Exploring dietary patterns of a vegan population living in Auckland, New Zealand.

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

of

Master of Science

in

Nutrition and Dietetics

at Massey University, Auckland,

New Zealand

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2024

Abstract

Background: The vegan diet is increasing in popularity in New Zealand, however the current literature regarding dietary intake in NZ vegan populations is limited. Overseas studies in vegan populations have focused mostly on nutrient adequacy rather than broader dietary patterns. Dietary patterns can be used to measure diet quality as they look at the whole diet rather than single aspects. Given the diversity within vegan dietary practices, an increasing number of people choosing veganism and the growing market of ultra-processed vegan foods, this study seeks to fill a critical gap by examining the dietary patterns of vegans living in Auckland, New Zealand.

Aim: To identify and analyse dietary patterns among vegans living in Auckland, New Zealand, and explore associations with socio-demographic and lifestyle factors.

Methods : This study recruited participants as part of the larger Vegan Health Research Program at Massey University. Inclusion criteria were at least 2 years following the vegan diet, not pregnant or breastfeeding and living in Auckland, New Zealand. Dietary intake was assessed using a validated Food Frequency Questionnaire (FFQ) including 196 vegan foods, which were grouped into 34 food groups. Principal component analysis (PCA) was applied to identify common dietary patterns, and associations with socio-demographics such as 'age, gender, education, alcohol consumption and physical activity score' were examined.

Results : Participants (n=212) were 71% female with a mean age of 39.4 (12.2) years. Participants were mostly European (85%) and most had an education level of undergraduate or higher (68.2%). Four patterns emerged from principal component analysis explaining 35.3% of the variation in the diet; Health-Conscious, Convenience, Western and Traditional. The Health-Conscious pattern was positively associated with higher alcohol consumption (p= 0.005) and a higher physical activity score (p= <0.001). The Convenience pattern had a positive association with lower alcohol intake (p= 0.015). The Western pattern was positively associated with being female, having a higher physical activity score (p= 0.009), higher alcohol consumption (p = <0.001) and participants having less than a bachelor's degree of education (p= 0.027). The Traditional pattern was positively associated with older age and lower alcohol consumption (p = <0.001).

Conclusion: These results indicate that vegans following a Health-Conscious dietary pattern tend to consume more alcohol but engage in higher levels of physical activity. Those following a Western dietary pattern are also more likely to drink more alcohol and be more physically active but also have lower educational attainment. Those following the Convenience pattern are less likely to consume alcohol and similarly, the Traditional dietary pattern is associated with lower alcohol consumption and older vegans are more likely to follow this pattern.

Acknowledgments

Firstly, I would like to acknowledge my family, friends and partner for your continued support throughout my studies. Thank you to my parents who have always supported me through my university endeavours and for always inspiring me to chase my dreams. Thank you to my dietetic class for allowing me to create strong friendships and for the continued support we offered one another through our MSc. I hope you all go on to achieve great things and I'm so proud of you all for making it to this point. A huge thank you to my supervisors Professor Kathryn Beck and Professor Pamela von Hurst for supporting me through my thesis. Your guidance, knowledge and support have been invaluable to me this year and I appreciate all the feedback and patience you've provided. Additionally, I would like to extend my gratitude to Dr Karen Mumme who helped me with my statistical analysis. She helped me thoroughly throughout this process and was able to respond to my many emails in a timely and concise manner which helped me to learn valuable information. Lastly, I would like to thank those who completed prior studies for the Vegan Health Research Program. Your contributions to recruitment, data collection, entry and management were invaluable to my study. Finally, thank you to the participants who took part in the study without whom this thesis would not be possible.

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Abbreviation list:

NCD	Non-communicable disease
CVD	Cardiovascular disease
SFAs	Saturated fatty acids
BMI	Body-mass index
SCFAs	Short-chain fatty acids
EPA	Eicosapentaenoic acid
DHA	Docosahexaenoic acid
ALA	Alpha-linolenic acid
UPFs	Ultra-processed plant-based foods
PBMA	Plant-based meat alternatives
PBDA	Plant-based dairy alternatives
PBYA	Plant-based yoghurt alternatives
FFQ	Food frequency questionnaire
HNRU	Human Nutrition Research Unit
DXA	Dual-energy x-ray absorptiometry
SD	Standard deviation

Chapter One: Introduction

1.1 Background

In recent years the number of people following a vegan diet has grown exponentially (Kamiński et al., 2020). As this plant-based lifestyle becomes increasingly more popular, questions around the diversity of this diet begin to emerge, including whether differences exist in the diets of people following a vegan lifestyle. With little research done on this topic, an exploration of the vegan diet is needed to gain a comprehensive understanding of its dietary patterns.

The vegan diets are made up of only plant based foods and can be categorised as a version of plant-based eating with the exclusion of all foods derived from animals. (Łuszczki et al., 2023). Instead it is traditionally rich in foods from various plant-based groups such as fruits, vegetables, grains, legumes, nuts (Łuszczki et al., 2023). There's been an evolution from its ethical roots to a broader range of motivations including health concerns and environmental considerations (Alcorta et al., 2021). This diet which was once embraced by individuals with a compassionate stance for animals has become popular due to the positive research emerging around its health benefits and influence on environmental preservation by more sustainable farming practices (Hopwood et al., 2020).

Previous studies on the vegan diet have involved assessing the macro and micronutrient intakes and nutritional adequacy of the diet. These show that a carefully planned vegan diet can be nutritionally sufficient and can provide numerous health benefits such as reduced risk of premature mortality and protection against noncommunicable diseases (NCDS) (Haider et al., 2023). However, when nutritional adequacy is not met nutrient deficiencies such as protein, iron, calcium, and vitamin B-12 may occur. Although the vegan diet is renowned for improved health benefits this is largely due to the increased daily consumption of fresh fruits, vegetables, cereal grains, nuts, legumes and seeds. When such foods are paired with minimally processed food consumption and no animal products this creates a diet low in saturated fat and high in fibre and nutrients which have been shown to improve health outcomes (Haider et al., 2023). However, with the growing popularity of this diet, comes the introduction of ultra-processed vegan foods which can displace positive health associations attributed to fresh foods.

The study of dietary patterns within vegan populations remains relatively underexplored despite the increasing adoption of veganism worldwide. (Greenwell et al., 2023; Kamiński et al., 2020). Most of the existing research has predominantly focused on the nutritional adequacy of vegan diets rather than examining broader dietary patterns and their implications. Dietary patterns are critical for understanding how combinations of foods and their habitual consumption influence health outcomes (McNaughton, 2020; Schulze et al., 2018). In New Zealand, research on vegan dietary patterns is scarce and this lack of comprehensive dietary pattern research presents a critical gap, underscoring the need for more region-specific analyses that consider not only the types of foods consumed but also their frequency and combination. International studies using principal component or cluster analysis identified similar dietary patterns among vegan populations, such as "Health-Conscious," "Convenience," "Traditional", “Refined grains and sweets” and “Wholegrains and nuts” (Bez et al., 2024, Gallagher et al., 2021; Haider et al., 2023). Although there are inconsistencies in the labelling of dietary patterns in these three studies, in all cases there tended to be at least one healthier pattern characterised by higher intakes of fruits, vegetables, and plant-based protein sources and one unhealthy pattern characterised by higher intakes of ultra-processed vegan foods, refined grains and sweets. While these patterns have been labelled differently across each study they consistently highlight a division between a more health-conscious and ultra-processed vegan dietary approach. The latter, characterised by higher levels of sodium, sugars, and unhealthy fats, may undermine the health benefits traditionally associated with vegan diets (Monteiro et al., 2019; Sexton et al., 2022). These findings of which vegans have diverse dietary approaches which may be, influenced by lifestyle, sociodemographic factors, and food choices. However, the limited number of studies and their different geographical locations make it difficult to generalise findings globally, particularly in the context of New Zealand. As veganism continues to grow, the shift toward ultra-processed vegan foods raises concerns about their long-term health implications (Curtain & Grafenauer, 2019). Key dietary behaviours such as the shift from whole-food-based diets to reliance on ultra-processed vegan products are yet to be fully explored in the literature, particularly in relation to socio-demographic and lifestyle factors.

1.2 Purpose of this study

Health benefits and nutritional risks have been the main focus of previous research on the vegan diet; however, little has been published on the dietary patterns of this diet. Therefore, a critical gap persists as the collective interaction of foods, their combinations and frequency of consumption provide a perspective that is essential for understanding the broader implications of this lifestyle. Thus, the exploration of dietary patterns is necessary to understand this diet as a whole. Addressing this research gap will give an understanding of how vegan individuals structure their diets, whether some are at risk of nutritional deficiencies and just how broad the spectrum of eating is within a New Zealand vegan's diet.

1.2.1 Hypotheses

- This study hypothesises that dietary patterns will differ between vegans living in Auckland, New Zealand due to influences of socio-demographic, and socio-cultural factors.

1.2.2 Aim

- To investigate dietary patterns in a vegan population living in Auckland, New Zealand

1.2.3 Objectives

- To explore the dietary patterns of a vegan population using principal component analysis
- To explore the socio-demographic characteristics of a vegan population following different dietary patterns

1.3 Researchers Contributions

Table 1.1: Contribution of Researchers to the study

Phillipa Henderson MSc Nutrition and Dietetic Candidate	Main researcher and author, creation of food groups, writing, editing and statistical analysis and final composition of the thesis
Professor Kathryn Beck Primary Academic Supervisor	Primary supervisor of this study. Co-investigator in the Vegan Health Research Program. Assistance with food grouping, editing, statistical analysis and general guidance.
Professor Pamela von Hurst Co-Supervisor	Primary investigator of the Vegan Health Research Program. Editing and general guidance through thesis.
Dr Karen Mumme Statistician	Assistance with food grouping, advised and checked statistical analysis, methods and results.

Chapter Two: Literature Review

2.1 Introduction

This review will cover several aspects of the vegan diet and its relation to the dietary patterns of a vegan population in Auckland, New Zealand. The review will explore the historical context and modern motivations behind the adoption of this diet, such as health, ethical, environmental and economic reasons. It will highlight the prevalence of veganism in New Zealand, drawing on recent studies and surveys. With a focus on the demographic trends of veganism in both international and New Zealand figures. Additionally, the review will break down the characteristics and nutritional components of a vegan diet, discussing the advantages and disadvantages as well as possible nutritional deficiencies. Finally, it will assess various dietary assessment methods, the advantages and disadvantages of each and their relevance to understanding dietary patterns within a vegan population. This review aims to provide a detailed understanding of dietary habits and nutritional implications of veganism in Auckland, New Zealand.

2.2 Background

In traditional terms, the vegan diet can be described as one that excludes foods derived from animals but is rich in foods from various plant-based groups such as fruits, vegetables, grains, legumes, nuts etc. (Łuszczki et al., 2023). Consumers following this diet avoid all animal products. This includes not only products where the animal is killed such as meat and gelatine but also dairy products, eggs, honey and other animal-based food ingredients (Janssen et al., 2016). Individuals have various and diverse motives for becoming vegan including but not limited to concerns about animal rights and welfare, environmental sustainability, health issues (Łuszczki et al., 2023) and social influences. Differing reasons for following this diet may influence an individual's food and lifestyle choices.

Veganism has become more popular in recent years due to its growing popularity worldwide for health, ethical, economic and environmental reasons (Alcorta et al., 2021). A longitudinal study done in 2021 identified that 1.1% of New Zealand's population follows a vegan diet (Milfont et al., 2021). This percentage is expected to grow in the coming years as indicated in a 2021, PWC report which revealed 35% of New Zealanders were “likely” or “more than likely” to become vegetarian or vegan in the next 12 months (Skinner, 2021). As veganism continues to grow in popularity, the food industry has responded by producing more processed vegan food and drink items (Sexton et al., 2022), which are slowly making their way into the New Zealand food market. It is well reported that a nutritionally adequate vegan diet can meet all the nutritional requirements necessary for health (Łuszczki et al., 2023). It remains unclear if modern vegan dietary intakes can deliver the requirements to meet a nutritionally adequate diet. For example, traditionally vegans consume whole-plant-based foods with a focus on fruit and vegetable consumption, however, if vegans are choosing ultra-processed vegan food items over more natural plant-based sources, could this compromise the nutritional quality of vegan diets (Gallagher et al., 2022). Previous studies have provided us with valuable insights into the nutritional quality of this diet and the risk of nutritional deficiencies if a balanced diet is not achieved. Although several studies have evaluated the dietary patterns of other diets in comparison with vegan diets, few studies have subjected vegan diets to dietary pattern analysis (Haider et al., 2023, Gallagher et al., 2021, Orlich et al., 2014). Therefore, there is a wealth of knowledge about the health benefits of veganism, yet not much is known about the dietary patterns. With the expected growth of veganism in New Zealand a comprehensive national nutrition survey would be beneficial in providing detailed information on the prevalence of non-meat eaters; specifically, vegans in New Zealand (Greenwell et al., 2023). As well as more nutritional studies which focus on the intricacies of this diet such as dietary patterns.

2.3 Veganism worldwide and in New Zealand

Recent studies indicate that veganism continues to rise in popularity. Gehring et al., (2021) indicates that there has been a one to ten percent increase in individuals adopting a vegan or vegetarian diet in Western populations, such as the United Kingdom, America and Europe. Recent data shows that in Western countries such as the United States and United Kingdom about 1–4% of the population identify as vegan (Reinhart, 2018; Wunsch, 2024) Between 2014 to 2019 veganism in the UK increased to over half a million individuals or 1.16% of the population (Gallagher et al., 2022). Similarly, 2019 data in

America showed that 2% of the population followed a vegan diet, increasing from 4 million in 2014 to 19.6 million people in 2019 (Paslakis et al., 2020). This trend is evident worldwide, as veganism emerged as the most frequently searched diet in a global study of Google trends from 2004 to 2019 (Kamiński et al., 2020). Recent studies in 2018 and 2023 have estimated the proportion of New Zealanders following a vegan diet at 0.74-1.1% of the population (Greenwell et al., 2023) However, these studies are based on representative samples of the population thus the reliability of these estimates is uncertain. Although the percentage of New Zealanders following a vegan diet is small this is expected to have grown in recent years (Skinner, 2021) which revealed, that around a third of its New Zealand sample was considering becoming vegan in the future. Vegan diets have particularly grown in popularity among teenagers and youth, especially females (Craig, 2009). Veganism has also been of greatest interest to Google users compared to other diets (Kamiński et al., 2020) and the number of consumers following a vegan diet and demand for vegan food has increased notably in many industrialised countries (Janssen et al., 2016)

2.4 Motivations for veganism

Ethical considerations are attributed to the moral imperative to not harm animals for food or other reasons. Based on the argument that the consumption of animals is ethical because they do not deserve rights due to their lack of capacity for an ethical agency or sophisticated rational thought is implausible because this would also entail that many humans such as young children and severely mentally handicapped adults also lack rights (The (Ankeny, 2012) Handbook of Food History, 2012). Therefore, it seems humans deem the criterion for having intrinsic worth requires being an experiencing subject of life. However, many of the animals that humans eat, and use are also experiencing subjects of life thus these animals have moral rights just as strong as ours. Moreover, the real basis of a human's intrinsic worth is being a member of the homo-sapiens species therefore revealing the unethical power dynamic between human and animal lives (Kotzmann, 2023). Those who follow a vegan diet for ethical reasons do not believe in this power dynamic and refuse to exploit animals for human benefit.

