An audit of ultra-processed vegan food in the major supermarkets of 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, Albany,

New Zealand

Aimee Czifra

2023

Abstract

Background

The rising rates of veganism have led to an increased demand for plant-based meat and dairy analogues (PBMAs and PBDAs). These analogues fall into the category of ultra-processed foods (UPFs). There is an urgent need to obtain an understanding of vegan UPFs available to New Zealand consumers.

Aim

To audit ultra-processed vegan-labelled, PBMAs and PBDAs available in New Zealand supermarkets, including comparing their nutrient composition (energy, protein, saturated fat, carbohydrate, fibre, sodium, calcium, iron, zinc and B12) against the products of animal origin that these foods emulate.

Methods

The audit was completed during March – June 2022 using a combination of data collected online and directly from supermarkets. . Products were chosen that directly emulated foods of animal origin, naturally vegan foods such as Tofu and legumes were excluded. Data were collected from New Zealand's five major supermarkets, Countdown, Fresh Choice, New World, Pak 'n Save and Four Square. The data collected included the nutrient information listed on product labels, this information was available on some online shopping sites or taken directly from product labels by visiting the various supermarket stores. The nutrient information of the meat sources was taken from an average derived from no less than eight samples, calculated by the Food Standards Australia and New Zealand (FSANZ) and

FoodWorks. The nutrient information for meat burgers was collected from product labels available online or instore.

Results

The PBMAs generally had higher energy and lower protein than their meat counterparts., for the vegan burger had a mean of 15.2mg/100g compared to the meat burgers at 18.5mg/100g, the mince showed similar comparisons. The veggie burger had considerably lower protein with a mean of 6.6mg/100g. The vegan chicken breast had higher mean protein (27mg/100g) compared to the meat chicken breast (21.35mg/100g). The PBDA was generally lower in protein. Soy milk was the only plant milk with a similar protein to cow's milk, plant yoghurt had a range of 1.4 – 2mg/100g compared to dairy yoghurt (5.0-7.92mg/100g). Only one of the plant cheeses had a protein content above 1mg/100g (Vegan Parmesan 17.7mg/100g) when compared to dairy cheese (8.5-35.1 mg/100g). The PBMAs were high in sodium, with a mean across the various products of 351mg/100g to 693 mg/100g, compared to meat which had a mean of 47mg/100g to 796.7mg/100g (excluding bacon). The PBDAs showed a similar trend with sodium across the various analogues with a mean of 22.75mg/100mL to 68mg/100mL. The sodium across the various plant-based cheese analogues (PBCAs) had a mean of 603mg/100g to 4970mg/100g. The calcium of PBDA milk was separated into fortified and unfortified. Fortified PBDAs had a mean of 100.5mg/100mL to 147mL/100mL, 29.4% had no calcium fortification. Of the PBDAs soy milk had the closest protein quality to dairy milk, though the levels of protein were varied. Fortification of calcium was mostly

absent from both plant-based cheese and yoghurt analogues (PBYAs). Vitamin B12 had a mean of 0mcg/100g to 0.6mcg/100g across all the PBMAs.

Conclusion

The plant-based analogues offered a range of ultra-processed foods, very few of which could be considered in a healthy range of nutrients. The levels of sodium were high across the range of PBMA and PBDAs. The levels of fortification would need to be standardised to offer a product of similar nutritional value to animal-based foods.

Acknowledgements

I would like to thank everyone for their continued support through family crises, and natural disasters and for keeping me motivated to complete tasks during this journey to complete my thesis for my Master of Science in Nutrition and Dietetics, it's been a ride!

A special thanks to my thesis supervisor's; Professor Pamela von Hurst for her insight and amazing ability to condense text and encouragement to help me to strive for more, pushing me to achieve work to a high standard. Associate Professor Kathryn Beck for her knowledge of how to present data, and Dr Rachel Batty for her insight into New Zealand's manufacturers.

I would like to thank the staff at Massey University Library for their patience and help with referencing when I thought I had lost it all.

Lastly, I would like to thank my family, for not letting me give up, and my children for putting up with the constant distractions study brings.

Table of Contents

List of Tables

Chapter 1.

Chapter 2

Chapter 3.

Abbreviations

ANZFSC	Australia and New Zealand food standards code
ATP	Adenosine triphosphate
BMI	Body mass index
BP	Blood Pressure
CHO	Carbohydrate
CYS	Cysteine
DHA	Docosahexaenoic acid
DIAAS	Digestible indispensable amino acid score
EPA	Eicosapentaenoic acid
EPNZ	Emerging Proteins New Zealand
IAAS	Indispensable Amino Acid
IBD	Irritable bowel disease
LDL	Low-density lipoproteins
LYS	Lysine
MET	Methionine
MOH	Ministry of Health
MPI	Ministry of Primary Industries
MUFA	Monounsaturated fatty acids
NCD	Noncommunicable disease
PBCAs	Plant-based cheese analogues
PBDAs	Plant-based dairy analogues
PBMAs	Plant-based meat analogues
PBNMS	Plant-based meat substitutes
PBYAs	Plant-based yoghurt analogues
PDCAAS	Protein digestibility-corrected amino acid score
PUFA	Polyunsaturated fatty acids
SFA	Saturated fatty acids
SSB	Sugar-sweetened beverage
TC	Total cholesterol

TRP	Tryptophan
TVP	Textured vegetable protein
UPFs	Ultra-processed foods
WHO	World health organisation

Chapter 1

Introduction

Plant-based eating has seen rapid growth in recent years, with vegans estimated to make up between one and 10% of the population in Western countries (Gehring et al., 2021). The term plant-based is often used to describe a vegan foods, however, the plant-based diet refers to a diet that limits or excludes food of animal origin (Kent, Kehoe, Flynn, & Walton, 2022).The vegan diet excludes all foods of animal, fish and insect origin (Henderson, 2022). The global market for vegan foods increased by 105% between 2015- 2019 (Nunes., 2020). New Zealand ranks within the top five counties for veganism in the world (Herald., 2020), and the New Zealand vegan society currently lists over 70 manufacturers supplying vegan products to New Zealand supermarkets (The Vegan Society., 2022).

Meat alternatives and plant proteins have seen an expeditious expansion within the food industry, with big brands such as Burger King offering seven plant-based options (Burgerking, 2021a). Kentucky Fried Chicken (KFC) also has a range of vegan options, and McDonald's launched the McPlant burger in 2021 though neither are currently available in New Zealand.

The growth of plant-based convenience foods has made transitioning to a vegan plant-based diet easier. . Many vegan foods such as plant-based meat analogues (PBMAs) (mince, chicken, burgers, or sausage) look like familiar animal-based products, often used to replace foods that were traditionally made with meat (Tso & Forde, 2021). These plant-based options are convenient, but are heavily processed foods (Gallagher, Hanley, & Lane, 2021).

Evidence has previously supported a vegan whole-food diet as one to improve health and longevity (Dyett, Sabate, Haddad, Rajaram, & Shavlik, 2013). However, little is known about the health impact of a diet high in vegan ultra-processed foods (UPFs), and if they can offer

the same health benefits previously associated with the vegan diet (Alae-Carew et al., 2021; Gehring et al., 2021; van Vliet, Kronberg, & Provenza, 2020). The contribution of excess salt, sugar and saturated fat these UPFs contain may lead to health concerns (R. Mangels, 2022).

The nutritional profile considers both the macro and micronutrient of foods. Macronutrients are the protein, carbohydrate, and fats. The micro-nutrients are the vitamins and minerals. A vegan diet rich in ultra-processed convenience foods may be a deficient in certain nutrients such as protein, calcium, vitamin B12, D, and iron (Tso & Forde, 2021; Weikert et al., 2020) The traditional vegan diet has been associated with wholegrains, pulses and fruits and vegetables and their positive health benefits (Gallagher et al., 2021).

Novel foods require regulation by the food standards Australia and New Zealand to determine food safety, though this does not consider their nutritional adequacy. Neither does it regulate if a product can be considered a healthy food (Flint, Bowles, Lynn, & Paxman, 2023).

The term ‘plant-based’ and vegan are often used interchangeably and have been described by the New Zealand Nutrition Foundation, as inconsistent leading to confusion to the consumer (Shalee, 2021). A full definition of terms is given in chapter 2.

The primary aim of this research was to audit vegan/plant-based-labelled UPFs in New Zealand, to highlight any areas of nutritional inadequacy. It is well known that diets high in saturated fat, sodium and sugar increase the risk of developing non-communicable chronic diseases.

Aims and Objectives

Aim

To conduct an audit of processed and ultra-processed, vegan-labelled foods available in New Zealand's major supermarkets.

Objectives

1. To describe the nutritional value of vegan meat and dairy analogues in New Zealand's major supermarket chains- Woolworths (Countdown and Fresh choice), and Foodstuffs (New World, Pak 'n Save and Four Square).
2. To compare the nutrient composition (energy, protein, saturated fat, MUFA, PUFA, carbohydrate, fibre, cholesterol, sodium, calcium, iron, zinc and Vitamin B12), against their animal-based counterparts.

*N.B.*Products include but not limited to red meat, chicken (mince, sausage, burgers, nuggets), eggs and dairy (milk, cheese, yoghurt).*

Structure of Thesis

In this thesis there are four chapters. The first chapter, is a brief introduction describing the current trends in veganism and the reasons why this research is necessary. Chapter one also provides the aims and objectives, structure of the thesis and the researchers contributions. The second chapter is the literature review. This provides an in-depth review of current trends, key nutrients of concern and an overview of existing data of vegan processed foods. The third chapter is the primary research chapter, describing the methods, analysis, and findings of the research. This includes how the data was recorded, the results and conclusion. Chapter 4 provides a summary of the research, the strengths and limitations and recommendations for further research.

Table 1. Researcher's contributions

Aimee Czifra	Master's Student - Literature review - Lead researcher - Data collection and analysis - Presentation of findings - Manuscript - Conclusions
Professor Pamela R von Hurst	Main Supervisor - Thesis guidance and assistance - Research manuscript guidance and assistance - Finalising chapter and overview
Associate Professor Kathryn Beck	Co-Supervisor - Thesis guidance and assistance - Research manuscript guidance and assistance
Dr Rachel Batty	Co-Supervisor - Thesis guidance and assistance - Research manuscript guidance and assistance

Chapter 2

Literature Review

Introduction

Veganism or vegan is a term used for diets eliminating meat, poultry, fish, seafood, dairy, eggs, and excluding all foods of animal origin, such as honey. Vegetarianism is an umbrella term which encompasses a range of eating styles including veganism, vegetarian, pescatarian, ovo-vegetarian and lactovegetarian(Dagnelie & Mariotti, 2017).

. Another word often seen is, 'Flexitarian', which is a fusion of the words 'vegetarian' and 'flexible', used to describe a diet that is largely vegetarian but occasionally includes meat or fish (Flexitarianisim, 2007, 2013). A brief definition of terms can be found in table 1.

Veganism is the philosophy of living without the exploitation of animals by abstaining from the use and consumption of animal products (The Vegan Society, 1944-2021b). People may choose a vegan diet for a variety of reasons, although it is often associated with health or the environment. Global concerns about sustainability have led many to adopt a vegan diet, reducing the environmental burden associated with meat consumption (U. A. Saari, Herstatt, Tiwari, Dedehayir, & Mäkinen, 2021). The vegan foods industry has also seen a rapid growth in popularity leading to the development of processed vegan foods. These innovative foods are often heavily processed foods contending the positive health effects previously associated with veganism; posing the question: *Are vegan diets healthy?*

Veganism has seen a rapid increase in popularity in recent years, with 1- 10% of western populations (United Kingdom, America, and Europe) adopting some form of vegetarian diet (Gehring et al., 2021). The New Zealand Herald reported a 15% rise of veganism in New Zealanders in 2019 (New Zealand Herald, 2020). Independent 'think tank', data also records that one in three New Zealanders (NZ) limit their meat intake, with millennials making up

41% of vegans and 42% of vegetarians in NZ in 2019 (Food Frontier, 2019). According to Statista, Australia and New Zealand ranked 2nd and 5th (retrospectively) in veganism popularity in 2020 (Statista, 2020). However, a precise number is difficult to judge as other surveys show different figures. In 2019 the 'Vegetarian resource group' conducted an online poll, and recorded that 2% of Americans were vegan (Schiavone, Pelullo, & Attena, 2019). A survey at 'National talks', by ABC Australia recorded that just 1% of the nation identified as vegan (Sutton, 2019). This perceived increase has led food companies to adapt to the changing market.

The Vegan Society (UK) currently lists over 18,000 food and drink products from multiple companies (The Vegan Society, 2021). An Australian study in Sydney supermarkets reported an increase in plant-based foods from 26 to 137 products from 2015 - 2019 (F. Curtain & S. Grafenauer, 2019).The vegan food market has seen a global increase in recent years, with year-on-year increased consumption of plant-based foods. Figures from a United Kingdom (UK) study of consumption trends of plant-based foods, show an increase from 6.7% in 2008 to 13.1% by 2017-2019. Females (10.7%) aged to 24-39 were most likely to adopt a a plant-based diet than males (10.7%) (Alae-Carew et al., 2021).

The global market value of plant-based dairy alternatives alone was estimated at $22.6 billion (USD), with a projected worth of $40.6 billion by 2026 (Boukid, Lamri, Dar, Garron, & Castellari, 2021). The growth of plant-based convenience foods has made adopting a vegan diet an easier transition. Many vegan foods such as plant-based meat analogues (PBMAs) (mince, chicken, burgers, or sausage) are aimed to directly replace meat, similarly plant-based dairy analogues(PBDAs) (milk, yoghurt and cheese), are not whole foods, often unsuitable to be used in a like for like manner to dairy products (Clegg, Tarrado Ribes, Reynolds, Kliem, & Stergiadis, 2021). These plant-based options are convenient but are often heavily processed foods. Eating these foods to replace meat may not offer the same

health benefits previously associated with the vegan diet (Alae-Carew et al., 2021; Gehring et al., 2021), such as the reduction of non-communicable disease (cardiovascular disease, obesity and type-2-diabetes) and may even lead to nutrient deficiencies (van Vliet et al., 2020). Evidence has previously supported a vegan whole food diet rich in legumes, grains, fruits and vegetables as one to improve health and longevity, reducing the risk of non-communicable diseases such as type-2-diabetes, cardiovascular disease, obesity and colon cancer (Radnitz, Beezhold, & DiMatteo, 2015). However, the recent explosion of processed vegan foods available on the market may alter this belief.

Government Investment

In 2019 the Ministry of Primary Industries (MPI) in New Zealand invested $147,000 into a 2-year project to develop plant-based meat alternative foods (MPI, 2021). In November 2020 the MPI invested a further $8M in a five-year trial called the 'Leaf protein research and development programme', aiming to extract plant proteins from leafy crops for use in plant-based foods (MPI, 2022b).

Emerging proteins New Zealand (EPNZ) reported that the New Zealand government is yet to publish any 'specific strategy', in the development of plant proteins across three sectors (Ministry of Primary Industries, the Ministry of Business Innovation and Employment, and the Tertiary Education Commission). Based on the existing level of investment, development, and manufacture so far, New Zealand has a one-star rating, out of five. Additional funding had been pledged since the report was issued in July 2022, though this did not alter the star rating (Thompson, 2022). Australia achieved a four star rating based on the level of funds invested and their implementation so far (Thompson, 2022).

This review aims to collate existing data and research, on what we know about the nutritional value of PBMA and plant-based dairy analogues (PBDAs). This review will also explore how food trends for processed vegan foods are affected by the growing market. But most importantly to highlight the areas of nutrient deficits in vegan processed foods, any need for fortification and identify weakness in existing research.

History and Background

The term vegan was first coined by Donald Watson and a group of five other non-dairy vegetarians, forming the UK's 'The Vegan Society' in 1944, by using the first three and last two letters of the word 'vegetarian'. It was not until 1988 that the definition was finalised by the Vegan Society. However, as of 2011 there is still no legally binding definition of veganism in the European Union (EU) or at a member state level (European Vegetarian Union, 2011). North et al (2021), identified the lack of definition among vegans or veganism as significantly impacting its validity, and highlighted that any research undertaken should assume a singular definition (P. Jallinoja, M. V. Vinnari, & M. Niva, 2020; North, Kothe, Klas, & Ling, 2021). The Vegan Society in the UK describes more of a philosophy of veganism than a definition, seeking to exclude all exploitation of animals (The Vegan Society, 1944-2021a), while Vegan Australia is described as more of a social justice movement (Vegan Australia, 2021). Other societies such as The Vegan Society NZ are more descriptive, stating a vegan is a person who chooses not to consume, use or wear any animal products (Vegan society NZ, 2022). The American Vegan Society breaks this down further to explain what vegans do and don't do (American vegan society, 1960-2021).

There is no singular definition of veganism leading to inconsistencies, though the principle remains the same. Consequently, there is no acknowledgement of the spectrum of veganism

interpretation. Some vegan's exclude all animal products, others may follow a more extreme form of veganism, boycotting companies producing non-vegan goods (Lockwood, 2021).

Plant-based eating or plant-based are terms used to describe eating more plant foods as opposed to meat or dairy, and often seen on processed packaged food items. A study by Van Loo et al (2017), defines a plant-based diet as 'A diet eating meals made up of two-thirds (or more) plant-based foods and one-third (or less) animal-based foods" (Van Loo, Hoefkens, & Verbeke, 2017). The Heart Foundation of NZ defines a plant-based diet in more general terms, focussing on 'filling up your plate with plant foods' to establish a more balanced diet and reduce the consumption of meat, fish, and dairy (Henderson, 2022). If a food item is advertised as plant-based, it does not automatically mean it is vegan. The term plant-based may also be used to describe a product that is vegan or merely that is contains a high percentage of plant foods. For example, a vegan burger may be referred to as plant-based, if items such as cheese or aioli were added. Plant- based may also be used to describe a food that is vegan but cooked where meat is prepared or cooked such as a burger restaurant (Burgerking, 2021b).

Table 1. Definition of terms

Term	Definition
Vegan	Excludes meat, poultry, fish, seafood, dairy, eggs and any food of animal/insect origin
Vegetarian	Excludes meat, poultry and fish
Ovolactovegetarians	Excludes meat, poultry, fish and seafood
Lactovegetarian	Excludes meat,poultry, fish, seafood and eggs
Ovovegetarian	Excludes meat, poultry, fish, seafood and dairy
Pescatarian	Excludes meat and poultry
Flexitarian	Reduced meat diet

.

Why choose veganism?

