that could identify you (e.g. your name, date of birth, or address). The following groups may have access to your identifiable information:

- Research staff (to complete study assessments)
- Government agencies, like HDEC, ACC and its representatives, **if** you make a compensation claim for study-related injury. Identifiable information is required in order to assess your claim.

De-identified (Coded) Information

To make sure your personal information is kept confidential, information that identifies you will not be included in any report generated by the researcher. Instead, you will be identified by a code. The researcher will keep a list linking your code with your name, so that you can be identified by your coded data if needed.

The results of the study may be published or presented, but not in a form that would reasonably be expected to identify you.

Anonymised Information

The lead researcher may remove the code from your de-identified information – this is called 'anonymisation'. This makes it very difficult (but not impossible) to identify the information that belongs to you. The researcher may share this anonymised information with other researchers on request for the purpose of accumulating data from individual studies. The anonymous/anonymised data is unable to be accessed, corrected, or withdrawn; and return of individual results will not be possible.

Future Research Using Your Information

If you agree, your fully anonymous/anonymised information may be used for future research related to veganism. This is optional and you could still participate in the present study if you do not agree.

This future research may be conducted overseas. You will not be told when future research is undertaken using your information. Your information may be shared widely with other researchers. Your information may also be added to information from other studies, to form much larger sets of data.

You will not get reports or other information about any future research that is done using your information.

Your information may be used indefinitely for future research unless you withdraw your consent. However, it may be extremely difficult or impossible to access your information, or withdraw consent for its use, once your information has been shared for future research.

Security and Storage of Your Information

Your identifiable information is held at Massey University during the study. After the study it is transferred to a secure archiving site and stored for at least 10 years, then destroyed. Your coded information will be entered into electronic case report forms. Coded study information will be kept in secure, cloud-based storage indefinitely. All storage will comply with local and/or international data security guidelines.

The linked data in this study will be destroyed at the end of the study.

Risks.

Although efforts will be made to protect your privacy, absolute confidentiality of your information cannot be guaranteed. Even with coded and anonymised information, there is no guarantee that you cannot be identified. The risk of people accessing and misusing your information (e.g. making it harder for you to get or keep a job or health insurance) is currently very small but may increase in the future as people find new ways of tracing information.

Rights to Access Your Information

You have the right to request access to your information held by the research team. You also have the right to request that any information you disagree with is corrected.
Please ask if you would like to access the results of your scan (body composition) during the study. You can't access other study-specific information (e.g. diet analysis and blood test results) during the study, because these data will be analysed when the data from all participants are collected and the study is over.

If you have any questions about the collection and use of information about you, you should ask researcher.

Rights to Withdraw Your Information

You may withdraw your consent for the collection and use of your information at any time, by informing the study researchers.

If you withdraw your consent, your study participation will end, and the study team will stop collecting information from you.

Information collected up until your withdrawal from the study will continue to be used and included in the study. This is to protect the quality of the study.

What happens after the study or if I change my mind?

If you wish to withdraw from the study, please inform one of the research team. Information and data collected up until your withdrawal from the study will continue to be used and included in the study. This is to protect the quality of the study.

The data will be used for the purposes of this study, and fully anonymised, selected outcomes may be shared with other researchers on request for the purpose of accumulating data from individual studies. Only investigators and administrators of the study will have access to personal information, and this will be kept secure and strictly confidential. Participants will be identified only by a study identification number. Results of this project may be published or presented at conferences or seminars. No individuals will be able to be identified.

At the end of this study the list of participants and their study identification number will be disposed of. Any raw data on which the results of the project depend will be retained in secure storage for 10 years, after which it will be destroyed.

All participants will have access to a summary of the project findings when the study is completed.

Can I find out the results of the study?

All participants will have access to a summary of the project findings when it is completed. However, findings of any future research conducted using fully anonymised data collected in this project will not be made available to participants.

Who is funding the study?

This study is funded by the Lottery Health Project Grant.

Participants will not incur any costs for taking part in the study and will be reimbursed for travel.

Who Has Approved the study?

This study has been approved by an independent group of people called a Health and Disability Ethics Committee (HDEC), who check that studies meet established ethical standards. The Central Health and Disability Ethics Committee has approved this study.

Who do I contact for more information or if I have concerns?

If you have any questions, concerns or complaints about the study at any stage, you can contact:

Dr. Hajar Mazahery, study manager
Email: h.mazahery@massey.ac.nz

Rebecca Paul, research assistant
Phone: 022 1294112

Email: veganstudy@massey.ac.nz

The other members of the research team are: Professor Pamela von Hurst, Associate Professor Cathryn Conlon, Associate Professor Kathryn Beck, and Dr. Rachel Batty (College of Health, Massey University).

