Ultra-Processed Foods and Single-Use Plastic Packaging In Home-Packed School Lunchboxes: A New Zealand Study

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A thesis submitted to Auckland University of Technology in partial fulfilment of the requirements for the degree of Master of Public Health

2023

Human Potential Centre

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Thesis Abstract

Globally, two-thirds of children experience the triple burden of malnutrition, encompassing undernutrition, micronutrient deficiencies, and overweight/obesity. The excessive consumption of ultra-processed food and drinks (UPF) leads to dietary patterns lacking nutrient-dense wholefoods. UPF have been linked to various negative health outcomes including cardiometabolic risks and asthma, and the synthetic additives in UPF have been associated with immune and endocrine disruption. Moreover, highly-processed dietary patterns inherent to current food systems contribute to environmental degradation, including greenhouse gas emissions, plastic waste, land and water pollution, and biodiversity loss. Consequently, promoting sustainable healthy diets that nourish individuals while ensuring long-term ecological sustainability has become a priority across international public health agendas.

School food environments are a key setting for promoting healthier diets among children. In New Zealand (NZ), home-packed school lunchboxes are the norm; however, research on the extent of UPF in home-packed lunchboxes in NZ is lacking, and there is limited knowledge regarding the eco-environmental impacts of these packed-lunches. Drawing upon the emerging literature in eco-nutrition, this thesis aimed to explore the healthiness and sustainability of lunchboxes in terms of their level of food processing and their environmental impact from single-use plastic packaging.

To establish the context for this work, a narrative review was performed to cover two key areas: (1) the distinctive nature of UPF and their impact on human and planetary health, and (2) healthy and sustainable diets for children, with a focus on child-centred food systems, and schools as strategic intervention settings. The review highlighted the unique metabolic effects of UPF on gut and brain health, as well as concerns associated with excessive exposure to food additives, particularly in children. It also emphasised the need to update current dietary guidelines to consider the role of food processing, food matrix, and food sustainability, as well as the need to reorient existing food systems to meet children's unique nutritional needs. The review further revealed that most school lunchboxes fail to meet dietary guidelines, and an absence of national dietary regulations and school-level lunchbox policies.

A two-part cross-sectional study was undertaken, which included 110 children from four primary schools representing different socioeconomic deciles and regions in Auckland, NZ. Lunchboxes were digitally photographed and complemented with a Lunchbox Food Checklist. Part 1 of the study aimed to assess the level of food processing in home-packed lunches and investigate the relationship with the nutritional content (energy and sugar) of lunchbox items, while Part 2 aimed to determine the proportion of single-use plastic packaging waste in lunchboxes and examine the association with the level of food processing.

In Part 1, the nutritional composition (total energy and total sugars) of lunchboxes was calculated, and lunchbox items were also categorised into one of three levels of processing (unprocessed/minimally-processed, processed, ultra-processed) based on the NOVA classification system. Statistical analyses explored differences in energy (kJ) and sugar (g) among the processing levels, while adjusting for school, gender, and who packed the child's lunch (child, parent). Results revealed that UPF accounted for approximately two-thirds of the overall energy (61.8 ±27.0%), and half of total sugars (50.4 ±31.5%) in lunchboxes. Among the 599 food items (6.0 ±1.9 items per lunchbox), sweet and savoury UP snacks were the primary contributors to energy from UPF (40%), while there was a significant lack of minimally-processed foods (13.7±16.6%) in lunchboxes. Findings were consistent across genders, schools, and lunchbox packer (child/parent).

For Part 2 of the study, the packaging of lunchbox food and drink items was categorised into four groups (single-use plastic, single-use other, reusable, no packaging), and two methods of packaging coding were employed to account for packaging removed from food at home. Analysis revealed that of 541 lunchbox packaging items, 35.6% were single-use plastic packaging (SUPP). However, when considering the original packaging (removed at home), the proportion of SUPP increased significantly to 53.2% ($p < 0.001$, $g = 0.91$). The majority of SUPP originated from UPF (76.2%), while minimally-processed foods contributed to only 0.9% of SUPP. Soft plastic bags/wrappers from UP snacks (58.8%) were the most prevalent type of SUPP in lunchboxes.

Taken together, these results show that prioritising the inclusion of whole and minimally-processed foods in home-packed lunchboxes can reduce single-use plastic packaging waste while promoting healthier and environmentally-friendlier dietary patterns in school settings. Additionally, results underscore the need for updated dietary guidance for children that consider the impact of extreme food processing on the overall healthiness and sustainability of food choices.

This body of work makes important contributions to existing literature. This is the first known study to explore the association between the level of food processing and packaging waste in lunchboxes. It provides valuable and credible data for future eco-nutrition-based research and interventions in school settings. This research contributes to the emerging field of child-centred food system research, which seeks to identify the types of foods children are currently consuming (or not consuming) to help reorient existing food systems towards increased availability and demand for healthier child-oriented product choices. Future research should prioritise gathering population-level data on children's overall UPF consumption in NZ and investigate the environmental and social-economic determinants of lunchbox food choices. Exploring the potential eco-nutrition application of the 'NOVA-SUPP' model developed in this thesis could help foster healthier and more sustainable diets for children and improve planetary health.

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Attestation of authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Fern Pereira, July 2023

Co-authored works

Papers under review, or in submission:

Pereira, F., Schofield, G., Stewart, T. (*in submission*). The relationship between nutritional content and level of processing in primary school children's lunchboxes.

Pereira, F., Schofield, G., Stewart, T. (*in submission*). The relationship between single-use plastic packaging and level of food processing in primary school children's lunchboxes.

Research chapter contributions

Chapters 3 and 4 of this thesis are under review in peer-reviewed journals. The percentage contribution of each author is presented below.

Chapter 3: The relationship between nutritional content and level of processing in primary school children's lunchboxes.

Fern Pereira……………………………………………………..………………….…..………..90%
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Chapter 4: The relationship between single-use plastic packaging and level of food processing in primary school children's lunchboxes.

Fern Pereira…………………………………………….....……………………….…...………..90%
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Acknowledgements

I could not begin in any other way than by expressing my gratitude to Professor Grant Schofield. This has been a long journey for me, as you are well aware, but you have consistently been there for me throughout this thesis process. Thank you for being the best mentor I have ever had. Not only did you continuously pushed me to achieve my best, but you have also celebrated the high points with me and shown me patience and understanding during the challenging times. Your belief in me from the very beginning, Grant, starting from when I was a student on the Nutrition and Health Promotion paper and your guidance on my presentation about 'everything there is to know' on dietary guidelines (!), to the countless brainstorming sessions we have had since, has meant the world to me. Thank you for believing in the work I do in the community and for your continuous support. I sincerely hope that we will continue to find interesting topics to debate and investigate for years to come.

I consider myself incredibly fortunate not only to have had the perfect supervisor for this thesis but also the best secondary supervisor! Tom, as I have always told you, I knew we would make a great team. Your intelligence never fails to astonish me, yet you approach everything with such a down-to-earth attitude and kindness. Thank you for teaching me so much and assisting in creating beautiful and comprehensive analyses for our studies. I am grateful for the countless times you have given me your time, listened patiently, and helped me solve problems. This thesis would not be what it is without your involvement, and I hope we will have the opportunity to collaborate again in the future.

To my parents, Mum and Dad, thank you for giving me the opportunity to return to study at this stage of my life. I love you both so much. To my daughter Julia, my grandad Jayme, and all my siblings (both biological and chosen), you know who you are — thank you so much for your ongoing support and for simply being the best.

A heartfelt thank you goes to all the schoolchildren, staff, and wider school whānau who contributed in some way with the cross-sectional study for this thesis and helped me complete my master's degree. I extend my gratitude to anyone who collaborated in any capacity, regardless of age, including schools, community contacts, collaborating individuals and businesses, and grant providers for any of the Clean Plate community projects during the thesis period and beyond. Although these community projects are not directly linked to this thesis, the practical experience I gained through my work with Clean Plate has informed my reflections and critical thinking, while the thesis work has guided the community projects. I look forward to hopefully collaborating with you and your school again in the near future.

I would like to thank everyone at AUT with whom I have been a fellow student, worked with, taught, or been a student of, including those at AUT's Human Potential and Child and Youth Health research centres.

Lastly, I want to express my appreciation to my mentor and friend, Cath Conn. Cath, thank you for believing in me and providing me with numerous opportunities at AUT. Now that I have completed my master's, I hope we can finally collaborate on a cool research project!

Yes, this has been a long and winding journey, but I am proud of what I have achieved and feel prepared for the new phase of life that lies ahead. One thing is certain: this project is what it is because each of you has contributed to shaping it in some way. My sincere gratitude to you all.

I cannot conclude without acknowledging my dear pet friend, Oliver, who recently passed away. Dear Oli, you brought so much joy to my life, and I will miss you forever. Your wise and cool attitude taught me valuable lessons, and you provided comfort when I needed it the most. Thank you for getting me through this. Rest in peace, my Bobo.⭐

Chapter 1 – Introduction

Background

Diet is a crucial determinant of health, as evidenced by its substantial contribution to the burden of disease worldwide (G. B. D. Diet Collaborators, 2019). The impact of the triple burden of malnutrition on children, encompassing undernutrition, hidden hunger, and overweight/obesity is significant; an alarming two-thirds of children worldwide are affected (UNICEF, 2019). Suboptimal diets, characterised by nutrient deficiencies or excessive consumption of unhealthy foods, can exert a detrimental impact on important aspects of children's lives, including their development, growth, academic performance, mental well-being, quality of life, and longevity (Ministry of Health, 2012). During childhood, obesity is positively associated with a range of adverse cardiometabolic, gastrointestinal, and psychological health issues. These include conditions such as asthma, sleep apnoea, high blood pressure, and food addiction, as well as factors like low self-esteem, diminished educational attainment, and increased susceptibility to severe illness from COVID-19 (Chiavaroli et al., 2019; Filgueiras et al., 2019; Reichelt & Rank, 2017; Zachariah et al., 2020). In addition, overweight and obese children are significantly more likely to experience persistent obesity as they transition into adulthood (WHO, 2016).

As children progress through different stages of life, their dietary patterns continue to be significantly influenced by a range of sociocultural, economic, and political systems that shape society (UNICEF, 2019). These systems, which encompass the environments where children live, study, and play, exert a lasting impact on food choices. The accessibility, affordability, and promotion of foods within these environments, along with prevailing social norms, play a crucial role in shaping dietary decisions over time (Fox & Timmer, 2020; Swinburn et al., 2011).

NZ currently ranks as second-worst in the OECD for childhood obesity, with 39% of Kiwi children being overweight or obese UNICEF (2019). Rates are worse for Māori and Pacific children, with odds of obesity 1.6 times greater for Māori than non-Māori children and 3.3 times greater for Pacific than non-Pacific children, respectively, as well as for children living in areas of higher deprivation (MoH, n.d) For example, in New Zealand (NZ), children residing in socio-economically deprived neighbourhoods face a staggering 2.5 times higher risk of obesity compared to children in less deprived areas (Ministry of Health, 2021). Furthermore, children attending schools in lower decile areas in NZ are disproportionally exposed to marketing of unhealthy foods in close proximity to their schools, as compared to their peers in higher decile areas (Vandevijvere et al., 2018). This exposure contributes to increased consumption of nutrient-poor, ultra-refined food and beverages, leading to a preference for such items (Sadeghirad et al., 2016). These examples serve to highlight the disproportionate burden of malnutrition experienced by specific population groups, which is underpinned by pervasive health inequities (Gibb et al., 2019).

Significant transformations in industrial food systems, driven by increased urbanisation and globalisation, have facilitated the rapid proliferation of a wide array of cheap, convenient, highly-palatable, yet nutritionally deficient foods and beverages (HLPE, 2017). These products, commonly referred to as **"ultra-processed foods" (UPF)**, represent a tangible outcome of such changes (Monteiro et al., 2018a). According to Monteiro et al. (2018a) , UPF are *"Formulations of food substances often modified by chemical processes and then assembled into ready-to-consume hyper-palatable food and drink products using flavours, colours, emulsifiers and . . . other cosmetic additives" (p. 939)*. UPF encompass a vast range of items, including well-known discretionary foods such as confectionary, fast-foods, and sugary beverages, as well as 'everyday' food items like flavoured yoghurts, reconstituted meat products, and mass-produced breads (Monteiro et al., 2018a). The dominance of UPF is evident in dietary patterns and food supply chains worldwide, contributing to over half of the total energy intake in high-income countries (Monteiro et al., 2013; Pan American Health Organization, 2015). For instance, recent data from NZ indicates that UPF account for 45%, 42%, and 51% of the average daily energy intake in young children aged 12, 24, and 60 months, respectively (Fangupo et al., 2021). Moreover, UPF constitute a staggering 83% of food items available for purchase in NZ supermarkets (Luiten et al., 2016), including numerous child-oriented UPF often marketed as 'healthy and nutritious' choices (Al-Ani et al., 2016).

UPF have garnered increased recognition in the academic literature as synonymous for unhealthy foods, with consistent links between UPF consumption and a range of adverse health outcomes across all age groups (Chen et al., 2020; Elizabeth et al., 2020). These include an increased risk of cardio-metabolic complications, asthma, dental caries, as well as higher body fat during childhood and adolescence (Cascaes et al., 2023; Costa et al., 2018; Elizabeth et al., 2020). Of particular interest, is the suggestion that the deleterious effects of UPF extend beyond their poor nutrient profile, negatively impacting metabolic mechanisms that have evolved in response to wholefood diets and safeguard against the development of diet-related non-communicable diseases (NCDs) (Dagbasi et al., 2020; Hall et al., 2019; Zinöcker & Lindseth, 2018). For instance, multiple stages of extreme food processing alter the natural structural composition of wholefoods, disrupting human digestive processes and causing imbalances in the delicate ecosystem of the gut microbiota (Dagbasi et al., 2020; Zinöcker & Lindseth, 2018). Moreover, these highly-processed foods have the potential to disrupt gut-brain appetite signals, predisposing individuals to behaviours such as binge-eating (Contreras-Rodriguez et al., 2022; Schulte et al., 2021).

Highly-processed diets high in UPF, in the context of industrial food systems, also contribute to the degradation of eco-planetary health (Fardet & Rock, 2020). The production, manufacturing, transport, retail and disposal stages of UPF typically require considerably more natural resources and have a greater environmental footprint compared to less-processed dietary patterns (Kesse-Guyot et al., 2022; Leite et al., 2022; Rivera et al., 2014; Tubiello et al., 2022). Notably, the global food system plays a pivotal role in driving climate change, with industrial agricultural activities being a major contributor to greenhouse gas emissions (Willett et al., 2019). Furthermore, the excessive reliance on single-use plastic packaging for commercially-packaged food and beverages, is a leading driver of the global plastic waste crisis, further impacting the environment through indiscriminate waste and pollution (Chakori et al., 2021; Kadac-Czapska et al., 2023). While the environmental consequences of the global food system degrade the health of the planet, adverse changes in climate and the natural environment pose significant threats to the wellbeing of populations in return (Fanzo et al., 2021). For example, climate change-induced events, such as heatwaves, floods, and wildfires, adversely impact global food security. These events disrupt agricultural production, leading to reduced food yields and decimated staple crops (McMichael, 2013), in turn contributing to food inaccessibility and increased food costs (HLPE, 2017; Pérez-Escamilla, 2017). Consequently, the promotion of healthy and sustainable diets that nourish individuals while simultaneously ensuring the long-term sustainability of the natural environment for future generations has become a key focus of various international public health agendas. These include the United Nations (UN) Sustainable Development Goals (2015), the WHO/FAO Guiding Principles for Sustainable Healthy Diets (2019), the High Level Panel of Experts on Food Security and Nutrition (HLPE) Nutrition and Food Systems Report (2017), and UNICEF/GAIN's Innocenti Framework on Food Systems for Children and Adolescents (2019).

These profound shifts in population diets and food systems, along with the escalating prevalence of diet-related NCDs, and detrimental environmental consequences, have posed new challenges for traditional public health nutrition (PHN) science and action. Novel strategies and approaches are being developed within the field of PHN to address these evolving issues (Fanzo et al., 2021; Mozaffarian et al., 2018b). Of particular significance is the gradual shift in epidemiological research from focusing on nutrient profiling to exploring the intricate relationship between actual foods, their production processes, dietary patterns, and disease (Aguilera, 2019; Heindel et al., 2022; Lustig, 2020; Monteiro et al., 2019a). This paradigm shift acknowledges the comprehensive composition and characteristics of foods to better elucidate the associations between dietary patterns and health outcomes. Furthermore, the growing emphasis on planetary health has expanded the scope of PHN, demanding the integration of the multifaceted aspects of sustainable healthy diets across modern food systems (Miller et al., 2021; Seferidi et al., 2020). Consequently, addressing the complex challenges currently faced by PHN within a planetary health context demands a transdisciplinary, eco-nutrition approach (Cannon & Leitzmann, 2022; Drewnowski et al., 2020; Fanzo et al., 2021).

Thesis Rationale

According to UNICEF (2019), prioritising the unique and critical nutritional needs of children within modern food systems is essential to uphold their universal human rights to nutrition, health, and wellbeing. However, current drivers of food systems, such as food marketing and globalisation of food supplies, continue to shape children's dietary patterns towards 'less-healthy' food choices (Fox & Timmer, 2020). This poses challenges for children in achieving recommended nutrition goals and for parents and caregivers in guiding children towards more nutritious and sustainable diets (Hawkes et al., 2020; Kupka et al., 2020). Child-centred food system research aims to examine various key entry points within food systems, including supply chains (e.g., food production, processing, retail and waste disposal), personal and external food environments (e.g., households, schools, supermarkets), and the behaviours of children and caregivers (e.g., eating patterns, food preparation, socio-economic characteristics) (UNICEF, 2019). Hawkes et al. (2020) recently developed a tool based on UNICEF's Innocenti Framework (2019) which outlines six methodological steps necessary to realign existing food systems to better meet the nutritional needs of children. One of these steps involves conducting dietary assessments of children to identify gaps between dietary recommendations and actual consumption patterns. These assessments play a crucial role in guiding child-centred food systems by highlighting the specific foods that need to be provided and promoted more or less within food environments and supply chains (Hawkes et al., 2020).

UNICEF (2019) has identified schools as a key setting for child-centred food systems research. A recent study conducted in NZ found that food environments in schools remain largely unhealthy, including the promotion of unhealthy food options, failure to prioritise healthier dietary choices among schoolchildren, weak school-level nutrition policies, and a lack of official regulatory legislation by the government (D'Souza et al., 2022). Most research and health promotion efforts that have focused on healthy eating and nutrition in school settings have centred on preventing or reducing childhood obesity through conventional strategies such as limiting sugar, sodium, saturated fat, and promoting physical activity (Black et al., 2015; Micha et al., 2018). However, evidence indicates that these approaches have not yielded meaningful reductions in obesity prevalence (Micha et al., 2018; Nathan et al., 2019). Emerging literature proposes an eco-nutrition approach with an ecological sustainability focus as a promising and innovative alternative for promoting sustainable healthy diets in schools (Black et al., 2015; Goldberg et al., 2015; Jones et al., 2012; Oostindjer et al., 2017; Parker & Koeppel, 2020; Prescott et al., 2019). This approach recognises that altruism and environment concern are powerful motivators among school-aged children (Folta et al., 2018), and that combining food, sustainability, and health as an integrated educational tool is more appealing to children compared to traditional food and nutrition concepts and messages (Parker & Koeppel, 2020; Prescott et al., 2019).

In NZ, most children bring home-packed lunchboxes to school, accounting for up to one-third of their total dietary intake (Regan et al., 2008; Sanigorski et al., 2005; Sutherland et al., 2021). Other common food provision channels for NZ schoolchildren include purchasing foods at or near schools, such as from school canteens, vending machines, or through lunches delivered by external caterers. Government-funded programmes, such as the recently introduced Ka Ora Ka Ako free healthy school lunches initiative, the longstanding Fruit in Schools (FIS) programme, and other private and public-funded initiatives, like the Fonterra/Sanitarium co-sponsored Kickstart Breakfast program (KickStart Breakfast, n.d.), are also notable. Research on home-packed lunchboxes in the NZ context is limited and somewhat outdated, warranting further investigation (Dresler-Hawke et al., 2009). Previous studies examining the food and nutrient quality of lunchboxes have shown that discretionary snacks (i.e.; high in salt, sugar, fat) dominate home-packed school lunches (Dresler-Hawke et al., 2009; Regan et al., 2008; Rockell et al., 2011a), and these generally lack nutritious foods, such as vegetables (Dresler-Hawke et al., 2009). This evidence is consistent with recent studies conducted overseas, which have reported that a minority of school lunchboxes meet food and nutrition guidelines (Evans et al., 2020; Stanham et al., 2020; Sutherland et al., 2020). Furthermore, limited research has examined the extent of UPF content in home-packed school lunchboxes. Recent studies from Brazil (Barbosa et al., 2021), the UK (Parnham et al., 2022), and the US (Blondin et al., 2021) have reported concerningly high proportions of UPF in primary schoolchildren's home-packed lunches (80.0%, 81.2%, 70.0%, respectively). However, no study has investigated the processing level of children's school lunches in NZ, or explored how food processing is related to single-use plastic packaging waste.

A deeper comprehension of the food processing levels and packaging waste present in children's home-packed lunches holds the potential to decrease the consumption of UPF among schoolchildren, enhance the sustainability of these lunches, and offer valuable insights for the advancement and promotion of child-centred food systems that prioritise children's unique nutritional requirements. Given the existing knowledge gaps around the processing and environmental implications associated with lunchbox content, and the growing recognition of eco-nutrition approaches for fostering sustainable healthy diets, further research is warranted to advance understanding in this area. Therefore, the primary objectives of this thesis are:

1. To present a narrative review of the existing literature with a focus on:

    a. Examining ultra-processed foods (UPF), emphasising the impacts on human and planetary health (Chapter 2, Part 1)
    b. Examining healthy and sustainable diets for children from a Public Health eco-nutrition perspective, focusing on child-centred food systems, schools as a key setting for action, and home-packed lunchboxes (Chapter 2, Part 2).

2. To undertake a cross-sectional study on the healthiness and sustainability status of primary schoolchildren's home-packed lunchboxes in NZ, with a focus on:
    a) Describing the level of food processing in home-packed lunches among NZ primary schoolchildren (Chapter 3).
    b) Examining the relationship between the nutritional content (energy and sugar) of lunchbox food and drink items and their level of processing (Chapter 3).
    c) Determining the proportion of single-use plastic packaging in home-packed lunchboxes among NZ primary schoolchildren (Chapter 4).
    d) Examining the relationship between the single-use plastic packaging of lunchbox food and drink items and their level of processing (Chapter 4).

Thesis Structure

This thesis structure is illustrated in Figure 1-1. *In Chapter 1, the study context is introduced, including the identification of research objectives and the research rationale.* Chapter 2 presents a narrative review of the existing literature, divided into two parts. Part 1 examines UPF, with a special emphasis on their impacts on human and planetary health. Part 2 investigates healthy diets and sustainable food systems, focusing on a public health nutrition perspective. It places particular emphasis on sustainable healthy diets for children and child-centred food systems, while also exploring schools as a key setting for action. Chapters 3 and 4 are two distinct publications presented in chapter format. As these chapters are written as separate articles, there may be some repetition of information, such as data collection methods. Finally, Chapter 5 summarises the key findings from each study and discusses their limitations. It also highlights the implications for future work, both in terms of scientific research and the broader societal relevance.

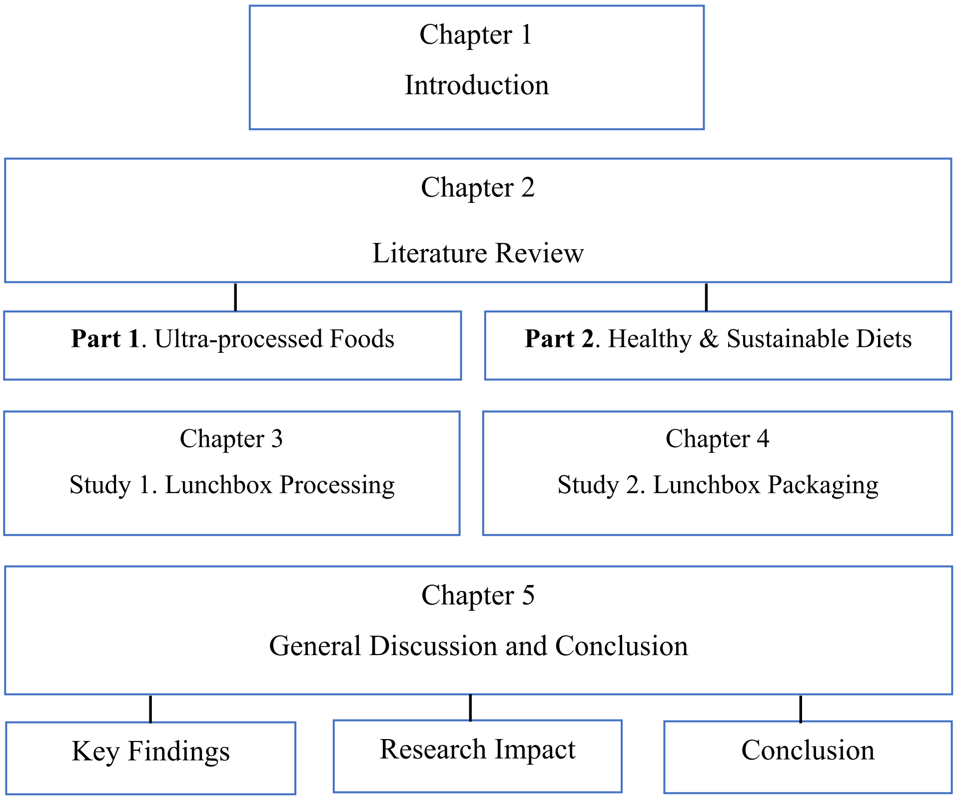


Figure 1-1. Structure of the thesis

Chapter 2 – Literature Review

Preface

The following literature review chapter establishes the thesis context in preparation for subsequent research chapters. The review is organised into two parts. Part 1 covers the distinct nature of ultra-processed foods and their impact on human and planetary health. Part 2 focuses on healthy and sustainable diets for children from a public health eco-nutrition perspective. Specifically, this covers child-centred food systems, schools as a strategic setting for intervention, and the significance of home-packed school lunchboxes.

Part one: Ultra-processed foods, impacts on human and planetary health

Introduction

Most foods that are purchased and consumed undergo some form of processing (Monteiro et al., 2018a). This is true even for minimally-processed, nutrient-dense foods, such as frozen vegetables, pasteurised milk, and brown rice. Food processing has been a practice since ancient times, with humans continuously improving methods to preserve fresh produce for longer periods, enhance taste, and ensure safety for consumption (Knorr & Watzke, 2019; Silva et al., 2018). Food processing benefits include providing a consistent, safe, and adequate food supply to individuals and communities. It also facilitates year-round access to a variety of nutritious foods, including out-of-season produce, and facilitates transportation of foods between various points of food systems, including manufacturers, retailers, and consumers' households (Knorr & Watzke, 2019; Silva et al., 2018). Examples of readily-available nutritious processed foods include cheese, salted nuts and seeds, and canned sardines (Monteiro et al., 2016).

However, the food industry underwent a significant transformation over the past century, with advances in agriculture and food processing technologies leading to the globalisation of food supply chains (Boye & Arcand, 2013; Lang, 2003). This was partly driven by significant migration of people from rural to urban areas and a greater demand for convenient and easy-to-prepare meals (Boye & Arcand, 2013; Lang, 2003). Consequently, food processing became no longer solely focused on ensuring longer shelf-life and food safety, but also on taste and convenience (Silva et al., 2018). In the 1980s, these shifts brought about an "explosion of flavours, colours, textures, and formats of processed foods" (Silva et al., 2018, p. 5), including pre-packaged products like instant noodles, flavoured crisps and cookies, and fluorescent-coloured sweetened beverages. Furthermore, food packaging evolved into a sophisticated and attractive means of communication between food manufacturers and consumers, with plastics becoming the predominant material used due to their low-cost and versatility (Silva et al., 2018).

Although traditional methods of food processing such as salting, fermentation, and pasteurisation continue to be used by food manufacturers of all sizes, a significant portion of current industrial food production utilises extreme processing techniques and non-food substances that were previously not used in food production. This has given rise to a category of processed foods that differ from traditional processed foods, commonly known as ultra-processed foods, that have transformed contemporary food supplies and dietary patterns worldwide (Monteiro et al., 2018a).

Defining Ultra-processed Foods

According to Monteiro et al. (2018a) ultra-processed foods and drinks (UPF) are not considered "real foods" in the traditional sense. Instead, they are formulated from food substances that are often modified by chemical processes and assembled into ready-to-consume hyper-palatable food and drink products using various flavours, colours, emulsifiers, and other cosmetic additives. UPF are typically made from cheaper, nutrient-poor ingredients and contain little to no intact food in their composition (Monteiro et al., 2019b). To compensate for the absence of wholefoods, UPF formulations often contain high amounts of sodium, added sugars, and ultra-refined oils, which are then combined with industrial cosmetic additives only found in this category of foods. Examples include bulking and debulking agents, emulsifiers, foaming and anti-foaming agents, artificial sweeteners, and several other additive categories which are generally not suitable or found in traditional kitchens or freshly-prepared meals (Monteiro et al., 2018a).

Moreover, UPF are industrial formulations that undergo multiple processing stages across multiple industries in the supply chain. These processes usually start with the fractioning of wholefoods into single components (e.g., sugars, protein, fibre), often through extreme-processing techniques such as hydrolysis and hydrogenation (Monteiro et al., 2018a). Modified substances are then combined with unmodified and/or other modified substances and cosmetic additives in industrial processes such as extrusion, re-shaping, or moulding to assemble the final product (Monteiro et al., 2018a). For instance, maltodextrin, a widely-used modified substance derived from starchy crops, is used as binding or bulking agent to add texture and volume to foods, sweetener, substitute for oil in low-fat products, and preservative to prolong shelf-life (Chronakis, 1998; Hofman et al., 2016). Maltodextrin is only one of thousands of food additives found in UPF products (Ravichandran et al., 2022). Finally, UPF are industrially packaged into sophisticated packaging, usually single-use plastics (Muncke et al., 2017).

It is essential to note that UPF include ‘everyday’ products such as ‘fruit’ yoghurts, breakfast ‘cereals’, reconstituted meats, and mass-produced packaged bread, highlighting the importance of distinguishing the term ‘processed’ from ‘ultra-processed’ (Monteiro et al., 2018a). For instance, processed foods and drinks (PF) generally contain one to three ingredients from unprocessed/minimally-processed foods (MPF) combined with culinary ingredients such as salt, sugar, and vinegars, and occasionally, preservatives or antioxidants for food safety and shelf-life. On the other hand, UPF formulations utilise multiple food additives to perform various functions such as enhancing taste, texture, aroma, appearance, or to replace sugar, salt, and saturated fats (Monteiro et al., 2019b), When additives typically found in UPF are added to MPF and PF, these foods are classified as ultra-processed, such as natural yoghurt with added flavourings and thickeners, or mass-produced breads with added emulsifiers (Monteiro et al., 2016).

NOVA Food Classification System

The term “ultra-processed foods” was coined in 2009 by Monteiro and colleagues (2009), who posited the classification of industrial food and beverage should extend beyond the binary categorisation of processed and unprocessed. They argued that food encompasses more than nutrients, with the nature, extent, and purpose of food processing potentially influencing its healthfulness (Monteiro et al., 2019a).

To address this, they proposed the NOVA (a name, not an acronym) food classification system, which includes four categories: unprocessed or minimally-processed, culinary ingredients, processed, and ultra-processed (Monteiro et al., 2016) (Table 2-1). NOVA has gained global recognition as a valuable tool in PHN research (Chang et al., 2021; Elizabeth et al., 2020; Steele et al., 2019), and is endorsed by organisations such as FAO and PAHO for the assessment of dietary patterns, their link to diet-related diseases, and the promotion of healthy and sustainable diets (Pan American Health Organization, 2015). Several countries, starting with Brazil in 2014, have incorporated the NOVA concept into their national food-based dietary guidelines, including France, Belgium, and Peru (Food and Agriculture Organization of the United Nations (FAO), n.d.; Monteiro et al., 2018a).

Table 2-1. The NOVA Food Classification System

NOVA	**Description**	**Examples**
GROUP 1 Unprocessed or minimally processed	***Unprocessed:*** Edible parts of plants or from animals, fungi, algae, and water. ***Minimally-processed:*** Unprocessed foods altered by industrial processes such as crushing, freezing, packaging; non-alcoholic fermentation, without added salt, sugar, oils or other substances.	Fresh, chilled, frozen, or dried fruit, vegetables/legumes; meat, fish/seafood; eggs; fresh or pasteurised milk, plain yoghurt; grains or flour; oats; nuts without salt/sugar; pasta herbs/spices; tea, coffee, water.
GROUP 2 Culinary ingredients	Substances obtained directly from group 1 foods or from nature by processes such as pressing, refining or extracting.	Salt; oils from seeds, nuts or fruit; butter/lard; starches from plants; sugar, honey, syrup from trees.
GROUP 3 Processed	Products made by adding group 2 ingredients to group 1 foods to enhance sensory qualities, prolong shelf-life, and ensure food safety. Processes include canning, bottling, non-alcoholic fermentation. May contain preservatives/antioxidants .	Canned or bottled vegetables, legumes and fruits; salted or sugared nuts and seeds; salted, cured, or smoked meats and fish; canned fish; cheeses; fresh unpackaged breads.
GROUP 4 Ultra-processed	Formulations of ingredients mostly of exclusive industrial use. Processes include fractioning of wholefoods, chemically modified substances, assembly of unmodified and modified substances, techniques like extrusion, moulding, pre-frying; extensive use of cosmetic additives to perform different functions like making the final product palatable/hyper-palatable, more attractive, sophisticated packaging usually plastic. ***Common ingredients:*** Added sugar/salt, ultra-refined oils/starches; high fructose syrups; protein isolates; flavour enhancers; colours; emulsifiers; hydrogenated fats; thickeners; or sweeteners.	**Ready-to-eat products:** Fizzy drinks; packaged snacks; confectionary; margarines; breakfast 'cereals, instant soups; energy drinks, flavoured milk, fruit drinks'; 'fruit' yoghurt; mass-produced breads. **Ready-to-heat products:** Chicken 'nuggets'/fish 'fingers'; reconstituted meats; powdered instant sauces, cup noodles, cake mixes; vegan/vegetarian meat-substitutes; baby formula; meal replacements.

Note: (adapted from Monteiro et al., 2019a)

UPF Consumption Trends

UPF dominate diets worldwide (Monteiro et al., 2013; Pan American Health Organization, 2015). In high income countries, over half of all energy intake comes from UPF (Adams et al., 2020), while lower-income countries may have diets comprising up to 30% of these products (Marrón-Ponce et al., 2018; Martins et al., 2013). UPF consumption is high across all age groups, appearing to decline with age (Bielemann et al., 2018; Chen et al., 2020; Nardocci et al., 2019). In NZ, introduction of UPF to children occurs early, with UPF contributing to 45%, 42%, and 51% of children's average energy intake at 12, 24 and 60 months, respectively (Fangupo et al., 2021, p. 306). In Canada, nearly half of total calories consumed by Canadians aged ≥ 2 years were from UPF in 2015, with children aged ≥ 9 years and adolescents being the highest UPF consumers (Moubarac, 2017). Meanwhile, UPF comprises approximately two-thirds of US youths (2–19 y) total dietary intake (Wang et al., 2021). Overall, UPF consumption in lower-income countries is higher among higher income classes (Khandpur et al., 2020a; Marrón-Ponce et al., 2018), possibly because UPF cost is relatively higher than that of MPF (Simões et al., 2018). In contrast, in high-income countries, UPF consumption appears to affect people of lower socio-demographics groups the most (Khandpur et al., 2020b; Machado et al., 2020).

The proportion of unhealthy foods in food supplies is often used as an indicator of overall population diet quality (Mackay et al., 2018). Between 2000–2013, global sales of UPF increased by 47.3%, with the Asian and Pacific region experiencing a 114.9% increase, overtaking North America as the leading global UPF consumer, accounting for nearly one-third (29.2%) of the UPF global market share (Pan American Health Organization, 2015). In NZ, 83% of food items sold in supermarkets were classified as UPF (Luiten et al., 2016), including many child-targeted UPF marketed as 'healthy' choices (Al-Ani et al., 2016). Studies also indicate supermarkets in the most deprived areas of NZ allocate more shelf space to unhealthy foods than retailers in the least deprived areas, and residents in higher deprivation neighbourhoods have lower access to healthy food outlets (1.3 outlets) compared to those in the least deprived areas (3.3 outlets) (Mackay et al., 2018). These examples illustrate that higher UPF accessibility is linked to broader social determinants of health and societal inequities (Mackay et al., 2018). This disparity is due to poverty, which affects upstream socioeconomic determinants such as food security, that is, an individual or household's level of accessibility, affordability, and availability to healthy foods based on their disposal income (Pérez-Escamilla, 2017). The high proportion of UPF in food supplies, particularly in low-income areas, highlights the need for equity-based PH policies that promote healthy dietary patterns and address underlying social determinants of health (Adams et al., 2020). Policy recommendations from the literature include taxing unhealthy foods and beverages, subsidising fresh fruit and vegetables, and regulating UPF labelling and advertising, especially those targeted at children (Adams et al., 2020; Mozaffarian et al., 2018a; UNICEF, 2019).