The reasons people choose a vegan diet or lifestyle may vary or have multiple driving factors including religious, cultural, environmental, and ethical reasons. Some may choose veganism for its related health benefits.

Religion

Different religions have different requirements. For example, religion may prohibit some animal or animal-derived foods at certain times such as Lent or Ramadan. Hindu, beliefs are that all of God's creatures deserve 'respect and compassion, leading to the majority of Hindus following a vegetarian or Lacto-vegetarian diet excluding meat, fish, and eggs (Stuckrath, 2018). In Hinduism meat such as beef is never eaten as the cow is seen as sacred, pork is prohibited, though dairy products are allowed (European Vegetarian Union, 2011). Muslims only eat herbivore animals and require those animals to be slaughtered in a particular way, known as halal meat. Muslims are prohibited from consuming blood or pork (Ghandi, 2018) . Jainism is the most strict regarding diet, and the only religion to follow a strictly vegan diet, (protecting all life) (Stuckrath, 2018). The Seventh Day Adventists (SDA) are not vegan, but do promote a healthy vegetarian/plant-based diet, rich in whole grains, fruits, vegetables, and legumes. Meats are described as either clean or unclean, in much the same way as kosher meats, pork and shellfish are forbidden (Seventh-Day Adventist Diet, 2021).

Culture

Food from animal or fish sources are consumed as part of everyday life. With fast food outlets and restaurants becoming part of our culture. Restaurants such as McDonalds, Burger King and KFC are household names, recognised globally, each claiming to have outlets in up

to 100 or more countries, (BK, 2021; KFC, 2022; McDonalds, 2017-2019). These companies traditionally included animal products in all their meals but are adapting to include several vegan or plant-based options on their menus.

Many cultures consume meat as part of celebratory events, religious or not. In countries such as the United States of America (USA), the United Kingdom and New Zealand, Christmas celebrations, are often centred around meat, cooked ham, or turkey. Other countries include vegan or plant-based meals as part of their culture, such as Israel where 5.2% of the population identify as vegan and where falafel is the most popular fast food option (Greenpeace, 2020).

In the Southern hemisphere, Australian rates of vegetarianism are reported as up to 11.2% (Sakkas et al., 2020). New Zealand was listed in the top 5 countries for Veganism (in 2020) with the highest relative search volume (RSV) through Google search (Kaminski, Skonieczna-Zydecka, Nowak, & Stachowska, 2020). Dunn (2019) describes how being '*a Māori vegan'* has in the past been seen as a cultural failure, associated with 'middle-class privilege', in opposition to cultural practices (Dunn, 2019). Dunn (2019) refers to the Whakapapa, relating to the world around us, both the animate and inanimate, bringing together the core values and principles of Māori customary practices. She identifies how *karohuarehe* (veganism), though culturally different, are not incompatible, drawing on the need to preserve Māori culture by protecting the resources in a sustainable way as 'sacred guardians of the earth' (Dunn, 2019). Dunn also discusses incorporating the traditional aspects of Māori culture to encourage a more health-conscious way of living, and eating (Dunn, 2019). Veganism is now becoming part of the Westernised culture, increasing acceptability through popular documentaries such as 'Forks Over Knives' and 'Cowspiracy', the vegan culture has become a 'cool' trend (Axworthy. N, 2018). Twine (2017), argues that these along with changes in taste and food creativity are what has led to the recent increase in

veganism (Twine, 2017). Other reasons can be attributed to the increased media coverage and activism by vegan groups, and publicity by pro-vegan celebrities helping to mobilise the vegan movement (P. Jallinoja, M. Vinnari, & M. Niva, 2020).

Environmental

The rapid increase in veganism may partly be driven by climate change (Alae-Carew et al., 2021) and concerns of greenhouse gas emissions and sustainability (environmental vegan), this includes reducing meat consumption due to the environmental impact and implications of farming animals on an industrial scale (e. a. Saari, 2021; Sintia Molina, 2022). Food is described as the 'single strongest lever' to improve both health and food sustainability, leading to the report by the 'EAT-Lancet Commission' in 2020 to develop scientific targets for healthy eating and sustainable food systems (Keerthana Priya, Rawson, Vidhyalakshmi, & Jagan Mohan, 2022). The report discusses the environmental impact of the entire food chain, focussing on a diet rich in plant-based foods, doubling intake of vegetables, fruits, nuts, and legumes, and reducing animal proteins such as red meat and sugar by 50%. The target is to achieve these substantial dietary changes by 2050 with increased consumption of whole grains, plant protein and modest amounts of animal sourced protein and dairy (Keerthana Priya et al., 2022). However, concerns were raised regarding the nutritional adequacy of the dietary suggestions made in the original EAT-Lancet planetary health diet report. In March 2023 'The Lancet', made suggestions to address micronutrient short falls, which affect certain population groups, (such as the increased iron requirement for women of reproductive age), and the adequate intake of micronutrients vitamin $B_{12,}$ calcium, zinc and iron (Beal, Ortenzi, & Fanzo, 2023). The new suggestions included the increased consumption of animal

sourced foods, and limiting intake of foods rich in phytate such as wholegrains, nuts and legumes (Beal et al., 2023).

Health

Veganism or diets that exclude meat have been described as a healthier choice (Malek & Umberger, 2021), promoting good nutrition (Estell, Hughes, & Grafenauer, 2021), often associated with improved health, increased life expectancy (Dyett et al., 2013), and weight loss (Tuso, Ismail, Ha, & Bartolotto, 2013). When compared to an omnivorous diet, the gut microbiota of those following a vegan diet is significantly higher and has more diverse levels of Bacteroidetes (Tomova et al., 2019), this refers primarily to the ratio of phyla Bacteroides to Firmicutes (Fabien Magne, 2020). The microbiome is heavily affected by the diet, it is the delicate balance of this ecosystem that can become the preventative or causative measure of conditions such as peptic ulcers, inflammatory bowel disease, obesity or type-2-diabetes (Tomova et al., 2019). Some studies have reported lower body mass index (BMI) in vegans when compared to omnivores or vegetarians (Brytek-Matera, 2020). This is partly attributed to the decreased intake of saturated fatty acid (SFA) (Mariseva & Beitane, 2020), associated with a whole plant-based diet (Fresan & Rippin, 2021). Omega 3 (*n*-3) and omega 6 (*n*-6) are essential fatty acids, *n*-3 is the most beneficial containing both eicosapentaenoic acid (20:5*n*-3 (EPA)) and docosahexaenoic acid (22:6*n*-3 (DHA)) found abundantly in fish (Lane, Wilson, Hellon, & Davies, 2022). Most vegan diets have a higher ratio of *n*-6 to *n*-3 reducing the rate of metabolic conversion (Lane et al., 2022). Vegan diets whilst generally lower in fat than the omnivore diet, contain more mono and polyunsaturated fats. These fats positively affect the microbiota and Bacteroidetes to Firmicutes ratio and their anti-inflammatory effects (Tomova et al., 2019). This positive effect on health has led many to reduce their meat and dairy

consumption in favour of a flexitarian diet (Tso & Forde, 2021). Legumes are often consumed as a protein source in the vegan diet. Legumes may have cardioprotective properties and reduce total cholesterol, and the occurrence of some gastrointestinal cancers (Sakkas et al., 2020).

Large scale Adventist studies ($n = 22{,}000-96{,}000$) have shown plant-based diets may reduce the mortality rate of cardiovascular disease, hypertension, type-2-diabetes, obesity (Le & Sabate, 2014; Orlich et al., 2013), and some cancers (Mariseva & Beitane, 2020). The diet is rich in antioxidants, vitamins C, B_1, B_6, E, fibre, and omega 6 fatty acids, though contain low levels of key nutrients such as calcium, iron, B_{12}, vitamin A, D, K_2, and zinc (Mariseva & Beitane, 2020; van Vliet et al., 2020). These nutrients must be added to the vegan diet either through careful dietary planning, fortification, or supplements to ensure adequate intake. Supplements, do not offer the same protective health effects as whole foods (van Vliet et al., 2020)

However, a cross-sectional study revealed evidence to the contrary. The online study involved 503 participants, (41.7% vegan), argued those following a vegetarian/vegan diet had a higher weight, through the consumption of ultra-processed foods (UPF) and sugar-sweetened beverages (SSB) (Silveira, Meneses, Quintana, & Santos, 2017). A separate study involving 75 subjects (34 female and 41 male) with a mean age of 27 looked at the effects of short-term vegan diet (over seven weeks) had on health. Biomarkers (blood pressure (BP), Total Cholesterol (TC), and low-density lipoprotein (LDL)) were taken before, during, and after the Ethiopian Orthodox Christian Lenten. Results reported a lower BP, TC, and LDL cholesterol, though any loss was regained within 7-weeks after returning to an omnivore diet (Sisay, Tolessa, & Mekonen, 2020). The results of these studies indicate it may not be the abstinence from animal foods that relate to the positive health implications of a vegan diet, but the quality of the alternative foods consumed. Many of the vegan foods available at

supermarkets are highly processed, convenience foods replicating those of animal origin in appearance and taste. These foods tend to be consumed in higher quantities by new, younger generation vegans (aged 24-39 years), and several studies mention that with increased age and knowledge, a healthier eating pattern is observed (Gehring et al., 2021; Twine, 2017).

Regardless of this, the protective health effects of a vegan or plant-based diet may be compromised or void if they contain large amounts of ultra-processed foods (Alae-Carew et al., 2021; Gehring et al., 2021), leaving vegans at the same risk of developing the noncommunicable diseases (NCDs) such as heart disease, T2D and obesity often associated with the general omnivorous population (Gehring et al., 2021). In addition, the vegan diet may cause adverse health conditions if macro and micronutrients requirements aren't met (Bali & Naik, 2023)

Rates of Veganism

The Vegan Society has seen a 49% increase in members across the world from 2018 to 2019 (The Vegan Society, 1944-2021a). In 2012 about one million people (0.05%) in the USA followed a vegan diet, although it was recognised that veganism was becoming part of the culture (Greenebaum, 2015), by 2017, 6% of Americans were claiming to be vegan (Report Buyer, 2017). Though 2023 data puts the figures nearer 4% (Statista, 2023a). A 2021 consumer advocacy group 'Choice' reported 2% of Australians identified as vegan, a 2023 study included data collected between 2018/19 - 2019/20 puts the percentage of New Zealand vegans at approximately 1% (Greenwell, Grant, Young, Mackay, & Bradbury, 2023). The UK reports veganism quadrupled between 2014 and 2019, leading to an increase in the manufacture of vegan processed foods (Gallagher et al., 2021). However, most Western Countries have an estimated vegan population of between 1% and 10% (Gehring et al.,

2021). Despite this growth a recent American review of plant-based meats reported, there are five times more former vegans/vegetarians than there are current (van Vliet et al., 2020). This appears to have had little effect on the growing market for plant-based foods. New Zealand's Ministry for Primary Industries supported the research of PBMA, to improve its stance on sustainable food and join the growing market of plant-based foods (MPI, 2021). The Vegan Society NZ currently lists over 70 companies producing vegan foods available in New Zealand (The Vegan Society., 2022), but many companies producing PBDAs available in New Zealand super markets did not appear on the list.

Market Availability

Vegan PBDAs, (milk, yoghurt, and cheese analogues) are expected to double with an estimated value of 40.4billion USD by 2026, the EU market estimated a similar growth from 28 million in 2018 to 60 million by 2020 (Boukid et al., 2021). The Covid 19 pandemic was reported to have accelerated the growth of PBDA products due to increased consumer concerns regarding health, this may also be attributed to non-vegan lactose intolerant consumer purchases (Boukid et al., 2021).

Ultra-processed Vegan foods

In 2014 Brazil produced a set of dietary guidelines based on the extent of food processing, known as the Nova classification scale (Fardet & Rock, 2019), distinguishing minimally processed foods from UPFs (Fardet & Rock, 2019). Many of the novel vegan foods available at supermarkets are convenience foods such as plant-based sausage, burgers, and plant-based milk, most of which are UPFs (Gehring et al., 2021). UPFs have been associated with increased rates of obesity and type 2 diabetes, though some criticisms regarding the evidence

of the Nova classification remain within the scientific community (Fardet & Rock, 2019). For clarification the Nova scale has four classifications. Nova1 contains mainly unprocessed or minimally processed foods such as chilled fruit, vegetables and meat, Nova2 contains refined foods such as oils and fats, Nova3 contains processed goods such as canned foods, and Nova4 is for ultra-processed foods (UPF) (Monteiro, Levy, Claro, Castro, & Cannon, 2010). Despite this, some UPFs still identify as healthy foods, with an ingredient list ranging from 5 to 33 (Derbyshire, 2019). A recent study by Gehring et al. (2021) describes vegetarians and vegans as consuming a higher proportion of UPFs in the diet compared to meat-eaters (Gehring et al., 2021).

Mareseva and Beitane (2020) describe vegan meat alternatives as a transition product (Mariseva & Beitane, 2020), for those new to the vegan diet. This is supported by Ale-Carew, et al (2021) who hypothesise that plant-based foods are highest among those with lower meat consumption in UK diets (Alae-Carew et al., 2021). However, research about the implications of diets high in plant-based meat alternatives are scarce (Alae-Carew et al., 2021). Longitudinal studies are needed to monitor and evaluate the long-term health effects of a plant-based diet high in UPFs (Gehring et al., 2021). Even the World Health Organisation (WHO) has called for more research due to the rapid increase in processed plant-based foods (Fresan & Rippin, 2021).

PBMA and PBDA foods have been described as high in energy, salt, and saturated fat, low sources of protein and fibre, and are not considered healthy food choices (Fresan & Rippin, 2021), despite being marketed as ‘sustainable and good for health’ (Tso & Forde, 2021). If plant-based alternatives are nutrient poor, they may lead to unintentional nutritional deficiencies (Tso & Forde, 2021). The market for PBMA foods is growing not only for vegans but also for those wanting to reduce their meat consumption and enjoy the health and environmental benefits associated with a plant-based diet, (Tso & Forde, 2021). However,

any health benefits that may be attributed to a diet high in PBMAs are not evidenced based, due to the lack of longitudinal and randomised controlled trials (Tso & Forde, 2021).

The growth of PBDA consumption Australia was matched by the same volume of decline in dairy products (Lawrence, Huang, Johnson, & Wycherley, 2023). Indicating a like for like swap.

Nutrient composition and nutrients of concern

Nutrients such as calcium, vitamin D, polyunsaturated fatty acids, zinc, iron, vitamin A, B12 and long chain fatty acids EPA, DHA and omega 6 (Burns-Whitmore, Froyen, Heskey, Parker, & San Pablo, 2019; Mariseva & Beitane, 2020), are limited or absent in many vegan alternatives. Vegan processed foods may be fortified to increase their nutrient content, though are unlikely to meet the nutritional complexity of animal derived whole foods which aid the absorption of nutrients (zinc and iron) (van Vliet et al., 2020). The vegan diet may also require increased intake of key nutrients such as vitamins A, B3, B6, iron, zinc, selenium and choline, due to their reduced bioavailability in plant foods, genetic variability also plays a role in absorption rates and may explain why some people thrive on the vegan diet while others develop nutrient deficiencies (van Vliet et al., 2020). Many of the processed vegan foods are poor in these nutrients, increasing the potential for nutritional deficiencies in vulnerable populations such as the elderly, children, and nursing mothers.

Sodium has been highlighted as a nutrient of concern, due to overconsumption. Many articles mention the increased levels of sodium in processed foods and the consequential harm to health (Dodd et al., 2020; Fresan & Rippin, 2021). Phosphorus is a mineral involved with the production of cellular energy adenosine triphosphate (ATP), and influences the metabolism of calcium (Peacock, 2021). Phosphorous is added to many UPFs, and improves the stability

of nutrients in PBMAs (Kołodziejczak, Onopiuk, Szpicer, & Poltorak, 2022) . High Phosphorus intake has also been linked with increased secretion of calcium in the urine (Sakr, 2022). A review by Bakaloudi, et.al (2021), showed that in three out of five studies, vegans had a higher intake of phosphorus than non-vegans (Bakaloudi et al., 2021). The traditional high fibre vegan diet may also interfere with fat absorption leading to increased requirements of essential fatty acids for vegans (Burns-Whitmore et al., 2019).

The following are all potential nutrients of concern if following a PBMA and PBDA vegan diet, particularly when moving away from the traditional vegan diet associated with legumes, pulses and vegetables (Tso & Forde, 2021).

Protein

Protein, is a complex macro-nutrient needed for growth and development (Nutrition Foundation NZ, 2022). Proteins are made up of essential and non-essential amino acids (AA), essential AAs can only be obtained from the food we eat. The non-essential AAs can be created by the body. Animal sourced protein is considered a high source of essential AA compared to plant proteins (van Vliet et al., 2020) due to their increased digestibility and availability of complete proteins (Górska-Warsewicz et al., 2018). The type of protein is significant when talking plant-proteins. A complete protein contains all nine essential AA (Histidine, isoleucine, leucine, lysine, methionine, phenylalanine, tryptophan, valine and threonine). Plant proteins often have an unbalanced AA profile or are lacking in one or more of these amino acids (Qin et al., 2022). However, this can be improved to some degree by eating complementary plant proteins such as wheat, rice and soy to obtain a full AA profile (van Vliet et al., 2020). The two main sources of protein for PBMAs come from Pea

(legumes) and Soy (Sha & Xiong, 2020) though sources also come from wheat, oats, seeds etc (Kyriakopoulou, Dekkers, & van der Goot, 2019).

Protein quality is most commonly measured using either or both the protein digestibility-corrected amino acid score (PDCAAS) or the digestible indispensable amino acid score (DIAAS), these standards are used to determine the quality of both animal and plant proteins (van Vliet et al., 2020). The score is calculated from the most limiting indispensable amino acid (IAA), divided by the estimated average requirement (EAR) (Wolfe, Rutherfurd, Kim, & Moughan, 2016). Scores may be calculated for adults or children, based on the recommended daily intake (RDI) and activity levels (Wolfe et al., 2016). The scores listed in the table below were from adult ranges.