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone: 0800 555 050
Fax: 0800 2 SUPPORT (0800 2787 7678)
Email: advocacy@advocacy.org.nz
Website: https://www.advocacy.org.nz/

For Maori health support please contact:

Dr Bevan Erueti, Taranaki, Te Ati Haunui-ā-Papārangi, Ngāti Tūwharetoa, Associate Dean Māori
Phone: 06 356 9099 Ext 83087
Email: B.Erueti@massey.ac.nz

You can also contact the health and disability ethics committee (HDEC) that approved this study on:

Phone: 0800 4 ETHIC
Email: hdecs@health.govt.nz

Appendix B: Participant Consent Form

Health Implications of a Vegan Diet

A clinical investigation project included in Phase 2 of The Vegan Health Research Programme

Please tick to indicate you consent to the following

I have read and I understand the Participant Information Sheet.	☐	
I have been given sufficient time to consider whether or not to participate in this study.	☐	
I have had the opportunity to use a legal representative, whanau/ family support or a friend to help me ask questions and understand the study.	☐	
I am satisfied with the answers I have been given regarding the study and I have a copy of this consent form and information sheet.	☐	
I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time.	☐	
I consent to the research staff collecting and processing my information, including information about my health.	☐	
I consent to my fully anonymous / anonymised information being shared with other researchers on request for future research and the purpose of accumulating data from individual studies, and the results of future studies using my anonymous / anonymised information will not be made available to me.	Yes ☐	No ☐
If I decide to withdraw from the study, I agree that the information collected about me up to the point when I withdraw may continue to be processed.	Yes ☐	No ☐
I agree to an approved auditor appointed by the New Zealand Health and Disability Ethics Committees, or any relevant regulatory authority or their approved representative reviewing my relevant medical records for the sole purpose of checking the accuracy of the information recorded for the study.	☐	

I understand that my participation in this study is confidential and that no material, which could identify me personally, will be used in any reports on this study.	☐	
I understand the compensation provisions in case of injury during the study.	☐	
I know who to contact if I have any questions about the study in general.	☐	
I understand my responsibilities as a study participant.	☐	
I wish to receive a summary of the results from the study.	Yes ☐	No ☐

Declaration by participant:
I hereby consent to take part in this study.

Participant's name: _____

Signature: _____ Date: _____

Declaration by member of research team:

I have given a verbal explanation of the research project to the participant and have answered the participant's questions about it.

I believe that the participant understands the study and has given informed consent to participate.

Researcher's name: _____

Signature: _____ Date: _____

Appendix C: Health and Demographic Questionnaire

Health and Vegan Diet

Health and Demographic Information

Please answer all questions. All the information you give us is in confidence and will only be used of the purposes of this study. If you need any help to complete questions, please ask one of the research team.

1. Do you have or have you ever had any acute illness?
   [ ] Yes
   [ ] No

2. If yes, please provide more details (including the diagnosis, date of diagnosis, by whom you were diagnosed, and any details you may think is relevant) below:

   _____
   _____
   _____

3. Do you have or have you ever had any chronic illness?
   [ ] Yes
   [ ] No

4. If yes, please provide more details (including the diagnosis, date of diagnosis, by whom you were diagnosed, and any details you may think is relevant) below:

   _____
   _____
   _____

5. Have you ever been diagnosed with any bone fracture (broken bone)?
   [ ] Yes
   [ ] No

6. If yes, please provide more details (which bone, age when it happened, how did it happen)

   _____
   _____
   _____

7. Do you usually have elevated blood pressure (systolic blood pressure ≥120 mmHg and/or diastolic blood pressure ≥75 mmHg)?