UPF and Human Health

UPF consumption has been associated with several negative health outcomes across all age groups (Adams et al., 2020; Elizabeth et al., 2020). Adverse effects include overweight and obesity, cardio-metabolic risks, cancers, type-2 diabetes, irritable bowel syndrome, depression, frailty conditions, and all-cause mortality in adults, and cardio-metabolic risks, asthma and wheezing in children (Chen et al., 2020; Elizabeth et al., 2020). UPF consumption has also been associated with increased body fat during childhood and adolescence (Chang et al., 2021; Costa et al., 2018). Notably, the simulation study by Livingstone et al. (2021) found that reducing UPF consumption among US children could result in a 16% decrease in overweight and a 9% decrease in obesity rates, respectively. Moreover, Thornley et al. (2021) reported that excessive consumption of added sugars and refined starchers, as those found in sugary UP snacks and drinks, were strongly associated with poor oral health and tooth decay in childhood, leading to negative impacts such as chronic pain, changes in eating habits, and disruptions to children and families' daily routines. In contrast, no study has identified benefits associated with UPF consumption (Elizabeth et al., 2020).

Metabolic effects of the food structure of UPF versus wholefoods

The high consumption of UPF raises concerns about the displacement of traditional, fresh, and minimally-processed meals from diets that contribute to overall good health and a reduced risk of chronic NCDs (Adams et al., 2020; Monteiro et al., 2013). Diets rich in wholefoods, such as the Mediterranean diet, emphasise the consumption of fruits, vegetables, wholegrains, nuts, seeds, and moderate protein intake, offering various health benefits, such as phytonutrients with antioxidant and anti-inflammatory properties (Dias, 2012; Evans, 2020a; van der Merwe, 2021). Phytonutrients help protect body cells, reduce the risk of diseases like cancer, heart disease, and Alzheimer's, and support overall wellbeing (Dias, 2012; van der Merwe, 2021). Conversely, UPF-dominant diets, prevalent in Western societies, interfere with the metabolic mechanisms developed for consuming wholefood diets, negatively impacting health outcomes (Dagbasi et al., 2020; Lustig, 2017; Zinöcker & Lindseth, 2018).

Whole plant-based foods have a unique structure composed of *cellular* nutrients enclosed within cell walls, primarily consisting of indigestible polysaccharides and dietary fibre (Zinöcker & Lindseth, 2018). These components resist digestion and reach the lower gut intact, where they are metabolised by gut microbiota into short-chain fatty acids (SCFA) (Dagbasi et al., 2020; Zinöcker & Lindseth, 2018). SCFA play a crucial role in the microbiota-gut-brain axis, influencing neurochemical pathways (Dias, 2012) and promoting satiety signals that help prevent overeating (Dagbasi et al., 2020). Additionally, fibre fermentation by the gut microbiota supports the growth, diversity, and behaviour of beneficial bacteria. The diet consumed by individuals affects the composition of their gut microbiota, influencing the strains of bacteria that thrive or decline throughout their lifetime (van der Merwe, 2021).

In contrast, the extensive processing of food destroys the cell walls of whole plant-based foods, resulting in easily digestible and absorbable *acellular* nutrients. These nutrients are primarily absorbed in the upper gut, reducing the amount of fibre that reaches the lower gut (Zinöcker & Lindseth, 2018). This deprivation of essential substrates for fermentation and SCFA production disrupts the balance of the gut microbiota, promoting the growth of harmful bacteria, leading to body inflammation, oxidative stress

(Martínez Leo & Segura Campos, 2020), and disrupted appetite signals in the gut-brain axis (Dagbasi et al., 2020). Excessive UPF may provide a unique environment in the gut that fosters the growth and evolution of microorganisms linked to various inflammation-related diseases, which are common denominators of diet-related NCDs (Zinöcker & Lindseth, 2018).

Brain Health Impacts of UPF Consumption

A growing body of evidence suggests UPF consumption has negative effects on brain function (Contreras-Rodriguez et al., 2022; Reichelt & Rank, 2017; Schulte et al., 2021). UPF intake may affect neural pathways involved in appetite control and food-related decision-making, including the reward system and biobehavioural mechanisms associated with adverse eating behaviours such as food addiction (Contreras-Rodriguez et al., 2022; Reichelt & Rank, 2017; Rolls, 2015; Schulte et al., 2021). UPF are specifically engineered to be highly rewarding, combining taste, texture, odour, and visual inputs that often involve highly-processed sugars, fats, and non-food substances – a combination that is not naturally found (Schulte et al., 2021). This engineered composition leads to heightened neural reward responses, surpassing the brain's perceived reward value of whole and minimally-processed foods, resulting in overstimulation of the reward system (Filgueiras et al., 2019; Lustig, 2020; Reichelt & Rank, 2017; Rolls, 2015). This overstimulation can override hunger and satiety cues, impairing the ability to regulate food intake based on feeling satiated (Contreras-Rodriguez et al., 2022; Reichelt & Rank, 2017). Frequent overstimulation of the reward system may have significant and long-lasting effects on the brain's appetite control system, contributing to impulsive eating and overeating (Contreras-Rodriguez et al., 2022; Reichelt & Rank, 2017).

Furthermore, UPF consumption appears to activate biobehavioural addiction-related mechanisms, such as dopamine sensitisation, which resemble those observed in substance-abuse (Schulte et al., 2021). A study by Filgueiras et al. (2019) examined the association between UPF consumption and food addiction in overweight children (9–11 y). The findings revealed that nearly one-quarter of participants had a food addiction diagnosis, and 95% displayed at least one symptom related to food addiction. Another study suggested excessive UPF consumption during adolescence can trigger neurobiological changes in brain reward systems, potentially interfering with the natural process of brain maturation (Reichelt & Rank, 2017). This disruption may result in impaired cognition, reward-seeking behaviour, and a preference for unhealthy foods (Reichelt & Rank, 2017). Moreover, the pervasive marketing of UPF may contribute to the automatic activation of brain-reward areas associated with consumption and choice, negatively impacting inhibitory control systems in the prefrontal cortex (Contreras-Rodriguez et al., 2022).

Beyond Nutrients – Direct and Indirect Additives in UPF

Further research is needed to determine the primary cause of adverse health effects resulting from UPF consumption. Two main factors are: (1) UPF's poor nutritional composition, characterised by high levels of added sugar, unhealthy fats, sodium, and low nutrient and fibre content, and (2) additional characteristics of UPF beyond nutritional value, such as direct and indirect additives introduced during food processing. These additives can be intentionally added to food products during processing or migrate into food from contact materials like packaging and processing machinery (Dicken & Batterham, 2021; Srour & Touvier, 2021; Trasande et al., 2018; Zinöcker & Lindseth, 2018).

Evidence suggests that factors introduced during food processing, beyond nutritional composition, have a significant impact on human physiology and metabolism (Contreras-Rodriguez et al., 2022; Heindel et al., 2022; Zinöcker & Lindseth, 2018). For example, a randomised trial by Hall et al. (2019) demonstrated that a UPF diet led to increased energy intake and weight gain in weight-stable adults compared to an unprocessed diet matched for calories and macronutrients. Conversely, individuals in the unprocessed diet group showed improved metabolic markers and increased satiation signals. Another study across 21 countries found that UPF subgroups, including processed meats, refined sweetened foods, and salty snacks, were associated with higher risks of irritable bowel syndrome (IBS), while unprocessed red meat, dairy, and starch showed no association (Narula et al., 2021). Furthermore, meta-analyses have indicated that higher whole-grain intake may protect against risk of type-2 diabetes, whereas there is no association between refined grain intake and this condition. Additionally, red processed meat intake has been linked to a higher incidence of coronary heart disease (CHD) and diabetes, while unprocessed red meat has shown no such associations (Aune et al., 2013; Micha et al., 2010) .

Among the various food additives, both direct and indirect, several substances have garnered strong evidence supporting cause for concern. Emulsifiers, non-nutritive sweeteners (NNS), bisphenol-A (BPA), and phthalates are widely used in the general industrial food supply. Emulsifiers, utilised for several purposes such as food texture stabilisation and enhancing palatability (Gultekin et al., 2020), can disrupt the gut microbiota, leading to low-grade gut inflammation (Paula Neto et al., 2017; Zinöcker & Lindseth, 2018) and potentially promoting colon cancer (Viennois et al., 2017). Consumption of NNS, such as aspartame and saccharin, has been associated with adverse effects on the microbiota, glucose intolerance, weight gain (Gultekin et al., 2020; Roca-Saavedra et al., 2018), and increased risks of cancer, reproductive and neurological disruptions, and metabolic syndrome (Heindel et al., 2022).

BPA, found in polycarbonate plastics used in food and beverage containers (Heindel et al., 2022; Trasande et al., 2018), can interfere with hormone function, impacting various bodily systems, including development, reproduction, metabolism, cardiovascular health, and the immune system (Bergman et al., 2012). Phthalates, found in numerous consumer products, including cling-wrap and fast-food wrappers (Heindel et al., 2022; Trasande et al., 2018), can damage the endocrine system, promote inflammation, increased oxidative stress (Bergman et al., 2012; Trasande et al., 2018), and adversely affect male hormones, potentially impacting fetal development, testosterone levels, and sperm production (Bergman et al., 2012). Given these concerns, the American Academy of Paediatrics (AAP) recommends avoiding consumer goods with phthalates and bisphenols (Trasande et al., 2018).

Current testing methods for direct and indirect food additives may not accurately assess the risks of additive 'cocktails' or the long-term effects of additive accumulation in the body. Risk assessments focus on individual food additives' acceptable daily intake (ADI), which represents the safe amount for daily consumption over a lifetime (Pressman et al., 2017). However, these methods do not adequately account for combined additive effects or the compounding effects of additive accumulation, particularly in modern diets dominated by pre-packaged UPF. Consequently, individuals may unknowingly be exceeding safety levels by consuming high amounts of single additives or additive 'cocktails' (Muncke et al., 2020; Paula Neto et al., 2017; Pressman et al., 2017; Trasande et al., 2018).

Children may be especially vulnerable to direct and indirect additives due to their higher exposure levels relative to body weight and ongoing organ development (Heindel et al., 2022; Trasande et al., 2018). Key recommendations to address these concerns include updating testing and regulatory processes based on current scientific knowledge, phasing out hazardous chemicals, incentivising research for safer alternatives, and improving food labelling to include food processing levels, additive lists, and proportion of wholefoods in the final product. Prompt action is necessary to ensure the safety of food additives and protect the health of populations, particularly vulnerable individuals and children (Paula Neto et al., 2017; Pressman et al., 2017; Trasande et al., 2018; Zinöcker & Lindseth, 2018).

UPF and Planetary Health

Planetary health, encompassing the overall wellbeing of human civilisation and the natural systems that support it (Whitmee et al., 2015), is greatly threatened by current global food production practices. These practices, driven by the goal of providing abundant and affordable food for a growing population, contribute significantly to climate change, land degradation, freshwater depletion, ocean acidification, biodiversity loss, and pollution (Global Panel on Agriculture and Food Systems for Nutrition, 2020; Willett et al., 2019). Industrial agriculture, characterised by harmful practices such as monocultures and industrial livestock production, prioritises the production of cheap staple crops like corn, rice, and wheat, which are extensively used in the mass production of UPF (Boye & Arcand, 2013; Fardet & Rock, 2020; Global Panel on Agriculture and Food Systems for Nutrition, 2016). There is urgent need for transformative actions in the industrial food system, including production and consumption of UPF. Without these changes, the threats to global human health and the planet's sustainability will escalate (Global Panel on Agriculture and Food Systems for Nutrition, 2020; HLPE, 2017; IPCC, 2022; Whitmee et al., 2015). With the world population projected to reach 9.6 billion by 2050 and the increased demand for food production, current practices further strain the earth's natural systems (Population Division of the Department of Economic and Social Affairs of the UN Secretariat, 2013; Willett et al., 2019).

Although the impact of UPF production on planetary health encompasses multiple dimensions, this research focuses specifically on two critical aspects: the relationship between UPF and climate change, and the association between UPF and the plastic waste crisis.

UPF and Climate Change

The global food system is a major contributor to climate change, accounting for 31% of total greenhouse gas emissions (GHGEs) worldwide (Tubiello et al., 2022). These emissions, including carbon dioxide, methane, and nitrous oxide, originate from various sources within the food system. For example, methane is produced through the digestive fermentation of ruminant animals, while nitrous oxide is released from the use of synthetic fertilisers and other chemicals in crop production. Additionally, carbon dioxide originates from burning fossil fuels during food production, processing, and transportation (Global Panel on Agriculture and Food Systems for Nutrition, 2016). Food waste is another significant contributor, producing methane when trapped in landfills, and it's unable to decompose naturally due to a lack of light and oxygen (FAO, 2019).

Animal-based foods generally have higher GHGEs than plant-based foods, although there are marked variations within both groups (Poore & Nemecek, 2018). For instance, pork and poultry have lower emissions (6 and 7 kg CO_2-e [GHGE per kilogram of food produced], respectively), compared to beef (60 kg CO_2-e), and certain plant-based foods like coffee and palm oil (17 and 8 kg CO_2-e, respectively) (Poore & Nemecek, 2018). Traditional assessments of food-related emissions for single foods and eating patterns, have typically focused on the production and land usage at farm level, neglecting emissions occurring in pre- and post-production processes such as fertiliser production, food manufacturing, packaging, and transportation (Boye & Arcand, 2013; Fardet & Rock, 2020; Tubiello et al., 2022). However, it is crucial to consider the entire lifecycle of food, as mass-produced UPF undergo multiple transformations and processes that contribute to their total energy and resource expenditure (Fardet & Rock, 2020). Additionally, studies have shown that assessments of overall dietary patterns and the sustainability impacts of the entire supply chain are vital for understanding the environmental impacts of food (Drewnowski et al., 2020; Tubiello et al., 2022).

For instance, recent research across 196 countries has highlighted the significant contribution of pre- and post-production stages to food system-related GHGEs, with emissions increasing by 17% between 1990–2019 (Tubiello et al., 2022). The comparison of industrially-made ready meals and matched home-made versions (i.e., made from scratch using wholefoods) has demonstrated that homemade meals have up to 35% less global warming and toxicity potentials, and up to 3 times lower levels of eutrophication (Rivera et al., 2014). Moreover, a study conducted in Australia examining the environmental effects of UPF consumption found that over a third of the total effects are associated with UPFs, including energy, land, and water usage (39%, 35%, 35%, respectively), as well as GHGEs (33%). According to the same study, if current dietary trends continue, GHGEs per capita are projected to nearly double by 2050 (Hadjikakou, 2017). Therefore, considering food processing as a crucial aspect of food sustainability is essential (Boye & Arcand, 2013; Drewnowski et al., 2020), and reducing UPF consumption is seen as an important step towards decreasing environmental impacts and diet-related carbon footprints (Fardet & Rock, 2020).

UPF & Single-use Plastic Food Packaging

Pollution and waste from food and drink packaging, particularly plastics, present a significant challenge associated with industrial food systems (Global Panel on Agriculture and Food Systems for Nutrition, 2020). Packaging plays a vital role in food processing by safeguarding the quality and freshness of food products during storage and transportation (Marsh & Bugusu, 2007). It extends a product's shelf-life, allows for traceability throughout supply chains, provides convenience, facilitates handling and preparation, and conveys important information to consumers, such as nutritional details and recycling instructions (Marsh & Bugusu, 2007, p. 40). Moreover, food packaging serves as a marketing tool often forming the initial point of contact between consumers and a product. While packaging materials include glass, metals, paper, cardboard, and various plastics, plastics have gained popularity due to their low-cost, lightweight nature, and design flexibility, allowing them to be easily moulded into unlimited shapes and forms, including bottles, pouches, and cling-film (Marsh & Bugusu, 2007).

However, the surge in plastic waste has led to a global plastic waste crisis with severe health and environmental impacts, primarily from water and land plastic pollution (Geyer et al., 2017). As of 2015, approximately 6.3 billion metric tons of plastic waste had been generated globally, with around 79% accumulating in landfills or the natural environment (Geyer et al., 2017). Single-use plastic food packaging (SUPP) constitutes the largest source, comprising 42% (Fardet & Rock, 2020). Studies on marine litter across various aquatic environments have identified SUPP as the primary source of litter, with single-use plastic bags, plastic drink bottles, disposable food containers/cutlery, and food wrappers being the most prevalent items (Morales-Caselles et al., 2021). The impact of SUPP littering on marine life is grave, resulting in ingestion and entanglement by seabirds, sea turtles, and marine mammals, leading to injuries, malnutrition, and even death (Thiel et al., 2018).

Plastic waste is non-biodegradable and persists in the environment for centuries, gradually fragmenting into microplastics (<5 mm particles) (Geyer et al., 2017; Peng et al., 2017). Microplastics pose significant concerns for human and animal health due to the toxic chemicals they contain from manufacturing and those absorbed from the surrounding environment (Peng et al., 2017). Microplastics have been detected in various components of the human food chain, including shellfish, honey, and tap and bottled water (Senathirajah et al., 2021). They can travel through animal organ systems and transfer from prey to predator (Peng et al., 2017). Recently, airborne microplastics have been found in human lung tissue (Jenner et al., 2022), and they can enter the human bloodstream (Leslie et al., 2022). Although further research is needed to fully understand the potential risks to human health associated with microplastics, evidence suggests that high concentrations in human tissue may contribute to chronic inflammation and be linked to the increased prevalence of autoimmune disorders, cancers, and neurodegenerative diseases in modern societies (Kadac-Czapska et al., 2023; Prata et al., 2020). Given the concerns surrounding the detrimental effects of plastics and microplastics on human and environmental health, there have been strong calls for a global reduction in SUPP waste (Chen et al., 2021; Peng et al., 2017).

Part 1 Conclusion

The widespread consumption of UPF has numerous negative impacts on human and planetary health. Besides being associated with unhealthy, nutritionally-poor diets and increased risk of NCDs, the production, processing, and disposal of UPF generally requires significantly more natural resources and are less-environmentally friendly than wholefoods. Shifting from UPF-rich dietary patterns to less-processed diets sourced from sustainable food systems is a crucial step towards improving both human and planetary health.

Part two: Healthy and sustainable diets for children: child-centred food systems, schools as a setting for action, and home-packed school lunchboxes

Introduction

Promoting healthy and sustainable diets is a key objective in global public and environmental health agendas, as evident in the UN 2016–2025 Decade of Action on Nutrition (FAO, 2016) and the UN 2015 Sustainable Development Goals (SDGs) (2015). Sustainable healthy diets are recognised as vital for achieving nearly all 17 SDGs, including ending hunger, improving nutrition, ensuring good health and wellbeing, promoting quality education, reducing inequalities, and addressing climate action (Grosso et al., 2020). This emphasis on sustainable diets is essential for food security and nutrition for all, and aligns with the goal of maintaining the economic, social, and environmental foundations necessary for future generations (FAO, 2018).

However, the prevalence of highly-processed Western-diets in developed countries provides challenges. While these diets often provide sufficient calories to meet or exceed requirements, they often lack the necessary nutrients for optimal health and chronic disease prevention (Global Panel on Agriculture and Food Systems for Nutrition, 2020; HLPE, 2017). Furthermore, the negative impacts of mass-industrialisation and globalisation of food systems have had adverse effects on human and planetary health (Cannon & Leitzmann, 2022; Fanzo et al., 2021; Ridgway et al., 2019; Willett et al., 2019). To address these issues, a paradigm shift has occurred in the field of Public Health Nutrition (PHN) towards an ecologically-oriented approach. This shift, also known as **"eco-nutrition"**, acknowledges the equal importance of health, the natural environment, society, and economy within the food and nutrition system (Ridgway et al., 2019).

Eco-nutrition recognises the significance of environmental factors on health outcomes, particularly in relation to food security, malnutrition, and diet-related NCDs among vulnerable populations, including children (FAO & WHO, 2019; HLPE, 2017; UNICEF, 2019). It expands the scope of PHN to encompass broader considerations of food and nutrition systems, such as the impact of industrial food production practices, food accessibility, availability, affordability, and the management of food and packaging waste (Miller et al., 2021; Seferidi et al., 2020). By adopting a transdisciplinary and holistic approach, which considers the multifaceted aspects of sustainable healthy diets within food systems, eco-nutrition aims to address the complex challenges currently faced by PHN in the context of planetary health (Drewnowski et al., 2020; Fanzo et al., 2021).

Evolution of Public Health Nutrition and dietary guidelines

PHN investigates the impacts of nutrients, foods, and diets on health and disease, with the aim of translating scientific knowledge into policies and guidance for promoting diet-related wellbeing in society (Ridgway et al., 2019; Tapsell, 2016). PHN has undergone several paradigm shifts since the discovery and synthesis of essential vitamins and minerals in the first half of the 20th century (Mozaffarian et al., 2018b; Ridgway et al., 2019). Back then, PHN focused on addressing nutrient-deficiency diseases, such as scurvy (vitamin C) and anaemia (B12), leading to the establishment of nutrient reference values (NRVs) and the fortification of staple foods to alleviate nutrient deficiencies and prevent disease (Ridgway et al., 2019).

However, a paradigm shift occurred as the prevalence of diet-related NCDs increased during the 2nd half of 20th century, linking these conditions to dietary imbalances and overconsumption (Ridgway et al., 2019). During this shift, PHN research continued to focus on single nutrients such as dietary fat, cholesterol, and sugar, and their association with chronic diseases, such as heart disease and type-2 diabetes (Ridgway et al., 2019). Dietary guidelines advised limiting calories, avoiding sugar, sodium, dietary fat, and cholesterol intake, and promoting the consumption of starch and fiber-rich foods (Fardet & Rock, 2014; Monteiro et al., 2015). The food industry responded by mass-producing low-fat/fat-free and low-sugar/sugar-free food products (Mozaffarian et al., 2018b).

In the 1990s, scientific advancements in research methods, including clinical trials and large cohort studies, revealed the complexity of foods and overall dietary patterns, leading to a more holistic approach in PHN (Mozaffarian et al., 2018b). Studies identified specific diets, such as the Mediterranean diet, and low-carb or low-fat diets, as better indicators to health outcomes (Fardet & Rock, 2014; Mozaffarian et al., 2018b). Additionally, PHN research expanded to include other modifiable risk factors and external co-determinants beyond dietary intake, such as physical activity, smoking, socio-economic factors, culture, and food environments (Fardet & Rock, 2014).

To reflect these changes, food-based dietary guidelines were introduced in 1995 by FAO/WHO (1998). Food-based dietary guidelines provide guidance on healthy eating and serve as the basis for food and agriculture policy development (FAO, 2016). They typically include recommendations for core food groups such as fruit and vegetables, grains, and dairy, and appropriate serving sizes for different age groups, often represented visually using food pyramids or plates (Herforth et al., 2019). The nutrient profiling approach informing food-based dietary guidelines (i.e., adequate intake of single nutrients within a varied diet composed of different food groups) continues to dominate PHN policy and action to this day, including the development, production, reformulation, marketing, and legislation, as well as front-of pack-labelling and health claims, of industrially-processed foods and drinks (Adams et al., 2020; Elizabeth et al., 2020; Mozaffarian et al., 2018b).

However, current dietary guidelines have faced criticism due to their nutrient profiling approach, which focuses on single nutrients within a varied diet (Astrup et al., 2019; Dicken & Batterham, 2021; Lustig, 2020; Monteiro et al., 2015). For example, recommendations to reduce saturated fat intake (WHO, 2020) have been challenged by studies showing no significant association between saturated fats and

NCDs, and by evidence suggesting the impact of saturated fat on health may depend more on the food matrix in which it is found than on saturated fat itself (Astrup et al., 2019). Additionally, the classification of UPF using the NOVA system has gained attention, in light of modern dietary patterns and UPF's association with increased disease risk (Elizabeth et al., 2020).

As a result, a growing number of experts are calling for an urgent update to dietary guidelines, considering the complexity of the food matrix, processing methods, direct and indirect additives, and their impact on health (Adams et al., 2020; Aguilera, 2019; Gultekin et al., 2020; Heindel et al., 2022; Monteiro, 2009; Narula et al., 2021; Roca-Saavedra et al., 2018; Zinöcker & Lindseth, 2018). Some argue, for instance, that reformulating mass-produced UPF staples by adding or removing single nutrients may unintentionally contribute to increased UPF consumption, as typically such products are labelled/perceived as healthy (Adams et al., 2020; Dicken & Batterham, 2021; Srour & Touvier, 2021; Zinöcker & Lindseth, 2018).

Recommendations for sustainable healthy diets

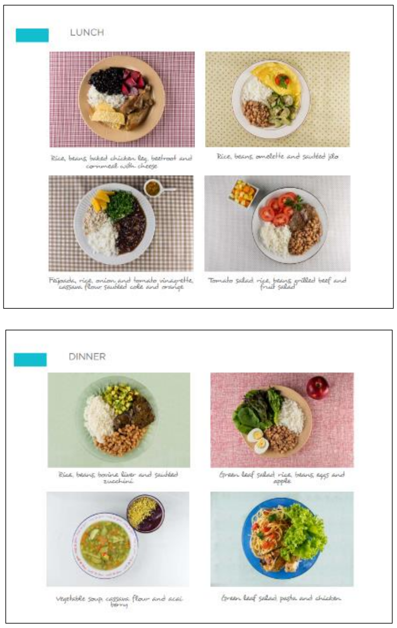
Ensuring sustainable nourishment for an expanding global population while preserving natural resources has become an ongoing concern, requiring comprehensive dietary recommendations (Drewnowski et al., 2020; Herforth et al., 2019). In 2019, following the launch of the 2015 UN-SDGs, the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems (Willett et al., 2019) proposed an alternative to unhealthy dietary trends by introducing a universal reference diet that promotes both health and sustainability. The EAT-Lancet diet, supported by multidisciplinary evidence-based literature on healthy dietary patterns, health outcomes, and sustainable food production, considers the safe operating spaces for food systems to prevent the environmental impacts from exceeding set planet boundaries, such as greenhouse gas emissions and freshwater usage (Willett et al., 2019).

The EAT-Lancet-diet is predominantly plant-based and establishes specific dietary intake targets for each food group, such as 811 kcal/day wholegrains and 15 kcal/day red meat, on a 2500kcal/day intake. It consists "*mainly of vegetables, fruits, wholegrains, legumes, nuts, and unsaturated oils, with low to moderate amounts of seafood and poultry, and minimal or no consumption of red meat, processed meat, added sugar, refined grains, and starchy vegetables*" (Willett et al., 2019, p. 447).

However, the EAT-Lancet diet has faced criticism due to the unique nutritional requirements of individuals and the influence of multiple external factors such as cultural relevance and socio-economic status, which a universal diet cannot fully address (Fanzo et al., 2021; Miller et al., 2021). For instance, children benefit from having meat and dairy in their diets to ensure adequate intake of protein, calcium, and other essential micro-nutrients required for healthy growth (Chouraqui, 2023; Hollis et al., 2020). A study on the affordability of the EAT-Lancet diet in 159 countries revealed that the cheapest option was unaffordable for at least 1.58 billion of the world's poorest, primarily due to insufficient household income (Hirvonen et al., 2020). Furthermore, ongoing debates persist regarding the definition of a healthy and sustainable diet (Fanzo et al., 2021).

The global shifts towards plant-based diets (Alae-Carew et al., 2022; Curtain & Grafenauer, 2019) has led to an increasing production and consumption of UP plant-based food and drink items, which may not be healthy. For example, high-tech meat substitutes like the Impossible Burger, *"designed to mimic the taste and experience of eating meat"* (Hu et al., 2019, p. 1547), and other UP plant-based dairy and meat substitutes (e.g.; soy "milk"; textured soy protein "sausages") (Gehring et al., 2021), have gained popularity (Alae-Carew et al., 2022; Curtain & Grafenauer, 2019; Gehring et al., 2021; Hu et al., 2019). Moreover, the environmental benefits of plant-based diets vary, as demonstrated in studies that have shown diets with one serving of meat per day produces fewer GHGs than vegetarian diets that allow eggs and dairy (due to the significant emissions associated with dairy production) (Scarborough et al., 2014). Similarly, the water usage per serving required for producing nuts, seeds, and fruits is comparable to that of certain animal-based dishes (Stylianou et al., 2021). Thus, sustainable diets are not always synonymous with healthy diets, just as healthy diets are not always sustainable (Fanzo et al., 2021; Stylianou et al., 2021).

Despite ongoing debates, consensus exists on the inclusion of plenty of fruits, vegetables, wholegrains, legumes, nuts, and smaller amounts of unprocessed animal foods in sustainable healthy diets (FAO & WHO, 2019; HLPE, 2017). Prioritising whole, seasonal, organic, and locally produced foods is also recommended (Fardet & Rock, 2020). The 2014 Dietary Guidelines for the Brazilian Population (Monteiro et al., 2015) serve as an exemplary eco-nutrition-aligned dietary guideline. Brazil's guide emphasises dietary patterns by replacing traditional food groups with one "golden rule", four easy-to-follow recommendations, and several photographs depicting culturally-diverse meal suggestions tailored for different lifestyles and geographical areas within Brazil (Figure 2-1). Furthermore, the guide incorporates sustainability across multiple dimensions, encompassing the natural environment, social, economic, and cultural impacts of UP dietary patterns (Monteiro et al., 2015). Currently, food-based dietary guidelines in only four countries worldwide explicitly address all of the multi-faceted domains of sustainable diets, with a few more countries partially including some of these domains, mainly the environment dimension (Herforth et al., 2019).



FOUR RECOMMENDATIONS AND ONE GOLDEN RULE

- Make natural or minimally processed foods the basis of your diet
- Use oils, fats, salt and sugar in small amounts for seasoning and cooking foods and to create culinary preparations
- Limit the use of processed foods, consuming them in small amounts as ingredients in culinary preparations or as part of meals based on natural or minimally processed foods
- Avoid ultra-processed products

"Always prefer natural or minimally-processed foods and freshly made dishes and meals to over-processed foods"

Figure 2-1. Dietary Guidelines for the Brazilian Population

Note: (adapted from Ministry of Health of Brazil, 2015).

Sustainable Heathy Diets for Children

Childhood nutrition

Childhood is a critical period of growth and development, encompassing various physiological, social, behavioural, and cognitive changes (UNICEF, 2019). It is well-established that nutrition during different childhood stages significantly influences children's ongoing growth and development, as well as health and wellbeing throughout their life course (Ministry of Health, 2012; UNICEF, 2019). For example, consuming a diverse range daily of fruits and vegetables from the introduction of solid foods is strongly associated with preventing NCDs and obesity later on (Rush et al., 2019). Additionally, regular fish consumption has been shown to enhance learning, thinking, and information retention in school-aged children (de Groot et al., 2012; Kim et al., 2010). Therefore, childhood is an ideal time for supporting the adoption of long-lasting dietary habits that are beneficial for both children and the planet (Hollis et al., 2020).

However, research indicates that the consumption of nutrient-dense foods, particularly fruits and vegetables, is generally low among most children worldwide (Kupka et al., 2020). Conversely, children's diets are increasingly characterised by the consumption of pre-packaged, nutrient-poor, highly-processed snacks, such as confectionary, flavoured crisps, and sweetened drinks, starting from an early age (UNICEF, 2019). This global trend of poor diet quality contributes to the triple burden of malnutrition, which includes undernutrition, micronutrient deficiencies, and overweight and obesity, affecting two-thirds of children and adolescents worldwide (UNICEF, 2019).

In NZ, only half of children meet the recommended intake of three or more servings of vegetables per day (Ministry of Health, 2003a), while UPF contribute to over half of the daily average energy intake of 5-year-olds (Fangupo et al., 2021). Moreover, NZ school-aged children (mean =12.6 y) consume an average of 5.2 discretionary snacks per day, with a preference for unhealthy snacks compared to healthy snack options at all times, regardless of location or activity (Gage et al., 2020). Snacking on unhealthy foods has been associated with poor nutrition and unhealthy dietary patterns among school-age children, leading to the displacement of nutrient-dense alternatives, childhood obesity, and increased weight in adulthood (Gage et al., 2020; Hollis et al., 2020; Kupka et al., 2020; Lee & Yoon, 2018).

Food and Nutrition Guidelines for Children

According to WHO (2020) a child's healthy diet should consist of sufficient amounts of safe and varied nutrient-dense wholefoods, such as fruits, vegetables, wholegrains, legumes, nuts, fish, and modest amounts of red meat. Meanwhile, the consumption of foods high in added sugar, salt, and fats should be limited (Hollis et al., 2020; UNICEF, 2019; WHO, 2020). Dietary requirements for children vary throughout different stages of childhood, depending on age, gender, physical activity levels, and the ongoing growth and development processes (Hollis et al., 2020; UNICEF, 2019; WHO, 2016). For example, the NZ Ministry of Health (2012) has estimated an average energy intake range of 1500–2100 kcal/day for moderately active children during middle childhood (5–10 y) compared to 2000–3300 kcal/day for moderately active adolescents (11–18 y) due to differences in body size, rapid growth patterns, and major physiological changes resulting in higher nutritional requirements (Hollis et al., 2020).

Furthermore, the WHO guidelines for sugar intake (2015) recommend that "free sugars" (added sugars and naturally-occurring sugars in honey, syrups, fruit juice, and fruit concentrates) should constitute less than 10% of total energy intake, with the ideal target being 5% of for long-term health benefits. However, the guidelines exclude "intrinsic sugars" (found in whole fruits and vegetables, and sugars from milk) due to the lack of reported evidence on adverse health effects associated with their consumption (WHO, 2015). Excessive consumption of free sugars is strongly associated with childhood dental caries, a leading cause of preventable hospitalisations in NZ (Thornley et al., 2021).

The current "Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2–18 Years)" by the NZ Ministry of Health (2012) are based on four food groups: 1) fruits and vegetables, 2) breads and cereals, 3) milk and milk products, and 4) lean meat, poultry fish, seafood, eggs, legumes, nuts. These guidelines provide recommended daily servings for each food group at different stages of childhood, and offer serving size examples (Table 2-2).

Table 2-2. Eating for Healthy Children aged 2 to 12 years: serving size examples

Food group	Vegetables	Fruits	Breads and Cereals	Milk & Milk Products	Legumes, nuts, seeds, fish/seafood, eggs, poultry, lean red meat
Daily servings	At least 3 servings	2 servings	At least 5 servings	At least 2–3 servings	At least 1 serving Vegetarians: At least 2 servings
Serving size	1 medium potato, or kūmara (130g)	1 apple, pear, banana or orange (130g)	1 medium slice bread (26g)	1 cup reduced-/low-fat milk (250ml)	2 slices cooked lean meat (100g)
	½ cup cooked vegetables (50-80g)	½ cup fresh fruit salad (120g)	1 cup cornflakes (30g)	1 pottle reduced-/low-fat yoghurt (150g)	¾ cup cooked beans (e.g., baked beans)
	½ cup salad (60g)	½ cup canned fruit (135g)	1 cup cooked pasta, noodles or rice (150g)	½ cup grated cheese (40g)	¾ cup tofu (200g) 1 egg

Note: (adapted from HealthEd, 2017)

The MoH guidelines also recommend limiting sugar, salt, and saturated fat intake, while suggesting reduced-fat/low-fat 'milk and milk products' for children over 2-years-old (Ministry of Health, 2012). However, it is important to note that limiting saturated fat consumption may result in the reduction or exclusion of nutrient-dense foods that are essential for healthy growth and overall health, as pointed out by Astrup et al. (2019). Moreover, the current guidelines do not consider the levels of food processing or synthetic additives present in foods or migrating from contact materials such as packaging (Contreras-Rodriguez et al., 2022; Trasande et al., 2018; Zinöcker & Lindseth, 2018). Furthermore, current food labelling regulations in NZ do not differentiate between intrinsic and free sugars (Ministry for Primary Industries, 2022a), making it challenging to determine the exact proportion of free sugars in processed food and drink items. However, excessive UPF consumption has been linked to overconsumption of free sugars across all age groups, highlighting the importance of limiting UPF intake, particularly pre-packaged sweet snacks and sugar-sweetened beverages (Machado et al., 2020; Rauber et al., 2019; Smirk et al., 2021; Thornley et al., 2021).

The implications of the current MoH guidelines in relation to children's consumption patterns can be illustrated by comparing two milk products available in NZ, both of which have a Healthy Star Rating (HSR). The Australia/NZ HSR is a voluntary labelling system that aims to facilitate consumers in making healthier choices when selecting package foods. The system uses a scoring range from 0.5 to 5 stars. When comparing similar foods, higher star ratings indicate healthier options compared to those with lower star ratings (Ministry for Primary Industries, 2022b).