Table 2. Digestible indispensable amino acid scores

Food	DIAAS	PDCAAS
Almonds	0.40	0.39
Chickpeas	0.83	0.74
Tofu	0.52	0.56
Rice (cooked)	0.54	0.61
Whole milk	1.14	1.00
Egg (hard boiled)	1.13	1.00
Chicken breast	1.08	1.00
Beef burger	1.19	**
Beyond burger	0.83	**

Plant protein scores referenced from (Marinangeli & House, 2017), animal protein scores referenced from (Phillips, 2017), and burger scores were referenced from (Fanelli et al., 2022). the PDCAAS scores were unavailable.*

The measures show that plant proteins scored between 0.4 and 0.9, and meat proteins were higher in the range of 0.9 or above, (van Vliet et al., 2020). The lower scores for plant proteins are partly related to how they are digested, plant proteins also have inhibitors which reduce their digestibility (van Vliet et al., 2020). A 2019 study showed that plant protein had 30-40% less amino acid circulation in the blood after a four-hour period, when compared to meat (Brennan et al., 2019). Despite this, the level of absorption of plant proteins was shown to be a good alternative to animal protein (Brennan et al., 2019). Some food processing heat

techniques may increase the nutritional value of some plant proteins due to the structural modification that occurs, such as enzymatic hydrolysis, which reportedly increase the solubility of proteins (Akharume, Aluko, & Adedeji, 2021; Sá, Moreno, & Carciofi, 2020).

Calcium

The most abundant mineral in the body is calcium (Sakr, 2022), involved in the regulation of blood pressure, hypertension, cholesterol and bone health (Sakr, 2022; Sisay et al., 2020). Calcium also plays a major role in muscle contraction and as a cofactor for multiple enzymes (Sakr, 2022). Rich sources of calcium include dairy products, milk, yoghurt, and hard cheese, which provide up to 1g calcium/100g of product. Plant sources such as almonds, sesame and chia can provide between 250-600mg/100g (Cormick & Belizán, 2019) . Cow's milk is considered a complete food rich in calcium,protein and vitamin D and B12 (Collard & McCormick, 2021). New Zealand has one of the highest milk consumption rates per capita (103.31 kg/per person in 2021) in the world, though milk consumption has seen a slow decline since 2018 (Statista, 2023b). However, dairy is a highly allergenic food, with up to 3.5% of infants intolerant, these figures are even higher in the United Kingdom (5%), and Finland (17%) (Clegg et al., 2021). Plant milk has a similar appearance and taste to cow's milk offering an easy alternative for those with allergy, or dietary preferences (Haas, Schnepps, Pichler, & Meixner, 2019). Plant-based milks are not naturally rich in calcium and may lead to nutrient deficiencies if unfortified plant milks are used in a like for like manner to dairy milk (Clegg et al., 2021).

Calcium intake from animal or plant sources is often related to the food consumption patterns of the population, up to 14% of daily energy requirements are from dairy, providing up to 58% of the calcium requirements in western/developed countries (Cormick & Belizán, 2019).

Chronic deficiency during early life and adolescence may inhibit peak bone mass potential leading to early development of osteoporosis in later life, deficiency may also cause disruption in cardiac muscle (Sakr, 2022). Calcium supplementation has in some cases led to hypercalcemia, causing abdominal cramps, fatigue, nausea, vomiting and hypertension (Sakr, 2022).

Zinc

Zinc is an abundant essential trace mineral, and catalyst for over 2000 enzymes (Read, Obeid, Ahlenstiel, & Ahlenstiel, 2019), and is required for protein and deoxyribonucleic acid (DNA) synthesis, immune function, cellular metabolism, growth and wound healing (National Institute for health, 2021). There is a high prevalence of deficiency worldwide, ranging between 10% and 20%, causes can be linked to age, the vegan/vegetarian diet, and inflammatory diseases such as IBD (Read et al., 2019; Sakkas et al., 2020). Some populations may be at an increased risk of deficiency (Gibson, Bailey, Parnell, Wilson, & Ferguson, 2011). In New Zealand certain ethnic groups such as Pacifica and Māori were at increased risk of deficiency during adolescence, when compared to their European counterparts, this may partly be attributed to increased stature and lean body mass (Gibson et al., 2011).

The RDI of zinc is higher for males, and increases during puberty from 6-13mg/day. For females, requirements increase only marginally from 6-7mg/day (Nutrient Reference Values for Australia and New Zealand). Zinc can be found in a wide variety of foods such as meat, wholegrains, seeds, dairy and seafood (NZ Nutrition Foundation, 2009-2018). The vegan diet is often rich in phytate containing legumes and whole grains which can reduce the body's ability to absorb zinc (NZ Nutrition Foundation, 2009-2018). However, dietary zinc

requirements can be met when following a vegan diet if a varied diet, rich in nuts, seeds and legumes is consumed regularly (van Vliet et al., 2020).

Iron

Iron is an essential mineral for the transport of oxygen, DNA synthesis, cellular metabolism, and the immune system (Ito, Kurokawa, & Matsui, 2021; Lal, 2020). There are two forms of iron, haem and non-haem. Haem iron, found in animal muscle, is a ferrous iron and is the most easily absorbed (13-35%). Non-haem iron is made up of ferric and some ferrous iron (Milman, 2020), and found in both plant and animal foods, but, is less well absorbed (2-20%) by the body (Ems, St Lucia, & Huecker, 2022; Henjum, Groufh-Jacobsen, Stea, Tonheim, & Almendingen, 2021). Iron deficiency anaemia is the most common deficiency worldwide (Piskin, Cianciosi, Gulec, Tomas, & Capanoglu, 2022), most prevalent in women of childbearing age, children under five years (Skolmowska & Głąbska, 2019), and those following a vegan diet (Henjum et al., 2021). Iron deficiency has also been linked to a sedentary lifestyle, obesity and a diet rich in fast-food (Shubham et al., 2020). Deficiency may occur due to poor intestinal absorption (Henjum et al., 2021), or related to factors such as iron inhibitors: calcium, polyphenols and phytates (Piskin et al., 2022) . Calcium has been shown to reduce the absorption of both haem and non-haem iron (Ems et al., 2022), it is recommended that iron supplements are taken at least 2 hours outside of consuming calcium rich foods (Sakr, 2022). Phytates, found in plant foods such as legumes, whole grains and nuts are potent inhibitors of iron (Piskin et al., 2022). Polyphenols found in tea, coffee, fruit and vegetables, wine and chocolate (Perron & Brumaghim, 2009), inhibit the absorption of hon-haem iron (Ems et al., 2022), though a systematic review by Speer et.al (2019), found polyphenols did not significantly affect the absorption of iron by the end of their cross-over study (Speer et al., 2019). In a study by Piskin et al. (2022), 20mg of red bean hulls were

added to bread (The phytic acid was destroyed during fermentation), had no effect on iron absorption, however if the red bean hulls were increased to 50mg iron bioavailability was reduced by 18% (Piskin et al., 2022).

Vitamin B_{12}

Methyl cobalamin and 5-deoxyadenosylcobalamin are the active forms of B12 collectively referred to as cobalamin (B12), and is required for the synthesis of DNA, protein and lipids (National Institutes of Health, 2022; Rashid, Meier, & Patrick, 2021).

Vitamin B12 is only found in animal-based foods (meat, eggs and dairy), so any vitamin B12 in the vegan diet would consequently have to come from fortification or supplementation (Boukid et al., 2021; National Institutes of Health, 2022). Vitamin B12 deficiency has consequences such as degeneration of the spinal cord, stroke or pernicious anaemia (Butola, Kanyal, & Ambad, 2021; Sakkas et al., 2020), and neurological disorders such as neuropathy and depression (Wolffenbuttel, Wouters, Heiner-Fokkema, & van der Klauw, 2019). Deficiency may also go undiagnosed due to the complexity of absorption and testing techniques using only serum levels, high folic acid intake may mask a vitamin B12 deficiency in a minority of people (Mills, Molloy, & Reynolds, 2018). This is more prevalent in older people in countries where fortification is common, folate intake is high and vitamin B12 intake is low (Johnson, 2007; Loedin & Speijer, 2021; Mills et al., 2018; Wolffenbuttel et al., 2019). Age may also be a factor in determining a deficiency state (Wolffenbuttel et al., 2019). Less than a quarter of PBMA and dairy analogue foods are fortified with B_{12} (van Vliet et al., 2020).

Nutrient composition

A 2022 study by Keerthana et al, analysed both the texture and nutrient composition of vegan sausage made with raw jack fruit or banana floret against a commercial chicken sausage. The results revealed that, with fortification the RJF and BF sausage had a higher, protein, lower fat, and higher fibre content than the chicken sausage (Keerthana Priya et al., 2022), however, the quality of protein was not discussed. A study comparing animal foods with plant-based alternatives foods reported, the LDL cholesterol and saturated fat of vegan foods to be less than those found in similar animal products they were imitating (Alae-Carew et al., 2021).

Plant-based dairy alternatives have been described as high in energy, salt, and saturated fat with low protein, calcium, and are not considered as a healthy food choice (Fresan & Rippin, 2021). Some have questioned if labelling vegan foods using words normally associated with animal products as misleading. Consuming processed vegan foods in a like-for-like manner to animal foods, puts consumers at risk of potential nutrient deficiencies (Boukid et al., 2021).

Health Claims and Certified foods

Health claims are voluntary statements that identify a health benefit of a food, backed by scientific evidence (MPI, 2022a). Nutrient content claims such as ‘Contains vitamin C’, must meet the requirements set out by the Australian New Zealand Food Standard Code (ANZFSC) (MPI, 2022a). Claims then have strict conditions associated with the wording of any health claim. For example, if the packaging advertises a claim such as, a ‘Good source of protein’, it must provide at least 10g of protein per serve (ANZFSC, 2022). Certified foods such as those that are certified vegan have a set criteria dependant on the country, though all certified vegan foods must be free of any animal products or by-products (AVS, 1960-2021).

To carry the 'New Zealand-certified' vegan logo, foods must meet the following criteria: Foods must be free of genetically modified organisms (GMO-free). Food cannot include any animal, fish, or insect products or by-products, including fats, gelatine, aspic, or rennet. Food must exclude dairy, eggs, honey, propolis, and cochineal, and prevent cross-contamination from occurring (Vegetarian society NZ, 2021)

Health claims are often advertised on packaging to let consumers know if foods are vegan or are fortified with key nutrients. Even labelling a product vegan is a source of contention in Europe due to the lack of definition of the term veganism (F. Boukid & Castellari, 2021; Burns-Whitmore, Froyen, Heskey, Parker, & San Pablo, 2019).

Food audits

Several audits have been conducted on PBMA and PBDAs across the globe over the last few years. These audits vary in style, some look at the main macronutrients of energy, protein, total fat, CHO, fibre, and micronutrients sodium and iron. Others concentrated on, taste and texture, including sugar content. Most of these studies did not record the micronutrients such as calcium and zinc.

An audit to compare PBMAs to their equivalent meat-based products was conducted in 2019. The audit used data collected from four of the main supermarkets across Australia, representing 80% if the market share (F. Curtain & S. Grafenauer, 2019). The total 137 products included plant-based burgers, sausages, mince, chicken, seafood and 'other', for foods that fell outside of these categories such as bacon style rashers and polony (a type of cooked sausage). The data also recorded a fivefold increase of PBMAs foods since a previous audit in 2015 (F. Curtain & S. Grafenauer, 2019). The reports identify the lack of micronutrients, including zinc, iron and vitamin B12 in many of the PBMAs. Only 24% of PBMAs were fortified with vitamin B_{12}, 20% were fortified with iron and just 18% were

fortified with zinc. Sodium was also an area of concern due to the high levels and lack of compliancy with sodium target levels set by Public Health England (F. Curtain & S. Grafenauer, 2019). Of the 137 products audited, only 50% were compliant with regulatory levels for sodium. On average plant-based mince contained six times more sodium than similar meat products, however, meat sausages contained 66% more sodium than the PBMAs. Iron levels were not compared due to the lack of information on meat product labels (F. Curtain & S. Grafenauer, 2019).

A study comparing the nutrient intakes of a standard western diet with a plant-based alternative diet in Singapore found the new vegan diet (using processed foods) had more sodium (↑43%) and saturated fat (↑34%) than the traditional omnivore diet, and less fibre , vitamin B_{12} (↓79%), calcium (↓62%), potassium (↓36%), magnesium (↓16%) and zinc (↓54%) (Tso & Forde, 2021).

Both studies follow a similar trend, highlighting the deficiencies of a diet high in PBMAs. Surprisingly, low fibre was reported. The traditional vegan diet was high in fibre with an average daily intake of 40.7g, showing a sharp drop when compared to the new vegan diet (17.6g), the omnivore diet provided an average of 19.5g of fibre (Tso & Forde, 2021). The perception of PBMA or PBDAs has led to a 'Health Halo' effect associated with vegan foods. The evidence suggests this perception may not be justified (F. Curtain & S. Grafenauer, 2019).

Comparison of plant-based foods

An audit conducted in May 2021 collected the data of PBDAs across Europe, the audit included newly launched cheese, milk, and yoghurt analogues. Data was collected using the Mintel Global New Product Database, and included 44 countries (Boukid et al., 2021). Products were then filtered to ensure only those with a vegan health claim/nonanimal

ingredients were included in the data collection for comparison using IBM SPSS analysis (Boukid et al., 2021). From this data, the nutrient composition of 182 plant-based yoghurt analogues (PBYAs), and 114 plant based cheese analogues (PBCAs) were compared to their dairy equivalents. The results showed both vegan and dairy had similar total fat, but PBCAs had significantly higher SFAs than dairy cheese, carbohydrates were also higher (Boukid et al., 2021), sugar and salt were higher in the dairy cheese (Boukid et al., 2021). The PBYAs also had more energy, CHO, and total fats than dairy (7). Calcium levels were not recorded.

A Spanish audit recorded the PBCAs from seven of the most common supermarkets from April to May 2021, supermarkets were also visited in person to capture any products that were not online. Nutritional data including calories, total fat, saturated fat, CHO, fibre, protein, and salt per 100g were recorded. The comparison showed dairy cheese was higher in calories, proteins, and fats, but lower in CHO, sugars, and fibre than the PBCAs. Salt was also lower in the tofu and cashew plant cheese when compared to both the coconut and dairy options (Fresan & Rippin, 2021). Refer to Table 4 for the literature summary.

Tomova et al. recorded vegan products available on the Latvian market between January and March 2020, 192 products from 20 different countries were recorded. Products included beverages, PBDAs, PBMAs, flour products, snacks, sweets, desserts, recording nutritional data on ingredients, energy, protein, fat, saturated fat, CHO, and sodium (Tomova et al., 2019). The analysis showed data characteristic of the vegan diet, of low fat and SFA content, similar protein content to meat proteins but less energy, and higher sodium than poultry meat (Tomova et al., 2019). The extent of processed food in the comparison was not discussed.

One study researched the nutritional difference between dairy milk and PBDAs for children. The PBDAs in the study were, soy, coconut, almond and rice. The comparison to full fat dairy milk is shown in table 4. Sugars were not measured in the study, though the high

glycaemic index of plant drinks was mentioned. PBDA milk for children <24months would be nutritionally inadequate, due to the difference in nutrient bioavailability, even if fortified (Verduci et al., 2019).

Table 3. Comparisons of PBDAs to cow's milk

Milk	Calcium g/100g	Protein g/100g
Cow's milk	112	3.3
Soy	13	2.9
Coconut	16	2.3
Almond	14	1.3
Rice	118	0.28

NB: Referenced from, Cow's milk substitutes for children: Nutritional aspect of milk from different mammalian species, special formula, and plant-based beverage (Verduci et al., 2019). The study did not state if the PBDA were fortified or not.

However, there are limited studies comparing the nutritional composition of plant-based UPFs against the traditional vegan diet (Gehring et al., 2021). Most of the studies failed to measure the total calcium content when making comparisons to dairy products, one study in Singapore found if removing all animal products (meat and dairy) calcium intake would be reduced by 62% (Tso & Forde, 2021). The study also described the novel vegan diet high in PBMAs as low in potassium, phosphorus, zinc, vitamin B12, in addition to calcium (Tso & Forde, 2021). It should be noted that even when fortified PBDAs that have a similar calcium content to cow's milk, have a reduced bioavailability, and would need further fortification of protein and both vitamin D and A to have a similar nutrient profile to cow's milk (Schuster, Wang, Hawkins, & Painter, 2018).

Table 4. Literature summary of Vegan food audits

Author, year, country	Aim	Audit Method	Nutrients investigated	Findings	Limitations
Boukid et al, 2021 Europe (Boukid et al., 2021)	Can vegan alternative cheese and yoghurt be considered more nutritionally equilibrated than traditional products	Data was collected using the Mintel Global New Product database, focusing on products launched in Europe during 2020. Products had complete mandatory nutritional information	Energy, total fat, saturated fatty acids (SFAs), carbohydrates (CHO), sugars, protein and salt	Yoghurt alternatives had more energy, total fat, and CHO than dairy yoghurt, SFAs, salt and sugar were all similar to those found in dairy. Cheese alternatives had a higher fat, SFSs and CHO content, but were lower in protein salt and sugar than dairy cheese. Dairy alternative products had a general lower protein content when compared to dairy.	Only products available on the EU market were included. Calcium content was not measured
Curtain and Grafenauer, 2019 Australia (F. Curtain & S. Grafenauer, 2019)	To provide an overview of plant-based meat substitutes available in Australian supermarkets and to compare their nutrient composition to animal products of a similar nature.	An audit of the four major supermarkets (Aldi, Coles, IGA and Woolworths in Sidney during June 2019, representing 80% of the Australian market, mobile phones were used to record data on food packaging on all plant-based foods that mimicked meat products including burgers, sausage, mince, chicken, seafood and 'other' for products that fell outside the categories	Energy, protein, fat, saturated fat, CHO, sugars, dietary fibre, sodium, iron	Sodium was a concern with only one of the ten plain meat alternative products and 38% of other meat alterative products were compliant with national sodium targets. The meat alternative foods were not a nutritional equivalent product to use as a meat replacement. The need to set nutrient targets may assist product development in the future.	Micronutrients were not recorded due to the limited scope of research
Mariseva and Beitane Lativia (Mariseva & Beitane, 2020)	To identify the supply of vegan products on the Latvian market by analysing the ingredients and nutritional profile.	Out of the 17 of the online supermarkets identified for the study, only four met the research criteria. 192 products from 20 countries were included, carried out between January and March 2020.	Protein, fat, saturated fat, CHO, sugars and sodium	Meat alternatives were higher in sodium than their meat equivalents were confirmed by these study results. The protein content of meat alternatives (13%) was similar to meat (17%) but the total energy was less. The results determined; vegan snacks made up one third of all products with a lack of basic vegan food products.	Of the 192 products analysed only 30 were meat substitutes and 28 dairy alternatives. Micronutrients were not recorded.

Literature summary cont.