[ ] Yes
[ ] No
[ ] Unsure

8. If yes, please provide more details (elevated systolic blood pressure, elevated diastolic blood pressure or both?)

_____
_____
_____

9. Have you ever been diagnosed with iron deficiency?
[ ] Yes
[ ] No
[ ] Unsure

10. If yes, please provide more details about your iron deficiency (self-diagnosed or diagnosed by a health care provider, date and treatment)

_____
_____
_____

11. Do you get nose bleeds?
[ ] Yes
[ ] No

12. If yes, how often do you get a nose bleed?

_____ Times a month or _____ Times a year

13. If yes, how heavy are your nose bleeds?
[ ] Light
[ ] Medium
[ ] Heavy

14. Have you had any blood loss (other than periods or nose bleeds) such as wounds, regular scratches from contact sports, blood in stools, or urine in the past year?
[ ] Yes
[ ] No

15. If yes, please describe below.

_____
_____
_____

16. Have you had any medical condition which has resulted in blood loss?
[ ] Yes
[ ] No

17. If yes, please describe and give approximate date below.

_____
_____
_____

18. Do you donate whole blood (i.e. not plasma)?
    [ ] Yes
    [ ] No

19. If yes, when did you last donate blood?

    Date _____ / _____ /_____
    Day Month Year

20. If yes, how many times have you donated whole blood in the past year?

    _____ (times in the past year)

21. Have you ever had iron infusion?
    [ ] Yes
    [ ] No

22. If yes, please provide details (reasons and date of infusion)

_____
_____
_____

23. Have you had a blood transfusion in the last year?
    [ ] Yes
    [ ] No

24. If yes, please provide details (reason and date of transfusion)

_____
_____
_____

25. Do you currently smoke?
    [ ] Yes
    [ ] No

26. If yes, how often do you smoke
    [ ] Occasionally
    [ ] A few times per week
    [ ] Daily

27. If no, have you ever smoked?
    [ ] Yes
    [ ] No

28. If yes, how often did you use to smoke?

[ ] Occasionally
[ ] A few times per week
[ ] Daily

29. Are you currently taking any medication (excluding nutritional supplements)?
    [ ] Yes
    [ ] No

30. If yes, please state what medication you are taking and why?

_____
_____
_____

31. Has any of your first-degree family members (parents and grandparents) had osteoporosis?
    [ ] Yes
    [ ] No
    [ ] Unsure

32. Has any of your first-degree family members (parents and grandparents) had the following illnesses when they were younger than 50 years old?

	Yes	No	Unsure
Cardiovascular diseases (i.e. angina, heart attack, transient ischaemic attack, stroke)	[ ]	[ ]	[ ]
Hypertension	[ ]	[ ]	[ ]
Diabetes	[ ]	[ ]	[ ]
Hypercholesterolemia	[ ]	[ ]	[ ]

33. In general, would you say your health is..
    [ ] Excellent
    [ ] Very good
    [ ] Good
    [ ] Fair
    [ ] Poor

Questions specific to women

34. Which of the following BEST describes your current Menstrual/Menopausal status?
[ ] Never menstruated
[ ] Still menstruating
[ ] Going through menopause
[ ] Postmenopausal
[ ] Other (Please explain)

35. Have you had a period in the last 3 months? (not including postmenopausal women)
    [ ] Yes

[ ] No

36. How regular are your periods (21-34 days)?
    [ ] Regular
    [ ] Irregular

37. How many days do you usually have between periods? (for instance, counting from the first day of your last period to the day you expect your next period to start)

    _____ days

38. Do you know when your last period started?
    [ ] Yes
    [ ] No

39. When did your last period start?

    _____ / _____ /_____
    Day Month Year

40. How many days does your period usually last?
    _____ days

41. Have you been pregnant within the last year?
    [ ] Yes
    [ ] No

42. If yes, did the pregnancy result in any significant blood loss that you are aware of? (Please comment below)

    _____

    _____

43. Are you on hormonal contraceptives?
    [ ] Yes
    [ ] No
    [ ] Not applicable

44. If yes, please describe details (i.e. injection, IUD, implant, oral)

    _____

    _____

45. Do you currently take Hormone Replacement Therapy?
    [ ] Yes
    [ ] No
    [ ] Not applicable

46. If yes, please provide more details (type of Hormone Replacement Therapy and for how long)

_____

Demographics (7 questions)

47. When were you born?

Day (DD)	Month (MM)	Year (YYYY)
_____	_____	_____

48. What is your gender?
[ ] Female
[ ] Male
[ ] Gender diverse
[ ] Other (Please state)

49. Which ethnic group do you belong to? Tick whichever applies to you (you may check [x] more than one box)
[ ] New Zealand European
[ ] Māori
[ ] Samoan
[ ] Cook Islands Māori
[ ] Tongan
[ ] Niuean
[ ] Chinese
[ ] Indian
[ ] Others, eg DUTCH, JAPANESE, TOKELAUAN. Please state below.
a) _____
b) _____

50. What is your HIGHEST level of EDUCATION?
[ ] Lower than high school
[ ] High school
[ ] Diploma/certificate
[ ] Bachelor's degree
[ ] Master's degree
[ ] Doctorate or PhD

51. Do you have tertiary education in the following fields? (you can choose more than one answer)
[ ] Medicine
[ ] Nutrition/Dietetics
[ ] Nursing
[ ] Midwifery

[ ] Other health related fields (Please specify)
[ ] Others (Please specify)
[ ] Not applicable

52. What is your current employment status?
[ ] Full time
[ ] Part time
[ ] Volunteer
[ ] Seeking opportunities currently
[ ] Retired
[ ] Other (e.g., caregiver, studying, homemaker). Please describe.