The comparison below reveals that a popular branded UP chocolate-flavoured milk drink receives a higher rating (4.5 stars) compared to regular full-fat milk (4.0 stars). This higher rating is primarily due to the lower saturated fat content achieved by using low-fat-milk in the production of the chocolate-flavoured milk drink, despite the fact that the chocolate-flavoured milk drink contains a lengthy list of ingredients, including added sugars and cosmetic additives, while the full-fat milk is simply “fresh milk” (Hemingway, 2023) (Figure 2-2).

Branded Chocolate Flavoured Milk Drink
Ingredients
Water, Skim Milk Powder, Maltodextrin (Wheat, Corn), Cane Sugar, Plant Fibre, Soy Protein, Vegetable Oils (Sunflower, Canola), Fructose , Oat Flour, Cocoa (0.5%), Flavours, Acidity Regulator (Potassium Citrate), Mineral (Calcium), Vegetable Gums (460, 466, 407), Stabiliser (452), Vitamins (C, B3, A, D2, B2, B1, B12, B6), Salt

Standard Milk
Ingredients
Fresh Milk

Figure 2-2. Ingredients list for flavoured (top) and standard fresh milk (bottom).

Table 2-3. Nutritional information panel and HSR comparison between flavoured milk and standard full-fat milk.

NPI	**Branded flavoured chocolate milk**	**Fresh milk, full-fat**
	*Per 100 ml**	
Energy	328 kJ	260 kJ
Protein	3.3 g	3.3 g
Fat, total	1.7 g	3.3 g
Saturated Fat	0.2 g	2.1 g
Total Sugars	6.5 g	4.7 g
Calcium	120 mg	120 mg
Health Star Rating		

*Serving size for both milk products is 250ml.

On the other hand, when examining the nutritional content of both milk products, they share certain similarities, such as equal amounts of protein and calcium. However, the chocolate-flavoured milk drink has much lower saturated fat content compared to standard milk (0.2 vs. 2.1 g) and slightly higher sugar content compared to standard milk (6.5 vs. 4.7 g). This example serves to illustrate how current food systems continuously influence children's diets. It represents just one small aspect of the broader factors that shape children's preference for "less-healthy" food options and may pose challenges for them to achieve recommended nutrition goals (Hawkes et al., 2020; Kupka et al., 2020; UNICEF, 2019).

Child-centred food systems

A child-centred food system makes healthy diets "*available, affordable, appealing, and aspirational for children*", taking into account the context of their lives (Hawkes et al., 2020, p. 2). In other words, child-centred food systems encourage children to make healthier food choices and make it easier for parents and caregivers to guide children towards nutritious foods (Hawkes et al., 2020; UNICEF, 2019). The UN Convention on the Rights of the Child (United Nations, 1989) requires countries to recognise children's rights to the "highest attainable standard of health", which includes access to adequate and nutritious food, nutrition knowledge for parents and children, and protection from information or materials that could be harmful to children's wellbeing (p. 7). According to UNICEF (2019), to realise children's universal human rights to nutrition, health, and wellbeing, it is crucial to prioritise children's unique nutritional needs in modern food systems.

To guide child-centred food system research and action, the 2018 UNICEF/GAIN Innocenti Framework on Food Systems for Children and Adolescents was developed in collaboration with the public, private, civil, and academic sectors during the 2018 Global Consultation on Food Systems for Children and Adolescents (UNICEF, 2019) (Figure 2-3). The aim of the consultation was twofold: 1) to provide a universal framework for child-centred food systems, and 2) to identify key action points in food systems that may support and promote healthy diets for children within the context in which malnutrition develops and where children live their lives (Hawkes et al., 2020). Priority action points include four key food system areas: 1) food supply chains; 2) behaviour of caregivers, children and adolescents; 3) personal food environments; and 4) external food environments. The key areas interlink in particular ways with multiple upstream food system drivers, such as socio-cultural, political-economic, demographic, and biophysical-environmental factors.

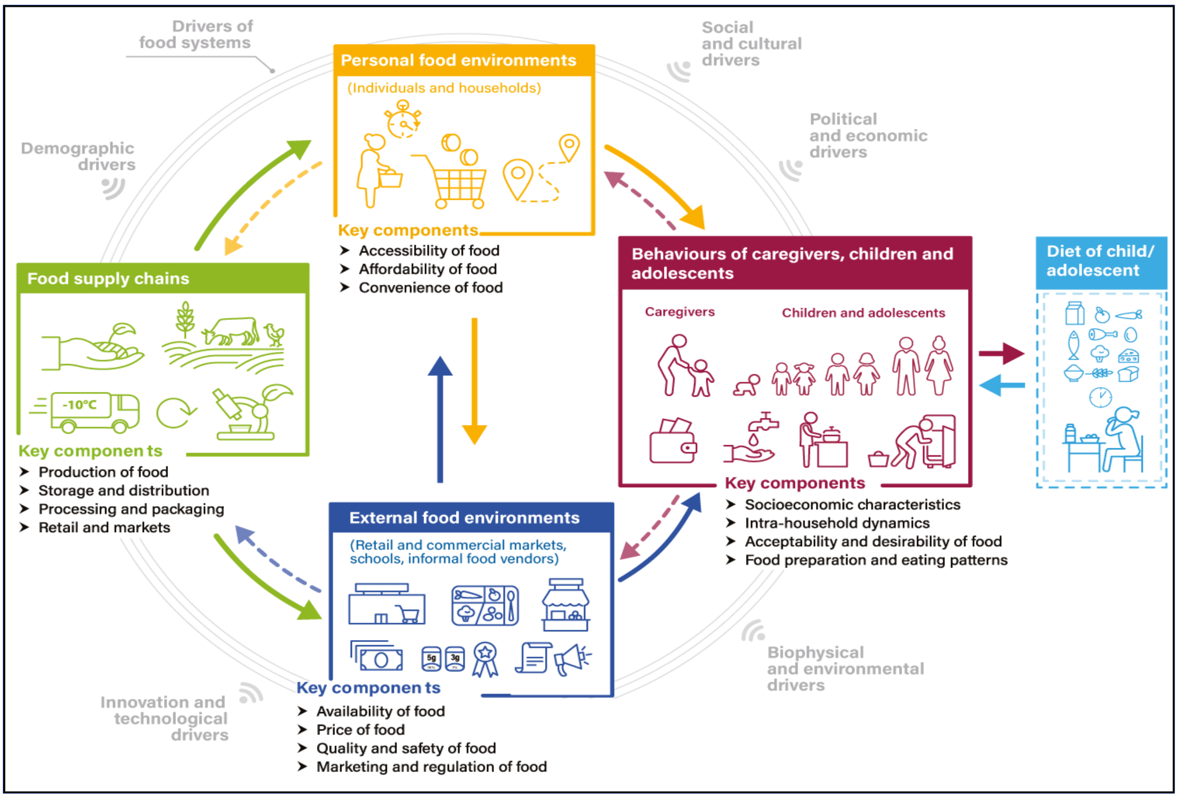


Figure 2-3. The UNICEF/GAIN Innocenti Framework on Food Systems for Children and Adolescents

Note: Adapted from (UNICEF, 2019)

Food environments encompass all the physical and social elements that influence where people, including children and their caregivers, acquire and consume food (Drewnowski et al., 2020). This includes the types of food and beverage options available for purchase, their affordability, convenience, and advertising strategies, which collectively shape individuals' preferences and influence their purchasing-behaviour (UNICEF, 2019). Moreover, food environments extend to socio-economic, political, and cultural factors that affect lifelong food choices. At an individual and household level, personal food environments are influenced by factors such as lack of income, time constraints for meal preparation, and knowledge of heathy cooking (UNICEF, 2019). As such, food environments play a pivotal role in determining children's dietary choices and eating behaviours, ultimately impacting children's nutritional status (Drewnowski et al., 2020; HLPE, 2017).

The behaviours of parents and caregivers also significantly influence children's diets through the food choices available at home, parent-child feeding practices, and household-diet-related cultural beliefs and habits (Fox & Timmer, 2020; O'Rourke et al., 2020; UNICEF, 2019). Therefore, targeting parents' purchasing behaviour becomes a crucial strategy for promoting healthier food choices among children (Fox & Timmer, 2020; Gage et al., 2020; Regan et al., 2008). However, food options marketed to and consumed by children often do not align with their nutritional needs and recommendations, both in terms of quality and variety. Notably, evidence suggests that food marketing strategies primarily promote UPF rather than healthier alternatives (Cairns et al., 2013), making it challenging for families to make informed choices. For instance, a recent study on nutrition claims on child-targeted food and drink products found that over half (56%) of UPF displayed nutrition claims, with only a minority of products (18%) complying with food labelling regulations (Pulker et al., 2018). These claims can effectively capture children's attention and influence their parents' purchasing decisions (Sato et al., 2022). Such claims not only breach parents' right to accurate nutrition information and children's right to protection from unhealthy foods (United Nations, 1989), but also misguide children's understanding of healthy foods (Sato et al., 2022).

Governments and the food industry are the primary influencers shaping food environments, consumers' food choices, and dietary patterns (Mozaffarian et al., 2018a; Vandevijvere et al., 2018; WHO, 2016). Food manufacturers and retailers influence through product characteristics, pricing, marketing, and placement. Governments exert influence through legislation and public health strategies (Vandevijvere et al., 2018; Mozaffarian et al., 2019). Recommendations from UNICEF include interventions such as financial incentives for businesses increasing the supply and affordability of healthy foods, and financial disincentives for unhealthy options, such as taxation of sugary UP beverages. UNICEF emphasises the importance of simultaneously increasing the demand for nutritious foods among children (UNICEF, 2019).

Intersectoral action

"*Good health is not the sole responsibility of the Ministry of Health but belongs to a range of private and public actors*" (Health Promotion Forum of NZ, 2012, p. 12). This statement underscores that many health determinants, such as poverty and climate change, fall outside the public health sector's jurisdiction, as reflected in the UN Sustainable Development Goals (2015). Sectors beyond PH include agriculture, the food industry, retailers, advertising, education, local communities, and all levels of government (Mozaffarian et al., 2018a). Each of these players has the potential to positively impact child-centred food systems through actions like investing in research and development of novel, healthier products, creating supportive food environments, and implementing legislation to enhance healthy food accessibility, availability, and affordability (Mozaffarian et al., 2018a; United Nations, 2015).

The demand for convenient, ready-to-consume foods remains substantial (Khandpur et al., 2020b; Nardocci et al., 2019; Pan American Health Organization, 2015). However, research indicates that consumers are increasingly seeking healthier and more sustainable food choices that not only benefit personal health but also have positive collective and environmental impacts (Cannon & Leitzmann, 2022; Fanzo et al., 2021; Miller et al., 2021; Silva et al., 2018). According to literature and prominent global PH reports, the food industry sector can and should be an essential part of the solution due to the urgent need for increased research and innovation in food production and reformulation (G. B. D. Diet Collaborators, 2019; Mozaffarian et al., 2018a; Silva et al., 2018; UNICEF, 2019). Therefore, government policies must incorporate incentives to promote transparent and unbiased nutrition research, with the aim of discovering novel methods to produce and manufacture foods that are healthier and accessible to consumers, while being environmentally-sustainable (Adams et al., 2020; Mozaffarian et al., 2018a).

A snapshot of NZ food environments

There is substantial evidence indicating that food environments in NZ, especially those affecting children (e.g., schools, sports clubs, takeaway shops, supermarkets) are predominantly unhealthy (Vandevijvere et al., 2019). Unhealthy food environments are the primary driver of the obesity pandemic in NZ, contributing significantly (18.6%) to the overall burden of disease in the country (Vandevijvere et al., 2018). Although excess calorie consumption and unhealthy diets are generally the primary causes of increased weight in individuals, these factors are modifiable, while people often have limited control over the healthiness of the food environments they encounter in their daily lives (Vandevijvere et al., 2019).

Currently, New Zealand ranks second globally in childhood obesity prevalence, with higher rates affecting Māori and Pacific children, as well as those living in the most disadvantaged areas (Chiavaroli et al., 2019; UNICEF, 2019). The triple burden of malnutrition disproportionally affects children facing food insecurity – defined as an individual or household's limited accessibility, affordability, and availability to foods based on their disposal income (Chiavaroli et al., 2019). For example, due to economic constraints, families with lower incomes often opt for lower-quality, more-affordable foods (UNICEF, 2019). Childhood food insecurity poses serious risks to physical, mental, and emotional health, including micronutrient-deficiencies, growth issues, poor academic outcomes, and overall reduced wellbeing (Dimov et al., 2021; Macaulay et al., 2022; Ministry of Health, 2019b). In NZ, poverty is recognised as the main driver of persistent food insecurity, particularly among Māori and Pacific children and those from disadvantaged areas (Ministry of Health, 2019b). According to the 2014/15 NZ Material Wellbeing Index (Perry, 2017), which measures levels of child poverty, 32% of households lacked regular access to fresh fruits and vegetables, and 10% were unable to include meat, fish, or a vegetarian protein alternative in meals at least every second day due to food costs. Additionally, children living in food-insecure households in NZ consume highly-processed 'fast foods' and sugary beverages (3 or more times/week) more frequently than their counterparts in food-secure homes (Ministry of Health, 2019b).

Moreover, many NZ children reside in 'food deserts' and/or 'food swamps' – areas characterised by lower accessibility to healthy foods and/or higher density of unhealthy food outlets (Vargas et al., 2017). Higher deprivation neighbourhoods have 13.7 more fast food and takeaways' outlets compared to 3.7 in lower deprivation neighbourhoods (Vandevijvere et al., 2018). Accessibility to healthy foods is lower in the most deprived area (1.3 outlets) compared to the least deprived (3.3 outlets) (Vandevijvere et al., 2018). Supermarkets in the most deprived areas allocate more shelf space (0.44/meter) to unhealthy foods than retailers in the least deprived areas (0.38/meter) (Vandevijvere et al., 2018b). Consequently, lower-income NZ families are most affected and may be unable to make the healthier food choice. Recommendations for the NZ government from the 2017 INFORMAS national food environments and policies assessment in NZ include adopting a 20% sugary drinks tax, ensuring healthy food school environments, restricting the marketing of unhealthy foods to children, and strengthening the HSR system (Vandevijvere et al., 2018). In terms of intersectoral action, one of NZ's major food retailers' initiatives, 'Free Fruits for Kids', distributes an average of 50,000 pieces of fruit per week nationwide to children visiting their stores, as one of five nutrition targets set by the chain in alignment with a food retailer sector-wide 'Reducing Childhood Obesity' pledge, in collaboration with the NZ Government (Supermarket News, 2017). On the other hand, the median value of the NZ food industry's commitment to reformulating UPF to healthier options sits at 34% (Vandevijvere et al., 2018).

Child-centred food systems research

Reorienting food systems to meet children's dietary needs is increasingly recognised in the literature (Fox & Timmer, 2020; Hawkes et al., 2020; UNICEF, 2019). Hawkes et al. (2020) developed a child-centred food system research tool that complements the recently launched UNICEF Innocenti Framework (2019). The tool aims to identify actions necessary to realign existing food systems to prioritise children's nutrition. Data collection can be conducted at the community and district levels, focusing on various entry points within the food system, such as supply chains, household and external food environments, and consumer behaviours (Hawkes et al., 2020; UNICEF, 2019).

Child-centred food system research, although relatively emergent, builds upon commonly used research methods. One of the six research steps involved is conducting dietary assessments to determine the disparity between recommended diets and actual food consumption by children (Figure 2-4 – Step 2). This step also identifies the specific foods that child-centred food systems need to increase or decrease. Subsequent steps investigate the factors that influence children's food choices, including the reasons behind their consumption or avoidance of certain food. For example, exploring food-related behaviours of children and caregivers, such as food preparation and household eating patterns. Additionally, the assessment encompasses the examination of food availability, affordability, safety, convenience, and promotion across personal and external food environments, as well as within the supply chain. This comprehensive assessment enables the development of a priority package of actions (Step 6) aimed at efficiently reorienting the system to provide more or less of the identified foods (Hawkes et al., 2020).

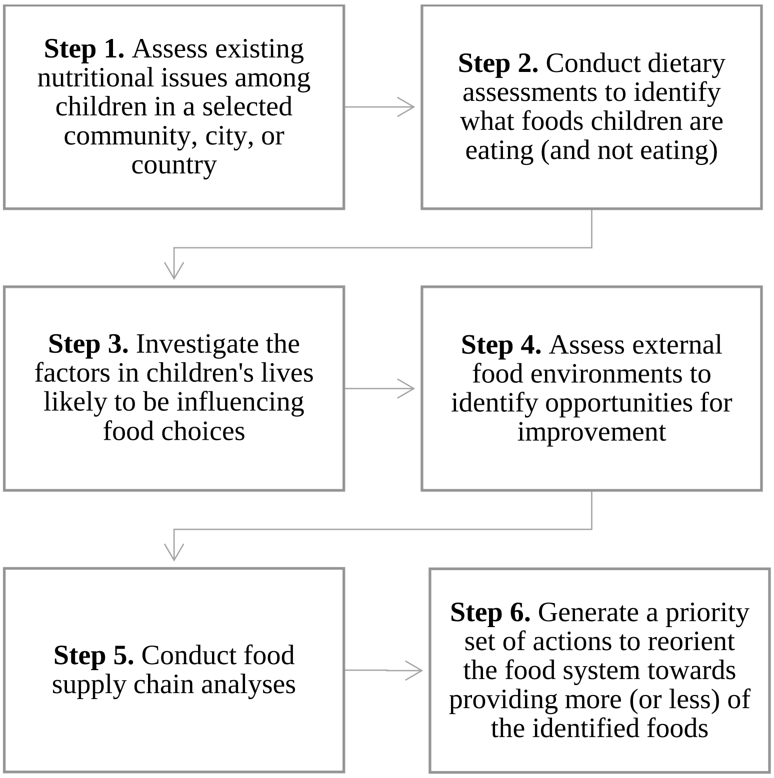


Figure 2-4. The six methodological steps to child-centred food system research

Note: (adapted from Hawkes et al., 2020)

Promoting sustainable healthy diets in the school setting

The UNICEF Innocenti Framework (2019) has identified schools as a key environment for promoting healthy, safe, and sustainable diets for children. Schools may achieve this through the provision and promotion of healthier and more nutritious food and drinks, as well as fostering sustainable eating habits. Moreover, schools are considered an ideal setting for promoting healthy eating due to their central location within communities, providing easy access to children, parents, extended whānau, and the wider community (WHO, 2016). Research has demonstrated that regular consumption of nutritious foods leads to better learning outcomes among children (Burrows et al., 2017; Ministry of Health, 2012), and healthy school environments are associate with lower levels of obesity (D'Souza, 2019). In contrast, diets high in 'junk foods' have been associated with poorer academic performance and decreased wellbeing (Smith & Richards, 2018).

In NZ, most children typically bring a home-packed lunchbox to school. Evidence shows that home-packed school lunches typically contribute to about one third of children's daily dietary intake (Nathan et al., 2019) including in NZ (Regan et al., 2008). However, recent studies from abroad indicate that only a small proportion of school lunchboxes meet national dietary guidelines, lacking core food groups such as vegetables, as well as protein and fibre (Evans et al., 2020; Manson et al., 2021; Stanham et al., 2020; Sutherland et al., 2020). They are instead dominated by nutrient-poor, pre-packaged discretionary snacks (Blondin et al., 2021; Evans et al., 2020; Manson et al., 2021). For example, a study conducted in Australia found the majority of primary-school children's lunchboxes (85%) included discretionary snacks, such as confectionary, biscuits, and chips, with two or more servings in two-thirds of observed lunchboxes (Sutherland et al., 2020). In NZ, outdated lunchbox studies show similar patterns, with a significant portion of children's energy intake during school hours coming from discretionary snacks (Dresler-Hawke et al., 2009; Regan et al., 2008; Rockell et al., 2011a). Moreover, NZ children are more likely to choose unhealthy snacks over healthy options, even when the latter are included in their lunchboxes (Dresler-Hawke et al., 2009).

In addition to the foods available in children's households, crucial factors within NZ children's immediate food environments that can positively or negatively influence their school-time diet include food outlets in and around schools, school fundraising, advertising and sponsorship practices, and school food and nutrition policies along with various public and private sector-funded programmes (D'Souza et al., 2022; Vandevijvere et al., 2018).

In NZ there are notable programmes and initiatives aimed at improving schoolchildren's diets. The Ka Ora Ka Ako | Healthy School Lunches government-funded programme, initiated in 2019, aims to address food insecurity among NZ children (Ministry of Education, 2022b). It offers free school lunches on a daily basis to all students enrolled at participating schools. Targeted toward schools facing significant socio-economic barriers that may impact student achievement, such as child poverty and child hunger, the Ka Ora Ka Ako program currently provides cost-free lunches to 960 of the 2500 existing schools across New Zealand (Ministry of Education, 2022b). Additionally, the long-running initiative Fruit in Schools (FIS) provides a daily piece of fresh produce to children attending schools in disadvantaged areas (Te Whatu Ora Health NZ, n.d.). FIS was introduced in 2005 and has consistently been evaluated as a high-value programme by students, whānau and schools (Te Whatu Ora Health NZ, n.d.). Furthermore, the private sector co-sponsored Fonterra/Sanitarium Kickstart Breakfast Club initiative, which is now co-funded by the NZ government, has been providing free cereal and milk to children in schools facing socio-economic challenges since 2009 (KickStart Breakfast, n.d.).

Despite these initiatives, D'Souza et al. (2022) have reported that school food environments in NZ are predominantly unhealthy and do not favour healthy food choices for children. For example, the majority of school canteen offerings are considered 'occasional' foods, and most fundraising practices in NZ schools (81%) involve selling UPF. Additionally, less than half of schools (40%) have a food and nutrition policy, and those policies, according to D'Souza et al. (2022), *"are weak and lack comprehensiveness" (p. 325).* Moreover, existing school-level food and nutrition guidelines generally lack mandatory provisions applicable to lunchboxes, except for a few exceptions such as the 'water and milk only' policy adopted by two-thirds of primary schools (D'Souza et al., 2022).

Furthermore, as in most countries, NZ lacks official regulatory legislation from the ministry of health for home-packed lunchboxes (Stanham et al., 2020), as existing guidelines typically apply to food provided by schools, excluding foods brought from home (Ministry of Health, 2019a). For example, the Ka Ora Ka Ako free school lunches programme has specific nutrition guidelines that participating schools and suppliers must adhere to (Ministry of Education, 2022b; Ministry of Health, 2019a).

This absence of official guidance places the responsibility on parents and caregivers to determine the lunchbox foods their children consume at school (Nathan et al., 2019; O'Rourke et al., 2020). However, research shows that decision-making in this regard is challenging due to complex factors influencing parent packing behaviour, particularly child preferences, cost, and convenience. Parents and caregivers require support in this area (O'Rourke et al., 2020). On the other hand, primary-aged children's preference for branded, pre-packaged UP snacks, driven by flavour, pervasive marketing tactics, and peer-pressure, influences their desire to consume such products at school (Sato et al., 2022). Further research is needed to understand lunchbox packing behaviours of parents and children (Lalchandani et al., 2023b; O'Rourke et al., 2020), including children's requirements and perceptions (Folta et al., 2018). It is also important to explore constraints and barriers, such as lack of time, food preparation skills, and financial constraints to inform interventions that support parents and children in packing nutritious school lunchboxes (Hawkes et al., 2020; Lalchandani et al., 2023b). Active involvement of children in decision-making, recognising their role as consumers and potential drivers of food system change, is recommended (UNICEF, 2019). Increasing children and parents' knowledge on food marketing tactics and their detrimental effects on children's food choices is also suggested (Sato et al., 2022).

Therefore, it is essential to improve school food environments to encourage healthier and more sustainable eating habits among schoolchildren. Experts emphasise the need to focus on schoolchildren's unique dietary requirements (Kupka et al., 2020; UNICEF, 2019) and improve school food and nutrition policies (D'Souza et al., 2022; O'Rourke et al., 2020; Parker & Koeppel, 2020; Parnham et al., 2022). Recommendations include developing official guidelines that consider the level of food processing (Parnham et al., 2022), particularly addressing the high prevalence of UP snacks brought from home, and strengthening existing policies and strategies (O'Rourke et al., 2020; Parker & Koeppel, 2020; Parnham et al., 2022; UNICEF, 2019).

Home-packed school lunchboxes: UPF and eco-nutrition

Research on the extent of food processing in home-packed school lunchboxes is limited. One study, which conducted a secondary analysis of a RCT in primary schools in the US (mean age, 9 y), found that the majority of foods in lunchboxes were UPF, accounting for 70 % of food energy. These UPF were primarily pre-packaged UP snacks (Blondin et al., 2021). Another study conducted in Brazilian private primary schools also observed a high prevalence of UPF in children' lunchboxes (80% of lunchbox items). Cakes, cookies, and juice drink cartons were the most frequently included UPF (Barbosa et al., 2021). When examining the association between meal type (school-provided vs. home-packed) and total UPF intake in primary and secondary students in UK schools, Parnham et al. (2022) found that UPF intake was high in both age groups, constituting 72.6% and 77.8% of total lunch calories, respectively. Children with home-packed lunches had higher UPF intake compared to those with school-provided meals, as they were more likely to contain the UP version of core foods (Parnham et al., 2022).

From an eco-environmental perspective, the consumption of UP snacks in lunchboxes contributes significantly to waste and pollution due to the disposal of plastic packaging (Chen et al., 2021; Fardet & Rock, 2020; Lalchandani et al., 2022; Seferidi et al., 2020). However, research on lunchbox packaging waste is scarce. In one study, an eco-nutrition guided intervention implemented in primary schools categorised lunchbox food packaging into three types: single-serve packaging, reusable containers, and other packaging such as cling-wrap and foil. At baseline, it was found that more than half (58.9%) of lunchbox items were packaged in single-serve packaging, while only 13.1% were in reusable containers. These proportions did not show significant changes at the follow-up assessment (Goldberg et al., 2015). Another study, which examined the environmental impacts of packed-lunches from an eco-nutrition lens, revealed that discretionary snacks were the primary source of soft plastic packaging in primary schoolers' lunchboxes, whereas most fruit and vegetables were packed in reusable containers (Lalchandani et al., 2023a).

While no academic study has examined single-use plastic packaging in schoolchildren's home-packed lunches in NZ, data from local government suggest that a typical "litter-full" lunchbox may generate up to 30 kg/year of food and packaging waste, contributing to the largest source of waste sent to landfill by the average NZ school (Kapiti Coast District Council, n.d.). To address this issue, schools are increasingly promoting zero-waste lunchboxes, encouraging the use of reusable containers and refillable drink bottles, and educating children about waste minimisation (Eames & Mardon, 2020; Kapiti Coast District Council, n.d.; Lalchandani et al., 2022). These environmentally-friendly practices provide a basis for developing interdisciplinary policies in primary schools to improve nutrition and environmental outcomes (Lalchandani et al., 2022).

Existing school-based healthy eating and nutrition interventions and policies have primarily focused on preventing childhood obesity through a combination of conventional nutritional messages and physical activity strategies (Black et al., 2015; Micha et al., 2018). However, these approaches have shown limited effectiveness in reducing obesity prevalence (Micha et al., 2018; Nathan et al., 2019). The eco-nutrition concept, which emphasises ecological sustainability, has emerged as a promising approach in promoting healthy and sustainable diets in school settings (Black et al., 2015; Goldberg et al., 2015; Jones et al., 2012; Oostindjer et al., 2017; Parker & Koeppel, 2020; Prescott et al., 2019). Several studies suggest that highlighting the connection between food choices that benefit both individual health and environmental sustainability can leverage two powerful motivators for school-aged children: altruism and concern for the planet. This approach may encourage children to adopt healthier and more sustainable dietary habits (Eames & Mardon, 2020; Folta et al., 2018). Moreover, a combined approach that integrates food, sustainability, and health as an educational tool is more appealing to children than traditional food and nutrition concepts that focus on reductionism constructs, such as limiting saturated fat and sugar. The latter approach can sometimes overly "medicalise" nutrition rather than promote sustainable healthy diets (Parker & Koeppel, 2020; Prescott et al., 2019).

An increasing number of schools internationally, including in Canada, Japan, the US, and Scandinavian countries, have adopted a school-wide sustainable food systems approach encompassing various aspects such as school food provision and consumption, programmes, and policies (Parker & Koeppel, 2020; Prescott et al., 2019). In NZ, 40% of primary and secondary schools participate in the long-term sustainability programme 'Enviroschools', with the two most popular action areas being 'Zero Waste' (adopted by 100% of these schools) and 'Kai/ Food Production' (93% of schools) (Eames & Mardon, 2020). Additionally, the NZ Ministry of Education (2022b) recommends that schools incorporate school-wide zero-waste policies, including measures to reduce food and single-use plastic packaging waste. This suggests there is considerable potential for NZ schools to embrace a child-centred sustainable food system approach. Moreover, this approach aligns well with the UN-SDGs (2015), such as 'Sustainable Cities and Communities', 'Responsible Production and Consumption', and 'Climate Change Action'.

Part 2 Conclusion

The promotion of nutritious and minimally-processed school lunchboxes may improve children's overall diet quality, reduce the burden of diet-related chronic diseases, and lessen the environmental impacts of UPF. Investigating the healthiness and sustainability status of NZ schoolchildren lunchboxes will help reorient and promote child-centred food systems that prioritise the nutritional needs of children.

Chapter 3 – The relationship between nutritional content and level of processing in primary school children's lunchboxes

Preface

The previous chapter emphasised the need to shift from UPF-dominated diets towards prioritising minimally processed foods sourced from sustainable food systems. Schools were also identified as a critical setting for public health nutrition action, but it was noted that most lunchboxes brought to school by children do not meet dietary requirements. Several gaps in the lunchbox literature were identified, particularly evidence around the level of food processing and the environmental impacts of lunchbox waste.

In response to these gaps, a cross-sectional study was conducted in four primary schools located in Auckland, NZ, with the objective of assessing the healthiness and sustainability of home-packed lunchboxes. The following chapter represents the first part of this study, which examines the relationship between the nutritional content (energy and sugar) of lunchbox food and drink items, and their level of food processing.

Abstract

Purpose: Ultra-processed foods have become a major public health concern, given their detrimental impacts on health, including in children. Despite home-packed school lunchboxes representing a significant portion of most children's diets in New Zealand, lunchbox-related research is limited and somewhat outdated. No study has investigated the level of processing of food and drink items in NZ children's lunchboxes. This study aims to assess the level of food processing in home-packed lunches among NZ primary schoolchildren and investigate its relationship with the nutritional content (energy and sugar).

Method: A cross-sectional study was conducted with 110 children in Auckland, NZ, using digital photographs and a pen-and-paper questionnaire. The energy (kJ) and sugar (g) of lunchbox food and drink items were estimated, before categorising each item into one of three levels of processing (unprocessed/minimally-processed, processed, ultra-processed) based on the NOVA classification system. Statistical analyses explored differences in energy and sugar among the processing levels, while adjusting for school, gender, and who packed the child's lunch (child, parent).

Results: UPF accounted for approximately two-thirds of the overall energy (61.8 ±27.0%), and half of total sugars (50.4 ±31.5%) in lunchboxes. Among the 599 food items (6.0 ±1.9 items per lunchbox), sweet and savoury UP snacks were the primary contributors to energy from UPF (40%), while there was a significant lack of minimally-processed foods (13.7±16.6%) in lunchboxes. Findings were consistent across genders, schools, and lunchbox packer (child/parent).

Conclusion: NZ primary schoolchildren's home-packed lunches were highly processed, with an overreliance on branded, pre-packaged ultra-processed snacks, while fresh and minimally-processed foods from core food groups were underrepresented. This study highlights the need for updated dietary guidelines and guidance for children and parents that consider the impact of extreme food processing on the overall healthiness status of foods.

Background

Childhood (0–18 years) is a period of continuous growth and development, including multiple physiological, social, behavioural, and cognitive changes (UNICEF, 2019). It is well-established that regular, nutritious, sufficient, safe, and varied wholefood-rich diets (combined with limited intake of sugar, salt, and unhealthy fats) are supportive not only of normal growth and development during all stages of childhood but also contribute to lifelong positive health and wellbeing outcomes across all ages (UNICEF, 2019; WHO, 2020). Plus, nutrient-rich dietary patterns protect children's immune systems (Calder et al., 2020; Childs et al., 2019; Hosseini et al., 2017), fuel the young brain for learning (Burrows et al., 2017; Florence et al., 2008), provide the daily energy children require to move and play (Wu et al., 2019), and reduce the risk of poor health outcomes in childhood, such as overweight and obesity (Chiavaroli et al., 2019; Costa et al., 2018), dental caries (Thornley et al., 2021), and anxiety and mood disorders (Dimov et al., 2021; O'Neil et al., 2014). However, children's dietary patterns worldwide are increasingly characterised by excessive consumption of unhealthy, pre-packaged, highly-refined foods and drinks, such as confectionery, sugary and salty snacks, and sweetened beverages, as well as by low intake of nutrient-rich foods, particularly fruit and vegetables (Kupka et al., 2020; UNICEF, 2019). Taken together, these global trends contribute to suboptimal diets and poor health outcomes among children (Dicken & Batterham, 2021).

Traditionally, public health nutrition (PHN) research and efforts have focused on key nutrients to prevent diet-related non-communicable diseases (NCDs) and promote nutritionally-adequate diets across populations (Mozaffarian et al., 2018b; Ridgway et al., 2019). For example, the Ministry of Health 'Food and Nutrition Guidelines for Healthy Children and Young People (2–18y)' (2012) support the reduction of sugar, salt and saturated fats, and increased dietary fiber intake. Similarly, the voluntary front-of-pack Healthy Star Rating (HSR) labelling system, aimed at helping consumers make healthier packaged food choices, scores the 'healthiness' of foods from 0.5 to 5 stars ("the more stars, the healthier") by awarding 'positive' points for higher fibre, protein, fruit, vegetable, nut, or legume content, and subtracting points for 'risk' nutrients (total kilojoules, saturated fat, total sodium, and total sugars, but not added sugars) (Ministry for Primary Industries, 2022b). Based on traditional food groups and a limited set of single nutrients, this approach overlooks the complexity of foods and the broader composition of the food source where these nutrients are found (Astrup et al., 2019; Dickie et al., 2018; Mozaffarian et al., 2018b). Additionally, it fails to consider other crucial factors related to modern industrial food processing methods that are increasingly associated with poor diets and health outcomes in populations across all ages (Adams et al., 2020; Lustig, 2017; Monteiro, 2009; Mozaffarian et al., 2018b; Srour & Touvier, 2021). For example, multiple stages of extreme food processing alter the food structure of wholefoods and negatively affect human digestive processes and the gut microbiota (Dagbasi et al., 2020; Zinöcker & Lindseth, 2018), as well as disrupt gut-brain appetite signals, predisposing individuals to overeating (Contreras-Rodriguez et al., 2022; Dagbasi et al., 2020). Moreover, there is growing concern associated with excessive consumption and 'mixing' (i.e., cocktail-effect) of synthetic additives present in heavily-processed dietary patterns, both from food additives directly added to foods during processing (e.g., emulsifiers, artificial sweeteners), as well as other chemicals migrating into foods from food packaging and other food contact materials during manufacturing (e.g., plasticisers, bisphenols). These have been associated with metabolic syndrome in populations (Bergman et al., 2012; Heindel et al., 2022), including potential disruption of the endocrine and immune systems in infants and children (Trasande et al., 2018).

Concurrently, a more inclusive approach increasingly applied in PHN analysis has emerged (Ridgway et al., 2019). The NOVA (a name, not an acronym) food classification system, focuses on the healthiness of foods beyond their nutritional characteristics, by considering the type, extent, and purpose of food processes undertaken by food and drink items prior to purchase and consumption (Monteiro et al., 2018a). According to NOVA, food and drink items are classified into four groups: 1) unprocessed or minimally-processed; 2) culinary ingredients; 3) processed; and 4) ultra-processed (Monteiro et al, 2018). Ultra-processed food and drink items (UPF) differ considerably from foods found in other food processing categories. Contrary to unprocessed/minimally-processed (fruit and vegetables; milk; rice) and processed foods (salted nuts; canned vegetables; cheeses), UPF generally contain little or no intact wholefoods in their composition (Monteiro et al., 2019). Additionally, UPF are formulated to be highly palatable, usually containing high amounts of sodium, added sugar, ultra-refined oils and starches, as well as cosmetic additives (e.g.; flavourings, colourings, emulsifiers, bulking agents), to compensate for the lack of wholefood in their industrial formulations (i.e., "recipes") (Monteiro et al., 2018). Popular UPF are not limited to 'junk foods' – but also include "everyday" products, such as breakfast 'cereals', 'fruit' yoghurts, mass-produced breads, and reconstituted meat products (Monteiro et al., 2018). The Food and Agricultural Organisation of the United Nations (FAO) officially advises limiting UPF intake and encourages countries to consider NOVA when developing national food-based dietary guidelines (Monteiro et al., 2019a).

