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The role of plant-based foods in the diets of adults (18-90y) in Ireland

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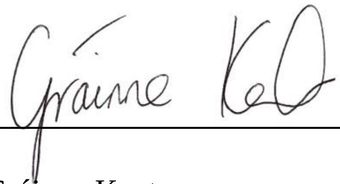
Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork, Munster Technological University or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork and Munster Technological University concerning plagiarism and intellectual property.



Gráinne Kent

Personal contribution to this thesis

This thesis is based on data from the National Adult Nutrition Survey (NANS) which was carried out between October 2008 and April 2010. This survey was carried out by the nutrition units in University College Cork (UCC) and University College Dublin (UCD), which form part of the Irish Universities Nutrition Alliance (IUNA). I was responsible for coding the food consumption database into the plant-based components as described in this thesis and all database analyses in this thesis were performed by me.

Contribution to the research group

During the timeframe of my PhD, I worked with the National Dietary Surveys Research Team in UCC and Munster Technological University (MTU) as a researcher on the National Teens' Food Survey II (NTFS II) which was carried out between March 2019 and March 2020.

In my role as a fieldworker on this survey, I collected data from 106 participants and their parents/guardians in the Cork, Kerry and Waterford area including data related to dietary intake, health & lifestyle, eating behaviour, anthropometric measurements, in addition to collecting spot urine samples. I was involved in the management of blood clinics for blood sample collection and in the batch processing of urine and blood samples. Following data collection, I entered the dietary intake data into Nutritics© and the questionnaire data into DaSurvey©. I was also involved in the quality control of these data.

Gráinne Kent

Publications

Peer-reviewed publications

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

Kent, G., Kehoe, L., McNulty, B. A., Nugent, A. P., Flynn, A. and Walton, J. (2022). A standardised methodological approach for characterising the plant-based component of population or individual diets. *Journal of Food Composition and Analysis,* **114**, 104727.

Conference abstracts

Kent, G., Kehoe, L., McCarthy, R., McNulty, B., Nugent, A., Flynn, A. and Walton, J. (2021). Characterising the plant-based component of the Irish diet in terms of its micronutrient content. *Proceedings of the Nutrition Society,* 80 (OCE1), E20. doi:10.1017/S0029665121000215

Kent, G., Kehoe, L., McCarthy, R., Walton, J., McNulty, BA., Nugent, A. P and Flynn, A. (2020). Characterising the plant-based component of the Irish diet in terms of its nutritional quality. *Proceedings of the Nutrition Society,* 79 (OCE2), E562 doi:10.1017/S002966512000511X

Summary reports

Irish Universities Nutrition Alliance (2021) *National Teens' Food Survey II Summary Report on Food and Nutrient Intakes, Body Weight, Physical Activity and Eating Behaviours in Teenagers Aged 13-18 Years in Ireland* (contributing author)

Non-peer reviewed articles

Kent, G., Kehoe, L., Flynn, A. and Walton, J. (2022). What is a plant-based diet? A review of the definitions and nutritional role of plant-based foods in the adult diet. *Professional Nutrition & Dietetic Review* **7** (1) 27-28

Training/contributions during this training period

Modules

October 2020: PG6003 Teaching and Learning Module for Graduate Studies (UCC) 5 ECTS

October 2020: EDUC9039 Research Skills Development (MTU) 5 ECTS

February 2020: FS 6634 Leadership for Agri Food Researchers (UCC) 5 ECTS

Other training/contributions

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December 2019: Epigeum Research Integrity Training (online)

September 2019-2022 Nutrition Society Student Ambassador, UCC

Abstract

Background: Plant-based (PB) diets are generally associated with good health and are also recommended for environmental sustainability, however there is a broad range of PB diet definitions in the literature and there is a growing body of evidence that not all PB foods are 'healthy'. While food-based dietary guidelines (FBDG) have traditionally placed PB foods, such as fruit, vegetables and starchy staples, particularly wholegrain cereals and potatoes as central components of their guidelines, ongoing updates to FBDG globally are placing even more emphasis on PB foods in parallel with a reduction in the consumption of animal-derived foods. However, data from national food consumption surveys show that Western populations generally consume an omnivorous diet and the World Health Organisation (WHO) have recently highlighted a need for more research on real-world dietary patterns regarding PB foods to assist policymakers with developing evidence-based dietary guidelines, food policy and general health. Hence, there is a need for studies to investigate the role of PB diets in populations currently accustomed to consuming a primarily omnivorous diet.

Objectives: The overall aim of this PhD thesis was to examine the current role of PB components and PB foods in the diet of adults (18-90y) in Ireland using data from the National Adult Nutrition Survey (NANS) (2008-2010), which is a nationally representative dietary survey of adults in the Republic of Ireland. The individual objectives were to first develop a systematic methodology to identify the PB component of a diet using two extremes of PB diet definitions, i.e., plant-based (all) (PB-A) which included 'all plant-based foods' regardless of dietary quality and plant-based (healthful) (PB-H) which included 'healthful plant-based foods' only (both of which excluded all meat and fish and placed heavy restrictions on animal products, such as dairy and eggs) and then to use this systematic methodology to examine the nutritional quality of the PB component of the diet using the two definitions (PB-A and PB-H) compared to the baseline diet (the overall diet consumed by the NANS population) in adults in Ireland. Additionally, this thesis aimed to estimate the current intake of 'fruit & vegetables' and 'cereals, grains & potatoes' in adults (18-90y) in Ireland, to assess compliance with recommendations and to determine their contribution to overall energy and nutrient intakes.

Methods: The analyses for this thesis were based on data from the NANS, which is a nationally representative cross-sectional study that collected food and beverage consumption data from 1500 adults aged 18-90 years in the Republic of Ireland, between 2008 and 2010. Food and beverage intakes were estimated using a 4-day semi-weighed food diary. Energy and nutrient intakes were estimated using WISP© which contains food composition data from the UK 'McCance and Widdowson's The Composition of Foods', sixth and fifth edition (plus all nine supplemental volumes). During the NANS, modifications were made to the food composition database to include recipes of composite dishes, fortified foods, nutritional supplements, generic Irish foods and new foods on the market. Mean daily intakes (MDI) of food groups and nutrients were estimated using SPSS© Version 26.0 for Windows by summing the weight of each food or nutrient consumed and dividing the total by the number of recording days (four). The nutritional quality of the PB-A and PB-H components and baseline diet was assessed by estimating energy-adjusted intakes (%E or /10MJ) of macronutrients, dietary fibre, vitamins and minerals. Differences in the MDI of food groups and nutrients between PB diet components (PB-A, PB-H) and sexes (men, women) were assessed using independent sample t-tests. Differences in the MDI of food groups and nutrients between age groups (18-35y, 36-50y, 51-64y, 65y+) were assessed using ANOVA and Tukey tests were used for post-hoc analysis. The percent contribution of food groups to energy and nutrient intakes were calculated by the mean proportion method.

Results: A novel 23-step protocol was developed which outlined the exclusion and inclusion criteria for the PB-A and PB-H components of the diets. Each food code of the NANS was examined and coded (excluded/included) into PB-A and PB-H with consensus from three independent research nutritionists. Each food code was first examined for animal content, to inform the coding of PB-A and PB-H. For PB-H, the food code was additionally examined based on the level of refinement (i.e., wholegrain vs refined grain) and dietary quality (i.e., foods recommended in FBDG). The food codes were examined using the packaging label ingredient list and recipe ingredients for composite dishes. The coding of complex food codes (e.g., composite dishes or retail products with minimal quantities of eggs and dairy) involved discussions and considerations on the amount of egg/dairy within the food and its functionality within the dish.

This methodology was then used to examine the nutritional quality of the PB component of the diet using the two definitions (PB-A and PB-H) compared to the

baseline diet (the overall diet consumed by the NANS population) in adults in Ireland. When compared to the baseline diet, both the PB-A and PB-H components of the diet were of better nutritional quality in terms of total and saturated fat, carbohydrate, dietary fibre, vitamin C, thiamin, biotin, vitamin B6, folate, sodium, potassium, iron, magnesium and copper but of poorer nutritional quality in terms of protein, MUFA, PUFA, total sugars, vitamin D, vitamin B12, calcium and iodine (PB-A only). With regard to free sugars and zinc, the PB-A component of the diet was of poorer nutritional quality compared to the baseline diet, but the PB-H component was of better nutritional quality.

When both PB diet components were compared to each other, this study found that the PB-H component of the diet was of better nutritional quality compared to the PB-A with regards to total fat, saturated fat, PUFA, protein, carbohydrate, dietary fibre, free sugars and many micronutrients, including B-vitamins, vitamin C, potassium and iron. However, compared to PB-A, the PB-H component of the diet was of poorer quality for vitamin D and vitamin B12 mainly due to the exclusion of refined and processed fortified foods, such as RTEBC, fat spreads and beverages in the PB-H component.

While ‘fruit & vegetables’ were consumed by all adults in Ireland, with a mean daily intake (MDI) of 285g/d (approximately 3.6 servings), only one fifth of adults are meeting the WHO or the Irish FBDG recommendations for fruit & vegetable intake For the most part, there were no differences in ‘fruit & vegetable’ intake between men and women however the younger age groups (18-35y and 36-50y) had lower intakes of fruit & vegetables compared to those aged 51-64y and 65y+, with the exception of ‘vegetables in composite dishes’. ‘Fruit & vegetables’ contributed minimal proportions of intakes of energy (7%), protein (4%) total fat (5%), saturated fat (2%) and MUFA (4%) but made important contributions to intakes of PUFA (10%), carbohydrate (11%), dietary fibre (29%), vitamin C (41%), vitamin A (39%), potassium (17%), total folate (13%), DFE (11%), vitamin E (12%), magnesium (11%) and thiamin (10%), while also contributing to intakes of total sugars (23%) and free sugars (11%).

‘Cereals, grains & potatoes’ were consumed by all adults, with an MDI of approximately 4.5 servings, however, only 2.1 servings were from ‘wholemeal cereals and breads, potatoes, pasta and rice’, which is below the Irish FBDG recommendation of 3-5 servings per day. Men had a higher MDI of overall ‘cereals, grains & potatoes’ compared to women. Those aged 18-35y had higher intakes of convenience foods, e.g., ‘low-fibre RTEBC’, ‘pasta’, ‘other savoury dishes & products’, ‘chipped, fried & roasted potatoes’ and ‘pizza’ compared to older age groups. Overall, ‘cereals, grains & potatoes’ made significant contributions to the MDI of energy (32%), carbohydrate (52%), dietary fibre (53%), protein (24%), B vitamins, such as folate (32%), thiamin (27%), niacin (26%) and vitamin B6 (22%) and minerals, such as iron (40%), magnesium (35%), calcium (29%), potassium (28%) and zinc (27%) but also made significant contributions to intakes of sodium (32%) and smaller contributions to the intake of saturated fat (15%) and free sugars (7%).

Conclusions: In summary, this is the first study to provide a standardised methodology to identify the PB component of a diet and to examine the nutritional quality of the PB component of the diet of adults (18-90y) in Ireland, compared to a baseline (omnivorous) diet. Additionally, this study identified the current intakes and nutrient contributions of ‘fruit & vegetables’ and ‘cereals, grains & potatoes’ in the diets of adults in Ireland and compared these to existing recommendations. This study highlighted that the consumption of a more PB diet may improve the nutritional quality of the diet of adults in Ireland, in terms of many nutrients, such as total fat, saturated fat, carbohydrate, free sugars, dietary fibre, sodium, potassium and folate, but may exacerbate potential deficiencies of other nutrients, such as vitamin D, vitamin B12, calcium and iodine and may cause concern for the bioavailability of other nutrients, such as protein, PUFA, iron and zinc. This study found that the current intake of both fruit & vegetables (approximately 3.6 servings/day) and wholemeal cereals and breads, potatoes, pasta and rice (approximately 2.1 servings) are below the Irish FBDG recommendations. However, ‘fruit & vegetables’ and ‘cereals, grains & potatoes’ together made important contributions to energy and were key contributors to intakes of carbohydrate and dietary fibre and other nutrients including protein, MUFA, PUFA, vitamins A, E and C, B vitamins (folate, thiamin, niacin and vitamin B6), iron, potassium, magnesium, calcium and zinc. ‘Cereals, grains and potatoes’ also contributed to intakes of saturated fat and salt while ‘fruit juice’ and RTEBC made small contributions to intakes of free sugars. The data presented in this study may benefit the scientific community, health professionals, policymakers and the food industry in understanding how intakes of PB foods can be improved in adults in

Ireland. The data presented can inform policy changes to improve intakes, such as product reformulation, and can also inform other research areas. Additional research into strategies which target the food environment (workplace initiatives), accessibility of healthful PB foods (government subsidisations and incentives) and personal determinants (education and choice) of PB food intake is needed in adults in Ireland to help increase the intake of high-quality plant foods in light of the shift towards a more PB diet for health and environmental benefits.

Abbreviations

ANIBES	Anthropometry, Intake and Energy Balance in Spain Study
ANOVA	Analysis of Variance
CHO	Carbohydrate
CVD	Cardiovascular Disease
COVID-19	Coronavirus Disease
DFE	Dietary Folate Equivalents
DANSDA	Danish National Survey of Dietary Habits and Physical Activity
DASH	Dietary Approaches to Stop Hypertension
DOH	Department Of Health
DNFCS	Dutch National Food Consumption Survey
EFSA	European Food Safety Authority
FAO	Food and Agriculture Organisation
FBDG	Food-Based Dietary Guidelines
FSAI	Food Safety Authority of Ireland
IU	International Units
IOM	Institute Of Medicine
IUNA	Irish Universities Nutrition Alliance
IAN-AF	The National Food, Nutrition, and Physical Activity Survey of Portugal
INRAN-SCAI	Italian National Food Consumption Survey
MDI	Mean Daily Intake
MUFA	Monounsaturated Fatty Acids
MTU	Munster Technological University
NANS	National Adult Nutrition Survey
NDNS	National Diet and Nutrition Survey
NNR	Nordic Nutrition Recommendation
NSIFCS	North/South Ireland Food Consumption Survey
NSP	Non-Starch Polysaccharide
PB	Plant-Based
PB-A	Plant-Based (All)
PB-H	Plant-Based (Healthful)
PDI	Plant-Based Dietary Index

PUFA	Polyunsaturated Fatty Acids
RTEBC	Ready-To-Eat Breakfast Cereals
SACN	The Scientific Advisory Committee on Nutrition
SPSS	Statistics Package for Social Sciences
UCC	University College Cork
UCD	University College Dublin
WISP-DES©	Weighed Intake Software Package Data Entry System
WCRF	World Cancer Research Fund
WHO	World Health Organisation

Chapter 1

Literature review part I

Plant-based diets: a review of the definitions and nutritional role of plant-based diets in the adult diet

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

Introduction

The consumption of a plant-based (PB) diet has been associated with a reduced risk of type 2 diabetes, cardiovascular disease and other cardiometabolic risk factors, some cancers and all-cause mortality (Dinu *et al.*, 2017; Chiavaroli *et al.*, 2018a; Toumpanakis *et al.*, 2018; Qian *et al.*, 2019; Rees *et al.*, 2019). A recent report from the Eat-Lancet Commission recommends a global shift towards PB diets, emphasising an increased intake of PB foods such as fruit, vegetables, whole grains, legumes and nuts and a reduced intake of animal-derived foods, for both health and environmental sustainability (Willett *et al.*, 2019). While food-based dietary guidelines (FBDG) have traditionally provided guidance to consume PB foods, such as fruit, vegetables and starchy staples, particularly wholegrain cereals and potatoes, as the bulk of the diet, ongoing updates to FBDG globally are placing even more emphasis on PB foods (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Gonzalez Fischer and Garnett, 2016). Nonetheless, almost all countries still recommend the consumption of animal-derived foods, along with other food groups, in recognition of the important contribution of animal-derived foods towards providing high-biological value protein, bioavailable omega-3 and a range of micronutrients, including riboflavin, niacin, vitamin B6, vitamin B12, iron and zinc (Swanson *et al.*, 2012; Allen *et al.*, 2019; Herforth *et al.*, 2019; Cocking *et al.*, 2020).

The term ‘plant-based diet’ encompasses a wide spectrum of dietary patterns which emphasise plant products, such as fruit, vegetables, whole grains, legumes, nuts and seeds and PB alternatives and limit or exclude animal-derived products (Satija and Hu, 2018; Plant-Based Foods Association, 2019). However, there is huge variability in PB definitions between studies and as the popularity of PB diets grow, PB terminology is also evolving as PB diets are being described as ‘plant-centred’, ‘plant-predominant’, ‘plant-rich’, ‘plant-focused’, ‘plant-forward’ etc (Graça *et al.*, 2019; Katz, 2019; Rajaram *et al.*, 2019; Remde *et al.*, 2021).

In the Western world, media sources, consumer bodies and vegan and vegetarian societies are reporting a shift towards an increase in PB consumers (Alcorta *et al.*, 2021), however, data from national food consumption surveys continues to show that 98-99% of people in all population groups still consume meat (Bates *et al.*, 2011; Irish Universities Nutrition Alliance, 2011; Juan *et al.*, 2015). While these figures may not be reflective of other PB diets that include small amounts of meat and/or dairy, generally the number of PB diet consumers remains largely unknown and difficult to elucidate due to the large variation in definitions of PB diets.

It has been acknowledged that not all PB diets are necessarily healthy and yet few studies have differentiated between ‘healthful’ and ‘unhealthful’ PB diets (Satija *et al.*, 2016; Kim *et al.*, 2018). Furthermore, concerns remain regarding the nutritional adequacy of some restrictive PB diets, such as vegan diets with respect to some key micronutrients such as vitamin D and B12, which are only naturally occurring in animal-derived products (Bakaloudi *et al.*, 2020). Simultaneously, the global market for PB alternative foods and beverages is growing rapidly (Markets and Markets, 2021; Smart Protein, 2021) however, the dietary quality of ultra-processed PB alternative products is under scrutiny, with some studies showing that PB alternative foods may contain higher sodium and many do not contain key micronutrients, such as vitamins D, B12, iron or zinc, that would traditionally be found in their animal-source counterparts (Curtain and Grafenauer, 2019; Gehring *et al.*, 2020; Safefood, 2021; Wickramasinghe *et al.*, 2021).

While there is a general consensus that consuming a PB diet confers health and environmental benefits, there remains a significant challenge in understanding the nutritional role of PB diets due to the variations in definitions and the paucity of studies reporting nutrient intake from PB diets. This review aims to summarise the definitions of PB diets globally and to investigate the nutritional role of PB diets in adults.

Inclusion criteria

This review includes definitions of PB diets from peer-reviewed literature, position statements and vegan and vegetarian society websites. Furthermore, this review includes intervention or large observational studies of adults (≥18 years) that report nutrient intakes from those consuming a PB diet compared to a general omnivorous/baseline diet (Fagerland, 2012; European Food Safety Authority, 2014).

Plant-based definitions

Table 1 outlines the PB diet definitions identified in this review. Traditionally, PB diets referred to vegetarian diets, which include fruit, vegetables, grains, nuts, seeds and pulses but exclude animal-derived foods in different amounts (The Vegetarian Society UK, 2021). A lacto-vegetarian diet excludes meat, fish and eggs but includes dairy; an ovo-vegetarian diet excludes meat, fish and dairy, but includes eggs and a lacto-ovo vegetarian diet generally excludes meat and fish but includes dairy and eggs (Davey *et al.*, 2003; Newby, 2005; Ferdowsian and Barnard, 2009; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Barnard *et al.*, 2015; Corrin and Papadopoulos, 2016; Melina *et al.*, 2016; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Dinu *et al.*, 2017; Kahleova *et al.*, 2017; Patel *et al.*, 2017; Yokoyama *et al.*, 2017; Satija and Hu, 2018; Rocha *et al.*, 2019; Bowman, 2020). Veganism refers to a philosophy or way of life rooted in animal welfare, which seeks to exclude the use of animals for food, clothing and other purposes (The Vegan Society, 2021). In dietary terms, the vegan diet is the most extreme form of a vegetarian diet and excludes all foods and beverages wholly or partly derived from animals (Melina *et al.*, 2016; Rocha *et al.*, 2019; The Vegan Society, 2021). Iterations of a vegan diet are defined in the literature, such as a whole-food vegan diet (excludes processed foods); a whole-food low-fat vegan diet (excludes processed and high fat plant foods) and a raw food vegan diet (excludes all cooked food) (Trapp and Levin, 2012; Mishra *et al.*, 2013; Tuso *et al.*, 2013; Bunner *et al.*, 2015; Tuso *et al.*, 2015; Melina *et al.*, 2016; McMacken and Shah, 2017; Ostfeld, 2017; Wright *et al.*, 2017; Najjar *et al.*, 2018; Storz, 2018; Rocha *et al.*, 2019; Jakse *et al.*, 2020).

Other variations of vegetarian diets include the pescatarian diet, which is similar to a lacto-ovo vegetarian diet but additionally includes fish (Turner-McGrievy *et al.*, 2015; Corrin and Papadopoulos, 2016; Patel *et al.*, 2017; Yokoyama *et al.*, 2017; Satija and

Hu, 2018; Rocha *et al.*, 2019; Wozniak *et al.*, 2020). The flexitarian or semi-vegetarian diet is described as a primarily vegetarian diet but allows some animal food consumption, however, the amount and type of animal foods varies, from a specified amount of animal food per month to exclusion of red meat only but inclusion of poultry, fish and other animal foods (Newby, 2005; Ferdowsian and Barnard, 2009; Clarys *et al.*, 2014; Turner-McGrievy *et al.*, 2015; Corrin and Papadopoulos, 2016; Derbyshire, 2016; Harland and Garton, 2016; Yokoyama *et al.*, 2017; Satija and Hu, 2018; Hemler and Hu, 2019a; Rocha *et al.*, 2019).

Other primarily PB diets, associated with good health and sustainability, are now included within the PB literature. These diets are also high in fruit, vegetables, grains, nuts, seeds and pulses and encourage moderate (or no) intake of animal-derived foods but emphasise certain PB components. The Portfolio diet, originally developed to incorporate cholesterol-lowering foods into one diet, is a primarily vegetarian diet, but with specific proportions of 4 core PB components, i.e., 42g of nuts, 50g plant protein, 20g viscous soluble fibre and 2g plant sterols (Ferdowsian and Barnard, 2009; Chiavaroli *et al.*, 2018a; Chiavaroli *et al.*, 2019). The Mediterranean-style diet places an emphasis on olive oil, olives, nuts and moderate red wine consumption (Trichopoulou *et al.*, 2014; Nelson *et al.*, 2016; Rogerson *et al.*, 2018; Hemler and Hu, 2019a; Hemler and Hu, 2019b). The Dietary Approaches to Stop Hypertension (DASH) diet emphasises fat-free/low-fat dairy over full fat, and limits sodium and added sugar, which is quite similar to the Healthy US-Style diet (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Eichelmann *et al.*, 2016; Chiavaroli *et al.*, 2019; Hemler and Hu, 2019a; Hemler and Hu, 2019b). Both the DASH and Healthy US-style diet additionally promote protein sources other than red and processed meats, such as seafood, lean meats, poultry, eggs, soy products, nuts and seeds. The Planetary Health diet places an emphasis on limiting highly processed foods and the Nordic-style diet emphasises low-fat dairy, fish, fruit, berries, rye and local foods (Adamsson *et al.*, 2011; Kanerva *et al.*, 2014; Eichelmann *et al.*, 2016; Hemler and Hu, 2019a; Willett *et al.*, 2019).

As not all PB diets conform to one diet type, plant-based dietary indexes (PDIs) have recently been developed to measure adherence to a PB dietary pattern within an omnivorous population (Martínez-González *et al.*, 2014). PDIs are a type of dietary quality index which positively weight PB foods and negatively weight animal foods.

They offer an alternative to defining PB diets in terms of complete exclusion of some or all animal foods. While not all PB foods are necessarily 'healthy', some studies have differentiated between what the authors describe as 'healthy' and 'unhealthy' PB dietary patterns by positively weighting healthy PB foods (e.g. wholegrain cereal products) and negatively weighting low-quality PB foods (e.g. refined cereal products) however, what is included and excluded in the healthy plant-based dietary index (hPDI) and unhealthy plant-based dietary index (uPDI) varies between studies (Satija *et al.*, 2016; Chen *et al.*, 2018; Kim *et al.*, 2018).

While PDIs can help to make associations between adherence to a PB diet and health outcomes, they rarely provide information on nutrient contributions to the diet from the various components and so little is known about the impact of PB diets on nutritional quality. Therefore, this review also aimed to examine the nutritional role of PB diets in adults specifically investigating the intake of energy, macro- and micronutrients and compliance with current dietary recommendations when consuming a PB diet compared to an omnivorous diet.

The nutritional role of plant-based diets

Eleven observational and intervention studies comparing PB diets (raw vegan, vegan, lacto-vegetarian, lacto- and/ovo vegetarian, pescatarian, semi-vegetarian and Mediterranean) with omnivorous diets (meat-eater or baseline diets) met the eligibility criteria for this review and are described in **Table 2**. Hereafter, all variations of PB diets within these studies will be referred to collectively as PB diets and all comparative/baseline diets will be described as omnivorous. **Tables 3, 4 and 5** present the energy, macronutrients, dietary fibre and micronutrient intake data from these studies. All values are reported as mean intakes with the exception of one study, which reported medians, as outlined in the respective tables. Where energy in MJ and percentage energy (%E) of nutrients were not provided, this was calculated using standardised conversion factors for easier comparison between studies (The Royal Society, 1972). Micronutrient intakes are reported from the food component of the diet only (i.e., intakes from nutritional supplements are not included). Where retinol was presented as International Units (IU), this was converted using standardised conversions for easier comparison between studies (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015).

Energy and macronutrients

Data from both observational and intervention studies showed that the intake of energy from PB diets (regardless of type) (5-12MJ) was lower or similar than that of omnivorous diets (6-13MJ) (Davey *et al.*, 2003; Newby, 2005; Mishra *et al.*, 2013; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). While this may be expected due to the lower energy density of many staple plant foods, such as fruit, vegetables, legumes and whole grains, compared to animal-derived products, it may also be partly explained by the conscious lifestyle choice of many who consume PB diets (Bedford and Barr, 2005; Orlich *et al.*, 2013; De Backer and Hudders, 2014). With regard to protein intake, this review found that despite protein intake being lower or similar from PB diets (8-18% of total energy intake (%E)) compared to omnivorous diets (15-18%E) (Davey *et al.*, 2003; Newby, 2005; Mishra *et al.*, 2013; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020), protein intake from both PB and omnivorous diets met generally accepted population guidelines (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). In contrast, at an individual level, a study by Allès *et al.* (2017) found that 27% of vegans and 15% of vegetarians had intakes below the acceptable distribution intake range for total protein compared to 4% of omnivores and Sobiecki *et al.* (2016) reported that 8-16% of vegans and 6-10% of vegetarians had inadequate intakes for protein compared to 1-3% of meat-eaters. Since many PB diets lack the main sources of high biological value protein that are found in animal-derived products, protein intake from PB diets should be carefully considered to ensure that not only an adequate amount of protein is consumed, but that the variety of protein sources provides a full complement of essential amino acids (Mariotti and Gardner, 2019).

With regard to total fat intake, PB diets (19-38%E) provided a lower or similar amount of fat compared to omnivorous diets (31-42%E) (Davey *et al.*, 2003; Newby, 2005; Mishra *et al.*, 2013; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020) with studies generally showing that intake of total fat from both the PB and omnivorous diets was in line with widely accepted population recommendations for fat intake (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). Given that some of the key sources of saturated fat, (i.e., animal products) are restricted or eliminated from PB diets, it is not unexpected that intake of saturated fat from PB diets (4-14%E) was lower or similar compared to omnivorous diets (10-16%) (Davey *et al.*, 2003; Newby, 2005; Mishra *et al.*, 2013; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). A study by Sobiecki *et al.* (2016) investigating compliance to nutrient recommendations found that mean saturated fat intake from PB diets (7-9.5%E) met dietary recommendations from the UK Department of Health (DOH) of <10%E, while intake from omnivorous diets exceeded recommendations, however only by 0.4%E. However, it is important to acknowledge that intakes of saturated fat in most Western populations is considerably greater than 10%E and so the wider applications of this study should be interpreted with caution (Rippin *et al.*, 2017).

Studies in this review found that intake of monounsaturated fatty acids (MUFA) was lower or similar from PB diets (7-15%E) compared to omnivorous diets (11-14%E) (Newby, 2005; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). Regarding polyunsaturated fatty acids (PUFA) intakes, most studies reported a similar or higher intake of PUFA from PB diets (5-11%E) compared to omnivorous diets (5-9%E) (Davey *et al.*, 2003; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Rogerson *et al.*, 2018; Bowman, 2020), however two studies reported a lower intake of PUFA from PB diets (4-5%E) compared to omnivorous diets (4-8%E) (Newby, 2005; Najjar *et al.*, 2018). Regardless, studies investigating compliance to nutrient recommendations, found that PUFA intake from both PB and omnivorous diets met recommendations from the UK DOH and the Nordic Nutrition Recommendations (NNR) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). Intake of omega-3 and omega-6 was similar or higher from the PB diets (omega-3: 1-2g, omega-6: 7-15g), compared to omnivorous diets (omega-3: <1-2g, omega-6: 7-9g) (Allès *et al.*, 2017; Rogerson *et al.*, 2018) with the exception of Najjar *et al.* (2018) who reported a lower intake of omega-6 from a raw vegan diet (6g), compared to an omnivorous diet (19g) which may be explained by the exclusion of oils and PB fats from this diet. It should be noted that while the body can convert α-linolenic acid (ALA) from PB foods, such as nuts and seeds to omega-3, research suggests that the process is inefficient and that omega-3 from animal sources (i.e., oily fish) is more bioavailable (Saunders *et al.*, 2012; Swanson *et al.*, 2012; Lane *et al.*, 2014).

This review found that carbohydrate intake was similar or higher from PB diets (40-73%E) compared to omnivorous diets (39-51%E) (Davey *et al.*, 2003; Newby, 2005; Mishra *et al.*, 2013; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020) with studies showing that carbohydrate intake from PB diets met recommendations while carbohydrate intake in omnivorous diets was below recommendations from the UK Scientific Advisory Committee on Nutrition (SACN) and the NNR (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). Furthermore, at an individual level, a study by Allès *et al.* (2017) showed that 36% of meat-eaters had intakes below the acceptable distribution range for carbohydrates, compared to 16% of vegans and 23% of vegetarians. With regard to dietary sugars, those consuming PB diets had a similar or higher intake (22-27%E) of total sugars compared to omnivorous diets (20-23%E) (Clarys *et al.*, 2014; Sobiecki *et al.*, 2016; Allès *et al.*, 2017). No study reported free sugars intake and only Kristensen *et al.* (2015) provided an estimate of added sugar intake, where intake of added sugars in the PB diet was lower (3-4%E) than the omnivorous diet (8%E) (data not shown). However, the omnivorous diet in this study may not be representative of a typical adult diet in the Western world where intakes of added sugars are typically ~10%E (Walton *et al.*, 2021). Intake of dietary fibre was similar or higher from PB diets (20-56g) compared to omnivorous diets (17-27g) (Davey *et al.*, 2003; Newby, 2005; Mishra *et al.*, 2013; Bradbury *et al.*, 2014; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020) with studies showing that dietary fibre intake from PB diets (NSP 25-29g, dietary fibre 40-56g) met recommendations from the UK SACN and NNR, while intake from omnivorous diets (NSP 22g, dietary fibre 20-23g) did not (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). These findings may be expected due to the high dietary fibre content of PB foods such as fruit, vegetables, legumes and whole grains, compared to animal-derived products.

Micronutrients

Intake of vitamin A from PB diets (692-10016µg) was generally higher than omnivorous diets (627-2480µg), however two studies reported lower intakes from the PB diet (542-1098µg) compared to the omnivorous diet (929-1394µg) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). One study reported that retinol intakes from the PB diet were lower than the omnivorous diet which is not surprising given that animal-derived products are key sources of retinol (Davey *et al.*, 2003). Regardless, the prevalence of inadequate intakes of vitamin A is low with just 1-8% of those consuming PB diets and 1-3% of omnivores having inadequate intakes of vitamin A (Sobiecki *et al.*, 2016).

Vitamin D intake was lower or similar from PB diets (0-4µg) compared to omnivorous diets (2-5µg) (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020), which is not an unexpected finding, given that, natural dietary sources of vitamin D are limited to animal-derived products (with the exception of mushrooms grown under ultraviolet light). Kristensen *et al.* (2015) found that vitamin D intakes from the PB diet and the omnivorous diet were below national recommendations (NNR) which is not surprising given that low intakes of vitamin D are reported in populations globally (Kiely and Black, 2012; Cashman and Kiely, 2014). Even in non-vegetarians, supplementation is often recommended to ensure adequate intakes particularly in winter months (Amrein *et al.*, 2020; Cashman, 2020). Furthermore, foods fortified with vitamin D, e.g., ready-to-eat breakfast cereals or PB alternative foods may make a useful contribution to vitamin D (Kiely and Black, 2012; Buttriss and Lanham-New, 2020; Alcorta *et al.*, 2021).

Intake of vitamin E was similar or higher from PB diets (11-20mg) compared to omnivorous diets (7-12mg) (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018), partially explained by the presence of vitamin E in vegetable oils, nuts and green vegetables. Studies showed that intake of vitamin E from both PB diets and omnivorous diets did not meet recommendations from the US Institute of Medicine (IOM) and the NNR, however, one study found that vitamin E intake from the PB diet met population recommendations (NNR) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016).

Intake of vitamin C was similar or higher from PB diets (109-413mg) compared to omnivorous diets (88-167mg) (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018), but vitamin C intake from both PB and omnivorous diets met population recommendations nonetheless (UK DOH and NNR) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016).

Intakes of thiamin, folate and biotin were similar or higher from PB diets compared to omnivorous diets (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). Studies investigating compliance with recommendations found that intakes of thiamin and folate in both PB and omnivorous diets were in line with recommendations from the UK DOH for general population intake (however, for folate this is dependent on the dietary reference value used as recommendations vary between countries) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). Vitamin B6 intake was lower or similar from PB diets (1.4-2.3mg) in most studies, compared to omnivorous diets (1.7-2.6mg) (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Rogerson *et al.*, 2018; Bowman, 2020), which is expected as meat and fish are good sources of vitamin B6. However, vitamin B6 intake from the vegan diet according to Allès *et al.* (2017) and Kristensen *et al.* (2015) was similar or higher (1.8-2.5mg) compared to omnivorous diets (1.4-1.8mg). Regardless, intake of vitamin B6 from both PB and omnivorous diets met population recommendations from the UK DOH and the NNR (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). Intakes of other B vitamins, such as riboflavin, niacin and pantothenate, were lower or similar from PB diets compared to omnivorous diets (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). Studies investigating compliance with recommendations found that intakes of riboflavin and niacin from both PB and omnivorous diets met national population recommendations (UK DOH and NNR) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). Vitamin B12 intake was lower or similar from PB diets (0-6µg) compared to omnivorous diets (4-8µg) (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020), which is expected as vitamin B12 is naturally found in animal-derived products, including meat, fish eggs and dairy and not usually a constituent of PB foods (Institute of Medicine, 1998). Vitamin B12 intake from diets which included some animal-derived foods, including lacto-and/ovo vegetarian and pescatarian diets, as well as omnivorous diets met population recommendations, however, intake of vitamin B12 from the vegan diet did not meet population recommendations (UK DOH and NNR) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). As vegan foods do not naturally contain vitamin B12, the consumption of dietary supplements and/or fortified foods is required to maintain an adequate supply of vitamin B12 in the diet of vegans or those who significantly limit their intake of animal-derived foods (Rizzo *et al.*, 2016).

Generally, calcium intake from PB diets varied depending on the level of exclusion of dairy products (Davey *et al.*, 2003; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). For example, intake of calcium from vegan diets was lower or similar (566-885mg) compared to omnivorous diets (747-1199mg) (Davey *et al.*, 2003; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018), while intake of calcium from other PB diets which include dairy (i.e. vegetarian, pescatarian, semi-vegetarian and Mediterranean) was similar or higher (960-1470mg) compared to omnivorous diets (Davey *et al.*, 2003; Clarys *et al.*, 2014; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Rogerson *et al.*, 2018; Bowman, 2020). Kristensen *et al.* (2015) showed that intake of calcium from both the PB and omnivorous diet generally met population recommendations (NNR). However, Sobiecki *et al.* (2016) found that the prevalence of inadequate intake of calcium was notable in meat eaters (26-39%) but higher in vegans (52-64%).

Intake of iron from PB diets was similar or higher (13-23mg) compared to omnivorous diets (9-17mg) (Davey *et al.*, 2003; Clarys *et al.*, 2014; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020), which may be unexpected, however, a recent review has suggested that higher iron intakes from PB diets may be due to consumption of green leafy vegetables, beans, nuts and seeds which are highly consumed in PB diets (Bakaloudi *et al.*, 2020). While studies considered in this review found that iron intake from both PB and omnivorous diets met recommendations from the UK DOH and the NNR, it is important to acknowledge the bioavailability of haem iron compared to non-haem iron. The US IOM recommends an iron intake 1.8 times higher for vegetarians than that of omnivores due to the lower bioavailability of non-haem iron arising from PB foods compared with the haem iron from animal-derived sources (Trumbo *et al.*, 2001;

Sobiecki *et al.*, 2016). While lower ferritin levels have been reported in those consuming PB diets compared to omnivorous diets, a recent systematic review found that there is no difference in the prevalence of iron-deficiency between those following a PB diet and those following an omnivorous diet (Bakaloudi *et al.*, 2020).

Zinc intake was lower or similar from PB diets (7-11mg) compared to omnivorous diets (9-13mg) (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). Kristensen *et al.* (2015) showed that both PB and omnivorous diets met population recommendations (NNR). While Sobiecki *et al.* (2016) found that 4-27% of vegetarians and vegans had inadequate intake of zinc compared to 2-8% of meat-eaters, however when adjusted for bioavailability, 30-55% of vegetarians and 56-74% vegans had inadequate intake of zinc. Those consuming PB diets may have up to 50% higher requirements of zinc due to lower bioavailability of zinc-rich plant foods, which contain phytate, a zinc inhibitor, compared to animal-derived sources (Trumbo *et al.*, 2001; Allen *et al.*, 2019; Bakaloudi *et al.*, 2020).

Intake of iodine was generally lower or similar from PB diets (19-197µg) compared to omnivorous diets (145-213µg), which is as expected given key sources of iodine include fish, seafood, eggs and milk (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Rogerson *et al.*, 2018). One exception was a study by Allès *et al.* (2017), who reported higher iodine intakes in PB diets. A high consumption of PB drinks was observed among vegans (419g/d), which (if fortified with iodine) may explain this higher iodine intake (Allès *et al.*, 2017). However, studies comparing intakes to recommendations from the US IOM and NNR found that intakes from omnivorous diets generally met recommendations for iodine while intakes from PB diets did not, with approximately 30% of vegetarians and 93-94% of vegans estimated to have inadequate intakes of iodine (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016).

Intake of selenium was lower or similar from PB diets (25-66µg) compared to omnivorous diets (39-71µg) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Rogerson *et al.*, 2018). While animal-derived foods are a good source of selenium, the content of selenium in plant foods depends on the content of the soil in which it is grown and therefore varies significantly but is generally lower (Trumbo *et al.*, 2001). However, studies which compared intakes to recommendations from the

US IOM and NNR found that intakes from both the PB and omnivorous diets did meet recommendations (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016).

Those consuming PB diets had similar or higher intakes of magnesium compared to omnivorous diets and studies showed that magnesium intake from both diets met population recommendations (UK DOH and NNR) (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020). Few studies provided data on intakes of copper, manganese and phosphorous however, where available, intakes of copper and manganese were similar or higher and intake of phosphorous was lower or similar from PB diets compared to omnivorous diets (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020).

Potassium intake was generally similar or higher from PB diets (3063-5078mg) compared to omnivorous diets (2668-3965mg) (Davey *et al.*, 2003; Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016; Allès *et al.*, 2017; Najjar *et al.*, 2018; Rogerson *et al.*, 2018; Bowman, 2020), with the exception of two studies which showed a lower intake of potassium in vegetarian diets compared to omnivorous diets (Sobiecki *et al.*, 2016; Bowman, 2020). Nonetheless, studies found that potassium intake in both the PB and omnivorous diets met population recommendations (World Health Organisation and NNR) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016).

Sodium intake was lower or similar from PB diets (839-2701mg) compared to omnivorous diets (1569-4226mg) however, intake of sodium in both the PB and omnivorous diets exceeded population recommendations (UK DOH and NNR) (Kristensen *et al.*, 2015; Sobiecki *et al.*, 2016). This is not unexpected as it is widely reported that sodium intake worldwide is well in excess of recommendations (Brown *et al.*, 2009).

Conclusions

A global shift towards a more PB diet has been recommended for both health and environmental sustainability. This review aimed to summarise the definitions of PB diets globally and to investigate the nutritional role of PB diets in adults. This review found that there is a wide range of PB diet definitions in the literature including the traditional vegetarian diets, which exclude animal-derived foods in different amounts including lacto-vegetarian, ovo-vegetarian, lacto-ovo vegetarian, pescatarian and vegan. Furthermore, definitions have expanded to include semi-vegetarian/flexitarian diets which allow some animal-derived food consumption. Other diets (e.g. Portfolio, Mediterranean-style, DASH, Healthy US-style, Planetary Health and Nordic diets) are generally high in fruit, vegetables, legumes, whole grains, nuts & seeds, and place further emphasis on certain PB components, such as olive oil, olives, nuts and moderate red wine intake or specific proportions of PB components and encourage moderate (or no) intake of animal-derived foods. Plant-based dietary indexes (PDIs), which positively weight PB foods and negatively weight animal foods, have also been developed to measure adherence to a PB dietary pattern in an omnivorous diet, however, what is defined within each PDI varies.

Notwithstanding the variations in PB diet definitions, data from observational and intervention studies have shown that those consuming a PB diet have lower or similar intakes of energy, protein, total fat, saturated fat, MUFA and added sugar and higher or similar intakes of carbohydrate, PUFA (including omega-3 and omega-6), total sugars and dietary fibre than those consuming an omnivorous diet.

Those consuming a PB diet had lower or similar intakes of vitamin D, riboflavin, niacin, pantothenate, vitamin B6, vitamin B12, zinc, iodine, selenium, phosphorous and sodium and higher or similar intakes of vitamins A, E, C, thiamin, folate, biotin, iron, magnesium, copper, manganese and potassium than those consuming an omnivorous diet. Findings for calcium varied depending on the level of exclusion of dairy products with intakes from vegan diets being lower than other PB and omnivorous diets.

Overall, this review has highlighted that those consuming a PB diet are more likely to meet recommended intakes for carbohydrate, dietary fibre and vitamin E and are less likely to meet recommendations for protein, vitamin B12 and iodine compared to omnivores. Regardless of consumer type, both PB consumers and omnivores were noted to have low intakes of vitamin D and calcium and high intakes of sodium compared to recommendations.

While intakes of protein, omega 3, iron and zinc were generally sufficient from the PB diet, it is important to acknowledge the lower bioavailability of these nutrients from PB foods compared to animal-derived products. As dietary patterns shift towards a more PB diet there is a need for further studies to investigate the role of PB diets for nutritional adequacy and status in populations currently accustomed to consuming a primarily omnivorous diet.

Table 1. Definitions of plant-based diets

Plant-based diet	**Definition**
Vegetarian[1]	Includes: fruit, vegetables, grains, nuts, seeds, pulses ± dairy and/eggs Excludes meat & fish ± dairy and/eggs
Lacto-[2-7]	Includes: fruit, vegetables, grains, nuts, seeds, pulses & dairy Excludes: meat, fish & eggs
Ovo-[2,4,5,7,8]	Includes: fruit, vegetables, grains, nuts, seeds, pulses & eggs Excludes: meat, fish & dairy
Lacto-ovo-[2,3,5,7, 9-18]	Includes: fruit, vegetables, grains, nuts, seeds, pulses & dairy & eggs Excludes: meat & fish
Vegan[2,7,19]	Includes: fruit, vegetables, grains, nuts, seeds & pulses Excludes: all animal & animal-derived products
Whole-food vegan[2,20-23]	Includes: unprocessed fruit, vegetables, grains, nuts, seeds & pulses Excludes: all animal & animal-derived products & processed foods
Whole-food low-fat vegan[24-29]	Includes: unprocessed and low-fat fruit, vegetables, grains & pulses Excludes: all animal & animal-derived products & processed & high fat plant foods (oils, avocado, nuts etc.)
Raw vegan[2,7,27,30]	Includes: uncooked fruit, vegetables, grains, nuts, seeds & pulses Excludes: all animal & animal-derived products & cooked foods
Pescatarian (pescetarian, pesco-vegetarian, fish-eater)[2-5,7,8, 31,32]	Includes: fruit, vegetables, grains, nuts, seeds, pulses & fish, dairy & eggs Excludes: meat
Semi-vegetarian/flexitarian[3,5-8,12, 17, 32-35]	Includes: fruit, vegetables, grains, nuts, seeds, pulses & fish, dairy, eggs & meat (on some but not all days of the week) Excludes: restrictions on meat
Portfolio diet[2,36,37]	A primarily vegetarian diet with the inclusion of 4 core food components: 42g nuts (tree nuts or peanuts); 50g plant protein from soy products or dietary pulses such as beans, peas, chickpeas & lentils; 20g viscous soluble fibre from oats, barley, psyllium, eggplant, okra, apples, oranges, or berries; & 2g plant sterols initially provided in a plant sterol-enriched margarine
Mediterranean-style diet[35,38-40,42]	Moderate meat & dairy & emphasis on certain plant-based components, such as olive oil, olives, nuts & moderate red wine intake
Dietary Approaches to Stop Hypertension (DASH) diet[35,37,41]	Fat-free/low-fat dairy over full-fat dairy products. Poultry & fish in place of red & processed meats. Limited sugar-sweetened foods & beverages & sodium
Healthy US-style diet[35,42,43]	Based on recommendations from the USDA Dietary Guidelines for Americans. Moderate dairy, mostly low-fat or fat-free. Protein sources from seafood, lean meats, poultry, eggs, soy products, nuts & seeds. Limited saturated fats, sodium & added sugars
Planetary Health diet[35,44]	Moderate seafood, poultry & dairy (if included at all). Limit red meat, processed meat, added sugar, refined grains, starchy vegetables & highly processed foods
Nordic-style diet[41,45,46]	Rich in fruit & berries, vegetables, rye, low-fat dairy products & fish. Emphasis on local foods

[1]The Vegetarian Society UK (2021) [2]Rocha *et al.* (2019) [3]Satija and Hu (2018) [4]Patel *et al.* (2017) [5]Corrin and Papadopoulos (2016) [6]Newby (2005) [7]Melina *et al.* (2016) [8]Yokoyama *et al.* (2017) [9]Kahleova *et al.* (2017) [10]Dinu *et al.* (2017) [11]Barnard *et al.* (2015) [12]Ferdowsian and Barnard (2009) [13]Bowman (2020) [14]Allès *et al.* (2017) [15]Sobiecki *et al.* (2016) [16]Bradbury *et al.* (2014) [17]Clarys *et al.* (2014) [18]Davey *et al.* (2003) [19]The Vegan Society (2021) [20]Jakse *et al.* (2020) [21]Storz (2018) [22]Ostfeld (2017) [23]McMacken and Shah (2017) [24]Wright *et al.* (2017) [25]Bunner *et al.* (2015) [26]Tuso *et al.* (2015) [27]Tuso *et al.* (2013) [28]Mishra *et al.* (2013) [29]Trapp and Levin (2012) [30]Najjar *et al.* (2018) [31]Wozniak *et al.* (2020) [32]Turner-McGrievy *et al.* (2015) [33]Derbyshire (2016) [34]Harland and Garton (2016) [35]Hemler and Hu (2019a) [36]Chiavaroli *et al.* (2018b) [37]Chiavaroli *et al.* (2019) [38]Rogerson *et al.* (2018) [39]Nelson *et al.* (2016) [40]Trichopoulou *et al.* (2014) [41]Eichelmann *et al.* (2016) [42]Hemler and Hu (2019b) [43]U.S. Department of Health and Human Services and U.S. Department of Agriculture (2015) [44]Willett *et al.* (2019) [45]Adamsson *et al.* (2011) [46]Kanerva *et al.* (2014)

Table 2. Characteristics of studies comparing nutrient intakes from plant-based diets with omnivorous diets

Reference	Study type	Country	Study year(s)	Age (years)	No. of participants per diet group	Dietary assessment method	Diets compared
Bowman (2020)	Observational	USA	2013-2016	20+	Non-vegetarian (9389) Vegetarian (675)	24-hr recall	Non-vegetarian diet (non lacto-ovo) vs. vegetarian (lacto-ovo) diet*
Allès *et al.* (2017)	Observational	France	2009-2015	18-65+	Meat-eaters (90,664) Vegans (789) Vegetarians (2370)	3 x 24-hr recall	Meat-eater diet (non-vegetarian) vs. vegan and vegetarian (lacto-ovo) diets†
Sobiecki *et al.* (2016)	Observational	UK	2010	30-90	Meat-eaters (18244) Vegans (803) Vegetarians (6673) Fish-eaters (4531)	Semi-quantitative FFQ	Meat-eater diet (omnivorous) vs. vegan, vegetarian (lacto-and/ovo) and fish-eater (pescatarian) diets*
Kristensen *et al.* (2015)	Observational	Denmark	2013-2014 DANSDA: 2005-2008	18-61	Non-vegetarians (1257) Vegans (70)	4-day food diary	Non-vegetarian diet (DANSDA data excluding vegetarian and vegan diets) vs. vegan diet†
Bradbury *et al.* (2014)	Observational	UK	1993-2001	20-90	Meat-eaters (424) Vegans (422) Vegetarians (423) Fish-eaters (425)	FFQ	Meat-eater diet (omnivorous) vs. vegan, vegetarian (lacto-and/ovo) and fish-eater (pescatarian) diets*
Clarys *et al.* (2014)	Observational	Belgium	2012	20+	Omnivores (155) Vegan (104) Vegetarians (573) Semi-vegetarians (498) Pesco-vegetarians (145)	FFQ	Omnivorous diet vs. vegan, vegetarian (lacto-ovo), semi-vegetarian and pesco-vegetarian (pescatarian) diets*
Newby (2005)	Observational	Sweden	1987-1990	40+	Omnivores (54 257) Vegans (83) Lacto-vegetarians (159) Semi-vegetarians (960)	FFQ	Omnivorous diet vs. vegan, vegetarian (lacto) and semi-vegetarian (description is pescatarian) diets†
Davey *et al.* (2003)	Observational	UK	1993-2001	20-97	Meat-eaters (33883) Vegans (2596) Vegetarians (18840)	FFQ	Meat-eater diet vs. vegan, vegetarian (lacto-ovo) and fish-eater (pescatarian) diets*

					Fish-eaters (10110)		
Mishra *et al.* (2013)	Intervention	USA	Not stated	18+	Baseline (119) Low fat vegan (119)	2 x 24-hr recall	Baseline diet vs. low-fat vegan diet (same participants)
Najjar *et al.* (2018)	Intervention	USA	2017	32-69	Baseline (30) Raw vegan (30)	2 x 24-hr recall	Baseline diet vs. raw vegan diet vs. (same participants)
Rogerson *et al.* (2018)	Intervention	UK	Not stated	18-35	Baseline (12) Mediterranean diet (12) Baseline (12) Vegan diet (12)	3-day food diary	Baseline (omnivorous) diet vs. Mediterranean diet (same participants) and baseline (omnivorous) diet vs. vegan diet with B12 supplement (same participants)

DANSDA: The Danish National Survey of Dietary Habits and Physical Activity
*classified into consumer groups by the researcher based on participant self-reported intakes
†self-reported consumers

Table 3. Mean daily energy and macronutrient intakes from plant-based diets compared to omnivorous diets