53. What is your marital status?
[ ] Married / cohabiting / civil union / de facto
[ ] Divorced / Separated
[ ] Widowed
[ ] Single
[ ] Other (please describe)

54. How many children have you given birth to? (If female)
[ ] No children
[ ] 1 child
[ ] 2 children
[ ] 3 children
[ ] 4 children
[ ] 5 or more children

Appendix D: Dietary Practices and Supplement Use

Health and Vegan Diet

Dietary Practices and Supplement Use

Please answer all questions. All the information you give us is in confidence and will only be used of the purposes of this study. If you need any help to complete questions, please ask one of the research team.

VEGANISM MOTIVATION

1. How long have you been following a vegan lifestyle?

	2 to 4 years	**5 to 10 years**	**>10 years**
I have been a vegan	[ ]	[ ]	[ ]

2. On a scale of 1 (not important) to 7 (very important) rate the importance of each of the following reasons for you to EXCLUDE MEAT OR ANIMAL PRODUCTS from your diet.

		Not important		**Moderately important**			**Very important**	
		1	**2**	**3**	**4**	**5**	**6**	**7**
1	I want to be healthy							
2	Plant-based diets are better for the environment							
3	Animals do not have to suffer							
4	Animals' rights are respected							
5	I want to live a long time							
6	Plant-based diets are more sustainable							
7	I care about my body							
8	Eating meat is bad for the planet							
9	Animal rights are important to me							

10	Plant-based diets are environmentally-friendly							
11	It does not seem right to exploit animals							
12	Plant products have less of an impact on the environment than animal products							
13	I am concerned about animal rights							
14	My health is important to me							
15	I don't want animals to suffer							

3. There might be other reasons for following a vegan diet. On a scale of 1 (NOT IMPORTANT) to 7 (VERY IMPORTANT), rate the importance of each of the following reasons for you to EXCLUDE MEAT OR ANIMAL PRODUCTS from your diet.

		Not important		**Moderately important**			**Very important**	
		1	**2**	**3**	**4**	**5**	**6**	**7**
1	Cultural/religious beliefs							
2	Allergy/intolerance to animal-based foods							
3	Having a vegan partner or family member							
4	Having a vegan friend							
5	Having a vegan classmate							
6	Having a vegan co-worker/colleague							

DIETARY HABITS

4. On a scale of 1 (NOT AT ALL IMPORTANT) to 5 (EXTEREMELY IMPORTANT), rate the importance of other people's support in helping you following a vegan diet.

[ ] 1 (not important)
[ ] 2 (slightly important)
[ ] 3 (moderately important)
[ ] 4 (very important)
[ ] 5 (extremely important0

5. In a typical week, how often do you eat the following MEALS during the week?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always
Breakfast	[ ]	[ ]	[ ]	[ ]	[ ]
Lunch	[ ]	[ ]	[ ]	[ ]	[ ]
Dinner	[ ]	[ ]	[ ]	[ ]	[ ]

6. In a typical week, how often you eat the following MEALS at the weekend?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always
Breakfast	[ ]	[ ]	[ ]	[ ]	[ ]

Lunch	[ ]	[ ]	[ ]	[ ]	[ ]
Dinner	[ ]	[ ]	[ ]	[ ]	[ ]

7. In a typical week, where are most of your..?

	At home	Out	Don't eat meal
Breakfast	[ ]	[ ]	[ ]
Lunch	[ ]	[ ]	[ ]
Dinner	[ ]	[ ]	[ ]

8. How much responsibility do you have for:

	Little or none	About half	Most or all
Food shopping?	[ ]	[ ]	[ ]
Planning meals?	[ ]	[ ]	[ ]
Preparing meals?	[ ]	[ ]	[ ]

9. What type of food do you preferentially buy? (you can choose more than one answer)

[ ] Pre-cooked meals
[ ] Fresh foods
[ ] Frozen foods
[ ] Canned foods
[ ] Other (please state)
[ ] I don't do food shopping

10. How often do you eat convenient/frozen meals?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

11. Concerning fat content in food products, how often you have the followings?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always	Don't know
Non-fat products	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Low fat products	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Reduced fat products	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
High fat products	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

12. How often do you use following cooking methods to cook the foods you eat?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always	Don't know
Boiling/Steaming	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Stir-frying	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Deep-fat frying	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Baking/Microwave/Grill	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

13. What type of oil do you usually use in cooking (e.g., for frying, roasting, etc.)? (You can choose more than one answer).