Concerns around the environmental impact of the consumption of animal-based products are becoming increasingly prominent among new vegans due to warnings of global warming and the significant contributions animal agriculture has towards this (Espinosa-Marrón et al., 2022). Studies on the influences of vegetarianism and veganism show that these diets are less harmful to the environment by reducing pollution, intensive farming, and land degradation by grazing (Fox & Ward, 2008). The vegan lifestyle makes fewer demands upon the shared environmental resources than the typical omnivore diet (Ankeny, 2012). More arable land and water are required to produce grain to feed animals to produce a calorie of meat than to produce a calorie of plant-based food (Ankeny, 2012). The economic pressures on animal agriculture have led to increased industrialised farming leading to increased damage to land and water systems from environmentally toxic byproducts generated by farming (Ankeny, 2012). Other factors such as health concerns, social influence and preference play a role in an individual's switch to veganism (Vestergren & Uysal, 2022). Many studies have discussed the protective effect of plants against chronic disease, weight and digestion. Furthermore, many have discussed the potentially harmful effects of excessive animal consumption due to their higher fat content (Bazzano et al., 2003). These findings have shifted the way people think about food and the effect it has on our health leading to more people following a vegan diet for its potentially health-improving effect. This ties in closely with the social influences of veganism as the expansion of the internet gives people access to more information about the diet and allows them to connect with people who may influence, promote or endorse this diet for different reasons (Vestergren & Uysal, 2022). People often make dietary changes to align with the practices and beliefs of those who surround them. This means family, friends, celebrities, influences and media can play a large role in shaping one's beliefs by compelling them to stand up for what's right or what they believe in (Vestergren & Uysal, 2022). Lastly, factors such as personal preference can lead to the adaptation of diets such as veganism through taste preference, experimentation and personal belief (Vestergren & Uysal, 2022).

2.5 Sociodemographics of vegans

The results from the 2018-2020 New Zealand health survey conducted in adults >15 years, showed that 0.74% of the sample population followed a vegan diet and there appeared to be a correlation between socio-demographic factors such as age, sex, ethnicity and adherence to a vegan diet (Greenwell et al., 2023). The statistics showed that for both men and women, vegans were younger (mean age 36-38yrs) than red-meat eaters (mean age 45-46yrs), prevalence of vegans among Asians was higher (6.42-8.53%) than NZ Europeans (1.67-2.82%) and those with tertiary education were more likely (3.96-6.62%) to be vegan compared to those with less than upper secondary schooling (1.79-4.7%) (Greenwell et al., 2023). A survey conducted on 1107 New Zealanders by Colmar Brunton in 2019 commissioned by Food Frontier found that vegans were most likely to be millennials, most likely to reside in Auckland and were vegan for health-motivated reasons (Foods, 2019). Similarly, worldwide the younger generations appear to be choosing veganism. The UN reports that 7 out of 10 young people aged 18-35 want to be part of the green movement, reflecting a generational shift towards plant-based diets (Raptou et al., 2024; team, 2023).Generation Z (people born between 1995 and 2010 (Mahapatra et al., 2022)) appear to driving the plant-based food industry with research showing their purchasing of vegan food items such as tofu at 57% increase and plant-based milk 550% increase over any other generation (Trauth, 2020). This is likely due to the presence of Gen Z on social media, which is leading them to be more conscious of what they consume and how a product is portrayed online (Britainthinks, 2019; Francis, 2018.). The current literature suggests that women are more likely to follow a vegan diet than men (Modlinska et al., 2020). It is suggested that this is due to men generally suffering more from conflicting thoughts between their intrinsic preferences and gender norms, whereas women are less concerned about these issues (Modlinska et al., 2020). With meat often being perceived as part of a masculine diet, it appears more women are opting for veganism than their male peers (Modlinska et al., 2020). This rise in veganism represents a growing social movement, shaped by environmental awareness, gender trends, and market responses to the demand for more

2.6 Advantages of a vegan diet

Adequately balanced vegan diets are nutritionally sufficient and can provide numerous health benefits. Plant-based diets have been linked to a lower risk of premature mortality and protection against noncommunicable diseases (NCDs) (Haider et al., 2023). Vegans typically consume greater quantities of fruits and vegetables (Alcorta et al., 2021). Increased consumption of these foods, which are rich in fibre, folic acid, antioxidants, and phytochemicals, is associated with lower blood cholesterol, lower incidence of stroke, and a reduced risk of mortality from stroke and heart disease (Craig, 2009).

The general components of a vegan diet contribute to health benefits through various mechanisms. The diet is rich in fibre, which slows digestion, increases satiety, delays gastric emptying, and reduces glucose and cholesterol absorption. It is also high in antioxidants, has a low caloric density, and is generally nutrient-dense. These properties are particularly beneficial in reducing the risk of cardiovascular disease (CVD), weight gain, and certain cancers.

2.6.1 Cardiovascular Disease and Vegan Diets

Vegan diets are associated with a lower risk of CVD (Koutentakis et al., 2023). These benefits are attributed to increased daily consumption of fresh fruits, vegetables, cereal grains, nuts, legumes, and seeds. Both low saturated fat intake and fibre are protective factors for CVD. Low saturated fat intake can enhance lipid profiles, as saturated fatty acids (SFAs) contribute to chronic inflammation (Koutentakis et al., 2023). The consumption of lower-energy foods is linked to a lower body-mass index (BMI), which is an important factor in reducing blood lipids and lowering the risk of heart disease (Craig, 2009). Nutrients in fruits and vegetables, including fibre, folate, antioxidant vitamins, and potassium, have anti-inflammatory effects, aid in blood pressure regulation and contribute to lipid profile control (Bazzano et al., 2003).

2.6.2 Weight Management

A vegan diet is commonly associated with maintaining a healthy weight. This is likely due to the reduced calorie intake that accompanies plant-based diets, which are lower in saturated fats and higher in fibre than animal-based foods (Łuszczki et al., 2023). Most plant foods have a low caloric density except for plant oils and nuts. The high water and fibre content of plant-based foods also contributes to lower energy intake, aiding in weight management (Stelmach-Mardas et al., 2016). The combination of a balanced vegan diet and lifestyle factors such as regular physical activity enhances these benefits and can prevent chronic diseases such as obesity and cardiovascular disease (Łuszczki et al., 2023).

2.6.3 Cancer Prevention

A vegan diet may provide protective effects against cancer. Antioxidants and other bioactive compounds found in plant foods are associated with a reduced risk of various cancers, particularly lung, mouth, oesophagus, and stomach cancers (Donaldson, 2004). Red and processed meat consumption has been linked to an increased risk of some cancers (World Health Organization, 2015) and is associated with higher blood cholesterol levels (Vestergren & Uysal, 2022). In contrast, plant-based protein sources, such as legumes and iso-flavone-containing soy products, have been found to have protective effects against cancer (Zhu et al., 2015). Legume consumption has been associated with a reduced risk of colon and prostate cancer (Zhu et al., 2015), while isoflavone-containing soy products may provide protective effects against breast cancer, particularly when consumed during childhood and adolescence (Zhu et al., 2015).

2.6.4 Fibre and Gut Health

Dietary fibre is an integral component of the vegan diet, classified as either soluble or insoluble. Soluble fibre, found in foods like fruits, oats, and beans, slows digestion and increases satiety by forming a gel-like matrix in the digestive tract, delaying gastric emptying and glucose absorption to support glucose regulation (Łuszczki et al., 2023). Insoluble fibre, found in whole grains and vegetables, adds bulk to faecal matter, promoting regular bowel movements and preventing constipation (Łuszczki et al., 2023). Additionally, fibre has a beneficial impact on gut microbiota. Bacterial fermentation of fibre leads to the production of short-chain fatty acids (SCFAs), which play a role in lipid metabolism regulation, cholesterol and glucose regulation, inflammatory responses, immune function, and maintaining gut barrier integrity (Łuszczki et al., 2023).

2.6.5 Nutrient Density and Antioxidant Protection

Plant foods contain essential nutrients required for a well-balanced diet. They provide an abundant source of magnesium, calcium, potassium, vitamins, and bioactive compounds such as polyphenols, fibre, and carotenoids (Łuszczki et al., 2023). A healthy vegan diet consists of a diverse range of antioxidants, which protect cells from oxidative stress and damage caused by free radicals (Clem & Barthel, 2021). Free radicals are produced due to metabolic processes, lifestyle activities, and environmental factors. Antioxidants such as vitamins C and E, polyphenols, and carotenoids counteract free radical damage by disrupting oxidation chain reactions (Chaudhary et al., 2023). The antioxidant-rich nature of a vegan diet contributes to cellular health and reduces susceptibility to chronic diseases.

2.7 Disadvantages of a vegan diet

To obtain a nutritionally adequate diet consumers must consume a variety of nutrients. The vegan diet is rich in antioxidants and nutrients from plant-based foods but without animal products, some nutritional shortfalls may occur. This is primarily because food containing high levels of bioavailable nutrients from animal origin are removed from the vegan diet (Craig, 2009). Vegans therefore must maintain a varied plant-based diet to bridge and protect from decreased or missing nutrients without animal product consumption. Nutrients and minerals such as calcium, vitamin D, iron, zinc, and vitamin B12 are found in high doses in animals (Bakaloudi et al., 2021), thus considerations should be made to meet daily requirements.

Low calcium intake is associated with bone loss and fractures. However, bone health is not entirely dependent on calcium. it's influenced by protein and nutrient intakes such as vitamin D, vitamin K, potassium and magnesium which are found in high doses within soy products, fruit and vegetables (Craig, 2009). Adequate consumption of these foods ensures a vegan diet that's rich in these protective factors. Soy products, leafy greens and fortified cereals, rice, soy and juice beverages are rich in calcium (Craig, 2009) thus adequate consumption paired with adequate Vitamin D should be maintained to protect bone health. vitamin D is found naturally in some animal products such as the flesh of fatty fish, fish liver oils, eggs, and cheese (Benedik, 2022). All of which are omitted from a vegan diet. Foods such as soy milk, rice milk, orange juice, cereals and margarine are mostly fortified with vitamin D (Benedik, 2022), However, the form of vitamin D acceptable to vegans (D2) is less bioavailable than animal-derived vitamin D3 (Craig, 2009). Thus, vegans rely on both sun exposure and vitamin D-fortified foods to meet their requirements. To ensure an adequate vitamin D status, especially during the winter, vegans must regularly consume vitamin D–fortified foods. Where fortified foods are unavailable daily supplementation with 5-10ug of vitamin D is necessary (Craig, 2009).

A vegan diet is more likely to be iron deficient than other diets due to the bioavailability of haem iron from animal products being substantially higher than non-haem iron from plant foods (Bakaloudi et al., 2021). Highly consumed foods in vegan diets such as green-leafy vegetables, grains, nuts and beans are iron-rich however these foods have low bioavailability (Bakaloudi et al., 2021). This could be improved by parallel consumption of vitamin C-rich foods in conjunction with nonheme iron to improve its absorption markedly (Lynch & Cook, 1980). Adequate consumption of vitamin C-rich foods (e.g. citrus fruits, strawberries, kiwis) and foods rich in organic acids (e.g. citric and malic acid) is essential for maintaining adequate iron stores (Bakaloudi et al., 2021). Iron supplements are also recommended for specific populations such as premenopausal vegan females and in the presence of specific needs such as high iron losses (Hunt, 2003).

Vitamin B12 is found almost exclusively in animal-based foods and therefore is a nutrient of potential concern for those following a vegan diet (Zeuschner et al., 2013). Vitamin B12 is produced by bacteria in the large intestines of animals thus plant-based foods are not a good source. Vitamin B12 is an essential vitamin for DNA synthesis and for maintaining nerve myelin integrity, thus deficiencies can result in anaemia, inhibition of cell division and neurological symptoms (Ankar & Kumar, 2024). In younger children, this can cause failure to thrive and macrocytic anaemia at all ages (Sharma et al., 2023). It can also impact the metabolism of folate, which can lead to high concentrations of homocysteine in the blood, a known risk factor for cardiovascular disease (Mohan et al., 2023). Vegans therefore require B12-fortified food or supplements such as fortified soy and rice beverages, certain breakfast cereals or daily B12 supplements (Zeuschner et al., 2013). Regular assessments of B12 status should also be done to identify potential problems (Zeuschner et al., 2013). Lastly, phytates which are found in large quantities in foods such as grains, seeds, and legumes bind zinc decreasing its bioavailability (Craig, 2009).

These foods are common components of a healthy vegan diet which can pose a risk for zinc deficiency. To overcome this, vegans should consume foods rich in zinc such as nuts, whole grains, and soy products and zinc-fortified foods such as cereals and vegan dairy alternatives (Craig, 2009).

A key nutritional concern in vegan diets is the lack of long-chain omega-3 fatty acids, specifically eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are predominantly found in marine sources such as fatty fish and seafood (Burns-Whitmore et al., 2019). These fatty acids play key roles in maintaining cardiovascular function, cognitive performance, and inflammation regulation (Swanson et al., 2012)however vegan diets do not include food from animal origin. Consequently, vegans must rely on alternative sources to meet their omega-3 requirements. In vegan diets, alpha-linolenic acid (ALA), found in flaxseed, chia, walnut, and echium oils, is the primary omega-3 source. However, ALA conversion to EPA and DHA in the body is limited, with studies demonstrating that dietary ALA does not significantly increase DHA levels (Burns-Whitmore et al., 2019; Lane et al., 2014). Additionally, high dietary intake of linoleic acid (LA), prevalent in vegan diets, can further inhibit ALA conversion (Burns-Whitmore et al., 2019; Rosell et al., 2005). To address deficiencies, vegans can incorporate supplements or fortified foods to provide sources of DHA and EPA. Algal oil has emerged as a promising source of DHA, with supplementation shown to effectively raise blood levels of these long-chain fatty acids (Lane et al., 2014). Eating a variety of plant-based omega-3s is particularly important for mitigating the potential health risks associated with the exclusion of marine-based omega-3s.

Protein quality is a crucial aspect of vegan diets, as plant-based protein sources typically exhibit lower digestibility and suboptimal amino acid profiles compared to animal-derived proteins (Soh et al., 2024). Plant proteins are often limited in one or more essential amino acids, with cereal grains deficient in lysine and legumes low in methionine and cysteine (Mariotti & Gardner, 2019). However, the combination of complementary protein sources, such as grains and legumes, can provide a complete amino acid profile, ensuring all essential amino acids are obtained. Additionally, the presence of antinutritional factors such as phytates and tannins in plant foods can reduce protein digestibility. Bioavailability can be enhanced by reducing these anti-nutrient factors using processing methods such as soaking, sprouting, fermenting, and cooking (Samtiya et al., 2020). To compensate for the lower digestibility of plant proteins, it is recommended that individuals following vegan diets increase their total protein intake by 10–20% (Rolands et al., 2024).

For the most part, plant-based diets are associated with healthy minimally processed plant foods. However, with the industrialization of the vegan diet comes the introduction of ultra-processed plant-based foods (UPFs). Minimally processed plant-based foods are whole grains, fruits, vegetables, legumes, nuts and seeds. However UPFs such as, refined grains, sugar-sweetened beverages, snacks and confectionery can still be considered plant-based foods when their ingredients do not originate from animal products. Close attention should be paid to the quality and composition of the vegan diet as the associated health benefits are inversely related to the consumption of minimally processed plant foods. UPFs are full of additives and flavourings to extend their shelf life and enhance the flavour (Monteiro et al., 2019).