Author, year, country	Aim	Audit Method	Nutrients investigated	Findings	Limitations
Fresan and Rippen, 2021 Spain (Fresan & Rippin, 2021)	To evaluate the nutritional adequacy of plant-based cheese alternatives available in Spanish supermarkets	An audit conducted in the top seven supermarkets were selected to represent the majority of consumers, between April and May 2021. Supermarkets were visited in person to ensure all products were included.	Calories, total fat, saturated fat, CHO, sugars, fibre, protein and salt	Most plant-based cheese had a poor nutritional profile, high in calories, fat and saturated fat and salt, low in protein and fibre. However, some cheeses made from cashew or tofu were lower in saturated fat and sugars, and higher in fibre and protein than other plant-based cheeses. Over all plant-based cheeses were higher in saturated fat, CHOs and sugars while being lower in protein and calories than dairy cheese.	Micronutrients were not recorded
Kerslake et al. 2021 New Zealand (Fresan & Rippin, 2021)	To explore the facilitators, barriers and negotiations (i.e., tensions, trade-offs) that various dietary groups encounter when considering consuming meat substitutes	A total of six focus groups each with five to seven participants, 35 in total. Recruiting through social media vegan/vegetarians' groups and meat free Mondays.	General health and nutrition.	Conflicting results from both omnivores and vegetarians. The omnivores perceived that the PBMA were not as filling or lacked nutrients, the vegetarians believed both with particular reference to protein, the vegetarian/vegans also considered PBMS as a treat. Both groups perceived that a diet excluding meat was a healthier choice, if using proteins such as tofu and falafel.	Small study size, lack of quantifiable nutrition related knowledge.
Verduci et al, 2019 Italy (Verduci et al., 2019)	Review – of the different macronutrient compositions of different mammalian species and special milk formulas indicated for CMPA and plant-based milk alternatives	A review	Energy, water, protein, fat, lactose, ash, calcium, iron, magnesium, phosphorous, potassium, sodium, zinc, copper, selenium and manganese	Cow's milk is clearly superior if comparing its nutritional profile against plant-based alternatives. The study identifies the different nutrients of plant milk, and their strengths and weakness if they are to be used to replace dairy milk.	Not all plant milk were included in the study. Sugars were not measured.

Conclusion

The global interest in health and environmental concern has led many people to evaluate their diet and to reduce meat consumption, with some adopting a vegan diet. This shift in dietary preference has led to the increased development and sales of vegan processed foods, sparking its rapid growth, which is set to double by 2026. This rapid growth has brought with it many new challenges and associated health concerns; a term that had previously only been positively associated with a vegan diet. The health concerns relate to the huge increase in UPFs consumed by vegans and in a higher proportion of vegans aged 24-39. Several studies have looked at the type and availability of products on the market as well as nutrients of plant-based foods in comparison to meat. There is still a huge gap in the nutritional adequacy of plant-based processed foods available. The market for PBMA and PBDAs currently has no regulation with regards to adequate fortification. This offers a confusing predicament for consumers and new vegans with limited nutritional knowledge, leading to the potential for nutrient deficiencies if these products are used in a like for like manner with animal-based products.

The review highlights the need for further longitudinal studies and research looking specifically to compare the micronutrients and the bioavailability of vegan processed foods against the animal products they imitate.

Chapter 3

An audit of ultra-processed vegan food in New Zealand's major supermarkets

Abstract

Background

The availability of vegan ultra-processed foods (UPFs) has steadily increased in line with dietary trends. The increased of consumption of vegan UPFs raises concerns regarding their nutritional adequacy if used in a like for like manner to replace foods of animal origin, and if these foods require fortification.

Aims and Objectives

The audit was restricted to vegan-labelled, plant-based meat and dairy analogues (PBMAs and PBDAs) available in New Zealand major supermarkets, including comparing their nutrient composition (energy, protein, Saturated fat, carbohydrate, fibre, sodium, calcium, iron, zinc and B12) against products of animal origin that these foods emulate.

Methods

The audit was completed during March – June 2022 using a combination of data collection from supermarkets and online sources. Data was collected from New Zealand's five major supermarkets, Countdown, Fresh Choice, New World, Pak 'n' Save and Four Square.

Results

The PBMAs generally had higher energy and lower protein than their meat counterparts. The PBMAs were high in sodium, with a mean across the various products of 351mg/100g to 693

mg/100g, compared to meat which had a mean of 47mg/100g to 796.7mg/100g (excluding bacon). The PBDAs showed a similar trend with sodium across the various analogues with a mean of 22.75mg/100mL to 68mg/100mL. The sodium for the various plant-based cheese analogues (PBCAs) had a mean of 603mg/100g to 4970mg/100g. Calcium of PBDA milk were separated in to fortified and unfortified. Fortified PBDAs had a mean of 100.5mg/100mL to 147mg/100mL, 29.4% had no calcium fortification. Of the PBDAs soy milk had the closest protein quality to dairy milk, though the levels of protein were varied. Fortification of calcium was mostly absent from both plant-based cheese and yoghurt analogues (PBCAs, PBYAs). Vitamin B12 had a mean of 0mcg/100g to 0.6mcg/100g across all the PBMAs.

Conclusion

The plant-based analogues offered a range of ultra-processed foods, very few of which could be considered in a healthy range of macro and micronutrients. The levels of fortification would need to be standardised to offer a product of similar nutritional value to animal-based foods.

Keywords: vegan, plant-based meat analogues (PBMAs), plant-based dairy analogues (PBDAs)s, plant-based cheese analogues (PBCAs), plant-based yoghurt analogues (PBYAs), audit, New Zealand, ultra -processed food (UPFs)

Introduction

The global market for vegan foods has increased steadily, with an estimated worth of $7.9 billion (US) in 2022, and an anticipated growth of $15.7 billion by 2027 (Huang et al., 2022). The Vegan Society has seen a 49% increase in members across the world from 2018 to 2019 (Vegan Society, 2021), with between 1-10% of people in Western countries adopting some form of a vegetarian diet (Gehring et al., 2021). Many following a traditional omnivore diet have reduced their consumption of meat, New Zealand alone saw a reduction of 34% in 2019 (Soryl, 2022).

The number of vegans has increased globally year on year, and New Zealand is no exception, with an increase of 19% in 2021 in those following a vegetarian or vegan diet (Statista, 2023c). The Best Practice Advocacy Centre New Zealand (BPAC) reported from the national data on plant based eating (2018), 4.5% followed a vegetarian diet, and 1.1% were vegan, a two-fold increase from the same study conducted in 2015 (BPACNZ, 2021). The move towards reducing meat consumption and increasing plant foods for a healthier lifestyle has been supported by the New Zealand government, which pledged $18M to the development of alternative protein food in New Zealand (Thompson, 2022). A grant of $1.25M was awarded to the 'Sustainable Foods Ltd,' (the parent company of Plan*t' food), as part of 'The New Zealand Government's Regional Strategic Partnership Fund (Food Frontier, 2022). Its aim; to boost growth in plant alternatives (Food Frontier, 2022). According to chief executive officer (CEO) Justin Lemmens 'The Sustainable Food Company', has seen an 850% growth rate in the last three years (Food Frontier, 2019)..

Reasons for becoming vegan may vary. Some may turn to veganism for environmental reasons and concerns of unsustainability, (greenhouse gas emissions, soil erosion and deforestation) (e. a. Saari, 2021). Others may turn to veganism to improve their health; reducing the high fat and cholesterol associated with meat and dairy-based products.

Veganism has been described as a healthier choice, associated with improved nutrition (Gehring et al., 2021), and lowered mortality (Dyett et al., 2013).

The rising popularity of veganism has led to an increased demand for processed PBMAs (Gehring et al., 2021). Even fast-food giants like McDonald's and Burger King have developed their own plant-based menus. In the rapidly changing food market, many food companies are responding by introducing plant-based products to keep up with demand (Gallagher et al., 2021), and increased consumption of PBMAs and awareness of the health benefits associated with a vegan diet (Gallagher et al., 2021; Gehring et al., 2021; Gehring et al., 2020).

These PBMAs are made up of water, vegetable proteins, binding agents, flavour, and colouring, and are designed to mimic the sensory characteristics of meat such as taste, texture and appearance (Kyriakopoulou et al., 2019). Consequently, these PBMAs are highly processed, typically associated with convenience foods, and generally formulated from sources containing little or no whole food (Moubarac, Parra, Cannon, & Monteiro, 2014)

Processed foods have become increasingly complex, often produced by large-scale industries, there was a need for a standard classification. The NOVA scale was developed in 2009 as a way to classify processed foods (Fardet & Rock, 2019). UPFs are described as, 'convenient, ready to eat or require minimal preparation time, and often contain high energy, saturated fat, salt, and contain a low level of nutrients' (Ohlau, Spiller, & Risius, 2022). Many foods marketed as healthy, such as vegan substitutes for meat, egg and dairy are ultra-processed foods (UPFs), with questionable nutrition and health benefits for the consumer (Gehring et al., 2021; Ohlau et al., 2022).

Food labelling has become an important focus for those following a vegan diet. The market has seen a global increase of 105% in foods making a vegan health claim from 2015 -2019

(Nunes., 2020). The Vegan Society currently lists 18,000 certified vegan food and drink products from over 2,500 companies (Vegan Society, 2021). However, food labelling is complex. If a product is labelled as vegan, it would need to be certified by the Vegan Society, in New Zealand this would mean a product be free of genetically modified organisms (GMO-free), excluding all dairy, eggs, honey, propolis, and cochineal, and ensure no cross-contamination has occurred (Vegetarian society NZ, 2021). Many foods are simply labelled as, 'plant-based', though being plant based does not necessarily mean a product is vegan. Food ingredients would need to be checked, to confirm no animal ingredients.

Meeting the recommended daily intake (RDI) of certain nutrients may be problematic for vegans, due to the low availability of macronutrients (protein), and micronutrients such as calcium, zinc, iron, and vitamins D, and B12 which are often low or absent from a poorly planned vegan diet, especially those high in UPFs. Vegan UPFs would require fortification for most of these nutrients (Burns-Whitmore et al., 2019; Gallagher et al., 2021; Tso & Forde, 2021).

There is currently no mandatory fortification of plant-based dairy analogues (PBDAs) or plant-based meat analogues (PBMAs) in New Zealand. The absence of essential macro and micronutrients may be of concern as the vegan diet has been described as a healthier option, promoting good nutrition (Estell et al., 2021) when compared to a high-meat diet.

The aim of this study was to audit vegan processed food available in the five major New Zealand supermarkets. From this, the major nutrients were recorded for comparison with the animal foods they imitated. Its purpose, to gain a fuller understanding of the level of nutrients in vegan UPFs available on the New Zealand market.

Methods

The audit was conducted between March and June 2022.

The audit recorded vegan and plant-based labelled products imitating meat, (chicken, mince, beef, sausage, burgers, vege burgers, bacon, nuggets), and dairy ((milk:- almond, coconut, soy, rice and oat) cheese :- Mozzarella, tasty/Cheddar, flavoured cheese, Parmesan, cream style cheese) and yoghurt:- plain, Greek, vanilla, and fruit)) available from the fresh and frozen departments of New Zealand's major supermarkets. Naturally vegan products such as legumes and tofu were excluded.

Data was collected from the five main supermarkets across New Zealand (NZ), to reflect the main choices available to consumers in NZ. These supermarkets are owned by two major conglomerates: Foodstuffs and Woolworths New Zealand (the latter previously known as Progressive Enterprises). Woolworths (Countdown and Fresh Choice), and Foodstuffs (New World, Pac 'nSave and Four Square). These two conglomerates make up over 85% of the market share (Australian trade and investment commission, 2022; Flanagan, 2022).

The audit was completed using a combination of methods including online, from supermarkets web page record of nutritional information, or directly from supermarket stores using photographs, if neither of these were available the individual companies were contacted via email or through social media pages such as Facebook. However, online offered a wider scope across New Zealand as it both saved time and offered the full range of consumer choice for products that may not be found at individual stores. Data was then transcribed into Microsoft Excel spreadsheet for analysis.

All products were recorded per 100g (or 100mL for liquids) in each category (Table 1). The data were collated on an Excel spreadsheet and used to calculate the mean and standard

deviation of the macro and micronutrients: energy, protein, saturated fat, sodium, calcium, iron, zinc and B12. These figures were then used to compare against animal foods that they emulated.

The nutrient composition of meat, and dairy were collected from an average derived from no less than eight samples, previously calculated by the Food Standards Australia and New Zealand (FSANZ), FoodWorks (version 10, Xyris Software) and nutrient data from the New Zealand Food Composition database FOODfiles 2018 Version 01 (The New Zealand Institute for Plant and Food Research Limited and Ministry of Health, 2018).. Raw data for meat products could not be collected from supermarkets as the food labelling did not provide full nutrient information for unfortified products such as Iron and vitamin B12, these figures were taken from FSANZ. Beef mince; for example, was calculated from an average of low-fat, regular-fat and premium mince from no less than eight samples of each and then the three products were entered into excel to get the mean. Any gaps in the data were recorded as zero. The nutrient information for meat burgers was taken from produce labels available in store or online, as FSANZ included the burger bun and cheese with their findings and the reference range of 8 products was not available on foodworks.

Results

The food products included for comparison fell into the following categories: set out as shown in table 1.

Table 1. Classification of food categories

Category	Type
PBMAs	Vegan burger (15), vege burger (14), vegan mince (10), vegan chicken (2), vegan chicken tenders (7), vegan sausage (13), vegan bacon (3)
PBDAs: Milk	Coconut (7), coconut*(4), almond (13), almond* (11), soy (10) , soy* (6), oat (14), oat * (7), rice (2), rice* (2)
PBCAs: Cheese	Vegan mozzarella (3), vegan tasty/Cheddar (5), flavoured cheese (3), Parmesan (1), cream style cheese (1)
PBYAs: Yoghurt	Plain (7), Greek (4), vanilla (9), fruit (16)

*N.B. Unsweetened plant milks use the abbreviation **

Plant-based meat analogues

Table 2 show the mean and (±SD) per 100g for each product.

The types of protein in the PBMA burgers were made up of either soy, pea protein, or a mix of soy, hemp, wheat, and pea isolate.

The protein content varied between 20—30%. The PBMA chicken was between 11-46% protein, although most products were in the lower range and made of a mix of soy, pea, and wheat proteins.

The most significant difference was with the sodium content. The vegan mince had 351mg/100g and the beef mince had 62.3mg/100g, (563% higher), than the beef mince, as did the vegan chicken, (with 1147% more sodium than the chicken breast). The plant-based sausage and bacon both had less sodium when compared to meat.

Surprisingly the protein content was higher in the fortified vegan chicken, which a had 28% more protein than chicken breast.

As expected, no plant-based products contained cholesterol.

B vitamins (B1, B2, B3, B5 and B6) were present in one of the two vegan chicken products in comparable amounts to chicken breast except for vitamin B3 which was less. Vitamin B12 was lower in all the PBMAs when compared to meat, fortification was intermittent and scarce. The chicken and chicken tenders had zero B12 fortification.

Table 2. Plant-based meat analogue comparison

Product	Beef Burger	Mince Beef	Chicken breast	Chicken tenders	Sausage	Bacon	Vegan Burger	Vege Burger	Vegan Mince	Vegan Chicken	Vegan Chicken tenders	Vegan Sausage	Vegan Bacon Range
Total products	N=10	N=24	N=8	N=9	N=8	N=8	N=15	N=13	N=10	N=2	N=7	N=13	N=3
Energy (Kj) Range	890 ± 149.8	672 ± 117	539 ± 179.6	1014 ± 106	862.1 ± 110.9	1220 ±126.9	863.3 ± 220.1 450 - 1046	704 ± 167 495 - 961	755 ± 191 400 - 974	720 ± 309 502 -939	1098 ± 168 910 - 1330	764 ± 172 588 - 1044	966 ± 21 951 - 990
Protein (g) Range	17.1 ± 1.9	22.6 ± 0.3	21.35 ± 1.63	16.5 ± 5	14.0 ± 1.01	25.10 ± 13.72	15.2 ± 4.02 4.6 - 22.5	6.6 ± 2.9 2 - 14	19 ± 6.2 5 - 27.7	27 ± 12 18.6 - 36.1	13.2 ± 2.8 10 – 18.3	13.7 ± 3.4 7.9 – 18.8	25.1 ± 12 14 – 37.6
Total fat (g) Range	14.5 ± 3.9	7.8 ± 3.3	4.75 ± 5.59	14 ± 4	15.2 ± 3.12	21.40 ± 9.62	12.4 ± 4.41 3.9 - 19	5.2 ± 2.3 0.8 - 10.3	7 ± 4.0 0.9 - 12	4.6 ± 2 3.1 -6.1	15.5 ± 3.3 11.8 – 21.2	9.6 ± 3.9 5.6 – 14.9	10.8 ± 5 7.1 - 17
Saturated fat (g) Range	6.± 1.43	7.8 ± 3.3	1.46 ± 170	3 ± 2	6 ± 2.44	8.03 ± 4.14	3.5 ± 3.02 0 - 8.2	0.8 ± 0.6 0.2-1.8	4.5 ± 3.5 0.1-8.3	1.2 ± 0.4 0.4 -1.2	2.8 ± 1.4 1.2 – 5.1	3.2 ± 2.3 0.6 – 7.5	1.6 ± 1 0.6 - 3
Trans (mg) Range	0.6	0	0	17 ± 29	0	0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
PUFA (g) Range	0	0	0	4 ± 2	0	0	0.6 ± 1.28 1.8 - 4	0 0	0.6 ± 1.8 0- 5.7	2.4 ± 0.7 1.9 – 2.9	1.8 ± 4.9 0 – 12.9	0.3 ± 1.2 0 – 4.3	0.3 ± 0.5 0 – 0.9
MUFA (g) Range	0	0	0	5 ± 1	0	0	1.1 ± 2.51 0 - 7.9	0 0	0.47 ± 0.9 0-2.6	1.4 ± 0.8 0.8 -2	0.8 ± 2.1 0 – 5.5	0.2 ± 0.6 0 – 2.3	0.2 ± 3.5 0 – 6.1
Cholesterol (mg) Range	0	76.7 ± 1.2	70 ± 2.38	44 ± 4	50.1 ± 3,54	70.50 ± 14.85	0 0	0 0	0 0	0 0	0 0	0 0	0 0
CHO (g) Range	4 ± 2.1	0	0	16 ± 3	3.2 ± 0.23	0.10 ± 0.14	9.8 ± 5.29 3.1-24.4	21 ± 6.0 14.3-30.6	8.2 ± 3.3 3.6-12.2	3 ± 2.5 0.7 – 4.3	15.9 ± 5.7 7 – 25.4	8.5 ± 3.4 2.3 – 14.8	9.4 ± 6 4.8 – 16.4
Sugars (g) Range	1 ± 0.4	0	0	1 ± 0.4	0.1 ± 0.23	0.10 ± 0.14	1.5 ± 1.45 0-6	3.2 ± 1.1 1.5 - 5.6	2.4 ± 1.6 0.3-5.1	0.5 ± 0.1 0.4 -0.5	1.4 ± 1 0 – 2.9	1.7 ± 0.9 0.2 – 2.2	1.7 ± 2 0.3 – 3.6
Dietary fibre Range	1 ±0.5	0	0	1 ± 0.1	1.1 ± 0.93	0	2.3 ± 3 0-10.7	5 ± 2.5 0 - 9.2	3.4 ± 2.4 0 - 6.6	4.9 ± 3.5 2.4 -7.5	1.2 ± 1.2 2 0 – 1.9	3.4 ± 3.4 0 – 11.5	1.7 ± 2 0 – 3.7
Sodium (mg) Range	489 ± 72.8	62.3 ± 9.8	47 ± 1.41	684 ± 205	796.7 ± 81.45	1837 ± 796	436.3 ± 179.9 400-750	403 ± 135 230-630	351 ± 101 240 - 581	539 ± 12 530 - 547	693 ± 162 516 - 942	599 ± 161 299 - 761	675 ± 216 530 - 924
Vit B12 (mcg) Range	0	2.6 ± 0.7	0.15 ± 0.07	0.2 ± 0	1.0 ± 1.16	0.78 ± 0.25	0.6 ± 0.97 0-2.4	0.2 ± 0.6 0-2	0.5 ± 0.8 0-2	0 0	0 0	0.2 ± 0.6 0 – 2	0.7 ± 1 0 - 2
Vit D (mcg) Range	0	3.2 ± 0	3.99 ± 0.40	1 ± 3	1.0 ± 0.88	0	0 ± 0.04 0-0.14	0 0	0.4 ± 0.8 0-2.04	0 0	0 0	0 0	0 0