Study	Energy (MJ)*	Protein (%E)*	Fat (%E)*	Saturated fat (%E)*	MUFA (%E)*	PUFA (%E)*	Omega-3 (g)	Omega-6 (g)	CHO (%E)*	Total sugars (%E)	Dietary fibre (g)
Bowman (2020)											
Non-vegetarian	9.0	15.8	35.6	11.7	12.4	8.5	-	-	43.5	-	17.0
Lacto-ovo vegetarian	7.6 ↓	12.0	34.3	10.9	12.1	8.0	-	-	49.5	-	20.0
Allès *et al.* (2017)											
Meat-eater	7.9	17.6	39.0	15.6	14.0	4.5	1.3	9.2	43.3	20.4	19.5
Vegan	7.9	12.8 ↓	35.0	9.6	14.8	7.1	1.7	15.0 ↑	51.2	23.6	34.1 ↑
Lacto-ovo vegetarian	7.6	14.2 ↓	38.0	14.2	14.9	5.4	1.5	11.2 ↑	47.3	22.5	25.9 ↑
Sobiecki *et al.* (2016)											
Meat-eater	8.7	17.2	31.3	10.4	-	7.1	-	-	48.0	23.2	21.7†
Vegan	8.1 ↓	13.1 ↓	30.5 ↓	6.9 ↓	-	10.3 ↑	-	-	54.0 ↑	23.7	28.9† ↑
Lacto-&/ovo- vegetarian	8.4 ↓	14 ↓	30.0 ↓	9.5 ↓	-	7.8 ↑	-	-	52.8 ↑	24.5 ↑	25.6† ↑
Pescatarian	8.5 ↓	15.5 ↓	30.3 ↓	9.4 ↓	-	7.9 ↑	-	-	50.7 ↑	24.0 ↑	24.9† ↑
Kristensen *et al.* (2015)‡											
Omnivorous	10.6 (m) 8.0 (f)	15.0 (m) 14.9 (f)	36.6 (m) 34.9 (f)	15.0 (m) 14.4 (f)	12.9 (m) 12.0 (f)	5.2 (m) 5.1 (f)	-	-	43.3 (m) 46.1 (f)	-	23.0 (m) 20.0 (f)
Vegan	11.7 (m↑) 8.7 (f)	10.9 (m↓) 11.6 (f↓)	27.9 (m↓) 28.4 (f↓)	5.4 (m↓) 5.6 (f↓)	8.2 (m↓) 9.4 (f↓)	8.2 (m↑) 8.1 (f↑)	-	-	45.3 (m) 41.0 (f↓)	-	56.0 (m↑) 40.0 (f↑)
Bradbury *et al.* (2014)											
Meat-eater	8.1	16.0 (m) 17.0 (f)	32.0 (m) 31.0 (f)	12.0 (m) 11.0 (f)	11.0 (m) 11.0 (f)	6.0 (m) 6.0 (f)	-	-	48.0 (m) 49.0 (f)	-	19.0 (m) 20.0 (f)
Vegan	7.1	13.0 (m) 13.0 (f)	29.0 (m) 29.0 (f)	6.0 (m) 7.0 (f)	10.0 (m) 10.0 (f)	10.0 (m) 10.0 (f)	-	-	54.0 (m) 55.0 (f)	-	27.0 (m) 26.0 (f)
Lacto-&/ovo- vegetarian	8.0	13.0 (m) 14.0 (f)	31.0 (m) 30.0 (f)	11.0 (m) 10.0 (f)	10.0 (m) 10.0 (f)	7.0 (m) 7.0 (f)	-	-	51.0 (m) 53.0 (f)	-	23.0 (m) 23.0 (f)
Fish-eater	7.6	14.0 (m) 15.0 (f)	31.0 (m) 30.0 (f)	11.0 (m) 10.0 (f)	10.0 (m) 10.0 (f)	7.0 (m) 7.0 (f)	-	-	50.0 (m) 52.0 (f)	-	23.0 (m) 22.0 (f)
Clarys *et al.* (2014)											
Omnivorous	12.5	15.0	36.0	16.0	13.9	6.6	-	-	44.0	21.0	27.0
Vegan	10.0 ↓	14.0 ↓	25.0 ↓	8.0 ↓	7.2 ↓	10.6 ↑	-	-	57.0 ↑	27.0 ↑	41.0 ↑
Lacto-ovo vegetarian	11.4 ↓	14.0 ↓	31.0 ↓	13.0 ↓	10.2 ↓	7.9	-	-	51.0 ↑	24.0 ↑	34.0 ↑
Pescatarian	11.5	15.0	32.0 ↓	14.0 ↓	10.5 ↓	7.9	-	-	49.0 ↑	23.0	33.0 ↑
Semi-vegetarian	11.9	15.0	33.0 ↓	14.0 ↓	11.4	7.9	-	-	48.0 ↑	22.0 ↑	34.0 ↑
Newby (2005)											
Omnivorous	5.8	16.3	30.7	13.0	11.2	4.4	-	-	50.9	-	17.0
Vegan	4.8 ↓	12.4 ↓	23.0 ↓	9.0 ↓	8.1 ↓	4.1	-	-	62.7 ↑	-	23.0 ↑

Lacto-vegetarian	5.1 ↓	13.5 ↓	25.2 ↓	11.1 ↓	8.4 ↓	3.7 ↓	-	-	59.8 ↑	-	22.4 ↑
Pescatarian	5.2 ↓	14.7 ↓	26.0 ↓	11.4 ↓	8.8 ↓	3.9 ↓	-	-	57.3 ↑	-	20.9 ↑
Davey *et al.* (2003)											
Meat-eater	9.2 (m)	16.0 (m)	31.9 (m)	10.7 (m)	-	5.2 (m)	-	-	46.9 (m)	-	18.7 (m)
	8.0 (f)	17.3 (f)	31.5 (f)	10.4 (f)		5.2 (f)			48.3 (f)		18.9 (f)†
Vegan	8.0 (m)	12.9 (m)	28.2 (m)	5.0 (m)	-	7.5 (m)	-	-	54.9 (m)	-	27.7 (m)
	7.0 (f)	13.5 (f)	27.8 (f)	5.1 (f)		7.2 (f)			56.1 (f)		26.4 (f)†
Lacto-&/ovo- vegetarian	8.8 (m)	13.1 (m)	31.1 (m)	9.4 (m)	-	5.7 (m)	-	-	51.2 (m)	-	22.7 (m)
	7.6 (f)	13.8 (f)	30.4 (f)	9.3 (f)		5.3 (f)			52.9 (f)		21.8 (f)†
Pescatarian	8.9 (m)	13.9 (m)	31.1 (m)	9.4 (m)	-	5.6 (m)	-	-	49.8 (m)	-	22.1 (m)
	7.8 (f)	14.9 (f)	30.7 (f)	9.3 (f)		5.4 (f)			51.2 (f)		21.8 (f)†
Mishra *et al.* (2013)											
Baseline	7.9	15.7	35.1	11.3	-	-	-	-	50.1	-	19.3
Low-fat vegan	6.8 ↓	14.6 ↓	31 ↓	8.5 ↓	-	-	-	-	56.6 ↑	-	22.9 ↑
Najjar *et al.* (2018)											
Baseline	8.6	16.5	36.4	11.6	13.2	8.4	2.1	18.5	46.3	-	20.4
Raw vegan	5.7 ↓	7.5 ↓	19.0 ↓	3.8 ↓	7.0 ↓	5.4 ↓	2.1	6.0 ↓	72.6 ↑	-	51.0 ↑
Rogerson *et al.* (2018)											
Baseline (vegan arm)	8.7	16.4	41.5	16.3	13.3	5.8	0.8	6.5	39.3	-	20.5
Vegan	7.6	12.6 ↓	36.6 ↓	7.2 ↓	14.8	8.9	1.5	13.5	47.6	-	37.7 ↑
Baseline (Mediterranean arm)	8.7	15.9	38.0	13.2	13.0	5.8	1.4	7.4	39.7	-	20.1
Mediterranean	7.8	17.6	35.6 ↓	9.6 ↓	15.4	7.2	1.4	6.8	40.0	-	26.9 ↑

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; CHO=carbohydrate; - indicates no data available; m=males f=females

All values are reported as mean intakes, except for where ‡ (median) is present *Where energy in MJ and percentage energy (%E) of nutrients were not provided, this was calculated using standardised conversion factors (The Royal Society, 1972)

†Non-starch polysaccharide (NSP) reported

↑↓ indicates significantly higher or lower in plant-based diet. Arrows within () indicate a significant difference within males or females only

Table 4. Mean daily vitamin intakes in plant-based diets compared to omnivorous diets

Study	Vitamin A (µg)	Vitamin D (µg)	Vitamin E (mg)	Vitamin C (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Pantothenate (mg)	Vitamin B6 (mg)	Biotin (µg)	Folate (µg)	Vitamin B12 (µg)
Bowman (2020)												
Non-vegetarian	629	4.8	-	-	-	-	-	-	2.2	-	-	5.1
Lacto-ovo vegetarian	692	4.0 ↓	-	-	-	-	-	-	1.8 ↓	-	-	3.5 ↓
Allès *et al.* (2017)												
Meat-eater	1049	2.7	11.3	117	1.2	1.8	19.1	5.3	1.8		327	5.3
Vegan	1361 ↑	1.9 ↓	17.6 ↑	165 ↑	1.6 ↑	1.7 ↓	18.2 ↓	5.3	2.3 ↑	-	481↑	2.7 ↓
Lacto-ovo vegetarian	1163	2.4 ↓	14.3 ↑	131 ↑	1.2	1.7	16.1 ↓	5.1 ↓	1.8	-	394 ↑	3.6 ↓
Sobiecki *et al.* (2016)												
Meat-eater	1394	3.8	12.1	167	1.9	2.4	25.1	-	2.6		413	7.9
Vegan	1083 ↓	1.8 ↓	16.3 ↑	190 ↑	2.3 ↑	1.8 ↓	21.5 ↓	-	2.4 ↓	-	504 ↑	0.8 ↓
Lacto-&/ovo- vegetarian	1085 ↓	2.0 ↓	13.6 ↑	174 ↑	2.0 ↑	2.3 ↓	19.1 ↓	-	2.4 ↓	-	452 ↑	3.1 ↓
Pescatarian	1098 ↓	3.7 ↓	13.5 ↑	174 ↑	2.0 ↑	2.3 ↓	21.4 ↓	-	2.5 ↓	-	446 ↑	6.4 ↓
Kristensen *et al.* (2015)*												
Omnivorous	1240 (m)	2.9 (m)	7.9 (m)	100 (m)	1.5 (m)	1.9 (m)	37.4 (m)	-	1.7 (m)		339 (m)	6.1 (m)
	929 (f)	2.2 (f)	7.1 (f)	110 (f)	1.1 (f)	1.5 (f)	26.8 (f)		1.4 (f)		308 (f)	4.2 (f)
Vegan	592 (m↓)	0 (m↓)	19.6 (m↑)	221 (m↑)	2.1 (m↑)	1.2 (m↓)	21.3 (m↓)	-	2.5 (m↑)	-	628 (m↑)	0 (m↓)
	542 (f↓)	0 (f↓)	15.3 (f↑)	221 (f↑)	1.5 (f↑)	1.0 (f↓)	17.5 (f↓)		1.9 (f↑)		578 (f↑)	0 (f↓)
Davey *et al.* (2003)												
Meat-eater	740 (m)†	3.4 (m)	11.8 (m)	119 (m)	1.7 (m) 1.7	2.3 (m)	24.7 (m)	-	2.3 (m)	-	329 (m)	7.4 (m)
	654 (f)†	3.3 (f)	10.7 (f)	138 (f)	(f)	2.2 (f)	23.2 (f)		2.2 (f)		321 (f)	7.0 (f)
Vegan	74.2 (m)†	0.9 (m)	16.1 (m)	155 (m)	2.3 (m)	2.3 (m)	23.9 (m)	-	2.2 (m)	-	431 (m)	0.4 (m)
	76.6 (f)†	0.9 (f)	14.0 (f)	169 (f)	2.1 (f)	2.1 (f)	21.1 (f)		2.1 (f)		412 (f)	0.5 (f)
Lacto-&/ovo- vegetarian	306 (m)†	1.6 (m)	13.7 (m)	123 (m)	1.9 (m)	2.2 (m)	20.8 (m)	-	2.0 (m)	-	367 (m)	2.6 (m)
	277 (f)†	1.5 (f)	11.6 (f)	147 (f)	1.8 (f)	2.1 (f)	18.3 (f)		1.9 (f)		350 (f)	2.5 (f)
Pescatarian	337 (m)†	2.9 (m)	13.0 (m)	130 (m)	1.8 (m)	2.2 (m)	21.7 (m)	-	2.1 (m)	-	358 (m)	5.0 (m)
	308 (f)	2.8 (f)	11.4 (f)	147 (f)	1.7 (f)	2.1 (f)	19.5 (f)		2.0 (f)		346 (f)	4.9 (f)
Najjar *et al.* (2018)												
Baseline	2480‡	4.0	9.9	88.0	-	-	-	-	-	-	298	4.0
Raw vegan	10016‡ ↑	0.3	10.6	413 ↑	-	-	-	-	-	-	741 ↑	0.3 ↓
Rogerson *et al.* (2018)												
Baseline (vegan arm)	799	2.4	9.7	107	1.5	1.7	32.0	5.5	1.7	34.0	223	4.9
Vegan	1123	2.0	11.6	109	1.6	1.1 ↓	23.0	3.5	1.4	41.0	272	0.9 ↓
Baseline (Mediterranean arm)	627	3.4	10.1	99.0	1.5	1.6	40.2	5.6	1.8	34.0	278	4.6
Mediterranean	1054 ↑	4.3	10.7	116	2.2 ↑	1.7	47.9	6.3	2.3	36.0 ↑	295	5.0

†retinol; ‡converted to µg from IU using standardised conversions EFSA Panel on Dietetic Products Nutrition and Allergies (2015). All values are reported as mean intakes, except for where * (median) is present ↑↓ indicates significantly higher or lower in plant-based diet. Arrows within () indicate a significant difference within males or females only

Table 5. Mean daily mineral intakes in plant-based diets compared to omnivorous diets

Study	Calcium (mg)	Iron (mg)	Magnesium (mg)	Zinc (mg)	Copper (mg)	Iodine (µg)	Manganese (mg)	Selenium (µg)	Phosphorous (mg)	Potassium (mg)	Sodium (mg)
Bowman (2020)											
Non-vegetarian	956	14.3	305	11.4	-	-	-	-	1408	2668	3615
Lacto-ovo vegetarian	975	13.9	315	8.7 ↓	-	-	-	-	1177 ↓	2343 ↓	2426 ↓
Allès *et al.* (2017)											
Meat-eater	924	13.4	336	10.9	1.7	180	4.1	70.5	1276	2997	2719
Vegan	760 ↓	18.6 ↑	495↑	10.0 ↓	2.5 ↑	248 ↑	7.7 ↑	64.1 ↓	1250	3676 ↑	2590 ↓
Lacto-ovo vegetarian	960 ↑	15.4 ↑	408 ↑	9.9 ↓	2.0 ↑	223 ↑	6.0 ↑	64.5 ↓	1258	3139 ↑	2480 ↓
Sobiecki *et al.* (2016)											
Meat-eater	1083	16.3	390	10.5	1.6	212	-	66.3	-	4158	2624
Vegan	848 ↓	18.3 ↑	470 ↑	8.7 ↓	2.1 ↑	58.5 ↓	-	54.9 ↓	-	4115	2645
Lacto-&/ovo- vegetarian	1117 ↑	16.7 ↑	419 ↑	10.3 ↓	1.7 ↑	148 ↓		47.2 ↓	-	4013 ↓	2631
Pescatarian	1131 ↑	16.7 ↑	421 ↑	10.2 ↓	1.7 ↑	197 ↓	-	65.5	-	4140	2701
Kristensen *et al.* (2015)*											
Omnivorous	1154 (m) 1054 (f)	12.0 (m) 9.3 (f)	412 (m) 332 (f)	13.0 (m) 9.6 (f)	-	213 (m) 178 (f)	-	52.0 m) 39.0 (f)	1686 (m) 1297 (f)	3871 (m) 3183 (f)	4226 m) 3020 (f)
Vegan	885 (m↓) 724 (f↓)	18.5 (m↑) 13.5 (f↑)	645 (m↑) 484 (f↑)	10.5 (m↓) 8.6 (f↓)	-	64.0 (m↓) 65.0 (f↓)	-	33.0 (m↓) 25.0 (f↓)	1555 (m↓) 1249 (f↓)	4274 (m↑) 3602 (f↑)	2068 (m↓) 1589 (f↓)
Clarys *et al.* (2014)											
Omnivorous	1199	17.0	-	-	-	-	-	-	-	-	3296
Vegan	738 ↓	23.0 ↑	-	-	-	-	-	-	-	-	1316 ↓
Lacto-ovo vegetarian	1465 ↑	20.0 ↑	-	-	-	-	-	-	-	-	2228 ↓
Pescatarian	1470	20.0	-	-	-	-	-	-	-	-	2371
Semi-vegetarian	1470	20.0	-	-	-	-	-	-	-	-	2679
Davey *et al.* (2003)											
Meat-eater	1057 (m) 989 (f)	13.4 (m) 12.6 (f)	366 (m) 341 (f)	9.8 (m) 9.2 (f)	-	-	-	-	-	3965 (m) 3839 (f)	-

Vegan	610 (m) 582 (f)	15.3 (m) 14.1 (f)	440 (m) 391 (f)	8.0 (m) 7.2 (f)	-	-	-	-	-	4029 (m) 3817 (f)	-
Lacto-&/ovo- vegetarian	1087 (m) 1012 (f)	13.9 (m) 12.6 (f)	396 (m) 352 (f)	8.4 (m) 7.7 (f)	-	-	-	-	-	3867 (m) 3656 (f)	-
Pescatarian	1081 (m) 1021 (f)	14.0 (m) 12.8 (f)	396 (m) 358 (f)	8.6 (m) 7.9 (f)	-	-	-	-	-	3940 (m) 3759 (f)	-
Najjar *et al.* (2018)											
Baseline	796	15.4	288	12.2	-	-	-	-	-	2668	3730
Raw vegan	566 ↓	15.3	488 ↑	7.8 ↓	-	-	-	-	-	5078 ↑	839↓
Rogerson *et al.* (2018)											
Baseline (vegan arm)	988	9.7	284	9.2	1.1	169	3.6	50.2	1368	2796	2092
Vegan	669	13.5 ↑	375 ↑	7.0	1.9 ↑	19.1 ↓	5.8 ↑	38.1	1020 ↓	3063	1161 ↓
Baseline (Mediterranean arm)	747	12.1	423	8.5	1.3	145	3.2	52.6	1337	3151	1569
Mediterranean	836	13.6 ↑	412	9.3	1.6	131	3.8 ↑	65.7	1292	3142	2146

All values are reported as mean intakes, except for where * (median) is present ↑↓ indicates significantly higher or lower in plant-based diet. Arrows within () indicate a significant difference within males or females only

Chapter 1

Literature review part II

Dietary guidance for, consumption patterns of and contributions of plant-based foods in adults in the WHO European region

Introduction

Plant foods, such as fruit & vegetables (including legumes), cereals, grains & potatoes (particularly whole grains) and nuts & seeds are at the core of any plant-based (PB) diet (Kent *et al.*, 2022). Health organisations remain steadfast in their recommendations to consume fruit, vegetables and whole grains and recently, even more emphasis is being placed on these foods as diets shift towards the consumption of a more PB diet for health and environmental sustainability (World Health Organisation, 2005; World Health Organisation, 2014; Gonzalez Fischer and Garnett, 2016; World Cancer Research Fund/American Institute for Cancer Research, 2018; Kent *et al.*, 2022).

Part I of this literature review examined the definitions and the nutritional role of PB diets in adults and part II aims to examine the available literature on PB foods including fruit & vegetables and cereals, grains & potatoes in adults in countries within the World Health Organisation (WHO) European region, with respect to dietary guidance, consumption patterns and their contribution to energy and nutrient intakes.

Inclusion criteria

This review included data on dietary guidelines for fruit & vegetables, and cereals, grains & potatoes consumption from the most recent food-based dietary guidelines (FBDG) of countries within the WHO European region, which were published (or part-published) in English in peer-reviewed journal articles or governmental websites. Additionally, this review included data on actual intakes of these food groups and the contribution of these food groups to nutrient intakes in adults in countries within the WHO European region, from nationally representative dietary surveys collected via food records or 24-hour recalls, published as reports, online web pages or peer-reviewed journal articles, in English and post the year-2000.

Fruit & vegetables

The fruit of a plant is the edible, pulpy, seeded tissue that typically has a sweet (apples, oranges, pears, blueberries) or tart (lemons, limes, cranberries) taste. Vegetables are defined as the edible parts of plants, such as stems and stalks (celery), roots (carrots), tubers (potatoes), bulbs (onions), leaves (lettuce), flowers (broccoli) and some fruit (tomatoes, cucumber, pumpkin, avocado, olives). Mushrooms (fungi), pulses (the edible seeds from a legume plant) (beans, peas, lentils) and sweetcorn (a cereal grain) are usually, but not always included in this definition. The term vegetable excludes other cereal grains, nuts, peanuts (a type of pulse) and other fruit (International Agency for Research on Cancer, 2003; Pennington and Fisher, 2009). Fruit is often consumed as a snack, dessert, beverage, or as part of a composite (mixed) dish, while vegetables are usually consumed as salads, cooked side dishes or as part of a composite dish. Both can generally be consumed raw or cooked (International Agency for Research on Cancer, 2003; Pennington and Fisher, 2009).

Fruit & vegetables are nutrient-dense, supplying dietary fibre, vitamins and minerals to the diet and are sources of phytochemicals that function as anti-oxidants, phytoestrogens and anti-inflammatory agents and therefore hold an important place in FBDG for all population groups including adults (Slavin and Lloyd, 2012; Department of Health, 2016; Herforth *et al.*, 2019; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020). Evidence consistently shows a positive association between fruit & vegetable intake and the reduced risk of non-communicable diseases, such as cardiovascular disease and stroke, cancer and diabetes as well as with the prevention and alleviation of micronutrient deficiencies, such as vitamins A and C, particularly in developing countries (World Health Organisation, 2002; World Health Organisation/Food and Agriculture Organisation, 2003; World Cancer Research Fund/American Institute for Cancer Research, 2018).

This section of the review aimed to examine the dietary guidelines for fruit & vegetable consumption in the WHO European region and to examine the available data on current fruit & vegetable consumption in adults across the WHO European region to understand intakes and classifications of fruit & vegetables compared to recommendations, as well as the contributions of this food group to nutrient intakes.

Guidelines for fruit & vegetable consumption in the WHO European region

Guidelines for fruit & vegetables consumption for the general population, including adults in countries within the WHO European region are outlined in **Table 1**. The WHO recommend the consumption of a minimum of 400g/day of fruit & vegetables (excluding potatoes and other starchy tubers) for the general population and all countries reviewed (Norway, Denmark, Sweden, the UK, Ireland, Albania, Greece, Bulgaria, Finland, Germany, Malta, the Netherlands, Switzerland, Turkey, Austria, Georgia and Slovakia) have recommendations in line with this guideline as part of their FBDG, with some countries recommending higher intakes, such as 500g in Sweden and Finland, 600g in Denmark, 650g in Germany and 700-900g in Georgia (Ministry of Labor Health and Social Affairs, 2005; World Health Organisation, 2005; National Center of Public Health Protection (NCPHP), 2006; Department of Public Health, 2008; Ministry of Health and the National Nutrition Commission, 2010; Swiss Society for Nutrition, 2011; Finnish Food Authority, 2014; Institute of Preventive Environmental & Occupational Medicine (Prolepsis), 2014; Health Council of the Netherlands, 2015; Health Promotion and Disease Prevention Directorate, 2015; Swedish Food Agency, 2015; Department of Health, 2016; Ministry of Health (Turkey), 2016; Norwegian Directorate of Health, 2016; Public Health Authority of the Slovac Republic, 2016; Public Health England, 2016; German Nutrition Society, 2017; Ministry of Food Agriculture & Fisheries, 2022).

While there is some variation in the quantities recommended for fruit & vegetable consumption across FBDG in countries within the WHO European region, there are also differences with regards to the inclusion and exclusion of individual components of the fruit & vegetable group within these guidelines. Examples of these include the inclusion/exclusion of and limits for fruit juice, dried fruit, legumes, potatoes, nuts and tinned fruit or vegetables within country-specific guidelines (**Table 2**).

For fruit and/or vegetable juice, the majority of countries (Albania, Austria, Bulgaria, Denmark, Finland, Greece, Georgia, Ireland, Malta, the Netherlands, Turkey, the UK and Switzerland) include juice of varying quantities (100ml, 125ml, 150ml, 180ml, 200ml, no specific recommendations) in their FBDG and of these, Albania, Austria, Denmark, Greece, Ireland, Malta and the UK limit fruit juice intake to one portion (Ministry of Labor Health and Social Affairs, 2005; National Center of Public Health Protection (NCPHP), 2006; Department of Public Health, 2008; Austrian Ministry of Health and the National Nutrition Commission, 2010; Swiss Society for Nutrition, 2011; Finnish Food Authority, 2014; Institute of Preventive Environmental & Occupational Medicine (Prolepsis), 2014; Health Council of the Netherlands, 2015; Health Promotion and Disease Prevention Directorate, 2015; Department of Health, 2016; Ministry of Health (Turkey), 2016; Public Health England, 2016; Ministry of Food Agriculture & Fisheries, 2022). No guidance was available regarding juice for Germany, Norway, Slovakia, and Sweden (Swedish Food Agency, 2015; Norwegian

Directorate of Health, 2016; Public Health Authority of the Slovac Republic, 2016; German Nutrition Society, 2017).

Dried fruit is included as a portion of fruit with varying quantities (1 ½ tbsp, 30g, no specific recommendation) in Bulgaria, Georgia, Greece, Ireland, Malta, the Netherlands, Turkey and the UK, but in Denmark, dried fruit, such as raisins do not count towards fruit & vegetable recommendations (Ministry of Labor Health and Social Affairs, 2005; National Center of Public Health Protection (NCPHP), 2006; Swiss Society for Nutrition, 2011; Institute of Preventive Environmental & Occupational Medicine (Prolepsis), 2014; Health Council of the Netherlands, 2015; Health Promotion and Disease Prevention Directorate, 2015; Department of Health, 2016; Ministry of Health (Turkey), 2016; Public Health England, 2016).

The majority of countries do not include legumes as part of their guideline for vegetable consumption, with the exceptions of Austria (150-200g cooked) and Finland and Sweden (no specific recommendations) (Austrian Ministry of Health and the National Nutrition Commission, 2010; Finnish Food Authority, 2014; Swedish Food Agency, 2015). No guidance was available regarding legumes for Germany and Slovakia (Public Health Authority of the Slovac Republic, 2016; German Nutrition Society, 2017). Unlike the majority of the countries within the WHO European region, potatoes are included in the recommendation for vegetables in Turkey (Ministry of Health (Turkey), 2016). In Germany, 25g of nuts can replace one serving of fruit, but no other country includes nuts as part of their guideline for fruit & vegetable consumption and no guidance was available for Georgia (Ministry of Labor Health and Social Affairs, 2005; German Nutrition Society, 2017). Tinned fruit or vegetables are included in the guidelines in Bulgaria, Denmark, Malta, the Netherlands, Norway and the UK, with no specific guidance provided for portion sizes, however in Malta, whole fresh fruit & vegetables are recommended over tinned (National Center of Public Health Protection (NCPHP), 2006; Health Council of the Netherlands, 2015; Health Promotion and Disease Prevention Directorate, 2015; Norwegian Directorate of Health, 2016; Public Health England, 2016; Ministry of Food Agriculture & Fisheries, 2022). Interestingly, Denmark do not include mushrooms as part of their guidelines for fruit & vegetable consumption, however, it is recognised that mushrooms can be part of a healthy plant-based diet (Lassen *et al.*, 2020; Ministry of Food Agriculture & Fisheries, 2022). In Bulgaria, the fruit & vegetables group includes pickles, nectars, compotes, marmalades and jams and while there are no specific portion size recommendations, it is suggested that these foods should be limited due to their salt and sugar content (National Center of Public Health Protection (NCPHP), 2006).

Fruit & vegetable intakes

The mean intake of fruit & vegetables (including juices) in adults from national dietary survey data in countries within the WHO European region are outlined in **Table 3** and ranged from 329-473g/d, with a higher intake of 756g/d reported in Germany. While classifications of fruit & vegetable intake in adults vary between countries, intakes can be broadly compared with the WHO guideline and for most countries, intakes are lower than the recommended minimum intake of 400g/d of fruit & vegetables daily (World Health Organisation, 2005). The mean intake of fruit & vegetables was lower than the 400g/d minimum recommendation in Belgium (329g/d), the Netherlands (336g/d), the UK (345g/d), Portugal (346g/d), Finland (390g/d) and Spain (393g/d), while the intake of fruit & vegetables in Denmark (445g/d), Italy (473g/d) and Germany (756g/d) were in line with the WHO recommendations, with the significantly higher intake in Germany attributable to a particularly high intake of fruit juice and nectars (265g/d) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Heuer *et al.*, 2015; Pedersen *et al.*, 2015; Lopes *et al.*, 2018; Bel *et al.*, 2019; Partearroyo *et al.*, 2019; Public Health England, 2020; van Rossum, 2020).

Contribution of fruit & vegetables to energy and nutrient intakes

The contribution of fruit & vegetables (including juices) to energy and nutrient intakes are reported for adults in Finland (25-64y), Italy (18-64.9y), Spain (18-64y), the Netherlands (19-79y) and the UK (19-64y) and are included with other population groups for Denmark (4-75y) and Portugal (3m-84y) (**Tables 4 & 5**). Fruit & vegetables contributed 8-13% of energy intake in adults in Denmark, Finland, Italy, Portugal, Spain, the Netherlands and the UK (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). In the available disaggregated data, fruit & fruit juices contributed the majority (5-8%) of energy intake and vegetables contributed 2-7% (Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Public Health England, 2020; van Rossum, 2020). Fruit & vegetables also contributed to intakes of protein (5-10%), total fat (3-

7%), saturated fat (1-5%), MUFA (1-9%) and PUFA (6-12%) in adults in countries within the WHO European region (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). Fruit & vegetables contributed 11-22% of carbohydrate intakes with fruit & fruit juices contributing the majority (7-14%) of carbohydrate intake compared to vegetables (3-11%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). Fruit & vegetables contributed 25-36% of total sugars intake in adults across countries, with the majority of contributions from fruit (16-24%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; van Rossum, 2020). Additionally, intakes from the available literature in adults showed that fruit juice contributed 2-7% of free sugars intake (Ruiz *et al.*, 2017; Lopes *et al.*, 2018; Public Health England, 2020). Fruit & vegetables contributed 27-51% of dietary fibre intake in adults, with vegetables contributing to the majority of dietary fibre intake from this group in Italy, Spain, the Netherlands and the UK (17-33%), while both fruit and vegetables contributed to similar proportions of dietary fibre in Denmark (18% each) (Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Public Health England, 2020; van Rossum, 2020).

Fruit & vegetables contributed three quarters or more of vitamin C intake in adults in Denmark (74%), Finland (76%), Spain (80%) and Italy (89%) and made lower but still significant contributions to vitamin C intake in Portugal (57%), the UK (54%) and the Netherlands (39%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; van Rossum, 2020). The lower contribution of 39% in the Netherlands may be due to the exclusion of juices when reporting nutrient contributions (van Rossum, 2020). Where disaggregated data were available, fruit & fruit juices contributed to 18-41% of vitamin C intake (8-12% from fruit juice), while vegetables contributed to 21-53% of vitamin C intake in adults (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; van Rossum, 2020). Fruit & vegetables contributed 20-41% of vitamin A intake in Denmark, Finland, Portugal, Spain, the Netherlands and the UK and contributed a higher proportion (58%) of vitamin A intake in adults in Italy. Vegetables contributed to the majority of these intakes (19-33%) in Denmark, Spain, the Netherlands and the

UK and contributed to 44% of vitamin A intake in Italy (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). The contribution of fruit & vegetables to vitamin E intake was 16-23% in Finland, Italy, Portugal, Spain, the Netherlands and the UK and significantly higher at 38% in Denmark. Vegetables (rather than fruit) made up the majority of the contribution to vitamin E intake in Italy, Spain and the UK (13-15%) and fruit made up the majority of the contribution in Denmark (23%) (no disaggregated data for Finland or Portugal), while there were equal contributions from 'fruit' and 'vegetables' in the Netherlands (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; van Rossum, 2020). For B vitamins, fruit & vegetables made significant contributions to intakes of folate (24-41%), thiamin (12-22%), riboflavin (8-20%), vitamin B6 (15-29%) and niacin (6-12%) in adults in countries within the WHO European region (Helldán *et al.*, 2013; Pedersen *et al.*, 2015; Partearroyo *et al.*, 2017; Lopes *et al.*, 2018; Mielgo-Ayuso *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

For mineral intakes in adults, fruit & vegetables contributed 21-37% of potassium intake, with similar contributions from fruit & fruit juices (9-16%) and vegetables (11-22%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). Fruit & vegetables contributed to 13-16% of iron intake in Denmark, Finland, Portugal, the Netherlands and the UK, but contributed to a higher proportion in Italy and Spain (25% each) and where disaggregated data were available, vegetables contributed to the majority of this intake (8-18%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017b; Samaniego-Vaesken *et al.*, 2017; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). For other minerals, fruit & vegetables contributed to intakes of magnesium (14-27%), calcium (8-17%), and zinc (7-14%) in adults in countries within the WHO European region (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017b; Olza *et al.*, 2017a; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

To summarise so far, fruit & vegetable intakes in adults in countries within the WHO European region (329-393g/d) are generally below the WHO recommendations of 400g of fruit & vegetables per day, with the exception of Denmark (445g/d), Italy

(473g/d) and Germany (756g/d). Fruit & vegetables contribute little to energy intake but make significant contributions to intakes of carbohydrate, total sugars, dietary fibre, vitamins (vitamin C, vitamin A, B vitamins) and minerals (potassium, iron and magnesium).

Cereals, grains & potatoes

Cereal crops are grasses, grown to produce cereal grains. The term 'grain' refers to the edible seeds of cereals, such as wheat, rice, corn (maize), oats, barley, rye, sorghum and millet, as well as pseudo-cereal grains, such as amaranth, buckwheat and quinoa, which are seeds from other plant species (non-grasses) but are nutritionally similar to 'true' grains and are prepared in similar ways (van der Kamp *et al.*, 2014; McSweeney and Day, 2016). The grain kernel consists of three distinct sections including bran, the fibre-rich outer layer; germ, the micronutrient-rich layer and endosperm, the starchy main body of the grain (van der Kamp *et al.*, 2014). Whole grain refers to the bran, germ and endosperm sections in the same proportions that were present in the kernel, either intact, ground, cracked or flaked although some small processing losses are allowed within this definition (European Food Information Council, 2011; van der Kamp *et al.*, 2021). A whole grain can refer to a food on its own, such as porridge oats, popcorn, brown rice, or it can be processed and used as an ingredient in a product, such as in breads, crackers, pasta and breakfast cereals (Miller, 2020).

The nutritional composition of grains varies considerably, depending on grain variety and environment, and additionally, the nutrient bioavailability of grains differs depending on processing methods (McKevith, 2004). Generally, grains contain mainly carbohydrates, but also consist of proteins, unsaturated fats, vitamin E, some B vitamins, and minerals such as iron, zinc, and magnesium (McKevith, 2004). Grains, especially whole grains are also an important source of dietary fibre and bioactive compounds like flavonoids and carotenoids, which together may be responsible for the health-promoting effects of wholegrain foods (McKevith, 2004; Carcea, 2020). Observational studies have linked greater intakes of whole grains with lower prevalence and risk of cardiovascular disease, type 2 diabetes and some cancers and all-cause mortality (Chen *et al.*, 2016; Miller, 2020). However, grains are often consumed as refined grains, i.e., grains which are stripped of their germ and bran layers along with associated dietary fibre and micronutrients and are therefore, not as nutrient-rich as their whole grain counterparts.

Potatoes are also a staple crop consumed worldwide and typically cereals, grains & potatoes are categorised together as starchy staples in FBDG (Herforth *et al.*, 2019; Devaux, 2020). Nutritionally, potatoes are a carbohydrate-rich food, similar to grains and are rich in several micronutrients, such as vitamin C, some B vitamins and the minerals potassium, phosphorus and magnesium (Food and Agriculture Organisation of the United Nations, 2008). Potatoes also contain dietary fibre (especially when skins are consumed), folate, pantothenate and riboflavin and are a moderate source of iron (Food and Agriculture Organisation of the United Nations, 2008). However, the overall nutritive value of potatoes and potato dishes depends on the cooking method, such as boiling versus frying, as well as other components of the dish, e.g., added fats, salt etc (Food and Agriculture Organisation of the United Nations, 2008).

This section of the review aimed to examine the dietary guidelines for cereals, grains & potato consumption in the WHO European region and to examine the available data on current consumption of cereals, grains & potatoes in adults within the WHO European region to understand intakes and classifications of cereals, grains & potatoes compared to recommendations, as well as the contributions of this food group to nutrient intakes.

Guidelines for cereals, grains & potato consumption in the WHO European region

The guidelines for the consumption of cereals, grains & potatoes for the general population, including adults, in countries within the WHO European region are outlined in **Table 6.** There is no global recommendation for the intake of cereals, grains & potatoes in adults and recommendations vary greatly across countries. Adult populations in Bulgaria and Germany are advised to consume 200-560g of cereals, grains & potatoes, while the advice in Georgia is to consume between 500-600g of cereals and grains with a separate guideline to consume an additional 200-300g of potatoes per day (Ministry of Labor Health and Social Affairs, 2005; National Center of Public Health Protection (NCPHP), 2006; German Nutrition Society, 2017). Other countries, such as Albania, Austria, Finland, Greece, Ireland, Malta, Switzerland and Turkey recommend the consumption of between 3-11 servings, portions or units of cereals, grains & potatoes per day (of varying quantities), while the UK and Slovakia do not provide quantitative guidance for the consumption for cereals, grains & potatoes (Department of Public Health, 2008; Austrian Ministry of Health and the National Nutrition Commission, 2010; Swiss Society for Nutrition, 2011; Finnish Food Authority, 2014; Institute of Preventive Environmental & Occupational Medicine (Prolepsis), 2014; Health Promotion and Disease Prevention Directorate, 2015; Department of Health, 2016; Ministry of Health (Turkey), 2016; Public Health Authority of the Slovac Republic, 2016; Public Health England, 2016). Most countries recommend the consumption of whole grains over refined cereal foods, which is in line with the WHO and the World Cancer Research Fund (WCRF) recommendations to consume whole grains for a healthy diet, to reduce the risk of non-communicable diseases (World Cancer Research Fund/American Institute for Cancer Research, 2018; World Health Organisation, 2020). However there is a lack of clear and consistent messaging around these recommendations, ranging from qualitative guidelines (e.g., choose whole grains) to quantitative recommendations in Norway, Denmark, Sweden and the Netherlands (at least 70-90g of wholegrain products) (Health Council of the Netherlands, 2015; Swedish Food Agency, 2015; Norwegian Directorate of Health, 2016; Ministry of Food Agriculture & Fisheries, 2022). Potatoes are typically categorised with cereals & grains in FBDG (with the exception of Turkey, where potatoes are included with fruit & vegetables) and while potatoes are generally recognised as being part of a healthy diet, Greece and Malta recommend limiting intake to ≤3 servings per week (Institute of Preventive Environmental & Occupational Medicine (Prolepsis), 2014; Health Promotion and Disease Prevention Directorate, 2015; Ministry of Health (Turkey), 2016).

Cereals, grains & potato intakes

The mean intake of cereals, grains & potatoes in adults in countries within the WHO European region range from 149-359g/d and are outlined in **Table 7**. The mean intake of cereals, grains & potatoes was reported for adults in Belgium (287g/d), Germany (318g/d), Italy (314g/d), Finland (359g/d), Portugal (311g/d), the Netherlands (276g/d) and the UK (328g/d) (Leclercq *et al.*, 2009; Helldán *et al.*, 2013; Heuer *et al.*, 2015; Lopes *et al.*, 2018; Bel *et al.*, 2019; Public Health England, 2019; van Rossum, 2020). The mean intake of cereals & grains (excluding potatoes) was reported for adults in Spain (149g/d), which is much lower than other countries due to the exclusion of potatoes from the estimation of intakes (Partearroyo *et al.*, 2019). The mean intake of brown and wholegrain cereal foods was reported in the UK (29g/d), Belgium (50g/d) and the Netherlands (93g/d) and was estimated to contribute 9%, 17% and 29% of the intake of total cereals, grains & potatoes, in the UK, Belgium and the Netherlands respectively (data not shown) (Bel *et al.*, 2019; Public Health England, 2019; van Rossum, 2020). These findings indicate that despite variations in the recommended consumption of cereals, grains & potatoes, intakes were broadly similar, between 276-359g/d (excluding Spain), for adults across the countries and intake of brown and wholegrain cereal foods was low.

Contribution of cereals, grains & potatoes to energy and nutrient intakes

Cereals, grains & potatoes are recognised as a source of energy, carbohydrate, protein, dietary fibre, vitamins and minerals in the diet (McKevith, 2004; Food and Agriculture Organisation of the United Nations, 2008) and the contribution of these food groups to energy and nutrient intakes are reported for adults in Finland (25-64y), Italy (18-64.9y), Spain (18-64y), the Netherlands (19-79y) and the UK (19-64y) and are included with other population groups for Denmark (4-75y) and Portugal (3m-84y) (**Table 8**). Cereals, grains & potatoes contributed to significant proportions of energy (26-40%) intake in adults across the countries (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). Furthermore they contributed to significant proportions of carbohydrate (43-53%) in adults in Denmark, Finland, Portugal, Spain, the Netherlands and the UK and to a higher proportion in Italy (71%) and to dietary fibre intake (40-60%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). Cereals, grains & potatoes contributed 17-30% of protein, 7-20% of total fat, 5-18% of saturated fat, 4-19% of MUFA and 15-23% of PUFA intake in adults in most countries (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). However, the contributions of cereals, grains & potatoes to total fat, saturated fat and MUFA intake were much higher in the UK (26%, 24% and 24% respectively), compared to other countries likely due to the inclusion of biscuits, buns, cakes, pastries, puddings, potato products and dishes in the 'cereals and cereal products' food group in the UK (Public Health England, 2020). Cereals, grains & potatoes also contributed 9-18% of the intake of total sugars (Helldán *et al.*, 2013; Sette *et al.*, 2013;

Ruiz *et al.*, 2016; Lopes *et al.*, 2018) and 7% of the intake of free sugars in Denmark, 19% in Spain and 26% in the UK with the higher contributions in Spain and the UK likely related to the inclusion of pastry and other bakery products in the cereals food group (Pedersen *et al.*, 2015; Ruiz *et al.*, 2017; Public Health England, 2020).

Cereals, grains & potatoes also made important contributions to micronutrient intakes in the diet of adults in countries within the WHO European region, particularly to intakes of B vitamins, contributing 19-35% of folate intake, 17-47% of thiamin intake, 15-30% of vitamin B6 intake, 15-29% of niacin intake and 10-21% of riboflavin intake (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Partearroyo *et al.*, 2017; Lopes *et al.*, 2018; Mielgo-Ayuso *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). Cereals, grains & potatoes contributed minimally to vitamin B12 intake (1-8%) in Finland, Italy, Portugal, Spain and the UK, but did not contribute to vitamin B12 intake in Denmark or the Netherlands, with contributions to this nutrient (where reported) likely due to fortification practices or animal-source ingredients within cereal/potato dishes (Helldán *et al.*, 2013; Hennessy *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Partearroyo *et al.*, 2017; Lopes *et al.*, 2018; Mielgo-Ayuso *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

Cereals, grains & potatoes contributed 6-18% of vitamin C intake in adults in Denmark, Finland, Italy, Portugal the Netherlands and the UK and a lower contribution of 1% in Spain, likely related to the exclusion of potatoes from the estimation of nutrient contributions in Spain (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; van Rossum, 2020). Cereals, grains & potatoes also contributed 4-13% of vitamin E intake in adults in Denmark, Italy, Portugal, Spain and the Netherlands, while cereals, grains & potatoes contributed a higher proportion (24% and 26%, respectively) of vitamin E intakes in Finland and the UK (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; van Rossum, 2020). Cereals, grains & potatoes contributed 1-12% of vitamin A intake in adults across countries (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). For vitamin D, cereals, grains & potatoes contributed 1-16% of intake in adults, with variations likely related to differences in the classification of cereals, grains & potatoes and fortification practices across the countries within the WHO European region (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017b; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

Cereals, grains & potatoes made significant contributions to iron intake in adults across countries, contributing 45% in Finland, 42% in the UK, 40% in Denmark 34% in Italy, 29% each in Portugal and the Netherlands and 27% in Spain (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Samaniego-Vaesken *et al.*, 2017; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). Mandatory fortification of wheat flour with iron in some countries, such as the UK may explain some of these findings, while in Spain, only a voluntary food fortification scheme of food products such as breakfast cereals and bars is in place (Food Standards Agency, 1998; Hennessy *et al.*, 2013; Samaniego-Vaesken *et al.*, 2017). Cereals, grains & potatoes contributed 8-13% of calcium intake in Denmark, Finland, Italy, Portugal, Spain and the Netherlands and contributed 32% of calcium intake in the UK, likely related to the fortification of wheat flour in the UK to restore losses of calcium during processing (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017b; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). Cereals, grains & potatoes also contributed to 23-35% of magnesium intake, 21-35% of zinc intake and 19-27% of potassium intake (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Olza *et al.*, 2017b; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). For sodium, cereals, grains & potatoes contributed 21-35% of intake in adults in Denmark, Finland, Portugal, the Netherlands and the UK and where disaggregated data was available for Denmark, the Netherlands, the UK and Finland, cereals and their products contributed to the majority of this intake (22-33%) (data not shown) (Helldán *et al.*, 2013; Pedersen *et al.*, 2015; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

The consumption of fortified cereal products, such as ready-to-eat breakfast cereals (RTEBC) may partially explain the contributions to intakes of some micronutrients, such as vitamin D, thiamin, riboflavin, niacin, vitamin B6, folate and iron, as it is known that fortified RTEBC contribute significantly to intakes of these nutrients (Galvin *et al.*, 2003; Hennessy *et al.*, 2013).

To summarise for cereals, grains & potatoes, this review shows that there is a broad range of dietary guidelines available on the consumption of cereal foods and potatoes for adults in countries within the WHO European region. Cereals, grains & potatoes are generally recommended to be consumed every day and some countries provide quantitative guidelines for whole grain consumption (Norway, Denmark, Sweden) and limit potato consumption (Greece, Malta). Despite variations in the recommended consumption of cereals, grains & potatoes, intakes in adults were similar across most countries (276-359g/d) and the intake of brown and wholegrain cereal foods were low.

Cereals, grains & potatoes made significant contributions to energy, protein, carbohydrate, dietary fibre, vitamins (particularly B vitamins) and minerals (iron, calcium, magnesium, zinc) in the diets of adults in the WHO European region, but also contributed to significant intakes of sodium. Cereals, grains & potatoes generally contributed negligibly to intakes of saturated fat and free sugars, however due to the classification of this food group, cereals, grains & potatoes, contributed significantly to intakes of saturated fat and free sugars in some countries (Spain and the UK).

Conclusions

This review aimed to examine the current dietary guidelines for fruit & vegetables and cereals, grains & potatoes for adults in the WHO European region, to assess the current intakes of these food groups and to investigate the contribution of these food groups to energy and nutrient intakes in nationally representative samples of adults in countries within the WHO European region.

Overall, the FBDG of all countries recommended the consumption of at least 400g of fruit & vegetables per day. The mean intakes of fruit & vegetables in adults in countries within the WHO European region were generally below the WHO recommendations of 400g of fruit & vegetables per day (range across countries: 329-393g/d), with the exception of Denmark (445g/d), Italy (473g/d) and Germany (756g/d). Fruit & vegetables contributed little to energy intake in adults but made significant contributions to intakes of carbohydrate, total sugars, dietary fibre, vitamins (C, A and B vitamins) and minerals (potassium, iron, magnesium). Regarding cereals, grains & potatoes, there was a broad range of dietary guidelines for the consumption of cereals, grains & potatoes in adults across countries. Cereals, grains & potatoes were generally recommended to be consumed every day and some countries provide quantitative guidelines for whole grain consumption (Norway, Denmark, Sweden) and limit potato consumption (Greece, Malta). Despite variations in the recommended consumption of cereals, grains & potatoes, where comparable, intakes were broadly similar ranging between 276-359g/d for adults across countries and intake of brown and wholegrain cereal foods was low (29-93g/d) (where data were available). Cereals, grains & potatoes made significant contributions to energy, protein, carbohydrate, dietary fibre, vitamins (particularly B vitamins) and minerals (iron, calcium, magnesium, zinc, potassium) in the diets of adults in the WHO European region, but also contributed to significant intakes of sodium. Cereals, grains & potatoes generally contributed negligibly to intakes of saturated fat and free sugars, however due to the classification of this food group, cereals, grains & potatoes, contributed significantly to intakes of saturated fat and free sugars in some countries (Spain and the UK).

This section of the review provides an overview of the role of fruit & vegetables and cereals, grains & potatoes in the diets of adults in countries within the WHO European region and may benefit stakeholders, including researchers, policymakers and the food industry. As even more emphasis is being placed on the consumption of a plant-based diet for health and environmental sustainability, it is important to continue monitoring the consumption of these food groups and their role in the diet of populations.