2.8 Rise of ultra-processed foods

As veganism has gained popularity around the world there has been a significant shift in consumer preferences towards plant-based eating leading to increased industry mimicking of animal-based products (Szenderák et al., 2022). Consumer interest is driving a change within the food sector as more food producers develop innovative vegan food products (Saari et al., 2021), particularly plant-based meat and dairy alternatives. Initially niche, these alternatives are becoming more mainstream as they seek to appeal to consumers who value the taste and texture of animal products but desire sustainable or ethical options (Curtain & Grafenauer, 2019). These items, however, are classified as ultra-processed foods as per the NOVA classification system (Moubarac et al., 2014). UPFs often contain little to no wholefoods with increased use of refined oils, salt, sugars and additives (such as flavours, flavour enhancers, colours, emulsifiers, emulsifying salts, sweeteners, thickeners, and anti-foaming, bulking, carbonating, foaming, gelling and glazing agents (Monteiro et al., 2019) raising concerns about their long-term health implications (Moubarac et al., 2014; Monteiro et al., 2023). UPFs are often formulations of many ingredients exclusive to industrial use, created by a series of industrial techniques and processes (Ohlau et al., 2022). They're mostly made from substances extracted from foods (e.g. fats, starches, added sugars, hydrogenated fats) with their main purpose being to create convenient, non-perishable food, and ready-to-eat products (Haneberg et al., 2024). However, this often comes at a nutritional loss as UPFs are often energy-dense, low in micronutrients and low in fibre (Ohlau et al., 2022). Ultra-processed vegan foods include plant-based meat alternatives (PBMA), plant-based dairy alternatives (PBDA), plant-based yoghurt alternatives (PBYA), animal-free egg replacements and other processed items, for example, sweet or savoury processed snacks. Many PBMAs are designed to closely resemble the appearance and flavour profile of meat, even simulating elements like "blood," using beetroot juice, designed to appeal to consumers who favour meat consumption (Curtain & Grafenauer, 2019). PBMAs are lower in calcium, potassium, magnesium, zinc, and vitamin B12 (Cole et al., 2022; Tso & Forde, 2021). Moreover, many plant-based meats are higher in sodium, sugars and saturated fat compared to meat alternatives (Alessandrini et al., 2021; Tso & Forde, 2021). While processed vegan foods offer convenience, they may also contribute to health issues similar to those associated with conventional ultra-processed foods if consumed in excess due to the lack of whole food components and high levels of refined ingredients (Gastaldello et al., 2022). As highlighted in recent studies, these may include nutrient deficiencies such as metabolic syndrome, cardiovascular disease, and obesity (Sexton et al., 2021). Although these products are marketed for health-conscious consumers, they may provide fewer nutritional benefits than unprocessed vegan foods, raising the need for consumer awareness about the nutritional trade-offs involved. The PBMA global market was estimated to USD $1.6 billion in 2019 with a projected annual growth rate of 12% (Boukid, 2021). With the rapid expansion of this market and therefore shift in traditional vegan dietary intakes, there is an urgent call for balancing ethical and environmental goals with the promotion of whole, nutrient-dense foods (Foods, 2019; Henchion et al., 2021). To fully align with health recommendations, experts suggest that consumers should prioritize whole in plant-based diets, minimizing the intake of ultra-processed alternatives to ensure they are maintaining nutritional adequacy in a diet that already poeses a higher risk for nutritional deficiencies (Sexton et al., 2021; Bouvard et al., 2022).

2.9 Assessing dietary intake

Dietary assessments have great significance in research as they allow us to investigate relationships between diet, health and disease (Bailey, 2021). Dietary assessments are used to measure dietary intake in the past or present time. There's a range of methods available to measure dietary intake in individuals and a population. The four most common of these are Food records, Food frequency questionnaires, 24-hour diet recall and Diet history (Naska et al., 2017). The varying characteristics of these include being; retrospective or prospective, short or long term and qualitative or quantitative (Biró et al., 2002). The food frequency questionnaire (FFQ), diet history and 24-hour recall are examples of Retrospective methods as these rely on an individual's memory to obtain dietary information (Thompson & Subar, 2017). Food records are a prospective method as this involves the participant recording their foods and beverages at the time of consumption (Willett, 1998). Dietary assessments vary from short to long-term durations, typically ranging between 24 hours (24-hour recall), to 3-7 consecutive days (food record), to a month, several months or a year (Longer durations usually assessed with an FFQ and diet history) (Biro et al., 2002; Lee & Nieman, 2003). Dietary assessments are either qualitative or quantitative. Qualitative methods include the FFQ and diet history as these methods measure habitual intake of food items, food groups and dietary patterns (Federico et al., 2017). 24-hour recalls and Food records that use household measures or food scales are examples of quantitative measures as these methods provide information on actual nutrient intake (Fenner, 2015). Using different dietary assessment methods, we can obtain useful information on the food and nutrient intakes of both individuals and population groups. These assessment methods are used at three different levels of food consumption categorised as – national, household and individual. Information such as frequency of intake, types of foods eaten, portion size of food and dietary habits expressed as nutrients, foods or dietary patterns can be obtained from these categories (Biró et al., 2002). Dietary assessment at an individual level is used to investigate associations between dietary intake, health and disease. It can be used in both clinical and research settings.

2.9.1 Food record

A food record is a participant-guided comprehensive recording of all foods, beverages and dietary supplements that the respondent consumes over a designated period (Bailey, 2021). In addition, the recorded amounts should be given in weighed or estimated quantities using scales, household utensils (e.g. Cups, tablespoons) or food models (Biró et al., 2002). Food records should be completed over 1-7 days, randomised to cover seasonal and weekday variations (Biró et al., 2002). To avoid participant burden a shorter recording-keeping duration should be required; 3-4 days is enough to provide variation yet short enough to ensure the quality of information remains consistent (Bailey, 2021). The advantages of this method include detailed information on foods consumed and eating patterns, information on portion size, preparation and cooking methods, and does not rely on participant memory (Shim et al., 2014). It also provides relatively accurate information with respect to foods consumed. When the foods are weighed and recorded this can provide the most accurate results as respondents aren't required to recall quantities and omission from food might be minimal (Biró et al., 2002). However strong the advantages may be this method relies largely on good cooperation from participants. The disadvantages of this method include the requirement of motivated and literate participants (To record, weigh and estimate portions) (Gurinović et al., 2017). It is also of high participation burden which could lead to altered eating patterns, inaccurate recording and decreased reliability of records over time due to participant fatigue (Biró et al., 2002).

2.9.2 FFQ

The food frequency questionnaire gathers long-term dietary intake data (Shim et al., 2014). Used to assess usual intake over a specified period (mostly last month(s) or year(s)) they query how frequently a person consumes certain food items (Bailey, 2021). Foods are listed in a questionnaire often including questions regarding portion size for estimation of quantities of foods eaten and/or nutrient intakes to be assessed (Biró et al., 2002). To obtain relevant and reliable data the development of a comprehensive food list is crucial (Biró et al., 2002). FFQs should be developed specific to a study population due to the influence of ethnicity, culture and economic status on the diet (Shim et al., 2014). Food lists should include enough items to accommodate differing dietary habits between participants (Biró et al., 2002). FFQs can rank individuals regarding their nutrient or food exposure which is a critical aspect of examining dietary patterns and diet relationships. However, the disadvantage of FFQs is the limited scope of foods that can be queried thus the lack of precision in measuring absolute intakes of food components. As well as increased participant burden due to the complexity of questioning and reliance on participant memory.

2.9.3 24-hour recall

The 24-hour recall is typically carried out through an interview between a trained researcher and a participant. The interview usually takes 20-30 minutes to complete where the researcher gathers a 24-hour recall of an individual's food and beverage intake, typically from the day prior (Shim, Oh, & Kim, 2014). The advantages of this dietary assessment include the researcher's ability to probe a participant for detailed information about brands, portions and added ingredients with minimal participant burden (Biró et al., 2002). There is no level of literacy required for participants and the administration time is short with assessments only taking roughly 15-20 minutes which can be done in person or over the phone (Thompson & Subar, 2017). The interview process is open-ended to obtain accurate dietary information and the assessment does not alter the food intake pattern (Biró et al., 2002). The disadvantages of this method include participants' recall ability being based on memory (Thompson & Subar, 2017). It's difficult for participants to remember what they've eaten in days prior let alone having to recall portion sizes which can lead to intake often being underreported (Shim et al., 2014). The 24-hour recall only provides dietary information over a 24-hour period which is not enough information to give an accurate representation of one's diet, thus is an inappropriate method to analyse an individual's dietary patterns.

2.9,4 Diet History

The diet history method starts with an interview to determine the usual meal pattern (Biró et al., 2002). Meal patterns can be established by analysing dietary data over a specific period (usually the past month, several months, or year) (Bailey, 2021). This method is useful for estimating usual dietary intake and gathering information on the whole diet as it does not influence participants' dietary patterns (Shim et al., 2014). The disadvantages of such a method include it not being suitable for participants with unusual eating patterns and participants underreporting of intake due to the cognitive strain associated with extensive recall (Shim et al., 2014).

2.10 Analysing dietary intake

Analysing dietary intake has evolved from a traditional reductionist approach which focuses solely on individual nutrients or foods to a more holistic approach. The reductionist approach is and has been the dominant approach in nutrition research (Hoffmann, 2003). This means that parts of the diet rather than the whole, single food components or food habits, are studied (Hoffmann, 2003). This paradigm has led us to fractionate foods into their essential nutrients, i.e., macro-, micro- and phyto-nutrients (Fardet & Rock, 2015). It forms the basis for dietary guidelines and recommendations often centred on meeting recommended daily intakes. While valuable for preventing deficiencies and understanding nutrient-specific impact, there are several reasons why dietary and health issues go beyond the reach of the reductionist approach (Hoffmann, 2003). The holistic approach to analysing dietary intake encompasses a comprehensive assessment that considers multiple dimensions of dietary habits and past nutrient content (Fardet & Rock, 2015). This approach integrates the study of nutrients, foods and food groups in dietary patterns (Tapsell et al., 2016). Holism suggests that the whole is more than the sum of its parts emphasizing the role of studying overall dietary patterns, including the role of ultra-processed foods, in influencing health outcomes (Fardet & Rock, 2015). Using more holistic approaches will allow us to better understand the complexities of diet and dietary patterns.

2.11 What is a dietary pattern?

Dietary patterns examine the combinations, types and amounts of foods consumed in the diet (McNaughton, 2020). They can be described as the quantities, proportions, variety or combinations of different foods, drinks and nutrients in the diet and the frequency in which they are habitually consumed (Schulze et al., 2018). Dietary patterns play an important role in health as they capture the need for dietary balance by incorporating multiple aspects or dimensions of diet simultaneously and recognising that a critical factor in disease prevention may be the balance between protective and harmful components of the diet (McNaughton, 2020). As they consider the whole diet and are shaped by personal preference, income, culture and the environment they've allowed healthy and unhealthy dietary patterns to be identified (Gherasim et al., 2020). Understanding dietary patterns allows us to understand that small changes or differences in individual foods may not have positive associations with health outcomes rather there may be cumulative health benefits with changes to multiple foods.

2.12 Assessing dietary patterns

Dietary patterns are assessed using two approaches, data-driven methods (empirical and theoretical) (McNaughton, 2020). Dietary patterns can be derived using empirical methods (a-posteriori approach) whereby patterns are data-driven (Oude Griep et al., 2013). Two empirical techniques are used to analyse dietary information from food consumption data. These are factor analysis and cluster analysis (Michels & Schulze, 2005). Factor analysis describes both principal component analysis and common factor analysis (Riffenburgh & Gillen, 2020). It uses information reported on FFQs or in dietary records to identify common underlying factors or patterns (Hu, 2002). A correlation between food groups and food items will group them as dietary compounds, distinct from components that have no correlation (Gherasim et al., 2020). Cluster analysis groups individuals into clusters with similar dietary intake (Waijers et al., 2007). Individuals are classified into clusters based on the frequency of food consumed, the percentage of energy contributed by each food or food group, nutrient intakes or a combination of dietary and biochemical measures (Hu, 2002).

Both statistical methods are used to derive summary scores for each pattern which can be to examine relationships between eating patterns and health outcomes (Hu, 2002). Theoretically derived dietary patterns include diet quality indices (DQIs). These indices are typically constructed based on dietary recommendations such as the healthy eating index (Hu, 2002), They allow diet quality to be measured as a single exposure. DQIs utilize a priori approach as they're based on current knowledge of what constitutes a healthy diet by using national dietary guidelines and recommendations (Burggraf et al., 2018). A priori indices often use dietary data collected by food records, 24-hour dietary recalls, or food frequency questionnaires to provide an overall diet quality score (Burggraf et al., 2018).

2.13 Dietary intake of vegans

Table 2.1 Previous literature on vegan dietary patterns

Study	Author	Year	Population	Dietary assessment method	Dietary patterns identified	% Variance
Pattern analysis of vegan eating reveals healthy and unhealthy patterns within the vegan diet **https://pmc.ncbi.nlm.nih.gov/articles/PMC9991567/**	Cathrine T Gallagher	2021	Country: UK 129 healthy vegan participants (87% female, 13% male) Mean age: 18-24 years	FFQ, Factor and cluster analysis	**Convenience** (vegan sweets and desserts, vegan crisps, vegan sauces and condiments, vegan biscuits and cakes, fats and oils, vegan convenience meals & snacks and dairy alternatives) **Health conscious** (cooking from scratch, creating recipes and protein alternatives to meat/fish) **Unhealthy** (alcohol, takeaways and salt, **Traditional** (potatoes, vegetables, fruit and refined grains)	Convenience 22% Health conscious 12% Unhealthy 9% Traditional 7%
The Association between Vegan Dietary Patterns and Physical Activity—A Cross-Sectional Online Survey **https://www.mdpi.com/2072-6643/15/8/1847**	Sandra Haider	2022	Country: Germany 516 healthy vegan participants (81.5% female, 14.8% male) Mean age: (SD) 28.0 years	FFQ, Principal component analysis	**Convenience** (processed fish and meat alternatives, vegan savoury snacks, processed foods, sauces and condiments, cakes and biscuits, sweets and desserts, convenience meals and snacks, fruit juices/smoothies, and refined grains.) **Health conscious** (vegetables, fruits, protein alternatives (e.g., tofu), dairy alternatives, potatoes, whole grains, vegetable oils and fats, and cooking with fresh ingredients and creating own recipes)	NA

Development of a diet quality score and adherence to the Swiss dietary recommendations for vegans **https://jhpn.biomedcentral.com/articles/10.1186/s41043-024-00498-3**	Natalie S. Bez	2024	Country: Switzerland 52 healthy vegan Participants (61.5% female, 38.5% male) Mean age: 29 years	Food record, Principal component analysis	**Wholegrains and nuts** (green leafy vegetables, wholegrains, wholegrain bread, oils and fats, as well as nuts and seeds) **Refined grains and sweets** (refined grains, white bread, legumes, potatoes, sweet and salty snacks, sugar-sweetened beverages, tea, low fruit intakes)	Wholegrains and nuts 26.5% Refined grains and sweets 15%

The current literature on dietary patterns within the vegan diet is limited. However, three previous studies summarised in Table 3. had similar findings to one another (Gallagher et al., 2021, Haider et al., 2023, Bez et al., 2024). A study done on 129 vegans in the UK established the following four dietary patterns from factor analysis; a convenience, health conscious, unhealthy and traditional. The convenience pattern was the most identifiable pattern with a prominence of ultra-processed vegan foods such as vegan convenience meals, snacks, sweets, desserts, sauces, condiments and fats (Gallagher et al., 2021). Another similar study done in 516 vegans in Germany, had similar results. This study aimed to assess the association between vegan dietary patterns and physical activity. Principal component analysis identified a Convenience dietary pattern and a Health-Conscious pattern. Similarly, participants who consumed more ultra-processed vegan foods fit into the Convenience pattern and the Health-Conscious pattern was characterised by higher consumption of wholefoods such as fruit, vegetables, whole grains, dairy-alternatives, meat-alternatives (e.g. tofu), vegetable oils and fats. Interestingly vegans who followed this diet also practiced more physical activity (Haider et al., 2023). This study had positive associations between sociodemographic such as length of time being vegan, female, employment, smoking and BMI (Haider et al., 2023). A third study completed on 52 vegans in Switzerland identified a (Wholegrains and nuts) and (Refined grains and sweets) dietary pattern (Bez et al., 2024). The first pattern was characterised by high intakes of green leafy vegetables, whole grains, whole grain bread, fats and oils, as well as nuts and seeds. The second dietary pattern was characterized by high intakes of refined grains, legumes, potatoes, sweet and salty snacks, sugar-sweetened beverages, tea and coffee, and low intakes of fruits. (Bez et al., 2024). These derived patterns have similar loadings to the other studies and could also be characterised as convenience/unhealthy and health-conscious/healthy patterns. All three studies had similar findings to one another with prevalence of three main patterns; convenience, traditional and health conscious. The convenience pattern is centred around vegan convenience foods with the diet consisting of higher intakes of ultra-processed and non-processed vegan foods that are quick and easy to prepare. The traditional and health-conscious patterns are more in line with typical vegan definitions with a focus on whole foods like fruit vegetables and wholegrains as well as eating more protein alternatives such as nuts, soya and legumes rather than ultra-processed alternatives.