[ ] Coconut oil
[ ] Olive oil, canola oil, avocado oil, soybean oil, peanut oil, rice bran oil
[ ] Sunflower oil, corn oil, safflower oil, cottonseed oil, sesame seed oil, grapeseed oil
[ ] Other oil (please state)
[ ] I don't use oil in cooking
[ ] Don't know

14. How often do you add salt to your foods/meals?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always	Don't know
Whilst cooking	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
At the table to meals/snacks	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

15. Are you on a doctor-prescribed low sodium diet?

[ ] Yes
[ ] No

16. What type of milk do you usually have?

[ ] Soy milk (regular)
[ ] Soy milk (light)
[ ] Soy milk (unsweetened)
[ ] Soy milk (protein plus)
[ ] Coconut milk (regular)
[ ] Coconut milk (light)
[ ] Coconut milk (unsweetened)
[ ] Oat milk
[ ] Rice milk
[ ] Almond milk (regular)
[ ] Almond milk (high protein)
[ ] Almond milk (unsweetened)
[ ] Cashew milk
[ ] Peanut milk
[ ] Seeds milk

[ ] Other milk (please state)
[ ] I don't use/drink milk
[ ] Don't know

17. How often do you choose whole grain breads and cereals (e.g. whole grain or multigrain breads, porridge or oats, oatmeal, oat flakes, bran based breakfast cereals, brown rice, wholemeal pasta, quinoa, buckwheat, food made with wholegrain, whole wheat or rye flour; food made from wheat flakes, whole barley, bulgur wheat) rather than more refined breads and cereals? (e.g. white breads, cornflakes, rice bubbles, white rice, white pasta, food made with white flour)

[ ] Never
[ ] Rarely (1/4 of the time)
[ ] Sometimes (1/2 of the time)
[ ] Usually (3/4 of the time)
[ ] Always
[ ] Not applicable – I don't eat bread and cereals
[ ] Don't know

18. What type of spread do you usually use on bread?

[ ] Monounsaturated fat margarine (e.g. spreads based on olive oil, rice bran oil , canola oil)
[ ] Polyunsaturated fat margarine (e.g. spreads based on sunflower oil)
[ ] Light monounsaturated fat margarine (e.g. Olivio spread light)
[ ] Light polyunsaturated fat margarine (e.g. Flora spread light)
[ ] Plant sterol enriched margarine - both full and low fat varieties (e.g. ProActive, Logical)
[ ] Other (please state)
[ ] I don't use spreads on bread
[ ] Don't know

19. How often do you eat savory snacks such as potato chips?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

20. How often do you eat sweet snacks such as biscuits, cakes, sweets, lollies, chocolate or ice blocks or puddings (e.g., fruit pies, crumbles, sponge puddings, steamed puddings)?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

21. How often do you have the following drinks?cordials or fizzy drinks (do not include diet or low-calorie varieties)?

	Less than once a week	Once per week	2 or more times per week	Don't know
Cordials (do not include diet or low calorie variety	[ ]	[ ]	[ ]	[ ]
Diet or low calorie cordials	[ ]	[ ]	[ ]	[ ]
Fizzy drinks (do not include diet or low calorie variety)	[ ]	[ ]	[ ]	[ ]
Diet or low calorie fizzy drinks	[ ]	[ ]	[ ]	[ ]

22. How often do you eat processed/ultra-processed foods?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 times per week
[ ] 3 times per week
[ ] 4 times per week
[ ] 5 times per week
[ ] 6 times per week
[ ] 7 or more times per week
[ ] Don't know

23. How often do you eat at a restaurant/café?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

24. How often do you eat at a fast food outlet?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

25. How often do you eat meal with friends?

[ ] Never
[ ] Less than once a week

[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

26. How often do you eat at establishments such as work/education canteen?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

27. How often do you eat convenient/frozen meals?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

SUPPLEMENT USE

28. For the following NUTRIENT supplements, please check [x] the *YES* column and fill in the dose and brand name for those you USUALLY use; then state how often you use the supplement. For those you do not use, check [x] the *NO column*.