Product	Beef Burger	Mince Beef	Chicken breast	Chicken tenders	Sausage	Bacon	Vegan Burger	Vege Burger	Vegan Mince	Vegan Chicken	Vegan Chicken tenders	Vegan Sausage	Vegan Bacon Range
Vit E	0	0	0	1 ± 2	0	0	0	0	0	0	0	0	0
Range							0	0	0	0	0	0	0
Calcium (mg)	0	6.0 ± 1.7	5 ± 1.41	18.8 ± 8	19.9 ± 15.68	5.40 ± 1.97	21.7 ± 47.48	0	5.3 ± 17	0	0	0	85.6 ± 148
Range							0-155.1	0	0-53	0	0	0	0 – 256.7
Iron (mg)	0	1.5 ± 0.1	0.30 ± 0.06	1 ± 0	2.6 ± 2.81	0.54 ± 0.15	1.2 ± 1.63	0.3 ± 1	2.1 ± 3	4.55 ± 6	0	0.5 ± 1.3	1.1 ± 2
Range							0-3.5	0-3.5	0-7.1	0 - 9.1	0	0 – 3.5	0 – 3.5
Zinc (mg)	0	2.2 ± 0.1	0.53 ± 0.01	1 ± 0	1.8 ± 0.85	1.84 ± 1.48	1.2 ± 2.04	0.3 ± 1.2	1.7 ± 2.1	1.6 ± 2	0	0.3 ± 1.2	3 ± 2
Range							0 - 4.6	0 - 4.4	0 - 4.4	0 – 3.2	0	0 – 4.4	0 – 4.4

N.B. Beef burger data were taken from nutrient labels online and instore, no data for cholesterol, vitamin B12, iron , calcium or zinc was shown..

Plant-based dairy analogues (PBDAs)

The calcium content in both plant-based cheese and yoghurt analogues was low. Most of the plant-based cheese and yoghurt analogues were made with coconut oil, containing low levels of protein and high levels of saturated fat. Due to the poor nutrient profile and high saturated fat content, PBCAs are not considered a healthy food (Fresan & Rippin, 2021).

Our results (Table 3) showed a general trend across all the plant-based dairy of lower protein when compared to dairy products.

Plant-based dairy analogue milk

The figures show the mean and standard deviation (±SD) per 100mL for each of the 12 varieties.

All the PBDAs had less energy, protein, CHO, sugar and saturated fat than full fat cow's milk, except for rice and oat milk which had higher levels of both CHO and sugar in the original and unsweetened varieties. The sodium of all plant milks was markedly higher than full fat cow's milk, oat milk had nearly double the sodium content. Of all the plant milk, soy was the nearest to full fat cow's milk, followed by oat milk, though they still had less protein than dairy.

The protein content was highly variable due mainly to the concentration of the main named ingredient. The soy content ranged between 3.5-15% of the total ingredient. For coconut milk the range was between 3.5-59%, often with a mixture of coconut milk, coconut water or coconut cream. The almond milks were generally around 3% of total ingredients, a few had a range 5-7% and one had a 10% almond. Oat milks were all in the range of 10%, and rice milk were 13-14% of the total ingredient.

The levels of calcium fortification were sporadic, 29.4% did not fortify, for this reason calcium fortified plant milk is shown in a separate table (Table 4). Calcium in cow's milk was generally between 109-120mg/mL, plant milks ranged from 0-120mg/100mL. Most of the fortified plant-based milks showed levels equal to cow's milk, however several had varying levels in the range of 64-91mg/100mL.

Table 3. Plant-based dairy milk analogue comparison

	Milk Fresh Full fat	**Milk Fresh trim**	**Coconut**	**Coconut***	**Almond**	**Almond***	**Soy**	**Soy***	**Oat**	**Oat***	**Rice**	**Rice***
Total products	N=8	N=8	N=7	N=4	N=13	N=13	N=10	N=6	N=14	N=7	N=2	N=2
% of title ingredient	NA	NA	19 ± 20	20 ± 20	3.5 ± 2	4 ± 1.8	10 ± 6.1	9 ± 6	11 ± 2	12 ± 2	14 ± 0	13.5 ± 0.71
Content per 100mL												
Energy (Kj)	279	152	177 ± 43.5	93 ± 14.6	129.5 ± 26.5	93 ± 25	255 ± 38	180 ± 28	205 ± 71	214 ± 22.9	219.5 ±14.8	206.5 ± 9.19
Range			127 – 242	72 -103	99 - 163	67 - 129	177 - 311	134 - 208	138 - 298	188 - 239	209- 230	200 - 213
Protein (g)	3.4	3.7	0.6 ± 0.5	0.3 ± 0.17	0.94 ± 1	0.6 ± 0.08	3.3 ± 0.3	2.9 ± 0.5	0.81 ± 0.31	1.09 ± 0.41	0.5 ± 0.14	0.45 ± 0.21
Range			0.2 – 0.8	0.2 -0.5	0.4 -4.1	0.5 -0.6	3 -4.2	1.9 -3.4	0.2 -1.2	0.6 -1.8	0.4 – 0.6	0.3 -0.6
Total Fat (g)	3.5	0	2.7 ± 1.2	1.9 ± 0.32	1.92 ± 1	1.7 ± 0.36	3.2 ± 0.7	2 ± 0.8	2 ± 0.7	2.1 ± 0.78	0.85 ± 0.49	1 ± 0.28
Range			1.4 – 4.6	1.5 -2.2	1.2 -2.9	1.2 -2.5	1.9 -4.7	1.3 -3.4	0.2 – 3.1	1.1 -3.1	0.5 -1.2	0.8 -1.2
Saturated (g)	2.38	0	2.5 ± 1.2	1.48 ± 0.81	0.25 ± 0.32	0.2 ± 0.3	0.4 ± 0.06	0.25 ± 0.08	0.34 ± 0.3	0.3 ± 0.08	0.1 ± 0	0.1 ± 0
Range			0.7 – 2.4	0.3 -2.1	0.1 -1.2	0.1 -0.2	0.3 -0.5	0.2 -0.4	0.1 -1.2	0.2 -0.4	0.1 -0.1	0.1 -0.1
CHO (g)	5.5	5.5	4 ± 2.5	0.7 ± 0.67	2.4 ± 1.2	1.21 ± 1.5	4.4 ± 1.2	3.1 ± 1.9	7.3 ± 1.91	6.9 ± 0.68	11 ± 0.35	9.25 ± 0.35
Range			1 – 7.8	0.1 -1.6	0.3 -4.4	0.2 -3.5	2.2 -5.1	0.4 -4.9	4.2 -11.7	6 -7.7	10.3 -10.8	9 – 9.5
Sugars (g)	5.5	5.5	2.6 ± 1.1	0.58 ± 0.68	1.8 ± 1	0.48 ± 0.7	2.2 ± 0.7	1.4 ± 0.6	3.1 ± 1.26	3.3 ± 1.3	3.35 ± 3.35	4.45 ± 1.91
Range			0.8 – 3.8	0.2 -1.6	0.2 -2.5	0.1 -1.6	0.7 -2.5	0.4 -1.9	0.9 – 4.5	1.1 -4.4	3.1 - 3.6	3.1 – 5.8
Sodium (mg)	36	40	26.7 ± 19.3	22.75 ± 7.37	30.8 ± 12	42 ± 4.9	48 ± 15.4	48 ± 24	41 ± 10	44 ± 4.38	68 ± 0	65 ± 0
Range			4 - 61	14 -31	0 -40	36 -51.6	30 - 80	15 -80	11.8 -52.6	38 - 50	68 - 68	6.5 -6.5

*Unsweetened plant milks use the abbreviation *. The standard deviation for dairy milks was not shown as the raw data were collected from an average of 8 samples calculated by the Food Standards Australia and New Zealand (FSANZ)*

Table 4. Calcium Fortified plant-based dairy analogue comparison

	Milk Fresh Full fat	Milk Fresh trim	Coconut	Coconut*	Almond	Almond*	Soy	Soy*	Oat	Oat*	Rice	Rice*
Fortified	N=8	N=8	N=4	N=4	N=9	N=5	N=6	N=4	N=12	N=6	N=2	N=2
Calcium Range	109	120	108 ± 12.9 96 - 120	103 ± 21.6 75 - 120	100.5 ± 31 31 - 120	105 ± 22.3 74 - 120	147 ± 21.4 120 - 160	120 ± 0 0	115 ± 16.2 64 - 120	118 ± 4.7 109 - 120	100 ± 28 80 -120	120 ± 0 0
Unfortified			N=3	N=0	N=2	N=4	N=2	N=2	N=2	N=1	N=0	N=0

Plant-based cheese analogues

There were several major differences with PBCAs (Table 5) regarding protein, CHO and fortification. Some brands or types of plant-based cheese were fortified, other brands had no fortification. In each category of plant cheese only 1 mozzarella, 1 cheddar/tasty, and 1 of the flavoured cheese were fortified with calcium. The ingredients for PBCAs were generally made from a base of 24% coconut oil and starches.

Table 5. Plant-based cheese analogue comparison

Content per 100g	**Mozzarella**	**Tasty**	**Flavoured cheese**	**Parmesan**	**Cream cheese**	**Vegan Mozzarella**	**Vegan Tasty/Cheddar**	**Vegan flavoured cheese**	**Vegan Parmesan**	**Vegan Cream cheese**
Total products	N=8	N=8	N=8	N=8	N=8	N=3	N=5	N=3	N=1	N=1
Energy (Kj)	1213	1689	1458	1690	1420	1178 ± 82	1210 ± 76	1127 ± 46	1610	1370
Range						1100 - 1263	1100 - 1263	1100 - 1180		
Protein (g)	22.2	24.6	21.4	35.1	8.5	<1	<1	<1	17.7	<1
Range						<1 – 0.2	<1 – 0.22	<1 – 0.2		
Total Fat (g)	22.1	33.5	28.4	28.8	34.2	22 ± 2.5	23 ± 2	20 ± 2	17.4	30.8
Range						19 - 24	19.6 - 24	19 – 22.5		
Saturated (g)	14.37	22.72	18.8	18.2	22.07	20 ± 2	20 ± 2	18 ± 2	6.2	28.2
Range						17.5 21.3	17.8 - 21.3	17.5 -20.3		
CHO	0	0.3	1.2	0	0.2	21 ± 1.9	21.6 ± 2	20 ± 0.35	39.4	13.2
Range						19.4 – 23.1	19.4 -23.1	19.4 -20		
Sugars	0	9.3	1	0	0.2	0.5 ± 0.7	<1	0.05 ± 0	6.3	2.6
Range						0.05 - 1	<1 – 0.05	<1 – 0.05		
Sodium (mg)	522	686	1052	1300	320	614 ± 120	603 ± 141	754 ± 25	4970	879
Range						500 - 739	500 -775	739 -783		
Calcium (mg)	685	760	675	970	69	110 ± 191	66.4 ± 148	110 ± 191	0	0
Range						0 -331	0 - 332	0 -331		

Plant-based yoghurt analogues

Fortification with calcium was mostly absent from PBYAs, just one of the Greek and one of the vanilla PBYAs were fortified with calcium. The PBYAs (Table 6) were generally made from coconut milk or coconut cream, this is evident in the results with each plant yoghurt having considerably less protein and higher levels for energy, fat and saturated fat than dairy yoghurt.

Table 6. Plant-based yoghurt analogues

Data sheet Yoghurt	Plain yoghurt	Greek yoghurt	Vanilla yoghurt	Fruit yoghurt	Plant plain	Plant Greek	Plant Vanilla	Plant fruit
Total products	N=6	N=6	N=6	N=5	N=7	N=4	N=9	N=16
Content per 100mL								
Energy (Kj)	276 ± 79	358 ± 127	377 ± 68	391 ± 115	744 ± 240	584 ± 196	673 ± 272	593 ± 191
Range	173 -400	234 – 560	286 – 453	295 - 600	362 - 969	353 - 747	362 - 1010	362 - 924
Protein (g)	5.2 ± 2.6	7.92 ± 1.69	6.6 ± 2.5	5.0 ± 1.3	1.58 ± 0.59	1.4 ± 0.3	2 ± 1	2 ± 1.1
Range	3.2 - 10	5.3 -9.3	3.9 – 9	4 – 7.3	0.7 -2.2	0.9 -1.5	0.7 -3.9	0.9 – 4.1
Total Fat (g)	3.3 ± 1.6	3.72 ± 2.61	2.6 ± 1.9	3 ± 2.5	17 ± 7	12 ± 6.4	13.3 ± 8	11 ± 6.3
Range	1.4 -5.9	0.2 – 7.5	0.2 – 5.1	1 – 7.3	6.5 -23	6.4 – 17.5	3.5 -22.4	3.5 -22.6
Saturated (g)	2.1 ± 1	2.47 ± 1.8	1.7 ± 1.3	2 ± 1.6	15 ± 7	10.3 ± 6.7	13.1 ± 7	11 ± 5.8
Range	0.8 – 3.9	0.1 – 5.2	0.1 -3.4	0.6 -4.7	5.7 - 21	3.4 – 16.1	<1 – 20.4	<1 – 20.7
CHO	3.9 ± 1.6	5.4 ± 3.1	10.1 ± 1.1	11.2 ± 2.4	5 ± 4	6.5 ± 4.8	7.4 ± 4	9 ± 4.2
Range	0.8 – 5.3	1.5 -8.4	8.6 - 11.7	7.5 -13.5	2.2 -13.7	4 -13.7	3.6 – 15.4	2.8 -16.6
Sugars	3.3 ± 1.8	4.8 ± 2.6	9.0 ± 1.5	10 ± 2.1	2 ± 1	1.7 ± 0.25	4.8 ± 3	5.1 ± 1.4
Range	0.8 – 5.3	1.5 -7.2	7.4 – 11.5	7.1 -13.2	0.6 -2.3	1.3 -1.8	0.6 -10	2.3 - 7.1
Sodium (mg)	48.2 ± 15.3	49 ± 23	49.5 ± 20.1	51.3 ± 20	25 ± 21	25 ± 28	15.7 ± 10	17.4 ± 17.9
Range	38 – 78	25 – 79	30 - 81	30 -84	10 -66	8 - 66	<5 -31.1	<5 - 18
Calcium	146.8 ± 39.8	145 ± 38	145 ± 32	155 ± 19	0	44 ± 88	16.8 ± 50.3	0
Range	108 - 200	95 = 190	100 - 180	125 = 170		0 - 175	0 -151	

Discussion

The primary driving factor in the development and production of PBMA foods has been the texture and taste, leaving the nutritional composition lacking (Sha & Xiong, 2020). PBMAs are generally made of soy and wheat gluten, gluten for texture and soy for its amino acid profile and gelling properties (Schreuders et al., 2019).

The vegan/plant-based meat market has seen several changes during 2022, at the beginning of the data collection it was difficult to keep up with new products flowing into the market, during the year these slowed down, with several products being discontinued, some of the recipes changed, for new or improved varieties, and some companies discontinued production of some lines. One company stated their products had not seen significant sales to warrant its continued production, so withdrew the range from the New Zealand market.

To achieve meat like sensory properties such as texture, taste, and the look of meat, all PBMAs must go through rigorous processing techniques, at high temperatures, to homogenize and blend ingredients, which results in the loss of some nutrients (Qin, Wang, & Luo, 2022; Sha & Xiong, 2020). The increased intake of UPFs has the same risks of developing noncommunicable disease (NCDs) as those following a traditional omnivorous diet (Gehring et al., 2021; Lauber, Rutter, & Gilmore, 2021). These high-energy UPFs are often nutrient-poor and contain higher levels of sodium, fat and energy than similar ultra-processed non-vegan foods (R. Mangels, 2022).

In regards to health it is unclear if the health benefits associated with the vegan diet apply to a diet rich in PBMAs (Hertzler, Lieblein-Boff, Weiler, & Allgeier, 2020). Suggesting the fortification with key nutrients may be an option to explore in the prevention of deficiency associated with poor health effects and mortality.

Comparisons of Nutrients

There were some key differences between the foods across all the vegan and animal-based food groups. As expected, the major differences regarded the nutrients, protein, sodium, CHO, sugars, saturated fat, calcium, vitamin B12 and iron. Other studies looking at the nutrient profile of PBMAs in Australia (Felicity Curtain & Sara Grafenauer, 2019), United Kingdom (Alessandrini et al., 2021) and America (Harnack et al., 2021) have shown similar nutritional outcomes to those found in this study, relating to sodium , vitamin B12 and zinc (F. Curtain & S. Grafenauer, 2019), and iron due to reduced bioavailability (Alessandrini et al., 2021; F. Curtain & S. Grafenauer, 2019; Harnack et al., 2021) raising several concerns about the nutritional quality of plant-based meat and dairy analogues (Romão et al., 2023). It was noted in all three studies that the majority of PBMAs were lower in total fat, protein, and higher in fibre than the meat products they emulate.