These studies highlight the need for further research into the dietary patterns within the vegan diet in order to strength the validity of these patterns and determine any that may be unknown. They emphasize the importance of distinguishing between different types of vegan diets when considering their health effects and the necessity for ongoing research to better understand these patterns and their broader implications. Furthermore, the studies would benefit from inclusion of complete nutritional analysis and blood metabolite analysis to ratify these results.

Chapter 3: Manuscript

3.1 Abstract

3.1.1 Background: Current literature on what vegans are eating is limited, with most past research focusing on nutrients and only a few studies looking at dietary patterns. Furthermore, prior research on this topic has focused on veganism in its traditional form rather than acknowledging the diversity of vegan diets which can range from whole-food plant-based eating to reliance on ultra-processed vegan products. As Ultra-processed foods are becoming more popular it complicates our understanding of vegan dietary habits. With vegan diets becoming increasingly popular in NZ, more targeted research is needed to fully understand vegan dietary patterns.

3.1.2 Objectives: To explore dietary patterns among vegans in Auckland, New Zealand to provide insights into the dietary habits of vegans.

3.1.3 Methods: The "Vegan Diet Research Program" a larger cross-sectional study from Massey University recruited 212 vegan participants through social media, online advertisements and local outreach. Anthropometric data, body composition, bone density and nutrient biomarkers were measured. Participant demographics, lifestyle and dietary data were collected through self-administered questionnaires and a food frequency questionnaire. 196 vegan foods were compiled into 34 food groups. Principal component analysis was applied to the food group consumption reported in each participant FFQ to derive dietary patterns.

3.1.4 Results: 212 participants, 71% female, with a mean age of 39.4 years (12.21) completed the study. Participants were mostly European (85%) and had an education level of Undergraduate or above (68.2%), however, females were more likely to have a higher education than men p=0.015. Four patterns emerged from factor analysis explaining 35.28% of the variation in the diet; Health-Conscious, Convenience, Western and Traditional. The Health-conscious pattern was positively associated with alcohol consumption (p= 0.005) and a higher physical activity score (p=0.0008). The

Convenience pattern was associated with lower alcohol intake (p= 0.015). The Western pattern was positively associated with the intercept (female and ‘no university education’ (p =0.027)), being physically active (0.009) and higher consumption of alcohol (p = <0.001). The Traditional pattern was positively associated with age and lower alcohol consumption (p = <0.001).

3.1.5 Conclusion: The results of this study indicate that vegan dietary patterns in New Zealand are diverse with distinct associations between dietary choices, alcohol consumption and physical activity. The findings highlight the need for further research to explore these patterns in a more ethnically diverse and representative sample of vegans in New Zealand. Furthermore, the inclusion of complete nutritional analysis and blood metabolite analysis would help to ratify these results.

3.2 Introduction

Veganism is a growing trend, with studies globally showing a steady rise in the number of people following the diet, particularly in developing countries (North et al., 2021). The number of vegans in New Zealand is also increasing (Greenwell et al., 2023) sitting between 0.74- 1.1% of the population as of 2021 (Greenwell et al., 2023). The vegan diet omits all foods derived from animals including meat, chicken, fish, seafood, dairy products, eggs, honey and gelatine (Łuszczki et al., 2023). Veganism may be adopted for a range of motivations which can impact how people choose to structure their diets (Alcorta et al., 2021)The vegan diet is known for its numerous health benefits (Key et al., 2022); however, it involves the exclusion of many food groups which can lead to nutrient deficiencies. These nutrients include but are not limited to iron, vitamin B12 and calcium which are found in high amounts in foods such as red meat and dairy products (Menzel et al., 2021). A traditional vegan diet (A plant-based diet composed of high-quality whole foods like grains, fruits, vegetables, legumes, nuts, and seeds (Clem & Barthel, 2021)), consists of low volumes of sodium, cholesterol, saturated fats and refined carbohydrates (Hassall, 2023). High intakes of these nutrients are associated with the development and proliferation of non-communicable diseases (NCDs) such as hypertension (HTN), cardiovascular disease (CVD), type two diabetes (T2D) and obesity (Hassall, 2023). In recent years there has been an increase in vegan products on the market, however many are classified as UPFs and contain high amounts of sodium, saturated fats, trans fat and added sugar (Elizabeth et al., 2020). With the expansion of vegan UPFs in the food market this brings uncertainty for the benefits versus risks of this diet.

An analysis of dietary patterns would be beneficial to help understand the associated risks or benefits of following a vegan diet. Dietary patterns consider the diet as a whole, rather than isolated nutrients or foods in order to provide insight into an individual's overall health and disease risk (McNaughton, 2020); Schulze et al., 2018). Dietary patterns are analysed empirically or theoretically to determine the quantities, proportions, variety or combinations that different foods and drinks are habitually consumed by individuals (McNaughton, 2020; Schulze et al., 2018). There are likely to be differences between the dietary patterns of people following a vegan diet due to differences in sociodemographic factors, personal preferences, and environmental influences leading to varying eating habits (Fresán et al., 2020). While dietary pattern studies have been done in broad global populations (da Costa et al., 2022), limited research exists on the vegan community, particularly in smaller populations like those in New Zealand. However, three recent studies the UK, Germany and Switzerland had similar findings to one another. Despite reporting a different range of patterns each study showed an overall division between a more health conscious and ultra-processed vegan dietary approach (Gallagher et al., 2021, Haider et al., 2023, Bez et al., 2024). Haider et al. found positive associations between females, students, nonsmokers, longer time being vegan and higher physical activity score in those following the health-conscious dietary pattern. Gallagher et al. and Bez et al. did not explore associations between dietary patterns and sociodemographic factors. The lack of data in specific populations makes it difficult to draw conclusions about the overall patterns and health impacts of vegan diets. This calls for an increased need for further dietary analysis in the New Zealand vegan population to explore vegan dietary patterns and the sociodemographic and lifestyles of vegans following these particular dietary patterns.

3.3 Study design

The exploration of dietary patterns within the diet of New Zealand vegans was undertaken as part of the larger cross-sectional Vegan Health Study undertaken at Massey University. This study assessed a range of health indicators in a sample of vegans living in Auckland, New Zealand. The focus of this sub-study was to determine participants' quantities, proportions, variety, or combinations of different foods contributing to their dietary patterns. The Vegan Health Study was approved by the Health & Disability Ethics Committee – HDEC 2022 EXP12312. Written informed consent was obtained from all participants.

3.4 Participants and Recruitment

The aim was to recruit over 200 men and women aged ≥18 years living in Auckland, New Zealand following a vegan diet. Inclusion criteria were following a vegan diet for at least two years. Participants were excluded if pregnant/breastfeeding, planning a pregnancy or had any known NCDs. Recruitment and data collection took place between May 2022 and January 2023. Recruitment was carried out via targeted messaging to vegan groups on Facebook and other social media platforms, as well as advertisements at the Massey University Albany campus and to local businesses and through word of mouth. Eligible participants were invited to the Human Nutrition Research Unit (HNRU) at Massey University, Auckland, NZ, for data collection. All participants were given unique identification numbers for analysis throughout the study to retain anonymity.

3.5 Data Collection

During their visit to the HNRU, participants blood pressure, body composition, nutrient biomarkers and bone density measurements were undertaken. All procedures were carried out by trained study personnel following standardized protocols. Body composition and bone density were measured using dual-energy x-ray absorptiometry (DXA). The Inbody 230 scale was used to assess weight, and height was measured using the SECA 510 stadiometer. BMI was then calculated by dividing weight by height squared (kg/m2), and reported by comparison to the reference ranges established by the World Health Organization (WHO, 2010). Health and demographic data were collected through a self-administered questionnaire. This included questions about participant age, gender, sex, ethnicity and education level. Education levels were collapsed into smaller groups to condense the numbers in each category and increase the effect size. “Lower than high school”, “High school” and “Diploma/Certificate” were collapsed into “Lower than bachelor’s degree”. “Bachelor's degree” remained the same and “Master's degree” and doctoral level” were collapsed into higher than bachelor. Participants were also asked to complete a self-administered Food frequency questionnaire. Upon completion, answers were checked by the study personnel to ensure the data was accurate and complete.

3.6 FFQ design

A semi-quantitative FFQ designed using an FFQ from the NZ Reach (Researching Eating, Activity and Cognitive Health) study, was adapted to suit a vegan diet (Hassall, 2023). The FFQ was found to have relatively acceptable validity and reproducibility for determining dietary patterns and nutrient intake (Hassall, 2023). The FFQ contained 196 New Zealand vegan food items chosen based on an audit of NZ supermarkets and a small selection of participant food diaries. Participants were asked for the frequency in which they had eaten a range of foods from the following food groups; Fruit, vegetables, nuts and seeds, legumes and soy, cereals and grains, alcohol, non-alcoholic drinks and vegan dairy, meat and snack alternatives. The frequency questions were “I never eat this food”, “Not this month but I have sometimes”, “1 to 3 times a month”, “once per week”, “2 to 3 times per week”, “4 to 6 times per week”, “once per day”, “2 to 3 times per day”, “4 to 5 times per day”, “6 plus times per day”. Each food group included a variety of food products and their serving size. Similar foods were condensed into the same food group based on their composition i.e. oils and vegan butter alternatives. The FFQ was validated for nutrients using Correlation coefficients, paired t-tests, Wilcoxon tests, and cross-classification with weighted kappa statistics. Bland-Altman plots with linear regression and energy adjustment analyses were also conducted.

3.7 **Dietary assessment**

The daily intake of 196 food items was collapsed into 34 food groups for dietary pattern analysis. Foods were grouped into consolidating them based on their similarity, macronutrient composition and culinary use. This allows for the analysis of dietary patterns by grouping foods with comparable nutrient profiles and roles in the diet.

Table 3.1 Food grouping for dietary pattern analysis

Food Groups (n=34)	**Food Items**
Berries	Strawberries, blackberries, cherries, blueberries, boysenberries, loganberries, cranberries, gooseberries, raspberries (fresh, frozen, canned)
Citrus fruit	Orange, tangelo, tangerine, mandarin, grapefruit, lemon, lime
Dried fruit	Sultanas, raisins, currants, figs, apricots, prunes, dates, fruit filled bars
Other fruit	Feijoa, persimmon, tamarillo, kiwifruit, grapes, mango, melon, watermelon, pawpaw (papaya), pineapple, rhubarb, bananas, apricots, nectarines peaches, plums, lychees, olives, apples
Alliums	Onions, leeks, garlic
Cruciferous vegetables	Broccoli, cauliflower, brussel sprouts, cabbage (all varieties), green leafy vegetables e.g., spinach, silver beet, swiss chard, watercress, puha, whitloof, chicory, kale, chard, collards, Chinese kale, bok choy, taro leaves (palusami)
Other vegetables	Corn, pumpkin, mushrooms, capsicum, peppers, courgette, gherkins, marrow, squash, asparagus, radish, eggplant, artichoke, carrots, salad vegetables (e.g. lettuce, cucumber, celery, sprouts, tomato's (all varieties))

Root vegetables	Kumara, taro, green banana, cassava, potato (e.g. boiled, mashed, baked, jacket, instant, roasted), other root vegetables (e.g. yams, parsnip, swedes, beetroot, turnips)
Processed starchy vegetables	Hot potato chips, french fries, wedges, hash brown
Nuts, seeds	Nut butters or spreads (e.g. cashew butter, almond butter, peanut butter, pesto), nuts e.g. (peanuts, macadamias, pecan, hazelnuts, brazil nuts, walnuts, cashews, pistachios, almonds, pine nuts, coconut), seeds (e.g. pumpkin seeds, sunflower seeds, pinenuts, sesame seeds, chia seeds, flaxseed, linseed), seed butter (e.g. sesame seed butter (tahini), sunflower seed butter, pumpkin seed butter), nuts and seeds snack bars, nuts and seeds snack pieces
Legumes	Kidney beans, black beans, navy beans, adzuki beans, white beans, black eye beans, lima beans, butter beans, mung beans, fava beans, baked beans, refried beans, chili beans, chickpeas or garbanzo beans, split peas, lentils, dahl, pigeon peas, falafel, hummus, green beans, broad beans, runner beans, peas, green
Soybeans	Soya beans, silken tofu, firm and high protein tofu, tempeh
Protein powder/bars	Bean or fava bean protein powder, soy protein powder, pea protein powder, protein bars
Non sweetened cereals	Bran based cereals, muesli, porridges (e.g. rolled oats, oat bran, oatmeal, All bran, Sultana bran), Weetabix, cornflakes, rice bubbles, Special K, Light and tasty

Sweetened cereals	Nutri grain, Froot loops, Frosties, milo cereal, Coco pops
Refined grains	White rice, white pasta, noodles (e.g. spaghetti, canned spaghetti, vermicelli, rice noodles, instant noodle, couscous, congee, white bread and rolls (including sliced and specialty breads such as focaccia, panini, pita, naan, chapatti, ciabatta, turkish, english muffin, crumpet, pizza base, wraps, tortillas, burrito, roti, rewena bread, french bread), bread crumbs, crackers (e.g. crisp bread, water crackers, rice cakes, cream crackers, Meal mates, Vita wheat)
Whole grains	Brown rice, whole meal pasta, noodles, barley, cornmeal, bulgur wheat, spelt, millet, quinoa, whole meal or wheatmeal bread and rolls (including sliced and specialty breads), wholegrain or multigrain bread and rolls (including sliced and specialty breads), rye bread and rolls, sprouted bread (including sliced)
Other meat alternatives	Chicken substitute strips, other chicken substitutes (e.g. nuggets, tenders, burgers), fish substitutes, bacon substitutes, pate substitutes
Vegetable or legume-based meat alternative	Soy based meat substitutes (including beef mince, beef meatballs), Other meat substitutes (e.g. Bean supreme, Sanitarium beef mince, pea-based meat), soy-based burgers, tofu-based sausages, other types of sausages (e.g. Soy or pea based), Other burger substitutes (e.g. mushroom, cauliflower, sweet potato/kumara, chickpeas, beetroot or quinoa-based)
Egg alternatives	Easy egg, egg replacer