Nutrient supplement	Yes	No	Dose	Brand name	How often you use the supplement (please provide more details)
Calcium					
Vitamin D					
Vitamin B12					
B vitamins					
Zinc					
Iron					
Folate					
Iodine					
Selenium					
Multivitamin/ supplement					
Mineral supplement					
Omega-3 fatty acids					
Amino acids (please specify)					
a)					
b)					
c)					
Others (specify below)					
a)					
b)					

c)					
"I do NOT use any nutrient supplements" [ ] ***True*** [ ] ***False***					

29. For the following FOOD/HERBAL/DIETARY supplements, check [x] the *YES* column and fill in the dose and brand name for those you USUALLY use; then state how often you use the supplement. For those you do not use, check [x] the *NO column*.

Food/herbal/dietary supplement	Yes	No	Dose	Brand name	How often you use the supplement (please provide more details)
Nutritional yeast					
Wheat germ					
Soy/vegetable protein powder					
Spirulina					
Chlorella					
Others (specify below)					
a)					
b)					
c)					
"I do NOT use any food/herbal/dietary supplements" [ ] ***True*** [ ] ***False***					

Appendix E: Example of the 4-Day Food Diary (Size and formatting changed; template duplicated for each of the four days)

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Health and Vegan Diet

4 Day Food Record

Thank you very much for taking part in this study. We are extremely grateful for your time, effort and commitment

If you have any questions, please contact Rebecca Paul on 022 1294112 (Email: veganstudy@massey.ac.nz)

All information in this diary will be treated with the strictest confidence. No one outside the study will have access to this.

Please bring the food diary with you when you come in for assessment at Massey University

4 day food diary - what to do?

- Record all of the food that you eat and drink on the following dates.

- **Please complete the diary on consecutive days for 1 weekend day and 3 week days at your convenience. For example, Sunday, Monday, Tuesday and Wednesday <u>OR</u> Wednesday, Thursday, Friday and Saturday.**

- If possible record food at the time of eating or just after – try to avoid doing it from memory at the end of the day.

- Include all meals, snacks, and drinks, even tap water.

- Include anything you have added to foods such as sauces, gravies, spreads, dressings, etc.

- Write down any information that might indicate size or weight of the food to identify the portion size eaten.

- Use a new line for each food and drink. You can use more than one line for a food or drink. See the examples given.

- Use as many pages of the booklet as you need.

- You can also save any packets such as muesli bar wrappers and bring them in with your food diary

<u>Describing Food and Drink</u>

- Provide as much detail as possible about the type of food eaten. For example **brand names and varieties / types** of food.

General description	Food record description
Breakfast example – cereal, milk, sugar	2 Weetbix (Sanitarium) 1 cup So Good unsweetened almond milk 1 tsp Chelsea white sugar
Lunch – Meat Free Bacon Style Rashers sandwich and home-made fries	2 slices of wholegrain bread (Vogels) 2 slices Vegie Delights Meat Free Bacon Style Rashers 25g zenzo Dairy Free Vegan Cheddar Cheese Alternative 2 tsp Tablelands Dairy Free Buttery Spread ½ cup fries (home-made, deep fried in Pam's sunflower oil)

	½ Tbs vegan aioli (Heinz Mayonnaise Vegan Aioli) Water 1 cup to drink
Dinner – Vegan lentils spaghetti bolognese	½ cup lentil sauce (see attached recipe) 1 cup spaghetti pasta (Homebrand)
Snacks	Tam & Luke Snack Ball Salted Caramel (2 balls, 28g) 1 small banana 2 Salada crackers with 1 tsp peanut butter 20g Doritos Spicy Sweet Chili Flavored Tortilla Chips

- Give details of all the **cooking methods** used. For example, fried, grilled, baked, poached, boiled…

General description	**Food record description**
Potatoes	2 medium size potatoes cut in slices and fried in 2tbs canola oil 2 large potatoes with skin (boiled)
Black bean and kumara burger	85g black bean and kumara burger (recipe provided) pan-fried in 2tsp olive oil 85g black bean and kumara burger (recipe provided) oven baked

- When using foods that are cooked (eg. pasta, rice, vegetables, etc), please record the **cooked portion** of food.