In addition, during the manufacturing process, vegan plant-based protein may be significantly altered by thermal processing, reducing their digestibility and the bioavailability of some amino acids (Qin et al., 2022).

Protein

The commonly used methods of measuring protein digestibility are either the Protein Digestibility Corrected Amino Acid Score (PDCAAS), or the digestibility amino acid score (DIAAS) the score is based on the most limiting indispensable amino acid. Plant proteins are incomplete proteins, limited in one or more essential amino acids (Hertzler et al., 2020). In broad terms, pea proteins are deficient in methionine and wheat proteins are deficient in

lysine (Manus et al., 2021). Plant proteins are also less bioavailable than animal proteins. All the PBMAs in this audit were made from a base of pea, soy or wheat protein, the majority having a mixture of all three, data was collected from the ingredient list, protein levels were recorded from the nutritional information. The two main sources of PBMA protein come from Pea and Soy (Sha & Xiong, 2020). Pea proteins are incomplete proteins from legumes, other sources include seeds and pulses (Sha & Xiong, 2020). Typically, pea proteins are made up of protein flour, protein concentrate and protein isolate (Fatma Boukid, Rosell, & Castellari, 2021), each has different levels of digestibility (Qin et al., 2022, J. Migala, 2020, Schreuders et al., 2019).

Soy protein is sustainable, and offers binding and structural properties ideal for texture and provides the sensory characteristics that resemble meat (T. Zhang et al., 2021), (T. Zhang et al., 2021). Soy is also considered a complete protein, containing all nine essential amino acids (Hertzler et al., 2020). It has a PDCAAS like some animal proteins, but is limited in sulphur-containing amino acids (SAA) methionine and cysteine (Qin et al., 2022)

The audit showed variation across the PBDA:- Cheese and yoghurt all had less protein than their dairy versions. Plant milks have a varied level of protein depending on what the base ingredient is, and the level of fortification. Amino acids such as Lysine are often the limiting factor in grains, whereas methionine and cysteine are the limiting factor in legumes. Soy, a complete protein, and the only plant-milk to have a PDCAAS similar to that of cow's milk (Hertzler et al., 2020). However, cow's milk is considered a whole or complete food, containing a good balance of all macro and micronutrients (Paul, Kumar, Kumar, & Sharma, 2020), PBDAs in comparison have a low variety of both micronutrient and amino acids (Bocker & Silva, 2022). Furthermore, they require stabilisers, sweeteners, thickeners and fortification of calcium, vitamin D, and iron to resemble the nutrition found in cow's milk

(Drewnowski, 2021). PBDAs are heavily processed, made from plant oils, achieved through a combination of soaking and grinding (Drewnowski, 2021), then requiring pasteurisation and heat processing techniques (Bocker & Silva, 2022).

Saturated fat

The audit showed variation across the PBDAs which all showed a trend of less energy, total fat, and saturated fat. The PBMAs had considerably lower saturated fat content when compared to meat references, apart from the PBMA burger that had a slightly higher range. The PBMAs and PBCAs followed this trend, however PBYAs differed with significantly more saturated fat than dairy yoghurt. A Norwegian study had similar findings , though it noted that the plant sourced saturated fat may be more beneficial than that in dairy milk (Tonheim, Austad, Torheim, & Henjum, 2022). Coconut yoghurt is rich in flavour due to its high saturated fat content (Wanikorn, Samakradhamrongthai, & Yupanqui, 2022). Plant yoghurts made from coconut milk have the highest levels of saturated fat. All the New Zealand PBYAs recorded in this study were made from a coconut base, three of the Australian PBYAs were made from a soy base. The health effects of saturated fat in coconut milk has been debated in recent years, however recent studies note the benefits of the saturated fat in coconut raising high-density lipoprotein (HDL) and decreasing low density lipoproteins (LDL) (Karunasiri, Gunawardane, Senanayake, Jayathilaka, & Seneviratne, 2020). A 2021 study by Bharti et al also found coconut milk raised HDL (Bharti, Badshah, & Beniwal, 2021).

The saturated fat range for plant-based foods is highly variable, the difference is the most significant in plant-based yoghurts, and some plant-based cheese. The plant-milks all had a

considerably lower saturated fat than full fat dairy milk, except for coconut milk which was slightly higher. However, the dairy trim milk had zero fat or saturated fat, all the plant milks had some saturated fat content.

Carbohydrate

The carbohydrates derived from plants display a range of different molecular and biological properties (McClements & Grossmann, 2021), added to plant foods for sensory texture (Huang et al., 2022), making between 5% -13% of PBMA foods total volume (Romão et al., 2023). This was often due to their base ingredients; such as legumes and cereals being a rich source of CHO (Romão et al., 2023). The figures from this study also show a higher level of CHO across all PBMAs, the only similarity was seen between the chicken tenders and the PBMA tenders which were both crumbed. Studies in Australia (Felicity Curtain & Sara Grafenauer, 2019), and in Norway (Tonheim et al., 2022), also followed this trend. Additional carbohydrates may be added to processed PBMAs in the form of starches, flour and gums (Rizzolo-Brime, Orta-Ramirez, Puyol Martin, & Jakszyn, 2023).

Calcium

Calcium is a vital nutrient required for muscle contraction (Garg & Mahalle, 2019), bone health and the regulation of blood pressure (Sakr, 2022; Sisay et al., 2020). Rich sources are found in dairy (milk, cheese and yoghurt), as well as almonds, nuts and seeds (Cormick & Belizán, 2019).

Over 40% of plant-based food sales come from PBDA milks (McClements & Grossmann, 2021), making their nutritional profile of increasing importance. Even when fortified plant milks are disadvantaged when compared to dairy milks due to sedimentation (Chalupa-Krebzdak, Long, & Bohrer, 2018) and reduced bioavailability (Schuster et al., 2018). If sedimentation occurs just 31% of fortified calcium is retained, and as little as 59% if the product were shaken (Chalupa-Krebzdak et al., 2018; Heaney & Rafferty, 2006). Some foods such as almonds are a good source of calcium, however almond milk generally has a very low percentage of almonds (2.5%-3.8%). It should be noted that PBDA milks would need to be fortified with both calcium and vitamin D to provide a similar bioavailability to the calcium from cows milk (Schuster et al., 2018).

The audit showed calcium was lower across all PBDAs except for soy original and rice unsweetened which had more than blue top milk. The PBCAs and PBYAs followed the same trend with calcium and sodium. The figures for calcium, such as the standard deviation and mean figures were sporadic, 29.4% did not fortify, for this reason calcium fortified plant milk is shown in a separate table , The level of fortification in those brands that fortified their products were generally fortified to a level similar to cow's milk, (the maximum allowance), fortification is limited to less than 25% of the recommended daily allowance (RDI), which is500mg/day for infants and toddlers (aged 1-3yr) (Food Standards Agency Australia and New Zealand, 2002; Karunasiri et al., 2020; National health and medical research council., 2005). Two of the PBCAs (Parmesan and cream cheese), had no fortification at all. Concurring with existing audits (Clegg et al., 2021; Craig, Mangels, & Brothers, 2022), this is of concern due to the low level nutrition if consumed as a substitute for dairy cheese or yoghurt (Craig et al., 2022). The PBCA also all had a coconut oil base, mixed with starches (modified starch, potato starch or modified pea and maise starch). Dairy cheese is considered a good source of calcium as with milk, however only 30% of the PBCA were fortified with

calcium. A standardised widespread fortification of calcium for vegan PBCA and PBDA milks would make these products more nutritional viable (Craig et al., 2022), and prevent deficiency (Clegg et al., 2021).

Iron

Iron was present in all the PBMAs apart from the chicken tenders. We found iron in processed PBMAs in comparable amounts to meat, though this was only non-haem iron, with reduced bioavailability. The fortified PBMA chicken had more iron than chicken breast, and the PBMA mince had more iron than the meat mince. Bioavailability of iron is a key factor to consider with plant-based foods (Zhang, Stockmann, Ng, & Ajlouni, 2021). Many plant-based foods such as legumes, whole grains and nuts, contain phytates (Piskin et al., 2022), and polyphenols (Perron & Brumaghim, 2009) which inhibit the absorption of haem and non-haem iron retrospectively. However, vitamin C is an effective enhancer of non-haem iron absorption, mitigating these effects to some degree, and is generally consumed in higher amounts in the vegan diet (van Wonderen, Melse-Boonstra, & Gerdessen, 2023). Some plant foods may actually enhance and promote iron absorption in biofortification, though the exact mechanisms of action are still being explored (Zhang et al., 2021).

Sodium

High sodium intake has been well documented and linked with adverse health conditions such as cardiovascular disease and hypertension (Mente, O'Donnell, & Yusuf, 2021). The Ministry of Health's (MOH) suggested daily intake for sodium (for adults in New Zealand) is

an upper limit of 2g per/day (MOH, 2021). A PBMA burger had a range of 252-690mg sodium/100g product, any foods containing 600mg or more sodium per 100g are considered a high sodium food (MOH, 2021). High sodium was seen across most of the vegan UPFs in the audit. The PBMAs all had considerably more sodium than raw meat (mince and chicken breast), the processed meat products burgers, chicken tenders, bacon, and sausage were considered high in sodium. The increased sodium of PBMAs may reduce their health benefits (Sha & Xiong, 2020).

Vitamin B12

Cobalamin (vitamin B12) is synthesized in the gastrointestinal tract of animals, therefore only found in foods of animal origin (Butola et al., 2021; Sakkas et al., 2020). The risk of Vitamin B12 deficiency is a well-known concern amongst vegans, and consequently supplementation is common (Weikert et al., 2020). However, the vegan diet often relies on fortified products to reduce the risk of deficiency (Sakkas et al., 2020). Despite this the fortification of vitamin B12 is sporadic. Just 21% of all the PBMAs and 35% of all PBDAs were fortified with vitamin B12 in our audit of New Zealand's major supermarkets.

Strengths and limitations

This study is currently the only New Zealand based audit of vegan/plant-based processed foods. The audit was conducted in a time of rapid growth within the field of processed vegan

foods, consequently many of the products initially in the study are no longer available, (the effects of covid had often altered the manufacturing and shipping costs), making this study a unique snap shot in time.

The study was conducted during the COVID19 global pandemic, this may have negatively affected the availability of some stock due to manufacturing and processing delays. To reduce the impact COVID19 had in the study Foodstuffs (New World, Pak 'n' Save and Four Square) and Woolworths (Countdown and Fresh Choice) were contacted to confirm if a product was discontinued or if supply issues were the reason for the items being unavailable. If confirmation could not be gained, the product was removed from the audit.

The audit did not consider regional or seasonal variations, product availability, or trial periods.

Conclusion

Plant-based, processed foods have evolved at a rapid rate, offering a valuable alternative for those with intolerances, allergies, or food preferences. As many people opt to increase their consumption of plant-foods for health or environmental reasons it is important that the nutrient profile of PBMA and PBDAs meets that of the healthy option foods they emulate.

Vegan foods may give the impression of being healthy, as consumers look to reduce their meat consumption. However, ultra-processed vegan foods have increased levels of sodium, saturated fat, and reduced levels macro and micronutrient such as protein, calcium, and vitamin B12, and do not offer the same health benefits as the traditional wholefood vegan diet. The increased intake of UPFs will have detrimental effects on the health of vegans and

put them at the same risk of developing the NCDs normally associated with a high fat omnivore diet.

Further education is needed for both manufactures and consumers regarding the long-term health effects of vegans that continue to consume high levels of nutrient poor UPFs.

Chapter 4

Overview

Summary

New Zealand has seen a rapid growth of vegan ultra-processed foods available on the market. Many of these foods new to the market and are trying to imitate foods of animal origin. As the drive to reduce the environmental impact of industrial farming, improve health and reduce NCDs such as obesity and T2D, the demand for plant-based foods has increased. Unfortunately, the key motivating factor for manufacturing and production seems to be taste, texture and colour, leaving the nutrient composition lacking. The PBMA and PBDAs are mostly convenience UPFs, requiring fortification if they were to be consumed in a like for like manner, replacing the animal foods they imitate. These UPFs are also high in sodium, saturated fat and generally nutrient poor.

Aims and Objectives

Aim

To conduct an audit of processed, vegan-labelled foods available in New Zealand's major supermarkets.

Objectives

1. To explore and compare the nutritional value of Vegan plant-based foods* in New Zealand's major supermarket chains- Woolworths (Countdown and Fresh choice), and Foodstuffs (New World, Pak 'n Save and Four Square).
2. To compare the nutrient composition (Energy, Protein, Saturated fat, MUFA, PUFA, carbohydrates, Fibre. Cholesterol, Sodium, Calcium, Iron, Zinc and B12).

Strengths and limitations

The original aim was altered from vegan-labelled foods to both plant-based and vegan-labelled foods. This was due to the limitations of only including vegan-labelled foods. If a food carries the vegan logo, it would need to be certified 'vegan', by the strict criteria set by the country of origin (Vegan.org, 2022). In New Zealand, that criteria includes being free of any genetically modified organisms (GMO), animal, fish or insect products or their by-products (Vegetarian society NZ, 2021). Many of the vegan foods available on the market are not certified by the 'Vegan Society', often these foods may advertise as being plant-based. However, being plant-based does not mean a product is vegan. A plant-based food may simply have a higher percentage of plant-based ingredients. For this reason, many of the foods included in the audit were labelled 'plant-based', and did not carry the certified vegan logo. If any plant-based products were found to contain any products of animal or insect origin, they were removed from the audit.

Imported foods may also carry a different version of a health star rating such as the Nutri-score (eurofins, 2023) found in Europe or the UK's traffic light system (Agency, 2020), these different ratings may lead to confusion, also as to how each system works and why some products do not carry any rating system.

The nutrient composition of meat, dairy and egg was collected from an average nutrient composition derived from no less than 8 samples, calculated by the Food Standards Australia and New Zealand (FSANZ) and Foodworks. Beef mince for example, was calculated from an average of high-fat, low-fat and regular-fat mince from approximately 8 samples.

The data was then refined to only include the macro and micronutrients: energy, protein, saturated fat, MUFA, PUFA, carbohydrate, fibre, cholesterol, sodium, calcium, iron, zinc and B_{12}.

Recommendation

Further research regarding the frequency of PBMAs and PBDAs in the diet would be beneficial to determine if any macro or micronutrients are of concern for vegans in New Zealand.

Standard fortification of PBDAs. Adding calcium to PBDAs especially plant milk might be an option to explore, to reduce the risk of deficiency and subsequent health related problems later in life.

A standardised nutrient requirement for PBMAs regarding protein, vitamin b12, zinc, vitamin d and sodium would help make plant-based foods a healthier nutritional option for both vegans and flexitarians.

Conclusions

The audit analysis has shown that the plant-based vegan foods available to the general public are mostly high sodium foods. The PBDA foods were generally lower in protein, calcium, and calcium than dairy foods, therefore increasing the possibility of nutrient deficiency.

Of the PBMAs the burgers, mince and chicken were all higher in energy, CHO, fibre, and sodium, and all lower in protein (except for plant-based chicken), saturated fat, and vitamin B12. This poses concern as these foods are often seen as a healthy alternative to meat. The

vegan sausage and bacon provided less total fat, saturated fat, sodium, and cholesterol than the meat, which may be considered a healthier option to meat in the flexitarian diet.

In conclusion plant-based meat and dairy analogues offer a wide variety of options to vegans and those looking to reduce their meat intake. Increasing the nutritional education for both manufacturers and consumers on the recommended daily intake (RDI) of both macro and micronutrients is needed to avoid over consumption of UPFs and prevent nutrient deficiency. However, further longitudinal studies are needed to determine if vegans will adapt to the healthier whole food vegan diet in the long term.

References

Agency, F. S. (2020). Check the label. Retrieved from https://www.eurofins.de/food-analysis/food-news/food-testing-news/nutri-score/

Akharume, F. U., Aluko, R. E., & Adedeji, A. A. (2021). Modification of plant proteins for improved functionality: A review. *Comprehensive Reviews in Food Science and Food Safety, 20*(1), 198-224. doi:https://doi.org/10.1111/1541-4337.12688

Alae-Carew, C., Green, R., Stewart, C., Cook, B., Dangour, A. D., & Scheelbeek, P. F. D. (2021). The role of plant-based alternative foods in sustainable and healthy food systems: Consumption trends in the UK. *Sci Total Environ*, 151041. doi:10.1016/j.scitotenv.2021.151041

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. Retrieved from https://www.mdpi.com/2072-6643/13/12/4225

American vegan society. (1960-2021). American vegan society. *Vegan is.* Retrieved from https://americanvegan.org/vegan-is/

Australian trade and investment commission. (2022, 2022). Export Markets New Zealand. Retrieved from https://www.austrade.gov.au/australian/export/export-markets/countries/new-zealand/industries/food-and-beverage

Axworthy. N. (2018). https://vegnews.com/2018/12/veganism-is-now-cool-according-to-social-scientists. Retrieved from https://vegnews.com/2018/12/veganism-is-now-cool-according-to-social-scientists

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

Bali, A., & Naik, R. (2023). The Impact of a Vegan Diet on Many Aspects of Health: The Overlooked Side of Veganism. *Cureus, 15*(2).

Beal, T., Ortenzi, F., & Fanzo, J. (2023). Estimated micronutrient shortfalls of the EAT-Lancet planetary health diet. *Lancet Planet Health, 7*(3), e233-e237. doi:10.1016/s2542-5196(23)00006-2

Bharti, B. K., Badshah, J., & Beniwal, B. (2021). A review on comparison between bovine milk and plant based coconut milk. *Journal of Pharmaceutical Innovation, 10*(3), 374-378.