Vegan cheese	Cheese not fortified with calcium (including mozzarella, tasty, cheddar, pizza blend) cheese fortified with calcium (e.g. Angel food cheddar and mozzarella), parmesan, cream cheese
Vegan yogurt	Plain and non-flavoured vegan greek yogurt, vegan flavoured yogurt
Vegan milk	Coconut milk (fortified), coconut milk (not fortified), tinned coconut milk (regular), tinned coconut milk (light), almond milk (fortified), almond milk (not fortified), almond milk (high protein), soy milk (regular), soy milk (lite), soy milk (unsweetened), oat milk, rice milk, cashew milk, seeds milk
Sweetened 'dairy' products	Plant based milk smoothies, flavoured milk, plant-based milk puddings, ice cream individual pack, ice cream for tub
Vegan cream	Soy based, cashew based, coconut based (regular), coconut based (light), condensed and evaporated milk, sour cream
Alcohol	Beer, lager, cider (all varieties), red wine, white wine, port, sherry, liquor, spirits (e.g. gin, brandy, whisky, vodka), RTD's (e.g. Canadian club, Smirnoff ice)
Sweetened drinks	Vegan hot chocolate, drinking chocolate, cocoa, milo, cordials (including syrups, powders i.e. Raro), fruit and vegetable juice all varieties, fruit or vegetable juice calcium fortified, energy drinks, soft/fizzy drinks (e.g. Sprite, Coke), sports drinks
Low or non-sweetened drinks	Coffee, tea, herbal tea, fruit tea, low calorie cordials, diet soft/fizzy drinks, water

Vegan oils/ butter substitutes	Shea-based butter (eg. Natruli vegan block), coconut-based spreads/butter (nut telex coconut, alpha one coconut, butter), olive oil or rapeseed oil-based spreads/butter (e.g. olivine, avocado, nut telex olive), other vegetable oils-based spreads/butter (nut telex reduced fat), olive oil, canola oil, rice bran oil, avocado oil, peanut oil, other vegetable oils (e.g. sunflower oil, corn oil, sesame oil), coconut oil
Sweet snacks/desserts	Cakes, slices, brownie, pastries, cheesecake, pies, puddings, cookies, plain biscuits, chocolate or cream filled biscuits, chocolate, muesli bars, coconut cocoa bar, sweets, lollies, fruit filled bars
Savoury snacks	Potato crisps, corn/tortilla chips, pretzels, popcorn
Sweet condiments	Jam, marmalade, syrups, sweet spreads or preserves, sugar
Savoury condiments	Marmite, Vegemite, vegan mayo and aioli, vegan peri-peri mayo, vegan white sauce, cheese sauce, gravies, tomato sauce, tomato paste, barbecue sauce, chili sauce, salsa, Worcestershire sauce, soy sauce, dips (all varieties), pickles, chutney, mustard,
Spices and flavourings	Spices, nutritional yeast

3.8 Data

Implausible energy intakes occur when participants over or underreport intake leading to bias in the magnitude and/ or direction of diet-health-related findings (A. N. Previdelli, 2019). Average daily energy intake was considered implausible if < 2100 kJ (500 kcal) or > 14,700 kJ (3500 kcal) for women and < 3360 kJ (800 kcal) or > 16,800 kJ (4000 kcal) for men (Willett, 1998).

3.9 Statistical analysis

A statistical analysis was carried out using IBM SPSS (version 29) and Microsoft Excel (Version 16.85). All statistical tests were two-sided, and p-values <0.05 were considered statistically significant. Participant characteristics were presented using descriptive statistics. Continuous variables were presented as the mean ± standard deviation (SD) (for parametric data) or median (25, 75 percentile) (for non-parametric data) and categorical variables were described by number or frequency (%). No data was transformed before statistical analysis; however, data screening and cleaning were conducted to remove outliers.

Dietary patterns were derived using a posteriori approach. Food and beverage items from the FFQ were combined into 34 food groups for applying principal component analysis (PCA). The Bartlett's test (chi-squared = 1657.026, p= <0.001) and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO = 0.67) confirmed the dietary data was suitable for PCA. The 34 food groups were entered in grams/day into principal component analysis using varimax rotation. Rotated components were extracted based on the following criteria: identification of a break or flattening in the scree plot, interpretability of the components and eigenvalues > 1. Factor loadings for each food group represented the correlation between the factor (dietary pattern) and the food group. Food groups were not included if they had an absolute loading ≥0.364.

Dietary pattern z-scores were calculated to quantify each participant's intake in relation to each dietary pattern, compared to other participants in the sample. Factor loadings directly affect the dietary pattern z-score. An increased intake of food groups with positive factor loadings increases the dietary pattern z-score and an increased intake of food groups with negative factor loadings decreases the dietary pattern z-score. Each dietary pattern was labelled with the most appropriate term which best described the underlying pattern, and where possible, was consistent with labelling schemes from other studies or similar (Gallagher et al., 2021, Haider et al., 2023)

3.10 Results

3.10.1 Participants

A total of 212 participants took part in this study. Twenty-seven participants were excluded from dietary analysis due to not completing a FFQ and 4 had implausible energy intakes leaving 181 participants. Table 4. displays participant characteristics, health and demographic information (n=212). Dietary data for daily energy intake (KJ) and units of alcohol unit were also reported in Table 4. (n= 181). Male and female data is compared. Participants were predominantly female (n=138, p = **<0.001**), had a mean age (SD) of 39.43 (12.41) years and were under the age of 50 (77%). The distribution of education levels between males and females was significantly different (p= **0.002**), with males more likely to have an education level "Lower than Bachelor" (46% vs 26%) or "Higher than Bachelor" (28% vs 22%), while females were more likely to have a "Bachelor" degree (52% vs 26%) Most participants were NZ European (n= 178; 85%) and had an education level of a bachelor's degree or higher (68.2%).

There was no significant difference in age, energy intake, alcohol consumption or smoking status between males and females.

Table 3.2 Participant Demographics and Health

Characteristic	Total N = 212 N (%) or Mean (SD)	Male, N = 42 N (%) or Mean (SD)	Female, N = 138 N (%) or Mean (SD)
Age			
Mean (SD)	39.43 (12.41)	40.12 (12.11)	39.18 (12.55)
Under 50	163 (77%)	43 (75%)	120 (77%)
Over 50	49 (23%)	14 (25%)	35 (23%)
Length of Time vegan			
2 to 4 years	69 (32%)	14 (33%)	55 (39%)
5 to 10 years	80 (37%)	23 (54%)	57 (41%)
More than 10 years	32 (23%)	6 (14%)	26 (18%)
BMI			

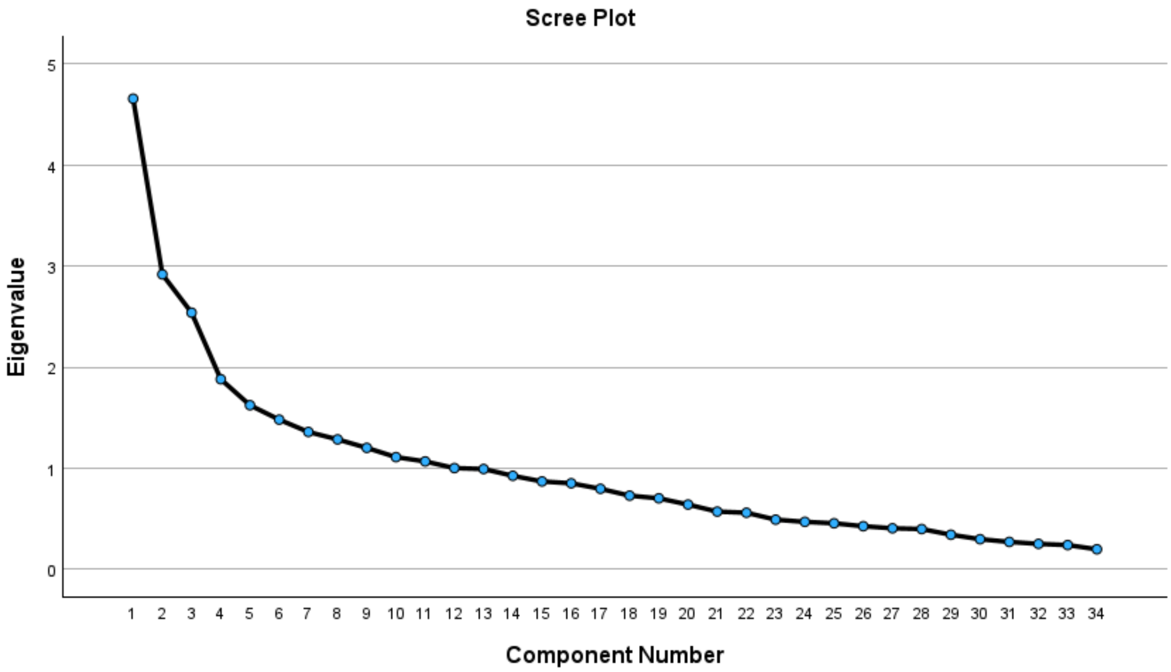
Mean (SD)	23.92 (3.11)	24.48 (2.97)	23.71 (3.15)
Body fat %			
Mean (SD)	30.46 (7.43)	22.66 (4.97)	33.33 (5.99)
Ethnicity			
European	178 (85%)	49 (88%)	129 (84%)
Māori	8 (3.8%)	0 (0%)	8 (5.2%)
Pacific Peoples	1 (0.5%)	1 (1.8%)	0 (0%)
Asian	16 (7.6%)	3 (5.4%)	13 (8.4%)
Middle Eastern/Latin American/African	7 (3.3%)	3 (5.4%)	4 (2.6%)
Missing	2	1	1
Education			
Lower than bachelor	66 (31%)	26 (46%)	40 (26%)
Bachelor's degree	96 (45%)	15 (26%)	81 (52%)
Higher than Bachelor's degree	50 (24%)	16 (28%)	34 (22%)
Employment status			
Full time	129 (61%)	41 (72%)	88 (57%)
Part time	40 (19%)	8 (14%)	32 (21%)
Volunteer	3 (1%)	0 (0%)	3 (2%)
Seeking opportunities currently	11 (5%)	4 (7%)	7 (5%)
Retired	6 (2.8%)	1 (1.8%)	5 (3%)
Student	20 (9.5%)	3 (5.3%)	17 (11%)
Other	2 (0.9%)	0 (0%)	2 (1%)
Missing	1	0	1
Marital status			
Married	149 (76%)	44 (86%)	105 (72%)
Single	47 (24%)	7 (14%)	40 (28%)
Missing	16	6	10
Smoking status	10 (5%)	3 (7%)	7 (5%)

Daily energy intake (KJ) (n=181)			
Mean (SD)	6,796.76 (2,526.54)	7,310.68 (2,696.12)	6,636.63 (2,459.62)
Alcohol units/day (n=181)			
Mean (SD)	4.01 (6.25)	3.5 (4.11)	4.15 (6.78)

3.10.2 Dietary patterns

Four dietary patterns were identified within the sample, as indicated by the scree plot (Figure 1), collectively explaining 35.28% of the variation in dietary intake. The number of components selected was based on an assessment of the scree plot, with eigenvalues >1 considered appropriate for identifying patterns that account for the largest proportion of variance. While 12 components had eigenvalues exceeding 1, the scree plot demonstrated a flattening after the fourth component, indicating a plateau in explained variance. Consequently, the first four components were retained. Table 5 provides detailed information on the factor loadings for the retained patterns, the range of dietary pattern scores, eigenvalues, and the variance explained by each dietary pattern.

Figure 3.1



The dietary pattern Health Conscious accounted for 10.96% of the variation in dietary intake. This dietary pattern was characterized by higher intakes of alliums, beans and legumes, berries, cruciferous vegetables, other fruits, other vegetables, root vegetables, spices and flavourings.

Dietary pattern two included Convenience food groups and was characterised by milk alternatives, non-sweetened cereals, protein bars and powders, soybeans, sweetened dairy products and yogurt alternatives. This dietary pattern explained 8.52% of the variance intake.

Dietary pattern three was labelled a Western dietary pattern and was characterised by higher intakes of alcohol, other meat alternatives, refined grains, savoury condiments, savoury snacks and vegan oil/butter substitutes. This dietary pattern explained 8.54% of the variance intake.

Dietary pattern four was labelled a Traditional pattern due to including included 'traditional' vegan food groups. This pattern was characterised by beans and legumes, berries, dried fruit, nuts and seeds, other fruit, and sweetened cereals. Negative loadings included refined grains. This dietary pattern explained 7.24% of the variance intake.

Table 3.3 Dietary patterns derived from principal component analysis.

Food groups	**Dietary Patterns**			
	Health Conscious	Convenience	Western	Traditional
Alcohol	0.22	-0.18	**0.41**	-0.26
Allium	**0.60**	0.05	0.20	-0.13
Bean and Legumes	**0.58**	0.20	0.02	**0.37**
Berries	**0.39**	0.20	-0.35	**0.39**
Cheese alternatives	-0.30	0.03	0.35	0.03
Citrus fruit	0.30	-0.18	-0.03	0.36
Cream alternatives	0.01	-0.06	0.16	0.24
Cruciferous	**0.77**	-0.01	-0.07	0.07
Dried fruit	0.12	-0.02	-0.14	**0.60**

Egg	0.03	-0.04	0.07	0.08
Low/non sweetened drinks	0.22	0.09	-0.01	0.19
Milk alternatives	-0.05	**0.47**	0.04	0.25
Non sweetened cereals	0.23	**0.56**	-0.06	0.14
Nuts and seeds	0.16	0.08	0.12	**0.62**
Other fruit	**0.48**	0.07	-0.23	**0.49**
Other meat alternatives	-0.08	0.01	**0.38**	-0.09
Other vegetables	**0.65**	0.17	-0.05	0.04
Processed starchy vegetables	-0.15	-0.11	0.36	0.06
Protein powders and bars	0.26	**0.68**	-0.13	-0.06
Refined grains	0.25	0.13	**0.50**	-**0.45**
Root vegetables	**0.50**	0.07	-0.05	0.25
Savoury condiments	0.10	0.08	**0.63**	-0.01
Savoury snacks	-0.10	-0.07	**0.61**	0.02
Soybeans	0.34	**0.69**	-0.13	-0.04
Spices and flavourings	**0.61**	0.01	0.02	0.02
Sweet condiments	0.03	0.30	0.35	0.06
Sweet snacks and desserts	0.11	0.06	0.52	0.03
Sweetened cereals	-0.05	0.06	0.03	**0.39**
Sweetened dairy products	-0.10	**0.71**	0.29	-0.19

Sweetened drinks	-0.30	0.17	0.34	0.28
Vegan oils/butter substitutes	-0.05	-0.03	**0.45**	0.16
Vege/legume-based meat	0.28	0.22	0.25	0.36
Wholegrains	0.33	-0.19	0.33	0.28
Yogurt alternatives	-0.09	**0.66**	-0.09	-0.03
Score range	-2.37 to 4.85	-1.39 to 9.85	-3.22 to 4.60	-2.68 to 5.24
Variance explained	10.96	8.54	8.52	7.24
Eigenvalue	4.65	2.91	2.54	1.88

Loadings ≥ 0.364 as per Stevens (2009). Positive loadings are positively associated with the dietary pattern, and negative loadings are negatively associated. A higher loading indicates a greater contribution to the dietary pattern.