General description	**Food record description**
Rice	1 cup cooked Jasmine rice (cooked on stove top)
Meat alternatives	1 cup of cooked lentil sauce or 5 oven baked chicken style strips (Fry's)
Vegetables	½ cup cooked mixed vegetables (Wattie's peas, corn, carrots)

- Please specify the **actual amount of food eaten** (eg. for leftovers, foods where there is waste)

General description	**Food record description**
Apple	1 x 120g Granny Smith Apple (peeled, core not eaten – core equated to ¼ of the apple)

Fried chicken alternative strips	100g chicken alternative strips (100g includes batter); fried in 3 Tbsp Nuttelex buttery margarine

General description	Food record description
Milo	I x cup Milo made with plant based Milo powder and 150mls So Good unsweetened almond milk, 100 ml hot water. No sugar

- **Record recipes** of home prepared dishes where possible and the proportion of the dish you ate. There are blank pages for you to add recipes or additional information.

Recording the amounts of food you eat

It is important to also record the quantity of each food and drink consumed. This can be done in several ways.

- By using household measures – for example, cups, teaspoons and tablespoons. Eg. 1 cup frozen peas, 1 heaped teaspoon of sugar.

- By weight marked on the packages – e.g. a 425g tin of baked beans, a 32g cereal bar.

- Weighing the food – this is an ideal way to get an accurate idea of the quantity of food eaten, in particular for foods such as meat alternatives, fruits, vegetables and cheese alternatives.

- For bread – describe the size of the slices of bread (e.g. sandwich, medium, toast) – also include brand and variety.

- Using comparisons – e.g. Meat alternative equal to the size of a pack of cards, a scoop of vegan chocolate ice cream equal to the size of a hen's egg.

- Use the food record instructions provided to help describe portion sizes.

General description	Food record description
Cheese alternatives	1 heaped tablespoon of grated dairy free cheddar cheese 1 slice dairy free cheddar cheese (8.5 x 2.5 x 2mm) 1 cube dairy free cheddar cheese, match box size

- If you go out for meals, describe the food eaten in as much detail as possible.

- ***Please try to eat as normally as possible – e.g., Don't adjust what you normally eat just because you are keeping a diet record and be honest! This record will give us important information about your diet, and help us identify any possible deficiencies which we can then help you correct.***

Example day

Time food was eaten	**Complete description of food (food and beverage name, brand, variety, preparation method)**	**Amount consumed (units, measures, weight)**
Example 7:55am	Sanitarium Weetbix	2 weetbix
" "	So good unsweetened almond milk	150ml
" "	Chelsea white sugar	2 heaped teaspoons
" "	Orange juice (Citrus Tree with added calcium – nutrition label attached)	1 glass (275 ml)
10.00am	Raw Apple (gala)	Ate all of apple except the core, whole apple was 125g (core was ¼ of whole apple)
12.00pm	Home-made pizza (recipe attached)	1 slice (similar size to 1 slice of sandwich bread, 2 Tbsp tomato paste, 4 olives, 2 meat free bacon style rashers (zenzo), 1 Tbsp chopped spring onion, 3 Tbsp vegan mozzarella cheese)
1.00pm	Water	500ml plain tap water
3.00pm	Biscuits	2 x Lotus Biscoff biscuits
6.00pm	Lasagne	½ cup cooked Sunfed Bull free beef meat alternative mince, 1 cup cooked Budget lasagne shaped pasta, ½ cup homemade (recipe attached) vegan bechamel sauce made with soy milk (So Good, regular), ½ cup mixed vegetables (Pam's carrots, peas and corn), 4 Tbsp Veesey grated pizza blend cheese
6.30pm	Vegan banana cake with chocolate icing (homemade, recipe attached)	1/8 of a cake (22cm diameter, 8 cm high), 2 Tbsp chocolate icing

" "	Tip Top Crave dairy free salted caramel fudge frozen dessert	1/2cup (g) (125g)

Date_____ DAY 1

Time food was eaten	**Complete description of food (food and beverage name, brand, variety, preparation method)**	**Amount consumed**

Recipes (Day 1)

Appendix F: Gastrointestinal Symptom Rating Scale (GSRS) Questionnaire

THE GASTROINTESTINAL SYMPTOM RATING SCALE (GSRS)

Please read this first:

This survey contains questions about how you have been feeling and what it has been like DURING THE PAST WEEK. Mark the choice that best applies to you and your situation with a cross.