BK. (2021). International Locations. Retrieved from https://www.bk.com/international

Bocker, R., & Silva, E. K. (2022). Innovative technologies for manufacturing plant-based non-dairy alternative milk and their impact on nutritional, sensory and safety aspects. *Future Foods, 5*, 100098. doi:https://doi.org/10.1016/j.fufo.2021.100098

Boukid, F., Lamri, M., Dar, B. N., Garron, M., & Castellari, M. (2021). Vegan Alternatives to Processed Cheese and Yogurt Launched in the European Market during 2020: A Nutritional Challenge? *Foods, 10*(11). doi:10.3390/foods10112782

BPACNZ. (2021). Plant-based diets: are they healthy for a child? . Retrieved from https://bpac.org.nz/2021/plant-based-diets.aspx

Brennan, J. L., Keerati, U. R. M., Yin, H., Daoust, J., Nonnotte, E., Quinquis, L., . . . Bolster, D. R. (2019). Differential Responses of Blood Essential Amino Acid Levels Following Ingestion of High-Quality Plant-Based Protein Blends Compared to Whey Protein-A Double-Blind Randomized, Cross-Over, Clinical Trial. *Nutrients, 11*(12). doi:10.3390/nu11122987

Brytek-Matera, A. (2020). Interaction between Vegetarian Versus Omnivorous Diet and Unhealthy Eating Patterns (Orthorexia Nervosa, Cognitive Restraint) and Body Mass Index in Adults. *Nutrients, 12*(3), 646. Retrieved from https://www.mdpi.com/2072-6643/12/3/646

Burgerking. (2021a). Plant Based. Retrieved from https://www.burgerking.co.nz/menu/plant_based

Burgerking. (2021b). Plant Based, have burger king your way. Retrieved from https://www.burgerking.co.za/veggie-kings
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). doi:10.3390/nu11102365
Butola, L. K., Kanyal, D., & Ambad, R. (2021). Vegetarian Diet-Dealing with Efficiency and Deficiency of It-A Review.
Chalupa-Krebzdak, S., Long, C. J., & Bohrer, B. M. (2018). Nutrient density and nutritional value of milk and plant-based milk alternatives. *International Dairy Journal, 87*, 84-92. doi:https://doi.org/10.1016/j.idairyj.2018.07.018
Clegg, M. E., Tarrado Ribes, A., Reynolds, R., Kliem, K., & Stergiadis, S. (2021). A comparative assessment of the nutritional composition of dairy and plant-based dairy alternatives available for sale in the UK and the implications for consumers' dietary intakes. *Food Research International, 148*, 110586. doi:https://doi.org/10.1016/j.foodres.2021.110586
Collard, K. M., & McCormick, D. P. (2021). A Nutritional Comparison of Cow's Milk and Alternative Milk Products. *Academic Pediatrics, 21*(6), 1067-1069. doi:https://doi.org/10.1016/j.acap.2020.12.007
Cormick, G., & Belizán, J. M. (2019). Calcium Intake and Health. *Nutrients, 11*(7), 1606. Retrieved from https://www.mdpi.com/2072-6643/11/7/1606
Craig, W. J., Mangels, A. R., & Brothers, C. J. (2022). Nutritional Profiles of Non-Dairy Plant-Based Cheese Alternatives. *Nutrients, 14*(6), 1247. Retrieved from https://www.mdpi.com/2072-6643/14/6/1247
Curtain, F., & Grafenauer, S. (2019). Plant-Based Meat Substitutes in the Flexitarian Age: An Audit of Products on Supermarket Shelves. *Nutrients, 11*(11). doi:10.3390/nu11112603
Curtain, F., & Grafenauer, S. (2019). Plant-Based Meat Substitutes in the Flexitarian Age: An Audit of Products on Supermarket Shelves. *Nutrients, 11*(11), 2603. Retrieved from https://www.mdpi.com/2072-6643/11/11/2603
Dagnelie, P. C., & Mariotti, F. (2017). In F. Mariotti (Ed.), *Vegetarian and Plant-Based Diets in Health and Disease Prevention* (pp. 3-10): Academic Press.
Derbyshire, E. (2019). Are all 'ultra-processed' foods nutritional demons? A commentary and nutritional profiling analysis. *Trends in Food Science & Technology, 94*, 98-104. doi:https://doi.org/10.1016/j.tifs.2019.08.023
Dodd, R., Santos, J. A., Tan, M., Campbell, N. R. C., Ni Mhurchu, C., Cobb, L., . . . Webster, J. (2020). Effectiveness and Feasibility of Taxing Salt and Foods High in Sodium: A Systematic Review of the Evidence. *Advances in Nutrition, 11*(6), 1616-1630. doi:10.1093/advances/nmaa067
Drewnowski, A. (2021). Perspective: Identifying Ultra-Processed Plant-Based Milk Alternatives in the USDA Branded Food Products Database. *Advances in Nutrition, 12*(6), 2068-2075. doi:10.1093/advances/nmab089
Dunn, K. (2019). Kaimangatanga Maori Perspectives on Veganism and Plant-based Kai. *Animal Studies Journal, Vol. 8* (1/4), 42-65. doi:https://ro.uow.edu.au/asj/vol8/iss1/4
Dyett, P. A., Sabate, J., Haddad, E., Rajaram, S., & Shavlik, D. (2013). Vegan lifestyle behaviors. An exploration of congruence with health-related beliefs and assessed health indices. *Appetite, 67*, 119-124. doi:https://doi.org/10.1016/j.appet.2013.03.015
Ems, T., St Lucia, K., & Huecker, M. R. (2022). Biochemistry, iron absorption. In *StatPearls [internet]*: StatPearls Publishing.
Estell, M., Hughes, J., & Grafenauer, S. (2021). Plant Protein and Plant-Based Meat Alternatives: Consumer and Nutrition Professional Attitudes and Perceptions. *Sustainability, 13*(3). doi:10.3390/su13031478
eurofins. (2023). The Nutri-Score – all important facts and novelties about the application at a glance. Retrieved from https://www.eurofins.de/food-analysis/food-news/food-testing-news/nutri-score/
European Vegetarian Union. (2011). European Vegetarian Union. Retrieved from https://www.euroveg.eu/?s=definition

Fabien Magne, M. G., Ramadass Balamurugan. (2020). The Firmicutes/Bacteroidetes Ratio: A Relevant Marker of Gut Dysbiosis in Obese Patients? *Nutrients, 12*(5), 1474. doi:doi: 10.3390/nu12051474

Fanelli, N. S., Bailey, H. M., Thompson, T. W., Delmore, R., Nair, M. N., & Stein, H. H. (2022). Digestible indispensable amino acid score (DIAAS) is greater in animal-based burgers than in plant-based burgers if determined in pigs. *European Journal of Nutrition, 61*(1), 461-475. doi:10.1007/s00394-021-02658-1

Fardet, A., & Rock, E. (2019). Ultra-processed foods: A new holistic paradigm? *Trends in Food Science & Technology, 93*, 174-184. doi:10.1016/j.tifs.2019.09.016

Flanagan, J. (2022). The big wins for shoppers in the government's supermarket shake-up. *The Spinoff.* Retrieved from https://thespinoff.co.nz/business/07-06-2022/the-big-wins-for-shoppers-in-the-governments-supermarket-shake-up

Flexitarianisim. (2007, 2013). For Abused, Confused, & Misused Words. Retrieved from https://www.thefreedictionary.com/Flexitarianism

Flint, M., Bowles, S., Lynn, A., & Paxman, J. R. (2023). Novel plant-based meat alternatives: future opportunities and health considerations. *Proceedings of the Nutrition Society*, 1-16. doi:10.1017/S0029665123000034

Food Frontier. (2019). Hungry for Plant-Based:

New Zealand

Consumer Insights. Retrieved from https://www.foodfrontier.org/wp-content/uploads/2019/10/Hungry-For-Plant-Based-New-Zealand-Consumer-Insights-Oct-2019.pdf

Food Frontier. (2022). Sustainable Foods nets sustainability funding. Retrieved from https://www.foodfrontier.org/sustainable-foods-nets-sustainability-funding/

Food Standards Agency Australia and New Zealand. (2002). *Calcium Fortification*. Retrieved from Food Standards Australia and New Zealand: https://www.foodstandards.gov.au/code/applications/documents/A424%20DAR%20-%20Calcium%20Fortification.pdf

Fresan, U., & Rippin, H. (2021). Nutritional Quality of Plant-Based Cheese Available in Spanish Supermarkets: How Do They Compare to Dairy Cheese? *Nutrients, 13*(9). doi:10.3390/nu13093291

Gallagher, C. T., Hanley, P., & Lane, K. E. (2021). Pattern analysis of vegan eating reveals healthy and unhealthy patterns within the vegan diet. *Public Health Nutr*, 1-11. doi:10.1017/S136898002100197X

Garg, M. K., & Mahalle, N. (2019). Calcium Supplementation: Why, Which, and How? *Indian J Endocrinol Metab, 23*(4), 387-390. doi:10.4103/2230-8210.268505

Gehring, J., Touvier, M., Baudry, J., Julia, C., Buscail, C., Srour, B., . . . Alles, B. (2021). Consumption of Ultra-Processed Foods by Pesco-Vegetarians, Vegetarians, and Vegans: Associations with Duration and Age at Diet Initiation. *J Nutr, 151*(1), 120-131. doi:10.1093/jn/nxaa196

Gehring, J., Touvier, M., Baudry, J., Julia, C., Buscail, C., Srour, B., . . . Allès, B. (2020). The consumption of ultra-processed foods by fish-eaters, vegetarians and vegans is associated with the duration and commencing age of diet. *Proceedings of the Nutrition Society, 79*(OCE2), E467. doi:10.1017/S0029665120004152

Ghandi, M. (2018). Muslims and food: What can be eaten safely and what should be avoided as per Islamic law Retrieved from https://www.firstpost.com/india/muslims-and-food-what-can-be-eaten-safely-and-what-should-be-avoided-as-per-islamic-law-4336851.html

Gibson, R. S., Bailey, K. B., Parnell, W. R., Wilson, N., & Ferguson, E. L. (2011). Higher risk of zinc deficiency in New Zealand Pacific school children compared with their Māori and European counterparts: a New Zealand national survey. *Br J Nutr, 105*(3), 436-446. doi:10.1017/s0007114510003569

Górska-Warsewicz, H., Laskowski, W., Kulykovets, O., Kudlińska-Chylak, A., Czeczotko, M., & Rejman, K. (2018). Food Products as Sources of Protein and Amino Acids-The Case of Poland. *Nutrients, 10*(12). doi:10.3390/nu10121977

Greenebaum, J. (2015). Veganism, Identity and the Quest for Authenticity. *Food, Culture & Society, 15*(1), 129-144. doi:10.2752/175174412x13190510222101

Greenpeace. (2020). 4 world cultures and religions that embrace plant-based eating. Retrieved from https://www.greenpeace.org.uk/news/world-cultures-and-religions-plant-based-vegetarian-vegan-diet/

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-Sourced Foods in a Representative Sample of New Zealand Adults. *Medical Sciences Forum, 18*(1), 11. Retrieved from https://www.mdpi.com/2673-9992/18/1/11

Haas, R., Schnepps, A., Pichler, A., & Meixner, O. (2019). Cow Milk versus Plant-Based Milk Substitutes: A Comparison of Product Image and Motivational Structure of Consumption. *Sustainability, 11*(18), 5046. Retrieved from https://www.mdpi.com/2071-1050/11/18/5046

Harnack, L., Mork, S., Valluri, S., Weber, C., Schmitz, K., Stevenson, J., & Pettit, J. (2021). Nutrient Composition of a Selection of Plant-Based Ground Beef Alternative Products Available in the United States. *Journal of the Academy of Nutrition and Dietetics, 121*(12), 2401-2408.e2412. doi:https://doi.org/10.1016/j.jand.2021.05.002

Heaney, R. P., & Rafferty, K. (2006). The settling problem in calcium-fortified soybean drinks. *J Am Diet Assoc, 106*(11), 1753; author reply 1755. doi:10.1016/j.jada.2006.08.008

Henderson, L. (2022). Plant-based, vegetarian and vegan diets. Retrieved from https://www.heartfoundation.org.nz/wellbeing/healthy-eating/nutrition-facts/plant-based-vegetarian-vegan-diets

Henjum, S., Groufh-Jacobsen, S., Stea, T. H., Tonheim, L. E., & Almendingen, K. (2021). Iron Status of Vegans, Vegetarians and Pescatarians in Norway. *Biomolecules, 11*(3), 454. Retrieved from https://www.mdpi.com/2218-273X/11/3/454

Herald., N. (2020). *New Zealand ranks fith in the World fr veganisim*. New Zealand Herald: New Zealand Herald.

Hertzler, S. R., Lieblein-Boff, J. C., Weiler, M., & Allgeier, C. (2020). Plant Proteins: Assessing Their Nutritional Quality and Effects on Health and Physical Function. *Nutrients, 12*(12), 3704. Retrieved from https://www.mdpi.com/2072-6643/12/12/3704

Huang, M., Mehany, T., Xie, W., Liu, X., Guo, S., & Peng, X. (2022). Use of food carbohydrates towards the innovation of plant-based meat analogs. *Trends in Food Science & Technology, 129*, 155-163. doi:https://doi.org/10.1016/j.tifs.2022.09.021

Ito, H., Kurokawa, H., & Matsui, H. (2021). Mitochondrial reactive oxygen species and heme, non-heme iron metabolism. *Arch Biochem Biophys, 700*, 108695. doi:10.1016/j.abb.2020.108695

Jallinoja, P., Vinnari, M., & Niva, M. (2020). Veganism and plant-based eating:

analysis of interplay between discursive strategies and lifestyle

political consumerism. *The Oxford Handbook of Political Consumerism*, 1-31.

Jallinoja, P., Vinnari, M. V., & Niva, M. (2020). Veganism and plant-based eating: Analysis of interplay between discursive strategies and lifestyle political consumerism. *Oxford Handbook of Political Consumerism*.

Johnson, M. A. (2007). If high folic acid aggravates vitamin B12 deficiency what should be done about it? *Nutr Rev, 65*(10), 451-458. doi:10.1111/j.1753-4887.2007.tb00270.x

Kaminski, M., Skonieczna-Zydecka, 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. doi:10.1016/j.nut.2020.110759

Karunasiri, A. N., Gunawardane, M., Senanayake, C. M., Jayathilaka, N., & Seneviratne, K. N. (2020). Antioxidant and Nutritional Properties of Domestic and Commercial Coconut Milk Preparations. *International Journal of Food Science, 2020*, 3489605. doi:10.1155/2020/3489605

Keerthana Priya, R., Rawson, A., Vidhyalakshmi, R., & Jagan Mohan, R. (2022). Development of vegan sausage using banana floret (Musa paradisiaca) and jackfruit (Artocarpus heterophyllus Lam.) as a meat substitute: Evaluation of textural, physico-chemical and sensory characteristics. *Journal of Food Processing and Preservation, 46*(1), e16118. doi:https://doi.org/10.1111/jfpp.16118

Kent, G., Kehoe, L., Flynn, A., & Walton, J. (2022). Plant-based diets: a review of the definitions and nutritional role in the adult diet. *Proceedings of the Nutrition Society, 81*(1), 62-74. doi:10.1017/S0029665121003839

KFC. (2022). Locations. Retrieved from https://global.kfc.com/our-locations/

Kołodziejczak, K., Onopiuk, A., Szpicer, A., & Poltorak, A. (2022). Meat Analogues in the Perspective of Recent Scientific Research: A Review. *Foods, 11*(1), 105. Retrieved from https://www.mdpi.com/2304-8158/11/1/105

Kyriakopoulou, K., Dekkers, B., & van der Goot, A. J. (2019). In C. M. Galanakis (Ed.), *Sustainable Meat Production and Processing* (pp. 103-126): Academic Press.

Lal, A. (2020). Iron in Health and Disease: An Update. *The Indian Journal of Pediatrics, 87*(1), 58-65. doi:10.1007/s12098-019-03054-8

Lane, K. E., Wilson, M., Hellon, T. G., & Davies, I. G. (2022). Bioavailability and conversion of plant based sources of omega-3 fatty acids – a scoping review to update supplementation options for vegetarians and vegans. *Critical Reviews in Food Science and Nutrition, 62*(18), 4982-4997. doi:10.1080/10408398.2021.1880364

Lauber, K., Rutter, H., & Gilmore, A. B. (2021). Big food and the World Health Organization: a qualitative study of industry attempts to influence global-level non-communicable disease policy. *BMJ Global Health, 6*(6), e005216. doi:10.1136/bmjgh-2021-005216

Lawrence, A. S., Huang, H., Johnson, B. J., & Wycherley, T. P. (2023). Impact of a Switch to Plant-Based Foods That Visually and Functionally Mimic Animal-Source Meat and Dairy Milk for the Australian Population—A Dietary Modelling Study. *Nutrients, 15*(8), 1825. Retrieved from https://www.mdpi.com/2072-6643/15/8/1825

Le, L. T., & Sabate, J. (2014). Beyond meatless, the health effects of vegan diets: findings from the Adventist cohorts. *Nutrients, 6*(6), 2131-2147. doi:10.3390/nu6062131

Lockwood, A. (2021). The Vegan KitKat Dilemma: Should Vegans Support Nestlé? . Retrieved from https://plantbasednews.org/opinion/opinion-piece/vegan-kitkat-should-vegans-support-nestle/

Loedin, A. K., & Speijer, D. (2021). Is There a Carcinogenic Risk Attached to Vitamin B12 Deficient Diets and What Should We Do About It? Reviewing the Facts. *Molecular Nutrition & Food Research, 65*(6), 2000945. doi:https://doi.org/10.1002/mnfr.202000945

Malek, L., & Umberger, W. J. (2021). Distinguishing meat reducers from unrestricted omnivores, vegetarians and vegans: A comprehensive comparison of Australian consumers. *Food Quality and Preference, 88*. doi:10.1016/j.foodqual.2020.104081

Manus, J., Millette, M., Uscanga, B. R. A., Salmieri, S., Maherani, B., & Lacroix, M. (2021). In vitro protein digestibility and physico-chemical properties of lactic acid bacteria fermented beverages enriched with plant proteins. *J Food Sci, 86*(9), 4172-4182. doi:10.1111/1750-3841.15859

Marinangeli, C. P. F., & House, J. D. (2017). Potential impact of the digestible indispensable amino acid score as a measure of protein quality on dietary regulations and health. *Nutrition Reviews, 75*(8), 658-667. doi:10.1093/nutrit/nux025

Mariseva, A., & Beitane, I. (2020). *Assessment of ingredients and nutritional value of vegan products in Latvian market*. Paper presented at the Research for Rural Development 2020 : annual 26th International scientific conference proceedings.