3.10.3 Dietary patterns vs socio-demographic and lifestyle factors

The Health-Conscious pattern was positively associated with alcohol consumption (p= 0.005) and a higher physical activity score (p=0.0008). The Convenience pattern was associated with lower alcohol intake. The Western pattern was positively associated with being female, having a lower than bachelor's degree of education (p =0.027), being physically active (0.009) and higher consumption of alcohol (p = <0.001). The Traditional pattern was positively associated with age and lower alcohol consumption (p = <0.001).

Table 3.4

Health-Conscious pattern

Coefficient	Estimate	95% CI	Standard error	p-value
Intercept	0.146	(-0.698, 0.990)	0.428	0.733

Age	-0.008	(-0.020, 0.005)	0.006	0.224
Male	-0.139	(-0.485, 0.207)	0.175	0.429
Bachelor's degree	-0.86	(-0.189, 0.627)	0.177	0.627
Higher than bachelor's degree	0.219	(0.057, 0.183)	0.207	0.291
Grams of alcohol	0.34	(0.010, 0.057)	0.012	**0.005**
Physical activity score	0.000	(0.000, 0.000)	0.00	**0.008**

Table 3.5

Convenience pattern

Coefficient	Estimate	95% Cl	Standard error	p-value
Intercept	0.275	(-0.587, 1.138)	0.437	0.529
Age	-0.007	(-0.19, 0.006)	0.006	0.279
Male	0.117	(-0.236, 0.471)	0.179	0.514
Bachelor's degree	0.011	(-0.347, 0.368)	0.181	0.954
Higher than bachelor's degree	-0.006	(-0.424, 0.411)	0.211	0.976
Grams of alcohol	-0.030	(-0.053, -0.006)	0.012	**0.015**
Physical activity score	-9.61 2E-5	(0.00, 0.000)	0.00	0.354

Table 3.6

Western pattern

Coefficient	Estimate	95% CI	Standard error	p-value
Intercept	0.915	(0.107, 1.723)	0.409	**0.027**
Age	-0.011	(-0.023, 0.001)	0.006	0.061
Male	-0.151	(-0.482, 0.180)	0.168	0.369
Bachelor's degree	-0.332	(-0.667, 0.003)	0.170	**0.052**
Higher than bachelor's degree	-0.009	(-0.400, 0.382)	0.198	0.964
Grams of alcohol	0.051	(0.029, 0.073)	0.011	**<0.001**
Physical activity score	0.00	(0.00, 0.000)	0.00	**0.009**

Table 3.7 Traditional pattern

Coefficient	Estimate	95% CI	Standard error	p-value
Intercept	-0.278	(-1.038, 0.481)	0.385	0.471
Age	0.031	(0.020, 0.042)	0.006	**<0.001**
Male	-0.407	(-0.718, -0.096)	0.158	0.11
Bachelor's degree	0.106	(-0.209, 0.420)	0.160	0.509
Higher than bachelor's degree	-0.099	(-0.466, 0.269)	0.186	0.597
Grams of alcohol	-0.046	(-0.067, -0.025)	0.011	**<0.001**
Physical activity score	-5.769E-5	(0.00, 0.000)	0.00	0.528

3.11 Discussion

In this study of Vegans living in Auckland, New Zealand, four dietary patterns were identified: Health-Conscious, Convenience, Western and Traditional, outlined in Fig. 1 and Table 6. These four patterns were derived from principal component analysis and accounted for 35.28% of the total variance intake. The Health-Conscious pattern was the most identifiable dietary behaviour to emerge from principal component analysis with a variance intake of 10.96%. It was characterised as a Health-Conscious pattern because positive associations were found with intakes of fruit, vegetables and legumes. These associations describe a dietary approach that emphasises nutrient-dense minimally processed foods whilst avoiding those which are high in added sugars, refined carbohydrates and additives. This may indicate vegans following this pattern are conscious about the foods they consume and may follow the diet for weight-related or other health reasons.

The second component of factor analysis identified a Convenience dietary pattern, characterised by positive associations between milk alternatives, non-sweetened cereals, protein bars and powders, and soybeans. This pattern indicates a reliance on processed foods or ready-to-eat foods that require minimal preparation, reflecting a movement away from 'traditional' vegan food consumption with the increased availability of vegan convenience foods. Participants following this pattern may be mindful of their protein intake as suggested by their intake of both natural (soybeans) and ultra-processed (protein bars and powder) sources. The inclusion of protein alternatives from both sources indicates an awareness of plant proteins having reduced digestibility and bioavailability than meat (Soh et al., 2024). However, this dietary pattern lacks significant intakes of both fruit and vegetables which are important for overall health and disease prevention (Pem & Jeewon, 2015). The association between this dietary pattern and processed food consumption is noteworthy given the rapid expansion of the UPF market in recent years. The growing availability of vegan-friendly convenience foods, such as protein bars and plant-based dairy alternatives, has made it easier for individuals to follow a vegan diet without needing to prepare meals from scratch (Alcorta et al., 2021). However, these products are characteristically energy-dense, fatty, sugary or salty and generally contain many added ingredients (e.g. sugar, salt, fat, artificial colours or sweeteners and preservatives) which can undermine the health benefits traditionally associated with a plant-based diet (Alcorta et al., 2021).

The third component from factor analysis revealed a Western dietary pattern. This pattern constituted intake of alcohol, meat alternatives (such as vegan bacon), refined carbohydrates and higher levels of fats and salt. These foods had positive factor loadings in the dietary pattern analysis, indicating that individuals with higher adherence to this dietary pattern consumed these foods more frequently. This falls in line with a typical Western dietary pattern which has been characterised by high intakes of pre-packaged foods, refined grains, processed meat, fried foods, and high-fat and high-fructose products (Clemente-Suárez et al., 2023). This pattern is often linked to poor nutritional quality and a higher risk of non-communicable diseases such as obesity, cardiovascular disease and type 2 diabetes (Fedacko et al., 2022). This pattern lacks the fibre and essential nutrients provided by whole grains, fruits, vegetables and dairy alternatives. These nutrient gaps suggest that participants following this pattern may not follow this diet for health-related motivations or may have lower health literacy.

The fourth component of factor analysis identified a Traditional vegan dietary pattern accounting for 7.24% of variance intake. Despite being the most representative of an expected vegan diet this pattern had the lowest variance in comparison to the other dietary patterns. This pattern had positive associations with beans and legumes, fruit, nuts and seeds, vegetable or legume-based meat alternatives and dairy alternatives. The associations fall in line with foods that constitute a traditional vegan diet (Łuszczki et al., 2023), and highlight that traditionally vegans follow strictly whole plant-based diets, void of all animal products. Yet the small variance explained by this pattern suggests that with the growth of the UPF market, fewer vegans are following traditional vegan approaches, potentially compromising the nutritional quality of their diet (Gallagher et al., 2021).

The Health-Conscious dietary pattern is positively associated with higher alcohol consumption and greater physical activity levels, suggesting that individuals following this pattern tend to engage more in these behaviours. Although alcohol is not typically conducive to a healthy diet, other studies found that an increasing alcohol intake was associated with a decrease in carbohydrate consumption and an increase in fibre, cereal and polyunsaturated fat consumption (Ruidavets et al., 2004). All of which fall in line with the positive loadings of this pattern. Conversely, the Convenience pattern was associated with lower alcohol intake. This may indicate individuals who consume convenience foods may be less inclined to socialise with alcohol or live busy lifestyles. The Western pattern was positively associated with females, lower educational attainment, physical activity and alcohol consumption. Those who are less educated have less access to nutritional information (Azizi Fard et al., 2021), which may lead to an unhealthy eating pattern such as this one. Nutrition literacy plays an important role in an individual's food choices as low health literacy is linked to less consultation of food labels, poor food choices and inaccurate estimation of appropriate food portions (Taylor et al., 2019). Lower educational attainment is also associated with increased alcohol consumption (Ruidavets et al., 2004), (Droomers et al., 1999). Another study found that an additional 3.61 years of education reduced the risk of alcohol dependency by 50% (Rosoff et al., 2021), indicating a significant relationship between education and alcohol consumption.

The Traditional pattern was positively correlated with age and lower alcohol consumption. This suggests older adults are more inclined to adhere to traditional vegan dietary practices. This could be attributed to several factors. Older adults often have greater food autonomy and financial stability, which may enable them to prioritise traditional whole foods and cooking practices. Additionally, the emergence of vegan ultra-processed foods in recent years is more likely to influence the dietary habits of younger vegans who may have started this diet through swapping to plant-based alternatives. However long-term vegans who adopted this diet before the availability of these alternatives are less likely to incorporate them into their diets. This is consistent with these findings from previous studies that middle-aged and older adults are more inclined to follow traditional dietary patterns, whereas younger generations tend to favour Western-style diets (Bull, 1992; Inelmen et al., 2008).

There are currently no official dietary guidelines for vegans in New Zealand. The Vegan Society organization provides some guidelines for aspects of a well-balanced vegan diet.

Although a nutritional analysis was not conducted in this study, the findings from the principal component analysis suggest that most of the study participants follow somewhat of a healthy vegan diet. However, the findings also suggest that some vegan diets are poorly constructed and there may be a risk of nutritional deficiencies. No pattern featured all food groups conducive to a balanced vegan diet. The Health Conscious pattern lacked dairy alternatives and the Convenience pattern lacked fruits and vegetables. Similarly, the Western pattern lacked fruit, vegetables and dairy alternatives. The Traditional pattern lacked dairy alternatives and vegetables. Whole grains were not featured in any pattern. Adequate consumption of dairy alternatives such as fortified plant milks and yogurts can help vegans meet dietary requirements for calcium which is essential for bone health (Ramsing et al., 2023). Fruit, vegetable and whole-grain consumption provide a wide range of vitamins, minerals, antioxidants and fibre (Wang et al., 2023). All of these are associated with lower risk of NCD and healthy gut microbiota (Wang et al., 2023). The dietary patterns found in this study suggest that more vegan diets consist of convenience food items with less intake of natural vegan foods. With the increasing availability of ultra-processed vegan food in New Zealand, further exploration of vegan dietary patterns in a New Zealand representative sample that incorporates nutritional analysis should be of priority. Exploring dietary patterns in combination with nutritional analysis may help us to understand the impact vegan dietary patterns have on nutritional outcomes.

The variance explained by the four dietary patterns identified in this study (35.28%) is comparable to findings from other research on vegan populations in Table 3. For instance, (Gallagher et al., 2021) UK-based study reported four dietary patterns explained approximately 50% of the variance, while (Haider et al., 2023) German study identified two patterns accounting for 34% of the variance. The similarities in variance suggest that the dietary patterns observed in vegan populations across different regions exhibit consistency, particularly in the emergence of Health-Conscious and convenience patterns. However, the slightly lower variance explained in this study may reflect the more homogeneous socio-demographic characteristics of the sample, predominantly New Zealand Europeans, compared to the more diverse populations analysed in these international studies. This highlights the potential influence of geographical and cultural influences on dietary behaviours. Moreover, the relatively low variance explained suggests that additional patterns may exist but were not captured, emphasizing the need for further research with larger, more diverse samples to enhance the understanding of dietary patterns in vegan populations.

3. 12 Strengths and limitations

This study had several strengths. This exploration of vegan dietary patterns among vegans is the first of its kind in New Zealand. A total of 212 participants from a range of ethnicities were recruited into the Vegan Health Research Program, a population in that has not been widely studied, making this a valuable contribution to understanding the intricacies of vegan dietary practices in New Zealand. The FFQ used in this study was also validated specifically for dietary patterns (Hassall, 2023); thus, the reproducibility and relative validity of dietary patterns are strong. However, there are some limitations to consider. This sample, is predominantly European (84%), which limits the applicability of findings to other ethnic groups in New Zealand. New Zealand is made up of a diverse range of ethnicities thus a study population of predominantly Europeans is not truly representative. Participants were only eligible for the study if they lived in Auckland, New Zealand, and were able to attend an in-person visit at Massey University. This introduces demographical limitations as Auckland spreads across a large area and is split up into north, east, south and west (each area in which has different ethnic proportions). Because Massey University is situated in the north of Auckland, vegans from other areas may not have been able to commute to the north shore campus therefore we cannot be sure this study was a representative sample. This is a cross-sectional study which although good for identifying associations between variables, restricts the ability to infer causality (Agnoli et al., 2019). Dietary data was measured using a population-validated FFQ but based on self-reported data which is subject to recall bias. Furthermore, principal component analysis can oversimplify individual dietary behaviours by grouping them into broader patterns. This has the potential to obscure the finer details of individuals' diets.

Chapter 4: Conclusion and future recommendations

4.1 Achievement of research aim and objectives

This study aimed to investigate dietary patterns in a vegan population living in New Zealand. To achieve the aim, two main objectives were identified (See Chapter 1) to guide the research process. These included exploration of dietary patterns in a vegan population using principal component analysis and exploration of socio-demographic characteristics of a vegan population following different dietary patterns. This study has provided evidence that the current dietary patterns of vegans in Auckland, New Zealand can be depicted as follows: Health-Conscious, Convenience, Western and Traditional. Interestingly most participants followed the Health-Conscious pattern and the Traditional pattern the least. Positive associations were found with the following socio-demographics; Female, lower than bachelor's education, alcohol and physical activity score. Every pattern had positive associations with either alcohol or physical activity scores.

4.2 Recommendations and future directions for research

With the vegan population continuing to grow in New Zealand, Further research should be prioritized to develop greater insight into veganism. Future research should aim to include a more ethnically diverse and representative sample of vegans living in New Zealand. This would help us to better understand variations in dietary patterns across different cultural groups. Additionally, prioritization of systemic change in the implementation of national vegan dietary guidelines and market regulation for vegan products would promote healthier, more accessible vegan diets in New Zealand. These recommendations involve the examination of the following:

More research focusing on health outcomes associated with vegan diets in New Zealand, such as the impacts on NCD risk and nutritional outcomes. As per this study, participants were categorised into four main dietary patterns; Health Conscious, Convenience, Western and Traditional. Given the nutritional variation of these patterns, it would be valuable to assess whether participants were meeting their nutritional needs. Processed foods were prevalent in three out of four dietary patterns, thus an evaluation of nutrient sufficiency in this group would also provide valuable insight into the impact of processed food consumption on vegan health. A longitudinal study would be beneficial in examining the long-term impacts of vegan dietary patterns as they enable the tracking of health outcomes and dietary behaviours over time. Thus, establishing more robust-cause-and-effect relationships. This would be particularly valuable in providing information into the health implications of a vegan diet, as an observation of biomarkers like vitamin B12, iron and omega-3 would allow us to understand nutrient sufficiency across multiple time points. Over time researchers would then be able to identify trends in how processed food impacts nutrient status, which is crucial as processed vegan foods can vary significantly in nutrient quality and are becoming more prevalent in the everyday vegan diet. Additionally, this method may assess how socio-demographics such as physical activity, alcohol consumption and social influences interact with dietary intake throughout a significant period of time.

Further research using a representative sample of vegans in New Zealand. While this study provides valuable insights, the study sample was not diverse or large enough to be a true representative sample. Therefore, the results may not be generalizable to all populations, particularly those from different cultural, socioeconomic, or ethnic backgrounds. This study recruited 212 participants from mostly European backgrounds (84%) living in Auckland, New Zealand. Although New Zealand's largest city the diversity of this sample is not truly representative of New Zealand's diverse ethnicities. Therefore, a similar study should be done using a larger population. Valuable data should also be collected using a national nutrition survey, which would provide insight into the ethnic proportions and percentage of vegans living in New Zealand and their dietary habits and intake. As well as providing an opportunity to recruit vegans into the study, thus increasing the validity of findings and contributing to vegan dietary guidelines that address the needs of a New Zealand-specific population.