Table 1. Guidelines for fruit & vegetables consumption in the general population, including adults, in countries within the WHO European region

Country	Age (years)	Quantitative recommendation (minimum)	Qualitative recommendation
Norway[a]	1y+	5 servings per day 1 serving = 100g, e.g., small bowl of salad, a carrot or a medium-sized fruit	Consume vegetables, fruit and berries every day
Denmark[b]	2y+	600g per day 100g of vegetable or fruit is equivalent to a large carrot or an apple	Consume fruit and vegetables of various colours every day. At least half must be vegetables. Choose fibre-rich vegetables such as onions, peas, broccoli, cauliflower, root vegetables and beans
Sweden[c]	2y+	500g per day	Consume plenty vegetables, fruit and berries every day. Choose high fibre vegetables such as root vegetables, cabbage, cauliflower, broccoli, beans and onions
United Kingdom[d]	2y+	5 portions per day 1 portion = 80g or 1 apple, banana, pear, orange or other similar-size fruit, 3 heaped tablespoons vegetables, a dessert bowl of salad, 30g dried fruit or 150ml glass of fruit juice or smoothie (counts as a maximum of one portion a day).	Consume a variety of fruit and vegetables every day
Ireland[e]	5y+	400g or 5-7 servings per day 1 serving = 1 apple, orange, pear, or banana/2 kiwis, plums or mandarin oranges/ 6 strawberries/10 grapes/16 raspberries/1/2 cup cooked veg, frozen or fresh/1 bowl salad - lettuce, tomato, cucumber/1 bowl homemade vegetable soup/150ml unsweetened fruit juice.	Consume a variety of fruit and vegetables every day
Albania[f]	Adults (age not specified)	5 portions per day 3 portions of vegetables and 2 portions of fruit 1 portion = 120g fruit, vegetables, salad or soup or 200ml fruit or vegetable juice with no sugar added (counts as 1 portion only)	Consume fruit and vegetables of various colours every day
Greece[g]	Adults (age not specified)	7 servings per day 4 servings of vegetables and 3 servings of fruit 1 serving = 150-200g of raw or cooked vegetables or 120-200g of fruit	Consume a variety of fruit and vegetables every day
Bulgaria[h]	Adults (age not specified)	400g per day	Consume a variety of vegetables and fruit, preferably raw
Finland[i]	Adults (age not specified)	500g or 5-6 portions per day 1 portion = one medium-sized piece of fruit, 100ml of berries or 150 ml of salads or grated vegetables	Consume uncooked and cooked vegetables (including legumes), fruit, berries and mushrooms
Germany[j]	Adults (age not specified)	650g per day 3 servings (400g) of vegetables and 2 servings (250g) of fruit. 1 serving = 1 small kohlrabi, 1 bell pepper, 1 handful of lentils or peas (raw	Consume both cooked and raw vegetables/salad and fruit (with skin on and fresh where possible) every day

		approx. 70 g, cooked approx. 125 g), 1 apple/orange/pear/banana, 2 handfuls of berries, 1 handful of dried fruit (e.g., 5 dried apricots), 25 g nuts (can replace 1 serving of fruit)	
Malta[k]	Adults (age not specified)	5-8 servings per day 3-5 servings of vegetables 2-3 servings of fruit 1 serving = 80g	Consume a wide variety of fruit and vegetables, ideally fresh.
The Netherlands[l]	Adults (age not specified)	400g per day 200g of vegetables and 200g of fruit	Consume fruit and vegetables every day
Switzerland[m]	Adults (age not specified)	5 portions per day 3 portions of vegetables and 2 portions of fruit 1 portion = 120g One daily portion of fruit or vegetables can be replaced by 2 dl of vegetable or fruit juice (with no added sugar).	Consume fruit and vegetables of various colours per day, preferably fresh
Turkey[n]	Adults (age not specified)	5 portions (400g) per day 2.5-3 portions of vegetables and 2-3 portions of fruit 1 portion of cooked vegetables is 150g and provides 25-85 kcal. 1 portion of fruit provides about 50-100 kcal	Consume fruit and vegetables every day
Austria[o]	General population	5 servings per day 3 servings of vegetables and/or pulses and 2 servings of fruit 1 portion = cooked vegetables (200-300g), raw vegetables (100-200g), salad (75-100g), legumes (raw approx. 70-100g, cooked approx. 150-200g), fruit (125-150g), vegetable or fruit juice (200ml).	Consume vegetables, legumes and fruit every day
Georgia[p]	General population	300-400g per day fruit 400-500g per day vegetables	Eat a variety of fruit and vegetables every day, preferably fresh and of local origin.
Slovakia[q]	General population	5 portions per day 1 portion = 1 glass (200 ml) of vegetables or fruit (e.g., 1 medium apple)	Consume different types of fruit and eat more vegetables. Fruit and vegetables should present 1/3 of your daily consumption.
WHO[r]	General population	400g per day	Consume non-starchy fruit and vegetables daily

[a]Norwegian Directorate of Health (2016) [b]Ministry of Food Agriculture & Fisheries (2022) [c]Swedish Food Agency (2015) [d]Public Health England (2016) [e]Department of Health (2016) [f]Department of Public Health (2008) [g]Institute of Preventive Environmental & Occupational Medicine (Prolepsis) (2014) [h]National Center of Public Health Protection (NCPHP) (2006) [i]Finnish Food Authority (2014) [j]German Nutrition Society (2017) [k]Health Promotion and Disease Prevention Directorate (2015) [l]Health Council of the Netherlands (2015) [m]Swiss Society for Nutrition (2011) [n]Ministry of Health (Turkey) (2016) [o]Austrian Ministry of Health and the National Nutrition Commission (2010) [p]Ministry of Labor Health and Social Affairs (2005) [q]Public Health Authority of the Slovac Republic (2016) [r]World Health Organisation (2005)

Table 2. Foods included in country-specific guidelines for fruit & vegetable consumption in the general population, including adults, in countries within the WHO European region

Country	Fruit/vegetable juice	Dried fruit	Legumes	Potatoes	Nuts	Tinned fruit & vegetables
Albania[a]	200ml vegetable or fruit juice with no added sugar as one portion only	-	Not included	Not included	Not included	-
Austria[b]	200ml vegetable or fruit juice as one portion only	-	70-100g raw, 150-200g cooked as one portion	Not included	Not included	-
Bulgaria[c] *	Included. No specific recommendations	Included. No specific recommendations	Not included	Not included	Not included	Included. No specific recommendations
Denmark[d] †	100ml fruit juice as one portion only	Not included	Not included	Not included	Not included	Included. No specific recommendations
Finland[e]	Included. No specific recommendations. Whole fruit recommended over juiced	-	Included. No specific recommendations	Not included	Not included	-
Georgia[f]	Included. A glass of 100% fruit juice	Included. No specific recommendations	Not included	Not included	-	-
Germany[g]	-	-	-	Not included	25g of nuts can replace one serving of fruit	-
Greece[h]	125ml natural fruit juice (100% without added sugar) as one portion	1½ tbsp. raisins, 4 dried apricots/plums as one portion	Not included	Not included	Not included	-
Ireland[i]	150ml unsweetened fruit juice as one portion only	Included. No specific recommendations	Not included	Not included	Not included	-
Malta[j]	Included. No specific recommendations. Whole, fresh fruit recommended over juiced. One portion per day only	Included. No specific recommendations. Whole fresh fruit and vegetables recommended over dried	Not included	Not included	Not included	Included. No specific recommendations. Whole fresh fruit and vegetables recommended over tinned
The Netherlands[k]	Included. No specific recommendations	Included. No specific recommendations	Not included	Not included	Not included	Included. No specific recommendations
Norway[l]	-	-	Not included	Not included	Not included	Included. No specific recommendations
Slovakia[m]	-	-	-	Not included	Not included	-

Sweden[n]	-	-	Included. No specific recommendations	Not included	Not included	-
Turkey[o]	Included. 180ml fruit juice. Whole fruit recommended over juiced. 150ml vegetable juice	3-4 dried apricots/ plum/fig/30g raisins/1 large date/3 small dates	Not included	Included. 1/2 medium size or 1 piece the size of a computer mouse	Not included	-
United Kingdom[p]	Included. 150ml glass of fruit juice or smoothie (maximum one portion/day)	Included. 30g dried fruit	Not included	Not included	Not included	Included. No specific recommendations
Switzerland[q]	One daily portion of fruit or vegetables can be replaced by 2 dl (200ml) of vegetable or fruit juice (with no added sugar)	-	Not included	Not included	Not included	-

[a]Department of Public Health (2008) [b]Austrian Ministry of Health and the National Nutrition Commission (2010) [c]National Center of Public Health Protection (NCPHP) (2006) [d]Ministry of Food Agriculture & Fisheries (2022) [e]Finnish Food Authority (2014) [f]Ministry of Labor Health and Social Affairs (2005) [g]German Nutrition Society (2017) [h]Institute of Preventive Environmental & Occupational Medicine (Prolepsis) (2014) [i]Department of Health (2016) [j]Health Promotion and Disease Prevention Directorate (2015) [k]Health Council of the Netherlands (2015) [l]Norwegian Directorate of Health (2016) [m]Public Health Authority of the Slovac Republic (2016) [n]Swedish Food Agency (2015) [o]Ministry of Health (Turkey) (2016) [p]Public Health England (2016) [q]Swiss Society for Nutrition (2011)
– data not available *includes pickles, nectars, compotes, marmalades, jams, etc. †excludes mushrooms

Table 3: Mean intake (g/d) of fruit & vegetables (including juices) in adults in countries within the WHO European region using data from national nutrition surveys

Country (reference)	Study	Study years	Age group	Fruit & vegetable description	Intake (g/d)	Males	Females
Belgium (Bel *et al.*, 2019)	Belgium National Food Consumption Survey II	2014-15	18-64y (*n* 12 26)	Fruit & vegetables (incl products & vegetable juice)	268	243	281
				Fruit juice (& olives)	61	61	56
Denmark (Pedersen *et al.*, 2015)	Danish National Survey of Dietary Habits and Physical Activity	2011-13	18-75y (*n* 3016)	Fruit & vegetables (incl products)	389	357	418
				Juices	56	59	54
Finland (Helldán *et al.*, 2013)	The National FINDIET Survey	2012	25-64 (*n* 1295)	Fruit & vegetables (incl. products & dishes)	343	302	384
				Juices	47	64	29
Germany (Heuer *et al.*, 2015)	German National Nutrition Survey II	2005-07	14-80y (*n* 15371)	Fruit & vegetables (incl products & pulses)	491	461	520
				Fruit juice/nectars	265	285	245
Italy (Leclercq *et al.*, 2009)	Italian National Food Consumption Survey (INRAN-SCAI)	2005-06	18-64.9y (*n* 2313)	Fruit & vegetables (incl pulses, nuts, seeds, olives, herbs & spices)	443	444	441
				Fruit & vegetable juices	30	30	30
Portugal (Lopes *et al.*, 2018)	National Food, Nutrition, and Physical Activity Survey of the Portuguese General Population (IAN-AF)	2015-16	18-64y (*n* 3102)	Fruit, vegetables & pulses (incl nuts & seeds)	301	-	-
				100% fruit juice & fruit/vegetable nectars	45	-	-
Spain (Partearroyo *et al.*, 2019)	The ANIBES study – Anthropometry, Intake and Energy Balance in Spain	2013	18-64y (*n* 1587)	Fruit & vegetables (incl pulses)	346	343	350
				Juices & nectars	47	53	40
The Netherlands (van Rossum, 2020)	Dutch National Food Consumption Survey (DNFCS)	2012-16	19-79y (*n* 2078)	Fruit & vegetables (incl legumes, nuts, seeds, olives)	282	269	294
				Fruit juice	54	60	48
The UK (Public Health England, 2020)	National Diet and Nutrition Survey (NDNS)	2016/17-2018/19	19-64y (*n* 1392)	Fruit & vegetables (incl. dishes)	311	314	309
				Fruit juice	34	40	29

– data not available

Table 4: The percent contribution (%) of fruit & vegetables (including juices) to energy and nutrient intakes in adults in countries within the WHO European region using data from national dietary surveys

	Denmark[a]	Finland[b]	Italy[c]	Portugal[d]	Spain[e-l]	The Netherlands[m]*	The UK[n,o]
	4-75y (*n* 3946)	25-64y (*n* 1295)	18-64.9y (*n* 2313)	3m-84y (*n* 5811)	18-64y (*n* 1587)	19-79y (*n* 2078)	19-64y (*n* 2526)
Energy	11	10	8	9	13	9	10
Protein	6	5	8	6	9	10	7
Total fat	6	5	3	4	3	7	6
Saturated fat	4	5	1	2	2	4	4
MUFA	6	5	1	3	2	9	7
PUFA	9	7	7	9	6	12	-
Carbohydrate	19	17	14	14	22	11	13
Total sugars	-	29	36	31	31	25	-
Free sugars	14†	-	-	8	3	-	9
Dietary fibre	36	27	49	33	51	30	28
Vitamin A	26	24	58	30	41	20	32
Vitamin D	0	2	2	0	0	0	1
Vitamin E	38	17	23	20	19	16	19‡
Vitamin C	74	76	89	57	80	39	54‡
Thiamin	15	16	22	17	12	12	14‡
Riboflavin	10	11	20	10	12	8	11
Niacin	10	8	-	7	12	10	6‡
Vitamin B6	25	21	26	18	29	15	15‡
Vitamin B12	0	2	0	1	0	0	1‡
Folate	39	29	-	27	41	24§	29
Sodium	5	8	-	2	-	4	8
Potassium	30	22	37	21	-	21	21
Calcium	8	8	17	10	15	8	10
Iron	15	13	25	16	25	14	16
Magnesium	16	14	26	16	27	15	16
Zinc	7	7	14	7	13	9	9

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids – data not available *Juices not included †Added sugar ‡NDNS Years 1-4 §Folate equivalents [a]Pedersen *et al.* (2015) [b]Helldán *et al.* (2013) [c]Sette *et al.* (2013) [d]Lopes *et al.* (2018) [e]Ruiz *et al.* (2015) [f]Ruiz *et al.* (2016) [g]Partearroyo *et al.* (2017) [h]Samaniego-Vaesken *et al.* (2017) [i]Ruiz *et al.* (2017) [j]Olza *et al.* (2017b) [k]Olza *et al.* (2017a) [l]Mielgo-Ayuso *et al.* (2018) [m]van Rossum (2020) [n]Public Health England (2020) [o]Public Health England (2014)

Table 5: The percent contribution (%) of fruit, vegetables & juice to energy and nutrient intakes in adults in countries within the WHO European region using data from national dietary surveys

	Denmark[a]			Italy[b]			Portugal[c]		Spain[d-k]			The Netherlands[l]			The UK[m,n]		
	4-75y (*n* 3946)			18-64.9y (*n* 2313)			3m-84y (*n* 5811)		18-64y (*n* 1587)			19-79y (*n* 2078)			19-64y (*n* 2526)		
	Fruit	Vegetables†	Juice	Fruit**	Vegetables*	Juice	Fruit & vegetables*	Juice	Fruit	Vegetables*	Juice	Fruit**	Vegetables*	Juice	Fruit	Vegetables†	Juice
Energy	7	3	1	5	3	1	8	1	5	7	1	7	2	-	4	5	1
Protein	2	4	0	2	6	0	5	0	2	7	0	4	6	-	1	6	0
Total fat	4	2	0	1	1	0	4	0	2	1	0	6	1	-	1	5	0
Saturated fat	2	2	0	1	1	0	2	0	1	0	0	3	1	-	1	3	0
MUFA	5	1	0	1	0	0	3	0	2	0	0	8	1	-	2	5	0
PUFA	6	3	0	3	4	0	9	0	3	3	0	9	2	-	-	-	-
Carbohydrate	12	5	2	9	4	1	12	2	8	11	3	8	3	-	6	6	1
Total sugars	-	-	-	24	9	3	28	4	16	8	6	18	6	-	-	-	-
Free sugars	13‡	1‡	0	-	-	-	0	7	0	0	2			-	0	3	6
Dietary fibre	18	18	1	22	27	0	33	1	17	33	0	13	17	-	8	20	0
Vitamin A	2	24	0	14	44	1	29	1	7	33	1	1	19	-	1	30	1
Vitamin D	0	0	0	0	2	0	0	0	0	0	0	0	0	-	0	1	0
Vitamin E	23	15	0	8	15	1	19	1	5	13	2	8	8	-	5§	13§	1§
Vitamin C	25	37	12	33	48	8	49	9	19	53	8	18	21	-	19§	23§	12§
Thiamin	5	8	2	8	13	1	16	2	3	9	-	5	7	-	3§	9§	2§
Riboflavin	4	5	1	6	14	1	8	1	4	9	-	3	5	-	3	7	1
Niacin	3	6	1	-	0		7	1	3	9	-	5	5	-	1§	5§	0§
Vitamin B6	11	12	2	11	14	1	17	2	9	21	-	7	7	-	6§	7§	2§
Vitamin B12	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0§	1§	0§
Folate	13	26	0	-	-	-	25	2	9	29	3	7‖	17‖	-	6	20	3
Sodium	2	3	0	-	-	-	2	0	-	-	-	2	2	-	1	7	0
Potassium	14	14	2	14	22	1	20	2	-	-	-	9	11	-	7	12	2
Calcium	3	4	1	6	11	0	10	1	4	10	1	2	6	-	2	7	1
Iron	6	8	1	7	17	1	15	1	7	18	-	5	9	-	3	12	1
Magnesium	8	7	1	8	17	1	15	1	8	17	2	9	6	-	5	10	1
Zinc	3	4	0	3	11	0	7	0	3	9	1	4	5	-	1	8	0

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids – data not available *includes legumes/pulses **includes nuts, seeds & olives †includes vegetable dishes ‡added sugar §NDNS years 1-4 ‖Folate equivalents [a]Pedersen *et al.* (2015) [b]Sette *et al.* (2013) [c]Lopes *et al.* (2018) [d]Ruiz *et al.* (2015) [e]Ruiz *et al.* (2016) [f]Partearroyo *et al.* (2017) [g]Samaniego-Vaesken *et al.* (2017) [h]Ruiz *et al.* (2017) [i]Olza *et al.* (2017b) [j]Olza *et al.* (2017a) [k]Mielgo-Ayuso *et al.* (2018) [l]van Rossum (2020) [m]Public Health England (2020) [n]Public Health England (2014)

Table 6. Guidelines for consumption of cereals, grains & potatoes in countries within the WHO European region

Country	Age (years)	Quantitative recommendation	Qualitative recommendation
Norway[a]	1y+	70-90g wholegrain cereals per day	Consume coarse grain products every day (wholegrain and high fibre). No specific guidelines for potato consumption
Denmark[b]	2y+	75g wholegrain cereals per day 100g of potatoes, several times a week	Consume wholegrain cereals, rice or pasta every day. Consume potatoes as part of a plant-rich and varied diet
Sweden[c]	2y+	70g wholegrain cereals per day for women 90g wholegrain cereals per day for men	Choose wholegrain varieties when you eat pasta, bread, grain and rice. No specific guidelines for potato consumption
United Kingdom[d]	2y+	-	Potatoes, bread, rice, pasta or other starchy carbohydrates should make up 1/3 of the food we eat. Choose higher-fibre, wholegrain varieties and leave skins on potatoes where possible
Ireland[e]	5y+	3-5 servings per day. Up to 7 depending on physical activity 1 serving = 2 thin slices wholemeal bread, 1.5 slices wholemeal soda bread or 1 pitta pocket, 1/3 cup dry porridge oats or 1/2 cup unsweetened muesli, 1 cup flaked type breakfast cereal, 1 cup cooked rice, pasta, noodles or couscous, 2 medium or 4 small potatoes, 1 cup yam or plantain	Consume wholemeal cereals and breads, potatoes, pasta and rice every day
Albania[f]	Adults (age not specified)	6-11 units per day. 1 unit = 40g, e.g., one slice of bread	Consume bread, grains, rice or potatoes, many times a day
Greece[g]	Adults (age not specified)	5-8 servings per day 1 serving = 1 slice of bread (30g), half a cup (120 ml) cooked pasta or rice (70-90g), half a cup (120ml) of breakfast cereals (30g) 3 servings per week of potatoes 1 serving = 1 medium potato (120-150 g cooked)	Consume a variety of cereals (preferably wholegrain) every day including bread, pasta, rice etc. Consumption of potatoes should be limited
Bulgaria[h]	Adults (age not specified)	300-500g per day (the amount depends on sex and physical activity)	Consume bread, other cereals and/or potatoes every day. Preferably wholegrain products.
Finland[i]	Adults (age not specified)	6 portions per day for women 9 portions per day for men 1 portion = 100ml cooked wholemeal pasta, barley, rice etc. or one slice of bread. A bowl of porridge = two portions.	Consume wholegrain cereals (bread, porridge, pasta, etc.) several times a day. At least half should be wholegrain. No specific recommendations for potatoes
Germany[j]	Adults (age not specified)	4-6 slices (200-300g) bread or 3-5 slices (150-250g) bread and 50-60g cereal flakes and 1 serving (200-250 g) potatoes (cooked) or	Consume cereals, cereal products and potatoes daily. Choose wholegrain cereals

		1 serving (200-250g) pasta (cooked) or 1 serving (150-180g) rice (cooked)	
Malta[k]	Adults (age not specified)	1 serving of cereals per meal (3 per day 1 serving = 1 medium slice of bread; 40g of breakfast cereals; 80-100g of raw cereals, pasta and rice ≤3 servings of potatoes per week (preferably with skins on). 1 serving = 80g	Consume bread, pasta, rice, couscous and other cereals and cereal products every day (preferably wholegrain). Consumption of potatoes should be limited and preferably with skins.
The Netherlands[l]	Adults (age not specified)	≥90g of brown bread, wholemeal bread or other wholegrain products per day	Replace refined cereal products with wholegrain products. No specific guidelines for potato consumption
Switzerland[m]	Adults (age not specified)	3 servings per day 1 serving is 75–125g bread/ pastry or 60–100g pulses (dry weight) or 180–300g potatoes or 45–75g crispbread/ wholegrain crackers/ flakes/ flour/ pasta/ rice/ corn/ other grains (dry weight)	Consume grains (preferably wholegrain cereals), potatoes and pulses
Turkey[n]	Adults (age not specified)	3-7 portions per day (potatoes not included) 1 portion = 50g (2 thin slices of bread), 70g (4-5 tablespoons or ½ cup) of cooked macaroni, 90g (4-5 tablespoons or ½ cup) of cooked bulgur or rice, about 30g or 1 cup of breakfast cereals	Consume bread, rice, macaroni, noodles, couscous, bulgur, oat, barley, and breakfast cereals every day. Consume with every meal. Whole grains or wholegrain products should be preferred.
Austria[o]	General population	4 servings per day (5 for active athletes and children) 1 serving = 50-70g bread/wholemeal bread, pastries, bread rolls, etc./50-60g muesli or cereal flakes/65-80g pasta (uncooked) or 200-250g cooked/50-60g rice or cereals (uncooked) or 150-180g cooked, potatoes (cooked) 200-250 g	Consume grains (preferably wholegrain cereals), breads, pasta, rice or potatoes every day
Georgia[p]	General population	500-600g cereal products; breads, rolls, pasta, rice, porridge 200-300g potatoes	Eat breads, cereals and pasta (preferably wholegrain) and rice several times a day.
Slovakia[q]	General population	-	Consume cereals in natural wholegrain form. Cereals should be 1/3 of your daily consumption. No specific guidelines for potato consumption

[a]Norwegian Directorate of Health (2016) [b]Ministry of Food Agriculture & Fisheries (2022) [c]Swedish Food Agency (2015) [d]Public Health England (2016) [e]Department of Health (2016) [f]Department of Public Health (2008) [g]Institute of Preventive Environmental & Occupational Medicine (Prolepsis) (2014) [h]National Center of Public Health Protection (NCPHP) (2006) [i]Finnish Food Authority (2014) [j]German Nutrition Society (2017) [k]Health Promotion and Disease Prevention Directorate (2015) [l]Health Council of the Netherlands (2015) [m]Swiss Society for Nutrition (2011) [n]Ministry of Health (Turkey) (2016) [o]Austrian Ministry of Health and the National Nutrition Commission (2010) [p]Ministry of Labor Health and Social Affairs (2005) [q]Public Health Authority of the Slovac Republic (2016) – data not available

Table 7. Mean intake (g/d) of cereals, grains & potatoes in adults in countries within the WHO European region using data from national nutrition surveys

Country (reference)	Study	Study year(s)	Age group	Cereals, grains & potatoes description	Intake (g/d)	Males	Females
Belgium (Bel *et al.*, 2019)	Belgium National Food Consumption Survey II	2014-15	18-64y (*n* 1226)	Bread & cereals (breakfast cereals, oatmeal, rusks) & potatoes, rice, pasta & other grains	287	338	237
Denmark (Pedersen *et al.*, 2015)	Danish National Survey of Dietary Habits and Physical Activity (DANSDA)	2011-13	18-75y (*n* 3016)	Bread & other cereals, potatoes & potato products	309	367	254
Finland (Helldán *et al.*, 2013)	The National FINDIET Survey	2012	25-64 (*n* 1295)	Cereals & bakery products (sweet bakery, savoury pastries, pancakes), potatoes & potato dishes	359	407	310
Germany (Heuer *et al.*, 2015)	German National Nutrition Survey II	2005-07	14-80y (*n* 15371)	Bread, cereals & cereal products (flours, rice, breakfast cereals, pasta, popcorn), potatoes & potato products (chips, potato pancakes, potato crisps)	318	357	278
Italy (Leclercq *et al.*, 2009)	Italian National Food Consumption Survey (INRAN-SCAI)	2005-06	18-64.9y (*n* 2313)	Cereals, cereal products & substitutes (bread, pasta, pizza, rice, other cereals, breakfast cereals, biscuits, cakes etc.) & potatoes	314	350	279
Portugal (Lopes *et al.*, 2018)	National Food, Nutrition, and Physical Activity Survey of the Portuguese General Population (IAN-AF)	2015-16	18-64y (*n* 3102)	Cereals, cereal products & starchy tubers (bread, rusks, pastry, breakfast cereals & bars, flour, pasta, rice and other grains, potatoes & other starchy tubers)	311	-	-
Spain (Partearroyo *et al.*, 2019)	The ANIBES study – Anthropometry, Intake and Energy Balance in Spain	2013	18-64y (*n* 1587)	Cereals & derivatives (grains & flours, breakfast cereals & cereal bars, bread, pasta, bakery & pastry)	149	164	135
The Netherlands (van Rossum, 2020)	Dutch National Food Consumption Survey (DNFCS)	2012-16	19-79y (*n* 2078)	Cereal & products (bread, crispbread, rusks, breakfast cereals, flours, starches, semolina, pasta, rice & other grains, dough & pastry etc.), potatoes and other tubers	276	322	229
The UK (Public Health England, 2019)	National Diet and Nutrition Survey (NDNS)	2012/13-2016/17	19-64y (*n* 2526)	Cereals & cereal products (pasta, rice, pizza, bread, breakfast cereals, biscuits, buns, cakes, pastries, puddings) & potatoes, potato products & dishes (chips, potato salad)	328	369	290

– data not available

Table 8: The percent contribution (%) of cereals, grains & potatoes to energy and nutrient intakes in adults in countries within the WHO European region using data from national nutrition surveys

	Denmark[a]	Finland[b]	Italy[c]	Portugal[d]	Spain[e-l]*	The Netherlands[m]	The UK[n,o]
	4-75y (*n* 3946)	25-64y (*n* 1295)	18-64.9y (*n* 2313)	3m-84y (*n* 5811)	18-64y (*n* 1587)	19-79y (*n* 2078)	19-64y (*n* 2526)
Energy	31	33	40	29	28	26	38
Protein	23	25	30	20	17	24	26
Total fat	10	20	11	7	10	10	26
Saturated fat	6	18	10	5	11	6	24
MUFA	8	19	6	4	7	12	24
PUFA	23	23	20	16	15	19	-
Carbohydrate	53	48	71	50	49	43	53
Total sugars	-	13	18	9	12	-	-
Free sugars	2†	-	-	7	19	-	26
Dietary fibre	60	59	49	46	40	50	48
Vitamin A	1	8	4	2	5	1	12
Vitamin D	2	7	9	4	15	1	16
Vitamin E	13	24	7	8	4	9	26‡
Vitamin C	10	6	8	17	1	12	18‡
Thiamin	34	30	36	28	17	23	47‡
Riboflavin	13	17	20	19	11	10	21
Niacin	15	20	-	23	17	19	29‡
Vitamin B6	23	20	30	29	15	19	30‡
Vitamin B12	0	8	3	1	2	0	7‡
Folate	27	35	-	34	19	27§	33
Sodium	23	35	-	21	-	26	30
Potassium	23	22	24	19	-	20	27
Calcium	10	13	11	11	11	8	32
Iron	40	45	34	29	27	29	42
Magnesium	34	33	31	24	23	29	35
Zinc	24	35	27	21	25	22	29

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids – data not available *Potatoes not included †Added sugar ‡NDNS Years 1-4 §Folate equivalents [a]Pedersen *et al.* (2015) [b]Helldán *et al.* (2013) [c]Sette *et al.* (2013) [d]Lopes *et al.* (2018) [e]Ruiz *et al.* (2015) [f]Ruiz *et al.* (2016) [g]Partearroyo *et al.* (2017) [h]Samaniego-Vaesken *et al.* (2017) [i]Ruiz *et al.* (2017) [j]Olza *et al.* (2017b) [k]Olza *et al.* (2017a) [l]Mielgo-Ayuso *et al.* (2018) [m]van Rossum (2020) [n]Public Health England (2020) [o]Public Health England (2014)

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Aims and objectives

The overall aim of this thesis was to examine how plant-based diet components and plant-based foods contribute to nutritional quality and intake in adults (18-90y) in Ireland. This research used data from the National Adult Nutrition Survey (NANS) (2008-2010), a nationally representative dietary survey of adults carried out by the Irish Universities Nutrition Alliance (www.iuna.net).

Objectives:

1. To develop a systematic methodology to identify the PB component of a diet, using two extremes of PB diet definitions, i.e., plant-based (all) (PB-A) which includes 'all plant-based foods' regardless of dietary quality and plant-based (healthful) (PB-H) which includes 'healthful plant-based foods' only (both of which exclude all meat and fish and place heavy restrictions on animal products, such as dairy and eggs)

2. To examine the nutritional quality of the PB component of the diet of adults in Ireland (18-90y) using the abovementioned two extremes of PB diet definitions, compared to the baseline diet (the diet consumed by the NANS population) and to examine the nutritional quality of these PB components between sexes and age groups

3. To examine the current intake of fruit & vegetables in adults (18-90y) in Ireland, to assess compliance with recommendations and to determine their contribution to overall energy and nutrient intakes

4. To examine the current intake of cereals, grains & potatoes in adults (18-90y) in Ireland, to assess compliance with recommendations and to determine their contribution to overall energy and nutrient intakes

Chapter 2

Methodology of the National Adult Nutrition Survey (NANS)

Methodology

The analyses for this thesis were based on data from the National Adult Nutrition Survey (NANS), which was a cross-sectional survey conducted in the Republic of Ireland from 2008 to 2010, by the Irish Universities Nutrition Alliance (IUNA) units at University College Cork and University College Dublin, to establish a database of habitual food and beverage consumption in a representative sample of 1500 adults aged between 18-90 years (men: *n* 760; women *n* 740).

This chapter provides an outline of the survey methodology and the methods relevant to this thesis. Further information and a detailed methodology of additional data collected in the NANS, such as the health and lifestyle, physical activity and food choice questionnaires, anthropometric and blood pressure measurements and urine and blood sample collection and analysis are available at www.iuna.net.

Ethical approval

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and ethical approval was obtained from the Clinical Research Ethics Committee of the Cork Teaching Hospitals, University College Cork and the Human Ethics Research Committee of University College Dublin. Written informed consent was obtained from all participants prior to the commencement of the survey.

Sampling and recruitment methodology

The fieldwork (data collection) phase was carried out between October 2008 and April 2010. Eligible participants were adults aged 18 years and over who were free-living and not pregnant or breastfeeding. A sample of adults was randomly selected from a database of names and addresses held by Data Ireland (An Post) and an introductory letter and information leaflet were posted to each person selected from the database. A second level of recruitment was used in which names and addresses were compiled through referrals from respondents and participation was invited for those who were contactable. A researcher called to prospective participants' homes to introduce the survey and invite participation. If the individual agreed to participate, a consent form was signed and the survey commenced. If the person was not at home, the researcher called on three more occasions on different days and at different times, before deeming them ineligible. The final response rate for the survey was 60%. Demographic analysis of the NANS sample has shown it to be nationally representative of adults in the Republic of Ireland with respect to age-group, gender, social class and geographical location, when compared to Irish Census 2006 data (Central Statistics Office, 2007).

Dietary data collection

Food and beverage intake data were collected using a 4-day semi-weighed food diary. For all participants, the study included at least one weekend day. Participants were provided with a food diary and a portable food scales and asked to record detailed information of the amount, type and brand of all food, beverages and nutritional supplements consumed over the four-day period and where applicable, the cooking methods used, the packaging size and type and details of recipes and any leftovers. Participants were also asked to keep all food/beverage/nutritional supplement packaging to provide further information (e.g., brand details, nutritional information).

The researcher made three visits to the participant during the 4-day recording period: an initial training visit to demonstrate how to complete the food diary and use the portable food scales that were provided, a second visit 24-36 hours into the recording period to review the food diary for completeness and to clarify details regarding specific food descriptors and quantities, and a final visit 1 to 2 days after the recording period to check the recording from the final days and to collect the food diary and portable food scales.

Food quantification and coding

A quantification protocol, established by the IUNA for the North/South Ireland Food Consumption Survey (NSIFCS) (Harrington *et al.*, 2001), was adapted for the

NANS. Further details can be found on www.iuna.net. In brief, a hierarchical approach to quantification was developed, where foods and beverages were quantified by specific methods. If it was not possible to quantify a food or beverage with a method on the first level of the hierarchy, a subsequent method was used. It is summarised as follows:

1) Weighed by participant/manufacturer weights – participants used a portable food scales (Tanita, Japan) to weigh 46% of foods and beverages consumed. A further 10% of weights were derived from the manufacturer information on product labels.
2) Photographic food atlas (Nelson *et al.*, 1997) – This was used to quantify 16% of foods and beverages consumed.
3) Food portion sizes (Food Standards Agency, 2002a) – This was used to quantify 11% of foods and beverages consumed.
4) Household measures– measures such as tablespoon, teaspoon, pint etc. were used to quantify 11% of foods and beverages consumed.
5) IUNA weights – average portion weights of certain foods, ascertained by the IUNA survey team were used to quantify 4% of foods and beverages consumed.
6) Estimated – food quantities were defined as estimated if the researcher made an estimate of the amount likely to have been consumed based in their knowledge of the participant's general eating habits as observed during the recording period. This method was used to quantify 2% of foods and beverages consumed.

Estimation of food and nutrient intakes

Each food, beverage and nutritional supplement consumed in the NANS was assigned a unique food code based on its nutritional profile and brand information. All foods and beverages were then entered into the Weighed Intake Software Package data entry system (WISP-DES©) (Tinuviel Software, Anglesey, UK). A total of 2552 food codes were included in the NANS database which were then categorised into one of nineteen food groups (**Appendix I**) and then further subdivided into sixty-eight food groups (**Appendix II**).

The nutritional software package WISP© (Tinuviel Software, Anglesey, UK) was then used to estimate nutrient intakes using data from McCance and Widdowson's The Composition of Foods, sixth (Food Standards Agency, 2002b) and fifth (Holland *et al.*, 1991a) editions plus all nine supplemental volumes (Holland *et al.*, 1988; Holland *et al.*, 1989; Holland *et al.*, 1991b; Holland *et al.*, 1992; Holland *et al.*, 1993; Chan *et al.*, 1994; Chan *et al.*, 1995; Chan *et al.*, 1996; Holland *et al.*, 1996). During the NANS, modifications were made to the food composition database to include recipes of composite dishes, nutritional supplements, fortified foods, generic Irish foods that were commonly consumed and new foods on the market (Black *et al.*, 2011). Additionally, the food composition database used was updated with values for total fat, saturated fat, monounsaturated fat, polyunsaturated fat, free sugars, sodium, vitamin D and iodine, which has been detailed elsewhere (Giltinan, 2012; Black *et al.*, 2015; Li *et al.*, 2016; McNulty *et al.*, 2017; Walton *et al.*, 2017).

The mean daily intake of food groups and nutrients were estimated for each individual by summing the weight of each food/nutrient consumed over the recording period and dividing the total by the number of recording days (four).

Quality control

To minimise error and ensure consistency throughout the collection and analysis of food intake data, a number of quality procedures were put in place. Researchers received comprehensive training on all standard operating procedures and completed role-play workshops prior to commencing fieldwork and were encouraged to engage with participants in a natural and friendly manner, and to avoid prompting foods. This was carried out to make respondents feel at ease and so that the most reliable data possible could be obtained. Participants were encouraged not to change or 'improve' their diet throughout the recording period. At the end of the recording period, participants were asked if there were any items consumed during the recording period which had not yet been written down. Details on such items were then recorded by the researcher in the food diary.

Each researcher was primarily responsible for the collection, quantification, coding and data entry of the food diaries of their own participants, in an attempt to maintain consistency and were provided with detailed guidelines regarding each task. WISP-DES© (the food data entry system) was set up to incorporate over-range checks for portion sizes, by generating a warning if a food weight was entered as five times a typical ‘large’ portion size.

Once the data entry was completed by the researcher, all diaries were re-checked by the researcher themselves and a percentage of diaries were re-checked by a different researcher. The survey co-ordinator then exported all data into SPSS© where further quality control took place. All food codes and corresponding brand codes were compared to ensure no mismatches occurred and each variable exported was quality controlled for errors and outliers.

Database

The NANS database comprises over 133,050 rows of data that describe every food and beverage item consumed by the 1500 participants at every eating occasion throughout the four recording days. For each item consumed, the database contains the actual day of the week and meal number in the day, the definition of the eating occasion, where the meal was prepared, the time and location of consumption, the weight of the food/beverage consumed, the brand information, packaging type and size and nutritional information based on the amount of food consumed for a number of nutrients.

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Chapter 3

A standardised methodological approach for characterising the plant-based component of population or individual diets

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Introduction

Plant-based (PB) diets and PB dietary patterns have received increasing attention in recent years due to their association with good health and environmental sustainability (Dinu *et al.*, 2017; Chiavaroli *et al.*, 2018; Toumpanakis *et al.*, 2018; Qian *et al.*, 2019; Rees *et al.*, 2019; Willett *et al.*, 2019). However, the definition of a PB diet, the prevalence and demographics of those consuming PB diets (or PB foods within an omnivorous diet) and the contribution of PB foods to energy and nutrient intakes and nutritional adequacy has not been widely studied (Bates *et al.*, 2011; Irish Universities Nutrition Alliance, 2011; Juan *et al.*, 2015; Hemler and Hu, 2019a; Rocha *et al.*, 2019; Alcorta *et al.*, 2021; Kent *et al.*, 2022).

PB diets encompass a wide spectrum of dietary patterns which emphasise the consumption of plant products, such as fruit and vegetables, whole grains, legumes, nuts and seeds and PB alternatives and limit or exclude animal-derived products (Satija and Hu, 2018; Plant-Based Foods Association, 2019). PB diet definitions within the literature range from vegan (excludes all animal and animal-derived products) and vegetarian diets, such as lacto- (includes dairy), ovo- (includes eggs), lacto-ovo-vegetarian diets (includes dairy and eggs), pescatarian diets (includes dairy, eggs and fish) to semi-vegetarian/flexitarian diets (includes dairy, eggs, fish and meat sparingly) (Derbyshire, 2016; Hemler and Hu, 2019a; Rocha *et al.*, 2019; The Vegan Society, 2021; The Vegetarian Society UK, 2021; Kent *et al.*, 2022). Furthermore, other diets which were originally developed due to their associations with positive health outcomes, such as the Portfolio, Mediterranean-style, DASH, Healthy US-style, Planetary Health and Nordic-style diets, have been encompassed in PB definitions due to their emphasis on certain PB components, such as plant protein and pulses (Portfolio diet), olive oil (Mediterranean diet) and minimally processed foods (Planetary Health diet) (Chiavaroli *et al.*, 2018; Chiavaroli *et al.*, 2019; Hemler and Hu, 2019a; Hemler and Hu, 2019b; Willett *et al.*, 2019; Kent *et al.*, 2022).

Plant-based dietary indexes (PDIs) (which positively weight PB foods and negatively weight animal-derived foods) have recently been developed to measure adherence to a PB dietary pattern within an omnivorous diet (Martínez-González *et al.*, 2014; Satija *et al.*, 2016; Chen *et al.*, 2018; Kim *et al.*, 2018). Furthermore, some PDIs have differentiated between PB dietary patterns by positively weighting ‘healthy’ PB foods (e.g., wholegrain cereal products) and negatively weighting 'low-quality' PB foods (e.g., refined cereal products) however, little detail is provided on what foods are categorised into each and clarity is needed to understand where some foods, such as composite foods fit within these indexes (Satija *et al.*, 2016; Chen *et al.*, 2018; Kim *et al.*, 2018).

Despite the increased media attention of PB diets and the expanding presence of PB foods on the market (Alcorta *et al.*, 2021; Smart Protein, 2021), data from national food consumption surveys continue to show that Western populations generally consume an omnivorous diet (Bates *et al.*, 2011; Irish Universities Nutrition Alliance, 2011; Juan *et al.*, 2015). While PDIs are useful in epidemiological studies for identifying associations between PB dietary patterns and health outcomes, such as type 2 diabetes and cardiovascular disease, there is still a need to understand the role of PB foods for nutritional adequacy and status in populations currently accustomed to consuming a primarily omnivorous diet. Furthermore, identifying the specific PB foods within an individual or population's diet will be useful to aid in developing public health dietary strategies with respect to PB foods and will benefit both policymakers and the food industry in understanding the position of these foods within the diets of population groups. A standardised methodology is required to identify PB foods and/or components within an omnivorous dietary pattern to provide reliable between-country comparisons. Therefore, this study aimed to develop a systematic methodology to identify the PB component of a diet, using two extremes of PB diet definitions, plant-based (all) (PB-A) which includes 'all plant-based foods' regardless of dietary quality and plant-based (healthful) (PB-H) which includes 'healthful plant-based foods' only (both of which exclude all meat and fish and place heavy restrictions on animal products, such as dairy and eggs).

Methodology

The National Adult Nutrition Survey food consumption database

This methodology for characterising the PB component of a diet was developed using the food consumption database from the Irish National Adult Nutrition Survey (NANS) (Irish Universities Nutrition Alliance, 2011) (www.iuna.net) as an example. The NANS investigated habitual food and beverage consumption (in addition to lifestyle, health indicators and attitudes to food and health) in a nationally representative sample of adults aged 18+ years living in the Republic of Ireland (*n* 1500) between 2008-2010. Food and beverage intake data (including nutritional supplements) were collected at brand level using a 4-day semi-weighed food diary. Details of recipes of composite dishes were also recorded and participants were asked to collect the packaging labels of all foods and beverages consumed over the recording period. Each food, beverage and nutritional supplement consumed during the survey was assigned an individual food code and food descriptor based on its nutritional profile resulting in 2552 unique food codes in the food consumption database. All food codes were categorised into previously defined food groups (**Table 1**), e.g., 'meat & meat products', 'breakfast cereals', 'vegetables & vegetable dishes' (Irish Universities Nutrition Alliance, 2011).

Plant-based diet definitions

Due to the significant amount of heterogeneity around the definition of a PB diet, two extremes of PB definitions were used in this study:

A. Plant-based diet including 'all plant-based foods' regardless of dietary quality (PB-A): The PB-A diet definition excluded all meat and fish including composite dishes containing even minimal quantities of animal flesh. Other animal products i.e., eggs and dairy were heavily restricted and were only included in this definition when they were a minimal component of a dish or product (<10%, typically with a functional role e.g., binding). All PB foods, such as fruit, vegetables and grains and their dishes were included, regardless of the nutritional quality of the food or beverage.

B. Plant-based diet including 'healthful plant-based foods' only (PB-H): The PB-H diet definition excluded all meat and fish including composite dishes containing even minimal quantities of animal flesh and placed heavy restrictions on eggs and dairy (as per PB-A) and additionally restricted refined and poorer quality PB foods and products. Refined PB foods and products were identified based on the description of unprocessed and minimally processed foods and beverages within the NOVA classifications described by Monteiro *et al.* (2016) and PB foods of poorer dietary quality were identified using food-based dietary guidelines (FBDG) (European Commission, 2022; Food and Agriculture Organisation of the United Nations, 2022). The PB-H diet definition included foods such as wholegrain foods and products and other minimally processed foods and beverages.

Methodology for coding PB foods

Each food code in the NANS food consumption database was examined and coded (excluded/included) into each of the PB diet definitions (PB-A and PB-H) based on a consensus from three independent researchers with qualifications in nutrition/dietetics and extensive experience in food composition and food consumption data (over 30 years collectively). Each food code was first examined for animal content, to inform the coding of PB-A and for PB-H the food code was examined based on the level of refinement (i.e., wholegrain vs refined grain) and dietary quality (i.e., foods recommended in FBDG). The food codes were examined using the packaging label ingredient list and recipe ingredients for composite dishes. The coding of complex food codes (e.g., composite dishes or retail products with minimal quantities of eggs and dairy) involved discussions between the three researchers with considerations given to the amount of egg/dairy within the food and its functionality within the dish. A novel 23-step protocol was developed which outlines the (a) exclusion and (b) inclusion criteria under each food group for both PB-A and PB-H diet definitions, with justifications and considerations outlined later (**Section 3.1**). Steps 1-5 were the same for both PB-A and PB-H, as the exclusion of animal-derived products were consistent in both definitions, but from step 6 onwards, steps were sub-divided by PB diet definition. **Table 1** provides an overview of the food groups and sub-groups identified and their exclusion or inclusion in PB-A and/or PB-H definitions.

Methodology for identifying the PB component of a diet

Step 1: Non-food items

PB-A & PB-H

a. Exclude:

i. nutritional supplements
ii. chewing gum and other non-food items

b. No inclusions

Step 2: Meat, meat dishes & products

PB-A & PB-H

a. Exclude:

i. discrete meat (e.g., raw, fried, boiled, grilled, baked, roasted), such as bacon, ham, beef, veal, lamb, pork, chicken, turkey, other poultry, game, offal

ii. meat dishes, such as Bolognese, savoury mince, chilli con carne, beef/other meat lasagne, meat stew, meat casseroles, marinated meat, meatballs, shepherd's/cottage pie, meat stir-fry, meat loaf, meat curry, meat soups and sauces, pasta/rice dishes containing meat, meat pizza

iii. meat products, such as luncheon meat, sausages, salami, pepperoni, sausage rolls, meat pies, burger patties, pâté, black and white pudding, meat stock/gravy

b. No inclusions

Note: *Meat alternative products are increasingly available on the market and using these steps, would be included in PB-A, but may be excluded in PB-H depending on level of refinement and overall dietary quality.*

Step 3: Fish & seafood, dishes & products

PB-A & PB-H

a. Exclude:

i. discrete fish and seafood (e.g., raw, fried, grilled, poached, steamed, baked, smoked), such as cod, hake, sole, plaice, haddock, salmon, mackerel, trout, tuna, prawns, oysters, other shellfish

ii. fish and seafood dishes, such as seafood chowder, fish pie, fish pizza, fish/seafood curry, fish cakes, seafood pasta/rice dishes, seafood in pastry

iii. fish and seafood products, such as breaded/battered fish, battered prawns, fish fingers, fish pâté, tinned fish, sushi, fish soup or sauce

b. No inclusions

Note: *Fish alternative products are increasingly available on the market and using these steps would be included in PB-A, but may be excluded in PB-H depending on level of refinement and overall dietary quality.*

Step 4: Eggs & egg dishes

PB-A & PB-H

a. Exclude:

i. discrete eggs (e.g., raw, fried, scrambled, boiled, poached, baked)

ii. egg dishes, such as omelettes, scotch eggs, quiches, French toast, egg fried rice

b. No inclusions

Note: *Egg alternative products are increasingly available on the market and using these steps these would be included in PB-A, but may be excluded in PB-H depending on level of refinement and overall dietary quality.*

Step 5: Dairy & dairy products

PB-A & PB-H

a. Exclude:

i. milks and milk products, such as any animal milk, buttermilk, dried milk, evaporated milk, milk-based drinks, such as milkshakes, milkshake-style drinks
ii. creams and cream products, such as fresh, pre-whipped, soured, crème fraiche
iii. cheese and cheese products, such as cream cheese, processed cheese, fromage frais
iv. yogurts and yogurt drinks
v. butter and animal fats, such as lard, suet, dripping
vi. Dairy and blended dairy spreads

b. No inclusions

Step 6: Non-dairy alternatives

PB-A

a. No exclusions

b. Include:

i. non-dairy alternative drinks, such as soya, oat, almond, coconut, rice
ii. non-dairy alternative yogurts, such as soya products
iii. non-dairy alternative cheeses, such as soya, nut and other cheese alternatives
iv. non-dairy alternative fat spreads, such as soya and other dairy-free spreads

PB-H

a. Exclude:

i. sweetened and/or unfortified non-dairy alternative drinks, such as soya, oat, almond, coconut, rice
ii. sweetened and/or unfortified non-dairy alternative yogurts, such as soya products

iii. non-dairy alternative cheeses, such as soya, nut and other cheese alternatives (highly refined)
iv. non-dairy alternative fat spreads, such as soya spread and other dairy-free spreads (highly refined)

b. Include:

i. unsweetened and (at least) calcium-fortified (for nutritional equivalence) non-dairy alternative drinks, such as soya, oat, almond, coconut, rice
ii. unsweetened and (at least) calcium-fortified (for nutritional equivalence) non-dairy alternative yogurts, such as soya products

Step 7: Vegetables & vegetable dishes

PB-A

a. Exclude:

i. dairy-based vegetable dishes, such as cauliflower cheese, lentils in cream or vegetable dishes made up with dairy cream sauces or cheese sauces, such as vegetable lasagne, moussaka
ii. vegetables cooked in animal fat (e.g., lard, suet, dripping)
iii. salads or vegetables with a mayonnaise-based sauce, such as Waldorf salad, coleslaw, Florida salad

b. Include:

i. discrete vegetables, (e.g., fresh, frozen, tinned, pickled, boiled, steamed, fried, roasted, juiced), including foods consumed as vegetables (i.e., tomatoes, olives, avocados), such as salad vegetables, root vegetables, green vegetables, legumes, pickled gherkins, tomato juice
ii. vegetables with or cooked in minimal proportions of butter, or dairy or non-dairy alternative fat spreads, such as carrots mashed with butter
iii. vegetable dishes containing no or minimal proportions of animal-derived ingredients, such as ratatouille, bean and vegetable stew, tofu and tofu dishes
iv. refined or other vegetable dishes and products, which may contain minimal proportions of animal-derived ingredients (egg and/or dairy), such as battered or deep-fried vegetables, vegetables in pastry, retail vegetable burgers, vegetarian products, such as mycoprotein products and dishes, other ‘meat-free’ products, takeaway vegetable dishes and products, such as takeaway vegetable curry, takeaway vegetable spring rolls

PB-H

a. Exclude:

i. refined vegetable dishes and products, such as baked beans, battered or deep-fried vegetables, vegetables in pastry, retail vegetable burgers, vegetarian products, such as mycoprotein products and dishes, other vegetable-based meat or fish alternative products, takeaway vegetable dishes and products, such as takeaway vegetable curry, takeaway vegetable spring rolls

ii. dairy-based vegetable dishes, such as cauliflower cheese, lentils in cream or vegetable dishes made up with dairy cream sauces or cheese sauces, such as vegetable lasagne or moussaka

iii. vegetables cooked in animal fat (e.g., lard, suet, dripping)

iv. salads or vegetables with a mayonnaise-based sauce, such as Waldorf salad

b. Include:

i. discrete vegetables, (e.g., fresh, frozen, tinned, pickled, boiled, steamed, fried, roasted, juiced), such as salad vegetables, root vegetables, green vegetables, legumes

ii. vegetables with or cooked in butter, or dairy or non-dairy alternative fat spreads, such as carrots mashed with butter

iii. unrefined vegetable dishes containing no or minimal proportions of animal-derived ingredients, such as ratatouille, bean and vegetable stew

iv. tofu and tofu dishes containing no or minimal proportions of animal-derived ingredients

Step 8: Fruit & fruit juices

PB-A

a. Exclude:

i. fruit smoothies made with dairy yogurt or milk

b. Include:

i. discrete fruit (e.g., fresh, frozen, dried, puréed, stewed (with or without sugar)), such as bananas, dried apricots, stewed apple

ii. tinned fruit, in juice or syrup

iii. candied fruit, such as glacé cherries, crystallised ginger, candied orange peel

iv. fruit or fruit and vegetable juices and smoothies made without dairy

PB-H

a. Exclude:
   i. puréed or stewed fruit (with sugar)
   ii. fruit tinned in juice/syrup
   iii. candied fruit, such as glacé cherries, crystallised ginger, candied orange peel
   iv. fruit juice and smoothies

b. Include:
   i. discrete fruit (e.g., fresh, frozen, dried, puréed, stewed (without sugar)), such as bananas, dried apricots, stewed apple (without sugar)

Step 9: Potatoes & potato dishes

PB-A

a. Exclude:
   i. dairy-based potato dishes, such as potato gratin, creamy potatoes, cheese and potato pies
   ii. potatoes cooked in animal fat (e.g., lard, suet, dripping)
   iii. potato salad with mayonnaise (egg-based)

b. Include:
   i. discrete potatoes (e.g., fried, boiled, steamed, baked, roasted), such as boiled/mashed potato (without butter/milk etc.), potatoes fried or roasted in vegetable oil
   ii. potatoes mashed with minimal proportions of milk, butter or cream, or dairy or other spreads
   iii. potato products, such as potato waffles, croquettes, potato cakes, potato fritters, deep-fried chips, potato wedges
   iv. potato dishes containing no or minimal proportions of animal-derived ingredients, such as potato stuffing

PB-H

a. Exclude:
   i. refined potato products, such as potato waffles, croquettes, potato cakes, potato fritters, deep-fried chips, potato wedges
   ii. dairy-based potato dishes, such as potato gratin, creamy potatoes, cheese and potato pies
   iii. potatoes cooked in animal fat (e.g., lard, suet, dripping)
   iv. potato salad with mayonnaise (egg-based)

b. Include:

i. discrete potatoes (e.g., fried, boiled, steamed, baked, roasted), such as boiled and mashed potato (without butter/milk etc.), potatoes fried or roasted in vegetable oil
ii. potatoes mashed with minimal proportions of milk, butter or cream, or dairy or other spreads
iii. unrefined potato dishes made with no or minimal proportions of animal-derived ingredients, such as potato stuffing

Step 10: Breads

PB-A

a. Exclude:

i. breads made with dairy, such as cheese bread, cheese scones, garlic bread (made with butter or dairy spreads), naan bread (made with yogurt), soda bread (made with buttermilk)

b. Include:

i. white, white with added fibre, brown (non-wholemeal/wholegrain breads) and wholemeal/wholegrain breads, such as sliced loaves, pitta breads, rolls, bagels, wraps
ii. other white, brown and wholemeal/wholegrain breads, such as white, brown and wholemeal scones, barm brack, malt bread, English muffins, fried bread

PB-H

a. Exclude:

i. refined white (including homemade), white with added fibre and brown breads (non-wholemeal/wholegrain breads), such as sliced loaves, pitta breads, rolls, bagels, wraps
ii. unrefined wholemeal/wholegrain bread made with dairy, such as cheese bread, garlic bread (made with butter or dairy spreads), naan bread (made with yogurt), soda bread (made with buttermilk)
iii. scones, such as sweet, wholemeal and cheese

b. Include:

i. wholemeal/wholegrain breads, such as sliced loaves, pitta, rolls, bagels, wraps

Step 11: Breakfast cereals

PB-A

a. Exclude:

i. porridge and hot oat cereals made up with dairy

b. Include:

i. ready-to-eat breakfast cereals (RTEBC) (without dairy products added)

ii. porridge and hot oat cereals made up without dairy, such as made with water and/or non-dairy alternative drinks

PB-H

a. Exclude:

i. refined RTEBC and refined hot oat cereals

ii. porridge made up with dairy

b. Include:

i. wholegrain RTEBC**,** such as wheat biscuits, shredded wheat-type cereals, no added sugar muesli

ii. porridge made up without dairy, such as made with water and/or unsweetened and (at least) calcium-fortified non-dairy alternative drinks

Step 12: Rice, pasta, flours, grains & starches

PB-A

a. Exclude:

i. dairy-based dishes and products based on rice, pasta, flours, grains and starches, such as cheese pizza, macaroni cheese, cheese pastry

ii. dishes and products based on rice, pasta, flours, grains and starches made with or cooked in animal fat (e.g., lard, suet, dripping), such as dumplings

iii. batter, used to make sweet and savoury pancakes, waffles, Yorkshire pudding etc.

b. Include:

i. discrete rice and pasta, refined and wholegrain, flours, discrete grains and starches

ii. dishes and products based on rice, pasta, flours, grains and starches, containing no or minimal proportions of animal-derived ingredients, such as vegetable risotto, pasta bake, tinned spaghetti, noodles, bread stuffing

PB-H

a. Exclude:

i. refined rice, pasta, flours, grains and starches, such as white rice, white pasta, semolina, white flour
ii. dishes and products based on refined rice, pasta, flours, grains and starches, such as risotto, pasta salad, pasta bake, pizza dough, pastry dishes, tinned spaghetti, bread stuffing
iii. dairy-based dishes and products based on unrefined rice, pasta, flours, grains and starches
iv. batter, used to make sweet and savoury pancakes, waffles, Yorkshire pudding etc.

b. Include:

i. discrete brown rice, whole-wheat pasta, wholemeal flours and whole grains, such as bulgur wheat, oats, quinoa
ii. dishes based on unrefined rice, pasta, flours, grains and starches, such as brown rice or whole-wheat pasta salad containing no or minimal proportions of animal-derived ingredients (mayonnaise, cheese etc.)