Approximately one third of children's daily energy and nutrient intake consumption occurs while at school (Regan et al., 2008; Sanigorski et al., 2005; Sutherland et al., 2021). As school lunchboxes represent a significant portion of children's daily dietary intake, it is crucial to prioritize the inclusion of foods and drinks that positively impact their health and help them achieve their nutrition goals. School-provided meals are an exception in NZ, with most children bringing a lunchbox from home. According to Dresler-Hawke et al. (2012), the nutritional status of children's overall diets, including the contents of their lunchboxes, are directly linked to "behaviour, performance, achievement, and obesity levels in school children" (p. 736). Findings from studies here and abroad investigating school lunchboxes indicate that highly-refined, nutritionally-poor snacks, dominate home-packed lunches

(Blondin et al., 2021; Dresler-Hawke et al., 2009; Evans et al., 2020; Regan et al., 2008; Rockell et al., 2011a; Sanigorski et al., 2005).

In NZ, it has been shown that UPF contribute to 45%, 42% and 51% of average daily energy intake in young children aged 12, 24 and 60 months, respectively (Fangupo et al., 2021, p. 306), but no study has investigated the extent of UPF in home-packed lunchboxes brought to school by children in NZ. A better understanding of food processing levels in children's home-packed lunches could help reduce UPF intake and improve the overall dietary quality and sustainability of such lunches. Therefore, the aims of this study were: 1) to describe the level of food processing of home-packed lunches among NZ primary schoolchildren; 2) to examine the relationship between the nutritional content (energy and sugar) of lunchbox items and their level of processing; and 3) to determine if the relationship between nutrients and level of food processing varies by child gender, school, and who packs the lunches (parent/guardian vs child).

Methods

Participants

In NZ, schools are categorized into deciles, with low decile schools falling within the range of 1–3, medium decile schools within 4–7, and high decile schools 8–10. Decile 10 schools represent the 10% of schools with the lowest proportion of students living in low socio-economic areas, while decile 1 schools represent the 10% of schools with the highest proportion of students living in these communities (ref). The recruitment process started by randomly selecting four primary schools from both lower and higher deciles, two from the East and two from the South regions in Auckland. This selection was made using the NZ MOE online database (ref). Schools were initially contacted by mail and invited to participate in the study. All the schools agreed to participate, as indicated through their response to an initial information letter sent to the school's principal, along with a "Permission for Researcher to Access School's Staff and Students" reply form. Information pertaining to the packed-lunch food and packaging guidelines of participating schools as well as any programs that may have influenced lunchbox choices (e.g., litterless lunchbox initiatives) was sought from the respective participating schools' websites during the data analysis process.

Within each consenting school, primary school students from Year 4–6 classrooms (classrooms selected by the schools) were invited to participate in the study and received an information pack to take home which contained parental consent and student assent forms. Those interested returned signed consent/assent forms to a classroom drop box prior to data collection. In total, 250 children were invited, with 115 children and their parents agreeing to participate. However, five children in total (across all schools) were absent from school during collection day. Parents and students were not notified of the data collection day in advance. Ethical approval was granted by the Auckland University of Technology Ethics Committee (AUTEC), reference number 21/174.

Sample size calculation

Using the PASS 15 software and a repeated measures analysis, we estimated that 53 subjects would allow us to detect a difference in the proportion of energy across the three levels of NOVA processing, with 90% power and a type I error rate of 0.05. This is based on an F Test with a single three-level within-subject factor, a conservative between-subject standard deviation of 40, an autocorrelation among the repeated measurements of 0.2, and applying the Greenhouse–Geisser degrees of freedom adjustment. We based our assumed means across the three processing levels on previous work from the United States (Blondin et al., 2020) and on unpublished data from Manurewa Primary School, NZ (MP = 18.7%, P = 18.8%, UP = 62.7%). We scaled the mean effect to 0.5 to allow us to detect a smaller mean difference across conditions. Allowing for 10% data loss, we increased the sample size to 59 participants.

Data Collection

Data collection in participating schools occurred during May-June 2022 and all data was gathered by the principal researcher. On data collection day, consenting students' lunchboxes were digitally photographed at the start of the school day, following a validated method for measuring lunchbox contents (Blondin et al., 2021). To ensure students' privacy and confidentiality, a privacy screen was placed on the edge of the data collection desk. One at a time, students placed their lunchbox items on a 28 x 43 cm placemat and photographed directly from above (Figure 3-1).

Digital photographs were complemented by a pen-and-paper Lunchbox Food Checklist (adapted from Blondin et al., 2021) (Figure 3-2). The Lunchbox Food Checklist was used for recording complementary information which would not be possible to gather from photos alone. This included details about sandwich fillings, foods within non-transparent wrappers or containers, and additional information from the children, such as the product's brand (if the product had been removed from its original packaging), whether the food item was homemade, or if it was typically purchased in bulk (e.g., nuts). Additionally, the lunchbox checklist enabled the collection of additional information from the children, such as the product's brand (if product had been removed from its original packaging), whether the food item was homemade, or if it was typically purchased in bulk (e.g., nuts). To protect the confidentiality of participants, photographs and lunchbox food checklist responses were matched by an ID number. Participants disposed lunchbox food packaging waste into lidded buckets which were collected by the researcher at the end of the day.

Figure 3-1. Digital photograph of lunchbox

Lunchbox Food Checklist **Total number of items: ______** ☐ **Photo taken**

School #: __________ **Lunchbox ID #: __________**

Who packed your lunchbox today?

☐Yourself ☐Parent/ Guardian ☐Other _________________________

Item Category	Subcategories		Extra Notes
Sweetened Beverage ☐ ☐Water/Milk	☐100% Fruit Juice ☐Fruit Drink ☐ Flavoured Water	☐ Flavoured Milk ☐Fizzy/Sports Drink	
Sandwich ☐	**Filling -meat & alternatives:** ☐Ham, Chicken, Tuna ☐Egg, Falafel ☐ Other_____________ **Filling - milk & alternatives:** ☐ Cheese ☐Cream Cheese ☐Other_____________	**Filling – spreads:** ☐Margarine ☐Butter ☐Mayo ☐Marmite ☐Jam ☐Nut Butter ☐Other _____________	**Bread:** ☐White ☐Wholemeal/ Wholegrain ☐Other ___________ ☐Homemade ☐Shop-bought
Vegetables ☐	☐Carrots ☐Cucumber ☐Tomatoes	☐Capsicums ☐Lettuce ☐Other: ___________	
Fruit ☐	**Fresh:** ☐Apple ☐Banana ☐Orange/Mandarin ☐Other: ___________	**Dried:** ☐Raisins ☐Sultanas ☐Apricots ☐Other: ___________	
Leftovers/ Takeaways ☐	☐Pizza ☐Burger ☐Rice/Pasta dish: ____________	☐Other: ___________	☐Homemade ☐Shop-bought
Misc. Foods ☐	**Bakery:** ☐Homemade ☐Shop-bought ☐ Item:_____________	**Yoghurt & other dairy:** ☐Flavoured Yoghurt ☐Cheese Strings ☐Other: ___________	**Meat & alternatives/Other:** ☐Salami Stick/Cheerios' ☐Hummus/Dip ☐Nuts/Seeds ☐Seaweed ☐Other: ___________
Snack Foods ☐	**Savoury:** ☐Crisps/Corn Chips/"Twisties" ☐Crackers/"Shapes" ☐ Rice Crackers ☐Corn/Rice Thins ☐Popcorn ☐Other: ___________	**Sweet:** ☐Fruit roll-ups/Gummies ☐Muesli/Energy Bars ☐Cookies/Biscuits ☐Candy ☐Chocolate ☐Other: ___________	

Figure 3-2. Lunchbox Food Checklist

Note: (adapted from Blondin et al., 2021)

Measures

Lunchbox food and drink items were coded into eight food categories (i.e., Fruit, Vegetables, Sandwich Filling, Sandwich Bread, Leftovers/Takeaways, Miscellaneous, Snacks, Beverages), and twenty subcategories (e.g., food item category [subcategories], Sandwich bread [white, wholemeal, other]; Sandwich filling [meat & alternatives; milk & alternatives]; Fruit [fresh; dried]) as per the Lunchbox Food Checklist. Sandwich components (i.e., bread, fillings, spread, vegetables) were coded as individual food items and assessed separately.

Nutritional composition

The nutritional composition (i.e., energy, total sugars) of branded, pre-packaged food items and respective serving sizes were obtained from the Nutrition Information Panel (NIP) on the food item's packaging or by consulting major food retailers and manufacturers' websites. Nutrient content of food items without a NIP (e.g., homemade culinary preparations, fresh fruit), were generated using a nutritional tracking software (Cronometer free Web version) (Cronometer, n.d.). Serving sizes were calculated following recommended serving sizes for school-aged children in the Ministry of Health Guidelines for Healthy Children 2–18 years (2012). Total energy (kJ) and total sugars (grams) of lunchboxes were subsequently calculated and subsequently extracted into Excel.

Level of food processing

Lunchbox food items were categorised into one of three food processing categories adapted from the NOVA food classification system (Monteiro et al., 2019a): MP = natural and minimally-processed foods and drinks, and homemade culinary preparations; P = processed food and drink items; and UP = ultra-processed food and drink items. Level of food processing of pre-packed items were ascertained by consulting the ingredients' list on the food item's packaging. Discretion was used when coding food items without nutritional labelling. For instance, handmade culinary preparations, such as leftovers/takeaways, when constituted of mainly minimally-processed and processed foods, with added culinary ingredients (oils, salt), were coded as MP (e.g., homemade minestrone, takeaway egg fried rice), whereas a homemade pizza with vegetables and cheese topping on a pre-packaged, shop-bought crust was coded as processed. Homemade baking (e.g., bread, cakes) were coded as processed, whereas shop-bought bakery items (baked in-store, pre-packaged) were coded following the ingredients' list on individual items. For subsequent analysis, the percentage of total energy and total sugar from each of the processing categories were calculated.

Statistical Analyses

Descriptive statistics were used to determine the mean total energy (kJ) and mean total sugar (grams) for the lunchboxes (Aim 1). A series of repeated measures ANOVA models were used to determine if the proportion of total energy and proportion of total sugars differed among the three levels of food processing (MP, P, UP), which was treated as the within-subject factor (Aim 2). Next, the ANOVA was repeated with the addition of school (four levels), gender (male, female), and who packed the child's lunch (child, parent) to determine if the relationship between level of processing and the two outcome variables differed by these factors (Aim 3). For each of the processing levels, estimated means and 95% confidence intervals were calculated, pairwise contrasts among the three processing levels were estimated, and p-values were adjusted for multiple comparisons using the Holm correction. All analyses were performed in R version 4.2.0.

Results

Table 3-1. Sociodemographic characteristics of participants across schools

Variable	**All (*n*=110)**	
	n	%
Gender (*n*. %)		
Female	71	64.5
Male	39	35.5
School year[a]		
Year 4	26	23.6
Year 5	41	37.3
Year 6	43	39.1
School region/decile[b]		
School 1 East Auckland, decile 3	25	22.7
School 2, East Auckland, decile 9	33	30.0
School 3, South Auckland, decile 4	29	26.4
School 4, South Auckland, decile 8	23	20.9

* SD = standard deviation

[a] School Year level: Primary school education system in NZ starts at Year 1 (approximately 5 years of age) and concludes at the end of Year 8 (approximately 12 years of age) (Ministry of Education, 2022a).

[b] School decile: The extent to which the school's students live in low socio-economic or poorer communities. Decile 1 schools are the 10% of schools with the highest proportion of students from low socio-economic communities. Decile 10 schools are the 10% of schools with the lowest proportion of students from these communities. School deciles in NZ are categorized as low decile = 1–3, medium decile = 4–7, high decile = 8–10 (Ministry of Education, 2022c).

The study sample included 110 participants aged 9‒11 years, and approximately two-thirds were girls (64.5%). There were proportionally more children from Year 5 (37.3%) and Year 6 (39.1%), compared to Year 4 (23.6%). The study included four schools in total, two from the East and two from the South regions in Auckland, NZ. Each region included a lower decile and a higher decile school. The distribution of participants was reasonably equal across the four region/decile categories (Table 3-1).

Table 3-2. Characteristics of lunchboxes brought to school by children.

Variable	All (*n*=110)	
	mean	SD
Total lunchbox items per child		
MP	1.3	1.0
P	1.2	0.9
UP	3.5	1.7
Total	6.0	1.9
Mean energy (kJ) per lunchbox	2504	1089
Mean sugars (g) per lunchbox	40.5	19.4
Proportion of total energy by processing level		
MP (%)	13.7	16.6
P (%)	24.5	22.4
UP (%)	61.8	27.0
Proportion of total sugars by processing level		
MP (%)	37.9	29.9
P (%)	11.7	17.2
UP (%)	50.4	31.5
	n	%
Packed by[c]		
Child	38	34.5
Parent/Guardian	72	65.5

* SD = standard deviation

[a] NOVA processing levels: MP = minimally processed, P = processed, UP = ultra-processed (adapted from Monteiro et al., 2019)

[b] Total energy (kJ) and total sugars (g) in home-packed lunchboxes brought to school were assessed one time at the beginning of the school day. Data collection method was adapted from Blondin et al., 2021, and used digital photography and a complementary lunchbox food checklist.

[c] Packed by: proportion of home-packed lunches brought to school packed by a parent/guardian or the child

In total, there were 599 food items (6.0 ±1.9 items per lunchbox) observed in all lunchboxes (Table 3-2). Mean total energy was 2504 kJ, with the ultra-processed food category contributing almost two-thirds of total energy (61.8% ±27.0), followed by 24.5% processed, and just 13.7% minimally-processed. Lunchboxes had a mean of 40.5 grams total sugars. Half of total sugars (50.4% ±31.5) originated from ultra-processed food items and over one-third of sugars (37.9% ± 29.9) was brought from the natural and minimally processed categories. Approximately two-thirds of participants' lunchboxes (*n*=72, 65.5%) were packed by a parent or guardian, compared to lunchboxes packed by the child (*n*=38, 34.5%) (Table 3-2).

Table 3-3. Most frequent food item categories across NOVA processing levels and their contribution to total energy and total sugars

Food item category and subcategory/processing level	Food item frequency	Mean energy (kJ)	Proportion energy (%) per lunchbox	Mean sugars (g)	Proportion sugars (%) per lunchbox
		Mean (SD)			
NOVA MP					
Fruits - fresh	122	202.1 (133.7)	9.7 (8.1)	12.7 (5.9)	31.9 (17.0)
Sandwich filling - meat & alternatives	6	449.9 (406.4)	15.9 (11.1)	0.4 (0.2)	1.5 (1.3)
Vegetables	6	159.4 (213.2)	9.5 (16.9)	3.1 (3.6)	9.6 (13.8)
NOVA P					
Sandwich filling -spreads	32	316.9 (180.4)	12.0 (6.7)	2.2 (2.9)	4.8 (6.3)
Leftovers/Takeaways	15	814.1 (530.4)	34.4 (22.8)	3.2 (4.0)	9.0 (10.4)
Sandwich filling - milk & alternatives	13	511.4 (241.2)	25.3 (12.8)	0.1 (0.2)	0.6 (1.5)
NOVA UP					
Snack Foods - sweet	113	546.1 (296.6)	19.8 (10.6)	11.6 (13.6)	25.0 (18.4)
Snack Foods - savoury	83	449.4 (245.2)	19.3 (13.4)	0.9 (1.1)	3.1 (4.5)
Sandwich bread - white	46	302.6 (277.0)	13.1 (12.8)	1.7 (0.5)	6.4 (5.4)

* NOVA processing levels – MP = minimally processed, P = processed, UP = ultra-processed (adapted from Monteiro et al., 2019a)

** Lunchbox food item categories [subcategories] as per Lunchbox Food Item Checklist used during data collection. (i.e., Fruit [fresh; dried], Sandwich [fillings, spreads, bread type], Vegetables, Leftovers/Takeaways, Miscellaneous Foods [meat & alternatives, milk & alternatives, other], Snacks [sweet, savoury], Sweetened Beverages [flavoured water, flavoured milk, fizzy/sport]).

The two food item categories with the highest frequency of ultra-processed food items present in lunchboxes were sweet and savoury snacks (*n*=113 and *n*=83 respectively), together representing nearly 40% of energy from UPFs (Table 3-3). *Sweet snacks* contributed most to the proportion of total sugars from UPFs in lunchboxes (25% ±18.4). *Fresh fruit* was the most frequent food item group (*n*=122) in the minimally-processed NOVA category, representing nearly one third of total sugars from minimally-processed food items in lunchboxes (31.9% ±17.0). Vegetables were markedly absent from the sample, with only 6 servings of vegetables across all 110 lunchboxes observed in the study. There were no fizzy or sport drink items present in lunchboxes (not on table).

Table 3-4. ANOVA results illustrating the relationship between total energy and sugar in lunchboxes, and level of food processing.

Measure	**SS**	**MS**	**F**	**η^2**	**p**
Energy (kJ)					
NOVA	10.80	5.40	69.70	0.397	< 0.001*
School	<0.001	<0.001	0.003	<0.001	1.000
Gender	<0.001	<0.001	<0.001	<0.001	0.989
Packed by	<0.001	<0.001	0.001	<0.001	0.974
NOVA*School	0.294	0.049	0.632	0.011	0.705
NOVA*Gender	0.005	0.003	0.033	<0.001	0.968
NOVA*Packed by	0.001	<0.001	0.009	<0.001	0.991
Total sugars (g)					
NOVA	7.363	3.681	33.211	0.236	< 0.001*
School	<0.001	<0.001	-0.001	<0.001	1.000
Gender	<0.001	<0.001	<0.001	<0.001	1.000
Packed by	<0.001	<0.001	-0.002	<0.001	1.000
NOVA*School	0.598	0.100	0.899	0.019	0.497
NOVA*Gender	0.136	0.068	0.613	0.004	0.543
NOVA*Packed by	0.022	0.011	0.100	<0.001	0.904

Note: * indicates statistically significant result (p <. 05)

SS = Type III sum of squares; MS = Mean square

NOVA processing levels: MP = minimally processed, P = processed, UP = ultra-processed (adapted from Monteiro et al., 2019a)

There were significant variations across the levels of food processing for total energy $F(2, 212) = 69.7$, $p < 0.001$ and total sugars $F(2, 212) = 33.2$, $p < 0.001$, present in lunchboxes. Figure 3-3 displays the estimated means for each processing level. There was a gradual increase in the proportion of total energy from MP food items (13.7%) to P food items (24.5%); however, the UP contribution to total energy in lunchboxes was nearly double the amount of these combined (61.8%). Similarly, UP was the highest contributor to total sugars (50.4%), P was lowest (11.7%), with MP contributing to over one-third total sugars (37.9%). No statistically significant differences in nutrient content were identified among the schools, between genders or who packed the lunchbox (Table 3-4), and the relationship between levels of processing and each nutrient did not vary by gender or who packed the lunchbox (Figure 3-4).

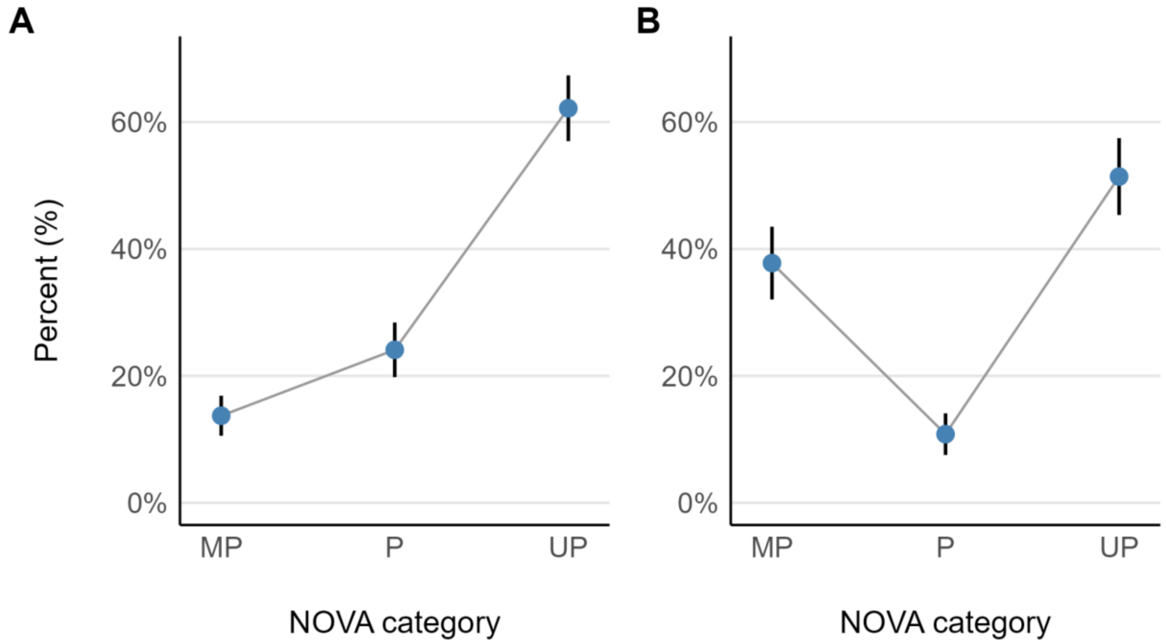


Figure 3-3. Estimated means and 95% confidence intervals for the proportion of total energy (A) and total sugars (B) in lunchboxes across the three NOVA processing levels

Note: MP = minimally processed, P = processed, UP = ultra-processed. These results are adjusted for gender, school, and who packed the lunchbox.

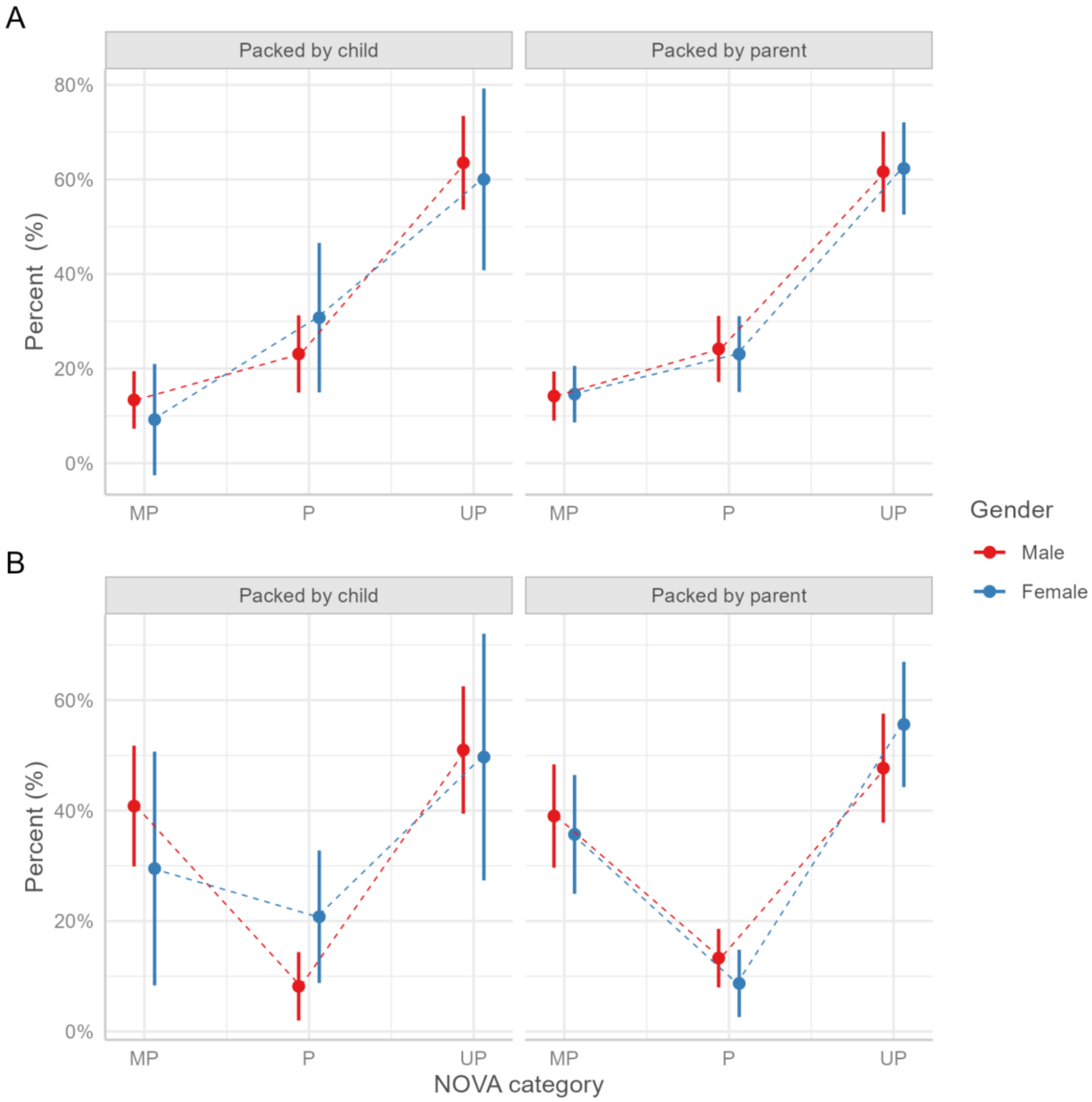


Figure 3-4. Estimated means and 95% confidence intervals for the proportion of (A) total energy, and (B) total sugar, across the three NOVA processing levels, split by gender and who packed the lunchbox.

Note: MP = minimally processed, P = processed, UP = ultra-processed.

Discussion

The present study is the first in NZ to evaluate lunchbox healthiness in the school context by level of processing. Results indicated consistently high levels of UPF in children's lunchboxes, accounting for nearly two-thirds of the overall energy (61.8 ±27.0%), and half of total sugars (50.4 ±31.5%), independently of children's gender, if a parent or child had packed the lunchbox, and school. Although no study has examined daily UPF intake in NZ primary school-aged children, the proportion of energy from UPF was higher than the estimate daily average UPF consumption by 5-year-old NZ children

(51.0%) (Fangupo et al., 2021), and higher than the total dietary share of UPF among Canadian children aged 9–13 (57.2%) (Moubarac, 2017). There is some evidence that UPF consumption during school hours may be higher than all other times of the day (Parnham et al., 2022). Given the association between UPF intake, poor dietary quality, and adverse health outcomes in children (Elizabeth et al., 2020), the high proportion of UPF in school lunchboxes is concerning.

Research examining school lunchboxes by NOVA processing level is still scarce. Recent studies from the US (Blondin et al., 2021), Brazil (Barbosa et al., 2021), and UK (Parnham et al., 2022) have reported even higher proportions of UPF in primary schoolchildren's lunchboxes (70.0, 80.0, 81.2% of energy from UPF, respectively). Across these UPF-related lunchbox analyses, including in the present study, pre-packaged, nutrient-poor sugary and salty UP snacks, such as cookies, muesli bars, and crisps, were overwhelmingly the most common food category across packed-lunches (Figure 3-5). As shown in Table 3-4, these food items were the highest contributors to total energy and total sugars from UPF in children's lunchboxes (40.0% and 25.0%, respectively). Previously conducted lunchbox food and nutrient quality analyses in NZ show high consumption of discretionary snacks (high in salt, sugar, fat), indicating this has been an issue of concern for some time (Dresler-Hawke et al., 2009; Regan et al., 2008; Rockell et al., 2011a). To illustrate, a 2009 study (Dresler-Hawke et al.) found the majority of packed-lunches had an average of three servings of discretionary snacks, such as biscuits, cakes, chocolate, and lollies – a trend that somewhat mirrors the present study. Evidence shows consumption of popular, commercially-produced UP snacks is a pervasive dietary pattern among school-aged children globally, and has been associated with poor nutrition and dietary patterns among this age group (Evans et al., 2020; Gage et al., 2020; Kupka et al., 2020).

Figure 3-5. Sample of observed packed-lunches dominated by sweet and savoury UP snacks.

The most concerning issue with excessive intake of UPF is the replacement of nutrient-dense whole and minimally-processed foods in children's diets, in favour of food-like products high in empty calories, added sugars, ultra-refined oils and starches, and cosmetic additives (Kupka et al., 2020; Monteiro et al., 2013; UNICEF, 2019). There was a significant lack of MPF/PF in lunchboxes, including only 6 servings of vegetables from across the entire sample – a markedly limited amount when compared to the current MoH recommendation of ≥ 3 servings of vegetables/day for school-aged children (Ministry of Health, 2012). In fact, apart from fresh fruit (*n*=122), most foods from core food groups such as 'milk and milk products', and 'meat and meat products', were under-represented, and when present, most items among these were UP, most likely impacting on children meeting set daily nutritional goals needed to grow, learn and thrive. Recent lunchbox analyses report primary school children's lunchboxes are failing to meet dietary guidelines of food groups and nutrient consumption at a global level, with current nutritional guidelines and efforts having little impact in improving children's dietary intake during school hours (Evans et al., 2020; Manson et al., 2021; Stanham et al., 2020). The overwhelming dominance of UPF, in contrast with the absence of wholefoods, support the increased calls in the literature for updated PHN approaches and guidance that consider the quality and level of industrial processing of foods, given the growing evidence on the relationship between UPF and adverse child health outcomes (Parnham et al., 2022; Trasande et al., 2018; Zinöcker & Lindseth, 2018). Updated dietary guidelines and front-of-pack food labelling systems, for example, could provide better nutrition guidance to help children and *whānau* make informed, healthier choices when purchasing and consuming foods and beverages (Dickie et al., 2018; UNICEF, 2019; Zinöcker & Lindseth, 2018). Support in school settings could also promote increased consumption of nutrient-dense, less-processed foods, and thus, improve children's diets (Parnham et al., 2022; Stanham et al., 2020).

As children's school lunchbox contents are mainly determined by parents and caregivers, and food choices available within children's households (O'Rourke et al., 2020), targeting parent buying behaviour is a key strategy where changes can be made to support and encourage healthier food choices among children (Gage et al., 2020; Regan et al., 2008). Evidence shows convenience, cost, and child preferences are the main factors motivating parents when purchasing for, and packing school lunches (O'Rourke et al., 2020). For example, parents choose popular-branded pre-packaged UPF because they are easy to pack and transport; to avoid wasting money (as 'children will eat them'); and because children have asked for them (Blondin et al., 2021; O'Rourke et al., 2020). However, as highlighted by UNICEF (2019), healthier diets for children cannot be demanded from parents and caregivers unless nutritious wholefoods are available, sufficient, convenient, and affordable to them. Research shows NZ food environments are largely unhealthy (Vandevijvere et al., 2018), including 83% of all packaged food items for sale in NZ supermarkets classified as UPF (Luiten et al., 2016); extensive usage of misleading 'nutrition claims' on pre-packaged, nutrient-poor foods and drinks (Al-Ani et al., 2016; Pulker et al., 2018; Sato et al., 2022); UPF products accounting for the majority of pre-packaged items displaying Healthy Star Rating (HSR) labels (Dickie et al., 2018); and food marketing strategies to children predominantly targeting UPF (Cairns et al., 2013). These are factors determined by food systems' upstream drivers, such as global food supply chains and nutrition-related policies by governments (or the lack thereof) (HLPE, 2017; Mozaffarian et al., 2018a), and thus, beyond individual control of children and caregivers, even though they are well-known critical influencers to parents' purchasing habits and children's food choices and dietary behaviours (Cairns et al., 2013; Folkvord & Hermans, 2020; Hawkes et al., 2020; UNICEF, 2019). Relevant PHN policies and strategies which may support children in reducing UPF intake and the overall quality of school lunchboxes include the increased production, promotion, and availability of healthier, less-processed child-targeted foods and snacks for sale (Hallez et al., 2020; UNICEF, 2019); strengthened regulations on health and nutrition claims on pre-packaged items (Al-Ani et al., 2016; Pulker et al., 2018); and adopting novel marketing strategies on food packaging, such as front-of-pack visual cues to promote healthier foods for children (Folkvord & Hermans, 2020; Hallez et al., 2020).

Strengths and Limitations

This study adds to the growing literature exploring the dietary share of UPF in schoolchildren's lunch boxes, as well as contributes to the somewhat outdated home-packed lunchbox research in NZ. One of the main strengths of the study was using a validated digital photography method complemented by a pen-and-paper lunch box food checklist, which allowed for precise measures of lunchbox contents, as opposed to relying on recalled data. However, the study only captured data from one school day and did not measure children's food intake from packed-lunches, to ascertain how much food was actually consumed by children within school hours. Classifying lunchbox items using NOVA, in addition to nutrient metrics, allowed for a more in depth analysis of the healthiness status of single food and drink items in packed lunches, as well as within traditional food groups when disaggregating food groups across the three processing levels. Seemingly alike products, such as processed and ultra-processed cheese, or two popular branded 'salt n' vinegar' flavoured crackers, for example, differed substantially in terms of the ingredients (e.g., additives) once NOVA was applied, even if items were similar in nutritional value, or sometimes, the ultra-processed item having 'healthier' nutritional scores or greater Health Star Rating, compared to the less-processed alternative. However, coding lunchbox food items using NOVA presents some limitations; for example, foods of different levels of nutrient content may fall in the same category (e.g., UP mass-produced bread with added iron *vs* UP snacks), and discretion was applied on several occasions to categorise food items without food labelling, such as shop-bought leftovers and bakery items.

The ubiquity of cheap UPF in NZ food environments may be an explanation for the absence of significant variations in the proportion of UPF between lunchboxes packed by boys vs. girls, parent/guardian vs. child, and across school decile/region. However, the lack of variations could also be influenced by considerably more girls (*n*=71) participating in the study than boys (*n*=39), or differences between schoolchildren who volunteered for the research and those who did not. The limited availability of socio-demographic data in existing literature makes it challenging to make comparisons, emphasising the need for further research in this area.

Future work

School lunchbox-related literature is somewhat limited and outdated in NZ, with all existing studies to date underpinned by traditional PH nutrition-based analyses and policies. Expanding this area of research by (1) adding NOVA as another layer to traditional nutrient-based analyses, as well as (2) using only NOVA, would not only update the existing data but help inform how the two approaches compare as a basis for better nutrition epidemiology. Additionally, future studies could investigate how the proportion of UPF in school lunchboxes predict overall UPF consumption in school-aged children's total daily dietary intake in NZ. Considering the growing availability of UPF in food environments and their potential health risks, other significant gaps to be explored include lunchbox packing behaviours of children and parents, how processing level is related to cost, and how NOVA-underpinned dietary guidelines and/or lunchbox nutrition policies at schools would benefit reduced UPF intake, increased wholefood consumption, and overall diet quality of school-aged children.

Conclusion

In the study, NZ primary schoolchildren's home-packed lunches were highly processed, independent of gender, school, or if lunchboxes were packed by a parent or child. Branded, pre-packaged UP sweet and savoury snacks dominated children's lunchboxes. Food items from traditional core food groups were generally under-represented, most notably vegetables, and when present, these core food items were more likely to be a UP version as opposed to their healthier, less-processed alternative. Therefore, this study highlights the need for updated PHN policies and guidance that consider the complexity of wholefoods and the impact of industrial food processing on the overall 'healthiness' status of foods. This may help to promote healthier diets and reduce UPF-related health risks among school-aged children.

Chapter 4 – The relationship between single-use plastic packaging and level of food processing in primary school children's lunchboxes

Preface

The previous chapter presented the first part of a cross-sectional study examining the healthiness and sustainability of home-packed lunchboxes in four primary schools located in Auckland, NZ. The first part explored the relationship between the total energy and sugar content of observed lunchboxes and their level of food processing. Building upon these findings, the next chapter presents the second part of this study, focusing on the relationship between single-use plastic packaging of food and drink items and the levels of food processing. By analysing packaging profile of lunchbox items and the connection with food processing level, this study aims to provide insights into the sustainability implications of home-packed lunchboxes.

Abstract

Purpose: Single-use plastic packaging contributes to global plastic waste and pollution. In response, numerous schools are promoting zero-waste lunchbox initiatives. However, limited research exists on the environmental impacts of home-packed lunchboxes to guide such initiatives. The relationship between single-use plastic packaging and the level of processing of lunchbox contents remains unexplored. This study aims to determine the proportion of single-use plastic packaging in home-packed lunches and investigate the association with the level of processing of food and drink items.

Design: A cross-sectional study was conducted with 110 children in Auckland, NZ, to estimate the proportion of single-use plastic packaging in lunchboxes, using digital photographs and a pen-and-paper questionnaire. Packaging of lunchbox food and drink items was categorised into four groups (single-use plastic, single-use other, reusable, no packaging), while the level of processing was assigned based on the NOVA classification system, with three levels (unprocessed/minimally processed, processed, ultra-processed). Two methods of waste coding were employed to account for packaging removed from food at home.

Results: Analysis of 541 lunchbox food and drink packaging items revealed that 35.6% (*n*=194) were single-use plastic packaging (SUPP). However, when considering the original packaging (removed at home), the proportion of SUPP increased significantly to 53.2% ($p < 0.001$, $g = 0.91$). Simultaneously, the percentage of food items with no packaging decreased from 44.4% to 34.0% ($p < 0.001$, $g = 0.63$). The majority of SUPP originated from ultra-processed foods (76.2%), while minimally-processed foods contributed to only 0.9% of SUPP. Soft plastic bags or wrappers from ultra-processed snacks (58.8%) were the most prevalent type of SUPP in lunchboxes.