1. Have you been bothered by PAIN OR DISCOMFORT IN YOUR UPPER ABDOMEN OR THE PIT OF YOUR STOMACH during the past week?

- ☐ No discomfort at all
- ☐ Minor discomfort
- ☐ Mild discomfort
- ☐ Moderate discomfort
- ☐ Moderately severe discomfort
- ☐ Severe discomfort
- ☐ Very severe discomfort

2. Have you been bothered by HEARTBURN during the past week? (By heartburn we mean an unpleasant stinging or burning sensation in the chest.)

- ☐ No discomfort at all
- ☐ Minor discomfort
- ☐ Mild discomfort
- ☐ Moderate discomfort
- ☐ Moderately severe discomfort
- ☐ Severe discomfort
- ☐ Very severe discomfort

3. Have you been bothered by ACID REFLUX during the past week? (By acid reflux we mean the sensation of regurgitating small quantities of acid from the stomach up to the throat.)

- ☐ No discomfort at all
- ☐ Minor discomfort
- ☐ Mild discomfort
- ☐ Moderate discomfort
- ☐ Moderately severe discomfort
- ☐ Severe discomfort
- ☐ Very severe discomfort

4. Have you been bothered by HUNGER PAINS in the stomach during the past week? (This hollow feeling in the stomach is associated with the need to eat between meals.)

- ☐ No discomfort at all
- ☐ Minor discomfort
- ☐ Mild discomfort
- ☐ Moderate discomfort
- ☐ Moderately severe discomfort
- ☐ Severe discomfort
- ☐ Very severe discomfort

5. Have you been bothered by NAUSEA during the past week? (By nausea we mean a feeling of sickness that may lead to retching and vomiting.)

- ☐ No discomfort at all
- ☐ Minor discomfort
- ☐ Mild discomfort
- ☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort

6. Have you been bothered by RUMBLING in your stomach during the past week? (Rumbling refers to vibrations or noise in the stomach.)

☐ No discomfort at all

☐ Minor discomfort

☐ Mild discomfort

☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort

7. Has your stomach felt BLOATED during the past week? (Feeling bloated refers to swelling often associated with a sensation of gasses in the stomach.)

☐ No discomfort at all

☐ Minor discomfort

☐ Mild discomfort

☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort

8. Have you been bothered by BELCHING during the past week? (Belching refers to the release of wind from the stomach via the mouth, often associated with easing a bloated feeling.)

☐ No discomfort at all

☐ Minor discomfort

☐ Mild discomfort

☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort

9. Have you been bothered by BREAKING WIND during the past week? (Breaking wind refers to the need to release air or gas from the bowel, often associated with easing a bloated feeling.)

☐ No discomfort at all

☐ Minor discomfort

☐ Mild discomfort

☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort

10. Have you been bothered by CONSTIPATION during the past week? (Constipation refers to a reduced ability to empty the bowels.)

☐ No discomfort at all

☐ Minor discomfort

☐ Mild discomfort

☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort

11. Have you been bothered by DIARRHOEA during the past week? (Diarrhoea refers to a too frequent emptying of the bowels.)

- ☐ No discomfort at all
- ☐ Minor discomfort
- ☐ Mild discomfort
- ☐ Moderate discomfort
- ☐ Moderately severe discomfort
- ☐ Severe discomfort
- ☐ Very severe discomfort

12. Have you been bothered by LOOSE STOOLS during the past week? (If your stools (motions) have been alternately hard and loose, this question only refers to the extent you have been bothered by the stools being loose.)

- ☐ No discomfort at all
- ☐ Minor discomfort
- ☐ Mild discomfort
- ☐ Moderate discomfort
- ☐ Moderately severe discomfort
- ☐ Severe discomfort
- ☐ Very severe discomfort

13. Have you been bothered by HARD STOOLS during the past week? (If your stools (motions) have been alternately hard and loose, this question only refers to the extent you have been bothered by the stools being hard.)

- ☐ No discomfort at all
- ☐ Minor discomfort
- ☐ Mild discomfort
- ☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort

14. Have you been bothered by an URGENT NEED TO PASS YOUR MOTIONS during the past week? (This urgent need to go to the toilet is often associated with a feeling that you are not in full control.)

☐ No discomfort at all

☐ Minor discomfort

☐ Mild discomfort

☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort

15. When going to the toilet during the past week, have you had the SENSATION OF NOT COMPLETELY EMPTYING THE BOWELS? (This feeling of incomplete emptying means that you still feel a need to pass your motions despite having exerted yourself to do so.)

☐ No discomfort at all

☐ Minor discomfort

☐ Mild discomfort

☐ Moderate discomfort

☐ Moderately severe discomfort

☐ Severe discomfort

☐ Very severe discomfort