Step 13: Beverages

PB-A

a. Exclude:

i. dairy-based alcoholic beverages, such as cream liqueurs
ii. tea and coffee made up with dairy, such as cappuccinos, lattes, tea with milk, coffee with cream
iii. chocolate and malt drinks made up with dairy

b. Include:

i. mineral water
ii. non-dairy alcoholic beverages, such as spirits, wine, beers, cider
iii. tea (including herbal tea), coffee and similar beverages (e.g., barley drink) without dairy, such as teas, coffees and other similar beverages made up with non-dairy alternative drinks
iv. chocolate and malt drinks made up without dairy
v. carbonated beverages (with and without added sugar)
vi. fruit juice drinks, cordials, squashes and other beverages (with and without added sugar)

PB-H

a. Exclude:

i. alcoholic beverages, such as liqueurs, spirits, wine, beers, cider

ii. tea and coffee made up with dairy, such as cappuccinos, lattes, tea with milk, coffee with cream

iii. refined beverages, such as carbonated soft drinks (with and without added sugar), energy drinks, fruit juice drinks, cordials and squashes (with and without added sugar), chocolate and malt drinks

b. Include:

i. mineral water

ii. tea (including herbal tea), coffee and similar beverages (e.g., barley drink) without dairy, such as teas, coffees and other similar beverages made up with unsweetened and (at least) calcium-fortified non-dairy alternative drinks

Step 14: Soups & sauces

PB-A

a. Exclude:

i. egg-based sauces, such as mayonnaise, salad cream, horseradish sauce, tartare sauce

ii. dairy-based soups and sauces or sauces made up with dairy, such as ‘cream of’ soups, white sauce, butter sauces, pesto, tikka masala sauce

b. Include:

i. vegetable soups and sauces containing no or minimal proportions of animal-derived ingredients

PB-H

a. Exclude:

i. refined soups and sauces, such and dried soup mixes, retail soups and sauces such as tomato sauce, curry sauces, pasta sauces

ii. egg-based sauces, such as mayonnaise, salad cream, horseradish sauce, tartare sauce

iii. dairy-based soups and sauces or sauces made up with dairy, such as ‘cream of’ soups, white sauce, butter sauces, pesto, tikka masala sauce

b. Include:

i. unrefined vegetable soups and sauces containing no or minimal proportions of animal-derived ingredients (including homemade and freshly made in-store soups)

Step 15: Oils

PB-A

a. No exclusions

b. Include:

i. seed, vegetable and nut oils and products

PB-H

a. Exclude:

i. oil products which do not contain 100% oil, such as some spray/low-calorie oils

b. Include:

i. seed, vegetable and nut oils (100% oil)

Step 16: Biscuits & crackers

PB-A

a. No exclusions

b. Include:

i. biscuits and crackers, such as plain and chocolate biscuits, cream crackers, table crackers, wholegrain crackers

PB-H

a. Exclude:

i. biscuits and refined crackers, such as plain and chocolate biscuits, cream crackers, table crackers

b. Include:

i. wholegrain crackers, such as wholegrain oat cakes, wholegrain crackerbread, wholegrain rye crackers

Step 17: Cakes, pastries & buns

PB-A

a. Exclude:

i. dairy-based cakes, pastries and buns, such as cream horns, cream eclairs, cream cakes, cream doughnuts

ii. custard cakes, pastries and buns, such as custard doughnuts, custard pastries

b. Include:

i. non-dairy or custard-based cakes, pastries and buns, such as tarts, hot cross buns, madeira, plain doughnuts, fruit cake

PB-H

a. Exclude:

i. cakes, pastries and buns

b. No inclusions

Step 18: Puddings & desserts

PB-A

a. Exclude:

i. dairy-based puddings and desserts, such as ice cream, milk puddings, rice pudding, cream puddings and desserts, cheesecake, mousse, bread and butter pudding, cream trifle

ii. meringue-based puddings and desserts, such as pavlova, queen of puddings, meringue pie

iii. custard and custard puddings and desserts, such as custard flan, crème brûlée, crème caramel, custard trifle

b. Include:

i. puddings and desserts not based on dairy or egg, such as sponge puddings, tarts, fruit pies, jelly

PB-H

a. Exclude:

i. puddings and desserts, such as ice-creams, milk puddings, custard puddings, tarts, flans, pavlova, trifle, sponge puddings

b. No inclusions

Step 19: Sugar, sweeteners, syrups & preserves

PB-A

a. Exclude:

i. intense sweeteners (used by consumers, rather than intense sweeteners added to products)

ii. fruit curds (made with butter)

b. Include:
   i. sugar (all types)
   ii. jams and marmalades
   iii. syrups and honey

PB-H

a. Exclude:
   i. sugar, intense sweeteners (used by consumers, rather than intense sweeteners added to products), syrups and preserves, such as jams, marmalades, honey, maple syrup

b. No inclusions

Step 20: Chocolate confectionery

PB-A

a. No exclusions

b. Include:
   i. chocolate confectionery, such as chocolate bars, chocolate covered fruit and nuts, chocolate covered rice cakes, chocolate spread

PB-H

a. Exclude:
   i. chocolate confectionery, such as chocolate bars, chocolate covered fruit and nuts, chocolate covered rice cakes, chocolate spread

b. No inclusions

Step 21: Non-chocolate confectionery

PB-A

a. No exclusions:

b. Include:
   i. non-chocolate confectionery, such as cereal bars, ice lollies and sweets

PB-H

a. Exclude:
   i. non-chocolate confectionery, such as cereal bars, ice lollies and sweets

b. No inclusions

Step 22: Savoury snacks

PB-A

a. Exclude:

i. prawn crackers (containing fish/seafood)

b. Include:

i. crisps and popcorn (all types and flavours), Bombay mix, papadums

PB-H

a. Exclude:

i. savoury snacks, such as crisps (all types and flavours) and salted, butter or flavoured popcorn, Bombay mix, papadums

b. Include:

i. unsalted popcorn

Step 23: Nuts, seeds, herbs & spices

PB-A

a. No exclusions

b. Include:

i. plain, salted or roasted nuts and seeds

ii. nut/seed spreads, such as peanut butter

iii. fresh or dried herbs and spices

PB-H

a. Exclude:

i. salted nuts and seeds and nut/seed spreads (except for 100% wholegrain nut/seed spreads)

b. Include:

i. unsalted nuts and seeds, roasted nuts and seeds and 100% nut/seed spreads

ii. fresh or dried herbs and spices

Results and discussion

The aim of this study was to develop a novel systematic methodological approach to identify the PB component of the diet of an individual or population using two extremes of PB diet definitions: plant-based (all) (PB-A) and plant-based (healthful) (PB-H) diets as displayed in **Figure 1**. Both PB diets excluded meat and fish including composite dishes containing even minimal quantities of animal flesh and placed heavy restrictions on eggs and dairy products. The PB-H further excluded refined PB foods and products and included PB foods traditionally described as being of better dietary quality and recommended within FBDG, such as wholegrain foods and products and other minimally processed foods and beverages. This methodological approach and the literature supporting the decisions are discussed below by food group to complement general FBDG.

Meat, fish, eggs, dairy & alternatives

PB diets typically exclude or restrict animal-derived foods and products, i.e., meat, fish, eggs and dairy (Tuso *et al.*, 2015; Eichelmann *et al.*, 2016; McMacken and Shah, 2017; Ostfeld, 2017; Patel *et al.*, 2017; Satija *et al.*, 2017; Satija and Hu, 2018; Storz, 2018; Toumpanakis *et al.*, 2018). In efforts to provide substitutes for these products and the nutrients that they provide, a variety of meat, fish, egg and dairy (i.e., milk, yogurt, cheese, cream, butter) alternatives have been (and are continually being) developed (Gorrepati *et al.*, 2015; Alcorta *et al.*, 2021; Montemurro *et al.*, 2021). These substitutes are typically made from processed PB components, such as soya and other beans, peas, mushrooms, wheat and other grains, mycoprotein, microalgae and nuts and seeds and generally attempt to mimic their animal-derived alternative in terms of texture and appearance (Curtain and Grafenauer, 2019; Hemler and Hu, 2019a; Grossmann *et al.*, 2021; Montemurro *et al.*, 2021).

Figure 2 presents the categorisation of meat, fish, eggs, dairy and alternatives and their dishes into the PB-A and PB-H diet definitions. In keeping with generally accepted PB definitions, both the PB-A and PB-H diet definitions excluded all meat and fish, including discrete cuts, dishes and products as well as other dishes and products containing even minimal quantities of meat and fish. PB meat and fish alternatives were included in the PB-A diet definition but were excluded in the PB-H diet definition as these are highly processed foods and may not be recommended as part of a healthy PB diet based on their overall dietary quality (Plant-Based Health Professionals UK, 2019).

Discrete eggs and dairy products, such as eggs, egg dishes, milk, cream, yogurt, butter and dairy spreads were excluded in both definitions. Where eggs or dairy products were a lesser component of composite dishes or retail products (<10%) and typically had a role as a functional ingredient of cereal, potato or vegetable dishes, these dishes and products were included in the definition for PB-A but were only included in the PB-H diet if they were unrefined. These dishes were identified through disaggregation of recipes of composite dishes or product labels and are described later under the relevant food groups. Non-dairy and egg alternatives as well as non-dairy alternative fat spreads, such as sunflower, olive and soya were included in the PB-A diet definition but most were excluded in the PB-H diet definition due to their high levels of processing and high fat and salt content (Plant-Based Health Professionals UK, 2019). Non-dairy alternative drinks and yogurts were included in the PB-H diet definition if they were unsweetened and (at least) calcium-fortified to be nutritionally equivalent to cow’s milk and yogurts as recommended in FBDG globally (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Department of Health, 2016; Public Health England, 2016; Clarkson, 2018).

Vegetables & vegetable dishes

Vegetables, including green leafy vegetables, roots and legumes as well as vegetable dishes are an integral part of all PB diet definitions. Vegetables are universally recommended in high quantities across FBDG globally, in line with the World Health Organisation guidance to eat at least 400g of fruit and vegetables a day (World Health Organisation, 2005; Herforth *et al.*, 2019). Some vegetable dishes and products, however, can contain a variable amount of animal-derived ingredients, can be highly refined and lower in nutritional quality and therefore should be assessed for content of animal-derived ingredients and nutritional quality.

Figure 3 presents the categorisation of vegetables and vegetable dishes into the PB-A and PB-H diet definitions. In this methodological approach, both the PB-A and PB-H diet definitions excluded vegetable dishes and products which contained a high proportion of eggs (in the form of mayonnaise), such as Waldorf salad, coleslaw and Florida salad, or dairy, such as cauliflower cheese, lentils in cream or vegetable dishes made up with cream sauces or cheese sauces, such as vegetable lasagne or moussaka. Furthermore, vegetable dishes which contained or were cooked in the fat from the body of animals, e.g., lard, suet and dripping, were excluded.

Vegetables, including dishes and products containing no animal-derived ingredients or low quantities of eggs or dairy were included in the PB-A diet definition. This included discrete vegetables, vegetable products, such as baked beans, retail vegetable burgers, Kievs and pâté and some vegetable dishes, including tofu. Refined vegetable dishes and products, such as fried vegetables, takeaway dishes, vegetables in pastry or batter and mashed vegetables were also included in the PB-A. Discrete vegetables including unrefined vegetable dishes and tofu dishes containing no or minimal animal-derived ingredients were included in the PB-H diet definition and refined vegetable dishes and products were excluded on the basis that fried and refined vegetable products contain added fat and salt and are not recommended in FBDG (Department of Health, 2016; Monteiro *et al.*, 2016).

Vegetable dishes made with non-dairy alternatives were included in the PB-A diet definition, but only vegetable dishes made with unsweetened and (at least) calcium-fortified non-dairy alternative drinks and yogurts were included in the PB-H diet definition.

Fruit & fruit juices

As with vegetables, fruits are a fundamental component of PB diet definitions. FBDG globally recommend fruit, along with vegetables to be consumed liberally as part of a healthy diet (World Health Organisation, 2005; Herforth *et al.*, 2019). However, not all fruit dishes and products contribute towards a healthful diet and many FBDG suggest limiting intake of some fruit products, such as fruit juice and smoothies due to their free sugar content (Scientific Advisory Committee on Nutrition, 2015; World Health Organisation, 2015). Additionally, some fruit products, such as smoothies can contain a significant amount of animal-derived ingredients and therefore should be examined based on ingredients and nutritional quality (Department of Health, 2016; Satija *et al.*, 2016; Kim *et al.*, 2018; Herforth *et al.*, 2019).

Figure 4 presents the categorisation of fruit and fruit juices into the PB-A and PB-H diet definitions. In this methodological approach, both the PB-A and PB-H diet definitions excluded fruit smoothies made with dairy. Fruit smoothies made without dairy as well as fruit juice were included in the PB-A diet definition but excluded in the PB-H diet definition on the basis that FBDG generally recommend limiting intakes of fruit juice and smoothies (Food Safety Authority of Ireland, 2011; Herforth *et al.*, 2019)

Fruit, including dishes and products containing no animal-derived ingredients, such as fresh, frozen or dried fruit, puréed fruit, fruit stewed with or without sugar, tinned fruit (in fruit juice or syrup) and candied fruit, such as glacé cherries, crystallised ginger and candied orange peel were included in the PB-A diet definition. Only discrete fruit (fresh, frozen, dried, puréed and fruit stewed without sugar), were included in the PB-H diet definition on the basis that FBDG recommend limiting sugar intake including that from fruit juice (Hebden *et al.*, 2017; Rong *et al.*, 2021).

Potatoes & potato dishes

In general, PB diet definitions include fresh, unprocessed potatoes. Potatoes are often included in FBDG and are an important starchy carbohydrate source, contributing energy, dietary fibre (when skins are eaten), vitamins and minerals (Department of Health, 2016; Herforth *et al.*, 2019). Some potato dishes and products, however, can contain a variable amount of animal-derived ingredients, can be highly refined and lower in nutritional quality and therefore should be assessed for content of animal-derived ingredients and nutritional quality (Satija *et al.*, 2016; Kim *et al.*, 2018; Hemler and Hu, 2019a).

Figure 5 presents the categorisation of potatoes and potato dishes into the PB-A and PB-H diet definitions. In this methodological approach, both the PB-A and PB-H diet definitions excluded potato dishes which contained a high proportion of eggs or dairy, identified through disaggregation of recipes of composite dishes or product labels. These included creamy potatoes, potato gratin, Dauphinoise potatoes, cheese and potato pies and potato salad made with mayonnaise (egg-based). Furthermore, potato dishes which contained or were cooked in the fat from the body of animals, e.g., lard, suet and dripping, were excluded.

Potatoes and potato dishes containing no animal-derived ingredients or low quantities of eggs or dairy, including discrete potatoes, potato products, potato stuffing and mashed potatoes were included in the PB-A diet definition. Refined potato dishes and products, such as fried potatoes, potato chips (fries), croquettes, waffles, wedges, hash browns were included in the PB-A but excluded in the PB-H diet definition on the basis that fried and refined potato products contain high proportions of fat and salt and are not recommended in FBDG (Monteiro *et al.*, 2016; Rong *et al.*, 2021).

Potato dishes made with any non-dairy alternatives were included in the PB-A diet definition, but only potato dishes made with unsweetened and (at least) calcium-fortified non-dairy alternative drinks and yogurts were included in the PB-H diet definition.

Cereals & cereal products

Generally, all PB diet definitions include cereals, such as wheat, rice, corn, barley, rye, oats and millet and their grains, as well as grains from other crops, which are similar to cereals, such as quinoa (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Eichelmann *et al.*, 2016; Toumpanakis *et al.*, 2018; Rees *et al.*, 2019). However, cereal-based dishes and products can vary in nutritional quality and can also contain varied quantities of animal-derived ingredients and therefore should be examined based on ingredients (Satija *et al.*, 2017; Kim *et al.*, 2018; Hemler and Hu, 2019a; Qian *et al.*, 2019).

Figure 6 presents the categorisation of cereals and cereal products, including cereal dishes, into the PB-A and PB-H diet definitions. In this methodological approach, both the PB-A and PB-H diet definitions excluded cereal dishes and products which contained a high proportion of eggs and/or dairy, identified through disaggregation of recipes of composite dishes or product labels. This included breads, such as soda bread (buttermilk), garlic bread (butter or dairy spreads), cheese bread, cheese scones, English muffins (egg) and naan bread (yogurt), porridge and hot oat cereals made up with milk, and cereal dishes, such as cheese pizza, lasagne, macaroni cheese, cheese pastry. Batter, used to make pancakes, waffles, Yorkshire puddings etc., were also excluded in both the PB-A and PB-H definitions due to a high proportion of animal-derived ingredients (egg and dairy), in contrast to previous literature, which included these products as part of an ‘unhealthy PDI’, as refined grain products (Satija *et al.*, 2016). Furthermore, cereal dishes which contained or were cooked in the fat from the body of animals, e.g., lard, suet and dripping were excluded.

Cereals and cereal products containing no animal-derived ingredients or small amounts of eggs or dairy products, such as most breads, RTEBC, bread stuffing, some pasta and rice dishes, were included in the definition of the PB-A diet but refined cereals and products were excluded from the PB-H diet definition on the basis that they are not generally recommended in FBDG due to the removal of fibre (European Food Information Council, 2011; Food Safety Authority of Ireland, 2011).

Cereal products, whether refined or wholegrain, made with any non-dairy alternatives, for example, garlic bread made with non-dairy alternative fat spreads or porridge made with non-dairy alternative drinks were included in the PB-A diet definition. Only wholegrain cereal dishes made with unsweetened and (at least) calcium-fortified non-dairy alternative drinks and yogurt were included in the PB-H diet definition.

Beverages

Beverages, other than those already discussed (i.e., milk and non-dairy alternative drinks and fruit juice), are scarcely mentioned in PB diet definitions. Coffee, tea and chocolate are generally acknowledged as PB foods as they are made from plant products (Agudo, 2005).

Figure 7 presents the categorisation of beverages into the PB-A and PB-H diet definitions. All beverages made up with dairy were excluded under both definitions, such as milky tea or coffee, or a hot chocolate or malt beverage made up with milk or cream.

Mineral water, tea (including herbal teas), coffee and other PB beverages, such as barley drinks, made without dairy were included under both PB diet definitions. Alcoholic beverages (except those with a high proportions of dairy, such as cream liqueurs), were included in the PB-A diet definition, as alcohol is generally a PB beverage, but are excluded in the PB-H as it is acknowledged that alcohol is not needed or recommended for health (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Department of Health, 2016). Carbonated beverages (with and without sugar), energy drinks, fruit juice drinks, cordials and squashes (with and without added sugar) and chocolate and malt drinks made up without dairy were included in the PB-A diet definition but excluded in the PB-H diet definition as these beverages can contain added sugar, are highly refined and processed and are, generally, not recommended as part of FBDG (World Health Organisation, 2015; Department of Health, 2016; Monteiro *et al.*, 2016). Although 'diet' and sugar-free drinks do not contain added sugar, frequent consumption can still damage teeth and they are not recommended for good dental health (Food Safety Authority of Ireland, 2011; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; World Health Organisation, 2015).

Beverages made up with non-dairy alternative drinks, such and tea, coffee, chocolate and malt drinks etc. were included under the PB-A diet definition but only tea, coffee, barley drinks or other grain beverages made with unsweetened and (at least) calcium-fortified non-dairy alternative drinks were included in the PB-H diet definition e.g., tea with unsweetened and (at least) calcium-fortified non-milk alternative drinks.

Foods high in fat, salt & sugar

Foods high in fat, salt and sugar, (including soups, sauces and other miscellaneous foods) are often not characterised in PB diet definitions.

Figure 8 presents the categorisation of foods high in fat, salt and sugar (including soups, sauces and miscellaneous foods) into the PB-A and PB-H diet definitions. In this methodological approach, intense sweeteners (used by consumers, rather than intense sweeteners added to products) were excluded under both PB-A and PB-H diet definitions as these are non-nutritive or provide little nutrition (American Dietetic Association, 2004; Gardner *et al.*, 2012).

Where dairy or eggs were a large component of the dish, identified through disaggregation of recipes of composite dishes or product labels, these foods were excluded in both diet definitions. This included cakes, pastries, buns, puddings, desserts and preserves which contained large amounts of dairy, eggs or custard, such as cream cakes, custard tarts, ice cream, milk puddings, cheesecake, meringue, crème caramel, trifle and fruit curds. Similarly, soups and sauces containing large proportions of dairy or eggs were excluded in both diet definitions. This included 'cream of' soups, white sauce or those made up with dairy, mayonnaise, salad cream and thousand island dressing.

Other cakes, pastries, buns, puddings, desserts and preserves which contained no or minimal proportions of animal-derived ingredients were included in the PB-A diet definition but were excluded in the PB-H diet definition as these high sugar/fat foods are not recommended as part of FBDG (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Department of Health, 2016; Public Health England, 2016; Rong *et al.*, 2021). This included tarts, hot cross buns, madeira, doughnuts, fruit cake, muffins, sponge cakes and puddings, mince pies, fruit crumble, fruit pies, jelly, sorbet, non-dairy ice-cream jams and marmalades. Vegetable soups and sauces containing no or minimal animal-derived ingredients were included in the PB-A diet definition, but refined soups and sauces, such as dried soup and sauce mixes, tomato sauce, curry etc. were excluded under the PB-H diet definition as these foods are highly processed and are not generally recommended in FBDG (Monteiro *et al.*, 2016).

Biscuits and crackers, chocolate and non-chocolate confectionery and savoury snacks were included in the PB-A diet definition (with the exception of prawn crackers due to the presence of fish/seafood) but only wholegrain crackers and plain, unsalted popcorn, were included in the PB-H diet definition on the basis that they contribute to healthy wholegrain intakes (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). All sugar, syrups and honey were included in the PB-A diet definition but excluded in the PB-H diet definition due to their free sugar content (Scientific Advisory Committee on Nutrition, 2015; World Health Organisation, 2015).

All seed, vegetable and nut oils, such as olive, rapeseed, sunflower, blended vegetable, walnut, peanut, grapeseed, sesame and soya oil and oil products such as spray oils, used for cooking or as dressings, were included under the PB-A diet definition but refined spray/low-calorie oils, which do not contain 100% oil, were excluded from the PB-H diet definition, on the basis that refined oils are not recommended as part of a healthy PB diet (Plant-Based Health Professionals UK, 2019).

Nuts, seeds, herbs & spices

Nuts and seeds play an important role in PB diets and are generally accepted under all PB diet definitions, along with herbs and spices (Agudo, 2005; Tuso *et al.*, 2013; McMacken and Shah, 2017; Ostfeld, 2017; Toumpanakis *et al.*, 2018).

Figure 9 presents the categorisation of nuts, seeds, herbs and spices into the PB-A and PB-H diet definitions. In this methodological approach, all nuts and seeds, including nut/seed spreads and herbs and spices were included in the PB-A diet definitions but salted nuts and seeds and nut/seed spreads containing added oils or sugar were excluded in the PB-H diet definition on the basis that added fat, salt and sugar are generally not recommended by FBDG (Herforth *et al.*, 2019). Only unsalted nuts and seeds and 100% wholegrain nut/seed spreads, herbs and spices were included in the PB-H diet definition.

Strengths and limitations of proposed method

To the authors' knowledge, this is the first study to describe a methodological approach to identify PB foods/components within an omnivorous diet based on actual food consumption data from an omnivorous population group. The detailed methodology used in this study was informed by the best available literature and reviewed by three independent researchers to reduce subjectivity. The food consumption database used to inform this methodology is based on data gathered between 2008-2010 in the adult population of Ireland and so does not capture some of the more recent foods and beverages on the market, such as many emerging meat, fish, egg and dairy alternatives, e.g., 'meat' burger patties, and sausages, cultured meat products, 'fish' cakes, fishless fingers, egg replacer, or culturally specific foods from other countries. However, the categorisation of different foods, beverages, dishes and products are systematically detailed in the method steps and decisions are discussed throughout the text in the context of the available literature. This detail allows the methodology to be easily adapted in line with continually changing dietary patterns and to account for new and emerging animal alternative products or foods with traditional origin which were not consumed in this database of adults in Ireland, but which may be consumed in other databases.

Conclusions

PB diets are garnering increasing attention and a global shift towards a more PB diet has been recommended for both health and environmental sustainability. The prevalence and demographics of those who consume a PB diet (or PB foods within an omnivorous diet) and the contribution of PB foods to energy and nutrient intakes and nutritional adequacy has not been widely studied, owing in part to the variations in definitions. As data from national food consumption surveys continues to show that Western populations generally consume an omnivorous diet, there remains a need to understand the role of PB foods in the diets of populations or individuals using standardised methods for reliable between-country comparisons.

This study has developed a systematic methodology to identify two extremes of PB diet definitions: the PB-A and PB-H component of a diet, using the Irish National Adult Nutrition Survey (NANS) (2008-2010) food consumption dataset as an example. This study was informed based on the best available literature and discussed in detail to allow the method to be easily adapted to other food databases to allow for more in-depth research on the relationship between PB foods and nutrition and health markers (within an omnivorous diet) and to construct PB dietary quality indexes for population groups. It is proposed that this novel systematic methodology be considered as a standardised approach to improve cross-study comparison and will be useful for researchers, health care professionals, policymakers and the food industry to understand the role of PB foods within the diet of populations or individuals.

Table 1. Categorisation (exclusion/inclusion) of food sub-groups into the plant-based (all) (PB-A) and plant-based (healthful) (PB-H) diet definitions

Food group	Sub-group	PB-A	PB-H
Non-food items			
Non-food items	Nutritional supplements	✗	✗
	Chewing gum	✗	✗
Meat, fish, eggs & dairy			
Meat, meat dishes & products	Discrete meat	✗	✗
	Meat dishes	✗	✗
	Meat products	✗	✗
Fish & seafood, dishes & products	Discrete fish & seafood	✗	✗
	Fish & seafood dishes	✗	✗
	Fish & seafood products	✗	✗
Eggs & egg dishes	Discrete eggs	✗	✗
	Egg dishes	✗	✗
Dairy & dairy products	Milk & milk products	✗	✗
	Cream & cream products	✗	✗
	Cheese & cheese products	✗	✗
	Yogurt & yogurt drinks	✗	✗
	Butter & animal fat (e.g., lard, suet, dripping)	✗	✗
	Dairy spreads & blended dairy spreads	✗	✗
Non-dairy alternatives			
Non-dairy alternative drinks	Non-dairy alternative drinks (sweetened & unfortified)	✓	✗
	Non-dairy alternative drinks (unsweetened & at least calcium-fortified)	✓	✓
Non-dairy alternative yogurts	Non-dairy alternative yogurts (sweetened & unfortified)	✓	✗
	Non-dairy alternative yogurts (unsweetened & at least calcium-fortified)	✓	✓
Non-dairy alternative cheeses	Non-dairy alternative cheeses	✓	✗
Non-dairy alternative fat spreads	Non-dairy alternative fat spreads	✓	✗
Vegetables & vegetable dishes			
Vegetables	Discrete vegetables	✓	✓
	Vegetables cooked in animal fat (e.g., lard, suet, dripping)	✗	✗

Food group	Sub-group	PB-A	PB-H
Vegetable dishes & products	Dairy-based vegetable dishes	✗	✗
	Salads/vegetables with a mayonnaise-based sauce	✗	✗
	Vegetables with/cooked in butter/dairy fat spreads/other fat spreads	✓	✓
	Vegetables in batter/breadcrumbs	✓	✗
	Other vegetable & vegetarian products (e.g., ‘meat free’ products)	✓	✗
	Refined vegetable dishes containing no/minimal animal-derived ingredients	✓	✗
	Unrefined vegetable dishes containing no/minimal animal-derived ingredients	✓	✓
	Tofu & tofu dishes containing no/minimal animal-derived ingredients	✓	✓
Fruit & fruit juices			
Fruit	Discrete fruit	✓	✓
	Puréed or stewed fruit with added sugar	✓	✗
	Fruit tinned in juice/syrup	✓	✗
	Candied fruit	✓	✗
Fruit juice & smoothies	Fruit smoothies made with dairy	✗	✗
	Fruit juice/fruit and vegetable juices & smoothies made without dairy	✓	✗
Potatoes & potato dishes			
Potatoes	Discrete potatoes	✓	✓
	Potatoes cooked in animal fats (e.g., lard, suet, dripping)	✗	✗
Potato dishes & products	Dairy-based potato dishes	✗	✗
	Potato salad with mayonnaise	✗	✗
	Refined potato products	✓	✗
	Potatoes mashed with no/minimal milk/butter/cream/dairy fat spreads/other fat spreads	✓	✓
	Unrefined potato dishes made with no/minimal animal-derived ingredients	✓	✓
Cereals & cereal products			
Breads	Breads made with dairy	✗	✗
	Wholegrain breads	✓	✓
	Refined breads	✓	✗
	Other breads	✓	✗
Breakfast cereals	Refined ready-to-eat breakfast cereals	✓	✗
	Wholegrain ready-to-eat breakfast cereals	✓	✓
	Porridge & hot oat cereals made up with milk	✗	✗

Food group	Sub-group	PB-A	PB-H
	Porridge made up without milk	✓	✓
	Hot oat cereals made up without milk	✓	✗
Rice, pasta, flours, grains & starches	Refined discrete rice, pasta, flours, grains & starches	✓	✗
	Wholegrain discrete rice, pasta, flours, grains & starches	✓	✓
	Dairy-based dishes & products based on rice, pasta, flours, grains & starches	✗	✗
	Dishes & products based on rice, pasta, flours, grains & starches made with/cooked in animal fat (e.g., lard, suet, dripping)	✗	✗
	Dishes & products based on refined rice, pasta, flours, grains & starches containing no/minimal animal-derived ingredients	✓	✗
	Batter used to make sweet & savoury pancakes & Yorkshire pudding	✗	✗
	Dishes based on unrefined rice, pasta, flours, grains & starches containing no/minimal animal-derived ingredients	✓	✓
Beverages			
Alcohol	Dairy-based alcoholic beverages	✗	✗
	Non-dairy alcoholic beverages	✓	✗
Tea & coffee	Tea, coffee & similar beverages made up with dairy	✗	✗
	Tea, coffee & similar beverages made up without dairy	✓	✓
Chocolate & malt beverages	Chocolate & malt drinks made up with dairy	✗	✗
	Chocolate & malt drinks made up without dairy	✓	✗
Other beverages	Carbonated beverages	✓	✗
	Cordials, squashes & other beverages	✓	✗
	Mineral water	✓	✓
Soups & sauces			
Dairy & egg-based soups & sauces	Dairy-based soups & sauces	✗	✗
	Egg-based sauces	✗	✗
Other soups & sauces	Refined vegetable soups & sauces containing no/minimal animal-derived ingredients	✓	✗
	Unrefined vegetable soups & sauces containing no/minimal animal-derived ingredients	✓	✓
Foods high in fat, salt & sugar			
Oils	Seed, vegetable & nut oils	✓	✓
	Spray oils	✓	✗
Biscuits & crackers	Biscuits & refined crackers	✓	✗

Food group	**Sub-group**	**PB-A**	**PB-H**
	Wholegrain crackers	✓	✓
Cakes, pastries & buns	Dairy-based cakes, pastries & buns	✗	✗
	Custard-based cakes, pastries & buns	✗	✗
	Other cakes, pastries & buns	✓	✗
Puddings & desserts	Dairy-based puddings & desserts	✗	✗
	Meringue-based puddings & desserts	✗	✗
	Custard & custard puddings & desserts	✗	✗
	Other puddings & desserts	✓	✗
Sugar, sweeteners, syrups & preserves	Sugar	✓	✗
	Intense sweeteners	✗	✗
	Fruit curds	✗	✗
	Jams & marmalades, syrups & honey	✓	✗
Chocolate confectionery	Chocolate confectionery	✓	✗
Non-chocolate confectionery	Non-chocolate confectionery	✓	✗
Savoury snacks	Prawn crackers	✗	✗
	Crisps, popcorn (salted/flavoured) & other savoury snacks	✓	✗
	Unsalted popcorn	✓	✓
Nuts, seeds, herbs & spices			
Nuts & seeds	Unsalted nuts & seeds	✓	✓
	Salted nuts & seeds	✓	✗
Nut/seed spreads	Nut/seed spreads (100% wholegrain)	✓	✓
	Nut/seed spreads (other)	✓	✗
Herbs & spices	Fresh/dried herbs & spices	✓	✓

PB-A: plant-based (all) PB-H: plant-based (healthful)

✓:Includes ✗:Excludes

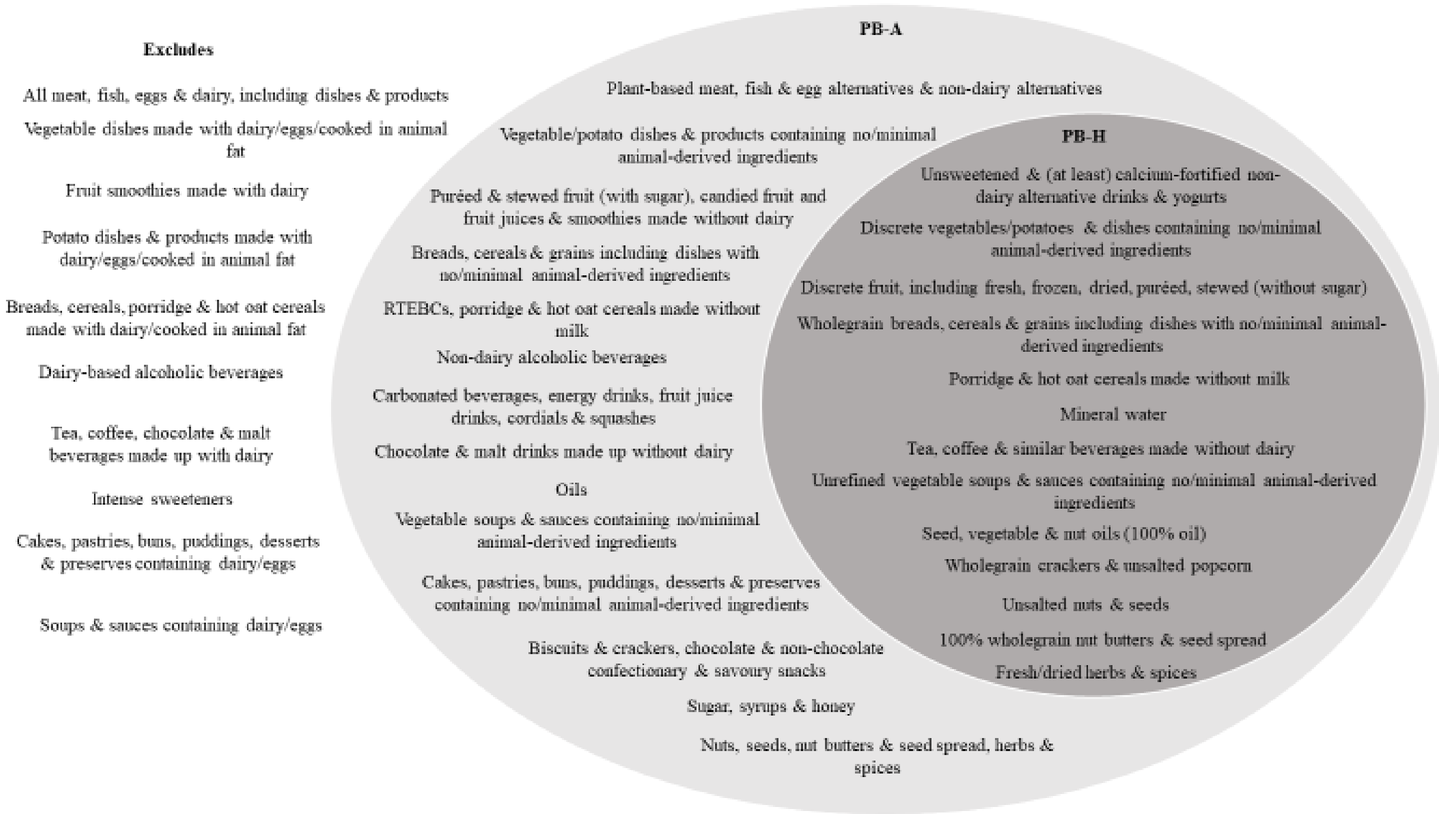

Figure 1.

Categorisation of foods & beverages under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

All foods & beverages, including products & dishes are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

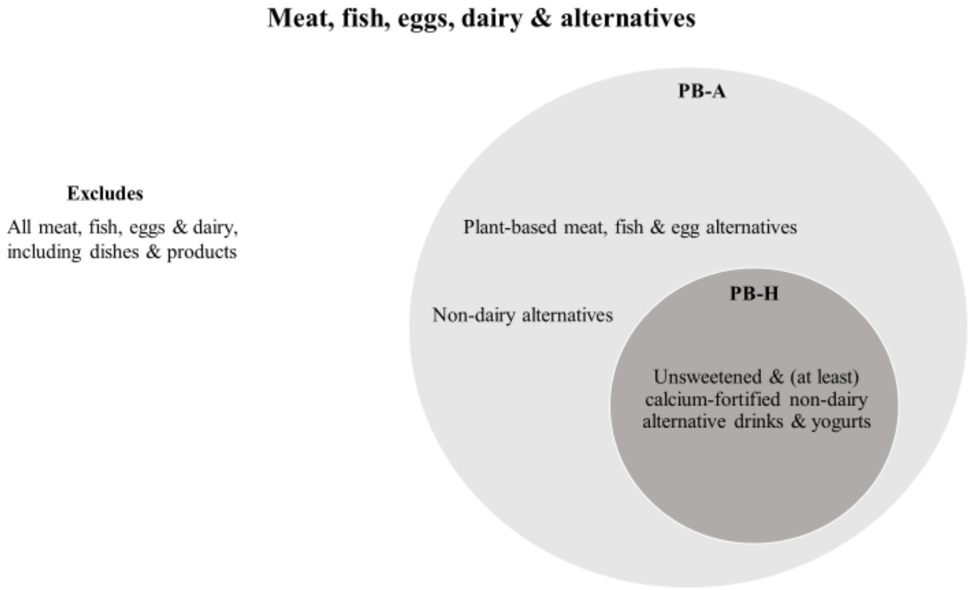

Figure 2.

Categorisation of meat, fish, eggs, dairy & alternatives under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

Meat, fish, eggs, dairy & alternatives, their dishes & products are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

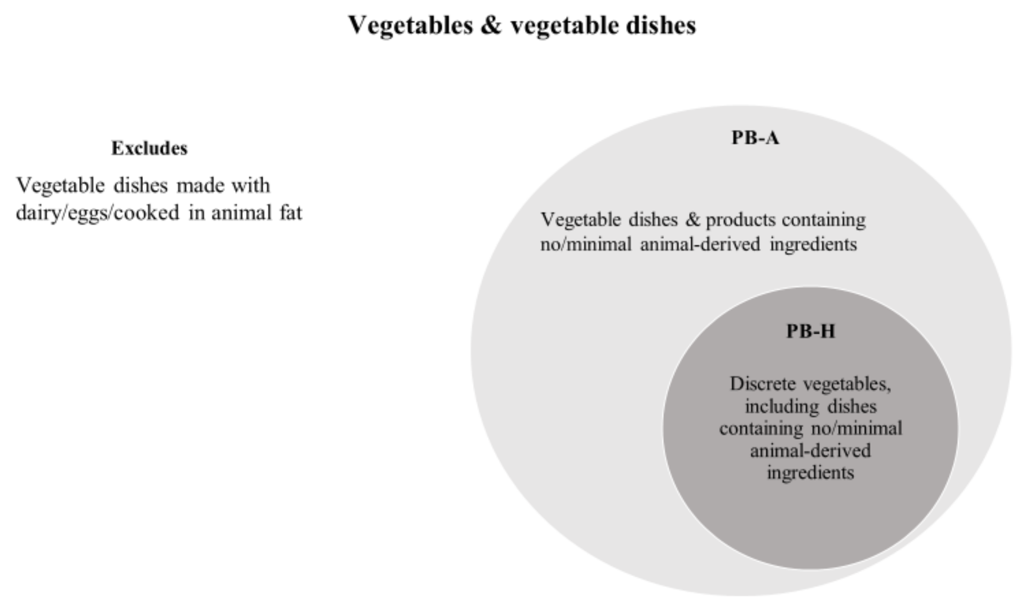

Figure 3.

Categorisation of vegetables & vegetable dishes under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

Vegetables & vegetable dishes (including vegetable products) are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

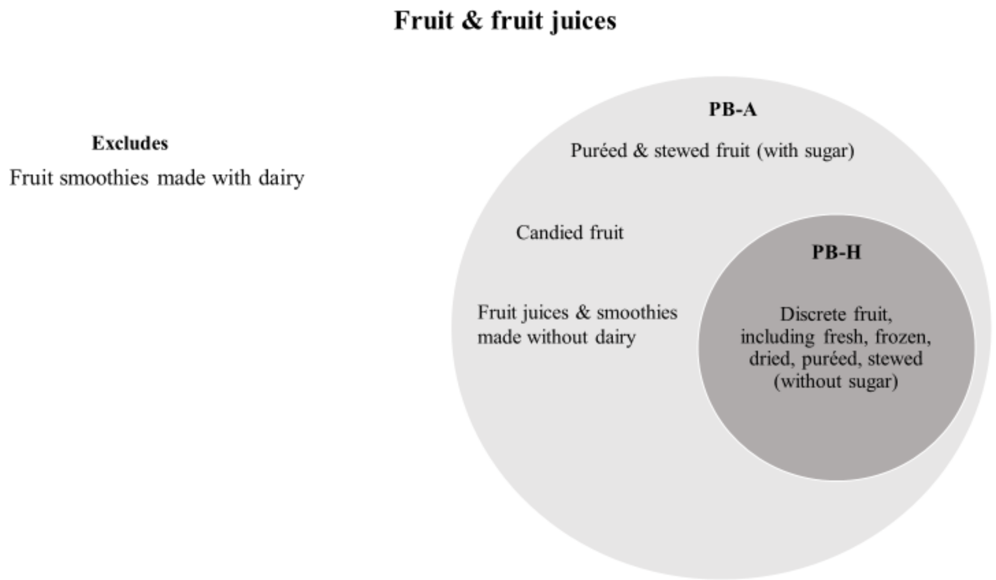

Figure 4.

Categorisation of fruit & fruit juices under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

Fruit & fruit juices are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

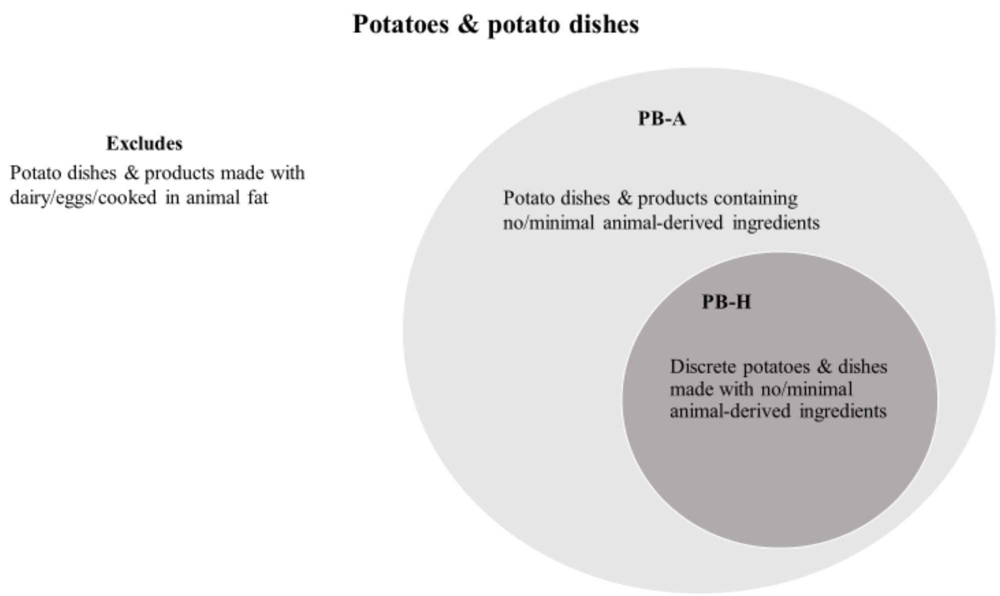

Figure 5.

Categorisation of potatoes & potato dishes under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

Potatoes & potato dishes (including potato products) are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

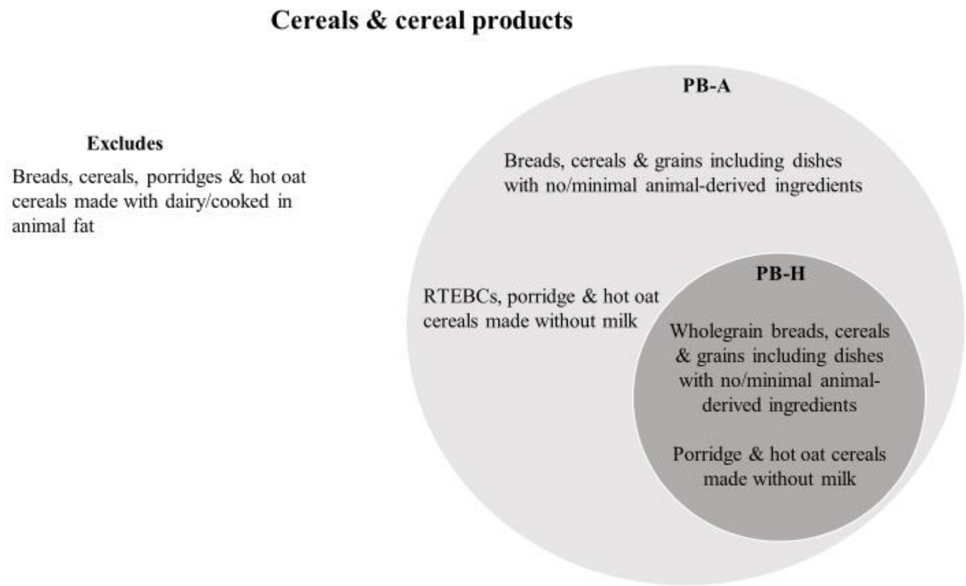

Figure 6.

Categorisation of cereals & cereal products under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

Cereals & cereal products (including their dishes) are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

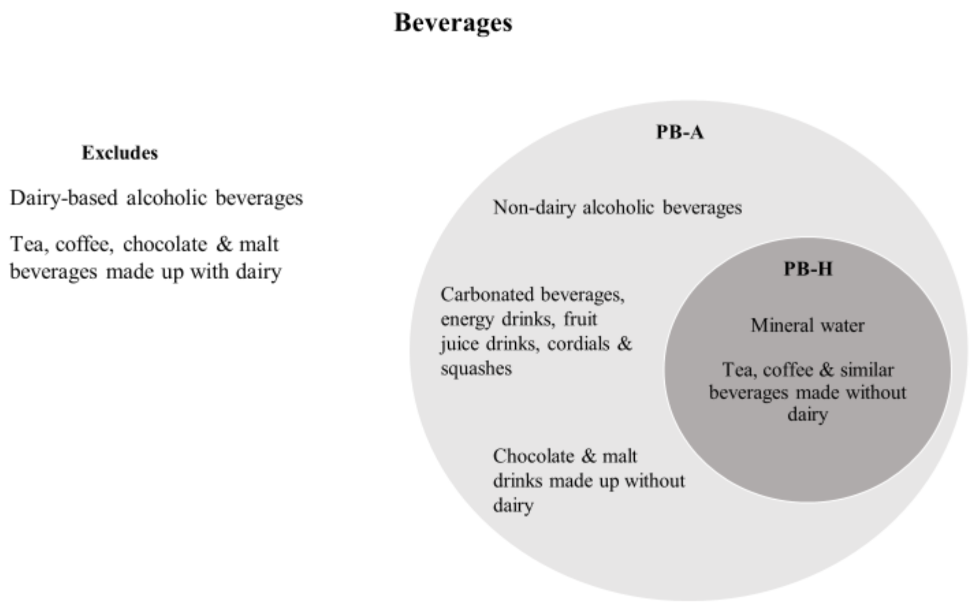

Figure 7.