Conclusion: The home-packed lunchboxes of primary schoolchildren in New Zealand generate a significant amount of single-use plastic packaging waste, primarily from the soft plastic bags and wrappers of ultra-processed sweet and savoury snacks. Prioritising the inclusion of wholefoods and minimally-processed items in home-packed lunches could contribute to reducing single-use plastic packaging waste while promoting healthier and more environmentally-friendly school lunches.

Background

Single-use plastic packaging, designed for one-time use and subsequent disposal, is the primary contributor to global plastic waste, with < 10% being recycled (Geyer et al., 2017). Specifically, single-use plastic food and beverage packaging (SUPP) waste, including disposable drink bottles, food wrappers, bags, and containers, account for approximately 42% of plastic waste accumulated in landfills and nature (Chen et al., 2021; Geyer et al., 2017). These items are also the most commonly littered across aquatic environments worldwide (Morales-Caselles et al., 2021). The impact of plastic waste on wildlife is devastating, with reports of entanglement, ingestion, and death among various species (Peng et al., 2017; Thiel et al., 2018). Additionally, SUPP waste may take hundreds of years to fragment into microplastics (< 5mm), releasing hazardous chemicals and perpetuating environmental pollution and contamination (Chen et al., 2021; Geyer et al., 2017; Peng et al., 2017). Microplastics have been found in the human bloodstream (Leslie et al., 2022), lung tissue (Jenner et al., 2022), and the human food chain, including water, salt, honey, and shellfish (Senathirajah et al., 2021). While more research is needed to fully understand the potential health risks of microplastics, concerns have been raised regarding their possible contribution to chronic inflammation, neurodegenerative diseases, autoimmune disorders, and cancers (Kadac-Czapska et al., 2023; Prata et al., 2020).

Consequently, there have been strong calls for SUPP reduction and minimisation of SUPP waste (Chen et al., 2021; Peng et al., 2017). The exponential increase in SUPP has been primarily driven by global demand for convenience, ready-to-eat foods, and increased preference for ultra-processed food and drink items (UPF) consumed ‘on the go’ (Chakori et al., 2021). Heavily-packaged UPF, dominant in food environments and diets worldwide (Monteiro et al., 2013; Pan American Health Organization, 2015), contribute to over 50% of total calorie consumption in high-income countries (Khandpur et al., 2020b; Marino et al., 2021). In NZ, UPF contribute to over half (51%) of the average dietary intake among 5-year-old children (Fangupo et al., 2021) and represent 83% of food and drink items available in supermarkets (Luiten et al., 2016). UPF tend to be nutrient-poor, lacking wholefoods, and high in added sugars, sodium, highly-processed oils and starches, as well as cosmetic additives (e.g.; emulsifiers; artificial sweeteners) (Monteiro et al.2019). UPF consumption has been associated with multiple negative health outcomes across all ages, including increased cardiometabolic risks and asthma in children (Adams et al., 2020; Elizabeth et al., 2020; Monteiro et al., 2018a). Marketing strategies, including visual cues on child-directed UPF packaging, also influence unhealthy eating behaviours (Cairns et al., 2013; Elliott, 2019; Hallez et al., 2020; Sato et al., 2022). Furthermore, synthetic additives commonly found in SUPP (e.g., bisphenols; phthalates), can migrate into foods (Muncke et al., 2020) and have been associated to immune and endocrine disruption in children (Trasande et al., 2018), and metabolic syndrome in adulthood (Heindel et al., 2022).

In NZ, most children bring home-packed lunchboxes to school, contributing to approximately one third of their daily energy and nutrient intake (Nathan et al., 2019; Regan et al., 2008; Sanigorski et al., 2005; Sutherland et al., 2020). Literature from both NZ and abroad indicate home-packed lunches generally consist of highly-processed foods, with pre-packaged UP snacks like biscuits, crisps, and confectionary dominating lunchboxes (Blondin et al., 2021; Dresler-Hawke et al., 2009; Evans et al., 2020; Manson et al., 2021; Rockell et al., 2011a; Stanham et al., 2020), while fresh and less-processed foods such as vegetables are lacking (Dresler-Hawke et al., 2009; Evans et al., 2020; Stanham et al., 2020). Moreover, child-oriented UP snacks are often designed for single-serve consumption, resulting in significant amounts of packaging waste (Chakori et al., 2021). An increasing number of schools are promoting zero-waste lunchboxes, where children are encouraged to use reusable food containers and refillable drink bottles instead of disposable plastic packaging and single-serve items, and take any lunchbox waste back home (Eames & Mardon, 2020; Lalchandani et al., 2022). While this initiative has become popular across schools in NZ (Eames & Mardon, 2020), data from local government on school waste audits suggest that a typical "litter-full" lunchbox may generate up to 30 kg/year of food and packaging waste, with lunchboxes being the largest source of waste sent to landfill by the average NZ school (Kapiti Coast District Council, n.d.).

Limited literature exists on food and drink packaging waste in schoolchildren's lunchboxes (Goldberg et al., 2015; Lalchandani et al., 2023a), with no studies conducted in NZ. Additionally, no research has explored the relationship between SUPP usage and level of processing of food and drink items brought from home to school. Eco-nutrition, which combines healthy eating with an ecological sustainability focus, has emerged as a promising concept for promoting sustainable healthy diets in schools (Folta et al., 2018; Goldberg et al., 2015; Prescott et al., 2019). This approach aligns with international public health agendas, including the United Nations (UN) Sustainable Development Goals (2015) and UNICEF's Innocenti Framework on Food Systems for Children and Adolescents (2019), which emphasise the importance of sustainable diets that nourish children while preserving the environment for future generations.

Given the knowledge gaps regarding the environmental impacts of school lunchbox contents and the growing recognition of eco-nutrition as a viable strategy, further research is warranted. This study aims (1) to determine the proportion of single-use plastic packaging in home-packed lunchboxes among NZ primary schoolchildren, (2) to examine the relationship between single-use plastic packaging in lunchboxes and the level of processing, and (3) to assess whether this association varies by child gender, school, and who packed the lunches (parent/guardian or child).

Methods

In NZ, schools are categorized into deciles, with low decile schools falling within the range of 1–3, medium decile schools within 4–7, and high decile schools 8–10. Decile 10 schools represent the 10% of schools with the lowest proportion of students living in low socio-economic areas, while decile 1 schools represent the 10% of schools with the highest proportion of students living in these communities (ref). The recruitment process started by randomly selecting four primary schools from both lower and higher deciles, two from the East and two from the South regions in Auckland. This selection was made using the NZ MOE online database (ref). Schools were initially contacted by mail and invited to participate in the study. All the schools agreed to participate, as indicated through their response to an initial information letter sent to the school's principal, along with a "Permission for Researcher to Access School's Staff and Students" reply form. Information pertaining to the packed-lunch food and packaging guidelines of participating schools as well as any programs that may have influenced lunchbox choices (e.g., litterless lunchbox initiatives) was sought from the respective participating schools' websites during the data analysis process.

Within each consenting school, primary school students from Year 4–6 classrooms (classrooms selected by the schools) were invited to participate in the study and received an information pack to take home which contained parental consent and student assent forms. Those interested returned signed consent/assent forms to a classroom drop box prior to data collection. In total, 250 children were invited, with 115 children and their parents agreeing to participate. However, five children in total (across all schools) were absent from school during collection day. Parents and students were not notified of the data collection day in advance. Ethical approval was granted by the Auckland University of Technology Ethics Committee (AUTEC), reference number 21/174.

Sample size calculation

Using the PASS 15 software and a repeated measures analysis, we estimated that 53 subjects would allow us to detect a difference in the proportion of energy across the three levels of NOVA processing, with 90% power and a type I error rate of 0.05. This is based on an F Test with a single three-level within-subject factor, a conservative between-subject standard deviation of 40, an autocorrelation among the repeated measurements of 0.2, and applying the Greenhouse–Geisser degrees of freedom adjustment. We based our assumed means across the three processing levels on previous work from the United States (Blondin et al., 2020) and on unpublished data from Manurewa Primary School, NZ (MP = 18.7%, P = 18.8%, UP = 62.7%). We scaled the mean effect to 0.5 to allow us to detect a smaller mean difference across conditions. Allowing for 10% data loss, we increased the sample size to 59 participants.

Data Collection

Data collection in participating schools occurred during May-June 2022 and all data was gathered by the principal researcher. On data collection day, consenting students' lunchboxes were digitally photographed at the start of the school day, following a validated method for measuring lunchbox contents (Blondin et al., 2021). To ensure students' privacy and confidentiality, a privacy screen was placed on the edge of the data collection desk. One at a time, students placed their lunchbox items on a 28 x 43 cm placemat and photographed directly from above (Figure 4-1).

Digital photographs were complemented by a pen-and-paper Lunchbox Food Checklist (adapted from Blondin et al., 2021). The Lunchbox Food Checklist was used for recording complementary information which would not be possible to gather from photos alone. This included details about sandwich fillings, foods within non-transparent wrappers or containers, and additional information from the children, such as the product's brand (if the product had been removed from its original packaging), whether the food item was homemade, or if it was typically purchased in bulk (e.g., nuts). Additionally, the lunchbox checklist enabled the collection of additional information from the children, such as the product's brand (if product had been removed from its original packaging), whether the food item was homemade, or if it was typically purchased in bulk (e.g., nuts). To protect the confidentiality of participants, photographs and lunchbox food checklist responses were matched by an ID number. Participants disposed lunchbox food packaging waste into lidded buckets which were collected by the researcher at the end of the day.

To further assist with lunchbox packaging profiling, participants were asked to dispose of any lunchbox food and packaging waste into lidded buckets provided during data collection which were collected by the researcher at the end of the day. Additionally, children were also asked who had packed their lunchbox that morning and whether they had brought a drink bottle to school, along with the type of drink it contained. To ensure the confidentiality of participants, photographs and lunchbox food checklist responses were matched with an ID number.

Figure 4-1. Digital photograph of lunchbox

Measures

Level of food processing

Lunchbox food and drink items were coded into eight food categories (i.e., Fruit, Vegetables, Sandwich Filling, Sandwich Bread, Leftovers/Takeaways, Miscellaneous, Snacks, Beverages), and twenty subcategories (e.g., food item category [subcategories], Sandwich bread [white, wholemeal, other]; Sandwich filling [meat & alternatives; milk & alternatives]; Fruit [fresh; dried]) as per Lunchbox Food Checklist. Sandwich components (i.e., bread, fillings, spread, vegetables) were coded as individual food items. Subsequently, lunchbox food and drink items were individually coded into three level of food processing categories adapted from the NOVA food classification system (Monteiro et al., 2019) as MP = natural and minimally processed foods and drink items; P = processed food and drink items; and UP = ultra-processed food and drink items. Level of food processing of pre-packed items were ascertained by consulting the ingredients' list on the food item's packaging. Discretion was used when coding food items without nutritional labelling. For instance, handmade culinary preparations, such as leftovers/takeaways, when constituted of mainly minimally-processed and processed foods, with added culinary ingredients (oils, salt), were coded as MP (e.g., homemade minestrone, takeaway egg fried rice), whereas a homemade pizza with vegetables and cheese topping on a pre-packaged, shop-bought crust was coded as processed. Homemade baking (e.g., bread, cakes) were coded as processed, whereas shop-bought bakery items (baked in-store, pre-packaged) were coded following the ingredients' list on individual items.

Food packaging

Lunchbox food and drink packaging items were coded based on their packaging type and material (e.g. Tetra-Pak drink carton, beeswax wrapper, paper/cardboard, foil). Subsequently, each item was further categorised into one of four packaging categories: SUPP = single-use plastic packaging; SUPO = single-use packaging other; RP = reusable packaging; and NP = no packaging (Table 4-1). Note that individual sandwich items (i.e., fillings, spreads) were not coded into packaging categories. For each participant, the proportion of total packaging that was SUPP was calculated and as the main outcome variable in subsequent analyses.

Table 4-1. Lunchbox food and drink packaging items coded into four packaging categories

Packaging Category	Lunchbox Packaging Item (examples)
Single-use plastic packaging (SUPP)	Soft plastic bag or wrapper (chip bag, muesli bar, cookies, confectionary, nuts) Plastic cup with peel off-lids (yoghurt pottle, fruit cup) Squeeze pouch & lid (yoghurt) Tetra-Pak carton with straw (juice, flavoured milk) Hard plastic bottles (fizzy, juice, water) Plastic tray with lid or wrapper (sushi, seaweed, crackers) Cling wrap

Single-use packaging other (SUPO)	Foil Paper & cardboard, brown/white (bags, napkins, kitchen towel) Paper & cardboard, waxed/plastic-coated/colour-printed Metal/aluminium cans (snack tuna)
Reusable packaging (RP)	Reusable container plastic Reusable container other (metal, glass) Zip-lock bags Beeswax wrappers
No packaging (NP)	Fruit and vegetables (no packaging) Sandwiches, rolls & homemade preparations (no packaging) Other foods (no packaging)

To ensure the robustness of our packaging coding strategy, we employed two methods of coding lunchbox packaging: observed, and original packaging. The first method involved coding each food item's packaging based on its observed state in the photograph. For instance, a cereal-type bar that was still in its original wrapper was coded as 'soft plastic bag or wrapper – SUPP' (Figure 4-2, lunchbox A), while the same-type bar found unwrapped inside a reusable plastic container was coded as 'other foods – NP' (Figure 4-2, lunchbox B). The second method involved coding each food item's packaging using the original packaging of food and drink items, regardless of whether the packaging was brought to school. This was done by asking the question, "Is this food/drink item usually packaged in SUPP? (yes/no)". In this method, the photographed unwrapped cereal-type bar (lunchbox B) would be coded as 'soft plastic bag or wrapper – SUPP', even though it had no packaging. Homemade items, such as baking and sandwiches, were still coded as NP. Sandwich fillings (e.g., spreads) were excluded from packaging coding in both methods.

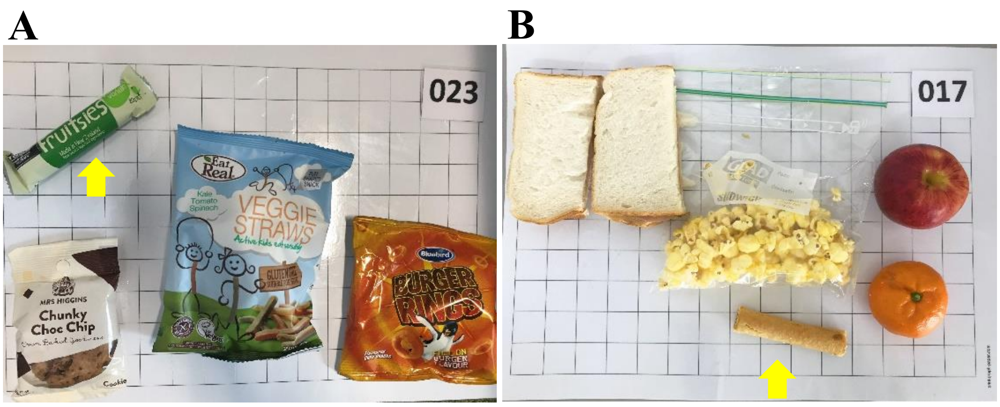


Figure 4-2. Comparison of lunchbox coding methods: observed packaging (A) and original packaging (B).

Statistical Analyses

Descriptive statistics were used to examine the frequency of different types of packaging (SUPP, SUPO, Reusable, and No packaging) in lunchboxes (Aim 1). To determine if these estimates varied by the packaging coding method employed (observed packaging, original packaging), we compared the proportion of food items in each of these categories between the two coding methods using a paired samples t-test. The magnitude of any differences were expressed as Hedge's *g* effect size. A series of ordinary least squares linear regression models were used to explore the relationship between SUPP from lunchboxes and the level of food processing of lunchbox content (Aim 2). The proportion of lunchbox packaging that was classified as SUPP was specified as the dependant variable, while the proportion of lunchbox items within each processing level (M, P, and UP) were treated as independent variables (separately). Next, gender (male, female), school (four levels), and who packed the child's lunch (child, parent) were added as additional independent variables to determine if the relationship between SUPP and level of food processing varied by these factors (Aim 3). For each of these additional covariates, interactions with the level of processing variable were tested. All analyses were performed in R version 4.2.0.

Results

Table 4-2. Sociodemographic characteristics of participants across schools

Variable	**All (*n*=110)**	
	n	%
Gender (*n*. %)		
Female	71	64.5
Male	39	35.5
School year[a]		
Year 4	26	23.6
Year 5	41	37.3
Year 6	43	39.1
School region/decile[b]		
School 1 East Auckland, decile 3	25	22.7
School 2, East Auckland, decile 9	33	30.0
School 3, South Auckland, decile 4	29	26.4
School 4, South Auckland, decile 8	23	20.9

[a] School Year level: Primary school education system in NZ starts at Year 1 at around 5 years old and concludes at the end of Year 8 (approximately 12 years old) (Ministry of Education, 2022a).

[b] School decile: The extent to which the school's students live in low socio-economic or poorer communities. Decile 1 schools are the 10% of schools with the highest proportion of students from low socio-economic communities. Decile 10 schools are the 10% of schools with the lowest proportion of students from these communities. School deciles in NZ are categorized as low = 1–3, medium = 4–7, and high = 8–10 (Ministry of Education, 2022c)

The study sample included 110 participants aged 9–11 years, and approximately two-thirds were girls (64.5%). There were proportionally more children from Year 5 (37.3%) and Year 6 (39.1%), compared to Year 4 (23.6%). The study included four schools in total, two from the East and two from the South regions in Auckland, NZ. Each region included a lower decile and a higher decile school. The distribution of participants was reasonably equal across the four region/decile categories (Table 4-2).

There were 599 food items (mean ±SD, 6.0 ±1.9 items per lunchbox) observed in all lunchboxes. Nearly two-thirds of all lunchbox food items were UP foods (3.5 ±1.7 UP food items per lunchbox), and there were nearly three times more UPF than MPF items present in lunchboxes (1.3 ±1.0 MPF per lunchbox) (Table 4-3). Approximately two-thirds of participants' lunchboxes (*n*=72, 65.5%) were packed by a parent or guardian, compared to lunchboxes packed by children themselves (*n*=38, 34.5%).

Table 4-3. Characteristics of food items and packaging in lunchboxes brought to school by children

Variable		
	Mean	**SD**
Lunchbox items brought across NOVA [a] (*n*=599)		
MP	1.3	1.0
P	1.2	0.9
UP	3.5	1.7
Total	6.0	1.9
Food item packaging group % [b] (observed in photo)		
SUPP	35.6	29.0
SUPO	2.4	7.0
Reusable	17.6	26.0
No packaging	44.4	32.0
Food item packaging group % (original packaging)		
SUPP	53.2	25.2
SUPO	1.9	6.7
Reusable	10.9	19.3
No packaging	34.0	25.2
Packed by [c]	**n**	**%**
Child	38	34.5
Parent/Guardian	72	65.5

SD = standard deviation

[a] NOVA food processing categories: MP = minimally processed, P = processed, UP = ultra-processed (adapted from Monteiro et al., 2019)

[b] SUPP = single-use plastic packaging (e.g., soft plastic bags and wrappers, Tetra-Pak drink cartons, clingwrap), SUPO = single-use packaging "other" (e.g., paper/cardboard, foil), RP = reusable packaging (e.g., Tupperware), NP = no packaging (e.g., fresh fruit)

[c] Proportion of home-packed lunches brought to school packed by a parent/guardian or the child

Figure 4-3 shows the differences between the packaging coding methods (observed vs. original packaging), for the proportion of lunchbox food items in each packaging category. When taking into account the original packaging, the percentage of SUPP increased from 35.6% to 53.2% ($p < 0.001$, $g = 0.91$), while the percentage of food items with no packaging decreased from 44.4% to 34.0% ($p < 0.001$, $g = 0.63$). There were no differences between coding methods for SUPO.

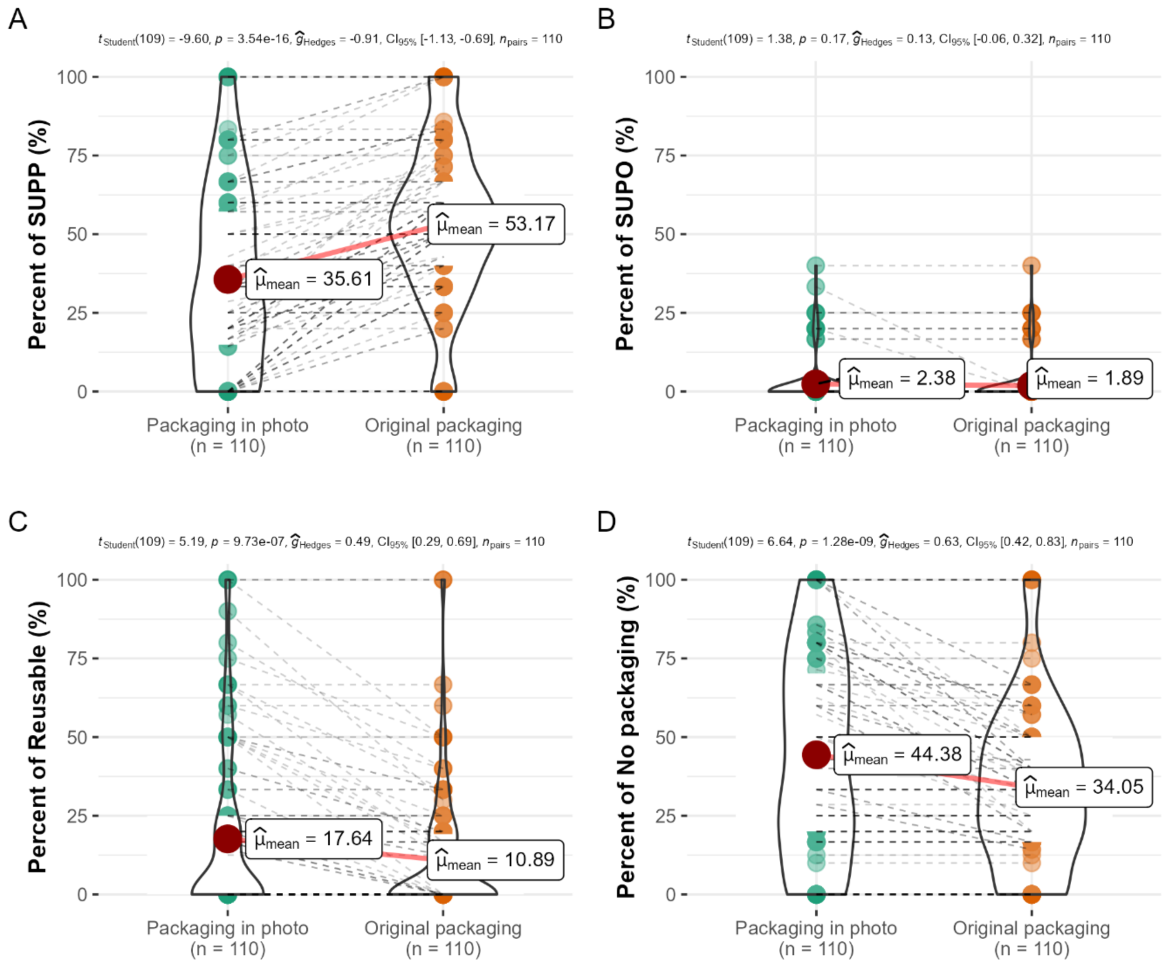


Figure 4-3. Difference in (A) SUPP, (B) SUPO, (C) Reusable packaging, and (D) No packaging, between packaging in the lunchbox photos and the original packaging.

Note: SUPP: single-use plastic packaging, SUPO: single-use packaging other. Results obtained from paired-samples t-test.

Table 4-4. Proportion of single-use plastic packaging across the NOVA processing categories

Variable		
	n	**%**
SUPP per food processing level [a]		
MP	2	0.9
P	26	11.9
UP	166	76.2
Most frequent SUPP items		
Soft plastic bag or wrapper	114	58.8
Plastic cup with peel-off lid	19	9.8
Plastic tray and lid	19	9.8
Cling wrap	16	8.2
Tetra pack carton with straw	10	5.2

[a] NOVA processing levels: MP = minimally processed, P = processed, UP = ultra-processed (adapted from Monteiro et al., 2019)

Of the 541 packaging items, 194 (35.6%) were SUPP. The majority of this SUPP was generated from UP foods (76.2%), while only 0.9% was generated from MP foods (Table 4-4). The three most frequent SUPP items present in lunchboxes were soft plastic bags or wrappers, plastic cups with peel-off lids, and plastic trays with lids (Table 4-4). The relationship between the proportion of SUPP and level of food processing is shown in Figure 4-4. As the proportion of MP food items increased, the proportion of SUPP decreased (Panel A); specifically, for every 1% increase in MP food, SUPP waste decreased by 0.7%. In contrast, as the proportion of UP food items increased, the proportion of SUPP also increased (Panel C); specifically, for every 1% increase in UP food, the proportion of SUPP increased by 0.6%. The regression coefficients from each of these three models are presented in Table 4-5.

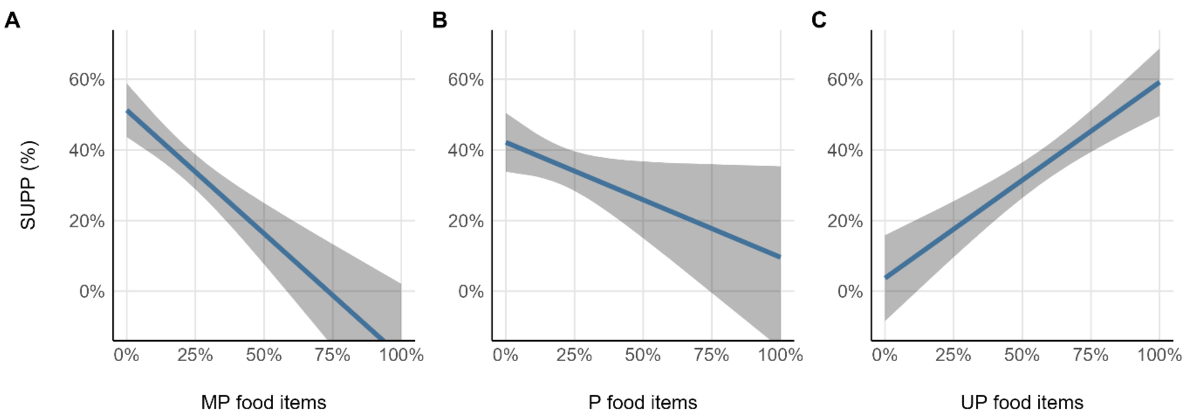


Figure 4-4. Relationship between proportion of SUPP and proportion of (A) minimally-processed food items, (B) processed food items, and (C) ultra-processed food items.

Note: The blue line represents the model-estimated mean, and the shaded ribbon represents the 95% confidence interval.

Table 4-5. Relationship between food processing category and proportion of single-use plastic packaging (SUPP)

Model	Unstandardized coefficient	95% CI		t	p
		LL	UL		
Minimally processed					
Intercept	0.51	0.44	0.59	13.4	< .001
Proportion MP (%)	-0.70	-0.96	-0.44	-5.34	< .001
Processed					
Intercept	0.42	0.34	0.50	10.05	<.001
Proportion P (%)	-0.34	-0.64	-0.01	-2.05	0.04
Ultra Processed					
Intercept	0.04	-0.085	0.16	0.60	0.55
Proportion UP (%)	0.55	0.36	0.75	5.67	<.001

Note. Dependent variable is the proportion of waste that is single use plastic packaging (%). CI = confidence interval; LL = lower limit; UL = upper limit. NOVA processing levels: MP = minimally processed, P = processed, UP = ultra-processed (adapted from Monteiro et al., 2019)

When the linear regression models were adjusted for school, gender, and who packed the lunchbox, only gender remained a significant predictor (Table 4-6). There was a significant interaction between gender and each level of processing, suggesting that the relationship between level of processing and SUPP varied by gender. These differences are visualised in Figure 4-5, where the association between SUPP and level of processing is stronger in females, compared to males.

Table 4-6. Analysis of Variance Table for adjusted regression models

Model	Variable	Mean square	F	p
Minimally-processed	Proportion MP	1.90	31.2	< 0.001
	School	0.12	2.10	0.106
	Gender	0.34	5.69	0.019
	Packed by	<0.01	0.08	0.793
	Proportion MP * Gender	0.25	4.17	0.044
Processed				
	Proportion P	0.34	4.64	0.034
	School	0.19	2.57	0.058
	Gender	0.34	4.71	0.032
	Packed by	<0.01	<0.01	0.969
	Proportion P * Gender	0.40	5.43	0.022
Ultra-processed				
	Proportion UP	2.09	35.5	<0.001
	School	0.14	2.37	0.075
	Gender	0.28	4.70	0.033
	Packed by	<0.01	<0.01	0.939
	Proportion UP * Gender	0.32	5.41	0.022

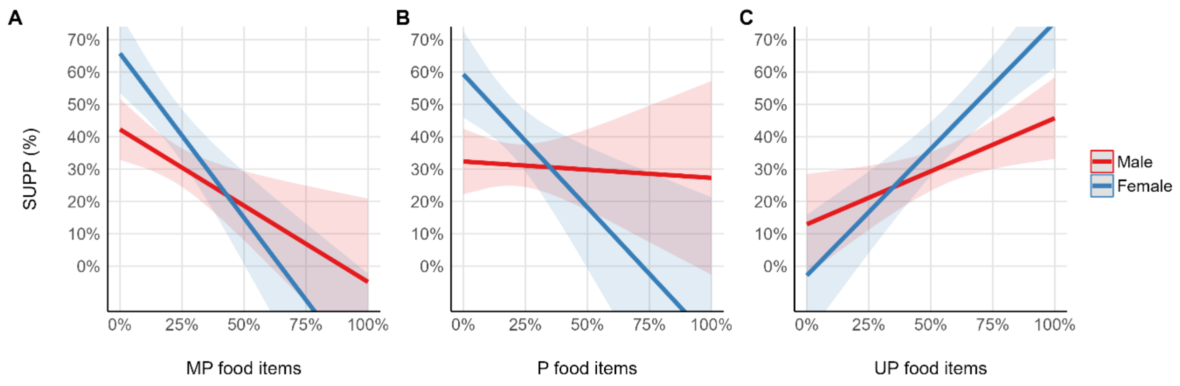


Figure 4-5. By gender, the relationship between proportion of SUPP and proportion of (A) minimally-processed food items, (B) processed food items, and (C) ultra-processed food items.

Note: The blue and red lines represents the model-estimated mean, and the shaded ribbons represents the 95% confidence interval.

Discussion

This is the first known study to explore the relationship between the proportion of ultra-processed food and drink items (UPF) and single-use food and beverage plastic packaging (SUPP) in lunchboxes brought from home to school by primary schoolchildren. Our findings revealed that UPF contributed considerably to SUPP in lunchboxes (76.2%) (Table 4-4), independently of school region/decile or whether lunches had been packed by a parent/guardian or children. Furthermore, the results demonstrated a strong inverse correlation between MPF and SUPP, with the amount of SUPP decreasing when lunches included a higher proportion of fresh and minimally-processed foods. Soft plastic bags and wrappers from single-serve UP snacks like biscuits, confectionary, and chips accounted for over half (58.8%) of SUPP, while reusable containers or no packaging were predominantly used for MPF such as fresh fruit, nuts, and homecooked leftovers. Similar findings regarding the packaging type of food and drink items in home-packed school lunches were reported in two recent studies. For instance, in Goldberg et al. (2015), over half (58.9%) of lunchbox items brought by primary schoolchildren (*mean age* = 9y) in elementary schools (*n*=12) in Massachusetts, US, were packaged in single-serve commercial packaging. Additionally, a recent audit by Lalchandani et al. (2023a) in primary schools (*n*=9) in South Australia identified soft plastic bags and wrappers from discretionary snacks as the main contributors to SUPP waste, while most fruits and vegetables were packed in reusable containers. Results of our study build upon these previous findings and support our hypothesis that prioritising MPF over UPF in home-packed lunches leads to a reduction of SUPP waste and promotes healthier lunchboxes.

Another notable finding emerged from our study when comparing the proportion of SUPP in lunchbox contents using the two packaging coding methods (observed 35.6% SUPP vs. original packaging 53.2% SUPP; $p < 0.001$, $g = 0.91$) (Figure 4-3). These results were likely influenced by the apparent high proportion of waste-free lunchboxes (i.e., removing packaging at home). The implications of these findings are relevant for schools promoting waste-free lunchbox initiatives, aiming to reduce plastic waste and instil environmentally-friendly behaviours in children. Although such initiatives may contribute to reducing single-use plastic waste within school premises (Pest Free Howick Ward, 2022), the substantial inclusion of UP snacks (i.e., originally packaged in soft plastic bags/wrappers) in packed-lunches suggests that a considerable amount of SUPP waste is still being generated in children's households, with potential implications for landfill (Waste MINZ, 2020). Furthermore, while waste-free lunchbox initiatives generally encourage the inclusion of healthy and sustainable food choices, such as fresh and minimally-processed items (Kapiti Coast District Council, n.d.; Lalchandani et al., 2022), our findings indicate that expectations related to the 'healthy food' component are likely not being fully met.

As observed in waste-free lunchbox initiatives in primary schools, the communication of these initiatives is generally informal through school websites, rather than formally integrated into school policy (Lalchandani et al., 2022). Moreover, the combination of healthy eating and environmentally-friendly components in school policies is uncommon, creating an opportunity to bridge this gap (Lalchandani et al., 2022). Growing evidence suggests that implementing an eco-nutrition approach within primary school settings, which emphasises the significance of sustainable food choices and environmental stewardship, can effectively motivate schoolchildren to enhance their dietary habits. This motivation stems from school-age children's desire to safeguard and nurture the natural environment (Folta et al., 2018; Jones et al., 2012). This approach is also in alignment with UNICEF's child-centred food systems concept (2019), which positions children as the central focus of food systems, recognising them as primary "consumers" and acknowledging their potential as change advocates (p. 23). For example, educating children about the resource-intensive nature of heavily-packaged UPF compared to wholefoods (Fardet & Rock, 2020; Hadjikakou, 2017; Seferidi et al., 2020), as well as highlighting the influential effects of persuasive food marketing targeting child-directed UPF on their eating habits and preferences (Cairns et al., 2013; Elliott & Truman, 2020), can empower children to make informed and environmentally-conscious food choices. Consequently, this empowerment could lead to an increased demand for improved availability, affordability, and quality of packaged foods specifically designed for children from food manufacturers and retailers across food systems (Fox & Timmer, 2020; UNICEF, 2019).

Moreover, existing waste-free lunchbox initiatives have already established meaningful connections between students, whānau, and extended school communities (Eames & Mardon, 2020; Lalchandani et al., 2022), including the promotion of waste reduction through audits supported by local government, nationwide programmes, and community organisations (Fight the Landfill, n.d.; Lalchandani et al., 2022; Pest Free Howick Ward, 2022). Other successful food environment indicators already embedded in NZ primary schools include the requirement of "milk and water only" as beverage options to be sold or brought to school (67.5%), nutrition education in the curriculum (96.1%) and the active use of a vegetable garden (85.3%) (D'Souza et al., 2022), and participation in the long-term sustainability programme Enviroschools (46%) (Eames & Mardon, 2020). Therefore, building upon these existing initiatives through an eco-nutrition lens, such as raising awareness of the interconnected relationship between sustainable food production and consumption patterns and the impacts of our food choices on human and planetary health (United Nations, 2015), and supporting this approach through clear and strong school policies, could be used to encourage less-processed packed-lunches, promote improved dietary habits among schoolchildren, and consequently, reduced SUPP and pollution (D'Souza et al., 2022; Lalchandani et al., 2022; Macari et al., 2018).

Related recommendations to support sustainable behaviours in children that contribute to meeting their nutritional needs and reducing SUPP waste include limiting the availability of UPF in school settings (e.g., canteens, fundraising activities) (Fox & Timmer, 2020; Macari et al., 2018), promoting home-packed lunches focused on unprocessed/minimally-processed foods (Parnham et al., 2022; UNICEF, 2019), and integrating eco-messages into school food and nutrition policies as well as communication channels to support and motivate children and families when purchasing for and packing school lunchboxes (Goldberg et al., 2015; Lalchandani et al., 2022; Nathan et al., 2019).

Strengths & Limitations

Grounded in the perspective of child-centred food systems (Hawkes et al., 2020), this study investigated, for the first time, the proportion of SUPP in home-packed lunchboxes in relationship to NOVA processing levels. The research yielded original and credible data that contribute to the emerging body of knowledge on the environmental impacts of school lunchbox contents sourced from home, an area that has received limited attention thus far.