Systemic changes could be implemented to improve the health outcomes of vegans in New Zealand. There are currently no vegan-specific guidelines provided by the Ministry of Health. This lack of tailored guidance leaves vegan consumers without reliable information on maintaining a balanced, nutrient-sufficient diet. Due to the nature of this diet excluding nutrient-rich foods, this is something that needs to be addressed. Future research should also advocate for the development of comprehensive vegan dietary guidelines that emphasize the importance of nutrient-dense food choices. Given the expansion of the vegan food market in New Zealand, this exacerbates the need for targeted guidelines as vegans been to move away from more traditional dietary. This could be seen in this study as the Traditional had the lowest variance intake. This is likely occurring as vegan convenience foods become cheaper, more accessible and better tasting. However, these foods do not contain the same nutrient ratios as whole foods which puts a group already at risk at an even bigger risk of nutrient deficiencies. Comprehensive guidelines would not only benefit individuals but inform healthcare providers, public health initiatives and communities so that they can provide reliable advice. Simultaneously, enhancing food industry standards by encouraging manufacturers to create fortified, whole-food-based products which policymakers could support to shift away from consumption of vegan UPF items.

References

Agnoli, C., Pounis, G., & Krogh, V. (2019). Chapter 4 - Dietary Pattern Analysis. In G. Pounis (Ed.), Analysis in Nutrition Research (pp. 75-101). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-814556-2.00004-X

Alcorta, A., Porta, A., Tárrega, A., Alvarez, M. D., & Vaquero, M. P. (2021). Foods for Plant-Based Diets: Challenges and Innovations. *Foods*, *10*(2). https://doi.org/10.3390/foods10020293

Ankeny, R. A. (2012). 461 Food and Ethical Consumption. In J. M. Pilcher (Ed.), *The Oxford Handbook of Food History* (pp. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199729937.013.0026

Alessandrini, R., Brown, M. K., Pombo-Rodrigues, S., Bhageerutty, S., He, F. J., & MacGregor, G. A. (2021). Nutritional Quality of Plant-Based Meat Products Available in the UK: A Cross-Sectional Survey. Nutrients, 13(12), 4225. https://www.mdpi.com/2072-6643/13/12/4225

Ankar, A., & Kumar, A. (2024). Vitamin B12 Deficiency. In StatPearls. StatPearls Publishing

Azizi Fard, N., De Francisci Morales, G., Mejova, Y., & Schifanella, R. (2021). On the interplay between educational attainment and nutrition: a spatially-aware perspective. EPJ Data Science, 10(1), 18. https://doi.org/10.1140/epjds/s13688-021-00273-y

Bailey, R. L. (2021). Overview of dietary assessment methods for measuring intakes of foods, beverages, and dietary supplements in research studies. Curr Opin Biotechnol, 70, 91-96. https://doi.org/10.1016/j.copbio.2021.02.007

Bakaloudi, D. R., Halloran, A., Rippin, H. L., Oikonomidou, A. C., Dardavesis, T. I., Williams, J., Wickramasinghe, K., Breda, J., & Chourdakis, M. (2021). Intake and adequacy of the vegan diet. A systematic review of the evidence. Clinical Nutrition, 40(5), 3503-3521. https://doi.org/https://doi.org/10.1016/j.clnu.2020.11.035

Bazzano, L. A., Serdula, M. K., & Liu, S. (2003). Dietary intake of fruits and vegetables and risk of cardiovascular disease. Current Atherosclerosis Reports, 5(6), 492-499. https://doi.org/10.1007/s11883-003-0040-z

Benedik, E. (2022). Sources of vitamin D for humans (Vol. 92). Hogrefe AG. https://doi.org/10.1024/0300-9831/a000733

Bez, N. S., Haddad, J., Tedde, G. S., Rose, K., Ivanov, A. V., Milazzo, M., Wickart, J., Casale, G., D'Ascanio, M., Van der Horst, K., Herter-Aeberli, I., & Bogl, L. H. (2024). Development of a diet quality score and adherence to the Swiss dietary recommendations for vegans. Journal of Health, Population and Nutrition, 43(1), 17. https://doi.org/10.1186/s41043-024-00498-3

Biró, G., Hulshof, K., Ovesen, L., Amorim Cruz, J. A., & for the, E. G. (2002). Selection of methodology to assess food intake. European Journal of Clinical Nutrition, 56(2), S25-S32. https://doi.org/10.1038/sj.ejcn.1601426

Boukid, F. (2021). Plant-based meat analogues: from niche to mainstream. *European Food Research and Technology*, *247*(2), 297-308. https://doi.org/10.1007/s00217-020-03630-9

Britainthinks. (2019). Generation Z: Exploring the food attitudes and behaviours of 16-25 year olds. F. S. Agency.

https://www.food.gov.uk/sites/default/files/media/document/fsa191102bt-gen-z_rea_full-report_081019-final.pdf
Bull, N. L. (1992). Dietary habits, food consumption, and nutrient intake during adolescence. Journal of Adolescent Health, 13(5), 384-388. https://doi.org/https://doi.org/10.1016/1054-139X(92)90034-9
Burggraf, C., Teuber, R., Brosig, S., & Meier, T. (2018). Review of a priori dietary quality indices in relation to their construction criteria. Nutr Rev, 76(10), 747-764. https://doi.org/10.1093/nutrit/nuy027
Burns-Whitmore, B., Froyen, E., Heskey, C., Parker, T., & San Pablo, G. (2019). Alpha-Linolenic and Linoleic Fatty Acids in the Vegan Diet: Do They Require Dietary Reference Intake/Adequate Intake Special Consideration? Nutrients, 11(10). https://doi.org/10.3390/nu11102365
Hassall, C. (2023). *Determining the relative validity of a Food Frequency Questionnaire (FFQ) for assessing nutrient intakes against Four-Day Food Diaries (4DFDs) of New Zealand adults following a vegan diet* Massey University]. https://mro.massey.ac.nz/handle/10179/69457
Chaudhary, P., Janmeda, P., Docea, A. O., Yeskaliyeva, B., Abdull Razis, A. F., Modu, B., Calina, D., & Sharifi-Rad, J. (2023). Oxidative stress, free radicals and antioxidants: potential crosstalk in the pathophysiology of human diseases. Front Chem, 11, 1158198. https://doi.org/10.3389/fchem.2023.1158198
Clemente-Suárez, V. J., Beltrán-Velasco, A. I., Redondo-Flórez, L., Martín-Rodríguez, A., & Tornero-Aguilera, J. F. (2023). Global Impacts of Western Diet and Its Effects on Metabolism and Health: A Narrative Review. Nutrients, 15(12). https://doi.org/10.3390/nu15122749
Cole, E., Goeler-Slough, N., Cox, A., & Nolden, A. (2022). Examination of the nutritional composition of alternative beef burgers available in the United States. International Journal of Food Sciences and Nutrition, 73(4), 425-432. https://doi.org/10.1080/09637486.2021.2010035
Craig, W. J. (2009). Health effects of vegan diets2. The American Journal of Clinical Nutrition, 89(5), 1627S-1633S. https://doi.org/https://doi.org/10.3945/ajcn.2009.26736N
Curtain, F., & Grafenauer, S. (2019). Plant-Based Meat Substitutes in the Flexitarian Age: An Audit of Products on Supermarket Shelves. Nutrients, 11(11). https://doi.org/10.3390/nu11112603
da Costa, G. G., da Conceição Nepomuceno, G., da Silva Pereira, A., & Simões, B. F. T. (2022). Worldwide dietary patterns and their association with socioeconomic data: an ecological exploratory study. Globalization and Health, 18(1), 31. https://doi.org/10.1186/s12992-022-00820-w
Donaldson, M. S. (2004). Nutrition and cancer: a review of the evidence for an anti-cancer diet. Nutr J, 3, 19. https://doi.org/10.1186/1475-2891-3-19
Droomers, M., Schrijvers, C. T. M., Stronks, K., van de Mheen, D., & Mackenbach, J. P. (1999). Educational Differences in Excessive Alcohol Consumption: The Role of Psychosocial and Material Stressors. Preventive Medicine, 29(1), 1-10. https://doi.org/https://doi.org/10.1006/pmed.1999.0496
Espinosa-Marrón, A., Adams, K., Sinno, L., Cantu-Aldana, A., Tamez, M., Marrero, A., Bhupathiraju, S. N., & Mattei, J. (2022). Environmental Impact of Animal-Based Food Production and the Feasibility of a Shift Toward Sustainable Plant-Based

Diets in the United States [Mini Review]. Frontiers in Sustainability, 3. https://doi.org/10.3389/frsus.2022.841106

Fardet, A., & Rock, E. (2015). From a Reductionist to a Holistic Approach in Preventive Nutrition to Define New and More Ethical Paradigms. Healthcare, 3(4), 1054-1063. https://www.mdpi.com/2227-9032/3/4/1054

Fedacko, J., Takahashi, T., Singh, R. B., Pella, D., Chibisov, S., Hristova, K., Pella, D., Elkilany, G. N., Juneja, L. R., Behl, S., Singh, J., & Smail, M. M. A. (2022). Chapter 1 - Western diets and risk of non-communicable diseases. In R. B. Singh, S. Watanabe, & A. A. Isaza (Eds.), Functional Foods and Nutraceuticals in Metabolic and Non-Communicable Diseases (pp. 3-21). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-819815-5.00042-2

Fenner, A. (2015). Development and validation of the New Zealand Women's Healthy Diet Index [Thesis http://hdl.handle.net/10179/7875

Foods, F. F. L. H. (2019). *Hungry for Plant Based: New Zealand Consumer Insights*. F. F. L. H. Foods. https://www.foodfrontier.org/wp-content/uploads/dlm_uploads/2022/10/Food-Frontier-Hungry-For-Plant-Based-New-Zealand-Consumer-Insights.pdf

Fox, N., & Ward, K. (2008). Health, ethics and environment: A qualitative study of vegetarian motivations. Appetite, 50(2), 422-429. https://doi.org/https://doi.org/10.1016/j.appet.2007.09.007

Francis, T., & Hoefel, F. (2018.). True Gen: Generation Z and its implications for companies. McKinsey & Company. Retrieved July 25, 2024. from https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/true-gen-generation-z-and-its-implications-for-companies

Fresán, U., Errendal, S., & Craig, W. J. (2020). Influence of the Socio-Cultural Environment and External Factors in Following Plant-Based Diets. Sustainability, 12(21), 9093. https://www.mdpi.com/2071-1050/12/21/9093

Gallagher, C. T., Hanley, P., & Lane, K. E. (2022). Pattern analysis of vegan eating reveals healthy and unhealthy patterns within the vegan diet. Public Health Nutrition, 25(5), 1310-1320. https://doi.org/10.1017/S136898002100197X

Gastaldello, A., Giampieri, F., De Giuseppe, R., Grosso, G., Baroni, L., & Battino, M. (2022). The rise of processed meat alternatives: A narrative review of the manufacturing, composition, nutritional profile and health effects of newer sources of protein, and their place in healthier diets. Trends in Food Science & Technology, 127, 263-271. https://doi.org/https://doi.org/10.1016/j.tifs.2022.07.005

Gehring, J., Touvier, M., Baudry, J., Julia, C., Buscail, C., Srour, B., Hercberg, S., Péneau, S., Kesse-Guyot, E., & Allès, B. (2021). Consumption of Ultra-Processed Foods by Pesco-Vegetarians, Vegetarians, and Vegans: Associations with Duration and Age at Diet Initiation. The Journal of Nutrition, 151(1), 120-131. https://doi.org/https://doi.org/10.1093/jn/nxaa196

Gherasim, A., Arhire, L. I., Niță, O., Popa, A. D., Graur, M., & Mihalache, L. (2020). The relationship between lifestyle components and dietary patterns. Proc Nutr Soc, 79(3), 311-323. https://doi.org/10.1017/s0029665120006898

Greenwell, J., Grant, M., Young, L., Mackay, S., & Bradbury, K. E. (2023). The prevalence of vegetarians, vegans and other dietary patterns that exclude some animal-source foods in a representative sample of New Zealand adults. Public Health Nutr, 27(1), e5. https://doi.org/10.1017/s1368980023002677

Gurinović, M., Zeković, M., Milešević, J., Nikolić, M., & Glibetić, M. (2017). Nutritional Assessment. In Reference Module in Food Science. Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-08-100596-5.21180-3

Haider, S., Sima, A., Kühn, T., & Wakolbinger, M. (2023). The Association between Vegan Dietary Patterns and Physical Activity-A Cross-Sectional Online Survey. *Nutrients*, *15*(8). https://doi.org/10.3390/nu15081847

Haneberg, J., Molin, M., Gjeitung Byfuglien, M., & Garnweidner-Holme, L. (2024). Vegetarians' and vegans' experiences with and attitudes towards ultra-processed foods (UPF): a qualitative study. BMC Nutrition, 10(1), 121. https://doi.org/10.1186/s40795-024-00925-y

Henchion, M., Moloney, A. P., Hyland, J., Zimmermann, J., & McCarthy, S. (2021). Review: Trends for meat, milk and egg consumption for the next decades and the role played by livestock systems in the global production of proteins. *Animal*, *15 Suppl 1*, 100287. https://doi.org/10.1016/j.animal.2021.100287

Hoffmann, I. (2003). Transcending reductionism in nutrition research23. The American Journal of Clinical Nutrition, 78(3), 514S-516S. https://doi.org/https://doi.org/10.1093/ajcn/78.3.514S

Hopwood, C. J., Bleidorn, W., Schwaba, T., & Chen, S. (2020). Health, environmental, and animal rights motives for vegetarian eating. *PLoS One*, *15*(4), e0230609. https://doi.org/10.1371/journal.pone.0230609

Hu, F. B. (2002). Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol, 13(1), 3-9. https://doi.org/10.1097/00041433-200202000-00002

Hunt, J. R. (2003). Bioavailability of iron, zinc, and other trace minerals from vegetarian diets23. The American Journal of Clinical Nutrition, 78(3), 633S-639S. https://doi.org/https://doi.org/10.1093/ajcn/78.3.633S

Inelmen, E. M., Toffanello, E. D., Enzi, G., Sergi, G., Coin, A., Busetto, L., & Manzato, E. (2008). Differences in dietary patterns between older and younger obese and overweight outpatients. The Journal of nutrition, health and aging, 12(1), 3-8. https://doi.org/https://doi.org/10.1007/BF02982157

Janssen, M., Busch, C., Rödiger, M., & Hamm, U. (2016). Motives of consumers following a vegan diet and their attitudes towards animal agriculture. Appetite, 105, 643-651. https://doi.org/https://doi.org/10.1016/j.appet.2016.06.039

Kamiński, M., Skonieczna-Żydecka, K., Nowak, J. K., & Stachowska, E. (2020). Global and local diet popularity rankings, their secular trends, and seasonal variation in Google Trends data. *Nutrition*, *79-80*, 110759. https://doi.org/https://doi.org/10.1016/j.nut.2020.110759

Key, T. J., Papier, K., & Tong, T. Y. N. (2022). Plant-based diets and long-term health: findings from the EPIC-Oxford study. Proc Nutr Soc, 81(2), 190-198. https://doi.org/10.1017/s0029665121003748