Categorisation of beverages under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

All beverages are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

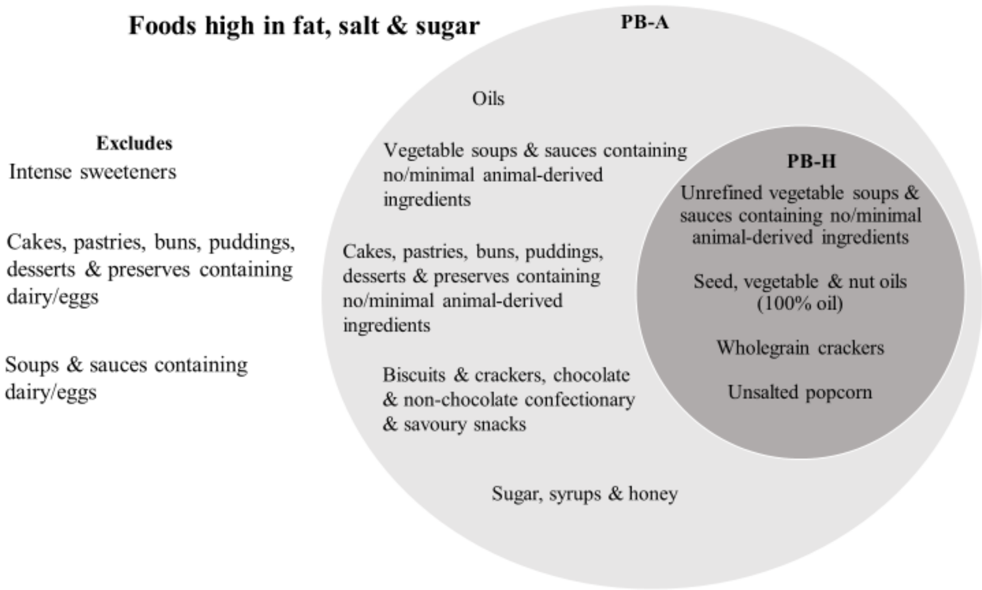

Figure 8.

Categorisation of foods high in fat, salt & sugar (including soups, sauces & miscellaneous foods) under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

Foods high in fat, salt & sugar (including soups, sauces & miscellaneous foods) are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

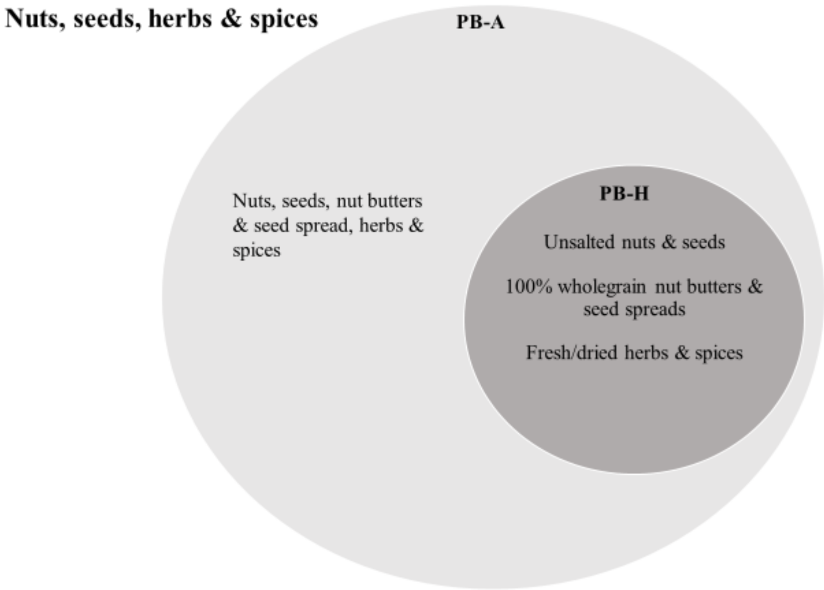

Figure 9.

Categorisation of nuts, seeds, herbs & spices under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

Nuts, seeds & herbs & spices are categorised into PB-A & PB-H. Foods excluded from both definitions are also shown.

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Chapter 4

Characterising the plant-based component of the diet of adults in Ireland in terms of its nutritional quality

Introduction

Plant-based (PB) diets encompass a wide spectrum of dietary patterns (as reviewed in detail in Chapter 1), which emphasise the consumption of foods derived from plant sources, such as fruit and vegetables, legumes, whole grains, nuts and seeds and plant-based alternative products, and limit or exclude animal-derived products in varying amounts (Kent *et al.*, 2022a).

PB diets are increasingly recommended for their association with health and environmental benefits (Dinu *et al.*, 2017; Chiavaroli *et al.*, 2018; Toumpanakis *et al.*, 2018; Qian *et al.*, 2019; Rees *et al.*, 2019; Willett *et al.*, 2019). PB diets may have beneficial effects on health through multiple mechanisms, including through improved weight status and glycaemic control, i.e., insulin and glycated haemoglobin (HbA1c) (a long-term marker for blood glucose control); improved blood plasma lipid profile, i.e., lower total and Low-Density Lipoprotein (LDL) cholesterol and higher High-Density Lipoprotein (HDL) cholesterol; improved inflammatory markers and improvements in the gut microbiome (Turner-McGrievy *et al.*, 2007; David *et al.*, 2014; Yokoyama *et al.*, 2014; O'Mahony *et al.*, 2015; Sutliffe *et al.*, 2015; Dinu *et al.*, 2017; Kahleova *et al.*, 2017). However, PB diets have also been associated with lower bone mineral density, may compromise overall bone health and therefore PB diets need to be carefully planned to ensure nutritional adequacy (Iguacel *et al.*, 2019; Li *et al.*, 2021; Ma *et al.*, 2021; Neufingerl and Eilander, 2021). While some studies show improved dietary intake of some nutrients from PB diets, there remains concern about the nutritional intake and adequacy of some restrictive PB diets, such as vegan diets, with respect to protein and key micronutrients, such as vitamin D and B12, which are only naturally occurring in animal-derived products (Bakaloudi *et al.*, 2020). Studies have shown that compared to omnivorous diets, PB diet consumers have higher or similar intakes of carbohydrate, dietary fibre, polyunsaturated fat (PUFA), vitamins A, E, C, thiamin, vitamin B6, folate, iron, magnesium and potassium and lower or similar intakes of energy, protein, total fat, saturated fat, monounsaturated fat (MUFA), riboflavin, niacin, vitamin D, vitamin B12, iodine, zinc, selenium and calcium (vegan diets only) (Bakaloudi *et al.*, 2020; Neufingerl and Eilander, 2021; Kent *et al.*, 2022a). In terms of nutritional adequacy, PB diet consumers were more likely to meet recommended intakes for carbohydrate, dietary fibre and vitamin E and are less likely to meet recommendations for protein, vitamin B12 and iodine compared to omnivores. Regardless of consumer type, neither PB consumers nor omnivores met recommendations for intakes of vitamin D, calcium and sodium (Bakaloudi *et al.*, 2020; Neufingerl and Eilander, 2021; Kent *et al.*, 2022a). While these studies have shown that intakes of iron and zinc were generally sufficient (with respect to dietary reference values) from the PB diet, a recent systematic review showed that biochemical status markers for many nutrients, including iron, zinc, iodine, vitamin B12, vitamin D and calcium were generally lower in those consuming a PB diet, compared to meat-eaters (Neufingerl and Eilander, 2021).

PB diets are often characterised by the exclusion of animal-derived foods, rather than the nutritional quality of plant-source foods and there is an increasing awareness that not all PB diets are healthy (Hemler and Hu, 2019; Wickramasinghe *et al.*, 2021; Kent *et al.*, 2022a). Consequently, there is growing interest in distinguishing ‘healthy’ PB diets, which contain whole and minimally processed fruit, vegetables and legumes, whole grains, nuts and seeds from ‘less healthy’ PB diets, containing sugar-sweetened beverages, snacks and confectionery and highly processed PB alternative foods, all of which may be considered ‘plant-based’ (Satija *et al.*, 2016; Kim *et al.*, 2018; World Health Organisation, 2021). Furthermore, the World Health Organisation (WHO) regional office for Europe have recently highlighted a need for more research on real-world dietary patterns regarding PB foods to assist policymakers with developing evidence-based dietary guidelines, food policy and general health advice (World Health Organisation, 2021).

In response to the demand to identify ‘healthy’ from ‘less healthy’ PB diets and to examine the dietary patterns of real food consumption data, we have recently developed a systematic methodology to identify the PB component of a diet, using two extremes of PB diet definitions, i.e., plant-based (all) (PB-A) which includes ‘all plant-based foods’ regardless of dietary quality and plant-based (healthful) (PB-H) which includes ‘healthful plant-based foods’ only, detailed extensively in Chapter 3 (Kent *et al.*, 2022b). The aim of this study was to use nationally representative food consumption data from the Irish National Adult Nutrition Survey (NANS) to examine the nutritional quality of the PB component of the diet of adults in Ireland (a population accustomed to consuming a primarily omnivorous diet) using these two extremes of PB diet definitions, compared to the baseline diet (the diet consumed by the NANS population) and to examine the nutritional quality of these PB components between sexes and age groups.

Methodology

The National Adult Nutrition Survey food consumption database

The analysis for this study was based on data from the Irish National Adult Nutrition Survey (NANS) (www.iuna.net). Briefly, the NANS was carried out in 2008-10 and investigated habitual food and beverage consumption (in addition to lifestyle, health indicators and attitudes to food and health) in a nationally representative sample of 1500 adults aged between 18 and 90 years in the Republic of Ireland. A detailed description of the survey methodology for the NANS is outlined in Chapter 2, with the methods pertinent to this chapter described below.

Food intake data collection

Food and beverage intake data (including nutritional supplements) were collected at brand level using a 4-day semi-weighed food diary. Details of recipes of composite dishes were also recorded and participants were asked to collect the packaging labels of all foods and beverages consumed over the recording period. Each food, beverage and nutritional supplement consumed during the survey was assigned an individual food code and food descriptor based on its nutritional profile.

Nutrient composition of foods

Dietary intake data were analysed using WISP © (Tinuviel Software, Anglesey, UK) which estimated nutrient intakes using data from McCance and Widdowson's The Composition of Foods, sixth (Food Standards Agency, 2002) and fifth (Holland *et al.*, 1991a) editions plus all nine supplemental volumes (Holland *et al.*, 1988; Holland *et al.*, 1989; Holland *et al.*, 1991b; Holland *et al.*, 1992; Holland *et al.*, 1993; Chan *et al.*, 1994; Chan *et al.*, 1995; Chan *et al.*, 1996; Holland *et al.*, 1996). During the NANS, modifications were made to this food composition database to include recipes of composite dishes, nutritional supplements, fortified foods, generic foods that were commonly consumed in Ireland and new foods on the market. Additionally, the food composition database has been updated with values for total fat, saturated fat, MUFA, PUFA, free sugars, sodium, vitamin D and iodine, which has been detailed elsewhere (Giltinan, 2012; Black *et al.*, 2015; Li *et al.*, 2016; McNulty *et al.*, 2017; Walton *et al.*, 2017). Dietary folate equivalents (DFE) were estimated using the following equation: 1µg DFE = 1µg food folate + (1.7 x folic acid) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014).

Coding of plant-based components of the diet

The coding of the PB components of the diet has previously been described in detail in Chapter 3, but in brief, each food code (*n* 2317) in the NANS food consumption database was categorised into 11 food groups (**Appendix III**) and examined and coded (excluded/included) using two extremes of PB diet definitions:

A. Plant-based diet including 'all plant-based foods' regardless of dietary quality (PB-A): The PB-A diet definition excluded all meat and fish including composite dishes containing even minimal quantities of animal flesh. Other animal products i.e., eggs and dairy were heavily restricted and were only included in this definition when they were a minimal component of a dish or product (<10%, typically with a functional role e.g., binding). All PB foods, such as fruit, vegetables and grains and their dishes were included, regardless of the nutritional quality of the food or beverage.
B. Plant-based diet including 'healthful plant-based foods' only (PB-H): The PB-H diet definition excluded all meat and fish including composite dishes containing even minimal quantities of animal flesh and placed heavy restrictions on eggs and dairy (as per PB-A) and additionally restricted refined and poorer quality PB foods and products. Refined PB foods and products were identified based on the description of unprocessed and minimally processed foods and beverages within the NOVA classifications described by Monteiro *et al.* (2016) and PB foods of poorer dietary quality were identified using food-based dietary guidelines (FBDG) (European Commission, 2022; Food and Agriculture Organisation of the United Nations, 2022). The PB-H diet definition included foods such as wholegrain foods and products and other minimally processed foods and beverages.

Baseline diet

The baseline diet consisted of the total food component of the diet as consumed by the population in the NANS study, i.e., the total diet excluding nutritional supplements, and was used as a reference diet for which the PB-A and PB-H component of the diet were compared in terms of overall nutritional quality.

Estimation of nutrient intakes

The mean daily intake (MDI) of energy, macronutrients, dietary fibre and micronutrients (from food sources only) were estimated by summing the total amount of energy and each nutrient consumed and dividing the total by the number of recording days (four). The nutrient density of the baseline diet and of the PB-A and PB-H components of the diet was assessed by estimating energy-adjusted intakes (%E or /10MJ) of macronutrients, dietary fibre, vitamins and minerals. Nutritional supplements were excluded from all analyses in this chapter.

Statistical analysis

Statistical analyses were carried out using SPSS© for Windows™ Version 26.0. Differences in energy and nutrient intakes between the baseline diet and the PB-A and PB-H components of the diet were assessed using paired samples t-tests. Differences in energy and nutrient intakes between sexes (men, women) were assessed using independent sample t-tests. Differences in the energy and nutrient intakes between age groups (18-35y, 36-50y, 51-64y, 65y+) were assessed using ANOVA and Tukey tests were used for post-hoc analysis. Parametric tests were used in all cases regardless of normality of the data, due to the large sample size (*n* 1500) (Fagerland, 2012). To minimise type 1 errors (as a result of multiple testing), the Bonferoni adjustment was used by dividing the alpha level (0.05) by the number of comparisons. Therefore, intakes were considered to be significantly different from each other if $P < 0.001$.

Results

Table 1 presents an overview of the number of food codes in the baseline diet and in the PB-A and PB-H components of the diet split into 11 pre-defined food groups (**Appendix III**).

The PB-A component of the diet included 1178 (of a possible 2317) food codes (excluding supplements and non-food items), of which 271 were from the food group 'foods high in fat, salt & sugar', 239 were from 'vegetables & vegetable dishes', 181 were from 'cereals & cereal products', 171 were from 'fruit & fruit juices', 101 were from 'beverages', 85 were from 'soups & sauces', 56 were from 'nuts, seeds, herbs & spices', 47 were from 'potatoes & potato dishes' and 27 were from the 'non-dairy alternatives' food group.

The PB-H component of the diet consisted of 489 food codes, of which, 204 were from 'vegetables & vegetable dishes', 116 were from 'fruit & fruit juices', 29 were from 'cereals & cereal products', 26 were from 'soups & sauces', 24 were from 'potatoes & potato dishes', 17 were from 'beverages', 13 were from 'foods high in fat, salt & sugar', 51 were from 'nuts, seeds, herbs & spices' and 9 were from the 'non-dairy alternatives' food group.

Table 2 presents the MDI of energy and energy-adjusted nutrients from the baseline diet and the PB-A component of the diet in the total population (*n* 1500).

The MDI of energy from the baseline diet was 8.3MJ while the MDI of energy from the PB-A component of the diet was 4.7MJ. When compared to the baseline diet, the nutrient density of the PB-A component of the diet was lower for protein (9 vs 17%E), total fat (21 vs 34%E), saturated fat (7 vs 13%E), MUFA (7 vs 12%E) and PUFA (5 vs 6%E) and higher for carbohydrate (62 vs 44%E), total sugars (23 vs 17%E), free sugars (13 vs 9%E) and dietary fibre (37 vs 24g/10MJ).

In terms of micronutrients, compared to the baseline diet, the nutrient density of the PB-A component of the diet was lower for vitamin D (2 vs 4µg/10MJ), riboflavin (1.6 vs 1.9mg/10MJ), niacin (36 vs 41mg/10MJ), pantothenate (5 vs 6mg/10MJ), vitamin B12 (1.0 vs 5µg/10MJ), sodium (2330 vs 2497mg/10MJ), calcium (732 vs 899mg/10MJ), zinc (7 vs 10mg/10MJ), phosphorous (1155 vs 1379mg/10MJ) and iodine (48 vs 151µg/10MJ). However, compared to the baseline diet, the nutrient density of the PB-A component of the diet was higher for vitamin C (152 vs 80mg/10MJ), thiamin (2.4 vs 1.8mg/10MJ), biotin (43 vs 37µg/10MJ), vitamin B6 (4 vs 3mg/10MJ), total folate (491 vs 317µg/10MJ), dietary folate equivalents (DFE) (576 vs 372µg/10MJ), potassium (3930 vs 3042mg/10MJ), iron (18 vs 12mg/10MJ), magnesium (383 vs 283mg/10MJ) and copper (1.6 vs 1.1mg/10MJ). There were no differences in nutrient density between the baseline diet and the PB-A component of the diet for vitamins A and E.

Table 3 presents the MDI of energy and energy-adjusted nutrients from the PB-A component of the diet, in the total population (*n* 1500), split by sex.

From the PB-A component of the diet, women had a lower MDI of energy (4.0MJ) compared to men (5.5MJ). Women had a higher MDI of protein (9.1 vs 8.7%E), total fat (22 vs 20%E), saturated fat (7 vs 6%E), MUFA (8 vs 7%E), PUFA (5.2 vs 4.6%E), total sugars (23 vs 22%E), dietary fibre (39 vs 34g/10MJ), vitamin A (1539 vs 1106µg/10MJ), vitamin E (13 vs 11mg/10MJ), vitamin C (178 vs 125mg/10MJ), potassium (4096 vs 3760mg/10MJ), iron (19 vs 17mg/10MJ), zinc (8 vs 7mg/10MJ) and copper (1.7 vs 1.5mg/10MJ) and a lower MDI of niacin (34 vs 37mg/10MJ) compared to men. There were no differences in intakes between men and women for carbohydrate, free sugars, vitamin D, thiamin, riboflavin, pantothenate, biotin, vitamin B6, vitamin B12, total folate, DFE, sodium, calcium, magnesium, phosphorous and iodine from the PB-A component of the diet.

Table 4 presents the MDI of energy and energy-adjusted nutrients from the PB-A component of the diet, in the total population (*n* 1500), split by age group.

The MDI of energy from the PB-A component of the diet was higher in those aged 18-35y (5.2MJ) compared to those aged 36-50y (4.7MJ) and 51-64y (4.6MJ) while intakes in those aged 65y+ were lower than all other age groups (4.0MJ). There was no difference in energy intake from the PB-A component of the diet between those aged 36-50y and 51-64y. The MDI of protein from the PB-A component of the diet was lower in those aged 18-35y (8%E), compared to all other age groups (9-10%E). There were no differences in intakes of total fat, saturated fat, MUFA or PUFA from the PB-A component of the diet between all 4 age groups examined. The MDI of carbohydrate from the PB-A component of the diet was higher in those aged 65y+ (66%E), compared to all other age groups, with no differences observed between other age groups (60-62%). The MDI of total sugars from the PB-A component of the diet was lower in those aged 36-50y (21%E), compared to those aged 65y+ (24%E), however, no differences were observed between other age-groups (22-23%E). The MDI of free sugars from the PB-A component of the diet was higher in those aged 18-35y (15%E), compared to all other age groups (12%E). The MDI of dietary fibre from the PB-A component of the diet was lower in those aged 18-35y (32g/10MJ) compared to all other age groups and intake in those aged 65y+ was higher compared to those aged 36-50y (44 vs 36g/10MJ).

The MDI of vitamin A from the PB-A component of the diet was lower in those aged 18-35y (919µg/10MJ) compared to all other age groups and intake in those aged 65y+ (1910µg/10MJ) was higher compared to those aged 36-50y (1359µg/10MJ). The MDI of vitamin D from the PB-A component of the diet was lower in those aged 18-35y (1.8µg/10MJ) compared to those aged 51-64y (2.6µg/10MJ), however, there were no other differences observed in intakes of vitamin D between age-groups. The MDI of vitamin E from the PB-A component of the diet was lower in those aged 18-35y (10mg/10MJ) compared to all other age groups (12-14mg/10MJ). The MDI of vitamin C from the PB-A component of the diet was lower in those aged 18-35y (137mg/10MJ) compared to those aged 65y+ (174mg/10MJ), however, there were no differences observed between the other age groups. The MDI of pantothenate from the PB-A component of the diet was higher in those aged 65y+ (6mg/10MJ) compared to those aged 18-35y (4mg/10MJ) and 36-50y (5mg/10MJ), however, there were no differences between the other age groups. The MDI of biotin from the PB-A component of the diet was lower in those aged 18-35y (36µg/10MJ), compared to those aged 36-50y (45µg/10MJ) and 65y+ (51µg/10MJ), however, there were no differences in intakes between the other age groups. The MDI of total folate from the PB-A component of the diet was lower in those aged 18-35y (441µg/10MJ) compared to those aged 51-64y (537µg/10MJ) and 65y+ (551µg/10MJ) and intake in those aged 65y+ was higher compared to those aged 36-50y (488µg/10MJ). The MDI of DFE from the PB-A component of the diet was lower in those aged 18-35y (520µg/10MJ) compared to those aged 51-64y (631µg/10MJ) and 65y+ (649µg/10MJ), but there were no differences in intakes between the other age groups. The MDI of potassium from the PB-A component of the diet was lower in those aged 18-35y (3516mg/10MJ) compared to all other age groups and intake in those aged 65y+ (4401mg/10MJ) was higher compared to those aged 36-50y (3992mg/10MJ). The MDI of calcium from the PB-A component of the diet was lower in those aged 18-35y (705mg/10MJ) compared to those aged 65y+ (790mg/10MJ) with no differences in intakes between the other age groups. The MDI of magnesium from the PB-A component of the diet was lower in those aged 18-35y (357mg/10MJ) compared to all other age groups (386-412mg/10MJ). The MDI of zinc from the PB-A component of the diet was lower in those aged 18-35y (7mg/10MJ) compared to all other age groups and intake in those aged 65y+ (8mg/10MJ) was higher compared to those aged 36-50y (7mg/10MJ). The MDI of phosphorous from the PB-A component of the diet was lower in those aged 18-35y (1091mg/10MJ) compared to those aged 51-64y (1191mg/10MJ) and 65y+ (1238mg/10MJ), however, there were no differences in intakes observed between the other age groups. The MDI of copper from the PB-A component of the diet was lower in those aged 18-35y (1.4mg/10MJ) compared to all other age groups and intake in those aged 65y+ (1.8mg/10MJ) was higher compared to those aged 36-50y (1.6mg/10MJ). There were no differences in intakes observed between age groups for thiamin, riboflavin, niacin, vitamins B6 and B12, sodium, iron and iodine from the PB-A component of the diet.

Table 5 presents the MDI of energy and energy-adjusted nutrients from the baseline diet and the PB-H component of the diet in the total population (*n* 1500).

The MDI of energy from the baseline diet was 8.3MJ, while the MDI from the PB-H component of the diet was 1.1MJ. When compared to the baseline diet, the nutrient density of the PB-H component of the diet was lower for protein (13 vs 17%E), total fat (19 vs 34%E), saturated fat (4 vs 13%E), MUFA (7 vs 12%E), PUFA (5.5 vs 5.9%E) and free sugars (1.0 vs 9%E) and higher for carbohydrate (68 vs 44%E), total sugars (26 vs 17%E) and dietary fibre (78 vs 24g/10MJ).

In terms of micronutrients, compared to the baseline diet, the nutrient density of the PB-H component of the diet was lower for vitamin D (1.0 vs 4μg/10MJ), vitamin B12 (0.1 vs 4.7μg/10MJ), sodium (1404 vs 2497mg/10MJ) and calcium (698 vs 899mg/10MJ), while the nutrient density of the PB-H component of the diet was higher for vitamin A (4861 vs 1024μg/10MJ), vitamin E (18 vs 10mg/10MJ), vitamin C (426 vs 80mg/10MJ), thiamin (4 vs 2mg/10MJ), riboflavin (4 vs 2mg/10MJ), pantothenate (13 vs 6mg/10MJ), biotin (216 vs 37μg/10MJ), vitamin B6 (6 vs

3mg/10MJ), total folate (1079 vs 317μg/10MJ), DFE (1133 vs 372μg/10MJ), potassium (12616 vs 3042mg/10MJ), magnesium (976 vs 283mg/10MJ), iron (25 vs 12mg/10MJ), zinc (11 vs 10mg/10MJ) and copper (4 vs 1mg/10MJ). There were no differences in intakes observed between the PB-H component of the diet and the baseline diet for niacin, phosphorous and iodine.

Table 6 presents the MDI of energy and energy-adjusted nutrients from the PB-H component of the diet in the total population (*n* 1500), split by sex.

From the PB-H component of the diet, women had a lower MDI of energy (1.0 MJ) compared to men (1.2 MJ), but had a higher MDI of total sugars (29 vs 23%E) and dietary fibre (81 vs 75g/10MJ). There were no differences in intakes between men and women for protein, total fat, saturated fat, MUFA, PUFA, carbohydrate and free sugars from the PB-H component of the diet. Compared to men, women had a higher MDI of vitamins E (19 vs 16μg/10MJ) and C (502 vs 348mg/10MJ) from the PB-H component of the diet. There were no differences in intakes between men and women for vitamins A and D, thiamin, riboflavin, niacin, pantothenate, biotin, vitamin B6, vitamin B12, total folate, DFE, sodium, potassium, calcium, iron, magnesium, zinc, phosphorous, copper and iodine form the PB-H component of the diet.

Table 7 presents the MDI of energy and energy-adjusted nutrients from the PB-H component of the diet in the total population (*n* 1500), split by age group.

The MDI of energy from the PB-H component of the diet in those aged 18-35y was lower (1.0MJ) compared to those aged 51-64y (1.3MJ) and 65y+ (1.3MJ) and the intake of energy in those aged 36-50y (1.1MJ) was lower compared to those aged 51-64y but there was no difference in energy intake in those aged 36-50y compared to the other age groups. The MDI of total fat from the PB-H component of the diet was higher in those aged 18-35y (20%E) compared to those aged 65y+ (16%E), while there were no differences in intakes between the other age groups (18%E). The MDI of MUFA from the PB-H component of the diet was higher in those aged 18-35y (7%E) compared to those aged 65y+ (5%E) and there were no differences in intakes between the other age groups (6-7%E) The MDI of carbohydrate from the PB-H component of the diet was lower in those aged 18-35y (66%E) compared to those aged 65y+ (72%E) and there were no differences in intakes between the other age groups (69-70%E).

There were no differences in intakes between age groups for protein, saturated fat, PUFA, total sugars, free sugars and dietary fibre from the PB-H component of the diet.

With regards to micronutrients, the MDI of vitamin E from the PB-H component of the diet was higher in those aged 18-35y (20mg/10MJ) compared to those aged 65y+ (15mg/10MJ), however, there were no differences in intakes between the other age groups (17mg/10MJ). The MDI of zinc from the PB-H component of the diet was lower in those aged 18-35y (11mg/10MJ) compared to those aged 65y+ (12mg/10MJ), but there were no differences in intakes between the other age groups (11mg/10MJ). There were no differences in intakes between the age groups for vitamins A, D and C, thiamin, riboflavin, niacin, pantothenate, biotin, vitamins B6 and B12, total folate and DFE, sodium, potassium, calcium, iron, magnesium, phosphorous, copper and iodine from the PB-H component of the diet.

Table 8 presents the MDI of energy and energy-adjusted nutrients from the PB-A and PB-H components of the diet in the total population (*n* 1500).

The MDI of energy from the PB-H component of the diet was 1.1MJ compared to the PB-A component of the diet (4.7MJ). When compared to the PB-A component of the diet, the nutrient density of the PB-H component of the diet was higher for protein (13 vs 9%E), PUFA (6 vs 5%E), carbohydrate (68 vs 62%E), total sugars (26 vs 23%E) and dietary fibre (78 vs 37g/10MJ). When compared to the PB-A component of the diet, the nutrient density of the PB-H component was lower for total fat (19 vs 21%E), saturated fat (4 vs 7%E), MUFA (6.5 vs 7.4%E), free sugars (1.0 vs 13%E) and sodium (1404 vs 2330mg/10MJ).

With regards to micronutrients, when compared to the PB-A component of the diet, the nutrient density of the PB-H component of the diet was higher for vitamin A (4861 vs 1326µg/10MJ), vitamin E (18 vs 12mg/10MJ), vitamin C (426 vs 152mg/10MJ), thiamin (4 vs 2mg/10MJ), riboflavin (4 vs 2mg/10MJ), niacin (60 vs 36mg/10MJ), pantothenate (13 vs 5mg/10MJ), biotin (216 vs 43µg/10MJ), vitamin B6 (6 vs 4mg/10MJ), total folate (1079 vs 491µg/10MJ), DFE (1133 vs 576µg/10MJ), potassium (12616 vs 3930mg/10MJ), iron (25 vs 18mg/10MJ), magnesium (976 vs 383mg/10MJ), zinc (11 vs 7mg/10MJ), phosphorous (1894 vs 1155mg/10MJ), copper (4 vs 2mg/10MJ) and iodine (165 vs 48µg/10MJ). When compared to the PB-A component of the diet, the nutrient density of the PB-H component of the diet was lower for vitamin D (1 vs 2.1µg/10MJ) and vitamin B12 (0.1 vs 1.0µg/10MJ), however there was no difference in nutrient density between the PB-A and PB-H components of the diet for calcium (698 vs 732mg/10MJ).

Table 1. Overview of the number of food codes from each food group in the baseline diet and in the plant-based (all) (PB-A) and plant-based (healthful) (PB-H) components of the diet

Food group *(sub-group)*	**Food codes in food group (*n*)**	**PB-A**	**PB-H**
Non-food items	**235**	**0**	**0**
Nutritional supplements and other non-food items	*235*	*0*	*0*
Meat, fish, eggs & dairy	**902**	**0**	**0**
Meat, meat dishes & products	*575*	*0*	*0*
Fish & seafood, dishes & products	*167*	*0*	*0*
Eggs & egg dishes	*40*	*0*	*0*
Dairy & dairy products (including milk, cream, cheese, yogurt, butter & their products)	*120*	*0*	*0*
Non-dairy alternatives	**27**	**27**	**9**
Non-dairy alternative drinks	*7*	*7*	*6*
Non-dairy alternative yogurts	*3*	*3*	*3*
Non-dairy alternative cheeses	*1*	*1*	*0*
Non-dairy alternative fat spreads	*16*	*16*	*0*
Vegetables & vegetable dishes	**264**	**239**	**204**
Vegetables (including discrete vegetables & vegetables cooked in animal fat)	*151*	*149*	*149*
Vegetable dishes & products	*113*	*90*	*55*
Fruit & fruit juices	**177**	**171**	**116**
Fruit (including discrete fruit, tinned fruit & candied fruit)	*136*	*136*	*116*
Fruit juice & smoothies	*41*	*35*	*0*
Potatoes & potato dishes	**60**	**47**	**24**
Potatoes (including discrete potatoes & potatoes cooked in animal fat)	*16*	*12*	*12*
Potato dishes & products	*44*	*35*	*12*
Cereals & cereal products	**232**	**181**	**29**
Breads	*74*	*60*	*6*
Breakfast cereals	*78*	*71*	*11*
Rice, pasta, flours, grains & starches (including their dishes & products)	*80*	*50*	*12*
Beverages	**114**	**101**	**17**
Alcohol (including dairy-based & other)	*35*	*34*	*0*
Tea & coffee (including made up with/without dairy)	*24*	*15*	*15*
Chocolate & malt beverages (including made up with/without dairy)	*10*	*7*	*0*
Other beverages (including carbonated, beverages, fruit juice drinks, cordials, squashes & other beverages)	*45*	*45*	*2*
Soups & sauces	**140**	**85**	**26**
Dairy & egg-based soups & sauces	*55*	*0*	*0*
Other vegetable soups & sauces	*85*	*85*	*26*
Foods high in fat, salt & sugar	**345**	**271**	**13**
Oils (including 100% oils & spray oils)	*10*	*10*	*9*
Biscuits & crackers (including wholegrain crackers)	*50*	*50*	*3*
Cakes, pastries & buns (including dairy & custard-based cakes, pastries & buns)	*83*	*76*	*0*
Puddings & desserts (including dairy, meringue & custard-based puddings & desserts)	*82*	*20*	*0*
Sugar, sweeteners, syrups & preserves	*20*	*16*	*0*
Chocolate confectionery	*31*	*31*	*0*
Non-chocolate confectionery	*40*	*40*	*0*
Savoury snacks	*29*	*28*	*1*
Nuts, seeds, herbs & spices	**56**	**56**	**51**
Nuts & seeds (including unsalted & salted)	*25*	*25*	*21*
Nut/seed spreads (including 100% wholegrain & other)	*3*	*3*	*2*
Herbs & spices	*28*	*28*	*28*
Total	**2552**	**1178**	**489**

Table 2. Mean daily intake of energy and energy-adjusted nutrients from the baseline diet and plant-based (all) (PB-A) component of the diet in the total population (*n* 1500) in Ireland

	Baseline diet		**Plant-based (all)**	
	Mean (SD)	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**
Energy (MJ)	8.3 (2.7)	8.0 (6.4-9.9)	4.7 (1.9)*	4.5 (3.4-5.8)
Protein (%E)	17.2 (3.7)	16.8 (14.8-19.2)	8.9 (2.0)*	8.8 (7.6-10.1)
Total fat (%E)	34.2 (6.2)	34.0 (30.0-38.1)	20.7 (7.6)*	20.3 (15.6-25.6)
Saturated fat (%E)	13.3 (3.4)	13.2 (10.9-15.4)	6.5 (2.9)*	6.2 (4.4-8.3)
MUFA (%E)	12.4 (2.7)	12.3 (10.6-14.0)	7.4 (3.4)*	7.1 (5.0-9.5)
PUFA (%E)	5.9 (2.0)	5.7 (4.6-7.0)	4.9 (2.6)*	4.5 (3.2-6.1)
Carbohydrate (%E)	43.5 (6.9)	43.6 (39.1-48.0)	61.8 (9.9)*	62.5 (55.4-68.8)
Total sugars (%E)	17.1 (5.9)	16.8 (13.1-20.8)	22.5 (8.8)*	21.9 (16.5-27.8)
Free sugars (%E)	8.8 (5.1)	8.0 (5.3-11.6)	13.2 (8.6)*	11.8 (7.1-17.6)
Dietary fibre (g/10MJ)	23.6 (8.1)	22.3 (17.9-28.1)	36.6 (13.9)*	34.5 (26.8-44.2)
Vitamin A (µg/10MJ)	1024 (833)	855 (518-1303)	1326 (1413)	910 (372-1766)
Vitamin D (µg/10MJ)	4.0 (2.9)	3.2 (2.0-5.1)	2.1 (2.8)*	1.2 (0.2-3.0)
Vitamin E (mg/10MJ)	9.5 (4.9)	8.6 (6.1-12.0)	11.8 (6.9)	10.5 (7.0-14.9)
Vitamin C (mg/10MJ)	79.5 (52.5)	68.6 (41.2-103.8)	152 (118)*	123 (70-201)
Thiamin (mg/10MJ)	1.8 (2.2)	1.5 (1.2-2.0)	2.4 (3.4)*	2.1 (1.6-2.7)
Riboflavin (mg/10MJ)	1.9 (0.8)	1.8 (1.3-2.4)	1.6 (0.8)*	1.5 (1.1-2.0)
Niacin (mg/10MJ)	41.1 (15.6)	38.6 (29.7-50.3)	35.8 (13.5)*	33.5 (27.1-41.5)
Pantothenate (mg/10MJ)	5.9 (2.4)	5.5 (4.3-7.0)	4.8 (2.5)*	4.3 (3.5-5.5)
Biotin (µg/10MJ)	37.4 (19.6)	34.2 (25.4-45.5)	42.6 (35.1)*	38.1 (28.0-50.2)
Vitamin B6 (mg/10MJ)	2.7 (1.4)	2.4 (1.8-3.3)	3.6 (2.2)*	3.1 (2.3-4.1)
Vitamin B12 (µg/10MJ)	4.7 (3.5)	4.0 (2.8-5.6)	1.0 (1.8)*	0.5 (0.1-1.2)
Total folate (µg/10MJ)	317 (150)	290 (214-392)	491 (200)*	461 (348-586)
DFE (µg/10MJ)	372 (211)	316 (231-460)	576 (288)*	509 (375-698)
Sodium (mg/10MJ)	2497 (902)	2381 (1873-3019)	2330 (757)*	2255 (1815-2768)
Potassium (mg/10MJ)	3042 (969)	2956 (2346-3616)	3930 (1231)*	3786 (3191-4478)
Calcium (mg/10MJ)	899 (372)	838 (639-1104)	732 (231)*	703 (579-859)
Iron (mg/10MJ)	12.1 (5.1)	11.1 (8.5-14.5)	17.9 (7.6)*	16.5 (13.1-20.8)
Magnesium (mg/10MJ)	283 (102)	270 (207-340)	383 (110)*	375 (309-440)
Zinc (mg/10MJ)	9.6 (3.6)	9.1 (7.1-11.6)	7.4 (2.8)*	7.0 (5.6-8.6)
Phosphorous (mg/10MJ)	1379 (462)	1332 (1042-1647)	1155 (311)*	1108 (948-1307)
Copper (mg/10MJ)	1.1 (0.6)	1.0 (0.8-1.2)	1.6 (0.5)*	1.5 (1.2-1.8)
Iodine (µg/10MJ)	151 (96.1)	134 (89.9-190)	48.1 (56.5)*	43.5 (34.9-54.6)

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE=dietary folate equivalents
*Statistically different ($P < 0.001$) from the baseline diet within the rows via paired samples t-test, adjusted for multiple testing

Table 3. Mean daily intake of energy and energy-adjusted nutrients in the plant-based (all) (PB-A) component of the diet in the total population (*n* 1500), split by sex

	Plant-based (all)			
	Men (*n* 740)		Women (*n* 760)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
Energy (MJ)	5.5 (2.0)	5.3 (4.1-6.8)	4.0 (1.4)*	3.9 (3.1-4.9)
Protein (%E)	8.7 (1.9)	8.6 (7.4-9.8)	9.1 (2.0)*	9.0 (7.7-10.3)
Total fat (%E)	19.6 (7.7)	19.2 (14.3-24.1)	21.8 (7.3)*	21.5 (17.0-26.4)
Saturated fat (%E)	6.1 (2.9)	5.9 (4.0-7.9)	6.9 (2.9)*	6.7 (4.8-8.7)
MUFA (%E)	7.0 (3.5)	6.6 (4.6-9.0)	7.8 (3.4)*	7.5 (5.6-9.8)
PUFA (%E)	4.6 (2.6)	4.1 (3.0-5.9)	5.2 (2.6)*	4.8 (3.5-6.4)
Carbohydrate (%E)	61.1 (10.7)	61.8 (54.5-68.6)	62.5 (9.1)	63.0 (56.2-69.1)
Total sugars (%E)	21.6 (9.0)	20.7 (15.2-27.5)	23.3 (8.5)*	22.7 (17.4-28.1)
Free sugars (%E)	13.4 (9.0)	12.1 (6.9-18.1)	13.0 (8.1)	11.6 (7.2-17.3)
Dietary fibre (g/10MJ)	33.9 (12.7)	32.1 (24.7-41.4)	39.2 (14.6)*	36.8 (29.3-47.3)
Vitamin A (µg/10MJ)	1106 (1073)	774 (328-1592)	1539 (1652)*	1098 (447-2013)
Vitamin D (µg/10MJ)	2.0 (2.9)	1.0 (0.2-2.6)	2.2 (2.7)	1.3 (0.3-3.2)
Vitamin E (mg/10MJ)	10.7 (6.7)	9.1 (5.7-13.7)	12.9 (6.9)*	11.8 (8.3-15.9)
Vitamin C (mg/10MJ)	125 (96.5)	99.2 (55.7-166.2)	178 (130)*	149 (87-230)
Thiamin (mg/10MJ)	2.2 (0.9)	2.0 (1.6-2.5)	2.7 (4.6)	2.1 (1.7-2.8)
Riboflavin (mg/10MJ)	1.6 (0.8)	1.5 (1.1-2.0)	1.6 (0.8)	1.4 (1.1-2.0)
Niacin (mg/10MJ)	37.4 (14.0)	35.3 (28.7-43.9)	34.2 (12.8)*	32.1 (26.2-39.5)
Pantothenate (mg/10MJ)	4.6 (2.3)	4.1 (3.3-5.3)	5.0 (2.6)	4.5 (3.6-5.6)
Biotin (µg/10MJ)	40.6 (27.1)	37.1 (26.6-49.3)	44.7 (41.4)	39.2 (28.7-51.1)
Vitamin B6 (mg/10MJ)	3.6 (2.2)	3.2 (2.4-4.3)	3.5 (2.1)	3.1 (2.3-4.1)
Vitamin B12 (µg/10MJ)	1.0 (1.8)	0.4 (0.1-1.1)	1.0 (1.7)	0.6 (0.1-1.2)
Total folate (µg/10MJ)	488 (191)	461 (352-585)	494 (209)	462 (348-586)
DFE (µg/10MJ)	573 (282)	511 (379-683)	579 (294)	508 (369-713)
Sodium (mg/10MJ)	2275 (709)	2203 (1763-2688)	2383 (797)	2309 (1854-2820)
Potassium (mg/10MJ)	3760 (1243)	3669 (3068-4237)	4096 (1197)*	3969 (3308-4754)
Calcium (mg/10MJ)	715 (223)	686 (563-829)	749 (236)	720 (590-880)
Iron (mg/10MJ)	17.0 (7.4)	15.9 (12.6-19.6)	18.7 (7.7)*	17.3 (13.7-21.6)
Magnesium (mg/10MJ)	377 (112)	368 (307-433)	389 (107)	380 (314-446)
Zinc (mg/10MJ)	7.0 (2.6)	6.6 (5.2-8.2)	7.8 (2.9)*	7.3 (6.1-9.0)
Phosphorous (mg/10MJ)	1146 (302)	1106 (946-1293)	1163 (320)	1113 (951-1320)
Copper (mg/10MJ)	1.5 (0.5)	1.5 (1.2-1.7)	1.7 (0.5)*	1.6 (1.4-1.9)
Iodine (µg/10MJ)	46.4 (77.8)	41.4 (33.7-50.8)	49.7 (20.2)	46.3 (36.6-58.2)

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE=dietary folate equivalents
*Statistically different ($P < 0.001$) from men within the rows via independent sample t-test, adjusted for multiple testing

Table 4. Mean daily intake of energy and energy-adjusted nutrients in the plant-based (all) (PB-A) component of the diet in the total population (*n* 1500), split by age groups

	Plant-based (all)							
	18-35y (*n* 531)		**36-50y (*n* 437)**		**51-64y (*n* 306)**		**65y+ (*n* 226)**	
	Mean (SD)	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**
Energy (MJ)	5.2 (2.1)^{a}	4.8 (3.7-6.6)	4.7 (1.7)^{b}	4.5 (3.4-5.8)	4.6 (1.7)^{b}	4.5 (3.4-5.7)	4.0 (1.6)^{c}	3.7 (2.9-4.8)
Protein (%E)	8.3 (2.1)^{a}	8.2 (7.0-9.5)	9.1 (1.8)^{b}	9.0 (7.8-10.1)	9.2 (1.8)^{b}	9.0 (7.9-10.3)	9.6 (1.9)^{b}	9.6 (8.3-10.8)
Total fat (%E)	20.5 (7.5)^{a}	20.1 (15.3-25.4)	21.1 (6.9)^{a}	20.7 (16.9-25.4)	21.5 (8.0)^{a}	21.3 (15.5-26.9)	19.5 (8.2)^{a}	19.2 (14.3-23.7)
Saturated fat (%E)	6.4 (3.0)^{a}	6.0 (4.2-8.3)	6.8 (2.8)^{a}	6.4 (4.8-8.6)	6.7 (3.0)^{a}	6.4 (4.4-8.7)	6.2 (2.7)^{a}	6.1 (4.1-7.8)
MUFA (%E)	7.5 (3.3)^{a}	7.3 (5.0-9.7)	7.6 (3.2)^{a}	7.4 (5.6-9.5)	7.5 (3.6)^{a}	7.1 (5.0-9.7)	6.6 (3.9)^{a}	6.1 (4.1-8.4)
PUFA (%E)	4.8 (2.4)^{a}	4.4 (3.2-5.9)	4.9 (2.3)^{a}	4.6 (3.4-6.1)	5.3 (2.8)^{a}	4.9 (3.2-6.9)	4.8 (3.0)^{a}	4.1 (2.7-6.2)
Carbohydrate (%E)	60.1 (10.3)^{a}	60.4 (53.8-67.4)	61.8 (9.2)^{a}	63.0 (56.1-68.6)	61.6 (9.8)^{a}	61.8 (55.2-67.9)	65.9 (9.7)^{b}	66.6 (61.0-73.3)
Total sugars (%E)	22.4 (8.5)^{ab}	21.7 (16.5-27.5)	21.4 (8.2)^{a}	20.6 (15.8-26.3)	22.7 (8.7)^{ab}	22.0 (16.5-28.4)	24.4 (10.2)^{b}	23.9 (17.9-29.9)
Free sugars (%E)	15.1 (8.5)^{a}	13.6 (9.1-20.3)	12.4 (8.2)^{b}	10.6 (6.9-15.9)	11.8 (8.0)^{b}	10.7 (5.9-15.8)	12.2 (9.2)^{b}	11.1 (5.4-16.8)
Dietary fibre (g/10MJ)	31.8 (12.2)^{a}	29.4 (22.9-39.0)	36.4 (11.9)^{b}	35.1 (27.9-43.2)	40.1 (14.9)^{bc}	37.7 (29.9-47.7)	43.5 (15.8)^{c}	41.8 (32.3-53.0)
Vitamin A (µg/10MJ)	919 (1064)^{a}	569 (258-1163)	1359 (1281)^{b}	1022 (487-1803)	1552 (1383)^{bc}	1207 (512-2158)	1910 (2015)^{c}	1413 (771-2541)
Vitamin D (µg/10MJ)	1.8 (2.7)^{a}	0.9 (0.1-2.2)	2.0 (2.7)^{ab}	1.2 (0.2-2.6)	2.6 (3.0)^{b}	1.6 (0.5-3.7)	2.5 (2.8)^{ab}	1.6 (0.3-3.6)
Vitamin E (mg/10MJ)	10.0 (5.4)^{a}	8.9 (6.2-12.8)	11.8 (6.4)^{b}	10.9 (7.6-14.5)	13.4 (7.7)^{b}	11.9 (7.4-18.6)	13.9 (8.5)^{b}	12.1 (8.0-17.8)
Vitamin C (mg/10MJ)	137 (108)^{a}	105 (57.0-186)	147 (107)^{ab}	124 (70.3-196)	168 (138)^{ab}	135 (81-215)	174 (125)^{b}	150 (86-227)
Thiamin (mg/10MJ)	2.6 (5.5)^{a}	1.9 (1.5-2.5)	2.3 (0.9)^{a}	2.1 (1.7-2.7)	2.3 (1.0)^{a}	2.1 (1.7-2.6)	2.5 (0.9)^{a}	2.4 (1.9-2.9)
Riboflavin (mg/10MJ)	1.7 (0.9)^{a}	1.5 (1.1-2.1)	1.7 (0.9)^{a}	1.5 (1.1-2.0)	1.6 (0.7)^{a}	1.4 (1.1-1.9)	1.5 (0.7)^{a}	1.3 (1.0-1.8)
Niacin (mg/10MJ)	37.5 (15.2)^{a}	35.2 (28.1-42.9)	36.0 (13.0)^{a}	34.6 (27.1-41.6)	33.9 (11.4)^{a}	31.8 (26.5-39.2)	34.1 (12.2)^{a}	32.4 (26.0-39.1)
Pantothenate (mg/10MJ)	4.4 (2.8)^{a}	3.7 (3.0-4.8)	4.7 (2.3)^{a}	4.4 (3.6-5.3)	4.9 (1.9)^{ab}	4.6 (3.9-5.5)	5.6 (2.5)^{b}	5.3 (4.2-6.3)
Biotin (µg/10MJ)	36.0 (38.8)^{a}	30.9 (21.7-41.8)	44.7 (24.7)^{b}	40.7 (31.6-51.5)	45.3 (19.5)^{ab}	42.8 (32.3-55.5)	50.7 (52.8)^{b}	43.0 (34.0-56.1)
Vitamin B6 (mg/10MJ)	3.4 (2.4)^{a}	2.9 (2.2-3.8)	3.4 (2.0)^{a}	3.1 (2.3-4.1)	3.7 (2.0)^{a}	3.2 (2.4-4.5)	3.9 (1.9)^{a}	3.5 (2.5-4.8)
Vitamin B12 (µg/10MJ)	1.2 (2.2)^{a}	0.6 (0.1-1.3)	0.8 (1.8)^{a}	0.4 (0.1-1.1)	0.9 (1.3)^{a}	0.5 (0.1-1.2)	0.9 (1.1)^{a}	0.4 (0.0-1.3)
Total folate (µg/10MJ)	441 (174)^{a}	418 (324-533)	488 (187)^{ab}	467 (350-582)	537 (229)^{bc}	485 (378-638)	551 (211)^{c}	518 (397-688)
DFE (µg/10MJ)	520 (251)^{a}	470 (352-635)	569 (267)^{ab}	506 (373-692)	631 (332)^{b}	545 (400-761)	649 (318)^{b}	562 (423-815)
Sodium (mg/10MJ)	2360 (794)^{a}	2256 (1796-2811)	2320 (733)^{a}	2276 (1839-2738)	2282 (731)^{a}	2169 (1814-2704)	2341 (749)^{a}	2289 (1819-2784)
Potassium (mg/10MJ)	3516 (1254)^{a}	3407 (2878-4003)	3992 (1041)^{b}	3911 (3324-4473)	4213 (1191)^{bc}	4020 (3471-4719)	4401 (1275)^{c}	4268 (3448-5174)
Calcium (mg/10MJ)	705 (232)^{a}	667 (543-814)	729 (229)^{ab}	701 (588-832)	740 (226)^{ab}	716 (589-863)	790 (227)^{b}	751 (643-936)
Iron (mg/10MJ)	17.4 (8.7)^{a}	16.0 (12.3-20.3)	18.3 (7.6)^{a}	16.9 (13.1-21.8)	17.7 (6.1)^{a}	16.5 (14.0-19.5)	18.4 (6.5)^{a}	16.7 (14.2-21.2)
Magnesium (mg/10MJ)	357 (112)^{a}	343 (290-419)	386 (95.6)^{b}	382 (321.4-436)	403 (104)^{b}	391 (331-461)	412 (123)^{b}	395 (330-485)
Zinc (mg/10MJ)	6.7 (3.0)^{a}	6.5 (5.0-7.9)	7.4 (2.5)^{b}	7.1 (5.8-8.5)	7.6 (2.4)^{bc}	7.3 (6.0-8.9)	8.4 (3.1)^{c}	7.9 (6.5-9.8)
Phosphorous (mg/10MJ)	1091 (271)^{a}	1063 (909-1248)	1163 (286)^{ab}	1134 (973-1306)	1191 (338)^{b}	1140 (961-1354)	1238 (375)^{b}	1187 (979-1418)
Copper (mg/10MJ)	1.4 (0.5)^{a}	1.4 (1.1-1.7)	1.6 (0.5)^{b}	1.6 (1.3-1.9)	1.7 (0.5)^{bc}	1.7 (1.3-1.9)	1.8 (0.5)^{c}	1.7 (1.4-2.0)
Iodine (µg/10MJ)	52.3 (92.1)^{a}	45.7 (35.5-56.3)	46.8 (17.6)^{a}	43.4 (35.3-55.0)	45.5 (16.3)^{a}	43.1 (34.3-53.3)	44.0 (17.0)^{a}	41.6 (33.5-50.6)

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE=dietary folate equivalents. Statistical differences ($P < 0.001$) between age groups are denoted by different superscript letters

Table 5. Mean daily intake of energy and energy-adjusted nutrients from the baseline diet and the plant-based (healthful) (PB-H) component of the diet in the total population (*n* 1500)