Another notable strength of the study was the utilisation of two distinct methods to quantify the packaging of lunchbox items: visual observation of photographs and examination of original packaging. This double-coding approach was crucial in accurately determining the packaging profile of food and drink items in lunchboxes and facilitated a more robust analysis, generating timely implications for waste-free lunchbox initiatives in schools. In addition, the use of digital photographs of lunchboxes, along with the pen-and-paper lunchbox checklist, proved to be a more reliable method for coding food packaging categories compared to the provided waste collection buckets used at the end of the school day. While some discretion was exercised during the coding process, primarily for a few packaging items where food had been removed from its original packaging, overall, the lunchbox checklist enabled the collection of additional information from children, such as the product's brand, whether the food item was homemade, or if it was typically purchased in bulk (e.g., nuts). This approach proved sufficient for accurately coding lunchbox packaging. Conversely, it was evident that a significant portion of packaging waste from participants' packed-lunches was not placed in the provided waste collection buckets, and some non-participating children also used the buckets to dispose of their lunchbox waste.

Although the study identified significant gender differences in the association between SUPP and level of food processing, the scarcity of lunchbox-related data on gender differences makes it challenging to compare these results. These findings could have been influenced by participation bias, as nearly twice the number of girls compared to boys participated in the study, or by other specific characteristics of participants' families and households, which were not collected and can be considered a limitation. Furthermore, the study captured data from only one school day. Nevertheless, the study has provided unique data that can serve as a foundation for future research, which is a strength in itself.

Future Work

Our study did not assess the proportion of food wastage from children's lunchboxes. Food waste poses a significant threat to planetary sustainability (FAO, 2019), and previous studies have indicated schoolchildren tend to discard a greater amount of uneaten healthy foods compared to discretionary foods from their lunchboxes (Dresler-Hawke et al., 2009; Lalchandani et al., 2023a). However, no analysis has been conducted to examine the relationship between food wastage, SUPP, and processing level. It is worth noting that capturing these variables would have required a more comprehensive data collection method, such as photographing the food wastage in each participant's lunchbox at the end of the school day. Implementing such a method would have required a considerable amount of additional time from both schools and participating students. Addressing this knowledge gap would be a valuable focus for future research.

Given the positive reception of the eco-nutrition concept in school settings, and the existing need for effective interventions to improve the healthiness of home-packed lunches (Nathan et al., 2019), further research should integrate the health and eco-environmental dimensions of sustainable diets for children. Building upon the findings of the present study, future investigations should examine food environments and social factors that may influence the contents of children's home-packed lunchboxes, including household characteristics, purchasing and packing behaviours, preferences of parents and children, as well as the branding, cost, and promotion of popular child-oriented UP snacks. It is also crucial to explore the impact of eco-nutrition-based school policies and strategies on the sustainability of home-packed lunches. Additionally, future research should adopt a child-centred food system approach, as advocated by UNICEF (Hawkes et al., 2020; UNICEF, 2019), to identify necessary actions for reorienting existing food environments and supply chains, thereby enhancing the availability and demand for heathier foods for children.

Conclusion

This study examined the relationship between ultra-processed foods and single-use plastic packaging in lunchboxes brought to school by primary schoolchildren. The findings revealed that a significant proportion of SUPP in lunchboxes was attributed to ultra-processed sweet and savoury snacks packaged in soft plastic bags and wrappers. Conversely, lunches consisting of fresh and minimally-processed foods had a lower proportion of SUPP. These results underscore the importance of prioritising less-processed foods to reduce single-use plastic waste and promote healthier lunchboxes in school settings. Waste-free lunchbox initiatives should be strengthened, with an emphasis on integrating healthy and environmentally friendly components into school policies. Educating children about sustainable food choices and the impact of UPF packaging on individual and planetary health can empower them to make informed decisions. Limiting the availability of UPF in school settings and promoting home-packed lunches focused on wholefoods and less-processed items can further contribute to reducing SUPP waste. Further research should integrate health and eco-environmental dimensions to foster nutritious and sustainable diets for school-age children, including their home-packed lunchboxes brought to school.

Chapter 5 – General Discussion

This research aimed to achieve two main objectives: (1) to conduct a narrative review on the impact of ultra-processed foods on human and planetary health, along with sustainable healthy diets for children, and (2) to undertake a cross-sectional study examining the healthiness and sustainability of home-packed lunchboxes among primary schoolchildren. This chapter begins with an overview of the key findings obtained from the narrative review and the cross-sectional study, before summarising the main contribution of these findings. The implications, limitations, and future directions are organised into two prominent themes that emerged upon reflection of the research process:

(1) Updating current dietary guidance and regulations for child-targeted food and drink products
(2) Exploration of the NOVA-SUPP model for PHN research and strategy

This chapter concludes by explaining the approach chosen for disseminating research findings to the intended audience (i.e., school children).

Key findings

Chapter 2 provided a comprehensive literature review on the impact of UPF on human and ecological health, as well as healthy and sustainable diets, with a focus on child-centred food systems and schools as a key setting for action. The review highlighted several key findings. Firstly, it emphasised the need to differentiate UPF from other food categories due to their unique composition and extreme processing methods. Various themes explored include the metabolic effects of UPF on the gut microbiota, and the influence of UPF composition and marketing on brain-reward responses. Concerns were also raised regarding high levels of exposure to direct and indirect food additive 'cocktails' and their negative health effects, especially in children. The specific factors within UPF that cause adverse health effects are still being investigated, although growing evidence suggests it is not solely poor nutritional characteristics, but the way UPF are manufactured.

The review also underscored how the widespread consumption of UPF significantly compromises diet quality and health outcomes on a global scale. UPF production requires more resources and energy compared to wholefoods and traditional culinary preparations, contributing to climate change and the plastic waste crisis. Addressing and mitigating the impact of UPF on public and planetary health is crucial. This issue is particularly important in low-income communities, where disproportionate UPF availability and targeted marketing exacerbate health inequities, particularly among children. There is growing consensus that current food-based dietary guidelines need updating to consider the role of food processing, food matrix, and overall food quality and sustainability.

Lastly, the review highlighted the significance of schools as a key setting for child-centred food system research and action. Many school lunchboxes, both domestically and internationally, fail to meet dietary guidelines. The absence of national regulations and limited school-level lunchbox policies places the responsibility on parents for children's food choices at school. Recommendations include developing improved school food and nutrition policies that prioritise children's specific dietary requirements, consider food processing levels, and promote sustainable eating habits. The increasing adoption of eco-sustainability initiatives like zero-waste lunchboxes in NZ primary schools, suggests the potential for child-centred food system research and the implementation of school-wide sustainable food strategies. Overall, the findings of the review informed critical thinking and enriched the empirical studies presented in subsequent chapters. Conducting a quantitative audit on the healthiness and sustainability of lunchboxes within NZ primary schools was determined as a suitable next step.

Chapter 3 examined the level of food processing in home-packed lunches and investigated the relationship between the nutritional content (energy and sugar) of foods and their processing level. The study observed consistently high levels of UPF in lunchboxes, accounting for approximately two-thirds of the overall energy (61.8%), and half of total sugars (50.4%). Among the 599 food items, sweet and savoury UP snacks were the highest contributors to total energy from UPF (40%), while sweet UP snacks provided the most sugar (25%). In contrast, there was a significant lack of MPF (13.7%), including a mere 6 servings of vegetables across the entire sample. These findings were consistent regardless of participants' gender, school, or whether the parent/caregiver or the child packed the lunchbox. This study highlighted the need for updated PHN policies and guidance that consider the complexity of wholefoods and the impact of industrial food processing on the overall healthiness status of foods.

Chapter 4 examined the proportion of single-use plastic packaging in lunchboxes and investigated the association between single-use plastic packaging and the level of food processing. The study analysed 541 food and drink packaging items in lunchbox photos, revealing that 35.6% were SUPP. However, when considering the original packaging discarded at home, the proportion of SUPP increased to 53.2%, while the percentage of food items with no packaging decreased from 44.4% to 34.0%. The majority of SUPP originated from UPF (76.2%), while MPF contributed only 0.9% to SUPP. Soft plastic bags or wrappers from UP snacks (58.8%) were the most common type of SUPP in lunchboxes. Gender differences were identified, with a stronger association between SUPP and level of processing in girls compared to boys. No differences were found regarding who packed the lunches and school. These results support the initial hypothesis that prioritising MPF over UPF in home-packed lunches can lead to a reduction of SUPP waste and promote healthier and environmentally-friendlier lunchboxes.

Main contributions

Previous studies have highlighted the poor nutritional quality of home-packed lunchboxes brought to school (Evans et al., 2020; Manson et al., 2021; Stanham et al., 2020; Sutherland et al., 2020), but this research stands out as the first of its kind conducted in NZ, and one of the few that has examined the extent of ultra-processed foods in schoolchildren's lunchboxes. By expanding on previous research conducted in NZ, this study offers original insights into the composition of school lunchboxes based on their level of processing. It also contributes to the growing body of research investigating children's UPF consumption.

Furthermore, this study is the first known research to investigate the association between NOVA level of food processing, food packaging, and the presence of UPF and SUPP waste in school lunches. There is an increasing focus on environmental sustainability and waste reduction initiatives in schools, both in NZ and worldwide (Clemente et al., 2012; Eames & Mardon, 2020; Goldberg et al., 2015; Lalchandani et al., 2022; Prescott et al., 2019). Hence, these research findings provide valuable and credible data for future school-based eco-nutrition strategies and research that aims to inform, develop, and promote healthier and more sustainable school food environments.

Lastly, previous studies on school food environments in NZ have generated compelling evidence around school food and nutrition policies, as well as food availability in and around schools (such as school canteens, vending machines, and nearby shops) (D'Souza et al., 2022; Vandevijvere et al., 2018). However, these assessments and Ministry of Education requirements (Ministry of Health, 2019a) primarily focus on foods provided within the school setting, excluding foods brought to school sourced from home. This research helps to fill this gap by identifying the types of foods children are currently consuming (and not consuming) from the perspective of their school-lunchboxes. By doing so, it contributes to the emerging field of child-centred food system research.

Research implications, limitations, and recommendations

Upon reflecting on the entirety of this research, two prominent themes have emerged:

(1) Updating current dietary guidance and regulations for child-targeted food and drink products
(2) Exploration of the NOVA-SUPP model for PHN research and strategy

This section will delve into both themes separately, while drawing upon insights derived from the study's results and relevant literature. The implications for PHN research, policy, and action will be discussed. Furthermore, each section will address the study limitations and provide recommendations for future work.

(1) Updating current dietary guidance and regulations for child-targeted food and drink products

The findings of this study shed light on the inadequacies and gaps in the current dietary guidance for children in NZ, emphasising the need for updated evidence-based guidelines that address the challenges in promoting healthy and sustainable diets among children.

Research from 15 years ago, on packed-lunches consumed by NZ children during school hours (Dresler-Hawke et al.), revealed a misrepresentation of core food groups, with discretionary snacks being predominant in lunchboxes, which is consistent with the findings of the present study. Furthermore, international analyses focusing on the nutritional content and food quality of packed-lunches consistently indicates a failure to meet recommended dietary guidelines for food groups and nutrients (Evans et al., 2020; Stanham et al., 2020; Sutherland et al., 2020). The results presented in Chapter 3 demonstrate that certain core food groups were mostly absent in lunchboxes, and when included, the majority of these foods fell into the category of UPF. For example, the 'Milk and Milk Products' food group, with a recommended intake goal of two-to-three servings per day for school-aged children (Ministry of Health, 2012), contributed to only 13 items among minimally-processed and processed food items in the sample, with the majority of items from this group being classified as UPF instead (*n*=23). These findings are consistent with Parnham et al. (2022), who reported that home-packed-lunches of UK schoolchildren were more likely to include UP versions of core foods.

Furthermore, the mean total sugar content in packed-lunches, at 40.5 grams, was comparable to the WHO (2015) recommended daily limit (approximately 42.0 grams) of free sugar intake in school-aged children (7–10 y). However, due to the current lack of mandatory distinction between intrinsic and free sugars in NZ food labelling (discussed in Chapter 2), the exact proportion of free sugars in lunchboxes remains uncertain. Nevertheless, these findings highlight the potential for excessive consumption of free sugars among NZ schoolchildren due to the inclusion of UPF in their lunchboxes. This aligns with evidence linking UPF intake to the overconsumption of free sugars across all age groups (Machado et al., 2020; Rauber et al., 2019) and supports recommendations for updated PHN guidance that emphasises the reduction of UPF consumption among children, particularly sweet UP snacks (Thornley et al., 2021).

These results are concerning as they indicate that school lunchboxes in NZ continue to have poor nutritional quality even after 15 years. Furthermore, they align with extensive data demonstrating that children globally are eating too many UP snacks and too little foods that are essential for their healthy growth and development (Kupka et al., 2020). When comparing the study results with evidence indicating that school lunchboxes in NZ contribute to one-third of children's daily diets (Regan et al., 2008), the mean total energy observed in lunchboxes, totalling 2,504 kJ (598.5 kcal), aligns with the NZ MoH (2012) guidelines of 1500–2100 kcal/day for moderately active children during middle childhood. These results are consistent with recent data from Australia, where primary schoolchildren's packed-lunches had a mean total energy of 2,472 kJ, also representing approximately one-third of children's daily dietary intake (Manson et al., 2021). Considering that home-packed lunchboxes brought to school represent a significant portion of school-aged children's overall diets, it is imperative to address the prominence of UPF and the inadequate representation of core foods in lunchboxes. Moreover, these findings support the call for a prompt revision of current dietary guidance for children to account for the complexity of wholefoods and the role of industrial food processing. This includes considering hazardous additives in food products and packaging, marketing practices, and sustainability impacts, all of which contribute to overall diet quality and have implications for children's short- and long-term health outcomes.

Some authors have expressed concern about restricting UPF (Fangupo et al., 2021; Jones, 2019), arguing that such measures may inadvertently exclude 'nutritious' UPF. This concern was raised in Chapter 3, when reflecting on the limitations of the NOVA classification system. For instance, both iron-enriched mass-produced bread and a packet of potato crisps are classified as UPF. However, the current results show that most UPF consumed by school-aged children were discretionary foods. When combined with the fact that other foods in lunchboxes, which are perceived as "everyday foods" following current MOH guidelines, were mostly classified as UPF, it is essential to consider the substantial body of evidence associating UPF with harmful impacts on child health outcomes. Furthermore, compelling evidence indicates that UPF as a whole group has distinct adverse effects on health compared to other food categories (Hall et al., 2019). These factors also align with concerns raised about the effectiveness of single-nutrient approaches to food and drink products reformulation, historically used as a PHN strategy to address micronutrient deficiencies (e.g., added calcium, iron) and prevent diet-related NCDs (e.g., low-fat/low-sugar) (Adams et al., 2020; Mozaffarian et al., 2018b). Additionally, these findings question current food labelling systems, such as the HSR, which predominantly appear on pre-packaged UPF (Dickie et al., 2018).

Literature suggests several strategies aimed at promoting healthier child-targeted products, discourage UP snack consumption, and increase public understanding of the detrimental effects of UPF. Examples include targeted legislation for UPF labelling (Zinöcker & Lindseth, 2018), banning the marketing of UPF to children (Sato et al., 2022), and educating consumers about the importance of dietary choices on planetary sustainability (Pérez-Escamilla, 2017). Other potential strategies involve incentivising the food industry to develop less-processed, convenient, and affordable options that appeal to children, including suitable choices for home-packed school lunches (UNICEF, 2019). Governments should create conditions that enable consumers to make healthier choices, such as fiscal policies that increase accessibility and affordability of healthier options (Mozaffarian et al., 2018a; Pérez-Escamilla, 2017).

While dietary assessments of UPF consumption in the NZ population are limited, including school-aged children and adolescents, the recent findings revealing that high levels of UPF consumption during early childhood (12–60 months; 45%, 51%, respectively) (Fangupo et al., 2021) highlight the pressing need for further research in this area. Rigorous research will not only aid in developing interventions aimed at reducing UPF consumption and improving overall food quality, but also provide evidence-based knowledge to policymakers' efforts in ensuring healthier and more sustainable food systems, as well as guidance to the public for making informed decisions.

Limitations and future research

The use of the NOVA classification system in coding lunchbox food and drink items in this research presents certain limitations, particularly when dealing with foods without a Nutritional Information Panel, such as homemade preparations, takeaway leftovers, and bakery items commonly found in children's lunchboxes. However, this limitation is not unique to this study but is acknowledged in other lunchbox-related research (Blondin et al., 2021). Furthermore, it is worth noting that NOVA does not consider the nutritional content when categorising UPF, which can pose challenges in effectively communicating the NOVA concept to the general public. Nevertheless, incorporating the NOVA system alongside nutrient composition analysis undoubtedly enhances the understanding of overall food quality and enriches the findings, as well as provides results that are more compatible with the characteristics of typically UPF-dominated diets that characterise children's modern dietary patterns.

Moreover, the lack of up-to-date descriptions of children's lunchboxes in NZ and the limited number of studies investigating the contribution of UPF to school lunchboxes have hindered comprehensive comparisons in this study. Additionally, the absence of additional information about participating children and their families serves as a limiting factor. It is important to note that there is a pressing need for population-level data on children's overall UPF consumption trends in NZ to make any future lunchbox-related research more comprehensive.

For future research, the following recommendations are proposed:

1. Collect data on children and adolescent's (5 years old and over) overall daily UPF consumption trends in NZ, including the dietary contribution of UP snacks.

2. Expand lunchbox studies by integrating the NOVA classification system into nutrient-based analyses to enhance nutrition epidemiology.

3. Investigate the relationship between UPF in school lunchboxes and overall UPF consumption in the daily diets of NZ children.

4. Assess the use and effectiveness of a NOVA-based dietary guideline in reducing UPF intake and promoting better lunchbox contents and overall dietary patterns.

5. Examine the various factors that influence lunchbox food choices, including quantitative and qualitative assessments of environmental and social determinants within the context of children's lives in existing food systems (Hawkes et al., 2020). This includes investigating household characteristics, lunchbox food purchasing/packing behaviours, constraints faced by children/parents, cost-processing level analyses of lunchboxes, and sources from which children/parents acquire lunchbox foods.

6. While the study did not find variations across school decile/regions, the data used represents a small part of the population. Future studies should expand the scope of this work, particularly considering the impact of food insecurity in disadvantaged communities in NZ.

By addressing these recommendations, which align with UNICEF's Innocenti Framework, future research can provide valuable insights into the consumption patterns of UPF among children, the effectiveness of interventions, and the development of evidence-based guidelines to improve the nutritional quality of children's diets and promote healthier eating habits.

(2) Exploration of the NOVA-SUPP model for PHN research and strategy

While numerous interventions have been implemented to improve the nutritional quality of home-packed lunchbox items, the effectiveness of interventions targeting the reduction of discretionary foods and the promotion of core foods remains uncertain (Nathan et al., 2019). The present research findings on the overall poor-quality of food contents in participants' packed-lunches are consistent with previous evidence, supporting recommendations in the literature for novel strategies to enhance children's food consumption at school (Nathan et al., 2019; Parker & Koeppel, 2020). The cross-sectional study employed a coding model that encompasses nutritional composition (energy and sugar), in addition to processing level (MPF, PF, UPF) and packaging category (SUPP, SUPO, RP, NP). This NOVA-SUPP model has demonstrated potential as a valuable tool for future eco-nutrition-based research in school settings. Knowledge generated from these tools can guide efforts aimed at promoting healthier and more sustainable diets within the school environment and beyond.

Significant findings from this research suggest that prioritising wholefoods in lunchboxes over UPF can lead to reduced SUPP waste and healthier home-packed lunchboxes. Recent findings by Lalchandani et al. (2023a) further support these results, identifying discretionary snacks as the primary source of SUPP in the lunchboxes of Australian schoolchildren, while fruits and vegetables were mainly packed in reusable containers. Other evidence indicates the positive impacts of eco-nutrition as an integrated educational strategy among school-aged children (Folta et al., 2018; Jones et al., 2012). Together, these quantitative insights provide a foundation on which future lunchbox-related eco-nutrition research and school initiatives can build healthy and sustainable eating practices. Such an approach could foster long-lasting nutritious and sustainable dietary habits for school-age children.

The results of this research, as well as calls from the literature (Evans et al., 2020; Manson et al., 2021), suggest there is a compelling case for official lunchbox-related guidelines in schools, especially given the high availability of UPF and their detrimental effects on children's health outcomes. Notable policy examples from other countries support this need. For instance, in the US, schools with a restrictive UP snacks policy (but not simply reducing UP snacks availability) have been associated with higher consumption of consumed fruits and vegetables among children compared to schools that allow UP snacks availability (Gonzalez et al., 2008). In Brazil, public schools participating in a meal provision programme with a policy requiring the majority of purchased foods to be minimally-processed and one-third to be sourced locally have shown lower UPF consumption and improved diet quality (Boklis-Berer et al., 2021). Although these examples are focused on school-provided meals rather than home-packed lunchboxes, they demonstrate the potential impact of stronger school policies, both at the school and national levels. These policies could be incorporated into an eco-nutrition approach, expanding existing school guidelines that aim to reduce lunchbox waste to also restrict UP snacks. Additionally, the 'water and milk only' policy implemented in two-thirds of NZ schools and the widespread adoption of 'zero-waste' lunchbox initiatives in primary schools, which have received strong support from students and families, could serve as a foundation for further research and development.

Previous studies in eco-nutrition have shown that both children and parents are receptive to food and nutrition strategies emphasising ecological sustainability to promote healthier lunchboxes, and they actively engage in these interventions (Folta et al., 2018). Additionally, research indicates that parents require urgent support in navigating the complex factors that influence decision-making regarding purchasing for and packing school lunchboxes, as well as guiding their children towards healthier options (O'Rourke et al., 2020). This research exemplifies how eco-nutrition research can potentially provide this support by raising awareness among children, families, and the wider-school community about the interconnections between UPF, SUPP waste, and their impacts on human and planetary health within food systems. Consequently, this heightened awareness can inspire children and whānau to seek less processed and plastic-packaged alternatives for their lunchboxes. While this alone will not transform the prevalence of UPF-dominate food environments, increased consumer demand for healthier and sustainable choices from the food supply chain may consequently influence the food industry to produce and provide more products that prioritise human and planetary health (Pérez-Escamilla, 2017; UNICEF, 2019).

Limitations and future research

The lack of studies on the eco-environmental impacts of home-packed lunchboxes hinders the comparison of the present research findings. Limited research has characterised lunchbox item packaging (Goldberg et al., 2015; Lalchandani et al., 2023a), with only one recent study reporting on soft plastics packaging from discretionary snacks (Lalchandani et al., 2023a). Moreover, there is a dearth of studies examining the relationship between SUPP and NOVA processing level in school packed-lunches. However, the NOVA-SUPP coding model developed for this research, proved to be reliable, efficient, and user-friendly. Additionally, the use of the two coding approaches for lunchbox packaging – observed packaging and original packaging – strengthened the coding process and provided relevant data to assess SUPP across NOVA levels. Furthermore, when used in conjunction with the data collection method (digital photographs and pen-and-paper lunchbox checklist), the NOVA-SUPP model yielded credible results in an underexplored research area.

Considering the limited studies in this area and the potential application of the NOVA-SUPP model in future eco-nutrition work, the following future research is recommended:

1. Examine the NOVA-SUPP model to ensure its validity and reliability in assessing the nutritional composition, NOVA levels, and packaging of lunchbox items.

2. Explore the impact of eco-nutrition-based school policies/initiatives on the healthier lunchbox choices among schoolchildren, comparing them with existing policies/initiatives to identify effective approaches for fostering sustainable dietary habits.

3. Investigate the feasibility and acceptability of implementing eco-nutrition strategies in diverse cultural and socioeconomic contexts, considering the unique challenges and opportunities in different communities.

By addressing these research gaps and pursuing the recommended research, a more comprehensive understanding of the potential this NOVA-SUPP model can be achieved. This knowledge can then potentially contribute to evidence-based policy development, intervention design, and the promotion of healthier and more sustainable dietary patterns among school-aged children.

Further Limitations/Recommendations

The study's small sample size limits the generalisability of the findings to the broader NZ population. However, efforts were made to enhance the study's robustness by including four schools representing two distinct regions in Auckland with unique characteristics. Each region comprised one lower decile and one higher decile school. The distribution of participants was reasonably equal across the four region/decile categories. Prior to the study, the sample size calculation estimated that 59 participants would be suitable for detecting differences in energy across NOVA processing levels. Notably, the study had 110 participants, nearly double the calculated sample size. To confirm the results, future research should encompass a larger sample of schools that is representative of the broader NZ population.

Research Dissemination

Disseminating research findings to study participants, including children, is an ethical responsibility (Chen et al., 2010; UNICEF, 2020). However, relying solely on academic publications for research dissemination often fails to effectively reach the intended audience, resulting in a significant gap between public health research findings and their practical application in real-world settings (Chen et al., 2010; Brownson et al., 2018). When disseminating the findings of this thesis, the primary audience of interest includes schoolchildren, their families, primary schools, and relevant parties within the wider school communities. This encompasses school principals and teachers, who hold decision-making roles within schools and can influence the implementation of evidence.

Children are receptive to information about health behaviours, particularly when conveyed using minimal text and emphasising visual elements such as colour and images; digital media is regarded as the preferred method for receiving information (Burke & D'Eath, 2014; Egli et al., 2019). As such, the dissemination strategy for this thesis includes a child-friendly printable digital infographic presenting a summary of the research findings, as well as an additional poster containing practical suggestions for schoolchildren and families to promote sustainable and healthy home-packed lunches. Furthermore, this material will be made available online, ensuring free-accessibility to other schools, professionals, and the general public. The full infographic is presented in Appendix 6 – Dissemination infographic.

Conclusion

This research has clearly demonstrated that prioritising whole and minimally-processed foods in home-packed lunchboxes can significantly reduce single-use plastic packaging waste, while simultaneously promoting healthier, eco-friendly dietary patterns. Our findings underscore the high prevalence of highly processed foods in the current diets of primary schoolchildren in New Zealand, alongside a disconcerting deficit of nutritionally dense core foods. This underscores the urgent need for comprehensive, eco-conscious dietary guidance for both children and parents, guidance that takes into account the detrimental effects of extensive food processing on both health and environmental sustainability. The interconnectedness between food, nutrition, and environmental sustainability has been a focal point throughout this work. This study therefore serves as a steppingstone towards the growing field of child-centred food system research. As interest in eco-nutrition-based strategies within school settings continues to grow, exploring the application of the 'processing-waste' model developed in this thesis could provide invaluable insights. This model has the potential to foster healthier and more sustainable dietary patterns, offering significant benefits for both our children and the planet.

Chapter 6 – References

Adams, J., Hofman, K., Moubarac, J.-C., & Thow, A. M. (2020). Public health response to ultra-processed food and drinks. *Bmj*, *369*. https://doi.org/ https://doi.org/10.1136/bmj.m2391

Aguilera, J. M. (2019). The food matrix: implications in processing, nutrition and health. *Critical reviews in food science and nutrition*, *59*(22), 3612-3629.

Al-Ani, H. H., Devi, A., Eyles, H., Swinburn, B., & Vandevijvere, S. (2016). Nutrition and health claims on healthy and less-healthy packaged food products in New Zealand. *British Journal of Nutrition*, *116*(6), 1087-1094. https://doi.org/10.1017/S0007114516002981

Alae-Carew, C., Green, R., Stewart, C., Cook, B., Dangour, A. D., & Scheelbeek, P. F. D. (2022). The role of plant-based alternative foods in sustainable and healthy food systems: Consumption trends in the UK. *Science of The Total Environment*, *807*, 151041. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.151041

Astrup, A., Bertram, H. C., Bonjour, J.-P., De Groot, L. C., de Oliveira Otto, M. C., Feeney, E. L., Garg, M. L., Givens, I., Kok, F. J., & Krauss, R. M. (2019). WHO draft guidelines on dietary saturated and trans fatty acids: time for a new approach? *Bmj*, *366*. https://doi.org/doi.org/10.1136/bmj.l4137

Aune, D., Norat, T., Romundstad, P., & Vatten, L. J. (2013). Whole grain and refined grain consumption and the risk of type 2 diabetes: a systematic review and dose–response meta-analysis of cohort studies. *European Journal of Epidemiology*, *28*(11), 845-858. https://doi.org/10.1007/s10654-013-9852-5

Barbosa, A. P. G., Maia, M. M., Reginatto, M. V., Costenaro, R. G. S., & Benedetti, F. J. (2021). Characteristics and degree of processing of foods contained in school children's lunch boxes.

Bergman, Å., Heindel, J., Jobling, S., Kidd, K., Zoeller, R., & eds. United Nations Environment Programme, W. H. O. (2012). *State of the science of endocrine disrupting chemicals*.

Bielemann, R. M., Santos, L. P., dos Santos Costa, C., Matijasevich, A., & Santos, I. S. (2018). Early feeding practices and consumption of ultraprocessed foods at 6 y of age: Findings from the 2004 Pelotas (Brazil) Birth Cohort Study. *Nutrition*, *47*, 27-32.

Black, J. L., Velazquez, C. E., Ahmadi, N., Chapman, G. E., Carten, S., Edward, J., Shulhan, S., Stephens, T., & Rojas, A. (2015). Sustainability and public health nutrition at school: assessing the integration of healthy and environmentally sustainable food initiatives in Vancouver schools. *Public health nutrition*, *18*(13), 2379-2391.

Blondin, S. A., AlSukait, R., Bleiweiss-Sande, R., Economos, C. D., Tanskey, L. A., & Goldberg, J. P. (2021). Processed and packed: How refined are the foods that children bring to school for snack and lunch? *Journal of the Academy of Nutrition and Dietetics*, *121*(5), 883-894. https://doi.org/10.1016/j.jand.2020.07.017

Boklis-Berer, M., Rauber, F., Azeredo, C. M., Levy, R. B., & Louzada, M. L. d. C. (2021). School meals consumption is associated with a better diet quality of Brazilian adolescents: results from the PeNSE 2015 survey. *Public health nutrition*, *24*(18), 6512-6520. https://doi.org/10.1017/S1368980021003207

Boye, J. I., & Arcand, Y. (2013). Current trends in green technologies in food production and processing. *Food Engineering Reviews*, *5*(1), 1-17. https://doi.org/10.1007/s12393-012-9062-z

Burke, L., & D'Eath, M. (2014). An exploration of dissemination tools and mechanisms among young people. *Children's Research Digest*, *1*(1), 42-43. https://www.universityofgalway.ie/media/healthpromotionresearchcentre/hbscdocs/presentations/2014---LB---Explorarion-of-dissemination-tools-&-mechanisms-among-YP---CRD-1.pdf

Burrows, T., Goldman, S., Pursey, K., & Lim, R. (2017). Is there an association between dietary intake and academic achievement: a systematic review. *Journal of Human Nutrition and Dietetics*, *30*(2), 117-140. https://doi.org/ https://doi.org/10.1111/jhn.12407

Cairns, G., Angus, K., Hastings, G., & Caraher, M. (2013). Systematic reviews of the evidence on the nature, extent and effects of food marketing to children. A retrospective summary. *Appetite*, *62*, 209-215.

Calder, P. C., Carr, A. C., Gombart, A. F., & Eggersdorfer, M. (2020). Optimal nutritional status for a well-functioning immune system is an important factor to protect against viral infections. *Nutrients*, *12*(4), 1181. https://doi.org/doi.org/10.3390/nu12041181

Cannon, G., & Leitzmann, C. (2022). Food and nutrition science: The new paradigm. *Asia Pacific Journal of Clinical Nutrition*, *31*(1), 1-15. https://doi.org/10.6133/apjcn.202203_31(1).0001

Cascaes, A. M., Silva, N. R. J. d., Fernandez, M. d. S., Bomfim, R. A., & Vaz, J. d. S. (2023). Ultra-processed food consumption and dental caries in children and adolescents: a systematic review and meta-analysis. *British Journal of Nutrition*, *129*(8), 1370-1379. https://doi.org/10.1017/S0007114522002409

Chakori, S., Aziz, A. A., Smith, C., & Dargusch, P. (2021). Untangling the underlying drivers of the use of single-use food packaging. *Ecological Economics*, *185*, 107063. https://doi.org/doi.org/10.1016/j.ecolecon.2021.107063

Chang, K., Khandpur, N., Neri, D., Touvier, M., Huybrechts, I., Millett, C., & Vamos, E. P. (2021). Association Between Childhood Consumption of Ultraprocessed Food and Adiposity Trajectories in the Avon Longitudinal Study of Parents and Children Birth Cohort. *JAMA pediatrics*, *175*(9), e211573-e211573. https://doi.org/10.1001/jamapediatrics.2021.1573

Chen, X., Zhang, Z., Yang, H., Qiu, P., Wang, H., Wang, F., Zhao, Q., Fang, J., & Nie, J. (2020). Consumption of ultra-processed foods and health outcomes: A systematic review of epidemiological studies. *Nutrition journal*, *19*(1), 1-10. https://doi.org/10.1186/s12937-020-00604-1

Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: Production, usage, disposal, and adverse impacts. *Science of The Total Environment*, *752*, 141772. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.141772

Chiavaroli, V., Gibbins, J. D., Cutfield, W. S., & Derraik, J. G. B. (2019). Childhood obesity in New Zealand. *World Journal of Pediatrics*, *15*(4), 322-331. https://doi.org/10.1007/s12519-019-00261-3

Childs, C. E., Calder, P. C., & Miles, E. A. (2019). Diet and immune function. *11*(8), 1933. https://doi.org/doi.org/10.3390/nu11081933

Chouraqui, J.-P. (2023). Risk Assessment of Micronutrients Deficiency in Vegetarian or Vegan Children: Not So Obvious. *Nutrients*, *15*(9), 2129. https://www.mdpi.com/2072-6643/15/9/2129

Chronakis, I. S. (1998). On the molecular characteristics, compositional properties, and structural-functional mechanisms of maltodextrins: a review. *Critical reviews in food science and nutrition*, *38*(7), 599-637.

Clemente, J. C., Ursell, L. K., Parfrey, L. W., & Knight, R. (2012). The impact of the gut microbiota on human health: an integrative view. *Cell*, *148*(6), 1258-1270.

Contreras-Rodriguez, O., Solanas, M., & Escorihuela, R. M. (2022). Dissecting ultra-processed foods and drinks: Do they have a potential to impact the brain? *Reviews in Endocrine and Metabolic Disorders*. https://doi.org/10.1007/s11154-022-09711-2

Costa, C., Del-Ponte, B., Assunção, M., & Santos, I. (2018). Consumption of ultra-processed foods and body fat during childhood and adolescence: A systematic review. *Public health nutrition*, *21*(1), 148-159. https://doi.org/doi:10.1017/S1368980017001331

Cronometer. (n.d.). *Cronometer*. Retrieved May from https://cronometer.com

Curtain, F., & Grafenauer, S. (2019). Plant-based meat substitutes in the flexitarian age: an audit of products on supermarket shelves. *Nutrients*, *11*(11), 2603. https://doi.org/https://doi.org/10.3390/nu11112603

D'Souza, E. (2019). *A systems approach to evaluating and improving school food environments in Aotearoa* ResearchSpace@ Auckland].

D'Souza, E., Vandevijvere, S., & Swinburn, B. (2022). The healthiness of New Zealand school food environments: a national survey. *Australian and New Zealand journal of public health*.

Dagbasi, A., Lett, A., Murphy, K., & Frost, G. (2020). Understanding the interplay between food structure, intestinal bacterial fermentation and appetite control. *Proceedings of the Nutrition Society*, *79*(4), 514-530. https://doi.org/10.1017/S0029665120006941

de Groot, R. H. M., Ouwehand, C., & Jolles, J. (2012). Eating the right amount of fish: Inverted U-shape association between fish consumption and cognitive performance and academic achievement in Dutch adolescents. *Prostaglandins, Leukotrienes and Essential Fatty Acids*, *86*(3), 113-117. https://doi.org/https://doi.org/10.1016/j.plefa.2012.01.002

Dias, J. S. (2012). Nutritional quality and health benefits of vegetables: A review. *Food and Nutrition Sciences*, *3*(10), 1354-1374.

Dicken, S. J., & Batterham, R. L. (2021). The role of diet quality in mediating the association between ultra-processed food intake, obesity and health-related outcomes: a review of prospective cohort studies. *Nutrients*, *14*(1), 23. https://doi.org/doi.org/10.3390/nu14010023

Dickie, S., Woods, J. L., & Lawrence, M. (2018). Analysing the use of the Australian Health Star Rating system by level of food processing. *International Journal of Behavioral Nutrition and Physical Activity*, *15*(1), 1-9. https://doi.org/10.1186/s12966-018-0760-7

Dimov, S., Mundy, L. K., Bayer, J. K., Jacka, F. N., Canterford, L., & Patton, G. C. (2021). Diet quality and mental health problems in late childhood. *Nutritional neuroscience*, *24*(1), 62-70. https://doi.org/https://doi.org/10.1080/1028415X.2019.1592288

Dresler-Hawke, E., Whitehead, D., & Coad, J. (2009). What are New Zealand children eating at school? A content analysis ofconsumed versus unconsumed'food groups in a lunch-box survey. *Health Education Journal*, *68*(1), 3-13.

Dresler-Hawke, E., Whitehead, D., & Parker, L. (2012). Children's selection of fruit and vegetables in a 'dream versus healthy'lunch-box survey. *Health Education Journal*, *71*(6), 736-745.