McClements, D. J., & Grossmann, L. (2021). A brief review of the science behind the design of healthy and sustainable plant-based foods. *npj Science of Food, 5*(1), 17. doi:10.1038/s41538-021-00099-y

McDonalds. (2017-2019). Franchising Overview. Retrieved from https://corporate.mcdonalds.com/corpmcd/franchising-overview.html

Mente, A., O'Donnell, M., & Yusuf, S. (2021). Sodium Intake and Health: What Should We Recommend Based on the Current Evidence? *Nutrients, 13*(9), 3232. Retrieved from https://www.mdpi.com/2072-6643/13/9/3232

Mills, J. L., Molloy, A. M., & Reynolds, E. H. (2018). Do the benefits of folic acid fortification outweigh the risk of masking vitamin B(12) deficiency? *Bmj, 360*, k724. doi:10.1136/bmj.k724
Milman, N. T. (2020). A Review of Nutrients and Compounds, Which Promote or Inhibit Intestinal Iron Absorption: Making a Platform for Dietary Measures That Can Reduce Iron Uptake in Patients with Genetic Haemochromatosis. *Journal of Nutrition and Metabolism, 2020*, 7373498. doi:10.1155/2020/7373498
MOH. (2021). Sodium added to food. Retrieved from https://www.mpi.govt.nz/food-safety-home/nutrients-added-food/sodium-added-to-food/
Monteiro, C. A., Levy, R. B., Claro, R. M., Castro, I. R. R. d., & Cannon, G. (2010). A new classification of foods based on the extent and purpose of their processing. *Cadernos de saude publica, 26*, 2039-2049.
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. doi:10.1007/s13679-014-0092-0
MPI. (2021). New food technology brings vegetables centre stage. Retrieved from https://www.mpi.govt.nz/news/media-releases/new-food-technology-brings-vegetables-centre-stage/
MPI. (2022a). Health and nutrition content claims for food and drink. Retrieved from https://www.mpi.govt.nz/food-business/labelling-composition-food-drinks/health-and-nutrition-content-claims-for-food-and-drink/
MPI. (2022b). *Leaf Protein Research and Development Programme*. Ministry of promary industries Retrieved from https://www.mpi.govt.nz/funding-rural-support/sustainable-food-fibre-futures/current-sff-futures-projects/sff-futures-projects-alternative-proteins/
National health and medical research council. (2005). *Calcium*. Retrieved from Australian government of health and ageing: https://www.foodstandards.gov.au/code/applications/documents/A424%20DAR%20-%20Calcium%20Fortification.pdf
National Institute for health. (2021). Zinc - Fact Sheet for Health Professionals. Retrieved from https://ods.od.nih.gov/factsheets/Zinc-HealthProfessional/
National Institutes of Health. (2022). Vitamin B12. In. National Institutes of health.
New Zealand Herald. (2020). New Zealand ranks fifth in the world for veganism. Retrieved from https://www.nzherald.co.nz/lifestyle/new-zealand-ranks-fifth-in-the-world-for-veganism/2KLKTB4UHNBFQPITTSNXNEO56U/
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*. doi:10.1016/j.foodqual.2021.104246
Nunes., K. (2020). Vegan claims on the upswing as plant-based innovation accelerates. *Food Business News*. Retrieved from https://www.foodbusinessnews.net/articles/15251-vegan-claims-on-the-upswing-as-plant-based-innovation-accelerates
Nutrient Reference Values for Australia and New Zealand. (2006). Zinc. Retrieved from https://www.eatforhealth.gov.au/nutrient-reference-values/nutrients/zinc
Nutrition Foundation NZ. (2022). Protein. Retrieved from https://nutritionfoundation.org.nz/nutrition-facts/nutrients/protein/
NZ Nutrition Foundation. (2009-2018). Zinc. Retrieved from https://nutritionfoundation.org.nz/nutrition-facts/nutrients/minerals/zinc/
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. *Front Nutr, 9*, 852936. doi:10.3389/fnut.2022.852936
Orlich, M. J., Singh, P. N., Sabate, J., Jaceldo-Siegl, K., Fan, J., Knutsen, S., . . . Fraser, G. E. (2013). Vegetarian dietary patterns and mortality in Adventist Health Study 2. *JAMA Intern Med, 173*(13), 1230-1238. doi:10.1001/jamainternmed.2013.6473

Paul, A. A., Kumar, S., Kumar, V., & Sharma, R. (2020). Milk Analog: Plant based alternatives to conventional milk, production, potential and health concerns. *Critical Reviews in Food Science and Nutrition, 60*(18), 3005-3023. doi:10.1080/10408398.2019.1674243

Peacock, M. (2021). Phosphate Metabolism in Health and Disease. *Calcified Tissue International, 108*(1), 3-15. doi:10.1007/s00223-020-00686-3

Perron, N. R., & Brumaghim, J. L. (2009). A Review of the Antioxidant Mechanisms of Polyphenol Compounds Related to Iron Binding. *Cell Biochemistry and Biophysics, 53*(2), 75-100. doi:10.1007/s12013-009-9043-x

Phillips, S. (2017). Current Concepts and Unresolved Questions in Dietary Protein Requirements and Supplements in Adults. *Frontiers in Nutrition, 4*. doi:10.3389/fnut.2017.00013

Piskin, E., Cianciosi, D., Gulec, S., Tomas, M., & Capanoglu, E. (2022). Iron Absorption: Factors, Limitations, and Improvement Methods. *ACS Omega, 7*(24), 20441-20456. doi:10.1021/acsomega.2c01833

Qin, P., Wang, T., & Luo, Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. *Journal of Agriculture and Food Research*.

R. Mangels, P., RD. (2022). Vegan Processed Foods. Retrieved from https://www.vrg.org/journal/vj2022issue1/2022_issue1_vegan_processed_foods.php

Radnitz, C., Beezhold, B., & DiMatteo, J. (2015). Investigation of lifestyle choices of individuals following a vegan diet for health and ethical reasons. *Appetite, 90*, 31-36. doi:10.1016/j.appet.2015.02.026

Rashid, S., Meier, V., & Patrick, H. (2021). Review of Vitamin B12 deficiency in pregnancy: a diagnosis not to miss as veganism and vegetarianism become more prevalent. *European Journal of Haematology, 106*(4), 450-455.

Read, S. A., Obeid, S., Ahlenstiel, C., & Ahlenstiel, G. (2019). The Role of Zinc in Antiviral Immunity. *Advances in Nutrition, 10*(4), 696-710. doi:https://doi.org/10.1093/advances/nmz013

Report Buyer. (2017). Top Trends in Prepared Foods 2017: Exploring trends in meat, fish and seafood; pasta, noodles and rice; prepared meals; savory deli food; soup; and meat substitutes. Retrieved from https://www.reportbuyer.com/product/4959853/top-trends-in-prepared-foods-exploring-trends-in-meat-fish-and-seafood-pasta-noodles-and-rice-prepared-meals-savory-deli-food-soup-and-meat-substitutes.html

Rizzolo-Brime, L., Orta-Ramirez, A., Puyol Martin, Y., & Jakszyn, P. (2023). Nutritional Assessment of Plant-Based Meat Alternatives: A Comparison of Nutritional Information of Plant-Based Meat Alternatives in Spanish Supermarkets. *Nutrients, 15*(6), 1325. Retrieved from https://www.mdpi.com/2072-6643/15/6/1325

Romão, B., Botelho, R. B. A., Torres, M. L., Maynard, D. d. C., de Holanda, M. E. M., Borges, V. R. P., . . . Zandonadi, R. P. (2023). Nutritional Profile of Commercialized Plant-Based Meat: An Integrative Review with a Systematic Approach. *Foods, 12*(3), 448. Retrieved from https://www.mdpi.com/2304-8158/12/3/448

Sá, A. G. A., Moreno, Y. M. F., & Carciofi, B. A. M. (2020). Food processing for the improvement of plant proteins digestibility. *Critical Reviews in Food Science and Nutrition, 60*(20), 3367-3386. doi:10.1080/10408398.2019.1688249

Saari, e. a. (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. doi:https://doi.org/10.1016/j.tifs.2020.10.003

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. doi:https://doi.org/10.1016/j.tifs.2020.10.003

Sakkas, H., Bozidis, P., Touzios, C., Kolios, D., Athanasiou, G., Athanasopoulou, E., . . . Gartzonika, C. (2020). Nutritional Status and the Influence of the Vegan Diet on the Gut Microbiota and Human Health. *Medicina (Kaunas), 56*(2). doi:10.3390/medicina56020088

Sakr, M. F. (2022). Calcium: Why Is It Important? In M. F. Sakr (Ed.), *Parathyroid Gland Disorders: Controversies and Debates* (pp. 47-80). Cham: Springer International Publishing.

Schiavone, S., Pelullo, C. P., & Attena, F. (2019). Patient Evaluation of Food Waste in Three Hospitals in Southern Italy. *International Journal of Environmental Research and Public Health, 16*(22), 4330. Retrieved from https://www.mdpi.com/1660-4601/16/22/4330

Schreuders, F., Dekkers, B., Bodnár, I., Erni, P., Boom, R., & Goot, A. J. (2019). Comparing structuring potential of pea and soy protein with gluten for meat analogue preparation. *Journal of Food Engineering, 261*. doi:10.1016/j.jfoodeng.2019.04.022

Schuster, M. J., Wang, X., Hawkins, T., & Painter, J. E. (2018). Comparison of the Nutrient Content of Cow's Milk and Nondairy Milk Alternatives: What's the Difference? *Nutrition Today, 53*(4), 153-159. doi:10.1097/nt.0000000000000284

Seventh-Day Adventist Diet. (2021). The Seventh Day Adventist Diet Food Beliefs. Retrieved from https://www.seventhdayadventistdiet.com/the-seventh-day-adventist-diet-food-beliefs/

Sha, L., & Xiong, Y. L. (2020). Plant protein-based alternatives of reconstructed meat: Science, technology, and challenges. *Trends in Food Science & Technology, 102*, 51-61. doi:https://doi.org/10.1016/j.tifs.2020.05.022

Shalee, H., Rhianna, Morgan.,. (2021). Defining a Plant-Based Diet - What are New

Zealanders Being Exposed to? Retrieved from https://nutritionfoundation.org.nz/wp-content/uploads/2021/12/Defining-a-Plant-Based-Diet.pdf

Shubham, K., Anukiruthika, T., Dutta, S., Kashyap, A. V., Moses, J. A., & Anandharamakrishnan, C. (2020). Iron deficiency anemia: A comprehensive review on iron absorption, bioavailability and emerging food fortification approaches. *Trends in Food Science & Technology, 99*, 58-75. doi:https://doi.org/10.1016/j.tifs.2020.02.021

Silveira, J. A. C. d., Meneses, S. S., Quintana, P. T., & Santos, V. d. S. (2017). Association between overweight and consumption of ultra-processed food and sugar-sweetened beverages among vegetarians. *Revista de Nutrição, 30*(4), 431-441. doi:10.1590/1678-98652017000400003

Sintia Molina, G. F. T. (2022). Eating, Community, Culture and Language: A Green Garden Approach. *Environmental Sciences proceedings, 15*(1). doi:doi.org/10.3390/environsciproc2022015020

Sisay, T., Tolessa, T., & Mekonen, W. (2020). Changes in biochemical parameters by gender and time: Effect of short-term vegan diet adherence. *PLoS One, 15*(8), e0237065. doi:10.1371/journal.pone.0237065

Skolmowska, D., & Głąbska, D. (2019). Analysis of Heme and Non-Heme Iron Intake and Iron Dietary Sources in Adolescent Menstruating Females in a National Polish Sample. *Nutrients, 11*(5), 1049. Retrieved from https://www.mdpi.com/2072-6643/11/5/1049

Soryl, Y. (2022). Focus on: Vegan product catagories in Australia and New Zealand 2022. Retrieved from https://www.vegansociety.com/sites/default/files/uploads/downloads/Vegan%20Categories%20Report%20-%20Australia%20and%20New%20Zealand%202022.pdf

Speer, H., D'Cunha, N. M., Botek, M., McKune, A. J., Sergi, D., Georgousopoulou, E., . . . Naumovski, N. (2019). The Effects of Dietary Polyphenols on Circulating Cardiovascular Disease Biomarkers and Iron Status: A Systematic Review. *Nutr Metab Insights, 12*, 1178638819882739. doi:10.1177/1178638819882739

Statista. (2020). Countries ranked by popularity of veganism worldwide in 2020, based on Google popularity Retrieved from https://www.statista.com/statistics/1279421/popularity-veganism-countries-worldwide/

Statista. (2023a). Diets and nutrition in the U.S. as of March 2023 Retrieved from https://www.statista.com/forecasts/997223/diets-and-nutrition-in-the-us

Statista. (2023b). Per capita consumption of milk in New Zealand from 2017 to 2021. Retrieved from https://www.statista.com/statistics/1102885/new-zealand-per-capita-milk-consumption/

Statista. (2023c). Year-on-year (YoY) change in plant-based vegetarian or vegan diets in New Zealand from 2018 to 2021. Retrieved from https://www.statista.com/statistics/1306000/new-zealand-yoy-change-in-plant-based-vegetarian-or-vegan-diet/

Stuckrath, T. (2018). Religious Dietary Restrictions: Your Essential Quick Reference Guide. Retrieved from https://thrivemeetings.com/2018/01/religious-dietary-restrictions-guide/

Sutton, M. (2019). Vegans a 1 per cent minority in a country of meat eaters, survey finds. *ABC*. Retrieved from https://www.abc.net.au/news/2019-10-26/vegans-comprise-just-1-per-cent-of-the-population-survey-finds/11635306
The New Zealand Institute for Plant and Food Research Limited and Ministry of Health. (2018). *New Zealand Food Composition Database: New Zealand FOODFiles 2018*. Retrieved from https://www.foodcomposition.co.nz/foodfiles
The Vegan Society. (1944-2021a). The Vegan Society Retrieved from https://www.vegansociety.com/go-vegan/definition-veganism
The Vegan Society. (1944-2021b). The Vegan Society. *History.* Retrieved from https://www.vegansociety.com/about-us/history
The Vegan Society. (2021). The Vegan Society statistics. Retrieved from https://www.vegansociety.com/news/media/statistics
The Vegan Society. (2022). Vegan alternatives. Retrieved from https://vegansociety.org.nz/vegan-alternatives/
Thompson, A. (2022). *Government investment in the*

opportunities of alternative proteins - What are other countries doing and how does

Aotearoa New Zealand compare? Retrieved from EmergingProteins NZ: https://www.emergingproteins.co.nz/
Tomova, A., Bukovsky, I., Rembert, E., Yonas, W., Alwarith, J., Barnard, N. D., & Kahleova, H. (2019). The Effects of Vegetarian and Vegan Diets on Gut Microbiota. *Front Nutr, 6*, 47. doi:10.3389/fnut.2019.00047
Tonheim, L., Austad, E., Torheim, L., & Henjum, S. (2022). Plant-based meat and dairy substitutes on the Norwegian market: comparing macronutrient content in substitutes with equivalent meat and dairy products. *Journal of Nutritional Science, 11*, 1-8. doi:10.1017/jns.2022.6
Tso, R., & Forde, C. G. (2021). Unintended Consequences: Nutritional Impact and Potential Pitfalls of Switching from Animal- to Plant-Based Foods. *Nutrients, 13*(8). doi:10.3390/nu13082527
Tuso, P. J., Ismail, M. H., Ha, B. P., & Bartolotto, C. (2013). Nutritional update for physicians: plant-based diets. *Perm J, 17*(2), 61-66. doi:10.7812/TPP/12-085
Twine, R. (2017). Materially Constituting a Sustainable Food Transition: The Case of Vegan Eating Practice. *Sociology, 52*(1), 166-181. doi:10.1177/0038038517726647
Van Loo, E. J., Hoefkens, C., & Verbeke, W. (2017). Healthy, sustainable and plant-based eating: Perceived (mis)match and involvement-based consumer segments as targets for future policy. *Food Policy, 69*, 46-57. doi:10.1016/j.foodpol.2017.03.001
van Vliet, S., Kronberg, S. L., & Provenza, F. D. (2020). Plant-Based Meats, Human Health, and Climate Change. *Frontiers in Sustainable Food Systems, 4*. doi:10.3389/fsufs.2020.00128
van Wonderen, D., Melse-Boonstra, A., & Gerdessen, J. C. (2023). Iron Bioavailability Should be Considered when Modeling Omnivorous, Vegetarian, and Vegan Diets. *The Journal of Nutrition*. doi:https://doi.org/10.1016/j.tjnut.2023.05.011
Vegan Australia. (2021). Vegan Austraila. Retrieved from https://www.veganaustralia.org.au/why_vegan
Vegan Society. (2021). General statistics. *News.* Retrieved from https://www.vegansociety.com/news/media/statistics
Vegan society NZ. (2022). Vegan Society *Why be a Vegan?* Retrieved from https://www.vegansociety.org.nz/why-vegan/
Vegan.org. (2022). Certification. Retrieved from https://vegan.org/certification/
Vegetarian society NZ. (2021). Vegan Certificatiion. *About Vegetarian Approval and Vegan Certification.* Retrieved from http://www.vegetarian.org.nz/about-us/trademark-programmes/
Verduci, E., D'Elios, S., Cerrato, L., Comberiati, P., Calvani, M., Palazzo, S., . . . Peroni, D. G. (2019). Cow's Milk Substitutes for Children: Nutritional Aspects of Milk from Different Mammalian Species, Special Formula and Plant-Based Beverages. *Nutrients, 11*(8). doi:10.3390/nu11081739

Wanikorn, B., Samakradhamrongthai, R. S., & Yupanqui, C. T. (2022). Physicochemical, Nutritional, Microbiological and Sensory Qualities of the Formulated Reduced-Fat Coconut Milk Cube. *Journal of Food Technology, Siam University, 17*(2), 96-106.

Weikert, C., Trefflich, I., Menzel, J., Obeid, R., Longree, A., Dierkes, J., . . . Abraham, K. (2020). Vitamin and Mineral Status in a Vegan Diet. *Dtsch Arztebl Int, 117*(35-36), 575-582. doi:10.3238/arztebl.2020.0575

Wolfe, R. R., Rutherfurd, S. M., Kim, I. Y., & Moughan, P. J. (2016). Protein quality as determined by the Digestible Indispensable Amino Acid Score: evaluation of factors underlying the calculation. *Nutr Rev, 74*(9), 584-599. doi:10.1093/nutrit/nuw022

Wolffenbuttel, B. H. R., Wouters, H. J. C. M., Heiner-Fokkema, M. R., & van der Klauw, M. M. (2019). The Many Faces of Cobalamin (Vitamin B12) Deficiency. *Mayo Clinic Proceedings: Innovations, Quality & Outcomes, 3*(2), 200-214. doi:https://doi.org/10.1016/j.mayocpiqo.2019.03.002

Zhang, Y. Y., Stockmann, R., Ng, K., & Ajlouni, S. (2021). Opportunities for plant-derived enhancers for iron, zinc, and calcium bioavailability: A review. *Comprehensive Reviews in Food Science and Food Safety, 20*(1), 652-685. doi:https://doi.org/10.1111/1541-4337.12669