	Baseline diet		**Plant-based (healthful)**	
	Mean (SD)	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**
Energy (MJ)	8.3 (2.7)	8.0 (6.4-9.9)	1.1 (0.8)*	1.0 (0.5-1.5)
Protein (%E)	17.2 (3.7)	16.8 (14.8-19.2)	12.9 (8.5)*	11.8 (9.9-13.9)
Total fat (%E)	34.2 (6.2)	34.0 (30.0-38.1)	18.5 (14.1)*	14.8 (7.5-26.2)
Saturated fat (%E)	13.3 (3.4)	13.2 (10.9-15.4)	4.2 (4.3)*	2.9 (1.3-5.7)
MUFA (%E)	12.4 (2.7)	12.3 (10.6-14.0)	6.5 (7.3)*	4.2 (0.8-9.9)
PUFA (%E)	5.9 (2.0)	5.7 (4.6-7.0)	5.5 (4.9)*	4.0 (2.1-7.2)
Carbohydrate (%E)	43.5 (6.9)	43.6 (39.1-48.0)	68.3 (15.1)*	71.4 (61.1-78.9)
Total sugars (%E)	17.1 (5.9)	16.8 (13.1-20.8)	25.6 (18.1)*	21.8 (11.5-35.4)
Free sugars (%E)	8.8 (5.1)	8.0 (5.3-11.6)	1.0 (2.7)*	0.0 (0.0-1.0)
Dietary fibre (g/10MJ)	23.6 (8.1)	22.3 (17.9-28.1)	78.3 (26.6)*	76.2 (62.7-89.3)
Vitamin A (µg/10MJ)	1024 (833)	855 (518-1303)	4861 (5482)*	3090 (942-6976)
Vitamin D (µg/10MJ)	4.0 (2.9)	3.2 (2.0-5.1)	1.0 (2.7)*	0.0 (0.0-0.8)
Vitamin E (mg/10MJ)	9.5 (4.9)	8.6 (6.1-12.0)	17.7 (13.4)*	14.7 (9.6-22.2)
Vitamin C (mg/10MJ)	79.5 (52.5)	68.6 (41.2-103.8)	426 (524)*	317 (201-507)
Thiamin (mg/10MJ)	1.8 (2.2)	1.5 (1.2-2.0)	4.1 (1.7)*	3.9 (3.1-5.0)
Riboflavin (mg/10MJ)	1.9 (0.8)	1.8 (1.3-2.4)	3.8 (9.9)*	2.3 (1.5-3.6)
Niacin (mg/10MJ)	41.1 (15.6)	38.6 (29.7-50.3)	59.9 (341.2)	41.6 (31.1-58.1)
Pantothenate (mg/10MJ)	5.9 (2.4)	5.5 (4.3-7.0)	13.0 (20.0)*	10.2 (7.9-13.2)
Biotin (µg/10MJ)	37.4 (19.6)	34.2 (25.4-45.5)	216 (1391)*	96 (66-147)
Vitamin B6 (mg/10MJ)	2.7 (1.4)	2.4 (1.8-3.3)	6.0 (2.6)*	5.7 (4.2-7.5)
Vitamin B12 (µg/10MJ)	4.7 (3.5)	4.0 (2.8-5.6)	0.1 (0.5)*	0.0 (0.0-0.0)
Total folate (µg/10MJ)	317 (150)	290 (214-392)	1079 (1545)*	849 (637-1119)
DFE (µg/10MJ)	372 (211)	316 (231-460)	1133 (1554)*	891 (647-1210)
Sodium (mg/10MJ)	2497 (902)	2381 (1873-3019)	1404 (1325)*	1049 (489-1927)
Potassium (mg/10MJ)	3042 (969)	2956 (2346-3616)	12616 (43911)*	9214 (7301-11576)
Calcium (mg/10MJ)	899 (372)	838 (639-1104)	698 (1220)*	570 (414-792)
Iron (mg/10MJ)	12.1 (5.1)	11.1 (8.5-14.5)	24.8 (15.3)*	20.9 (16.0-29.0)
Magnesium (mg/10MJ)	283 (102)	270 (207-340)	976 (3849)*	711 (610-841)
Zinc (mg/10MJ)	9.6 (3.6)	9.1 (7.1-11.6)	11.1 (4.3)*	10.7 (8.5-13.1)
Phosphorous (mg/10MJ)	1379 (462)	1332 (1042-1647)	1894 (3840)	1630 (1353-1931)
Copper (mg/10MJ)	1.1 (0.6)	1.0 (0.8-1.2)	3.5 (5.0)*	2.8 (2.4-3.4)
Iodine (µg/10MJ)	151 (96.1)	134 (89.9-190)	165 (1051)	66.9 (48.4-95.8)

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE=dietary folate equivalents
*Statistically different ($P < 0.001$) from the baseline diet within the rows via paired samples t-test, adjusted for multiple testing

Table 6. Mean daily intake of energy and energy-adjusted nutrients from the plant-based (healthful) (PB-H) component of the diet in the total population (*n* 1500), split by sex

	Plant-based (healthful)			
	Men (*n* 740)		Women (*n* 760)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
Energy (MJ)	1.2 (1.0)	1.0 (0.6-1.6)	1.0 (0.7)*	0.9 (0.5-1.4)
Protein (%E)	12.8 (8.8)	11.8 (9.7-13.8)	12.9 (8.1)	11.9 (10.0-14.1)
Total fat (%E)	18.1 (14.2)	14.4 (7.0-25.8)	18.9 (13.9)	15.0 (8.0-26.9)
Saturated fat (%E)	4.2 (4.4)	2.7 (1.2-5.9)	4.2 (4.2)	3.0 (1.4-5.6)
MUFA (%E)	6.4 (7.5)	3.8 (0.8-9.1)	6.7 (7.1)	4.5 (0.9-10.4)
PUFA (%E)	5.2 (4.8)	3.8 (2.0-6.9)	5.7 (5.1)	4.1 (2.2-7.5)
Carbohydrate (%E)	68.6 (15.6)	71.2 (61.4-79.5)	68.1 (14.6)	71.4 (60.9-78.5)
Total sugars (%E)	22.6 (17.7)	18.3 (9.1-30.2)	28.5 (18.0)*	25.1 (14.8-38.1)
Free sugars (%E)	0.9 (2.7)	0.0 (0.0-0.9)	1.1 (2.6)	0.1 (0.0-1.0)
Dietary fibre (g/10MJ)	75.4 (27.9)	73.7 (60.5-86.8)	81.1 (25.0)*	79.3 (64.7-94.8)
Vitamin A (µg/10MJ)	4566 (5486)	2711 (717-6554)	5148 (5466)	3527 (1232-7293)
Vitamin D (µg/10MJ)	0.9 (2.5)	0.0 (0.0-0.6)	1.1 (2.9)	0.0 (0.0-0.9)
Vitamin E (mg/10MJ)	15.9 (13.4)	12.9 (8.3-19.6)	19.4 (13.1)*	16.5 (11.6-24.3)
Vitamin C (mg/10MJ)	348 (331)	273 (172-429)	502 (651)*	359 (229-587)
Thiamin (mg/10MJ)	4.2 (1.9)	4.1 (3.2-5.2)	4.0 (1.5)	3.8 (3.0-4.8)
Riboflavin (mg/10MJ)	3.7 (10.0)	2.1 (1.4-3.5)	3.9 (9.8)	2.4 (1.6-3.8)
Niacin (mg/10MJ)	70.8 (484.0)	41.6 (30.9-58.3)	49.2 (40.2)	41.7 (31.2-57.7)
Pantothenate (mg/10MJ)	12.8 (20.0)	10.0 (7.6-13.1)	13.3 (20.0)	10.3 (8.3-13.4)
Biotin (µg/10MJ)	248 (1903)	91 (61-138)	184 (541)	103 (72-155)
Vitamin B6 (mg/10MJ)	6.0 (2.6)	5.8 (4.1-7.8)	5.9 (2.6)	5.7 (4.3-7.2)
Vitamin B12 (µg/10MJ)	0.1 (0.5)	0.0 (0.0-0.0)	0.2 (0.6)	0.0 (0.0-0.0)
Total folate (µg/10MJ)	1050 (1580)	815 (613-1073)	1108 (1511)	890 (667-1152)
DFE (µg/10MJ)	1105 (1586)	855 (618-1160)	1160 (1522)	918 (677-1270)
Sodium (mg/10MJ)	1356 (1301)	997 (446-1862)	1450 (1347)	1120 (524-2010)
Potassium (mg/10MJ)	13615 (60687)	8946 (7007-11355)	11643 (14840)	9423 (7504-11933)
Calcium (mg/10MJ)	691 (1690)	525 (387-714)	705 (403)	619 (461-855)
Iron (mg/10MJ)	24.2 (15.2)	20.1 (15.4-28.7)	25.3 (15.5)	21.5 (16.5-29.4)
Magnesium (mg/10MJ)	1068 (5365)	694 (589-807)	887 (1104)	738 (629-885)
Zinc (mg/10MJ)	11.0 (4.5)	10.6 (8.4-13.0)	11.3 (4.1)	10.9 (8.8-13.3)
Phosphorous (mg/10MJ)	1970 (5346)	1591 (1309-1893)	1819 (1136)	1681 (1389-1958)
Copper (mg/10MJ)	3.3 (5.0)	2.7 (2.3-3.2)	3.7 (5.0)	2.9 (2.5-3.6)
Iodine (µg/10MJ)	192.7 (1312.8)	63.0 (45.4-90.3)	138 (710)	71 (52-101)

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE=dietary folate equivalents
*Statistically different ($P < 0.001$) from men within the rows via independent sample t-test, adjusted for multiple testing

Table 7. Mean daily intake of energy and energy-adjusted nutrients from the plant-based (healthful) (PB-H) component of the diet in the total population (*n* 1500), split by age groups

	Plant-based (healthful)							
	18-35y (*n* 531)		**36-50y (*n* 437)**		**51-64y (*n* 306)**		**65y+ (*n* 226)**	
	Mean (SD)	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**
Energy (MJ)	1.0 (0.9)^{a}	0.8 (0.4-1.2)	1.1 (0.7)^{ac}	1.0 (0.6-1.4)	1.3 (0.9)^{b}	1.1 (0.8-1.7)	1.3 (0.8)^{bc}	1.1 (0.7-1.7)
Protein (%E)	12.8 (9.9)^{a}	11.3 (9.3-13.9)	13.2 (8.2)^{a}	12.0 (10.3-14.3)	12.9 (8.7)^{a}	11.9 (10.2-13.7)	12.5 (4.1)^{a}	11.8 (10.3-13.8)
Total fat (%E)	20.2 (16.5)^{a}	15.6 (6.8-29.6)	18.4 (13.5)^{ab}	15.3 (7.4-26.3)	17.7 (12.2)^{ab}	15.0 (8.1-25.1)	15.7 (10.7)^{b}	12.8 (8.1-21.1)
Saturated fat (%E)	4.6 (5.0)^{a}	3.0 (1.1-6.3)	4.1 (3.9)^{a}	2.9 (1.4-5.6)	4.1 (3.7)^{a}	2.8 (1.5-5.8)	3.8 (3.9)^{a}	2.5 (1.5-4.9)
MUFA (%E)	7.3 (8.6)^{a}	4.2 (0.4-11.5)	6.6 (6.9)^{ab}	4.4 (1.0-10.3)	6.3 (6.5)^{ab}	4.4 (1.4-8.6)	5.0 (5.4)^{b}	3.3 (1.0-7.2)
PUFA (%E)	6.0 (6.0)^{a}	4.0 (2.0-8.2)	5.4 (4.7)^{a}	4.0 (2.2-7.4)	5.1 (3.8)^{a}	4.1 (2.4-6.6)	4.8 (3.7)^{a}	3.8 (2.2-6.5)
Carbohydrate (%E)	66.1 (18.0)^{a}	69.0 (56.9-79.1)	68.5 (14.1)^{ab}	71.0 (60.8-78.8)	69.5 (13.3)^{ab}	72.8 (62.6-78.3)	71.9 (10.3)^{b}	73.1 (66.3-79.5)
Total sugars (%E)	25.4 (20.4)^{a}	19.9 (10.0-35.5)	25.2 (17.9)^{a}	21.0 (11.2-35.7)	26.6 (15.8)^{a}	23.8 (15.1-33.7)	25.4 (15.5)^{a}	23.0 (12.3-36.9)
Free sugars (%E)	1.0 (2.6)^{a}	0.0 (0.0-1.1)	0.8 (1.8)^{a}	0.1 (0.0-0.9)	1.2 (4.0)^{a}	0.1 (0.0-1.0)	0.9 (2.0)^{a}	0.0 (0.0-0.8)
Dietary fibre (g/10MJ)	77.4 (31.6)^{a}	75.0 (60.8-87.7)	77.5 (22.9)^{a}	76.1 (64.1-88.9)	79.2 (23.0)^{a}	76.0 (64.5-91.6)	80.8 (24.9)^{a}	78.9 (63.7-92.6)
Vitamin A (µg/10MJ)	4510 (5943)^{a}	2373 (599-6296)	5142 (5506)^{a}	3660 (1285-7059)	4707 (4651)^{a}	3265 (1029-7051)	5351 (5312)^{a}	3761 (1346-7618)
Vitamin D (µg/10MJ)	1.1 (3.0)^{a}	0.0 (0.0-0.7)	0.9 (2.6)^{a}	0.0 (0.0-0.6)	1.1 (2.7)^{a}	0.0 (0.0-1.1)	1.0 (2.4)^{a}	0.0 (0.0-0.9)
Vitamin E (mg/10MJ)	19.6 (18.1)^{a}	14.4 (9.3-25.1)	17.2 (9.9)^{ab}	15.3 (10.2-21.8)	16.8 (9.4)^{ab}	14.6 (9.8-21.2)	15.4 (9.4)^{b}	13.4 (9.5-19.6)
Vitamin C (mg/10MJ)	460 (776)^{a}	276 (164-505)	412 (344)^{a}	325 (211-517)	420 (276)^{a}	356 (228-561)	379 (263)^{a}	326 (221-472)
Thiamin (mg/10MJ)	4.1 (2.2)^{a}	3.8 (2.8-5.0)	4.2 (1.5)^{a}	4.1 (3.3-5.0)	4.0 (1.3)^{a}	3.9 (3.2-4.8)	4.3 (1.4)^{a}	4.1 (3.4-5.1)
Riboflavin (mg/10MJ)	4.1 (11.6)^{a}	2.1 (1.2-3.6)	3.9 (9.3)^{a}	2.4 (1.6-4.1)	3.8 (10.8)^{a}	2.4 (1.6-3.4)	3.1 (3.3)^{a}	2.2 (1.6-3.7)
Niacin (mg/10MJ)	78.7 (565)^{a}	43.5 (31.2-61.6)	56.6 (101)^{a}	44.0 (32.6-62.7)	43.5 (20.0)^{a}	38.5 (31.0-52.2)	44.1 (29.1)^{a}	38.4 (28.8-52.3)
Pantothenate (mg/10MJ)	13.1 (23.7)^{a}	9.1 (6.9-12.7)	13.1 (18.1)^{a}	10.5 (8.4-13.5)	13.2 (21.3)^{a}	10.6 (8.6-13.4)	12.5 (8.9)^{a}	11.2 (9.2-13.5)
Biotin (µg/10MJ)	279 (2212)^{a}	76.0 (48.1-131)	214 (692)^{a}	110 (79.5-167)	171 (541)^{a}	99.8 (70.2-142)	131 (165)^{a}	102 (73.9-143)
Vitamin B6 (mg/10MJ)	5.8 (3.1)^{a}	5.3 (3.8-7.3)	5.9 (2.2)^{a}	5.8 (4.4-7.4)	6.1 (2.1)^{a}	5.9 (4.5-7.5)	6.3 (2.3)^{a}	6.0 (4.6-7.9)
Vitamin B12 (µg/10MJ)	0.1 (0.6)^{a}	0.0 (0.0-0.0)	0.1 (0.4)^{a}	0.0 (0.0-0.0)	0.2 (0.6)^{a}	0.0 (0.0-0.0)	0.2 (0.5)^{a}	0.0 (0.0-0.0)
Total folate (µg/10MJ)	1112 (1880)^{a}	774 (562-1061)	1094 (1378)^{a}	899 (683-1153)	1084 (1640)^{a}	866 (688-1123)	967 (487)^{a}	894 (646-1184)
DFE (µg/10MJ)	1172 (1889)^{a}	814 (575-1170)	1146 (1384)^{a}	935 (689-1237)	1129 (1647)^{a}	914 (706-1169)	1020 (529)^{a}	922 (650-1287)
Sodium (mg/10MJ)	1553 (1597)^{a}	1142 (438-2106)	1384 (1176)^{a}	1068 (517-1947)	1314 (1188)^{a}	995 (542-1780)	1211 (993)^{a}	876 (479-1736)
Potassium (mg/10MJ)	14492 (70652)^{a}	8414 (6446-11115)	12494 (19872)^{a}	9678 (7653-12124)	11264 (14340)^{a}	9406 (7602-11482)	10275 (5214)^{a}	9392 (7815-11559)
Calcium (mg/10MJ)	734 (1933)^{a}	525 (380-767)	707 (661)^{a}	607 (422-817)	661.0 (360)^{a}	582 (443-765)	647 (310)^{a}	567 (436-800)
Iron (mg/10MJ)	26.0 (19.4)^{a}	21.0 (15.2-30.8)	25.0 (13.3)^{a}	21.4 (16.4-29.9)	22.8 (10.8)a	19.9 (16.1-26.1)	24.2 (13.0)^{a}	21.2 (16.0-27.6)
Magnesium (mg/10MJ)	1152 (6246)^{a}	693 (566-813)	958 (1617)^{a}	744 (642-900)	851 (1047)^{a}	705 (625-831)	769 (337)^{a}	716 (623-827)
Zinc (mg/10MJ)	10.8 (4.3)^{a}	10.6 (8.2-12.8)	11.0 (3.9)^{ab}	10.8 (8.6-12.9)	11.2 (4.2)^{ab}	10.7 (8.6-13.1)	12.0 (5.0)^{b}	11.4 (8.6-14.3)
Phosphorous (mg/10MJ)	2060 (6228)^{a}	1600 (1259-1940)	1869 (1554)^{a}	1705 (1412-1954)	1762 (1099)^{a}	1575 (1389-1874)	1728 (669)^{a}	1618 (1390-1929)
Copper (mg/10MJ)	3.6 (6.0)^{a}	2.7 (2.2-3.4)	3.5 (4.5)^{a}	2.9 (2.4-3.6)	3.5 (5.3)^{a}	2.8 (2.4-3.3)	3.2 (2.2)^{a}	2.9 (2.5-3.4)
Iodine (µg/10MJ)	298 (1743)^{a}	74 (50.1-111)	104 (198)^{a}	70.4 (49.5-103)	90.3 (226)^{a}	63.1 (48.6-78.9)	71.6 (49.9)^{a}	57.6 (44.0-82.6)

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE=dietary folate equivalents Statistical differences ($P < 0.001$) between age groups are denoted by different superscript letters

Table 8. Mean daily intake of energy and energy-adjusted nutrients from the plant-based (all) (PB-A) and plant-based (healthful) (PB-H) components of the diet in the total population (*n* 1500)

	Plant-based (all)		**Plant-based (healthful)**	
	Mean (SD)	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**
Energy (MJ)	4.7 (1.9)	4.5 (3.4-5.8)	1.1 (0.8)*	1.0 (0.5-1.5)
Protein (%E)	8.9 (2.0)	8.8 (7.6-10.1)	12.9 (8.5)*	11.8 (9.9-13.9)
Total fat (%E)	20.7 (7.6)	20.3 (15.6-25.6)	18.5 (14.1)*	14.8 (7.5-26.2)
Saturated fat (%E)	6.5 (2.9)	6.2 (4.4-8.3)	4.2 (4.3)*	2.9 (1.3-5.7)
MUFA (%E)	7.4 (3.4)	7.1 (5.0-9.5)	6.5 (7.3)*	4.2 (0.8-9.9)
PUFA (%E)	4.9 (2.6)	4.5 (3.2-6.1)	5.5 (4.9)*	4.0 (2.1-7.2)
Carbohydrate (%E)	61.8 (9.9)	62.5 (55.4-68.8)	68.3 (15.1)*	71.4 (61.1-78.9)
Total sugars (%E)	22.5 (8.8)	21.9 (16.5-27.8)	25.6 (18.1)*	21.8 (11.5-35.4)
Free sugars (%E)	13.2 (8.6)	11.8 (7.1-17.6)	1.0 (2.7)*	0.0 (0.0-1.0)
Dietary fibre (g/10MJ)	36.6 (13.9)	34.5 (26.8-44.2)	78.3 (26.6)*	76.2 (62.7-89.3)
Vitamin A (µg/10MJ)	1326 (1413)	910 (372-1766)	4861 (5482)*	3090 (942-6976)
Vitamin D (µg/10MJ)	2.1 (2.8)	1.2 (0.2-3.0)	1.0 (2.7)*	0.0 (0.0-0.8)
Vitamin E (mg/10MJ)	11.8 (6.9)	10.5 (7.0-14.9)	17.7 (13.4)*	14.7 (9.6-22.2)
Vitamin C (mg/10MJ)	152 (118)	123 (70-201)	426 (524)*	317 (201-507)
Thiamin (mg/10MJ)	2.4 (3.4)	2.1 (1.6-2.7)	4.1 (1.7)*	3.9 (3.1-5.0)
Riboflavin (mg/10MJ)	1.6 (0.8)	1.5 (1.1-2.0)	3.8 (9.9)*	2.3 (1.5-3.6)
Niacin (mg/10MJ)	35.8 (13.5)	33.5 (27.1-41.5)	59.9 (341.2)*	41.6 (31.1-58.1)
Pantothenate (mg/10MJ)	4.8 (2.5)	4.3 (3.5-5.5)	13.0 (20.0)*	10.2 (7.9-13.2)
Biotin (µg/10MJ)	42.6 (35.1)	38.1 (28.0-50.2)	216 (1391)*	96 (66-147)
Vitamin B6 (mg/10MJ)	3.6 (2.2)	3.1 (2.3-4.1)	6.0 (2.6)*	5.7 (4.2-7.5)
Vitamin B12 (µg/10MJ)	1.0 (1.8)	0.5 (0.1-1.2)	0.1 (0.5)*	0.0 (0.0-0.0)
Total folate (µg/10MJ)	491 (200)	461 (348-586)	1079 (1545)*	849 (637-1119)
DFE (µg/10MJ)	576 (288)	509 (375-698)	1133 (1554)*	891 (647-1210)
Sodium (mg/10MJ)	2330 (757)	2255 (1815-2768)	1404 (1325)*	1049 (489-1927)
Potassium (mg/10MJ)	3930 (1231)	3786 (3191-4478)	12616 (43911)*	9214 (7301-11576)
Calcium (mg/10MJ)	732 (231)	703 (579-859)	698 (1220)	570 (414-792)
Iron (mg/10MJ)	17.9 (7.6)	16.5 (13.1-20.8)	24.8 (15.3)*	20.9 (16.0-29.0)
Magnesium (mg/10MJ)	383 (110)	375 (309-440)	976 (3849)*	711 (610-841)
Zinc (mg/10MJ)	7.4 (2.8)	7.0 (5.6-8.6)	11.1 (4.3)*	10.7 (8.5-13.1)
Phosphorous (mg/10MJ)	1155 (311)	1108 (948-1307)	1894 (3840)*	1630 (1353-1931)
Copper (mg/10MJ)	1.6 (0.5)	1.5 (1.2-1.8)	3.5 (5.0)*	2.8 (2.4-3.4)
Iodine (µg/10MJ)	48.1 (56.5)	43.5 (34.9-54.6)	165 (1051)*	66.9 (48.4-95.8)

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE=dietary folate equivalents
*Statistically different ($P < 0.001$) from plant-based (all) within the rows via paired samples t-test

Discussion

The aim of this study was to examine the nutritional quality of the PB component of the diet of adults in Ireland (a population accustomed to consuming a primarily omnivorous diet) using two extremes of PB diet definitions: plant-based (all) (PB-A) and plant-based (healthful) (PB-H), compared to the baseline diet and to examine the nutritional quality of these PB components between sexes and age groups.

This study found that the PB-A component of the diet consisted of a large proportion of food codes from the food group ‘foods high in fat, salt & sugar’ as well as ‘vegetables & vegetable dishes’, ‘cereals & cereal products’, ‘fruit & fruit juices’ and ‘potatoes & potato dishes’. When compared to the baseline diet, the PB-A component of the diet was of better nutritional quality in terms of total and saturated fat, carbohydrate, dietary fibre, vitamin C, thiamin, biotin, vitamin B6, folate, sodium, potassium, iron, magnesium and copper, but of poorer nutritional quality in terms of protein, MUFA, PUFA, total sugars, free sugars, vitamin D, vitamin B12, riboflavin, niacin, pantothenate, calcium, phosphorous, zinc and iodine. Regarding differences in intakes between sexes, the nutritional quality of the PB-A component of the diet was generally better in women, with the exception of total fat, saturated fat, total sugars and niacin. Regarding differences between age groups, the nutritional quality of the PB-A component of the diet in those aged 18-35y was poorer than any other age group in terms of protein, free sugars, dietary fibre, vitamin A, vitamin E, potassium, magnesium, zinc and copper.

This study found that the PB-H component of the diet consisted mainly of food codes from the food groups ‘vegetables & vegetable dishes’ and ‘fruit & fruit juices’ with smaller proportions from ‘nuts, seeds, herbs & spices’, ‘cereals & cereal products’ and ‘potatoes & potato dishes’ and minimal proportions from ‘foods high in fat, salt & sugar’. The PB-H component of the diet was of better nutritional quality in terms of total and saturated fat, carbohydrate, free sugars, dietary fibre, vitamins A, E and C, thiamin, riboflavin, pantothenate, biotin, vitamin B6, folate, sodium, potassium, iron, magnesium, zinc and copper but of poorer nutritional quality in terms of protein, MUFA, PUFA, total sugars, vitamin D, vitamin B12 and calcium, compared to the baseline diet. Regarding differences in intakes between sexes, women had a higher intake of total sugars, dietary fibre, vitamin E and vitamin C compared to men, but no other differences were observed, indicating that the nutritional quality of the PB-H component of the diet was generally similar between men and women. Fewer differences in nutrient intakes were observed across age groups in the PB-H component of the diet compared to the PB-A component. The nutritional quality of the PB-H component of the diet in those aged 18-35y was poorer for total fat and carbohydrate but better for vitamin E compared to those aged 65y+.

When both PB diet components were compared, this study found that the PB-H component of the diet was of better nutritional quality compared to the PB-A with regards to protein, PUFA, carbohydrate, dietary fibre, total fat, saturated fat, free sugars, vitamins A, E and C, thiamin, riboflavin, niacin, pantothenate, biotin, vitamin B6, total folate and DFE, sodium, potassium, iron, magnesium, zinc, phosphorous, copper and iodine, but of poorer nutritional quality in terms of total sugars, MUFA, vitamin D and vitamin B12.

PB-A component of the diet

As PB diets consist mainly of foods from plant sources, it is unsurprising that a large proportion of the food codes included in the PB-A component of the diet were from 'vegetables & vegetable dishes', 'cereals & cereal products', 'fruit & fruit juices' and 'potatoes & potato dishes', however, the PB-A component of the diet also contained a large proportion of food codes from 'foods high in fat, salt & sugar', which supports the view that not all foods considered PB are necessarily 'healthful' (Hemler and Hu, 2019).

The intake of energy from the PB-A component of the diet (4.7MJ) was just over half that of the baseline diet (8.3MJ), which can be explained by the exclusion of animal-derived foods, including meat, fish and dairy, which were among the top contributors to energy intake in the baseline diet (Irish Universities Nutrition Alliance, 2011). Regarding macronutrients and dietary fibre, the PB-A component of the diet was of better nutritional quality in terms of total and saturated fat, carbohydrate and dietary fibre (partly explained by the exclusion of meat and dairy, which are key sources of total and saturated fat in the diets of adults in Ireland) and the inclusion of fruit, vegetables, potatoes and cereals, which are good sources of carbohydrates and dietary fibre (Irish Universities Nutrition Alliance, 2011; Feeney *et al.*, 2016; Li *et al.*, 2016). The PB-A component, however, was of poorer nutritional quality in terms of protein, MUFA and PUFA, which can be explained by the exclusion of key sources (meat and dairy) (Feeney *et al.*, 2016; Li *et al.*, 2016). Additionally, the PB-A component of the diet was of poorer nutritional quality in terms of total and free sugars, which may be partly attributed to the inclusion of the food group ‘foods high in fat, salt & sugar’. These findings are generally in line with previous reviews of PB diets, which showed that, compared to omnivorous diets, PB diets had lower intakes of energy, protein, total fat, saturated fat and MUFA and higher intakes of carbohydrate, total sugars and dietary fibre (Bakaloudi *et al.*, 2020; Neufingerl and Eilander, 2021; Kent *et al.*, 2022a). While previous studies have shown that intake of PUFA was higher in PB diets compared to omnivorous diets, this study showed that intake of PUFA was lower from the PB-A component of the diet compared to the baseline diet, which may be significant, given the relationship between higher PUFA intake (particularly omega-3 long chain PUFA) and lower risk of cardiovascular disease and also given the lower bioavailability of omega-3 fatty acids from PB sources, such as seed oils, compared to marine sources (Lane *et al.*, 2014; Trautwein and McKay, 2020).

In terms of micronutrients, compared to the baseline diet, the PB-A component of the diet was of better nutritional quality in terms of vitamin C, thiamin, biotin, vitamin B6, folate, sodium, potassium, iron, magnesium and copper which may be explained by the inclusion of micronutrient-rich foods, such as fruit, vegetables, potatoes and cereals, including fortified ready-to-eat breakfast cereals (RTEBC), which have been shown to be important contributors of a range of micronutrients including thiamin, vitamin B6, folate and iron (Galvin *et al.*, 2003; Irish Universities Nutrition Alliance, 2011; Hennessy *et al.*, 2013). This is reflected in the literature, with previous reviews of the PB literature showing similar or higher intakes of vitamins C, thiamin, vitamin B6, biotin, folate, potassium, iron, magnesium and copper in PB diets compared to omnivorous diets (Bakaloudi *et al.*, 2020; Neufingerl and Eilander, 2021; Kent *et al.*, 2022a). While findings from this study and previous literature show a similar or higher intake of iron from PB diets/diet components, the lower bioavailability of non-haem iron compared to haem has been acknowledged. The US Institute of Medicine recommends an iron intake 1.8 times higher for those consuming a vegetarian diet compared to an omnivorous diet due to the lower bioavailability of iron from PB foods compared to animal-derived foods (Trumbo *et al.*, 2001). It is not clear whether the similar or higher intake of iron seen in those consuming a PB diet is reflected in iron status, with two recent systematic reviews reporting mixed findings on the risk of iron deficiency in vegans and vegetarians (Bakaloudi *et al.*, 2020; Neufingerl and Eilander, 2021). The PB-A component of the diet was of poorer nutritional quality in terms of vitamins D and B12, which is not an unexpected finding, given that these key micronutrients are naturally occurring in animal-derived products only. Recently, there is an increase in food products fortified with vitamin D to the market, driven by global consumer demand (accelerated by the onset of the COVID-19 pandemic) and the acknowledgement that food fortification has the widest potential to increase vitamin D intake in populations (Kiely and Cashman, 2018; Buttriss and Lanham-New, 2020; Research and Markets, 2021). However, traditionally vitamin D used to fortify foods has been derived from animal sources (e.g., lanolin extracted from sheep’s wool) and is therefore not suitable for many PB diet consumers, and there is increasing demand from PB diet consumers for foods fortified with PB sources of vitamin D, e.g., fungus or lichen (Buttriss and Lanham-New, 2020; The Vegan Society, 2021; Benedik, 2022). The PB-A component of the diet was also of poorer nutritional quality in terms of riboflavin, niacin, pantothenate, calcium, phosphorous, zinc and iodine which may be partly explained by the exclusion of animal products, such as meat, fish, eggs and dairy, which are important contributors of these nutrients (Feeney *et al.*, 2016; McNulty *et al.*, 2017; Cocking *et al.*, 2020) and the inclusion of energy-dense, but nutrient-poor foods that would be considered PB, such as foods high in fat, salt and sugar. Previous reviews of the PB literature have shown similar findings, with PB diets having lower intake and status of vitamin D, vitamin B12, zinc and iodine compared to omnivorous diets (Bakaloudi *et al.*, 2020; Neufingerl and Eilander, 2021; Kent *et al.*, 2022a).

When intakes from the PB-A component of the diet were compared between the sexes, women had a lower intake of energy from the PB-A component of the diet compared to men (4.0 vs 5.5MJ, respectively) and women had higher intakes of protein, MUFA, PUFA, dietary fibre, vitamins A, E, C, potassium, iron, zinc and copper, however women also had higher intakes of total fat, saturated fat and total sugars and lower intakes of niacin. Therefore, this study found that the nutritional quality of the PB-A component of the diet was generally better in women, with the exception of total fat, saturated fat, total sugars and niacin. These findings may be a reflection of the gender-biased perception of the consumption of PB foods and diets seen in previous studies, showing that women are more open to the consumption of PB foods and diets for many reasons beyond the scope of this study (Modlinska *et al.*, 2020; Rosenfeld and Tomiyama, 2021).

When the PB-A component of the diet was compared across age groups, those aged 18-35y had a higher intake of energy (5.2MJ) compared to the other age groups (range: 4.0-4.7MJ) and the nutritional quality of the PB-A component of the diet in those aged 18-35y was poorer than any other age group in terms of protein, free sugars, dietary fibre, vitamin A, vitamin E, potassium, magnesium, zinc and copper. These findings may not be unexpected as studies suggest younger adults consume more energy-dense diets with preferences for packaged and convenience foods and sugar-sweetened beverages compared to older adults (Smith *et al.*, 2009; Guenther *et al.*, 2014; Livingstone *et al.*, 2022).

PB-H component of the diet

Most of the food codes included in the PB-H component of the diet were from the food groups 'vegetables & vegetable dishes' and 'fruit & fruit juices' with smaller proportions from 'nuts, seeds, herbs & spices', 'cereals & cereal products' and 'potatoes & potato dishes' and minimal proportions from the food group 'foods high in fat, salt & sugar', (e.g., vegetable, nut and seed oils, wholegrain crackers and plain popcorn) in line with definitions of 'healthful' PB diets within the literature (Satija *et al.*, 2016; Kim *et al.*, 2018; Kent *et al.*, 2022a).

The intake of energy from the PB-H component of the diet was significantly lower compared to the baseline diet (1.1 vs 8.3MJ, respectively), due to the significant restriction of all animal-derived and refined foods and beverages which are major contributors to energy intake in the diet of adults in Ireland and other developed countries (Irish Universities Nutrition Alliance, 2011; Auestad *et al.*, 2015). Subsequently, a population-level shift towards a more PB diet (recommended for health and sustainability) would require a concomitant shift in behaviour at population level, to significantly increase the consumption of healthful PB foods (fruit, vegetables, whole grains, nuts and seeds) to meet energy needs. Regarding macronutrients and dietary fibre, as with the PB-A component of the diet, the PB-H component of the diet was of better nutritional quality in terms of total and saturated fat compared to the baseline diet and of poorer nutritional quality in terms of protein, MUFA and PUFA. While intakes of carbohydrate, dietary fibre and total sugars were higher from the PB-H component of the diet compared to the baseline, intake of free sugars was lower. These findings can be explained by the proportions of carbohydrate-rich foods, such as fruit, vegetables and cereals (which also contain natural sugars) and the exclusion of refined free sugar sources, such as foods and beverages high in fat, salt and sugar in the PB-H component of the diet.

With regards to micronutrients, compared to the baseline diet, the PB-H component of the diet was of better nutritional quality in terms of vitamins A, E and C, thiamin, riboflavin, pantothenate, biotin, vitamin B6, folate, sodium, potassium, iron, zinc and copper due to the significant restriction of energy-dense but nutrient-poor foods and beverages which were not considered to be ‘healthful’. As previously discussed, while intake of iron has been shown in the literature to be higher in PB diets, the bioavailability of iron from PB foods may impact iron status in PB diet consumers (Bakaloudi *et al.*, 2020; Neufingerl and Eilander, 2021; Kent *et al.*, 2022a). Similarly, although intake of zinc was higher from the PB-H component of the diet, zinc status in PB consumers is generally lower (Neufingerl and Eilander, 2021). While some PB foods are rich in zinc, such as nuts and seeds, legumes and some whole grains, they also contain phytate, a zinc inhibitor, meaning those consuming a PB diet may have up to 50% higher zinc requirements than omnivores (Trumbo *et al.*, 2001; Allen *et al.*, 2019). The PB-H component of the diet, like the PB-A component, was less nutrient-dense in terms of vitamin D, vitamin B12 and calcium compared to the baseline diet. The exclusion of many foods fortified with vitamins D, B12 and calcium which are considered refined and highly processed, such as many RTEBC, fat spreads, juice drinks and other beverages may explain these findings (Hennessy *et al.*, 2015).

Similar to the PB-A component of the diet, when comparing the PB-H component between sexes, women had a lower intake of energy compared to men (1.0 vs 1.2MJ). Fewer differences in nutrient intakes were observed between men and women in the PB-H component of the diet compared to the PB-A component. Women had a higher intake of total sugars, dietary fibre, vitamin E and vitamin C compared to men, but no other differences were observed, indicating that the nutritional quality of the PB-H diet was generally similar between men and women.

When the PB-H component of the diet was compared across age groups, those aged 18-35y had a lower intake of energy compared to those aged 51-64y and 65y+. Fewer differences in nutrient intakes were observed across age groups in the PB-H component of the diet compared to the PB-A component. From the PB-H component of the diet, those aged 18-35y had higher intakes of total fat, MUFA and vitamin E and lower intakes of carbohydrate and zinc compared to those aged 65y+, with no differences observed for those aged 36-50y and 51-64y. Therefore, generally, the nutritional quality of the PB-H component of the diet was similar across the age groups, which suggests that relative to energy intakes, these age groups consume similar amounts of ‘healthful’ PB foods and beverages. However, despite potentially similar intakes of ‘healthful’ PB foods across the adult age groups, the adult population of many countries in Europe do not meet WHO recommendations for fruit and vegetables (400g/d) (World Health Organisation, 2006; Stea *et al.*, 2020).

Comparison of the PB-A vs PB-H components of the diet

These findings show significant differences in nutritional quality between PB diets depending on the definition used to characterise the PB component of the diet. The energy content of the PB-H component of the diet was lower compared to the PB-A component (1.1 vs 4.7MJ, respectively), due to the additional restriction of refined and ‘unhealthful’ PB foods and beverages. Compared to the PB-A component of the diet, the nutrient density of the PB-H component was higher for total sugars and lower for MUFA. However, the PB-H component of the diet was of better nutritional quality in terms of total fat, saturated fat, PUFA, protein, carbohydrate, dietary fibre and free sugars, which reflects the exclusion of foods high in fat, salt and sugar compared to the PB-A component of the diet. With regards to micronutrients, compared to the PB-A component, the PB-H component of the diet was of better nutritional quality in terms of vitamins A, E and C, thiamin, riboflavin, niacin, pantothenate, biotin, vitamin B6, total folate and DFE, potassium, iron, magnesium, zinc, copper, iodine and sodium. However, the PB-H component of the diet was of poorer nutritional quality in terms of vitamin D and vitamin B12, explained by the exclusion of refined products, such as fortified, RTEBC, fat spreads and beverages which contributed to intakes of these vitamins in the PB-A component. Although the nutrient density of PB-A component of the diet was higher for vitamin D and vitamin B12, intakes were still low from the

PB-A component of the diet. There was no difference in nutrient density between the PB-A and PB-H components of the diet for calcium.

The overall findings of this study adds to and complements previous research on PB dietary quality indexes, which show that the nutritional quality of the diet, with respect to carbohydrate, dietary fibre, saturated fat, vitamin A, vitamin C, folate, potassium, magnesium and iron improves with increasing intake of healthful PB foods and will have important implications for policy and guidance as recommendations shift towards the consumption of a more PB diet (Satija *et al.*, 2016; Kim *et al.*, 2019).

Public health implications

Diet-related non-communicable diseases and nutrient deficiencies remain significant in the general population in developed countries with poor compliance with guidelines noted for total and saturated fat, carbohydrate, free sugars, dietary fibre and sodium in the World Health Organisation (WHO) European region, including Ireland (Irish Universities Nutrition Alliance, 2011; World Health Organisation, 2014; Rippin *et al.*, 2017). In addition, iodine, iron and vitamin D have been identified as nutrients of concern and there is a potential risk of potassium, calcium and folate deficiency (Irish Universities Nutrition Alliance, 2011; Cashman *et al.*, 2013; World Health Organisation, 2014; McNulty *et al.*, 2017; Rippin *et al.*, 2017). This study outlines the findings from the PB components of a diet and not a PB diet per se. Those consuming a traditional PB diet, such as a vegan diet, are likely to substitute animal-derived foods for PB alternatives, modifying the nutritional composition and quality of the diet. Therefore, the nutritional quality of the PB components of an omnivorous diet cannot be directly compared to the nutritional quality of a PB diet, such as a vegan diet. Nonetheless, it suggests that the move towards the consumption of a more PB diet may improve the nutritional quality of the diet of adults in Ireland in terms of total fat, saturated fat, carbohydrate, free sugars, dietary fibre, sodium, potassium and folate, but may exacerbate potential deficiencies of iodine, iron, vitamin D and calcium and may additionally pose concern regarding intake of vitamin B12. The intake of the key nutrients, vitamin D and vitamin B12, were particularly low from the more restrictive PB-H component of the diet and highlights how the promotion of a 'healthful', minimally processed PB diet may predicate against the consumption of some fortified foods, which help to increase nutrient intake on a population basis. While fortified foods make a useful contribution to intake of vitamin D and B12, supplementation may still be required. Regardless of the type of diet consumed, PB or omnivorous diet, vitamin D supplementation is often recommended to ensure adequate intakes, particularly during Winter months (Cashman, 2020) and as plant sources provide only trace amounts of vitamin B12, the consumption of dietary supplements and/or fortified foods is required to maintain an adequate supply of vitamin B12 in the diets of vegans or those who significantly limit their intake of animal-derived foods (Rizzo *et al.*, 2016).

While nutritional status was not examined, this study acknowledges the inconsistencies between nutrient intake and nutrient status within PB nutrition for some nutrients. While intake of iron was high from both PB components of the diet compared to the baseline diet and intake of zinc was higher in the PB-H component of the diet, considerations need to be made for the lower bioavailability of these nutrients from PB foods. Importantly, the nutrient density of both PB components compared to the baseline diet was lower for calcium which may be a cause for concern given that calcium absorption may be reduced by phytate and oxalates present in plant foods, as well as low vitamin D status (Craig *et al.*, 2021). Similarly, the nutrient density of both PB components compared to the baseline diet was lower for PUFA and therefore should be an important consideration in the planning of PB diets, given the reduced bioavailability of omega-3 long chain PUFA from PB sources (Lane *et al.*, 2014). Protein intake from the PB components of the diet was lower compared to the baseline diet and while previous studies show intake of protein was generally adequate in PB diet consumers, protein intake should be carefully considered in vegans and older adults, who were seen to be potentially at higher risk of inadequacy (Bakaloudi *et al.*, 2020; Neufingerl and Eilander, 2021; Kent *et al.*, 2022a). Additionally, since many PB diets lack the main sources of high biological value protein (found in animal-derived foods), protein intake from PB diets should be carefully planned to ensure that not only an adequate amount of protein is consumed, but that the variety of protein sources provides a full complement of essential amino acids (Mariotti and Gardner, 2019).

As diets shift towards the consumption of more PB foods, the quality of the PB diet is gaining more attention. While the PB food market is growing in response to consumer demand for more PB products, the dietary quality of many of these foods, such as PB meat burgers and sausages has been questioned and may not be considered as part of a 'healthful' PB diet, with some studies showing many PB alternative foods contain higher sodium and do not contain key micronutrients, such as vitamins D and B12, iron or zinc, that would traditionally be found in their animal-derived counterparts (Safefood, 2021; Wickramasinghe *et al.*, 2021). While the consumption of healthful PB foods, such as fruit, vegetables, whole grains, nuts and seeds should be promoted on a population level, this may not be sufficient to meet nutritional requirements. When consuming a PB diet, knowledge of the definition and restrictiveness of the PB diet is important to help to mitigate against the risk of nutritional deficiencies and careful consideration should be given to meet nutritional recommendations through fortified foods and/or supplementation for nutrients whose requirements cannot be met through food alone.

Strengths and limitations

To the author's knowledge, this is the first study to examine the nutrient density and nutritional quality of the PB component of a diet, using real food consumption data from an omnivorous population group. A key strength of this study was the use of a nationally representative sample of adults and the detailed dietary intake data collected via a 4-day semi-weighed food diary.

While this data is the most up-to-date data on the diets of a nationally representative sample of adults in Ireland available at present, it is based on data gathered between 2008-2010 and as emphasis on the consumption of PB diets increases and as new foods, such as more PB food products (which may be fortified) come to the market, it remains to be seen whether the nutritional quality of the PB component of the adult diet will have changed when data for the National Adult Nutrition Survey II (which is currently being collected), becomes available (www.iuna.net).

Conclusions

This study aimed to examine the nutritional quality of the PB component of a diet, using real food consumption data from an omnivorous population group. This study found significant differences in the amount and types of foods included in the PB-A component and the PB-H component of the diet. Both PB components of the diet were of better nutritional quality in terms of total fat, saturated fat, carbohydrate, dietary fibre, vitamin C, thiamin, biotin, vitamin B6, total folate, DFE, sodium, potassium, iron, magnesium and copper compared to the baseline diet but were of poorer nutritional quality in terms of protein, MUFA, PUFA, total sugars, vitamin D, vitamin B12, calcium and iodine (for PB-A only). With regard to free sugars and zinc, the PB-A component of the diet was of poorer nutritional quality compared to the baseline diet, but the PB-H component was of better nutritional quality. The nutritional quality of the PB-A component of the diet was generally better in women, with the exception of total fat, saturated fat, total sugars and niacin but few differences were observed between the sexes in the PB-H component of the diet with women having a higher intake of total sugars, dietary fibre, vitamin E and vitamin C compared to men. The PB-A component of the diet for those aged 18-35y was of poorer nutritional quality in terms of protein, free sugars, dietary fibre, vitamin A, vitamin E, potassium, magnesium, zinc and copper but fewer differences in nutrient intakes were observed across age groups in the PB-H component of the diet compared to the PB-A component. The nutritional quality of the PB-H component of the diet in those aged 18-35y was poorer for total fat, carbohydrate and zinc and better for MUFA and vitamin E compared to those aged 65y+.

When both PB components of the diet were compared to each other, this study highlighted the differences in nutrient density in terms of key nutrients, depending on the definition of the PB diet component. Of note, the nutrient density of the PB-H component of the diet in terms of vitamin D and vitamin B12 was lower compared to the PB-A component, owing to the exclusion of many refined and processed, but fortified foods, such as RTEBC, fat spreads and beverages.

While a move towards the consumption of a more PB diet may improve the nutritional quality of the diet of adults in Ireland in terms of many key nutrients, such as total fat, saturated fat, carbohydrate, free sugars, dietary fibre, sodium, potassium and folate, it may exacerbate potential deficiencies of vitamin D, calcium, iodine, iron and may additionally pose concern regarding intake of vitamin B12. It is important to acknowledge the lower bioavailability of nutrients, such as protein, omega-3, iron, zinc and calcium from PB foods, compared to animal-derived products. More research is needed to investigate the role of PB diets for nutritional adequacy and status in Ireland. This research will benefit health professionals, policymakers and the food industry in understanding the position of PB foods within the diet of adults in Ireland

and comparing this research to future food consumption data for adults in Ireland (NANS II) will help to understand trends in the consumption of the more environmentally sustainable PB component of the diet.

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Chapter 5

‘Fruit & vegetables’ in the diets of adults in Ireland: the estimated intakes, compliance with recommendations and nutritional contributions

Introduction

Fruit & vegetables, a diverse group of plant foods and the cornerstone of a plant-based (PB) diet, have long been recognised for their importance in providing essential micronutrients, dietary fibre and health-promoting bioactive compounds to the diet (Slavin and Lloyd, 2012; Herforth *et al.*, 2019; Rocha *et al.*, 2019; Wallace *et al.*, 2020; Rong *et al.*, 2021). Evidence consistently shows a positive association between fruit & vegetable intake and the reduced risk of non-communicable diseases, such as cardiovascular disease and stroke, cancer and diabetes as well as with the prevention and alleviation of several micronutrient deficiencies, such as vitamins A and C, particularly in developing countries (World Health Organisation, 2002; World Health Organisation/Food and Agriculture Organisation, 2003; World Cancer Research Fund/American Institute for Cancer Research, 2018). Correspondingly, health organisations, such as the World Health Organisation (WHO) and the World Cancer Research Fund (WCRF) recommend the daily consumption of at least 400g of fruit & vegetables (excluding potatoes and other starchy tubers) (World Health Organisation, 2005; World Cancer Research Fund/American Institute for Cancer Research, 2018). In line with this, food-based dietary guidelines (FBDG) in countries within the WHO European region (reviewed in Chapter 1) recommend at least 400g of fruit & vegetables per day, with some countries recommending higher intakes, such as 500g in Sweden and Finland, 600g in Denmark, 650g in Germany and 700-900g in Georgia (Ministry of Labor Health and Social Affairs, 2005; Finnish food authority, 2014; Swedish Food Agency, 2015; German Nutrition Society, 2017; Ministry of Food Agriculture & Fisheries, 2022). In Ireland, the FBDG for the general population (over 5 years of age) recommend the consumption of 5-7 (80g) servings of fruit & vegetables per day limiting fruit juice to ≤150ml of unsweetened fruit juice, as juice is a source of free sugars which contribute to overall energy-density of diets and are associated with dental caries (Scientific Advisory Committee on Nutrition, 2015; World Health Organisation, 2015; Department of Health, 2016). Many other countries within the WHO European region (Albania, Austria, Denmark, Greece, Malta, the UK, Switzerland) also limit fruit and/or vegetable juice to one portion of varying quantities (100ml, 125ml, 150ml, 200ml, no specific recommendations) (National Center of Public Health Protection (NCPHP), 2006; Department of Public Health, 2008; Austrian Ministry of Health and the National Nutrition Commission, 2010; Swiss

Society for Nutrition, 2011; Institute of Preventive Environmental & Occupational Medicine (Prolepsis), 2014; Health Promotion and Disease Prevention Directorate, 2015; Public Health England, 2016; Ministry of Food Agriculture & Fisheries, 2022).

Despite the recommendation to consume plenty of fruit & vegetables, the actual intake of fruit & vegetables in adults across countries within the WHO European region varies greatly and for most countries, is lower than the recommended 400g/d. The mean intake of fruit & vegetables was lower than the 400g/d minimum recommendation in Belgium, the Netherlands, the UK, Portugal, Finland and Spain (329-393g/d), while intake of fruit & vegetables in Denmark (445g/d), Italy (473g/d) and Germany (756g/d) was in line with the WHO recommendations (Helldán *et al.*, 2013; Sette *et al.*, 2013; Heuer *et al.*, 2015; Pedersen *et al.*, 2015; Lopes *et al.*, 2018; Bel *et al.*, 2019; Partearroyo *et al.*, 2019; Public Health England, 2020; van Rossum, 2020).

Data from these studies of adults in countries within the WHO European region show that while intakes of fruit & vegetables are lower than recommended, they still make important contributions to nutrient intakes, particularly micronutrient intakes. Fruit & vegetables made small contributions to intakes of energy (8-13%), protein (5-10%), total fat (3-7%) and saturated fat (1-5%), yet provided significant contributions to intakes of carbohydrate (11-22%), total sugars (25-36%), free sugars (3-9%), dietary fibre (27-51%), vitamin C (39-89%), vitamin A (20-58%), folate (24-41%), potassium (21-37%), vitamin E (16-38%), vitamin B6 (15-29%), magnesium (14-27%), iron (13-25%), thiamin (12-22%), riboflavin (8-20%), calcium (8-17%), zinc (7-14%) and niacin (6-12%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Ruiz *et al.*, 2015; Ruiz *et al.*, 2016; Olza *et al.*, 2017a; Olza *et al.*, 2017b; Partearroyo *et al.*, 2017; Ruiz *et al.*, 2017; Samaniego-Vaesken *et al.*, 2017; Lopes *et al.*, 2018; Mielgo-Ayuso *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

In Ireland, data from the North/South Ireland Food Consumption Survey (NSIFCS) (1997-1999) found that adults aged 18-64 years had a low intake (276g/d) of fruit & vegetables relative to recommendations however more recent data are now available, including data on older adults (65y+) from the National Adult Nutrition Survey (NANS) for adults aged 18-90 years (O'Brien *et al.*, 2003). Therefore, the aim of this study is to use data from the NANS to estimate the current intake of fruit & vegetables in adults (18-90y) in Ireland, to assess compliance with recommendations and to determine their contribution to overall energy and nutrient intakes.