Drewnowski, A., Finley, J., Hess, J. M., Ingram, J., Miller, G., & Peters, C. (2020). Toward healthy diets from sustainable food systems. *Current developments in nutrition*, *4*(6), nzaa083. https://doi.org/10.1093/cdn/nzaa083

Eames, C., & Mardon, H. (2020). The enviroschools programme in Aotearoa New Zealand: Action-orientated, culturally responsive, holistic learning. In *Green schools globally* (pp. 49-60). Springer.

Egli, V., Carroll, P., Donnellan, N., Mackay, L., Anderson, B., & Smith, M. (2019). Disseminating research results to kids: Practical tips from the Neighbourhoods for Active Kids study. *Kōtuitui: New Zealand Journal of Social Sciences Online*, *14*(2), 257-275. https://doi.org/https://doi.org/10.1080/1177083X.2019.1621909

Elizabeth, L., Machado, P., Zinöcker, M., Baker, P., & Lawrence, M. (2020). Ultra-processed foods and health outcomes: a narrative review. *Nutrients*, *12*(7), 1955. https://doi.org/10.3390/nu12071955

Elliott, C. (2019). Tracking Kids' Food: Comparing the Nutritional Value and Marketing Appeals of Child-Targeted Supermarket Products Over Time. *Nutrients*, *11*(8), 1850. https://www.mdpi.com/2072-6643/11/8/1850

Elliott, C., & Truman, E. (2020). The power of packaging: a scoping review and assessment of child-targeted food packaging. *Nutrients*, *12*(4), 958. https://doi.org/10.3390/nu12040958

Evans, C. E. L. (2020a). Dietary fibre and cardiovascular health: A review of current evidence and policy. *Proceedings of the Nutrition Society*, *79*(1), 61-67. https://doi.org/10.1017/S0029665119000673

Evans, C. E. L., Melia, K. E., Rippin, H. L., Hancock, N., & Cade, J. (2020). A repeated cross-sectional survey assessing changes in diet and nutrient quality of English primary school children's packed lunches between 2006 and 2016. *BMJ open*, *10*(1), e029688. https://doi.org/10.1136/bmjopen-2019-029688

Fangupo, L. J., Haszard, J. J., Taylor, B. J., Gray, A. R., Lawrence, J. A., & Taylor, R. W. (2021). Ultra-processed food intake and associations with demographic factors in young New Zealand children. *Journal of the Academy of Nutrition and Dietetics*, *121*(2), 305-313. https://doi.org/doi.org/10.1016/j.jand.2020.08.088

Fanzo, J., Bellows, A. L., Spiker, M. L., Thorne-Lyman, A. L., & Bloem, M. W. (2021). The importance of food systems and the environment for nutrition. *The American Journal of Clinical Nutrition*, *113*(1), 7-16.

FAO. (2016). *UN general assembly proclaims Decade of Action on Nutrition*. https://www.fao.org/news/story/en/item/408970/icode/

FAO. (2018). *Sustainable food systems*. https://www.fao.org/3/ca2079en/CA2079EN.pdf

FAO. (2019). *The state of food and agriculture 2019. Moving forward on food loss and waste reduction*. https://www.fao.org/3/ca6030en/ca6030en.pdf

FAO, & WHO. (1998). .*Preparation and use of food-based dietary guidelines: A report of a joint FAO/WHO consultation; 880;* . https://apps.who.int/iris/bitstream/handle/10665/42051/WHO_TRS_880.pdf?sequence=1&isAllowed=y

FAO, & WHO. (2019). *Sustainable healthy diets – Guiding principles.* . Rome. https://www.fao.org/3/ca6640en/CA6640EN.pdf

Fardet, A., & Rock, E. (2014). Toward a New Philosophy of Preventive Nutrition: From a Reductionist to a Holistic Paradigm to Improve Nutritional Recommendations. *Advances in Nutrition*, *5*(4), 430-446. https://doi.org/10.3945/an.114.006122

Fardet, A., & Rock, E. (2020). Ultra-processed foods and food system sustainability: What are the links? *Sustainability*, *12*(15), 6280.

Fight the Landfill. (n.d.). *Waste minimisation at schools*. Hamilton City Council. https://www.fightthelandfill.co.nz/waste-minimisation/schools/

Filgueiras, A. R., de Almeida, V. B. P., Nogueira, P. C. K., Domene, S. M. A., da Silva, C. E., Sesso, R., & Sawaya, A. L. (2019). Exploring the consumption of ultra-processed foods and its association with food addiction in overweight children. *Appetite*, *135*, 137-145. https://doi.org/10.1016/j.appet.2018.11.005

Florence, M. D., Asbridge, M., & Veugelers, P. J. (2008). Diet quality and academic performance. *Journal of School Health*, *78*(4), 209-215. https://doi.org/doi.org/10.1111/j.1746-1561.2008.00288.x

Folkvord, F., & Hermans, R. C. J. (2020). Food Marketing in an Obesogenic Environment: a Narrative Overview of the Potential of Healthy Food Promotion to Children and Adults. *Current Addiction Reports*, *7*(4), 431-436. https://doi.org/10.1007/s40429-020-00338-4

Folta, S. C., Koch-Weser, S., Tanskey, L. A., Economos, C. D., Must, A., Whitney, C., Wright, C. M., & Goldberg, J. P. (2018). Branding a school-based campaign combining healthy eating and eco-friendliness. *Journal of nutrition education and behavior*, *50*(2), 180-189. e181. https://doi.org/http://dx.doi.org/10.1016/j.jneb.2017.07.015

Food and Agriculture Organization of the United Nations (FAO). (n.d.). *Food-based dietary guidelines*. Retrieved Apr 28 from https://www.fao.org/nutrition/education/food-dietary-guidelines/background/en/

Fox, E. L., & Timmer, A. (2020). Children's and adolescents' characteristics and interactions with the food system. *Global Food Security*, *27*, 100419. https://doi.org/https://doi.org/10.1016/j.gfs.2020.100419

G. B. D. Diet Collaborators. (2019). Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*, *393*(10184), 1958-1972. https://doi.org/10.1016/S0140-6736(19)30041-8

Gage, R., Girling-Butcher, M., Joe, E., Smith, M., Ni Mhurchu, C., McKerchar, C., Puloka, V., McLean, R., & Signal, L. (2020). The Frequency and Context of Snacking among Children: An Objective Analysis Using Wearable Cameras. *Nutrients*, *13*(1). https://doi.org/10.3390/nu13010103

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

Geyer, R., Jambeck, J., & Law, K. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*, e1700782. https://doi.org/10.1126/sciadv.1700782

Gibb, S., Shackleton, N., Audas, R., Taylor, B., Swinburn, B., Zhu, T., Taylor, R., Derraik, J. G., Cutfield, W., & Milne, B. (2019). Child obesity prevalence across communities in New Zealand: 2010–2016. *Australian and New Zealand journal of public health*, *43*(2), 176-181. https://doi.org/ https://doi.org/10.1111/1753-6405.12881

Global Panel on Agriculture and Food Systems for Nutrition. (2016). *Food systems and diets: Facing the challenges of the 21st century*. http://glopan.org/sites/default/files/ForesightReport.pdf

Global Panel on Agriculture and Food Systems for Nutrition. (2020). *Future food systems: For people, our planet, and prosperity*. London, UK.

Goldberg, J. P., Folta, S. C., Eliasziw, M., Koch-Weser, S., Economos, C. D., Hubbard, K. L., Tanskey, L. A., Wright, C. M., & Must, A. (2015). Great Taste, Less Waste: A cluster-randomized trial using a communications campaign to improve the quality of foods brought from home to school by elementary school children. *Preventive medicine*, *74*, 103-110.

Gonzalez, W., Jones, S. J., & Frongillo, E. A. (2008). Restricting snacks in U.S. elementary schools Is associated with higher frequency of fruit and vegetable consumption. *The Journal of Nutrition*, *139*(1), 142-144. https://doi.org/10.3945/jn.108.099531

Grosso, G., Mateo, A., Rangelov, N., Buzeti, T., & Birt, C. (2020). Nutrition in the context of the Sustainable Development Goals. *European journal of public health*, *30*(Supplement_1), i19-i23.

Gultekin, F., Oner, M. E., Savas, H. B., & Dogan, B. (2020). Food additives and microbiota. *Northern clinics of Istanbul*, *7*(2), 192. https://doi.org/10.14744/nci.2019.92499

Hadjikakou, M. (2017). Trimming the excess: environmental impacts of discretionary food consumption in Australia. *Ecological Economics*, *131*, 119-128. https://doi.org/https://doi.org/10.1016/j.ecolecon.2016.08.006

Hall, K. D., Ayuketah, A., Brychta, R., Cai, H., Cassimatis, T., Chen, K. Y., Chung, S. T., Costa, E., Courville, A., Darcey, V., Fletcher, L. A., Forde, C. G., Gharib, A. M., Guo, J., Howard, R., Joseph, P. V., McGehee, S., Ouwerkerk, R., Raisinger, K., . . . Zhou, M. (2019). Ultra-processed diets cause excess calorie intake and weight gain: An inpatient randomized controlled trial of ad libitum food intake. *Cell Metabolism*, *30*(1), 67-77.e63. https://doi.org/https://doi.org/10.1016/j.cmet.2019.05.008

Hallez, L., Qutteina, Y., Raedschelders, M., Boen, F., & Smits, T. (2020). That's My Cue to Eat: a systematic review of the persuasiveness of front-of-pack cues on food packages for children vs. adults. *Nutrients*, *12*(4), 1062. https://www.mdpi.com/2072-6643/12/4/1062

Hawkes, C., Fox, E., Downs, S. M., Fanzo, J., & Neve, K. (2020). Child-centered food systems: Reorienting food systems towards healthy diets for children. *Global Food Security*, *27*, 100414. https://doi.org/https://doi.org/10.1016/j.gfs.2020.100414

Health Promotion Forum of NZ. (2012). *The right to health: Proceedings of the health and human rights workshops*. http://www.hauora.co.nz/assets/files/Workshops/The%20Right%20to%20Health%20workshop%20report.pdf

HealthEd. (2017). *Eating for healthy children aged 2 to 12*. https://www.healthed.govt.nz/system/files/resource-files/HE1302_Eating%20for%20healthy%20children%202%20to%2012_0.pdf

Heindel, J. J., Howard, S., Agay-Shay, K., Arrebola, J. P., Audouze, K., Babin, P. J., Barouki, R., Bansal, A., Blanc, E., Cave, M. C., Chatterjee, S., Chevalier, N., Choudhury, M., Collier, D., Connolly, L., Coumoul, X., Garruti, G., Gilbertson, M., Hoepner, L. A., . . . Blumberg, B. (2022). Obesity II: Establishing causal links between chemical exposures and obesity. *Biochemical Pharmacology*, 115015. https://doi.org/https://doi.org/10.1016/j.bcp.2022.115015

Hemingway, B. (2023, 16/3/23). Why chocolate milk has more health stars than regular milk. *1News*. https://www.1news.co.nz/2023/03/16/why-chocolate-milk-has-more-health-stars-than-regular-milk

Herforth, A., Arimond, M., Álvarez-Sánchez, C., Coates, J., Christianson, K., & Muehlhoff, E. (2019). A global review of food-based dietary guidelines. *Advances in Nutrition*, *10*(4), 590-605. https://doi.org/10.1093/advances/nmy130

Hirvonen, K., Bai, Y., Headey, D., & Masters, W. A. (2020). Affordability of the EAT–Lancet reference diet: a global analysis. *The Lancet Global Health*, *8*(1), e59-e66. https://doi.org/10.1016/S2214-109X(19)30447-4

HLPE. (2017). *Nutrition and food systems. A report by the high level panel of experts on food security and nutrition of the committee on world food security*. http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-12_EN.pdf

Hofman, D. L., Van Buul, V. J., & Brouns, F. J. (2016). Nutrition, health, and regulatory aspects of digestible maltodextrins. *Critical reviews in food science and nutrition*, *56*(12), 2091-2100. https://doi.org/10.1080/10408398.2014.940415

Hollis, J. L., Collins, C. E., DeClerck, F., Chai, L. K., McColl, K., & Demaio, A. R. (2020). Defining healthy and sustainable diets for infants, children and adolescents. *Global Food Security*, *27*, 100401. https://doi.org/10.1016/j.gfs.2020.100401

Hosseini, B., Berthon, B. S., Wark, P., & Wood, L. G. (2017). Effects of fruit and vegetable consumption on risk of asthma, wheezing and immune responses: a systematic review and meta-analysis. *Nutrients*, *9*(4), 341. https://doi.org/doi.org/10.3390/nu9040341

Hu, F. B., Otis, B. O., & McCarthy, G. (2019). Can plant-based meat alternatives be part of a healthy and sustainable diet? *Jama*, *322*(16), 1547-1548. https://doi.org/10.1001/jama.2019.13187

IPCC, H.-O. P., D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. (2022). *Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of working group ii to the sixth assessment report of the intergovernmental panel on climate change. Summary for policymakers*. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

Jenner, L. C., Rotchell, J. M., Bennett, R. T., Cowen, M., Tentzeris, V., & Sadofsky, L. R. (2022). Detection of microplastics in human lung tissue using μFTIR spectroscopy. *Science of The Total Environment*, *831*, 154907. https://doi.org/https://doi.org/10.1016/j.scitotenv.2022.154907

Jones, J. M. (2019). Food processing: criteria for dietary guidance and public health? *Proceedings of the Nutrition Society*, *78*(1), 4-18. https://doi.org/10.1017/S0029665118002513

Jones, M., Dailami, N., Weitkamp, E., Salmon, D., Kimberlee, R., Morley, A., & Orme, J. (2012). Food sustainability education as a route to healthier eating: evaluation of a multi-component school programme in English primary schools. *Health education research*, *27*(3), 448-458.

Kadac-Czapska, K., Knez, E., Gierszewska, M., Olewnik-Kruszkowska, E., & Grembecka, M. (2023). Microplastics derived from food packaging waste—Their origin and health risks. *Materials*, *16*(2), 674. https://doi.org/ https://doi.org/10.3390/ma16020674

Kapiti Coast District Council. (n.d.). *The literless lunchbox*. https://www.kapiticoast.govt.nz/media/31ehb4fx/litterless-lunchbox.pdf

Kesse-Guyot, E., Allès, B., Brunin, J., Fouillet, H., Dussiot, A., Berthy, F., Perraud, E., Hercberg, S., Julia, C., Mariotti, F., Deschasaux-Tanguy, M., Srour, B., Lairon, D., Pointereau, P., Baudry, J., & Touvier, M. (2022). Environmental impacts along the value chain from the consumption of ultra-processed foods. *Nature Sustainability*. https://doi.org/10.1038/s41893-022-01013-4

Khandpur, N., Cediel, G., Obando, D. A., Jaime, P. C., & Parra, D. C. (2020a). Sociodemographic factors associated with the consumption of ultra-processed foods in Colombia. *Revista de saude publica*, *54*. https://doi.org/doi.org/10.11606/s1518-8787.2020054001176

Khandpur, N., Neri, D. A., Monteiro, C., Mazur, A., Frelut, M.-L., Boyland, E., Weghuber, D., & Thivel, D. (2020b). Ultra-processed food consumption among the paediatric population: an overview and call to action from the European Childhood Obesity Group. *Annals of Nutrition and Metabolism*, *76*(2), 109-113. https://doi.org/doi.org/10.1159/000507840

KickStart Breakfast. (n.d.). *KickStart Breakfast* https://www.kickstartbreakfast.co.nz/

Kim, J.-L., Winkvist, A., Åberg, M. A., Åberg, N., Sundberg, R., Torén, K., & Brisman, J. (2010). Fish consumption and school grades in Swedish adolescents: a study of the large general population. *Acta Paediatrica*, *99*(1), 72-77. https://doi.org/https://doi.org/10.1111/j.1651-2227.2009.01545.x

Knorr, D., & Watzke, H. (2019). Food processing at a crossroad. *Frontiers in Nutrition*, *6*, 85. https://doi.org/ https://doi.org/10.3389/fnut.2019.00085

Kupka, R., Siekmans, K., & Beal, T. (2020). The diets of children: Overview of available data for children and adolescents. *Global Food Security*, *27*, 100442. https://doi.org/https://doi.org/10.1016/j.gfs.2020.100442

Lalchandani, N., Miller, C., Crabb, S., Giles, L., Hendrikx, J., & Hume, C. (2023a). A snapshot of school children's lunchboxes in South Australia through a food and sustainability lens. *Proceedings of the Nutrition Society*, *82*(OCE2), E164, Article E164. https://doi.org/10.1017/S0029665123001738

Lalchandani, N. K., Crabb, S., Miller, C., & Hume, C. (2022). Content analysis of school websites: policies and programs to support healthy eating and the environment. *Health Educ Res*, *37*(1), 48-59. https://doi.org/10.1093/her/cyab040

Lalchandani, N. K., Poirier, B., Crabb, S., Miller, C., & Hume, C. (2023b). School lunchboxes as an opportunity for health and environmental considerations: a scoping review. *Health Promotion International*, *38*(1). https://doi.org/10.1093/heapro/daac201

Lang, T. (2003). Food industrialisation and food power: Implications for food governance. *Development Policy Review*, *21*(5-6), 555-568. https://doi.org/10.1111/j.1467-8659.2003.00223.x

Lee, E. Y., & Yoon, K.-H. (2018). Epidemic obesity in children and adolescents: risk factors and prevention. *Frontiers of Medicine*, *12*(6), 658-666. https://doi.org/10.1007/s11684-018-0640-1

Leite, F. H. M., Khandpur, N., Andrade, G. C., Anastasiou, K., Baker, P., Lawrence, M., & Monteiro, C. A. (2022). Ultra-processed foods should be central to global food systems dialogue and action on biodiversity. *BMJ Global Health*, *7*(3), e008269. https://doi.org/http://dx.doi.org/10.1136/bmjgh-2021-008269

Leslie, H. A., van Velzen, M. J. M., Brandsma, S. H., Vethaak, A. D., Garcia-Vallejo, J. J., & Lamoree, M. H. (2022). Discovery and quantification of plastic particle pollution in human blood. *Environment International*, *163*, 107199. https://doi.org/https://doi.org/10.1016/j.envint.2022.107199

Livingston, A. S., Cudhea, F., Wang, L., Steele, E. M., Du, M., Wang, Y. C., Pomeranz, J., Mozaffarian, D., & Zhang, F. F. (2021). Effect of reducing ultraprocessed food consumption on obesity among US children and adolescents aged 7–18 years: evidence from a simulation model. *BMJ nutrition, prevention & health*, *4*(2), 397. https://doi.org/10.1136/bmjnph-2021-000303

Luiten, C. M., Steenhuis, I. H., Eyles, H., Mhurchu, C. N., & Waterlander, W. E. (2016). Ultra-processed foods have the worst nutrient profile, yet they are the most available packaged products in a sample of New Zealand supermarkets. *Public health nutrition*, *19*(3), 530-538. https://doi.org/10.1017/S1368980015002177

Lustig, R. H. (2017). Processed food— an experiment that failed. *JAMA pediatrics*, *171*(3), 212-214. https://doi.org/10.1001/jamapediatrics.2016.4136

Lustig, R. H. (2020). Ultraprocessed food: Addictive, toxic, and ready for regulation. *Nutrients*, *12*(11), 3401. https://doi.org/10.3390/nu12113401

Macari, M., Calvillo, A., Espinosa, F., & El Poder del Consumidor. (2018). SDG 12. *Exploring*, 144. https://www.annd.org/uploads/publications/Spotlight_2018_web.pdf#page=144

Macaulay, G. C., Simpson, J., Parnell, W., & Duncanson, M. (2022). Food insecurity as experienced by New Zealand women and their children. *Journal of the Royal Society of New Zealand*, 1-17. https://doi.org/10.1080/03036758.2022.2088574

Machado, P. P., Steele, E. M., Levy, R. B., da Costa Louzada, M. L., Rangan, A., Woods, J., Gill, T., Scrinis, G., & Monteiro, C. A. (2020). Ultra-processed food consumption and obesity in the Australian adult population. *Nutrition & diabetes*, *10*(1), 1-11. https://doi.org/doi.org/10.1038/s41387-020-00141-0

Mackay, S., Buch, T., Vandevijvere, S., Goodwin, R., Korohina, E., Funaki-Tahifote, M., Lee, A., & Swinburn, B. (2018). Cost and affordability of diets modelled on current eating patterns and on dietary guidelines, for New Zealand total population, Māori and Pacific households. *International Journal of Environmental Research and Public Health*, *15*(6), 1255. https://www.mdpi.com/1660-4601/15/6/1255

Manson, A. C., Johnson, B. J., Zarnowiecki, D., Sutherland, R., & Golley, R. K. (2021). The food and nutrient intake of 5- to 12-year-old Australian children during school hours: a secondary analysis of the 2011–2012 National Nutrition and Physical Activity Survey. *Public health nutrition*, *24*(18), 5985-5994. https://doi.org/10.1017/S1368980021003888

Marino, M., Puppo, F., Del Bo, C., Vinelli, V., Riso, P., Porrini, M., & Martini, D. (2021). A systematic review of worldwide consumption of ultra-processed foods: Findings and criticisms. *Nutrients*, *13*(8), 2778.

Marrón-Ponce, J. A., Sánchez-Pimienta, T. G., Louzada, M. L. d. C., & Batis, C. (2018). Energy contribution of NOVA food groups and sociodemographic determinants of ultra-processed food consumption in the Mexican population. *Public health nutrition*, *21*(1), 87-93. https://doi.org/10.1017/S1368980017002129

Marsh, K., & Bugusu, B. (2007). Food packaging—roles, materials, and environmental issues. *Journal of food science*, *72*(3), R39-R55. https://doi.org/doi:10.1111/j.1750-3841.2007.00301.x

Martínez Leo, E. E., & Segura Campos, M. R. (2020). Effect of ultra-processed diet on gut microbiota and thus its role in neurodegenerative diseases. *Nutrition*, *71*, 110609. https://doi.org/https://doi.org/10.1016/j.nut.2019.110609
Martins, A. P. B., Levy, R. B., Claro, R. M., Moubarac, J. C., & Monteiro, C. A. (2013). Increased contribution of ultra-processed food products in the Brazilian diet (1987-2009). *Revista de saude publica*, *47*, 656-665. https://doi.org/doi.org/10.1590/S0034-8910.2013047004968
McMichael, A. J. (2013). Globalization, climate change, and human health. *New England Journal of Medicine*, *368*(14), 1335-1343. https://doi.org/10.1056/NEJMra1109341
Micha, R., Karageorgou, D., Bakogianni, I., Trichia, E., Whitsel, L. P., Story, M., Penalvo, J. L., & Mozaffarian, D. (2018). Effectiveness of school food environment policies on children's dietary behaviors: A systematic review and meta-analysis. *PloS one*, *13*(3), e0194555.
Micha, R., Wallace, S. K., & Mozaffarian, D. (2010). Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus. *Circulation*, *121*(21), 2271-2283. https://doi.org/doi:10.1161/CIRCULATIONAHA.109.924977
Miller, K. B., Eckberg, J. O., Decker, E. A., & Marinangeli, C. P. F. (2021). Role of food industry in promoting healthy and sustainable diets. *Nutrients*, *13*(8). https://doi.org/10.3390/nu13082740
Ministry for Primary Industries. (2022a, 03/05/22). *Food and drink labelling and composition rules*

Retrieved 24/3/23 from https://www.mpi.govt.nz/food-business/labelling-composition-food-drinks/food-and-drink-labelling-and-composition-rules/
Ministry for Primary Industries. (2022b). *Healthy Star Rating*. Retrieved 24/3/2023 from www.foodsafety.govt.nz/industry/general/labelling-composition/health-star-rating
Ministry of Education. (2022a). *Education in New Zealand*. Retrieved 24/03/2023 from https://www.education.govt.nz/our-work/our-role-and-our-people/education-in-nz/
Ministry of Education. (2022b, 27/10/22). *Ka Ora, Ka Ako | Healthy school lunches programme FAQs*. Retrieved 10/3/23 from https://www.education.govt.nz/our-work/overall-strategies-and-policies/wellbeing-in-education/free-and-healthy-school-lunches/free-and-healthy-lunches-in-schools-faqs/#numberofschools
Ministry of Education. (2022c). *Ministry funding deciles*. Retrieved 24/03/2023 from https://parents.education.govt.nz/secondary-school/secondary-schooling-in-nz/deciles/#measure
Ministry of Health. (2003a). *NZ Food NZ Children: Key results of the 2002 National Children's Nutrition Survey*. W. M. o. Health. https://www.health.govt.nz/system/files/documents/publications/nzfoodnzchildren.pdf
Ministry of Health. (2012). *Food and nutrition guidelines for healthy children and young people (aged 2–18 years): A background paper* (Partial revision February 2015 ed.). Wellington: Ministry of Health.
Ministry of Health. (2019a). *Healthy food and drink guidance - Schools.* https://consult.health.govt.nz/nutrition-and-physical-activity/healthy-food-and-drink-guidance-survey/supporting_documents/Healthy%20Food%20and%20Drink%20Guidance%20%20Schools.pdf
Ministry of Health. (2019b). *Household food insecurity among children in New Zealand.* . https://www.health.govt.nz/system/files/documents/publications/household-food-insecurity-among-children-new-zealand-health-survey-jun19.pdf
Ministry of Health. (2021). *Annual Data Explorer 2020/21: New Zealand Health Survey [Data File]*. https://minhealthnz.shinyapps.io/nz-health-survey-2020-21-annual-data-explorer/
Ministry of Health of Brazil. (2015). *Dietary guidelines for the Brazilian population*. https://bvsms.saude.gov.br/bvs/publicacoes/dietary_guidelines_brazilian_population.pdf
Monteiro, C., Cannon, G., Lawrence, M., Costa Louzada, M. d., & Pereira Machado, P. (2019a). Ultra-processed foods, diet quality, and health using the NOVA classification system. *Rome: FAO*.
Monteiro, C., Cannon, G., Levy, R. B., Moubarac, J.-C., Louzada, M. L., Rauber, F., Khandpur, N., Cediel, G., Neri, D., & Martinez-Steele, E. (2019b). Ultra-processed foods: what they are and how to identify them. *Public health nutrition*, *22*(5), 936-941. https://doi.org/10.1017/S1368980018003762

Monteiro, C. A. (2009). Nutrition and health. The issue is not food, nor nutrients, so much as processing. *Public health nutrition*, *12*(5), 729-731.

Monteiro, C. A., Cannon, G., Levy, R., Moubarac, J.-C., Jaime, P., Martins, A. P., Canella, D., Louzada, M., & Parra, D. (2016). NOVA. The star shines bright. *World Nutrition*, *7*(1-3), 28-38.

Monteiro, C. A., Cannon, G., Moubarac, J.-C., Levy, R. B., Louzada, M. L. C., & Jaime, P. C. (2018a). The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public health nutrition*, *21*(1), 5-17. https://doi.org/10.1017/S1368980017000234

Monteiro, C. A., Cannon, G., Moubarac, J.-C., Martins, A. P. B., Martins, C. A., Garzillo, J., Canella, D. S., Baraldi, L. G., Barciotte, M., Louzada, M. L. d. C., Levy, R. B., Claro, R. M., & Jaime, P. C. (2015). Dietary guidelines to nourish humanity and the planet in the twenty-first century. A blueprint from Brazil. *Public health nutrition*, *18*(13), 2311-2322. https://doi.org/10.1017/S1368980015002165

Monteiro, C. A., Moubarac, J.-C., Cannon, G., Ng, S. W., & Popkin, B. (2013). Ultra-processed products are becoming dominant in the global food system. *Obesity Reviews*, *14*(S2), 21-28. https://doi.org/https://doi.org/10.1111/obr.12107

Morales-Caselles, C., Viejo, J., Martí, E., González-Fernández, D., Pragnell-Raasch, H., González-Gordillo, J. I., Montero, E., Arroyo, G. M., Hanke, G., & Salvo, V. S. (2021). An inshore–offshore sorting system revealed from global classification of ocean litter. *Nature Sustainability*, *4*(6), 484-493. https://doi.org/10.1038/s41893-021-00720-8

Moubarac, J.-C. (2017). Ultra-processed foods in Canada: consumption, impact on diet quality and policy implications. *TRANSNUT: University of Montreal*.

Mozaffarian, D., Angell, S. Y., Lang, T., & Rivera, J. A. (2018a). Role of government policy in nutrition—barriers to and opportunities for healthier eating. *Bmj*, *361*. https://doi.org/doi.org/10.1136/bmj.k2426

Mozaffarian, D., Rosenberg, I., & Uauy, R. (2018b). History of modern nutrition science—implications for current research, dietary guidelines, and food policy. *Bmj*, *361*. https://doi.org/10.1136/bmj.k2392

Muncke, J., Andersson, A.-M., Backhaus, T., Boucher, J. M., Almroth, B. C., Castillo, A. C., Chevrier, J., Demeneix, B. A., Emmanuel, J. A., & Fini, J.-B. (2020). Impacts of food contact chemicals on human health: A consensus statement. *Environmental Health*, *19*(1), 1-12. https://doi.org/10.1186/s12940-020-0572-5

Muncke, J., Backhaus, T., Geueke, B., Maffini, M. V., Martin, O. V., Myers, J. P., Soto, A. M., Trasande, L., Trier, X., & Scheringer, M. (2017). Scientific challenges in the risk assessment of food contact materials. *Environmental Health Perspectives*, *125*(9), 095001. https://doi.org/10.1289/EHP644

Nardocci, M., Leclerc, B.-S., Louzada, M.-L., Monteiro, C. A., Batal, M., & Moubarac, J.-C. (2019). Consumption of ultra-processed foods and obesity in Canada. *Canadian Journal of Public Health*, *110*(1), 4-14. https://doi.org/10.17269/s41997-018-0130-x

Narula, N., Wong, E. C. L., Dehghan, M., Mente, A., Rangarajan, S., Lanas, F., Lopez-Jaramillo, P., Rohatgi, P., Lakshmi, P. V. M., Varma, R. P., Orlandini, A., Avezum, A., Wielgosz, A., Poirier, P., Almadi, M. A., Altuntas, Y., Ng, K. K., Chifamba, J., Yeates, K., . . . Yusuf, S. (2021). Association of ultra-processed food intake with risk of inflammatory bowel disease: prospective cohort study. *Bmj*, *374*, n1554. https://doi.org/10.1136/bmj.n1554

Nathan, N., Janssen, L., Sutherland, R., Hodder, R. K., Evans, C. E. L., Booth, D., Yoong, S. L., Reilly, K., Finch, M., & Wolfenden, L. (2019). The effectiveness of lunchbox interventions on improving the foods and beverages packed and consumed by children at centre-based care or school: a systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 38. https://doi.org/10.1186/s12966-019-0798-1

O'Neil, A., Quirk, S. E., Housden, S., Brennan, S. L., Williams, L. J., Pasco, J. A., Berk, M., & Jacka, F. N. (2014). Relationship between diet and mental health in children and adolescents: a systematic review. *Am J Public Health*, *104*(10), e31-42. https://doi.org/10.2105/ajph.2014.302110

O'Rourke, B., Shwed, A., Bruner, B., & Ferguson, K. (2020). What's for lunch? Investigating the experiences, perceptions, and habits of parents and school lunches: a scoping review. *Journal of School Health*, *90*(10), 812-819. https://doi.org/10.1111/josh.12944

Oostindjer, M., Aschemann-Witzel, J., Wang, Q., Skuland, S. E., Egelandsdal, B., Amdam, G. V., Schjøll, A., Pachucki, M. C., Rozin, P., & Stein, J. (2017). Are school meals a viable and sustainable tool to improve the healthiness and sustainability of children´ s diet and food consumption? A cross-national comparative perspective. *Critical reviews in food science and nutrition*, *57*(18), 3942-3958.

Pan American Health Organization. (2015). *Ultra-processed food and drink products in Latin America: Trends, impact on obesity policy implications*.

Parker, B., & Koeppel, M. (2020). Beyond Health & Nutrition: Re-framing school food programs through integrated food pedagogies. *Canadian Food Studies/La Revue canadienne des études sur l'alimentation*, *7*(2), 48-71.

Parnham, J. C., Chang, K., Rauber, F., Levy, R. B., Millett, C., Laverty, A. A., von Hinke, S., & Vamos, E. P. (2022). The ultra-processed food content of school meals and packed lunches in the United Kingdom. *Nutrients*, *14*(14), 2961. https://www.mdpi.com/2072-6643/14/14/2961

Paula Neto, H. A., Ausina, P., Gomez, L. S., Leandro, J. G., Zancan, P., & Sola-Penna, M. (2017). Effects of Food additives on immune cells as contributors to body weight gain and immune-mediated metabolic dysregulation. *Frontiers in immunology*, *8*, 1478. https://doi.org/10.3389/fimmu.2017.01478

Peng, J., Wang, J., & Cai, L. (2017). Current understanding of microplastics in the environment: occurrence, fate, risks, and what we should do. *Integrated environmental assessment and management*, *13*(3), 476-482. https://doi.org/10.1002/ieam.1912

Pérez-Escamilla, R. (2017). Food security and the 2015–2030 sustainable development goals: From human to planetary health: Perspectives and opinions. *Current developments in nutrition*, *1*(7), e000513. https://doi.org/doi.org/10.3945/cdn.117.000513

Perry, B. (2017). *Household income report*. www.msd.govt.nz/about-msd-and-our-work/publications-resources/monitoring/household-incomes/household-incomes-1982-2017.html

Pest Free Howick Ward. (2022). *School waste minimisation*. Retrieved 14/02/23 from https://pfhw.org.nz/waste-minimisation/

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987-992. https://doi.org/10.1126/science.aaq0216

Population Division of the Department of Economic and Social Affairs of the UN Secretariat. (2013). *World population prospects: The 2012 revision, highlights and advance tables*. https://population.un.org/wpp/publications/Files/WPP2012_HIGHLIGHTS.pdf

Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2020). Environmental exposure to microplastics: An overview on possible human health effects. *Science of The Total Environment*, *702*, 134455. https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.134455

Prescott, M. P., Burg, X., Metcalfe, J. J., Lipka, A. E., Herritt, C., & Cunningham-Sabo, L. (2019). Healthy planet, healthy youth: A food systems education and promotion intervention to improve adolescent diet quality and reduce food waste. *Nutrients*, *11*(8), 1869. https://doi.org/doi.org/10.3390/nu11081869

Pressman, P., Clemens, R., Hayes, W., & Reddy, C. (2017). Food additive safety: A review of toxicologic and regulatory issues. *Toxicology Research and application*, *1*, 2397847317723572.

Pulker, C. E., Scott, J. A., & Pollard, C. M. (2018). Ultra-processed family foods in Australia: nutrition claims, health claims and marketing techniques. *Public health nutrition*, *21*(1), 38-48. https://doi.org/doi:10.1017/S1368980017001148

Rauber, F., Louzada, M. L. d. C., Steele, E. M., Rezende, L. F. M. d., Millett, C., Monteiro, C. A., & Levy, R. B. (2019). Ultra-processed foods and excessive free sugar intake in the UK: a nationally representative cross-sectional study. *BMJ open*, *9*(10), e027546. https://doi.org/10.1136/bmjopen-2018-027546

Ravichandran, G., Lakshmanan, D. K., Arunachalam, A., & Thilagar, S. (2022). Food obesogens as emerging metabolic disruptors; A toxicological insight. *The Journal of Steroid Biochemistry and Molecular Biology*, *217*, 106042. https://doi.org/https://doi.org/10.1016/j.jsbmb.2021.106042

Regan, A., Parnell, W., Gray, A., & Wilson, N. (2008). New Zealand children's dietary intakes during school hours. *Nutrition & Dietetics*, *65*(3), 205-210.

Reichelt, A. C., & Rank, M. M. (2017). The impact of junk foods on the adolescent brain. *Birth defects research*, *109*(20), 1649-1658. https://doi.org/https://doi.org/10.1002/bdr2.1173

Ridgway, E., Baker, P., Woods, J., & Lawrence, M. (2019). Historical developments and paradigm shifts in public health nutrition science, guidance and policy actions: a narrative review. *Nutrients*, *11*(3), 531.

Rivera, X. C. S., Orias, N. E., & Azapagic, A. (2014). Life cycle environmental impacts of convenience food: Comparison of ready and home-made meals. *Journal of Cleaner Production*, *73*, 294-309. https://doi.org/10.1016/j.jclepro.2014.01.008

Roca-Saavedra, P., Mendez-Vilabrille, V., Miranda, J. M., Nebot, C., Cardelle-Cobas, A., Franco, C. M., & Cepeda, A. (2018). Food additives, contaminants and other minor components: effects on human gut microbiota—a review. *Journal of physiology and biochemistry*, *74*(1), 69-83.