Kotzmann, J. (2023). Sentience and Intrinsic Worth as a Pluralist Foundation for Fundamental Animal Rights. Oxf J Leg Stud, 43(2), 405-428. https://doi.org/10.1093/ojls/gqad003

Koutentakis, M., Surma, S., Rogula, S., Filipiak, K. J., & Gąsecka, A. (2023). The Effect of a Vegan Diet on the Cardiovascular System. Journal of Cardiovascular

Development and Disease, 10(3), 94. https://www.mdpi.com/2308-3425/10/3/94
Lane, K., Derbyshire, E., Li, W., & Brennan, C. (2014). Bioavailability and potential uses of vegetarian sources of omega-3 fatty acids: a review of the literature. Crit Rev Food Sci Nutr, 54(5), 572-579. https://doi.org/10.1080/10408398.2011.596292
Łuszczki, E., Boakye, F., Zielińska, M., Dereń, K., Bartosiewicz, A., Oleksy, Ł., & Stolarczyk, A. (2023). Vegan diet: nutritional components, implementation, and effects on adults' health. *Front Nutr*, *10*, 1294497. https://doi.org/10.3389/fnut.2023.1294497
Mahapatra, G. P., Bhullar, N., & Gupta, P. (2022). Gen Z: An Emerging Phenomenon. NHRD Network Journal, 15(2), 246-256. https://doi.org/10.1177/26314541221077137
Mariotti, F., & Gardner, C. D. (2019). Dietary Protein and Amino Acids in Vegetarian Diets—A Review. Nutrients, 11(11), 2661. https://www.mdpi.com/2072-6643/11/11/2661
McNaughton, S. A. (2020). Chapter 13 - Dietary patterns. In B. P. Marriott, D. F. Birt, V. A. Stallings, & A. A. Yates (Eds.), Present Knowledge in Nutrition (Eleventh Edition) (pp. 235-248). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-818460-8.00013-7
Menzel, J., Abraham, K., Stangl, G. I., Ueland, P. M., Obeid, R., Schulze, M. B., Herter-Aeberli, I., Schwerdtle, T., & Weikert, C. (2021). Vegan Diet and Bone Health-Results from the Cross-Sectional RBVD Study. Nutrients, 13(2). https://doi.org/10.3390/nu13020685
Milfont, T. L., Satherley, N., Osborne, D., Wilson, M. S., & Sibley, C. G. (2021). To meat, or not to meat: A longitudinal investigation of transitioning to and from plant-based diets. Appetite, 166, 105584. https://doi.org/https://doi.org/10.1016/j.appet.2021.105584
Modlinska, K., Adamczyk, D., Maison, D., & Pisula, W. (2020). Gender Differences in Attitudes to Vegans/Vegetarians and Their Food Preferences, and Their Implications for Promoting Sustainable Dietary Patterns–A Systematic Review. Sustainability, 12(16), 6292. https://www.mdpi.com/2071-1050/12/16/6292
Mohan, A., Kumar, R., Kumar, V., & Yadav, M. (2023). Homocysteine, Vitamin B12 and Folate Level: Possible Risk Factors in the Progression of Chronic Heart and Kidney Disorders. Curr Cardiol Rev, 19(4), e090223213539. https://doi.org/10.2174/1573403x19666230209111854
Monteiro, C. A., Cannon, G., Levy, R. B., Moubarac, J. C., Louzada, M. L., Rauber, F., Khandpur, N., Cediel, G., Neri, D., Martinez-Steele, E., Baraldi, L. G., & Jaime, P. C. (2019). Ultra-processed foods: what they are and how to identify them. Public Health Nutr, 22(5), 936-941. https://doi.org/10.1017/s1368980018003762
Moubarac, J. C., Parra, D. C., Cannon, G., & Monteiro, C. A. (2014). Food Classification Systems Based on Food Processing: Significance and Implications for Policies and Actions: A Systematic Literature Review and Assessment. Curr Obes Rep, 3(2), 256-272. https://doi.org/10.1007/s13679-014-0092-0
Naska, A., Lagiou, A., & Lagiou, P. (2017). Dietary assessment methods in epidemiological research: current state of the art and future prospects. F1000Res, 6, 926. https://doi.org/10.12688/f1000research.10703.1

North, M., Kothe, E., Klas, A., & Ling, M. (2021). How to define “Vegan”: An exploratory study of definition preferences among omnivores, vegetarians, and vegans. Food Quality and Preference, 93, 104246. https://doi.org/https://doi.org/10.1016/j.foodqual.2021.104246
Ohlau, M., Spiller, A., & Risius, A. (2022). Plant-Based Diets Are Not Enough? Understanding the Consumption of Plant-Based Meat Alternatives Along Ultra-processed Foods in Different Dietary Patterns in Germany [Original Research]. Frontiers in Nutrition, 9. https://doi.org/10.3389/fnut.2022.852936
Organization, W. H. (2015). Cancer: Carcinogenicity of the consumption of red meat and processed meat. World Health Organization. Retrieved July 25, 2024 from https://www.who.int/news-room/questions-and-answers/item/cancer-carcinogenicity-of-the-consumption-of-red-meat-and-processed-meat
Orlich, M. J., Jaceldo-Siegl, K., Sabaté, J., Fan, J., Singh, P. N., & Fraser, G. E. (2014). Patterns of food consumption among vegetarians and non-vegetarians. Br J Nutr, 112(10), 1644-1653. https://doi.org/10.1017/s000711451400261x
Oude Griep, L. M., Wang, H., & Chan, Q. (2013). Empirically-derived dietary patterns, diet quality scores, and markers of inflammation and endothelial dysfunction. Curr Nutr Rep, 2(2), 97-104. https://doi.org/10.1007/s13668-013-0045-3
The Oxford Handbook of Food History. (2012). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199729937.001.0001
Paslakis, G., Richardson, C., Nöhre, M., Brähler, E., Holzapfel, C., Hilbert, A., & de Zwaan, M. (2020). Prevalence and psychopathology of vegetarians and vegans - Results from a representative survey in Germany. Sci Rep, 10(1), 6840. https://doi.org/10.1038/s41598-020-63910-y
Pem, D., & Jeewon, R. (2015). Fruit and Vegetable Intake: Benefits and Progress of Nutrition Education Interventions- Narrative Review Article. Iran J Public Health, 44(10), 1309-1321.
Ramsing, R., Santo, R., Kim, B. F., Altema-Johnson, D., Wooden, A., Chang, K. B., Semba, R. D., & Love, D. C. (2023). Dairy and Plant-Based Milks: Implications for Nutrition and Planetary Health. Curr Environ Health Rep, 10(3), 291-302. https://doi.org/10.1007/s40572-023-00400-z
Raptou, E., Tsiami, A., Negro, G., Ghuriani, V., Baweja, P., Smaoui, S., & Varzakas, T. (2024). Gen Z's Willingness to Adopt Plant-Based Diets: Empirical Evidence from Greece, India, and the UK. *Foods*, *13*(13). https://doi.org/10.3390/foods13132076
Reinhart, R. (2018). *Snapshot: Few Americans Vegetarian or Vegan*. Gallup. Retrieved 11 March 2025 from https://news.gallup.com/poll/238328/snapshot-few-americans-vegetarian-vegan.aspx?g_source=link_NEWSV9%26g_medium=NEWSFEED%26g_campaign=item_%26g_content=Snapshot%253a%252520Few%252520Americans%252520Vegetarian%252520or%252520Vegan
Riffenburgh, R. H., & Gillen, D. L. (2020). 28 - Methods you might meet, but not every day. In R. H. Riffenburgh & D. L. Gillen (Eds.), Statistics in Medicine (Fourth Edition) (pp. 651-667). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-815328-4.00028-0
Rolands, M. R., Hackl, L. S., Bochud, M., & Lê, K. A. (2024). Protein Adequacy, Plant Protein Proportion, and Main Plant Protein Sources Consumed Across Vegan,

Vegetarian, Pescovegetarian, and Semivegetarian Diets: A Systematic Review. The Journal of Nutrition. https://doi.org/https://doi.org/10.1016/j.tjnut.2024.07.033
Rosell, M. S., Lloyd-Wright, Z., Appleby, P. N., Sanders, T. A., Allen, N. E., & Key, T. J. (2005). Long-chain n-3 polyunsaturated fatty acids in plasma in British meat-eating, vegetarian, and vegan men. Am J Clin Nutr, 82(2), 327-334. https://doi.org/10.1093/ajcn.82.2.327
Rosoff, D. B., Clarke, T. K., Adams, M. J., McIntosh, A. M., Davey Smith, G., Jung, J., & Lohoff, F. W. (2021). Educational attainment impacts drinking behaviors and risk for alcohol dependence: results from a two-sample Mendelian randomization study with ~780,000 participants. Mol Psychiatry, 26(4), 1119-1132. https://doi.org/10.1038/s41380-019-0535-9
Ruidavets, J.-B., Bataille, V., Dallongeville, J., Simon, C., Bingham, A., Amouyel, P., Arveiler, D., Ducimetière, P., & Ferrières, J. (2004). Alcohol intake and diet in France, the prominent role of lifestyle. European Heart Journal, 25(13), 1153-1162. https://doi.org/10.1016/j.ehj.2003.12.022
Saari, U. A., Herstatt, C., Tiwari, R., Dedehayir, O., & Mäkinen, S. J. (2021). The vegan trend and the microfoundations of institutional change: A commentary on food producers' sustainable innovation journeys in Europe. Trends in Food Science & Technology, 107, 161-167. https://doi.org/https://doi.org/10.1016/j.tifs.2020.10.003
Samtiya, M., Aluko, R. E., & Dhewa, T. (2020). Plant food anti-nutritional factors and their reduction strategies: an overview. Food Production, Processing and Nutrition, 2(1), 6. https://doi.org/10.1186/s43014-020-0020-5
Schulze, M. B., Martínez-González, M. A., Fung, T. T., Lichtenstein, A. H., & Forouhi, N. G. (2018). Food based dietary patterns and chronic disease prevention. Bmj, 361, k2396. https://doi.org/10.1136/bmj.k2396
Sexton, A. E., Garnett, T., & Lorimer, J. (2022). Vegan food geographies and the rise of Big Veganism. Progress in Human Geography, 46(2), 605-628. https://doi.org/10.1177/03091325211051021
Sharma, N. K., Bhattarai, M., Baral, K., Poudel, S., Hassan, N. F., Dhakal, T. R., & Baral, R. (2023). Vitamin B12 deficiency in an infant with neurological and hematological findings: A case report. Clin Case Rep, 11(8), e7770. https://doi.org/10.1002/ccr3.7770
Shim, J. S., Oh, K., & Kim, H. C. (2014). Dietary assessment methods in epidemiologic studies. Epidemiol Health, 36, e2014009. https://doi.org/10.4178/epih/e2014009
Skinner, R. (2021). The agribusiness food and fibre sector report. P. N. Zealand. https://www.pwc.co.nz/industry-expertise/food-production/afc-report-202109.pdf
Soh, B. X. P., Smith, N. W., R. von Hurst, P., & McNabb, W. C. (2024). Evaluation of Protein Adequacy From Plant-Based Dietary Scenarios in Simulation Studies: A Narrative Review. The Journal of Nutrition, 154(2), 300-313. https://doi.org/https://doi.org/10.1016/j.tjnut.2023.11.018
Stelmach-Mardas, M., Rodacki, T., Dobrowolska-Iwanek, J., Brzozowska, A., Walkowiak, J., Wojtanowska-Krosniak, A., Zagrodzki, P., Bechthold, A., Mardas, M., & Boeing, H. (2016). Link between Food Energy Density and Body Weight

Changes in Obese Adults. Nutrients, 8(4), 229. https://doi.org/10.3390/nu8040229

Swanson, D., Block, R., & Mousa, S. A. (2012). Omega-3 fatty acids EPA and DHA: health benefits throughout life. Adv Nutr, 3(1), 1-7. https://doi.org/10.3945/an.111.000893

Szenderák, J., Fróna, D., & Rákos, M. (2022). Consumer Acceptance of Plant-Based Meat Substitutes: A Narrative Review. Foods, 11(9). https://doi.org/10.3390/foods11091274

Tapsell, L. C., Neale, E. P., Satija, A., & Hu, F. B. (2016). Foods, Nutrients, and Dietary Patterns: Interconnections and Implications for Dietary Guidelines. Adv Nutr, 7(3), 445-454. https://doi.org/10.3945/an.115.011718

Taylor, M. K., Sullivan, D. K., Ellerbeck, E. F., Gajewski, B. J., & Gibbs, H. D. (2019). Nutrition literacy predicts adherence to healthy/unhealthy diet patterns in adults with a nutrition-related chronic condition. Public Health Nutr, 22(12), 2157-2169. https://doi.org/10.1017/s1368980019001289

team, E. (2023). *International Youth Day: Youth Emerge As Champions Of Vegan Way Of Life*. Healthsite. Retrieved 11 March 2025 from https://www.thehealthsite.com/fitness/diet/international-youth-day-youth-emerge-as-champions-of-vegan-way-of-life-1000261/

Thompson, F. E., & Subar, A. F. (2017). Chapter 1 - Dietary Assessment Methodology. In A. M. Coulston, C. J. Boushey, M. G. Ferruzzi, & L. M. Delahanty (Eds.), Nutrition in the Prevention and Treatment of Disease (Fourth Edition) (pp. 5-48). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-802928-2.00001-1

Trauth, E. (2020). Manly' Plates: Generation Z and the Rhetoric of Vegan Men. T. D. Repository. https://arrow.tudublin.ie/cgi/viewcontent.cgi?article=1218&context=dgs

Tso, R., & Forde, C. G. (2021). Unintended Consequences: Nutritional Impact and Potential Pitfalls of Switching from Animal- to Plant-Based Foods. Nutrients, 13(8), 2527. https://www.mdpi.com/2072-6643/13/8/2527

Vestergren, S., & Uysal, M. S. (2022). Beyond the Choice of What You Put in Your Mouth: A Systematic Mapping Review of Veganism and Vegan Identity. Front Psychol, 13, 848434. https://doi.org/10.3389/fpsyg.2022.848434

Waijers, P. M., Feskens, E. J., & Ocké, M. C. (2007). A critical review of predefined diet quality scores. Br J Nutr, 97(2), 219-231. https://doi.org/10.1017/s0007114507250421

Wang, T., Masedunskas, A., Willett, W. C., & Fontana, L. (2023). Vegetarian and vegan diets: benefits and drawbacks. Eur Heart J, 44(36), 3423-3439. https://doi.org/10.1093/eurheartj/ehad436

WHO. (2010). *A healthy lifestyle - WHO recommendations*. World Health Organization https://www.who.int/europe/news-room/fact-sheets/item/a-healthy-lifestyle---who-recommendations

Willett, W. C. (1998). Nutritional Epidemiology. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195122978.001.0001

Wunsch, N.-G. (2024). *Veganism and vegetarianism in the United Kingdom - statistics & facts*. Statista. https://www.statista.com/topics/7297/veganism-in-the-united-kingdom/#editorsPicks

Zeuschner, C. L., Hokin, B. D., Marsh, K. A., Saunders, A. V., Reid, M. A., & Ramsay, M. R. (2013). Vitamin B_{12} and vegetarian diets. Med J Aust, 199(S4), S27-32. https://doi.org/10.5694/mja11.11509

Zhu, B., Sun, Y., Qi, L., Zhong, R., & Miao, X. (2015). Dietary legume consumption reduces risk of colorectal cancer: evidence from a meta-analysis of cohort studies. Sci Rep, 5, 8797. https://doi.org/10.1038/srep08797