Methodology

The National Adult Nutrition Survey food consumption database

The analyses for this chapter are based on data from the Irish National Adult Nutrition Survey (NANS) (www.iuna.net). Briefly, the NANS is a nationally representative, cross-sectional study that collected habitual food and beverage consumption data (in addition to lifestyle, health indicators and attitudes to food and health) from 1500 adults aged 18-90 years in the Republic of Ireland between 2008 and 2010. The methodology for sampling, participant recruitment, data collection and food quantification for NANS is described in detail in Chapter 2, with methods specific to this chapter outlined below.

Food intake data collection

Food and beverage intake data (including nutritional supplements) were collected using a 4-day semi-weighed food diary. Participants were asked to record detailed information regarding the amount, type and brand name of all foods and beverages consumed over the recording period, which included at least one weekend day. Where applicable, details of cooking methods, recipes of composite dishes and any leftovers were also recorded. To facilitate the collection of data, participants were asked to collect the packaging labels of all foods and beverages consumed over the recording period. Where packaging labels were not available from the participant, the researchers sourced and photographed the packaging from local supermarkets.

A quantification protocol established by the Irish Universities Nutrition Alliance (IUNA) (Harrington *et al.*, 2001) was used for the NANS. In summary, 46% of foods and beverages were weighed using a portable food scales (Tanita, Japan) provided to each participant and a further 10% were derived from the manufacturer information on product labels. The remaining foods and beverages were quantified using either a photographic food atlas (16%) (Nelson *et al.*, 1997), stardard portion weights (11%) (Food Standards Agency, 2002a), household measures (11%), average weights ascertained by the IUNA team (4%) or estimated based on the participant's previous eating patterns (only used when no other quantification method was appropriate) (2%).

Nutrient composition of foods

Dietary intake data were analysed using WISP© (Tinuviel Software, Anglesey, UK) which estimated nutrient intakes using data from McCance and Widdowson’s The Composition of Foods, sixth (Food Standards Agency, 2002b) and fifth (Holland *et al.*, 1991a) editions plus all nine supplemental volumes (Holland *et al.*, 1988; Holland *et al.*, 1989; Holland *et al.*, 1991b; Holland *et al.*, 1992; Holland *et al.*, 1993; Chan *et al.*, 1994; Chan *et al.*, 1995; Chan *et al.*, 1996; Holland *et al.*, 1996). During the NANS, modifications were made to this food composition database to include recipes of composite dishes, nutritional supplements, fortified foods, generic foods that were commonly consumed in Ireland and new foods on the market. Additionally, the food composition database has since been updated with values for total fat, saturated fat, monounsaturated fat (MUFA), polyunsaturated fat (PUFA), free sugars, sodium, vitamin D and iodine, which has been detailed elsewhere (Giltinan, 2012; Black *et al.*, 2015; Li *et al.*, 2016; McNulty *et al.*, 2017; Walton *et al.*, 2017). Dietary folate equivalents (DFE) were estimated using the following equation: 1µg DFE = 1µg food folate + (1.7 x folic acid) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014).

Estimation of ‘fruit & vegetable’ intake

Each food, beverage and nutritional supplement consumed in the NANS was assigned an individual food code and food descriptor based on its nutritional profile. All food codes were categorised into previously defined food groups which were then further disaggregated for the purpose of this analysis (**Appendix I & Appendix II**).

In all, 2552 individual food codes were included in the NANS food consumption database and of these, 1108 included a fruit and/or vegetable component. These included discrete fruit and vegetables (i.e., fruit and vegetables consumed whole and/or not as part of a mixed (composite) dish), and fruit and vegetables contained in composite dishes/foods, such as fruit in yogurt, vegetables in soup etc. In this study, vegetables referred to the edible parts of plants commonly consumed as vegetables, including pulses, sweetcorn (botanically a cereal), mushrooms, seaweed and some botanical fruit, e.g., tomatoes, peppers, cucumbers, avocados and olives. Fruit referred to the edible parts of fresh, tinned, frozen and dried fruit. Cereals, potatoes and starchy tubers (e.g., sweet potatoes, yams) were not considered vegetables for these analyses.

Only the edible portions were included in the estimates; inedible or unconsumed portions, such as cores and uneaten peel were estimated and removed from the reported intake (Holland *et al.*, 1991a; Food Standards Agency, 2002b). In calculating the fruit and/or vegetable proportion of composite dishes and foods (hereafter known as composite dishes), all foods with a fruit and/or vegetable component, regardless of the nutritional profile of the dish/food, were included. The quantity of fruit & vegetables in each of these composite dishes was estimated using standard recipes from the UK food composition database, as well as from participants' recipes and manufacturers' product information.

Estimation of food group intakes

The mean daily intake (MDI) of 'fruit & vegetables' and their subgroups (listed below) were estimated for each participant by summing the weight of each food group (g) consumed over the recording period and dividing the total by the number of recording days (four).

Fruit & vegetables

- **Fruit & fruit juices**
    - **Discrete fruit**, of which, bananas, apples, citrus fruit, pears, grapes and other fruit (berries, stone fruit, tropical fruit, tinned fruit, kiwi, dried fruit, rhubarb etc.)
    - **Fruit juice** (100% fruit juice)
    - **Fruit smoothies** (the fruit content of smoothies only)
    - **Fruit in composite dishes**, including the fruit content of squashes, cordial and other fruit juice drinks
- **Vegetables**
    - **Discrete vegetables**, of which, **s**alad vegetables, peas, beans & lentils (of which baked beans), green vegetables, carrots and other vegetables (root vegetables excluding carrots, such as turnip and parsnips, onion, mixed vegetables, peppers, mushrooms, tinned vegetables, cauliflower, sweetcorn etc.
    - **Vegetables in composite dishes**, including vegetable juice

Compliance with food-based dietary guidelines

The WHO recommend the consumption of a minimum of 400g of fruit & vegetables per day for the general population (excluding potatoes and other starchy tubers), which equates to approximately five 80g servings (World Health Organisation, 2005), while the Irish FBDG advise the general population to consume 5-7 (80g) servings of fruit & vegetables per day, including no more than 150ml of unsweetened fruit juice (Department of Health, 2016). To determine the proportion of adults (18-90y) in Ireland meeting the WHO and Irish FBDG recommendations for fruit & vegetable intake, this study estimated the proportion of adults with an MDI (over the 4 day recording period) of ≥400g fruit & vegetables, with and without the 150ml limit on fruit juice intake. The study also determined the proportion of adults with an MDI of ≥4 servings (320g), ≥3 servings (240g), ≥2 servings (160g) and ≥1 servings (80g) of fruit & vegetables for both the WHO recommendations and the Irish FBDG.

Percent contribution of 'fruit & vegetables' to energy and nutrient intakes

Using descriptive frequencies, the percent contribution of 'fruit & vegetables' (and each subgroup) to the MDI of energy and nutrients was calculated by the mean proportion method (Krebs-Smith *et al.*, 1989). The mean proportion method calculates the proportions of nutrient intakes from food groups 'per person' and is the preferred method when determining important food sources of a nutrient within the food supply. The contribution of 'fruit & vegetables' to energy and nutrient intakes was estimated based on intake from the following subgroups:

- **Fruit & fruit juices**
    - *Discrete fruit*
    - *Fruit juice & smoothies*, including the non-fruit components, e.g., yogurt/milk
- **Vegetables & vegetable dishes**
    - *Discrete vegetables*
    - *Vegetable dishes*, including the non-vegetable components, e.g., rice in mushroom risotto

However, fruit and vegetables from composite dishes (e.g., vegetables as part of meat dishes) were not included in the contribution of 'fruit & vegetables' to energy and nutrient intakes. While many fruit and vegetables were disaggregated from meals and entered into the nutrition software separately, for some composite dishes, the nutritional composition of the individual foods within the dish were aggregated together, e.g. vegetables in a bolognese.

Statistical analysis

The MDI of ‘fruit & vegetables’ and each subgroup (‘fruit & fruit juices’, ‘discrete fruit’, ‘fruit juice’, ‘fruit smoothies’, ‘fruit in composite dishes’, ‘vegetables’, ‘discrete vegetables’ and ‘vegetables in composite dishes’) was calculated and the distribution of intake was reported as mean, standard deviation, median and interquartile range using SPSS© for Windows™ Version 26. Differences in the MDI of ‘fruit & vegetables’ and each subgroup between sexes (men, women) were assessed using independent sample t-tests. Differences in the MDI of ‘fruit & vegetables’ and each subgroup between age groups (18-35y, 36-50y, 51-64y, 65y+) were assessed using ANOVA and Tukey tests were used for post-hoc analysis. Parametric tests were used in all cases regardless of normality of the data, due to the large sample size (*n* 1500) (Fagerland, 2012). To minimise type 1 errors (as a result of multiple testing), the Bonferoni adjustment was used by dividing the alpha level (0.05) by the number of comparisons. Therefore, intakes were significantly different from each other if $P < 0.001$.

Results

Table 1 presents the MDI of ‘fruit & vegetables’ in adults (18-90y) in Ireland in the total population (*n* 1500) and in consumers only.

‘Fruit & vegetables’ were consumed by all adults (100%) with an MDI of 285g/d. Of this, ‘fruit & fruit juices’ were consumed by 95% of adults with an MDI of 144g/d in the total population and ‘vegetables’ were consumed by 100% of adults, with an MDI of 141g/d.

Of the ‘fruit & fruit juices’ intake, the MDI of ‘discrete fruit’ (in the total population) was 83g/d, ‘fruit juice’ was 39g/d, ‘fruit smoothies’ was 4g/d and ‘fruit in composite dishes’ was 18g/d.

Of the ‘vegetables’ intake, the MDI of ‘discrete vegetables’ (in the total population) was 88g/d and ‘vegetables in composite dishes’ was 53g/d.

Table 2 presents the MDI of ‘fruit & vegetables’ in adults (18-90y) in Ireland in the total population (*n* 1500), split by sex.

There were no differences observed in the MDI of ‘fruit & vegetables’, ‘fruit & fruit juices’ or ‘vegetables’, between men and women.

The MDI of ‘other discrete fruit’ was higher in women (20g/d), compared to men (10g/d), attributable to a higher MDI of ‘berries’ in women (5g/d) compared to men (2g/d) (data not shown). The MDI of ‘salad vegetables’ was higher in women (22g/d) compared to men (16g/d), while the MDI of ‘peas, beans & lentils’ was lower in women (12g/d) compared to men (17g/d).

There were no differences in the MDI of any other subgroup between men and women.

Table 3 presents the MDI of ‘fruit & vegetables’ in adults (18-90y) in Ireland in the total population (*n* 1500), split by age group.

The MDI of ‘fruit & vegetables’ was lower in those aged 18-35y (262g/d) compared to those aged 51-64y (321g/d), but there were no differences in the MDI of ‘fruit & vegetables’ among those aged 36-50y (279g/d) and 65y+ (301g/d) compared to the other age groups. There was no difference in the MDI of ‘fruit & fruit juices’ between age-groups. The MDI of ‘vegetables’ was lower in those aged 18-35y (130g/d) compared to those aged 51-64y (157g/d) but there was no difference in the MDI of 'vegetables' between the other age groups (138-146g/d).

The MDI of 'discrete fruit' was lower in those aged 18-35y (61g/d) compared to those aged 51-64y (112g/d) and 65y+ (107g/d) and there was no difference in the MDI of 'discrete fruit' in those aged 36-50y (78g/d) compared to those aged 65y+. Of the 'discrete fruit', the MDI of 'citrus fruit' was lower in those aged 18-35y (7g/d) compared to those aged 65y+ (16g/d), with no differences in intakes observed between the other age groups (13-14g/d). The MDI of 'pears' was higher in those aged 51-64y (12g/d) compared to those aged 18-35y (4g/d) and 36-50y (4g/d) with no differences observed in the MDI of 'pears' in those aged 65y+ (11g/d) compared to the other age groups. The MDI of 'grapes' was lower in those aged 18-35y (2g/d) compared to those aged 65y+ (7g/d) with no differences in the MDI observed between the other age groups (4-5g/d). The MDI of 'other discrete fruit' was lower in those aged 18-35y (9g/d) and 36-50y (12g/d) compared to the other age groups (22-25g/d). There were no differences observed in the MDI for 'bananas' or 'apples', 'fruit juice', 'fruit smoothies' and 'fruit in composite dishes' between age groups.

The MDI of 'discrete vegetables' was lower in those aged 18-35y (70g/d) compared to all other age groups (93-105g/d). Of the 'discrete vegetables', the MDI of 'salad vegetables' was lower in those aged 18-35y (14g/d) compared to those aged 36-50y and 51-64y (22-23g/d), but there were no differences observed in the MDI of 'salad vegetables' in those aged 65y+ (20g/d) compared to the other age groups. The MDI of 'green vegetables' was lower in those aged 18-35y (8g/d) compared to those aged 51-64y (20g/d) and 65y+ (19g/d), but there were no differences observed in the MDI of 'green vegetables' in those aged 36-50y (13g/d) compared to those aged 18-35y (8g/d) and 65y+ (19g/d). The MDI of carrots was lower in those aged 18-35y (10g/d) compared to all other age groups (15-17g/d). The MDI of 'other discrete vegetables' was lower in those aged 18-35y (23g/d) compared to those aged 51-64y (32g/d) but there were no differences observed in the MDI of 'other discrete vegetables' between the other age groups (27-28g/d). The MDI of 'vegetables in composite dishes' was higher in those aged 18-35y (60g/d) compared to those aged 65y+ (42g/d), with no differences observed in the MDI of 'vegetables in composite dishes' between the other age groups (52g/d). There were no differences observed in the MDI of 'peas, beans & lentils', including 'baked beans' between the age groups.

Table 4 presents the proportion (%) of adults (18-90y) in Ireland meeting the WHO and the Irish FBDG recommendations for 'fruit & vegetables' consumption.

The MDI of 'fruit & vegetables' (with unlimited fruit juice) was 285g/d, equating to approximately 3.6 servings of fruit & vegetables. When the intake of fruit juice was limited to 150ml/d, the MDI of 'fruit & vegetables' was 277g/d (data not shown), or approximately 3.5 servings. The MDI of 'fruit & vegetables' was below the WHO recommendations of at least 400g of 'fruit & vegetables' per day and the Irish FBDG of 5-7 servings of 'fruit & vegetables' per day (World Health Organisation, 2005; Department of Health, 2016).

At an individual level, 23% of adults met the WHO recommendation of at least 5 servings (≥400g) of 'fruit & vegetables' per day. Thirty-five percent of adults had ≥4 servings of 'fruit & vegetables' per day, 53% had ≥3 servings per day, 74% had ≥2 servings per day and 92% had ≥1 serving of 'fruit & vegetables' per day. Similar proportions of men (24%) and women (22%) met the WHO recommendations of at least 5 servings (≥400g) of 'fruit & vegetables' per day. A higher proportion of those aged 51-64y and 65y+ (26-27%) met the WHO recommendations of at least 5 servings (≥400g) of 'fruit & vegetables' compared to those aged 18-35y and 36-50y (21% for both groups).

When compared to the Irish FBDG (limiting fruit juice intake to 150ml/d), 21% of adults had ≥5 servings of 'fruit & vegetables' per day, 34% had ≥4 servings per day, 52% had ≥3 servings per day, 74% had ≥2 servings per day and 92% had ≥1 serving per day. Similar proportions of men (21%) and women (20%) met the Irish FBDG recommendations of ≥5 servings of 'fruit & vegetables' per day (including 150ml/d fruit juice limit). A higher proportion of those aged 51-64y and 65y+ (24-27%) met the Irish FBDG recommendations of ≥5 servings of 'fruit & vegetables' per day (including 150ml/d fruit juice limit), compared to those aged 18-35y and 36-50y (17%-19%).

Table 5 presents the percent contribution (%) of 'fruit & vegetables' to energy and nutrients in the diets of adults (18-90y) in Ireland in the total population (*n* 1500).

Overall, 'fruit & vegetables' contributed 7% of the MDI of energy, with 4% from 'fruit & fruit juices' and 3% from 'vegetables & vegetable dishes'. 'Fruit & vegetables' also contributed minimal proportions of the MDI of protein (4%), total fat (5%), saturated fat (2%), MUFA (4%) and a larger proportion of the MDI of PUFA (10%), with 9.6% from ‘vegetables & vegetable dishes’ and 0.5% from ‘fruit & fruit juices’.

‘Fruit & vegetables’ contributed 11% of the MDI of carbohydrate with 8% from ‘fruit & fruit juices’ and 3% from ‘vegetables & vegetable dishes’. For dietary fibre, ‘fruit & vegetables’ contributed 29% of intake, with 17% from ‘vegetables & vegetable dishes’ (15% from ‘discrete vegetables’ and 2% from ‘vegetable dishes’) and 12% from ‘fruit & fruit juices’ (11% from ‘discrete fruit’, 1% from ‘fruit juice & smoothies’). ‘Fruit & vegetables’ contributed 23% of the MDI of total sugars with ‘fruit & fruit juices’ contributing 19% (13% from ‘discrete fruit’ and 5% from ‘fruit juice & smoothies’) and ‘vegetables & vegetable dishes’ contributing 4%. ‘Fruit & vegetables’ contributed 11% of free sugars intake, with 10% from ‘fruit juice & smoothies’.

Regarding micronutrients, ‘fruit & vegetables’ contributed 41% of the MDI of vitamin C, with 26% from ‘fruit & fruit juices’ (equal contributions ‘discrete fruit’and ‘fruit juice & smoothies’) and 15% from ‘vegetables & vegetable dishes’ (12% from ‘discrete vegetables’ and 3% from ‘vegetable dishes’). ‘Fruit & vegetables’ contributed 39% of the MDI of vitamin A (38% from ‘vegetables & vegetable dishes’ and 1% from ‘fruit & fruit juices’). ‘Fruit & vegetables’ contributed 17% of the MDI of potassium (9% from ‘fruit & fruit juices’ and 8% from ‘vegetables & vegetable dishes’). ‘Fruit & vegetables’ contributed 13% to the MDI of total folate (9% from ‘vegetables & vegetable dishes’ and 4% from ‘fruit & fruit juices’). ‘Fruit & vegetables’ contributed 11% to the MDI of DFE (7% from ‘vegetables & vegetable dishes’ and 4% from ‘fruit & fruit juices’). ‘Fruit & vegetables’ contributed 12% of the MDI of vitamin E (8% from ‘vegetables & vegetable dishes’ and 4% from ‘fruit & fruit juices’).

‘Fruit & vegetables’ contributed 11% of the MDI of magnesium (6% from ‘fruit & fruit juices’ and 5% from ‘vegetables & vegetable dishes’), 10% of the MDI of thiamin, (7% from ‘vegetables & vegetable dishes’ and 3% from ‘fruit & fruit juices’) and also contributed to the MDI of iron (8%), vitamin B6 (7%), calcium (6%), sodium (5%), zinc (5%), niacin (4%) and riboflavin (3%). ‘Fruit & vegetables’ contributed negligibly to vitamin D (0.3%) and vitamin B12 (0.3%) intakes.

Table 1. Mean daily intake (g/d) of 'fruit & vegetables' in adults (18-90y) in Ireland in the total population (*n* 1500) and consumers only

	Total population		Consumers only		
	Mean (SD)	Median (IQR)		Mean (SD)	Median (IQR)
	g/d		%	g/d	
Fruit & vegetables	285 (176)	251 (155-383)	100	285 (176)	251 (155-383)
Fruit & fruit juices	144 (134)	109 (35.4-218)	95	151 (133)	117 (45.9-223)
Discrete fruit	83.4 (97.7)	53.2 (0.0-122)	71	118 (97.1)	88.4 (46.8-160)
of which					
Bananas	23.4 (34.9)	0.0 (0.0-37.5)	44	53.0 (34.5)	44.6 (25.0-71.3)
Apples	23.3 (41.9)	0.0 (0.0-34.6)	37	63.0 (47.4)	50.0 (29.0-83.4)
Citrus fruit	11.5 (31.4)	0.0 (0.0-0.0)	20	56.3 (48.0)	43.5 (24.2-72.7)
Pears	6.4 (24.6)	0.0 (0.0-0.0)	11	60.3 (49.3)	39.4 (30.7-76.3)
Grapes	3.8 (14.6)	0.0 (0.0-0.0)	13	29.6 (29.5)	20.0 (12.0-39.0)
Other discrete fruit*	14.9 (34.8)	0.0 (0.0-14.6)	33	44.5 (47.9)	28.0 (14.3-56.5)
Fruit juice	39.2 (77.4)	0.0 (0.0-51.0)	34	115 (94.1)	94.0 (50.0-151)
Fruit smoothies	3.7 (28.1)	0.0 (0.0-0.0)	4	100 (108)	62.8 (43.5-110)
Fruit in composite dishes	17.5 (23.7)	10.7 (3.5-23.3)	90	19.5 (24.2)	12.6 (5.5-25.4)
Vegetables	141 (81.4)	128 (84.6-179)	100	142 (81.2)	128 (85.2-180)
Discrete vegetables	87.8 (64.5)	76.2 (42.5-119)	96	91.4 (63.3)	78.8 (46.3-121)
of which					
Salad vegetables	19.2 (26.7)	9.6 (0.0-28.3)	62	30.7 (28.0)	21.5 (10.5-42.4)
Peas, beans & lentils	14.6 (23.0)	0.0 (0.0-22.0)	49	29.5 (25.1)	22.1 (13.8-39.0)
Baked beans	*6.5 (0.0)*	*16.4 (0.0-0.0)*	*20*	*31.8 (22.7)*	*26.5 (15.8-39.7)*
Green vegetables	13.7 (22.9)	0.0 (0.0-21.4)	44	31.1 (25.4)	24.0 (14.3-40.0)
Carrots	13.5 (18.5)	5.3 (0.0-22.5)	52	26.1 (18.2)	21.3 (13.8-33.5)
Other discrete vegetables†	26.8 (31.5)	17.8 (0.0-40.7)	73	36.8 (31.6)	28.3 (14.3-49.2)
Vegetables in composite dishes	53.4 (50.9)	39.6 (18.3-75.3)	94	56.7 (50.7)	42.0 (22.0-78.8)

*includes berries (strawberries, raspberries), stone fruit (peaches), tropical fruit (melon, pineapple), tinned fruit, kiwi, dried fruit, rhubarb etc. (≤3.5g)

†includes root vegetables, excl. carrots (turnip, parsnips), onion, mixed vegetables, peppers, mushrooms, tinned vegetables, cauliflower, sweetcorn etc. (≤5.5g)

Table 2. Mean daily intake (g/d) of 'fruit & vegetables' in adults (18-90y) in Ireland in the total population (*n* 1500), split by sex

	Men (*n* 740)		Women (*n* 760)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
	g/d		g/d	
Fruit & vegetables	283 (186)	242 (147-391)	287 (164)	265 (166-375)
Fruit & fruit juices	143 (146)	101 (24.3-219)	144 (121)	115 (47.7-218)
Discrete fruit	75.8 (97.4)	43.4 (0.0-112)	90.7 (97.4)	63.0 (12.1-136)
of which				
Bananas	24.4 (39.0)	0.0 (0.0-42.6)	22.4 (30.4)	0.0 (0.0-36.3)
Apples	23.7 (45.8)	0.0 (0.0-30.0)	23.0 (37.9)	0.0 (0.0-37.4)
Citrus fruit	8.7 (26.6)	0.0 (0.0-0.0)	14.2 (35.2)	0.0 (0.0-0.0)
Pears	5.8 (25.1)	0.0 (0.0-0.0)	7.0 (24.1)	0.0 (0.0-0.0)
Grapes	3.1 (12.5)	0.0 (0.0-0.0)	4.6 (16.3)	0.0 (0.0-0.0)
Other discrete fruit†	10.1 (27.4)	0.0 (0.0-2.4)	19.5 (40.1)*	0.0 (0.0-21.8)
Fruit juice	45.0 (87.8)	0.0 (0.0-62.5)	33.5 (65.2)	0.0 (0.0-49.5)
Fruit smoothies	3.7 (31.6)	0.0 (0.0-0.0)	3.8 (24.3)	0.0 (0.0-0.0)
Fruit in composite dishes	18.7 (26.8)	11.0 (2.9-25.2)	16.3 (20.2)	10.5 (3.9-21.4)
Vegetables	140 (79.6)	129 (81.5-179)	142 (83.2)	127 (89.1-180)
Discrete vegetables	86.6 (64.2)	75.1 (42.5-120)	89.0 (64.8)	77.4 (42.5-118)
of which				
Salad vegetables	16.2 (24.8)	5.1 (0.0-23.4)	22.1 (28.1)*	12.4 (0.0-32.2)
Peas, beans & lentils	17.2 (25.5)	6.0 (0.0-26.3)	12.1 (20.0)*	0.0 (0.0-18.3)
Baked beans	*7.7 (18.3)*	*0.0 (0.0-0.0)*	*5.3 (14.2)*	*0.0 (0.0-0.0)*
Green vegetables	13.1 (23.0)	0.0 (0.0-21.0)	14.4 (22.7)	0.0 (0.0-22.5)
Carrots	13.8 (18.8)	0.0 (0.0-22.5)	13.2 (18.1)	5.8 (0.0-20.9)
Other discrete vegetables‡	26.3 (32.7)	15.6 (0.0-38.5)	27.2 (30.4)	18.5 (2.3-41.8)
Vegetables in composite dishes	53.2 (48.7)	39.9 (17.3-76.9)	53.5 (53.1)	39.4 (19.2-72.5)

*Statistically different (P < 0.001) from men within the rows via independent sample t-test, adjusted for multiple testing †includes berries (strawberries, raspberries), stone fruit (peaches), tropical fruit (melon, pineapple), tinned fruit, kiwi, dried fruit, rhubarb etc. (≤3.5g)
‡includes root vegetables, excl. carrots (turnip, parsnips), onion, mixed vegetables, peppers, mushrooms, tinned vegetables, cauliflower, sweetcorn etc. (≤5.5g)

Table 3. Mean daily intake (g/d) of 'fruit & vegetables' in adults (18-90y) in Ireland in the total population (*n* 1500), split by age group

	18-35y (*n* 531)		36-50y (*n* 437)		51-64y (*n* 306)		65y+ (*n* 226)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
	g/d		g/d		g/d		g/d	
Fruit & vegetables	262 (175)^{a}	220 (137-354)	279 (168)^{ab}	247 (152-364)	321 (178)^{b}	297 (184-420)	301 (180)^{ab}	272 (179-403)
Fruit & fruit juices	133 (136)^{a}	98.5 (24.8-197)	133 (127)^{a}	98.9 (29.2-206)	164 (135)^{a}	144 (54.6-256)	163 (137)^{a}	148 (50.5-240)
Discrete fruit	61.4 (84.2)^{a}	28.9 (0.0-90.3)	78.1 (89.5)^{ac}	50.0 (0.0-121)	112 (112.0)^{b}	78.8 (29.5-168)	107 (107)^{bc}	84.5 (22.3-155)
of which								
Bananas	20.4 (35.0)^{a}	0.0 (0.0-30.8)	21.2 (33.4)^{a}	0.0 (0.0-32.1)	29.4 (36.0)^{a}	18.9 (0.0-50.0)	26.6 (34.9)^{a}	10.8 (0.0-47.1)
Apples	19.2 (36.7)^{a}	0.0 (0.0-28.3)	24.7 (41.6)^{a}	0.0 (0.0-35.9)	30.0 (49.7)^{a}	0.0 (0.0-45.2)	21.5 (41.8)^{a}	0.0 (0.0-33.1)
Citrus fruit	6.6 (21.3)^{a}	0.0 (0.0-0.0)	12.9 (35.3)^{ab}	0.0 (0.0-0.0)	14.4 (33.1)^{ab}	0.0 (0.0-11.3)	16.4 (38.5)^{b}	0.0 (0.0-2.1)
Pears	3.7 (17.4)^{a}	0.0 (0.0-0.0)	3.9 (15.5)^{a}	0.0 (0.0-0.0)	11.5 (37.0)^{b}	0.0 (0.0-0.0)	10.9 (29.9)^{ab}	0.0 (0.0-0.0)
Grapes	2.4 (10.1)^{a}	0.0 (0.0-0.0)	3.5 (13.1)^{ab}	0.0 (0.0-0.0)	4.7 (14.3)^{ab}	0.0 (0.0-0.0)	6.8 (23.4)^{b}	0.0 (0.0-0.0)
Other discrete fruit*	9.1 (24.4)^{a}	0.0 (0.0-1.3)	12.0 (27.4)^{a}	0.0 (0.0-10.7)	21.8 (45.8)^{b}	0.0 (0.0-23.7)	24.6 (45.6)^{b}	0.0 (0.0-29.8)
Fruit juice	50.0 (90.6)^{a}	0.0 (0.0-75.0)	36.4 (75.6)^{a}	0.0 (0.0-40.0)	29.5 (62.4)^{a}	0.0 (0.0-27.5)	32.3 (61.1)^{a}	0.0 (0.0-40.0)
Fruit smoothies	5.2 (34.6)^{a}	0.0 (0.0-0.0)	2.7 (24.5)^{a}	0.0 (0.0-0.0)	3.5 (26.7)^{a}	0.0 (0.0-0.0)	2.4 (17.8)^{a}	0.0 (0.0-0.0)
Fruit in composite dishes	15.9 (20.0)^{a}	9.5 (3.3-21.2)	16.2 (22.9)^{a}	9.4 (2.5-22.8)	19.1 (24.1)^{a}	12.7 (4.7-25.8)	21.5 (31.1)^{a}	13.4 (4.6-28.4)
Vegetables	130 (77.5)^{a}	116 (76.8-165)	146 (83.9)^{ab}	134 (93.3-177)	157 (82.7)^{b}	144 (101-201)	138 (79.9)^{ab}	121 (77.4-188)
Discrete vegetables	70.0 (59.4)^{a}	59.6 (26.8-99.2)	93.3 (62.3)^{b}	82.5 (47.4-128)	105 (69.4)^{b}	90.1 (57.7-140)	95.4 (64.0)^{b}	78.9 (54.5-129)
of which								
Salad vegetables	14.2 (22.1)^{a}	3.7 (0.0-20.0)	22.4 (28.0)^{b}	13.3 (0.0-34.9)	22.6 (28.0)^{b}	12.7 (0.0-35.4)	20.1 (30.2)^{ab}	9.9 (0.0-25.6)
Peas, beans & lentils	14.8 (24.6)^{a}	0.0 (0.0-20.2)	15.6 (23.9)^{a}	6.2 (0.0-24.0)	15.0 (22.4)^{a}	5.3 (0.0-23.2)	11.6 (17.4)^{a}	0.0 (0.0-19.0)
Baked beans	*7.5 (18.0)*^{a}	*0.0 (0.0-0.0)*	*6.9 (15.9)*^{a}	*0.0 (0.0-0.0)*	*5.9 (17.0)*^{a}	*0.0 (0.0-0.0)*	*4.0 (11.5)*^{a}	*0.0 (0.0-0.0)*
Green vegetables	8.3 (18.3)^{a}	0.0 (0.0-11.8)	13.4 (21.6)^{ac}	0.0 (0.0-21.0)	20.0 (27.7)^{b}	10.5 (0.0-31.7)	18.6 (24.7)^{bc}	7.9 (0.0-30.1)
Carrots	9.9 (15.9)^{a}	0.0 (0.0-15.8)	14.7 (18.9)^{b}	8.8 (0.0-23.9)	15.5 (20.3)^{b}	9.5 (0.0-24.1)	16.9 (19.4)^{b}	12.6 (0.0-27.5)
Other discrete vegetables†	22.7 (30.0)^{a}	13.4 (0.0-34.5)	27.3 (29.0)^{ab}	20.8 (1.8-42.2)	32.1 (35.1)^{b}	24.6 (2.3-45.5)	28.2 (33.3)^{ab}	17.4 (0.0-42.0)
Vegetables in composite dishes	59.7 (49.4)^{a}	46.8 (24.5-82.4)	52.3 (53.5)^{ab}	39.9 (18.8-72.7)	52.2 (52.0)^{ab}	38.3 (16.8-73.7)	42.1 (45.6)^{b}	26.5 (9.4-54.0)

Statistical differences (P < 0.001) between age groups are denoted by different superscript letters

*includes berries (strawberries, raspberries), stone fruit (peaches), tropical fruit (melon, pineapple), tinned fruit, kiwi, dried fruit, rhubarb etc. (≤3.5g)

†includes root vegetables, excl. carrots (turnip, parsnips), onion, mixed vegetables, peppers, mushrooms, tinned vegetables, cauliflower, sweetcorn etc. (≤5.5g)

Table 4. The proportion (%) of adults (18-90y) meeting the WHO[1] and the Irish FBDG[2] recommendations for the consumption of 'fruit & vegetables'

	≥5 servings/d (400g)		**≥4 servings/d (320g)**		**≥3 servings/d (240g)**		**≥2 servings/d (160g)**		**≥1 serving/d (80g)**	
	% meeting WHO and Irish FBDG recommendations									
	WHO	Irish FBDG	WHO	Irish FBDG	WHO	Irish FBDG	WHO	Irish FBDG	WHO	Irish FBDG
Total population (*n* 1500)	22.8	20.5	35.4	33.7	52.9	52.3	74.1	74.1	91.9	91.9
Men (*n* 740)	23.9	21.2	35.0	33.1	50.8	50.1	72.2	72.2	90.0	90.0
Women (*n* 760)	21.7	19.7	35.8	34.3	54.9	54.3	76.1	76.1	93.8	93.8
18-35y (*n* 531)	20.7	16.8	29.8	27.1	45.6	44.8	68.7	68.7	89.1	89.1
36-50y (*n* 437)	20.8	18.8	34.8	33.2	51.3	50.8	72.5	72.5	93.4	93.4
51-64y (*n* 306)	27.1	26.5	43.8	43.1	63.7	63.1	82.0	82.0	95.1	95.1
65y+ (*n* 226)	25.7	24.3	38.5	37.6	58.4	58.0	79.2	79.2	91.6	91.6

[1]The WHO advise the consumption of a minimum of 400g of 'fruit & vegetables' per day (World Health Organisation, 2005)

[2]Irish FBDG recommend the consumption of at least 5-7 servings (1 serving is 80g) of 'fruit & vegetables' per day, including no more than 150ml of unsweetened fruit juice (Department of Health, 2016)

Table 5. Percent contribution (%) of 'fruit & vegetables' to energy and nutrients in the diets of adults (18-90y) in Ireland in the total population (*n* 1500)

	Fruit & vegetables		**Fruit & fruit juices**		*Discrete fruit*		*Fruit juice & smoothies*		**Vegetables & vegetable dishes**		*Discrete Vegetables*		*Vegetable dishes*	
	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Energy (kcal)	139	7.0	72.3	3.6	53.0	2.7	19.3	1.0	66.3	3.3	41.4	2.0	26.6	1.3
Protein (g)	3.6	4.3	0.9	1.1	0.7	0.9	0.2	0.3	2.7	3.2	2.2	2.5	0.6	0.7
Total fat (g)	3.5	4.6	0.3	0.5	0.3	0.4	0.1	0.1	3.1	4.1	1.2	1.5	2.0	2.7
Saturated fat (g)	0.7	2.2	0.1	0.2	0.1	0.2	0.0	0.0	0.6	2.0	0.2	0.7	0.4	1.3
MUFA (g)	1.1	4.0	0.1	0.3	0.1	0.3	0.0	0.0	1.0	3.7	0.4	1.3	0.7	2.5
PUFA (g)	1.3	10.1	0.1	0.5	0.1	0.4	0.01	0.1	1.3	9.6	0.4	3.2	0.8	6.4
Carbohydrate (g)	24.8	10.9	17.5	7.7	12.7	5.6	4.8	2.1	7.3	3.2	6.0	2.5	1.6	0.7
Total sugars (g)	20.6	22.8	16.7	18.5	12.1	13.4	4.6	5.0	3.9	4.3	3.3	3.5	0.7	0.8
Free sugars (g)	5.3	11.1	4.8	10.0	0.2	0.5	4.5	9.5	0.5	1.1	0.4	0.9	0.1	0.2
Dietary fibre (g)	5.6	29.0	2.3	11.9	2.1	11.2	0.1	0.7	3.3	17.1	3.0	15.1	0.4	2.0
Vitamin A (µg)	435	38.6	14.3	1.3	5.2	0.5	9.1	0.8	421	37.4	394	33.6	42.5	3.8
Vitamin D (µg)	0.02	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.3	0.01	0.1	0.01	0.2
Vitamin E (mg)	1.5	11.8	0.5	3.7	0.4	2.7	0.1	1.0	1.1	8.0	0.7	4.8	0.4	3.2
Vitamin C (mg)	50.7	40.9	31.8	25.6	15.4	12.4	16.4	13.3	18.9	15.3	15.7	12.2	3.8	3.1
Thiamin (mg)	0.3	10.0	0.1	2.5	0.04	1.4	0.04	1.2	0.2	7.4	0.1	3.1	0.1	4.3
Riboflavin (mg)	0.1	3.1	0.05	1.5	0.03	1.1	0.01	0.5	0.05	1.5	0.04	1.2	0.01	0.3
Niacin (mg)	1.9	4.2	0.7	1.6	0.5	1.0	0.2	0.5	1.2	2.6	1.0	2.1	0.2	0.5
Vitamin B6 (mg)	0.3	7.4	0.2	3.9	0.1	2.9	0.04	1.0	0.1	3.5	0.1	2.8	0.0	0.7
Vitamin B12 (µg)	0.02	0.3	0.01	0.1	0.0	0.0	0.01	0.1	0.02	0.3	0.0	0.0	0.03	0.3
Total folate (µg)	48.8	13.2	16.4	4.4	8.8	2.4	7.6	2.1	32.4	8.8	28.7	7.5	4.8	1.3
DFE (µg)	49.4	10.7	17.0	3.7	8.8	1.9	8.2	1.8	32.4	7.0	28.7	6.0	4.8	1.0
Sodium (mg)	134	5.3	12.3	0.5	8.0	0.3	4.4	0.2	121	4.9	87.2	3.4	37.5	1.5
Potassium (mg)	507	16.6	271	8.9	204	6.7	67.6	2.2	236	7.7	204	6.4	40.6	1.3
Calcium (mg)	52.6	5.6	17.7	1.9	12.3	1.3	5.3	0.6	35.0	3.7	28.4	2.9	7.7	0.8
Iron (mg)	1.2	8.0	0.3	2.3	0.2	1.6	0.1	0.6	0.8	5.8	0.7	4.7	0.2	1.1
Magnesium (mg)	31.8	10.9	17.0	5.8	13.3	4.6	3.8	1.3	14.7	5.1	12.4	4.1	2.8	1.0
Zinc (mg)	0.5	4.7	0.1	1.2	0.1	1.1	0.01	0.1	0.4	3.5	0.3	2.6	0.1	1.0

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE= dietary folate equivalents

Discussion

The aim of this study was to use data from the NANS to estimate the intake of fruit & vegetables in adults (18-90y) in Ireland, to assess compliance with recommendations and to determine the contribution of fruit & vegetables to overall energy and nutrient intakes. Overall, 'fruit & vegetables' were consumed by all adults in Ireland with an MDI of 285g/d (equating to approximately 3.6 servings; 1.8 servings each for 'fruit & fruit juices' and 'vegetables') which is well below both the WHO and the Irish FBDG recommendations for fruit & vegetable intake. For the most part, there were no differences in 'fruit & vegetable' intake between men and women, with the exception of women having a higher intake of 'berries' and 'salad vegetables' and men having a higher intake of 'peas, beans & lentils'. Generally, the younger age groups (18-35y and 36-50y) had lower intakes of fruit & vegetables compared to those aged 51-64y and 65y+, with the exception of 'vegetables in composite dishes', which was higher in those aged 18-35y compared to those aged 65y+. Compliance with recommendations was low with only one fifth of the adult population of Ireland meeting the recommendations for fruit & vegetable intake from the WHO (23%) and Irish FBDG (21%). Fruit & vegetables contributed minimal proportions of intakes of energy (7%), protein (4%) total fat (5%), saturated fat (2%) and MUFA (4%) and made important contributions to intakes of PUFA (10%), carbohydrate (11%), dietary fibre (29%), vitamin C (41%), vitamin A (39%), potassium (17%), total folate (13%), DFE (11%), vitamin E (12%), magnesium (11%) and thiamin (10%), while also contributing to intakes of total sugars (23%) and free sugars (11%). These findings are discussed below in the context of the available literature and in terms of the public health implications.

'Fruit & vegetable' intake

The findings of this study showed that while all adults aged 18-90y in Ireland consumed 'fruit & vegetables', the mean intake was 285g/d (equating to approximately 3.6 servings), with equal contributions from 'fruit & fruit juices' (144g/d) and 'vegetables' (141g/d) (approximately 1.8 servings each), which is well below both the recommendations from the WHO and the Irish FBDG for fruit & vegetable intake (World Health Organisation, 2005; Department of Health, 2016). The MDI of 'discrete fruit' (83g/d) and 'discrete vegetables' (88g/d) was similar, equating to approximately one portion of fruit & vegetables each and the MDI of ‘fruit juice’ was 39g/d, less than half a portion of fruit. The MDI of ‘vegetables in composite dishes’ was 53g/d, showing that failing to account for vegetables in composite dishes would underestimate vegetable intake by 38% in adults in Ireland. This complements findings from other studies which highlight the important contributions vegetables in composite dishes make to vegetable intake. The findings from this study were slightly higher than findings from the NSIFCS (1997-1999) as well as more recent findings from the US, which showed vegetables from composite dishes account for 26% and 30% of total vegetable intake in adults, respectively (O'Brien *et al.*, 2003; Wambogo *et al.*, 2022).

The intake of ‘fruit & vegetables’ in Ireland can be broadly compared with nationally representative data from other countries within the WHO European region, despite variations in the categorisation of fruit & vegetables between studies. The intake of ‘fruit & vegetables’ in adults in Ireland (285g/d) was lower than other countries, however, the intake in adults in most countries (Belgium, the Netherlands, the UK, Portugal, Finland and Spain) were also lower (329-393g/d) than the minimum recommendation from the WHO (400g) (Helldán *et al.*, 2013; Lopes *et al.*, 2018; Bel *et al.*, 2019; Partearroyo *et al.*, 2019; Public Health England, 2020; van Rossum, 2020). Notable exceptions to this were for adults in Denmark (445g/d), Italy (473g/d) and Germany (756g/d) who had intakes in line with recommendations from the WHO, however, the significantly higher intake noted in Germany can be attributed to a particularly high intake of fruit juice and nectars (265g/d) (Leclercq *et al.*, 2009; Heuer *et al.*, 2015; Pedersen *et al.*, 2015).

In this study there were no differences in the intake of ‘fruit & vegetables’ between men and women, an unexpected finding given it has been previously documented in nationally representative data in Western countries (Europe and the US) that women consume more fruit & vegetables compared to men (Stea *et al.*, 2020; Ansai and Wambogo, 2021). However, women had a higher intake of ‘berries’ (5g/d) and ‘salad vegetables’ (22g/d) compared to men (2g/d and 16g/d, respectively) while men had a higher intake of ‘peas, beans & lentils’ (17g/d) compared to women (12g/d) therefore while there was no difference in overall intake of fruit & vegetables between men and women, there were some differences noted in the types of fruit and vegetables consumed which may reflect gender differences in fruit & vegetable choice.

Generally, the younger age groups (18-35y and 36-50y) had lower intakes of fruit & vegetables compared to those aged 51-64y and 65y+. Specifically, for overall 'fruit & vegetables', those aged 18-35y had a lower intake (262g/d) compared to those aged 51-64y (321g/d). Intake of 'discrete fruit' was lower in those aged 18-35y (61g/d) and 36-50y (78g/d) compared to those aged 51-64y (112g/d) and was lower in those aged 18-35y compared to those aged 65y+ (107g/d). For 'vegetables', intake was lower in those aged 18-35y (130g/d) compared to those aged 51-64y (157g/d). Interestingly, intake of 'discrete vegetables' was lower in those aged 18-35y (70g/d) compared to all other age groups (93-105g/d), however, intake of 'vegetables in composite dishes' was higher in those aged 18-35y (60g/d) compared to those aged 65y+ (42g/d). These findings describe some variability in how vegetables are consumed in younger adults and may highlight areas for policymakers to target for improving vegetable intake in young adults.

Compliance with recommendations

Findings from this study suggest a large proportion (approximately 80%) of the adult population in Ireland are not meeting recommendations for fruit & vegetable intake. This study has identified that the intake of 'fruit & vegetables' in adults in Ireland was 285g/d, approximately 3.6 servings, far below the WHO recommendation of at least 400g/d (World Health Organisation, 2005). When 'fruit juice' intake was limited to no more than 150ml per day, in line with the Irish FBDG, intake was moderately lower, at 277g/d (data not shown), or approximately 3.5 servings, falling significantly short of the 5-7 daily servings of 'fruit & vegetables' recommended in Irish FBDG (Department of Health, 2016). Only one fifth of the adult population of Ireland met the recommendations for 'fruit & vegetables' intake from the WHO (23%) and Irish FBDG (21%). When compared with the previous national survey of adults in Ireland, the findings of this study indicate that there has been no change in compliance with recommendations for fruit & vegetable intake among adults aged 18-64 years in Ireland over approximately 10 years (NSIFCS: 20%, NANS: 23%) (O'Brien *et al.*, 2003). In the current study, a similar proportion of men and women met the WHO (24% and 22%, respectively) and Irish FBDG recommendations (21% and 20%, respectively). More adults in the age groups 51-64y and 65y+ met the WHO recommendations (26-27%) and the Irish FBDG (24-27%), compared to those aged 18-35y and 36-50y (WHO: 21% for both age groups, Irish FBDG:17-19%). These findings are in line with findings from other countries which report that younger adults are less likely to meet fruit & vegetable recommendations compared to older adults (Peltzer and Pengpid, 2015; Lee *et al.*, 2022).

Contribution of ‘fruit & vegetables’ to energy and nutrients in the diet

Fruit & vegetables are well established as nutrient-dense foods, containing dietary fibre and a variety of vitamins and minerals but few studies investigate the actual contribution of fruit & vegetables to overall dietary intake. This study found that ‘fruit & vegetables’ contributed a small proportion of energy intake but made significant contributions to many other nutrients in the diets of adults (18-90y) in Ireland. Overall, ‘fruit & vegetables’ contributed 7% of energy intake, with 4% from ‘fruit & fruit juices’ and 3% from ‘vegetables & vegetable dishes’, which is at the lower range compared to other countries within the WHO European region, i.e., 8% in Italy, 9% in Portugal and the Netherlands, 10% in Finland and the UK, 11% in Denmark and 13% in Spain (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2015; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). In line with findings from adults in Ireland, ‘fruit’ and ‘vegetables’ individually contributed similarly to energy intake in other countries, with fruit contributing 4-7% and vegetables contributing 2-7% of energy intake (Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2015; Public Health England, 2020; van Rossum, 2020). Juice contributed just 1% of energy intake in this study and in other countries, suggesting that concerns of the impact of fruit juice on weight gain in adults may be unwarranted (Mozaffarian *et al.*, 2011; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2015; Hebden *et al.*, 2017; Lopes *et al.*, 2018; Public Health England, 2020). Nonetheless, in keeping with FBDG, the consumption of whole fruit over fruit juice should still be promoted to benefit from dietary fibre, the majority of which is lost in the juicing process (Herforth *et al.*, 2019; Seino *et al.*, 2021).

Fruit & vegetables are typically low in fat and protein and therefore, as expected, this study found that ‘fruit & vegetables’ contributed minimal proportions of total fat (5%), saturated fat (2%), MUFA (4%) and protein (4%). However, this study found that ‘fruit & vegetables’ contributed 10% to the intake of PUFA, with ‘vegetable dishes’ contributing the majority of this intake, which can be partly attributed to the presence of oils used to cook vegetable dishes. These findings are in keeping with data from other countries, which report fruit & vegetables contributed 3-7% of total fat intake, 1-5% of saturated fat intake, 1-9% of MUFA intake, 6-12% of PUFA intake and 5-10% of protein intake (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

This study found that ‘fruit & vegetables’ contributed 11% of carbohydrate intake, with ‘fruit & fruit juices’ accounting for 8% (6% from ‘discrete fruit’), explained by the natural sugar present in fruit. This finding is broadly in line with data from other countries within the WHO European region, where fruit & vegetables contributed 11-22% of carbohydrate intake, with fruit & fruit juices contributing the majority (7-14%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). ‘Fruit & vegetables’ contributed 29% of dietary fibre intake in adults in Ireland, with 15% from ‘discrete vegetables’ and 11% from ‘discrete fruit’, similar to findings from European dietary surveys where fruit & vegetables contributed 27-51% of dietary fibre intake, with vegetables also contributing the majority (17-33%) in most countries (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). While the contribution of ‘fruit & vegetables’ to dietary fibre intake was similar in Ireland compared to other countries, overall intake of dietary fibre in adults in Ireland (19g/d) is significantly lower than recommendations (25g/d) and an increase in consumption of plant foods, such as whole fruit & vegetables (as well as whole grains) would go a long way in increasing dietary fibre intake in adults in Ireland (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010; Irish Universities Nutrition Alliance, 2011).

In this study ‘fruit & vegetables’ contributed 23% of total sugars intake in adults and while this is a seemingly high proportion (approximately one fifth), over half came from ‘discrete fruit’ (13%), generally containing not only natural sugars, such as fructose, but dietary fibre, vitamins, minerals and phytochemicals which synergistically benefit health. This is broadly similar (although at the lower range) to findings from other countries (25-36%), where fruit also contributed to the majority (16-24%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; van Rossum, 2020).

On the other hand, ‘fruit & vegetables’ contributed 11% to intake of free sugars, with 10% from ‘fruit juice & smoothies’, which was higher than contributions from fruit juice in other countries within the WHO European region (2-7%) (Ruiz and Varela-Moreiras, 2017; Lopes *et al.,* 2018; Public Health England, 2020). Mean intake of free sugars in adults in Ireland is in excess of the UK recommendation of <5% total energy intake in adults and children at approximately 9% and is therefore of public health concern (Scientific Advisory Committee on Nutrition, 2015; World Health Organisation, 2015; Walton *et al.*, 2017). However, while limiting fruit juice to one serving (150ml) is an important measure to reduce free sugars intake, a higher priority should be to reduce population intake of food groups contributing most to the intake of free sugars, i.e., ‘sugars, syrups & jams’ (18%), ‘biscuits, cakes & pastries’ (15%) and ‘sugar-sweetened beverages’ (14%) (Department of Health, 2016; Walton *et al.*, 2017).