Rockell, J. E., Parnell, W. R., Wilson, N. C., Skidmore, P. M. L., & Regan, A. (2011a). Nutrients and foods consumed by New Zealand children on schooldays and non-schooldays. *Public health nutrition*, *14*(2), 203-208. https://doi.org/10.1017/S136898001000193X

Rolls, E. T. (2015). Taste, olfactory, and food reward value processing in the brain. *Progress in Neurobiology*, *127-128*, 64-90. https://doi.org/https://doi.org/10.1016/j.pneurobio.2015.03.002

Rush, E., Savila, F. a., Jalili-Moghaddam, S., & Amoah, I. (2019). Vegetables: New Zealand children are not eating enough. *Frontiers in Nutrition*, *5*. https://doi.org/10.3389/fnut.2018.00134

Sadeghirad, B., Duhaney, T., Motaghipisheh, S., Campbell, N., & Johnston, B. (2016). Influence of unhealthy food and beverage marketing on children's dietary intake and preference: a systematic review and meta-analysis of randomized trials. *Obesity Reviews*, *17*(10), 945-959. https://doi.org/https://doi.org/10.1111/obr.12445

Sanigorski, A., Bell, A., Kremer, P., & Swinburn, B. (2005). Lunchbox contents of Australian school children: room for improvement. *European journal of clinical nutrition*, *59*(11), 1310-1316.

Sato, P. d. M., Leite, F. H. M., Khandpur, N., Martins, A. P. B., & Mais, L. A. (2022). "I Like the One With Minions": The influence of marketing on packages of ultra-processed snacks on children's food choices. *Frontiers in Nutrition*, 1543.

Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D., Travis, R. C., Bradbury, K. E., & Key, T. J. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. *Clim Change*, *125*(2), 179-192. https://doi.org/10.1007/s10584-014-1169-1

Schulte, E. M., Chao, A. M., & Allison, K. C. (2021). Advances in the neurobiology of food addiction. *Current Behavioral Neuroscience Reports*, *8*(4), 103-112. https://doi.org/10.1007/s40473-021-00234-9

Seferidi, P., Scrinis, G., Huybrechts, I., Woods, J., Vineis, P., & Millett, C. (2020). The neglected environmental impacts of ultra-processed foods. *The Lancet Planetary Health*, *4*(10), e437-e438. https://doi.org/10.1016/S2542-5196(20)30177-7

Senathirajah, K., Attwood, S., Bhagwat, G., Carbery, M., Wilson, S., & Palanisami, T. (2021). Estimation of the mass of microplastics ingested–A pivotal first step towards human health risk assessment. *Journal of Hazardous Materials*, *404*, 124004. https://doi.org/10.1016/j.jhazmat.2020.124004

Silva, V. L., Sereno, A. M., & do Amaral Sobral, P. J. (2018). Food industry and processing technology: On time to harmonize technology and social drivers. *Food Engineering Reviews*, *10*(1), 1-13. https://doi.org/10.1007/s12393-017-9164-8

Simões, B. d. S., Barreto, S. M., Molina, M. d. C. B., Luft, V. C., Duncan, B. B., Schmidt, M. I., Benseñor, I. J. M., Cardoso, L. d. O., Levy, R. B., & Giatti, L. (2018). Consumption of ultra-processed foods and socioeconomic position: a cross-sectional analysis of the Brazilian Longitudinal Study of Adult Health. *Cadernos de saude publica*, *34*, e00019717. https://doi.org/doi.org/10.1590/0102-311X00019717

Smirk, E., Mazahery, H., Conlon, C. A., Beck, K. L., Gammon, C., Mugridge, O., & von Hurst, P. R. (2021). Sugar-sweetened beverages consumption among New Zealand children aged 8-12 years: a cross sectional study of sources and associates/correlates of consumption. *BMC public health*, *21*(1), 1-13.

Smith, A. P., & Richards, G. (2018). Energy drinks, caffeine, junk food, breakfast, depression and academic attainment of secondary school students. *Journal of Psychopharmacology*, *32*(8), 893-899.

Srour, B., & Touvier, M. (2021). Ultra-processed foods and human health: What do we already know and what will further research tell us? *EClinicalMedicine*, *32*, 100747. https://doi.org/https://doi.org/10.1016/j.eclinm.2021.100747

Stanham, K., Walton, K., Bell, A., Mayland, E., & Parrish, A.-M. (2020). Nutritional content and quality of food consumed at recess and lunchtime by 5–8-year-olds. *British Journal of Child Health*, *1*(5), 232-241.

Steele, E. M., Juul, F., Neri, D., Rauber, F., & Monteiro, C. A. (2019). Dietary share of ultra-processed foods and metabolic syndrome in the US adult population. *Preventive medicine*, *125*, 40-48. https://doi.org/doi.org/10.1016/j.ypmed.2019.05.004

Stylianou, K. S., Fulgoni, V. L., & Jolliet, O. (2021). Small targeted dietary changes can yield substantial gains for human health and the environment. *Nature Food*, *2*(8), 616-627. https://doi.org/10.1038/s43016-021-00343-4

Supermarket News. (2017). *Free fruit for kids at Countdown turns two* https://supermarketnews.co.nz/news/free-fruit-for-kids-at-countdown-turns-two/

Sutherland, R., Brown, A., Nathan, N., Yoong, S., Janssen, L., Chooi, A., Hudson, N., Wiggers, J., Kerr, N., & Evans, N. (2021). A multicomponent mhealth-based intervention (SWAP IT) to decrease the consumption of discretionary foods packed in school lunchboxes: type i effectiveness–implementation hybrid cluster randomized controlled trial. *Journal of medical Internet research*, *23*(6), e25256.

Sutherland, R., Nathan, N., Brown, A., Yoong, S., Reynolds, R., Walton, A., Janssen, L., Desmet, C., Lecathelinais, C., & Gillham, K. (2020). A cross-sectional study to determine the energy density and nutritional quality of primary-school children's lunchboxes. *Public health nutrition*, *23*(6), 1108-1116. https://doi.org/10.1017/S1368980019003379

Swinburn, B. A., Sacks, G., Hall, K. D., McPherson, K., Finegood, D. T., Moodie, M. L., & Gortmaker, S. L. (2011). The global obesity pandemic: shaped by global drivers and local environments. *The Lancet*, *378*(9793), 804-814. https://doi.org/https://doi.org/10.1016/S0140-6736(11)60813-1

Tapsell, L. C. (2016). Examining the relationship between food, diet and health. *Nutrition & Dietetics*, *73*(2), 121-124. https://doi.org/https://doi.org/10.1111/1747-0080.12276

Te Whatu Ora Health NZ. (n.d., August 30 2023). *Fruit in schools programme*. (https://www.tewhatuora.govt.nz/for-the-health-sector/specific-life-stage-health-information/child-health/fruit-in-schools-programme/).

Thiel, M., Luna-Jorquera, G., Álvarez-Varas, R., Gallardo, C., Hinojosa, I. A., Luna, N., Miranda-Urbina, D., Morales, N., Ory, N., Pacheco, A. S., Portflitt-Toro, M., & Zavalaga, C. (2018). Impacts of marine plastic pollution from continental coasts to subtropical gyres—Fish, seabirds, and other vertebrates in the SE Pacific. *Frontiers in Marine Science*, *5*. https://doi.org/10.3389/fmars.2018.00238

Thornley, S., Bach, K., Bird, A., Farrar, R., Bronte, S., Turton, B., Atatoa Carr, P., Fa'alili-Fidow, J., Morton, S., & Grant, C. (2021). What factors are associated with early childhood dental caries? A longitudinal study of the growing up in New Zealand Cohort. *International Journal of Paediatric Dentistry*, *31*(3), 351-360.

Trasande, L., Shaffer, R. M., & Sathyanarayana, S. (2018). Food additives and child health. *Pediatrics*, *142*(2). https://doi.org/10.1542/peds.2018-1410

Tubiello, F. N., Karl, K., Flammini, A., Gütschow, J., Obli-Laryea, G., Conchedda, G., Pan, X., Qi, S. Y., Halldórudóttir Heiðarsdóttir, H., Wanner, N., Quadrelli, R., Rocha Souza, L., Benoit, P., Hayek, M., Sandalow, D., Mencos Contreras, E., Rosenzweig, C., Rosero Moncayo, J., Conforti, P., & Torero, M. (2022). Pre- and post-production processes increasingly dominate greenhouse gas emissions from agri-food systems. *Earth Syst. Sci. Data*, *14*(4), 1795-1809. https://doi.org/10.5194/essd-14-1795-2022

UNICEF. (2019). *The state of the world's children 2019: Children, food and nutrition--Growing well in a changing world*. https://www.unicef.org/reports/state-of-worlds-children-2019

United Nations. (1989). Convention on the rights of the child. *Treaty Series*, *1577, 3*. https://www.refworld.org/docid/3ae6b38f0.html

United Nations. (2015). *Sustainable development goals*. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

van der Merwe, M. (2021). Gut microbiome changes induced by a diet rich in fruits and vegetables. *International Journal of Food Sciences and Nutrition*, *72*(5), 665-669. https://doi.org/10.1080/09637486.2020.1852537

Vandevijvere, S., Mackay, S., D'Souza, E., & Swinburn, B. (2019). The first INFORMAS national food environments and policies survey in New Zealand: A blueprint country profile for measuring progress on creating healthy food environments. *Obesity Reviews*, *20*(S2), 141-160. https://doi.org/https://doi.org/10.1111/obr.12850

Vandevijvere, S., Mackay, S., D'Souza, E., & Swinburn, B. (2018). *How healthy are New Zealand food environments? A comprehensive assessment 2014-2017*.

Vandevijvere, S., Waterlander, W., Molloy, J., Nattrass, H., & Swinburn, B. (2018b). Towards healthier supermarkets: A national study of in-store food availability, prominence and promotions in New Zealand. *European journal of clinical nutrition*, *72*(7), 971-978. https://doi.org/10.1038/s41430-017-0078-6

Vargas, C. M., Stines, E. M., & Granado, H. S. (2017). Health-equity issues related to childhood obesity: a scoping review. *Journal of Public Health Dentistry*, *77*(S1), S32-S42. https://doi.org/https://doi.org/10.1111/jphd.12233

Viennois, E., Merlin, D., Gewirtz, A. T., & Chassaing, B. (2017). Dietary emulsifier–induced low-grade inflammation promotes colon carcinogenesis. *Cancer Research*, *77*(1), 27-40. https://doi.org/10.1158/0008-5472.Can-16-1359

Wang, L., Steele, E. M., Du, M., Pomeranz, J. L., O'Connor, L. E., Herrick, K. A., Luo, H., Zhang, X., Mozaffarian, D., & Zhang, F. F. (2021). Trends in consumption of ultraprocessed foods among US youths aged 2-19 years, 1999-2018. *Jama*, *326*(6), 519-530. https://doi.org/doi:10.1001/jama.2021.10238

Waste MINZ. (2020). *The truth about plastic recycling in Aotearoa New Zealand in 2020*. https://gohealthy.co.nz/media/1990/the-truth-about-plastic-recycling-report.pdf

Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A. G., de Souza Dias, B. F., Ezeh, A., Frumkin, H., Gong, P., & Head, P. (2015). Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary health. *The Lancet*, *386*(10007), 1973-2028. https://doi.org/doi.org/10.1016/S0140-6736(15)60901-1

WHO. (2015). *Guideline: Sugars intake for adults and children.* https://www.who.int/publications/i/item/9789241549028

WHO. (2016). *Report of the commission on ending childhood obesity*. World Health Organisation. https://apps.who.int/iris/bitstream/handle/10665/204176/9789241510066_eng.pdf;jsessionid=4FDFABE925D4E2E13270E82E5D112A07?sequence=1%22

WHO. (2020). *Healthy diet: Fact sheet.* World Health Organisation. https://www.who.int/news-room/fact-sheets/detail/healthy-diet

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., & Wood, A. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*, *393*(10170), 447-492. https://doi.org/10.1016/S0140-6736(18)31788-4

Wu, X. Y., Zhuang, L. H., Li, W., Guo, H. W., Zhang, J. H., Zhao, Y. K., Hu, J. W., Gao, Q. Q., Luo, S., Ohinmaa, A., & Veugelers, P. J. (2019). The influence of diet quality and dietary behavior on health-related quality of life in the general population of children and adolescents: a systematic review and meta-analysis. *Quality of Life Research*, *28*(8), 1989-2015. https://doi.org/10.1007/s11136-019-02162-4

Zachariah, P., Johnson, C. L., Halabi, K. C., Ahn, D., Sen, A. I., Fischer, A., Banker, S. L., Giordano, M., Manice, C. S., Diamond, R., Sewell, T. B., Schweickert, A. J., Babineau, J. R., Carter, R. C., Fenster, D. B., Orange, J. S., McCann, T. A., Kernie, S. G., Saiman, L., & Group, C. P. C.-M. (2020). Epidemiology, Clinical Features, and Disease Severity in Patients With Coronavirus Disease 2019 (COVID-19) in a Children's Hospital in New York City, New York. *JAMA pediatrics*, *174*(10), e202430-e202430. https://doi.org/10.1001/jamapediatrics.2020.2430

Zinöcker, M. K., & Lindseth, I. A. (2018). The Western diet–microbiome-host interaction and its role in metabolic disease. *Nutrients*, *10*(3), 365. https://doi.org/10.3390/nu10030365

Chapter 7 – Appendices

Appendix 1 – Ethical Approval

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

26 July 2021

Grant Schofield
Faculty of Health and Environmental Sciences

Dear Grant

Re Ethics Application: **21/174 Auditing the healthiness and eco-friendliness of year 6 students' lunchboxes in socio-economically diverse Auckland schools**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 26 July 2024.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: fernhp16@gmail.com; Tom Stewart; Kayla-Anne Lenferna De La Motte

Appendix 2 – Parent Information Sheet and Consent Form

PARENT/GUARDIAN INFORMATION SHEET

Date Information Sheet Produced: 08 August 2021

Research Title: *Auditing the healthiness and eco-friendliness of year 6 students' lunchboxes in socio-economically diverse Auckland schools*
Students' Title: ***Planet-Friendly Lunchboxes Project***

Project Supervisor: **Professor Grant Schofield**
Researcher**: Fern Pereira**

An Invitation
Dear parent/legal guardian,

My name is Fern Pereira, and I am a Master of Public Health student at AUT University in Auckland. I am conducting a study to investigate the healthiness and sustainability of school lunchboxes of year 6 students at four schools across Auckland. I would like to invite your child to take part in the study. This information sheet contains important information on what is involved. Please read through it carefully with your child before signing the statement of consent.

What is the purpose of this research?

Most children in NZ take a lunchbox to school, which corresponds to about a third of their dietary intake. Emerging literature shows the level of processing and nature of foods impact individual health, beyond nutrient content. Findings from studies indicate that highly-processed, nutritionally-poor snacks, dominate home-packed lunches. Additionally, highly processed diets are detrimental to environmental sustainability, particularly single-use packaging waste.

Grounded in a novel eco-nutrition approach, my research will be the first school-based lunchbox analysis by food processing level in NZ (and the second worldwide). This will also be the first study globally to explore the relationship between the packaging sustainability of lunchbox foods and their processing level, whilst determining socioeconomic variations across schools.

The findings from this research will be published in academic journals and presented at conferences.

How was my child identified and why is he/she being invited to participate in this research?

Your child's school is one of four schools in Auckland that have decided to participate in this study. We are now inviting all students in the selected year 6 classroom (s) to take part.

What will happen in this research?

If your child agrees to participate, they will be invited to have the food and drink contents of their lunchbox measured, using digital photography and a complementary Lunchbox Food Checklist. Date of data collection will not be known in advance.

On data collection day, myself and a research assistant will set up a photo station at the beginning of the school day. Participating students will be asked, one at a time, to walk to the photo station and place all food/drink items from their lunchbox on a 2.5 cm grided placemat (for size reference). Only students will touch their foods.

The researchers will then fill in a complementary *Lunchbox Food Checklist*, asking the student to describe any item which cannot be seen using the photograph (e.g., foods inside non-transparent containers). Students will also be asked who packed their lunchbox that day. A digital photograph of the lunchbox will be taken from above (as in the photo below):

The photograph and *Lunchbox Food Checklist* will be matched by a number, and a portable screen will be placed by the placemat to shield food contents from other students, to protect participant privacy.

To help identify packaging waste profiles, students will be asked to dispose of any lunchbox packaging waste in a waste collection bucket placed at their classroom on data collection day. I will collect bucket at the end of the school day.

A selection of lunchbox photographs may be used when I share findings of the study with others. You/your child may choose to not have your child's lunchbox photograph included.

Another AUT will use these deidentified data (no names) to conduct a cost-nutrient analysis of lunchboxes next year. You/your child may choose to consent/participate in my study only, or both.

How does my child agree to participate in this research?

For children to participate, both the parent/guardian and the child must consent/assent. This means, if your child would like to take part in this research, then he/she will need to sign the **Student Assent Form** attached to the **Student Information Sheet** and you will need to sign the **Parent/Guardian Consent Form** attached to this sheet. Place both Assent & Consent forms in the envelope provided and return to the classroom drop box by ***Jun/22.***

Your child's participation in this research is entirely voluntary, and participation will neither advantage nor disadvantage your child. Your child is able to withdraw from the study at any time. If your child chooses to withdraw from the study, then you will be offered the choice between having any data that belongs to them removed or allowing it to continue to be used. However, once the findings have been produced, removal of your child's data may not be possible.

What are the discomforts and risks and how these will be aliviated?

It is unlikely that your child will encounter any greater risk than during a normal school day.

Should your child prefer to not provide information to any of the questions in the *Lunchbox Food Checklist* or have their lunchbox items photographed, they will not be disadvantaged in any way. Children may withdraw from the study at any point.

What are the benefits?

The data collected will hopefully provide all of us, including researchers, students, whānau and the wider-school community, with a better understanding of the current healthiness and sustainability status of lunchboxes in schools, and existing relationships between both. My research may raise awareness and increase knowledge regarding the level of processing of lunchbox foods, the relationship between our food choices and planetary health. This could potentially drive communities to opt for less processed, less packaged lunchbox alternatives. Consequently, this may encourage the development of more nutritious, less processed lunchbox snack options by food manufacturers, and implementation of public health policies that align with this notion.

Participating students and schools will receive a child-friendly summary of findings at the end of the study. Parents/guardians may also choose to have a report emailed with the study results at the end of the study.

This research will also help me to obtain my Master of Public Health qualification.

How will my/my child's privacy be protected?

Due to the nature of the study, participants' identities may be known to their classmates and teachers. All collected data will be treated confidentially, and will be sorted and stored by number codes, not by names. Only myself and my study's supervisors will have access to the records. We will not include information that will make it possible to identify your child in any presentations, publications or reports arising from this research. Your child's school will not be identified in reports, only the Auckland regions in which the research takes place will be named. No photographs of children will be taken.
Data will be stored for 6 years and will be permanently destroyed after this period.

The planned future research to analyse the cost of lunchboxes will not contain any identifiable data.

What are the costs of participating in this research?

There are no financial costs for participating in this research.

The study will involve your child having their lunchbox items photographed and noted down in the *Lunchbox Food Checklist*, as described above. Students will also be asked to dispose of any single-use packaging waste in a lidded bucket provided at the end of lunch break. In total, these should take no more than 15 minutes of your child's time (including an expected time of under three minutes for data collection per student).

Will I receive feedback on the results of this research?

On the consent form, you can indicate if you wish to receive a summary report of the research findings. I will also be sharing a child-friendly summary of findings with participating students and schools.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Professor Grant Schofield, at **grant.schofield@aut.ac.nz ,(09) 921 9169**.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Dr Carina Meares, **ethics@aut.ac.nz , (09) 921 9999 ext 6038**.

Whom do I contact for further information about this research?

Researcher's Contact Details: Fern Pereira, at fernhp16@gmail.com, 021 662413
Project Supervisor Contact Details: Professor Grant Schofield, at grant.schofield@aut.ac.nz , (09) 921 9169

AUT

PARENT/GUARDIAN CONSENT & RELEASE FORM

Research Title: *Auditing the healthiness and eco-friendliness of year 6 students' lunchboxes in socio-economically diverse Auckland schools*

Project Supervisor: **Professor Grant Schofield**
Researcher**: Fern Pereira**

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 08/08/21.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I agree to my child taking part in this research.
- ○ I understand that taking part in this study is my child's choice and that I may withdraw my child from the study at any time without being disadvantaged in any way.
- ○ I understand that my child can refuse to give assent to take part in this research, even if I agree with them participating in the study.
- ○ I understand that if I withdraw my child from the study then I will be offered the choice between having any data that is identifiable as belonging to my child removed or allowing it to continue to be used. However, once the findings have been produced, removal of data may not be possible.
- ○ I permit the researcher to use photographs that are part of this project and/or any other reproductions or adaptations from them, either complete or in part, alone or in conjunction with any wording and/or creative work solely and exclusively for (a) exhibition and examination purposes; and (b) all forms and media for advertising, trade, sharing of the findings or other lawful purposes as stated on the Information Sheet.
- ○ I understand that the copyright of lunchbox photograph created during data collection is deemed to be owned by the researcher and that I do not own its copyright.
- ○ I understand that data from this study will be retained by AUT and may be used in the future for comparative purposes.
- ○ I agree with unidentified data from this study being used in a future research to conduct a cost analysis of lunchboxes. ☐ Yes ☐ No
- ○ I wish to receive a summary of the research findings (please tick one): ☐ Yes ☐ No

Child's name: ....

Child's date of birth (dd/mm/yyyy): ....

Child's gender (please circle): Male / Female

Parent/Guardian's name: ....

Parent/Guardian's signature: ....

Parent/Guardian's Contact Details:

E-mail: ....

Date: ....

Approved by the Auckland University of Technology Ethics Committee on *26 July 2021*, AUTEC Reference number *21/174*.

Appendix 3 – Student Information Sheet and Consent Form

STUDENT INFORMATION SHEET

Date Information Sheet Produced: 08/08/2021

Project Title: Planet-Friendly School Lunchboxes

Project Supervisor: **Professor Grant Schofield**
Researcher: **Fern Pereira**

My name is Fern Pereira, and I am a Master of Public Health student at AUT University. I am doing a study that looks at how healthy year 6 students' school lunchboxes are, and the amount and type of packaging waste they produce. I will be conducting this study by collecting data from selected year 6 classrooms of four primary schools across Auckland, including yours. At the end of the study, I'll write a child-friendly report to share all the findings of my investigation with participating students and schools.

Another student from AUT is planning to use the data I collect in her own study next year, to find out the cost of foods in lunchboxes. You may choose to participate only in my study, or both.

You are invited to take part in this study. If you choose to participate, these are the things that will happen:

1. A research assistant and I will visit your school on data collection date.
2. We will set up a photo station with a grided placemat on a table (as in the photo), and a digital camera above it.

3. We will ask one student at a time to come to the photo station and place their lunchbox food and drink items on the placemat. Only students will touch their lunchbox items. Before taking the photo, we will ask you to describe any foods/drinks we would not be able to recognise by looking at the photograph, for example, sandwich fillings or foods inside non-transparent wrappers. We will write your answers in a Lunchbox Food Checklist form. We will also ask you who packed your lunchbox on that day.
4. To help us identify the packaging waste produced by lunchboxes, we will place a lunchbox waste collection bucket in your classroom, on the day of data collection. We will ask you to dispose of any single-use packaging waste (stuff you would normally throw away, compost or recycle, either at school or home) into the collection bucket, at the end of lunch time. We will collect the lunchbox waste bucket at the end of the school day.

Approved by the Auckland University of Technology Ethics Committee on *26 July 2021*, AUTEC Reference number *21/174*

Do you have any questions? Answers to some of the questions that you may have are answered here:

- **Before you start, your parent/guardian has to say that it is ok for you to take part in my study.** They will be able to do this by reading the Parent/Guardian Information Sheet (blue) and then sign the Parent/Guardian Consent and Release Form, to be returned to school.

- **You don't have to take part.** Taking part in my study is voluntary (which means it's entirely your choice). In fact, both you and your parent need to say it's ok before you take part, and even if your parent says it's ok, but you don't feel like taking part, you don't have to.

- **If you decide after we start that you don't want to take part anymore**, don't worry, that's also ok. Just ask your parent to let me or my supervisor know.

- **You can ask me questions at any time.** If you would like to ask me anything about this study, please just get in touch by asking your parent to email your questions to my supervisor, Professor Grant Schofield, using the email provided at the end of this information sheet. He will pass these onto me, and we'll be very happy to answer any queries you may have.

- **Your friends and teachers may know that you are taking part in the study, but I will keep all the information collected about you private, by doing these things:**
    - I will keep all your records in a secure location.
    - Both your lunchbox photograph and Lunchbox Food Checklist will be identified by a matching number (not your name).
    - I will use a placemat for the lunchbox photo, instead of photographing lunch items inside your school lunchbox – so no one can identify it back to you. I will place a screen by the placemat, so no one else can see your food items while we are taking the photo.
    - I will never use your real name when I'm writing, or talking, about the study.

Have you got any other questions?

If you or your parent/guardian have any other questions or want to know more about my study, please email my supervisor, Professor Grant Schofield, at grant.schofield@aut.ac.nz

If you want to take part in the study, please sign your name on the *Student's Assent Form*. Your parent/legal guardian also needs to sign the *Parent/Guardian Consent Form*. When both forms are filled in, put them in the envelope provided and place them in the drop box in your classroom by *Jun/22*. Thank you!

Approved by the Auckland University of Technology Ethics Committee on *26 July 2021*, AUTEC Reference number *21/174*

STUDENT ASSENT AND RELEASE FORM

Planet-Friendly School Lunchboxes Project

Project Supervisor: **Professor Grant Schofield**
Researcher**: Fern Pereira**

Tick & Sign

- I have read and understood the sheet telling me what will happen in this study and why it is important.
- I have had a chance to ask questions and to have them answered.
- I understand that I may decide to stop being part of the study at any time and it's perfectly ok for me to do this.
- I agree with the researcher having my lunchbox photograph and using it when sharing the findings of this study.
- I agree to be part of this study.
- I agree with my data collected for this study being shared with another researcher to find out the cost of lunchboxes. ☐ Yes ☐ No

Student's Name: ______________________________________

Year 6 Classroom: ____________________________________

Date: _________________

Note: The participant should retain a copy of this form.

Approved by the Auckland University of Technology Ethics Committee on *26 July 2021*, AUTEC Reference number *21/174*

Appendix 4 – School Principal Information Sheet and Consent Form

SCHOOL PRINCIPAL INFORMATION SHEET

8 June 2022

Research Title: *Auditing the healthiness and eco-friendliness of year 6 students' lunchboxes in socio-economically diverse Auckland schools*
Students' Title: *Planet-Friendly Lunchboxes Project*

Project Supervisor: **Professor Grant Schofield**
Researcher**: Fern Pereira**

To the Principal of ***The Gardens School,***

My name is Fern Pereira, and I am a Master of Public Health student at AUT University. As part of my master's qualification, I will be undertaking a research project investigating the healthiness and eco-friendliness status of year 6 students' lunchboxes.

My study will collect data from selected year 6 classrooms from 4 primary schools of diverse decile across Auckland (two low decile, two high decile). ***The Gardens School*** fits the study's criteria, and I would like to invite ***The Gardens School*** to participate in the study.

What is the purpose of this research?

Most children in NZ take a lunchbox to school, which corresponds up to a third of their dietary intake. Emerging literature shows the level of processing and nature of foods impact individual health, beyond nutrient content. Findings from studies here and abroad investigating school lunchboxes indicate that highly-processed, nutritionally-poor snacks, dominate home-packed lunches. Additionally, highly processed diets are detrimental to environmental sustainability, particularly single-use packaging waste.

Grounded in a novel eco-nutrition approach, my research will be the first school-based lunchbox analysis by food processing level in NZ. This will also be the first study globally to explore the relationship between the packaging sustainability of lunchbox foods and their processing level, whilst determining socioeconomic variations across Auckland schools.

How do I agree to participate in this research?

In each school my aim is to recruit ~30 year 6 students. If you agree for ***The Gardens School*** to participate, you will be asked to identify one year 6 classroom (or more, depending on the number of students per classroom). I will then organise with you (or the most appropriate person, as indicated by you), a suitable time for me to visit the class to introduce the research and invite the children interested in the project to take information and consent forms home for them and their parents to read and complete. I would leave a drop box in the classroom and ask students to return completed forms in the envelope provided and place it in the classroom drop box two weeks after they are provided.

What will happen in this research?

The study will involve analysing the level of processing of lunchbox food and drink items, the amount and type of single-use packaging in lunchboxes, how these relate to each other, and identifying any variations across school decile and regions.

On data collection day, consenting students' lunchboxes would be individually digitally photographed on a gridded placemat, at the start of the school day, following a validated method for measuring lunchbox contents (as in the photo below).

This will be complemented by a Lunchbox Food Checklist completed by me (and/or research assistant). This complementary checklist will help establish food content of lunchboxes which may not be possible to see from photographs (e.g., sandwich fillings or food in containers). Only students will touch their foods and the placemat will be sanitised between each photograph. To protect the confidentiality of participants, photographs and checklist responses will be matched by a unique ID number. I will also have a screen placed by the photo station, so foods being photographed cannot be seen by others.

After lunch, participating students will be asked to dispose their lunchbox packaging waste into a lidded bucket provided, which I will collect at the end of data collection day.

The step-by-step data collection process is included in the information sheets for parent/guardian and participating students (attached). I will also describe in detail what will happen during data collection and afterwards, during my initial meeting with the students.

Another AUT student will use these deidentified data (no names) to conduct a cost-nutrient analysis of lunchboxes next year. Participants and their parent/guardian may choose to participate in my study only, or both.

Implications of participation for the school

There are no foreseeable risks associated with ***The Gardens School*** participating in this study. The involvement of schools with this project is completely voluntary and school staff and/or the school's Board of Trustees may ask questions about the research at any time. If you choose for ***The Gardens School*** to be involved, you are free to withdraw the school from this research at any time without giving reason and with no adverse consequences.

There are no financial costs of your school being involved with this research; however, a small amount of time, of teacher(s) in participating class(es), will be needed. As well, we will require a space in which to set up the photo station and meet with participating students. **To acknowledge the school's contribution to the study a koha of $100 (voucher) will be provided.**

Will I receive feedback on the results of this research?

At the end of my study, I will provide participating students and schools with a child-friendly report including a summary of findings. If the school is interested, I will also be happy to present findings (grouped information of all participating schools, with no individual data identified) to the school in an oral format suitable to the audience (e.g., students, whānau, staff, Board of Trustees).

Additional information

Information sheets outlining the study procedures for participants and their parents have been appended to this invitation.

Your school will not be identified in reports on the research and no identifying information on any individual will be included in any documents or presentations resulting from the study. Due to the nature of the study, participants' identities may be known to their classmates and teachers. The Auckland regions in which the research takes place will be named.

If you agree for ***The Gardens School*** to be involved with this research, please complete and sign the consent form attached to this sheet. The form can then be returned by email to Fern Pereira, at **fernhp16@gmail.com**. Thank you for taking the time to consider this invitation to participate in the study.

Project Contacts

Whom do I contact for further information about this research?

If you have any queries about the project either before it commences in the school or during the study, please contact me, Fern Pereira, at **fernhp16@gmail.com, mob: 021 662413**, or my study's primary supervisor, Professor Grant Schofield, **grant.schofield@aut.ac.nz, (09) 921 9169**.

What do I do if I have concerns about this research?
Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Professor Grant Schofield, at grant.schofield@aut.ac.nz, (09) 921 9169.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Dr Carina Meares, **ethics@aut.ac.nz , (09) 921 9999 ext 6038**.

Permission for researcher to access school's staff and students

Research Title: *Auditing the healthiness and eco-friendliness of year 6 students' lunchboxes in socio-economically diverse Auckland schools*

Project Supervisor: **Professor Grant Schofield**
Researcher**: Fern Pereira**

○ I have read and understood the information provided about this research project in the Information Sheet dated *8 June 2022*

○ I give permission for the researcher to undertake research within ***The Gardens School***

○ I give permission for the researcher to access the staff and students of ***The Gardens School***

Principal's signature : ....

Principal's name : ....

Principal's Contact Details:

....

....

....

....

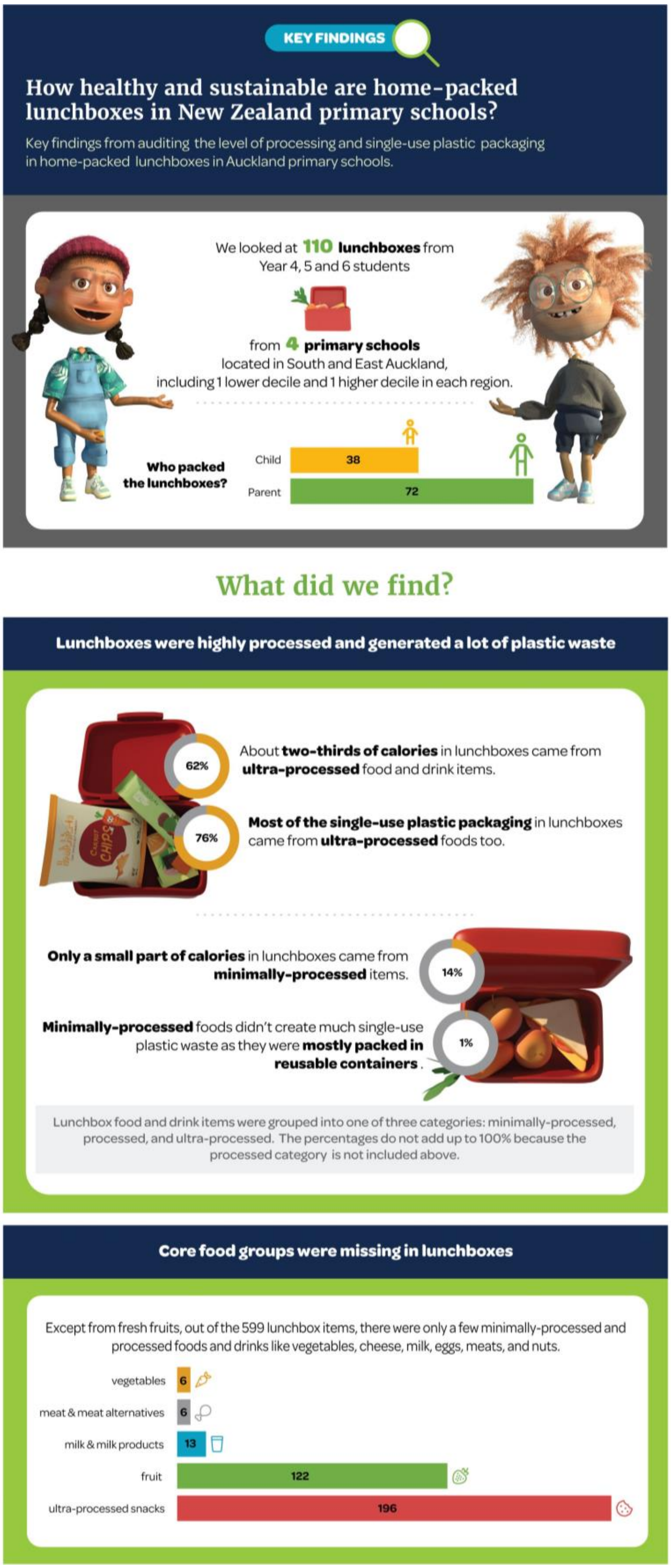
Date : ....

Approved by the Auckland University of Technology Ethics Committee on *26 July 2021*, AUTEC Reference number *21/174*

Appendix 5 – Sample size calculation

Using the PASS 15 software and a repeated measures analysis, we estimate that 53 subjects will allow us to detect a difference in the proportion of energy across the three levels of NOVA processing, with 90% power and a type I error rate of 0.05. This is based on an F Test with a single three-level within-subject factor, a conservative between-subject standard deviation of 40, an autocorrelation among the repeated measurements of 0.2, and applying the Greenhouse–Geisser degrees of freedom adjustment. We based our assumed means across the three processing levels on unpublished data from Manurewa primary school (MP = 18.7%, P = 18.8%, UP = 62.7%) and on previous work from the United States (Blondin et al., 2020). We scaled the mean effect to 0.5 to allow us to detect a smaller mean difference across conditions. Allowing for 10% data loss, we will increase the sample size to 59 participants.

Appendix 6 – Dissemination infographic



Ultra-processed snacks rule lunchboxes!

Sweet and savoury ultra-processed snacks, such as pre-packaged cookies, chips, and lollies, made up the biggest source of ultra-processed items in lunchboxes.

The packaging from these snacks, like soft plastic bags and wrappers, were the main type of single-use plastic waste in lunchboxes.

Tip For litterless lunchboxes

Litterless lunchboxes are all about using reusable containers instead of disposable plastic packaging.

But here's something to know:

Just removing food and drink packaging at home is not enough.

Our study found that even though some lunchboxes seemed waste-free, the actual amount of single-use plastic packaging increased when considering the original packaging of lunchbox items. This means that even if we can't see the packaging in our lunchboxes, plastic waste is still being generated at home and could end up in landfills or harm the environment.

KEY MESSAGE

Prioritising wholefoods and limiting pre-packaged ultra-processed snacks can contribute to healthier and environmentally-friendlier school lunchboxes.

Curious to learn more?

Scan the QR code for a child-friendly resource on ultra-processed foods and their impact on human and planetary health.

SCAN ME

https://qrco.de/beALea

AUT HUMAN POTENTIAL CENTRE

CleanPlate
Healthy eating Healthy planet