Fruit & vegetables are recognised as important sources of vitamins, minerals, and phytochemicals, especially antioxidants (e.g., vitamin C), which support health. In this study, ‘fruit & vegetables’ contributed 41% of vitamin C intake, with important and equal contributions from ‘discrete fruit’ (12%), ‘fruit juice & smoothies’ (13%) and ‘discrete vegetables’ (12%), which stands to reason as many fruit & vegetable categories contain rich sources of vitamin C (e.g., citrus fruit (including orange juice), strawberries, peppers). Therefore, despite relatively low overall fruit & vegetable intakes, a significant proportion (almost half) of vitamin C intake in the adult diet in Ireland comes from fruit & vegetables. Unsurprisingly, due to higher fruit & vegetable intakes, contributions to vitamin C intake in other countries was generally higher (54-89%), with the exception of the Netherlands (39%), likely related to the exclusion of juices when reporting the contribution of fruit & vegetables to nutrient intakes (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; van Rossum, 2020). ‘Fruit & vegetables’ contributed 39% of vitamin A intake, with the majority (34%) from ‘discrete vegetables’, likely a reflection of the provitamin A carotenoid content of many vegetables (e.g., carrots, tomatoes etc.). This finding was similar to other countries (20-58%) with the majority (19-44%) from vegetables (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). ‘Fruit & vegetables’ contributed 17% of potassium intake in this study (equal contributions from ‘fruit & fruit juices’ and ‘vegetables & vegetable dishes’) which, although a significant contribution, was lower than other countries within the WHO European region (21-37%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). ‘Fruit & vegetables’ also contributed to intakes of total folate (13%) and DFE (11%) (9% and 7% respectively from ‘vegetables & vegetable dishes’), which is significantly lower than other countries (24-41%), with the majority (17-29%) from vegetables (Helldán *et al.*, 2013; Pedersen *et al.*, 2015; Partearroyo *et al.*, 2017; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). In this study ‘fruit & vegetables’ also contributed to intakes of vitamin E (12%), magnesium (11%), thiamin (10%) and relatively small proportions of iron (8%), vitamin B6 (7%), calcium (6%), zinc (5%), sodium (5%), niacin (4%) and riboflavin (3%), however, data from other countries, with higher intakes of fruit & vegetables reported that fruit & vegetables contributed significantly to intakes of vitamin E (16-38%), magnesium (14-27%), thiamin (12-22%), iron (13-25%), vitamin B6 (15-29%), calcium (8-17%), zinc (7-14%) and niacin (6-12%) (Helldán *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Olza *et al.*, 2017b; Samaniego-Vaesken *et al.*, 2017; Lopes *et al.*, 2018; Mielgo-Ayuso *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

Public health implications

Diet-related non-communicable diseases remain significant in developed countries and there is poor compliance with guidelines for total and saturated fat, carbohydrate, free sugars, dietary fibre and sodium in the WHO European region, including Ireland (Irish Universities Nutrition Alliance, 2011; World Health Organisation, 2014; Rippin *et al.*, 2017). Additionally, potassium and folate, of which fruit & vegetables are good sources, have been identified as nutrients of concern, among others, such as vitamin D, iodine, iron and calcium (Irish Universities Nutrition Alliance, 2011; Cashman *et al.*, 2013; World Health Organisation, 2014; McNulty *et al.*, 2017; Rippin *et al.*, 2017). The previous chapter suggests a move towards the consumption of a more PB diet (including PB foods such as fruit & vegetables, whole grains, nuts and seeds) may improve the nutritional quality of the diet in terms of total fat, saturated fat, carbohydrate, free sugars, dietary fibre, sodium, potassium and folate, however, current intakes of fruit & vegetables are far below recommendations, suggesting reliance on PB foods to meet nutritional needs at population level is unrealistic at present. This highlights the need for multilevel strategies to improve the intake of fruit & vegetables in the population that address the food environment and accessibility of fruit & vegetables as well as personal determinants of fruit & vegetable intake. For example, government agricultural grants and schemes that help to incentivise growing fruit & vegetables for consumption, at national and local levels, may help to increase competitiveness and reduce cost for the consumer (Department of Agriculture Food and the Marine, 2017). A recent study suggests the subsidisation of fruit & vegetables may increase consumption by up to 15% (Pancrazi *et al.*, 2022). Additionally, while educational programmes targeting children exist, such as 'Incredible Edibles', education programmes and campaigns for adults may increase awareness and improve attitudes to fruit & vegetables consumption (Agri Aware, 2021). Education on what a serving of fruit & vegetables is, the health benefits of fruit & vegetables and the preparation and cooking of fruit & vegetables may help to improve intake in adults (Safefood, 2013).

Strengths and limitations

The key strengths of this study are the nationally representative sample of adults aged 18-90y and the use of detailed dietary data collected through a 4-day semi-weighed food diary. A further strength was the inclusion of fruit & vegetables from composite dishes in the estimation of intakes to avoid underestimating total fruit & vegetable intake in this population group. In addition, calculations were used to remove inedible or unconsumed portions of fruit and vegetables (cores and uneaten peel) when estimating intakes. Misreporting or underreporting of food intake is a known limitation with all dietary assessment and may be a source of bias. This issue was minimised by training the participants in the use of the food diary and the high level of researcher-participant interaction (three visits over the 4-day period) by trained research nutritionists. It is important to acknowledge that although NANS data are the most recent dietary data available for adults in Ireland, data were collected in 2008-2010 and current intakes of fruit & vegetables may have changed. Current dietary intake data for this population group are now being collected (National Adult Nutrition Survey II, www.iuna.net) and it will be useful to conduct time-trend analysis using data from the NSIFCS, NANS and NANS II to identify trends in consumption patterns which may inform future policy.

Conclusions

Fruit & vegetables are the basis of a PB diet and have long been recognised as crucial to good health. A population-level move towards the consumption of more plant foods, including fruit & vegetables, may improve the nutritional quality of the diet, however, currently, mean intake of fruit & vegetables (285g/d) (approximately 3.6 servings/day) is well below recommendations among adults in Ireland. For the most part, there were no differences in 'fruit & vegetable' intake between men and women, with the exception of women having a higher intake of 'berries' and 'salad vegetables' and men having a higher intake of 'peas, beans & lentils'. Generally, the younger age groups (18-35y and 36-50y) had lower intakes of fruit & vegetables compared to those aged 51-64y and 65y+, with the exception of 'vegetables in composite dishes', which was higher in those aged 18-35y compared to those aged 65y+. Compliance with recommendations was low with approximately one fifth of the adult population of Ireland meeting the recommendations for fruit & vegetable intake from the WHO (23%) and Irish FBDG (21%). Fruit & vegetables contributed to small proportions of energy intake and made important contributions to intakes of carbohydrate, dietary fibre, vitamin C, vitamin A, potassium, total folate and DFE but also contributed to intakes of total and free sugars. Despite making important contributions to some nutrient intakes, contributions to nutrient intakes from fruit & vegetables in Ireland are generally lower than from other countries within the WHO European region, probably related to the lower intake of fruit & vegetables in Ireland.

Overall, the findings of this study may benefit health professionals, policymakers and the food industry in understanding the role of 'fruit & vegetables' in the diet of adults in Ireland and may inform strategies to increase the intake of these plant foods in light of the shift towards a more PB diet for health and environmental benefits.

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Chapter 6

'Cereals, grains & potatoes' in the diets of adults in Ireland: the estimated intakes, compliance with recommendations and nutritional contributions

Introduction

Cereals, grains & potatoes (including starchy tubers, e.g., sweet potatoes, yams, cassava) are staple foods which form the foundations of the diet of many populations globally (Ritchie and Roser, 2017; Herforth *et al.*, 2019). They are generally categorised together in food-based dietary guidelines (FBDG), are major components of a plant-based (PB) diet, and are good sources of energy, carbohydrate, dietary fibre and micronutrients, such as B vitamins, iron, magnesium, potassium and zinc (McKevith, 2004; Food and Agriculture Organisation of the United Nations, 2008; Herforth *et al.*, 2019; Devaux, 2020). Grains, especially whole grains, are also an important source of dietary fibre and phytochemicals such as flavonoids and carotenoids, which together, may be responsible for the health-promoting effects of wholegrain foods (McKevith, 2004; Carcea, 2020). Potatoes are also good sources of health-promoting phytochemicals, however, the nutritive value of potatoes and potato dishes depends on the preparation (e.g., peeled/unpeeled) and cooking methods (e.g., fried/ boiled) used, as well as other components of a potato dish (e.g., added fats/salt), therefore, potatoes, when chipped/fried/roasted are often recommended to be consumed in moderation (Food and Agriculture Organisation of the United Nations, 2008; Burlingame *et al.*, 2009; Ezekiel *et al.*, 2013).

In the World Health Organisation (WHO) European region, the recommendations for the consumption of cereals, grains & potatoes within FBDG for the general population, including adults, vary between countries (as reviewed in Chapter 1). Cereals, grains & potatoes are generally recommended to be consumed daily, with most countries recommending the consumption of between 3-11 servings/portions/units (of varying quantities) while quantitative recommendations in other countries range from 200-900g (Ministry of Labor Health and Social Affairs, 2005; National Center of Public Health Protection (NCPHP), 2006; Department of Public Health, 2008; Austrian Ministry of Health and the National Nutrition Commission, 2010; Swiss Society for Nutrition, 2011; Finnish food authority, 2014; Institute of Preventive Environmental & Occupational Medicine (Prolepsis), 2014; Health Promotion and Disease Prevention Directorate, 2015; Department of Health, 2016; Ministry of Health (Turkey), 2016; German Nutrition Society, 2017). While most countries recommend the consumption of wholegrain over refined cereal foods, there is a lack of clear and consistent messaging around these recommendations, ranging from qualitative guidelines in most countries (e.g., choose whole grains), to quantitative recommendations in Norway, Denmark, Sweden and the Netherlands (70-90g/d of wholegrain products) (Health Council of the Netherlands, 2015; Swedish Food Agency, 2015; Norwegian Directorate of Health, 2016; Ministry of Food Agriculture & Fisheries, 2022). Potatoes are typically categorised with cereals & grains in FBDG (with the exception of Turkey, where potatoes are included with fruit & vegetables) and while potatoes are generally recognised as being part of a healthy diet, Greece and Malta recommend limiting intake to ≤3 servings per week (Institute of Preventive Environmental & Occupational Medicine (Prolepsis), 2014; Health Promotion and Disease Prevention Directorate, 2015; Ministry of Health (Turkey), 2016)

Data from national dietary surveys across the WHO European region showed that the mean intake of cereals, grains & potatoes in the general population, including adults ranged from 276g/d-359g/d in Belgium, Germany, Italy, Finland, Portugal, the Netherlands and the UK and the mean intake of cereals & grains (excluding potatoes) was 149g/d in Spain (Leclercq *et al.*, 2009; Helldán *et al.*, 2013; Heuer *et al.*, 2015; Lopes *et al.*, 2018; Bel *et al.*, 2019; Partearroyo *et al.*, 2019; Public Health England, 2019; van Rossum, 2020). Despite recommendations to consume wholegrain foods over refined, intake of brown and wholegrain cereal products (where data were provided) comprised a very small part of total cereals, grains & potatoes intake, i.e., 29g/d, 50g/d and 93g/d in the UK, Belgium and the Netherlands, respectively (Bel *et al.*, 2019; Public Health England, 2019; van Rossum, 2020).

Cereals, grains & potatoes made important contributions to the intakes of energy (26-40%), carbohydrate (43-71%), dietary fibre (40-60%), protein (17-30%), MUFA (4-24%), PUFA (15-23%), folate (19-35%), thiamin (17-47%), vitamin B6 (15-30%), niacin (15-29%), riboflavin (10-21%), iron (27-45%), magnesium (23-35%), zinc (21-35%), potassium (19-27%) and calcium (8-32%) while also contributing to intakes of sodium (21-35%), saturated fat (5-18%) and free sugars (7-19%) in adults within the WHO European region. Cereals, grains & potatoes made higher contributions to intakes of saturated fat (24%) and free sugars (26%) in the UK, likely due to the inclusion of biscuits, buns, cakes, pastries, puddings, potato products and dishes in the estimation of contributions (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health

England, 2014; Pedersen *et al.*, 2015; Ruiz *et al.*, 2015; Ruiz *et al.*, 2016; Olza *et al.*, 2017b; Olza *et al.*, 2017a; Ruiz *et al.*, 2017; Samaniego-Vaesken *et al.*, 2017; Lopes *et al.*, 2018; Mielgo-Ayuso *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

In Ireland, data from the North/South Ireland Food Consumption Survey (NSIFCS) (1997-1999) found that the intake of cereals, grains & potatoes in adults aged 18-64 years was 441g/d, which equates to approximately 5.2 servings (Irish Universities Nutrition Alliance, 1999). However, more recent data are now available, including data on older adults (65y+) from the National Adult Nutrition Survey (NANS) for adults aged 18-90 years. Therefore, the aim of this study was to use data from the National Adult Nutrition Survey (NANS) to estimate the current intake of cereals, grains & potatoes in adults (18-90y) in Ireland, to assess compliance with recommendations and to determine their contribution to overall energy and nutrient intakes.

Methodology

The National Adult Nutrition Survey food consumption database

The analyses for this chapter are based on data from the Irish National Adult Nutrition Survey (NANS) (www.iuna.net). Briefly, the NANS is a nationally representative, cross-sectional study that collected habitual food and beverage consumption data (in addition to lifestyle, health indicators and attitudes to food and health) from 1500 adults aged 18-90 years in the Republic of Ireland between 2008 and 2010. The methodology for sampling, participant recruitment, data collection and food quantification for NANS is described in detail in Chapter 2, with methods specific to this chapter outlined below.

Food intake data collection

Food and beverage intake data (including nutritional supplements) were collected using a 4-day semi-weighed food diary. Participants were asked to record detailed information regarding the amount, type and brand name of all foods and beverages consumed over the recording period, which included at least one weekend day. Where applicable, details of cooking methods, recipes of composite (mixed) dishes and any leftovers were also recorded. To facilitate the collection of data, participants were asked to collect the packaging labels of all foods and beverages consumed over the recording period. Where packaging labels were not available, the researchers sourced and photographed the packaging from local supermarkets.

A quantification protocol established by the Irish Universities Nutrition Alliance (IUNA) (Harrington *et al.*, 2001) was used for the NANS. In summary, 46% of foods and beverages were weighed using a portable food scales (Tanita, Japan) provided to each participant and a further 10% were derived from the manufacturer information on product labels. The remaining foods and beverages were quantified using a photographic food atlas (16%) (Nelson *et al.*, 1997), stardard portion weights (11%) (Food Standards Agency, 2002a), household measures (11%), average weights ascertained by the IUNA team (4%) and estimated based on the participant's previous eating patterns (only used when no other quantification method was appropriate) (2%).

Nutrient composition of foods

Dietary intake data were analysed using WISP© (Tinuviel Software, Anglesey, UK) which estimated nutrient intakes using data from McCance and Widdowson's The Composition of Foods, sixth (Food Standards Agency, 2002b) and fifth (Holland *et al.*, 1991a) editions plus all nine supplemental volumes (Holland *et al.*, 1988; Holland *et al.*, 1989; Holland *et al.*, 1991b; Holland *et al.*, 1992; Holland *et al.*, 1993; Chan *et al.*, 1994; Chan *et al.*, 1995; Chan *et al.*, 1996; Holland *et al.*, 1996). During the NANS, modifications were made to this food composition database to include recipes of composite dishes, nutritional supplements, fortified foods, generic foods that were commonly consumed in Ireland and new foods on the market. Additionally, the food composition database has since been updated with values for total fat, saturated fat, monounsaturated fat (MUFA), polyunsaturated fat (PUFA), free sugars, sodium, vitamin D and iodine, which has been detailed elsewhere (Giltinan, 2012; Black *et al.*, 2015; Li *et al.*, 2016; McNulty *et al.*, 2017; Walton *et al.*, 2017). Dietary folate equivalents (DFE) were estimated using the following equation: 1μg DFE = 1μg food folate + (1.7 x folic acid) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014).

Estimation of 'cereals, grains & potatoes' intake

Each food, beverage and nutritional supplement consumed in the NANS was assigned an individual food code and food descriptor based on its nutritional profile. All food codes were categorised into previously defined food groups (**Appendix I & Appendix II**). For these analyses, the food groups 'bread & rolls', 'breakfast cereals', 'grains, rice, pasta & savouries' and 'potatoes & potato products', which make up the 'wholemeal cereals and breads, potatoes, pasta and rice' section of the Irish FBDG (Department of Health, 2016), were analysed collectively and further disaggregated into the following groups and subgroups:

Cereals, grains & potatoes

- **Total breads**, including soft and crusty rolls, bagels, pitta bread etc.
    - **White bread**
    - **Wholemeal & brown bread**
    - **Other breads**, including scones, garlic bread, fruit bread, naan, chapatti, English muffins etc.

- **Breakfast cereals**
    - **Ready-to-eat breakfast cereals (RTEBC)** (dry weight)
        - *High-fibre RTEBC (≥6g fibre per 100g)* A claim that a food is high in fibre can only be made where the product contains at least 6g of fibre per 100g (European Commission, 2006).
        - *Low-fibre RTEBC (<6g fibre per 100g)*
    - **Porridge & hot oat cereals** (made up weight)
- **Grains, rice, pasta & savouries**, including brown & wholegrain varieties of rice and pasta
    - **Rice**
        - *Brown & wholegrain rice*
    - **Pasta**
        - *Brown & wholemeal pasta*
    - **Pizza**
    - **Other grains**, including barley, buckwheat, bulgur wheat, quinoa and grain products, such as flours, plain noodles, couscous etc.
    - **Other savoury dishes & products**, including instant/fried noodles, spaghetti hoops, pasta dishes (macaroni cheese), savoury pastry, bread stuffing, French toast, fried rice, Yorkshire pudding, dumplings etc.
- **Potatoes & potato products**, including sweet potatoes, yams
    - **Boiled, baked & mashed potatoes**
    - **Chipped, fried & roasted potatoes**
    - **Processed & homemade potato products**, including hash browns, potato croquettes, potato pies/cakes, potato salad etc.

The mean daily intake (MDI) of 'cereals, grains & potatoes' and their subgroups were estimated for each participant by summing the weight of each food group (g) consumed over the recording period and dividing the total by the number of recording days (four).

Compliance with food-based dietary guidelines

The Irish FBDG recommend a daily intake of 3-5 servings of wholemeal cereals and breads, potatoes, pasta and rice (Department of Health, 2016). For these analyses, the intake of 'cereals, grains & potatoes' were converted to servings using the FBDG recommendations and standard food portion sizes where necessary (Food Standards Agency, 2002a). The total intake of cereals, grains & potatoes (including white/wholemeal cereals, grains and potatoes, including processed potatoes) as well as the intake of wholemeal cereals and breads, potatoes, pasta and rice were compared with the recommended 3-5 servings from the Irish FBDG (Department of Health, 2016). One serving was defined as 2 thin slices of bread (50g), 1/3 cup dry porridge oats (40g dry, equivalent to 374g made up), 1 cup flaked type breakfast cereal (30g), one cup cooked rice, pasta, noodles or couscous (200g) and two medium or four small potatoes (120g) (Food Standards Agency, 2002a; Department of Health, 2016).

Percent contribution of 'cereals, grains & potatoes' to energy and nutrient intakes

Using descriptive frequencies, the percent contribution of 'cereals, grains & potatoes' (and each subgroup) to the mean daily intake of energy and nutrients was calculated by the mean proportion method (Krebs-Smith *et al.*, 1989). The mean proportion method provides information about the sources that are contributing to the nutrient intake 'per person' and is the preferred method when determining important food sources of a nutrient within the food supply. The contribution of 'cereals, grains & potatoes' to energy and nutrient intakes was estimated based on intake from the following subgroups:

- **Total breads**, including white, wholemeal & brown bread and rolls and other breads
- **Breakfast cereals**, including ready-to-eat breakfast cereals (RTEBC) (dry weight) and porridge & hot oat cereals (including milk from porridge made up with milk)
- **Grains, rice, pasta & savouries**, including brown & wholegrain varieties of rice and pasta, pizza, other grains and other savoury dishes (including non-cereal/grain components of a composite meal, e.g., meat or cheese on pizza, cheese in macaroni cheese)
- **Potatoes & potato products**, including sweet potatoes, yams, boiled, baked & mashed potatoes, chipped, fried & roasted potatoes and processed & homemade potato products (including non-potato components of composite meal, e.g., mayonnaise in potato salad).

However, cereals, grains or potatoes from composite dishes in other food groups (e.g., potato/pasta in meat dishes) were not included in the contribution of 'cereals, grains & potatoes' to energy and nutrient intakes. While cereals, grains and potatoes were generally disaggregated from meals and entered into the nutrition software separately, for some composite dishes, the nutritional composition of the individual foods within the dish were aggregated together, e.g., potato in cottage pie, pasta in lasagne.

Statistical analysis

The MDI of 'cereals, grains & potatoes' and each subgroup ('breads', 'breakfast cereals', 'grains, rice, pasta & savouries' and 'potatoes & potato products') was calculated and the distribution of intake was reported as mean, standard deviation, median and interquartile range using SPSS© for Windows™ Version 26. Differences in the MDI of 'cereals, grains & potatoes' and each subgroup between sexes (men, women) were assessed using independent sample t-tests. Differences in the MDI of 'cereals, grains & potatoes' between age groups (18-35y, 36-50y, 51-64y, 65y+) were assessed using ANOVA and Tukey tests were used for post-hoc analysis. Parametric tests were used in all cases regardless of normality of the data, due to the large sample size (*n* 1500) (Fagerland, 2012). To minimise type 1 errors (as a result of multiple testing), the Bonferoni adjustment was used by dividing the alpha level (0.05) by the number of comparisons. Therefore, intakes were significantly different from each other if P <0.001.

Results

Table 1 presents the mean daily intake (MDI) of ‘cereals, grains & potatoes’ in adults (18-90y) in Ireland in the total population (*n* 1500) and in consumers only.

‘Cereals, grains & potatoes’ were consumed by all adults (100%), with an MDI of 358g/d, which comprised of 116g/d of ‘total breads’, 62g/d of ‘breakfast cereals’, 60g/d of ‘grains, rice, pasta & savouries’ and 121g/d of ‘potatoes & potato products’.

‘Total breads’ were consumed by 98% of adults, with an MDI of 116g/d in the total population, of which 50g/d was from ‘white bread’, 53g/d was from ‘wholemeal & brown bread’ and 12g/d from ‘other breads’.

‘Breakfast cereals’ were consumed by 75% of adults, with an MDI of 62g/d in the total population, of which 23g/d was from ‘RTEBC’ (13g/d from ‘high-fibre’ RTEBC, 9g/d from ‘low-fibre RTEBC’) and 39g/d was from ‘porridge & hot oat cereals’.

‘Grains, rice, pasta & savouries’ were consumed by 69% of adults, with an MDI of 60g/d, of which 16g/d was from ‘rice’ (2g/d from ‘brown & wholegrain rice’), 13g/d was from ‘pasta’ (1g/d from ‘brown & wholemeal pasta’), 15g/d was from ‘pizza’, 3g/d was from ‘other grains’ and 13g/d was from ‘other savoury dishes & products’.

‘Potatoes & potato products’ were consumed by 94% with an MDI of 121g/d, of which, 76g/d was from ‘boiled, baked & mashed potatoes’, 40g/d from ‘chipped, fried & roasted potatoes’ and 5g/d was from ‘processed & homemade potato products’.

Table 2 presents the MDI of ‘cereals, grains & potatoes’ in adults (18-90y) in Ireland in the total population (*n* 1500), split by sex.

Men had a higher MDI of overall ‘cereals, grains & potatoes’ (417g/d), compared to women (301g/d), which was attributable to a higher intake of ‘total breads’ (men: 135g/d, women: 96g/d), ‘grains, rice, pasta & savouries’ (men: 71g/d, women: 49g/d) and ‘potatoes & potato dishes’ (men: 144g/d, women: 99g/d). There was no difference in the MDI of ‘breakfast cereals’ between men and women.

Of ‘total breads’, men had a higher MDI of ‘white bread’ (63g/d) and ‘wholemeal & brown bread’ (60g/d), compared to women (38g/d and 47g/d respectively) while there were no differences in the MDI of ‘other breads’. Of ‘breakfast cereals’, men had a higher MDI of ‘RTEBC’ (27g/d), compared to women (18g/d), which was attributable to a higher MDI of ‘high-fibre RTEBC’ in men (17g/d), compared to women (10g/d). There were no differences between men and women in the MDI of ‘low-fibre RTEBC’ (men: 10g/d, women: 8g/d) or ‘porridge & hot oat cereals’ (men: 40g/d, women: 39g/d). Of ‘grains, rice, pasta & savouries’, men had a higher MDI of ‘pizza’ (19g/d), compared to women (10g/d), however there were no differences in the MDI of ‘rice’, ‘pasta’, ‘other grains’ or ‘other savoury dishes & products’ between men and women. Of ‘potatoes & potato products’, men had a higher MDI of ‘boiled, baked & mashed potatoes’ and ‘chipped, fried & roasted potatoes’ (91g/d and 47g/d, respectively), compared to women (61g/d and 32g/d, respectively) but there was no difference in the MDI of ‘processed & homemade potato products’ between men (5g/d) and women (6g/d).

Table 3 presents the MDI of ‘cereals, grains & potatoes’ in adults (18-90y) in Ireland in the total population (*n* 1500), split by age group.

There was no difference observed in the MDI of overall ‘cereals, grains & potatoes’ between those aged 18-35y (353g/d), 36-50y (355g/d), 51-64y (371g/d) and 65y+ (358g/d).

The MDI of ‘total breads’ was higher in those aged 51-64y (124g/d) compared to those aged 18-35y (106g/d) and 36-50y (119g/d), but there was no difference in intakes between the other age groups (106-120g/d). The MDI of ‘wholemeal & brown bread’ was higher in those aged 51-64y (61g/d) compared to those aged 18-35y (45g/d) and 36-54y (53g/d) but there was no difference in the MDI of ‘wholemeal & brown bread’ in those aged 65y+ (61g/d) compared to the other age groups. The MDI of ‘other breads’ was higher in those aged 51-64y (15g/d) compared to those aged 18-35y (8g/d) and 36-50y (14g/d) but there was no difference in the MDI of ‘other breads’ in those aged 65y+ (15g/d) compared to the other age groups. There were no differences in the MDI of ‘white bread’ between age groups.

The MDI of ‘breakfast cereals’, was lower in those aged 18-35y (46g/d), compared to those aged 51-64y (74g/d) and 65y+ (90g/d) and was lower in those aged 36-50y (59g/d) compared to those aged 65y+ (90g/d). The MDI of ‘RTEBC’ was higher in those aged 18-35y (26g/d) compared to those aged 51-64y (18g/d) and 65y+ (16g/d), but there was no difference in the MDI of ‘RTEBC’ in those aged 36-50y (24g/d) compared to the other age groups. Those aged 18-35y had a higher MDI (12g/d) of ‘low-fibre RTEBC’ compared to those aged 51-64y (7g/d) and 65y+ (4g/d) and those aged 65y+ had a lower MDI of ‘low-fibre RTEBC’ (4g/d) compared to those aged 18-35y (12g/d) and 36-50y (11g/d). Those aged 18-35y had a lower MDI of ‘porridge & hot oat cereal’ (19g/d) compared to those aged 51-64y (56g/d) and 65y+ (74g/d) and those aged 65y+ had a higher MDI (74g/d) compared to those aged 18-35y (19g/d) and 36-50y (35g/d). There was no difference in the MDI of ‘high-fibre RTEBC’ between age groups.

The MDI of ‘grains, rice, pasta & savouries’ was higher in those aged 18-35y (90g/d) compared to all other age groups (24-55g/d) and was lower in those aged 65y+ (24g/d) compared to those aged 18-35y (90g/d) and 36-50y (55g/d). The MDI of ‘pasta’ was higher in those aged 18-35y (20g/d) compared to those aged 51-64y (9g/d) and 65y+ (3g/d) and was lower in those aged 65y+ (3g/d) compared to those aged 18-35y (20g/d) and 36-50y (14g/d). The MDI of ‘pizza’ was higher in those aged 18-35y (28g/d) compared to all other age groups (2-11g/d). There were no differences in the MDI of ‘rice’, including ‘brown & wholegrain rice’ and in the MDI of ‘brown & wholemeal pasta’ or ‘other grains’ between age groups.

There was no difference in the MDI of ‘potatoes & potato products’ between age groups, but the MDI of ‘boiled, baked & mashed potatoes’ was lower in those aged 18-35y (56g/d) compared to all other age groups (75-99g/d) and was higher in those aged 65y+ (99g/d) compared to those aged 18-35y (56g/d) and 36-50y (75g/d). The MDI of ‘chipped, fried & roasted potatoes’ was higher in those aged 18-35y (49g/d) compared to those aged 51-64y (32g/d) and 65y+ (22g/d) and was lower in those aged 65y+ (22g/d) compared to those aged 18-35y (49g/d) and 36-50y (43g/d).

Compliance with food-based dietary guidelines

The MDI of 358g/d for ‘cereals, grains & potatoes’ equated to approximately 4.5 servings per day of which 2.3 servings were from ‘total breads’, 0.8 servings from ‘RTEBC’, 0.1 servings from ‘porridge’, 0.3 servings from ‘grains rice, pasta & savouries’ and 1.0 serving from ‘potatoes & potato products’. Of the 4.5 servings, only

2.1 servings were from wholemeal cereals and breads, potatoes, pasta and rice, which is below the Irish FBDG recommendation of 3-5 servings per day (Department of Health, 2016). Men consumed 2.8 servings of wholemeal cereals and bread, potatoes, pasta and rice compared to 1.9 servings in women. Those aged 18-35y and 36-50y consumed 2.2 servings of wholemeal cereals and breads, potatoes, pasta and rice while those aged 51-64y and 64y+ consumed 2.6 servings.

Table 4 presents the percent contribution (%) of ‘cereals, grains & potatoes’ to energy and nutrient intakes in the diets of adults (18-90y) in Ireland.

Overall, ‘cereals, grains & potatoes’ contributed 32% of the MDI of energy, comprising of 14% from ‘total breads’, 8% from ‘potatoes & potato products’, 6% from ‘breakfast cereals’ and 5% from ‘grains, rice, pasta & savouries’. ‘Cereals, grains & potatoes’ contributed 24% of the MDI of protein, with 12% from ‘total breads’, 4% each from ‘breakfast cereals’ and ‘grains, rice, pasta & savouries’ and 3% from ‘potatoes & potato products’.

‘Cereals, grains & potatoes’ contributed 52% of the MDI of carbohydrate, with 24% from ‘total breads’, 11% from ‘potatoes & potato products’, 10% from ‘breakfast cereals’ and 7% from ‘grains, rice, pasta & savouries’. ‘Cereals, grains & potatoes’ contributed 53% of the MDI of dietary fibre, with 26% from ‘total breads’, 12% from ‘potatoes & potato products’, 11% from ‘breakfast cereals’ and 6% from ‘grains, rice, pasta & savouries’. ‘Cereals, grains & potatoes’ contributed 12% of the MDI of total sugars with 5% each from ‘total breads’ and ‘breakfast cereals’ and contributed 7% of the MDI of free sugars, with ‘breakfast cereals’ contributing the majority of this intake (6%).

‘Cereals, grains & potatoes’ contributed 18% of the MDI of total fat, with 7% from ‘potatoes & potato products’, 5% from ‘total breads’, 4% from ‘grains, rice, pasta & savouries’ and 2% from ‘breakfast cereals’. ‘Cereals, grains & potatoes’ contributed 15% of the MDI of saturated fat, with ‘total breads’, ‘grains, rice, pasta & savouries’ and ‘potatoes & potato products’ making similar contributions (4-5%) and ‘breakfast cereals’ contributing 2%. ‘Cereals, grains & potatoes’ contributed 16% of the MDI of MUFA, with 7% from ‘potatoes & potato products’, of which 6% was from ‘chipped, fried & roasted potatoes’ (data not shown). ‘Cereals, grains & potatoes’ contributed

23% of the MDI of PUFA, with 11% from ‘potatoes & potato products’, of which 8% from ‘chipped, fried & roasted potatoes’ (data not shown).

‘Cereals, grains & potatoes’ contributed to the MDI of DFE (32%), thiamin (27%), niacin (26%), vitamin B6 (22%), and riboflavin (15%). Of this, ‘breakfast cereals’ contributed 14% of the MDI of DFE, 11% of the MDI of riboflavin, 9% of the MDI of thiamin and niacin and 8% of the MDI of vitamin B6. ‘Total breads’ also contributed to the MDI of niacin (11%), DFE (11%) and thiamin (10%) and ‘potatoes & potato products’ were the main contributors of vitamin B6 (10%).

‘Cereals, grains & potatoes’ contributed 16% of the MDI of vitamin E, with similar contributions from ‘potatoes & potato products’, ‘total breads’, ‘breakfast cereals’ and ‘grains, rice, pasta & savouries’ (3-5%). ‘Cereals, grains & potatoes’ contributed 11% of the MDI of vitamin C, with the majority (8%) from ‘potatoes & potato products’. ‘Cereals, grains & potatoes’ contributed 11% of the MDI of vitamin D and 6% of the MDI of vitamin B12, with 8% and 4%, respectively, from ‘breakfast cereals’.

‘Cereals, grains & potatoes’ contributed 40% of the MDI of iron, with ‘breakfast cereals’ and ‘total breads’ contributing the majority (17% and 15%, respectively). ‘Cereals, grains & potatoes’ also contributed 35% of the MDI of magnesium, 29% of the MDI of calcium and 27% of the MDI of zinc. Of this, ‘total breads’ contributed 19% of the MDI of calcium, 15% of the MDI magnesium and 12% of the MDI of zinc.

‘Cereals, grains & potatoes’ contributed 32% of the MDI of sodium, with ‘total breads’ contributing 22% and ‘breakfast cereals’, ‘grains, rice, pasta & savouries’ and ‘potatoes & potato products’ making similar contributions (2-4%).

‘Cereals, grains & potatoes’ contributed 28% of the MDI of potassium, with the majority of this (15%) from ‘potatoes & potato products’ and 7% from ‘total breads’.

Table 1. Mean daily intake (g/d) of 'cereals, grains & potatoes' in adults (18-90y) in Ireland in the total population (*n* 1500) and consumers only

	Total population		Consumers only		
	Mean (SD)	Median (IQR)		Mean (SD)	Median (IQR)
	g/d		%	g/d	
Cereals, grains & potatoes	358 (148)	334 (260-439)	100	358 (147)	335 (260-440)
Total breads	116 (63.0)	111 (70.5-151)	98	117 (61.7)	112 (72.0-152)
of which					
White bread	50.2 (52.3)	35.4 (7.3-78.9)	76	65.8 (50.6)	51.3 (28.1-91.8)
Wholemeal & brown bread	53.0 (54.2)	38.8 (0.0-84.3)	73	72.6 (51.0)	62.0 (35.0-101)
Other breads*	12.3 (25.9)	0.0 (0.0-15.8)	32	38.0 (33.1)	30.0 (16.8-47.4)
Breakfast cereals	61.9 (81.2)	33.8 (0.0-80.8)	75	82.9 (84.2)	51.8 (28.3-107)
of which					
Ready-to-eat breakfast cereals (RTEBC)	22.5 (28.9)	13.0 (0.0-35.3)	59	38.1 (28.7)	30.5 (17.5-50.3)
High fibre RTEBC (≥6g fibre per 100g)	13.1 (24.5)	0.0 (0.0-19.0)	37	35.6 (28.7)	27.8 (14.5-49.1)
Low-fibre RTEBC (<6g fibre per 100g)	9.4 (18.0)	0.0 (0.0-13.0)	33	28.1 (21.1)	22.5 (13.0-36.2)
Porridge & hot oat cereals (made up)	39.4 (83.3)	0.0 (0.0-35.4)	28	143 (102)	120 (66.9-202)
Grains, rice, pasta & savouries	59.9 (71.4)	40.3 (0.0-92.3)	69	87.1 (71.0)	67.8 (37.5-113)
of which					
Rice	15.6 (31.4)	0.0 (0.0-21.3)	28	56.3 (35.5)	45.5 (32.8-70.0)
Brown & wholegrain rice	2.2 (12.6)	0.0 (0.0-0.0)	4	53.1 (32.8)	44.3 (28.8-72.5)
Pasta	13.3 (31.6)	0.0 (0.0-0.0)	22	61.1 (41.1)	53.5 (35.4-76.1)
Brown & wholemeal pasta	0.9 (8.1)	0.0 (0.0-0.0)	2	54.1 (35.4)	47.8 (33.1-57.2)
Pizza	14.5 (39.1)	0.0 (0.0-0.0)	19	77.9 (57.0)	62.5 (39.3-100.0)
Other grains†	3.1 (15.7)	0.0 (0.0-0.0)	8	39.8 (41.2)	30.4 (14.8-50.6)
Other savoury dishes & products‡	13.4 (32.7)	0.0 (0.0-12.5)	32	41.9 (46.4)	31.3 (12.5-58.5)
Potatoes & potato products	121 (85.4)	105 (60.5-165)	94	129 (82.2)	112 (68.9-169)
of which					
Boiled, baked & mashed potatoes	75.6 (75.6)	59.8 (17.1-111)	77	98.5 (72.0)	77.1 (46.5-130)
Chipped, fried & roasted potatoes	39.7 (49.2)	25.8 (0.0-60.0)	62	64.2 (48.3)	50.0 (33.0-84.0)
Processed & homemade potato products	5.4 (17.5)	0.0 (0.0-0.0)	16	33.0 (30.7)	24.8 (15.0-42.0)

*scones, garlic bread, fruit bread, naan, chapatti, English muffins etc. †barley, buckwheat, bulgur wheat, cornmeal, semolina, cornflour, plain noodles, couscous, quinoa etc. ‡instant/fried noodles, spaghetti hoops, pasta dishes (macaroni cheese), savoury pastry, bread stuffing, French toast, fried rice, Yorkshire pudding, dumplings etc.

Table 2. Mean daily intake (g/d) of 'cereals, grains & potatoes' in adults (18-90y) in Ireland in the total population (*n* 1500), split by sex

	Men (*n* 740)		Women (*n* 760)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
	g/d		g/d	
Cereals, grains & potatoes	417 (157)	401 (308-499)	301 (111)*	292 (229-364)
Total breads	135 (66.9)	128 (88.1-174)	96.4 (52.3)*	93.3 (58.8-129)
of which				
White bread	62.5 (59.4)	47.8 (15.5-95.2)	38.3 (41.1)*	27.0 (0.0-58.0)
Wholemeal & brown bread	59.5 (62.4)	43.9 (0.0-98.9)	46.7 (44.0)*	38.0 (4.8-72.8)
Other breads†	13.2 (29.2)	0.0 (0.0-17.5)	11.4 (22.2)	0.0 (0.0-15.0)
Breakfast cereals	67.2 (86.8)	39.5 (0.0-89.4)	56.7 (75.1)	30.0 (5.6-77.3)
of which				
Ready-to-eat breakfast cereals (RTEBC)	27.0 (33.6)	17.0 (0.0-44.2)	18.1 (22.7)*	10.3 (0.0-29.8)
High fibre RTEBC (≥6g fibre per 100g)	16.6 (29.2)	0.0 (0.0-25.0)	9.8 (18.1)*	0.0 (0.0-13.5)
Low-fibre RTEBC (<6g fibre per 100g)	10.4 (20.0)	0.0 (0.0-14.7)	8.3 (15.7)	0.0 (0.0-11.8)
Porridge & hot oat cereals	40.2 (88.6)	0.0 (0.0-22.1)	38.7 (77.8)	0.0 (0.0-40.0)
Grains, rice, pasta & savouries	70.7 (84.3)	50.0 (0.0-106)	49.4 (54.1)*	35.5 (0.0-76.9)
of which				
Rice	17.4 (35.4)	0.0 (0.0-21.3)	13.8 (26.8)	0.0 (0.0-21.4)
Brown & wholegrain rice	2.3 (13.8)	0.0 (0.0-0.0)	2.1 (11.3)	0.0 (0.0-0.0)
Pasta	15.9 (36.5)	0.0 (0.0-0.0)	10.7 (25.8)	0.0 (0.0-0.0)
Brown & wholemeal pasta	0.8 (9.5)	0.0 (0.0-0.0)	0.9 (6.5)	0.0 (0.0-0.0)
Pizza	19.1 (48.1)	0.0 (0.0-0.0)	10.1 (26.9)*	0.0 (0.0-0.0)
Other grains‡	3.1 (18.5)	0.0 (0.0-0.0)	3.1 (12.5)	0.0 (0.0-0.0)
Other savoury dishes & products§	15.1 (38.7)	0.0 (0.0-12.5)	11.7 (25.5)	0.0 (0.0-12.5)
Potatoes & potato products	144 (94.5)	128 (76.3-195)	98.5 (68.7)*	86.9 (50.0-135)
of which				
Boiled, baked & mashed potatoes	91.0 (87.5)	70.0 (26.3-131)	60.7 (58.1)*	49.4 (8.0-91.9)
Chipped, fried & roasted potatoes	47.3 (55.4)	34.8 (0.0-73.7)	32.2 (41.0)*	23.4 (0.0-49.9)
Processed & homemade potato products	5.3 (17.9)	0.0 (0.0-0.0)	5.6 (17.1)	0.0 (0.0-0.0)

*Statistically different ($P < 0.001$) from men within the rows via independent sample t-test, adjusted for multiple testing †scones, garlic bread, fruit bread, naan, chapatti, English muffins etc. ‡barley, buckwheat, bulgur wheat, cornmeal, semolina, cornflour, plain noodles, couscous, quinoa etc. §instant/fried noodles, spaghetti hoops, pasta dishes (macaroni cheese), savoury pastry, bread stuffing, French toast, fried rice, Yorkshire pudding, dumplings etc.

Table 3. Mean daily intake (g/d) of 'cereals, grains & potatoes' in adults (18-90y) in Ireland in the total population (*n* 1500), split by age group

	18-35y (*n* 531)		36-50y (*n* 437)		51-64y (*n* 306)		65y+ (*n* 226)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
	g/d		g/d		g/d		g/d	
Cereals, grains & potatoes	353 (150)^{a}	332 (250-436)	355 (136)^{a}	343 (264-432)	371 (157)^{a}	342 (261-463)	358 (151)^{a}	329 (262-440)
Total breads	106 (58.8)^{a}	101 (64.5-140.8)	119 (64.2)^{a}	116 (74.6-154)	124 (65.6)^{b}	115 (75.7-157)	120 (63.9)^{ab}	110 (74.4-161)
of which								
White bread	52.9 (50.5)^{a}	40.0 (15.0-79.3)	52.0 (52.2)^{a}	38.0 (9.9-82.5)	48.0 (54.3)^{a}	31.0 (0.0-76.0)	43.5 (53.6)^{a}	21.9 (0.0-76.9)
Wholemeal & brown bread	45.3 (48.2)^{a}	34.3 (0.0-74.3)	52.6 (56.2)^{a}	38.0 (0.0-84.1)	60.9 (57.4)^{b}	52.4 (0.0-90.3)	61.3 (56.9)^{ab}	56.5 (0.0-96.8)
Other breads*	8.0 (16.5)^{a}	0.0 (0.0-10.0)	14.1 (28.9)^{a}	0.0 (0.0-20.0)	15.1 (29.0)^{b}	0.0 (0.0-20.0)	15.1 (31.5)^{ab}	0.0 (0.0-20.0)
Breakfast cereals	45.6 (61.8)^{a}	28.0 (0.0-60.0)	58.9 (78.3)^{ab}	34.0 (0.0-75.0)	73.9 (96.5)^{bc}	38.1 (0.0-103)	89.8 (93.9)^{c}	53.0 (15.5-144)
of which								
Ready-to-eat breakfast cereals (RTEBC)	26.3 (32.2)^{a}	19.5 (0.0-38.0)	24.0 (29.5)^{ab}	15.0 (0.0-39.9)	18.3 (24.0)^{b}	7.5 (0.0-31.1)	16.2 (23.7)^{b}	0.0 (0.0-25.4)
High fibre RTEBC (≥6g fibre per 100g)	13.9 (27.1)^{a}	0.0 (0.0-19.0)	13.6 (24.2)^{a}	0.0 (0.0-20.0)	11.5 (21.3)^{a}	0.0 (0.0-14.4)	12.5 (22.3)^{a}	0.0 (0.0-19.6)
Low-fibre RTEBC (<6g fibre per 100g)	12.4 (20.8)^{a}	0.0 (0.0-20.3)	10.5 (19.0)^{ab}	0.0 (0.0-15.6)	6.7 (14.7)^{bc}	0.0 (0.0-4.6)	3.6 (8.9)^{c}	0.0 (0.0-0.0)
Porridge & hot oat cereals	19.2 (57.3)^{a}	0.0 (0.0-0.0)	34.9 (79.7)^{ab}	0.0 (0.0-0.0)	55.6 (100)^{bc}	0.0 (0.0-89.5)	73.6 (99.5)^{c}	0.0 (0.0-134)
Grains, rice, pasta & savouries	89.5 (84.7)^{a}	67.5 (23.5-134)	55.1 (55.6)^{b}	45.0 (0.0-85.6)	41.9 (63.2)^{bc}	17.8 (0.0-66.8)	24.0 (42.5)^{c}	0.0 (0.0-35.7)
of which								
Rice	18.8 (35.5)^{a}	0.0 (0.0-32.8)	15.3 (27.2)^{a}	0.0 (0.0-27.9)	14.4 (32.0)^{a}	0.0 (0.0-18.4)	10.2 (26.5)^{a}	0.0 (0.0-0.0)
Brown & wholegrain rice	3.0 (13.9)^{a}	0.0 (0.0-0.0)	1.4 (9.0)^{a}	0.0 (0.0-0.0)	2.3 (13.7)^{a}	0.0 (0.0-0.0)	1.9 (13.6)^{a}	0.0 (0.0-0.0)
Pasta	19.7 (39.5)^{a}	0.0 (0.0-27.5)	14.1 (31.4)^{ab}	0.0 (0.0-0.0)	8.8 (21.9)^{bc}	0.0 (0.0-0.0)	2.5 (13.7)^{c}	0.0 (0.0-0.0)
Brown & wholemeal pasta	1.5 (11.7)^{a}	0.0 (0.0-0.0)	0.6 (5.9)^{a}	0.0 (0.0-0.0)	0.5 (5.3)^{a}	0.0 (0.0-0.0)	0.2 (2.7)^{a}	0.0 (0.0-0.0)
Pizza	27.6 (54.8)^{a}	0.0 (0.0-36.0)	10.6 (27.9)^{b}	0.0 (0.0-0.0)	7.1 (24.5)^{b}	0.0 (0.0-0.0)	1.6 (10.7)^{b}	0.0 (0.0-0.0)
Other grains†	4.6 (22.5)^{a}	0.0 (0.0-0.0)	2.6 (11.2)^{a}	0.0 (0.0-0.0)	2.2 (9.8)^{a}	0.0 (0.0-0.0)	1.9 (8.7)^{a}	0.0 (0.0-0.0)
Other savoury dishes & products‡	18.8 (36.0)^{a}	0.0 (0.0-25.0)	12.5 (25.6)^{ab}	0.0 (0.0-12.5)	9.4 (40.3)^{b}	0.0 (0.0-0.0)	7.8 (21.9)^{b}	0.0 (0.0-0.0)
Potatoes & potato products	111 (90.5)^{a}	92.0 (47.5-152)	123 (82.0)^{a}	109 (65.5-169)	131 (84.4)^{a}	121 (70.0-170)	125 (79.2)^{a}	113 (68.4-167)
of which								
Boiled, baked & mashed potatoes	55.7 (70.0)^{a}	38.3 (0.0-80.0)	75.0 (72.2)^{b}	60.0 (22.9-110)	93.9 (78.8)^{bc}	77.0 (35.0-132)	99.0 (77.7)^{c}	84.5 (47.2-133)
Chipped, fried & roasted potatoes	48.5 (57.3)^{a}	33.0 (0.0-75.0)	43.0 (48.7)^{ab}	33.0 (0.0-62.9)	32.2 (37.4)^{bc}	20.6 (0.0-51.6)	22.4 (35.7)^{c}	0.0 (0.0-35.8)
Processed & homemade potato products	7.2 (20.6)^{a}	0.0 (0.0-0.0)	4.6 (12.1)^{a}	0.0 (0.0-0.0)	5.1 (20.4)^{a}	0.0 (0.0-0.0)	3.4 (13.2)^{a}	0.0 (0.0-0.0)

Statistical differences ($P < 0.001$) between age groups are denoted by different superscript letters *scones, garlic bread, fruit bread, naan/chapatti, English muffins etc. †barley, buckwheat, bulgur wheat, cornmeal, semolina, cornflour, plain noodles, couscous, quinoa etc. ‡instant/fried noodles, spaghetti hoops, pasta dishes (macaroni cheese), savoury pastry, bread stuffing, French toast, fried rice, Yorkshire pudding, dumplings etc.

Table 4. Percent contribution (%) of 'cereals, grains & potatoes' to energy and nutrients in the diets of adults (18-90y) in Ireland in the total population (*n* 1500)

	Cereals, grains & potatoes		**Total breads**		**Breakfast cereals**		**Grains, rice, pasta & savouries**		**Potatoes & potato products**	
	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Energy (kcal)	644	32.4	276	13.9	112	5.6	103	5.2	153	7.7
Protein (g)	19.8	23.6	10.0	11.9	3.4	4.1	3.5	4.2	2.8	3.3
Total fat (g)	13.7	18.1	3.9	5.1	1.7	2.3	2.9	3.8	5.2	6.9
Saturated fat (g)	4.3	14.5	1.3	4.5	0.6	1.9	1.1	3.6	1.3	4.5
MUFA (g)	4.5	16.3	0.9	3.3	0.5	1.9	1.0	3.8	2.0	7.4
PUFA (g)	3.1	23.4	0.7	5.4	0.4	2.9	0.5	4.0	1.5	11.1
Carbohydrate (g)	118	51.5	53.7	23.5	21.9	9.6	16.7	7.3	25.3	11.1
Total sugars (g)	11.2	12.4	4.5	5.0	4.6	5.1	1.0	1.1	1.1	1.3
Free sugars (g)	3.2	6.7	0.3	0.6	2.7	5.7	0.2	0.4	0.0	0.0
Dietary fibre (g)	10.2	53.1	4.9	25.7	2.0	10.5	1.0	5.5	2.2	11.5
Vitamin A (µg)	37.2	3.3	9.4	0.8	5.0	0.4	13.3	1.2	9.5	0.8
Vitamin D (µg)	0.6	10.6	0.1	1.1	0.4	7.6	0.1	1.1	0.0	0.9
Vitamin E (mg)	2.1	15.9	0.5	3.8	0.5	3.8	0.4	2.8	0.7	5.4
Vitamin C (mg)	13.5	10.9	0.1	0.0	3.5	2.8	0.4	0.3	9.5	7.7
Thiamin (mg)	0.8	27.2	0.3	9.5	0.3	9.3	0.1	1.8	0.2	6.5
Riboflavin (mg)	0.5	15.4	0.1	3.0	0.3	10.5	0.0	1.1	0.0	0.8
Niacin (mg)	11.7	26.1	5.1	11.3	3.9	8.6	1.3	2.8	1.5	3.4
Vitamin B6 (mg)	0.9	22.4	0.1	3.5	0.3	8.0	0.0	0.9	0.4	10.0
Vitamin B12 (µg)	0.4	5.8	0.0	0.2	0.3	3.9	0.1	1.5	0.0	0.1
Total folate (µg)	124	33.5	45.6	12.4	43.0	11.6	5.7	1.5	29.3	7.9
DFE (µg)	148	32.2	48.4	10.5	65.0	14.1	5.7	1.2	29.3	6.3
Sodium (mg)	799	32.0	551	22.1	89.5	3.6	102	4.1	56.3	2.3
Potassium (mg)	858	28.1	209	6.9	116	3.8	63.2	2.1	469	15.4
Calcium (mg)	277	29.3	175	18.5	48.6	5.2	42.2	4.5	11.2	1.2
Iron (mg)	5.9	40.4	2.2	15.4	2.5	17.2	0.5	3.3	0.7	4.5
Magnesium (mg)	102	34.9	43.8	15.0	23.8	8.2	11.5	4.0	22.6	7.8
Zinc (mg)	2.9	27.3	1.3	12.3	0.7	6.2	0.5	4.7	0.4	4.0

MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; DFE= dietary folate equivalents

Discussion

The aim of this study was to use data from the National Adult Nutrition Survey (NANS) to estimate the current intake of cereals, grains & potatoes in adults (18-90y) in Ireland, to assess compliance with recommendations and to determine their contribution to overall energy and nutrient intakes. Overall, ‘cereals, grains & potatoes’ were consumed by all adults in Ireland, with an MDI of 358g/d. This equated to approximately 4.5 servings, of which 2.1 servings were from wholemeal cereals and breads, potatoes, pasta and rice, which is below Irish FBDG of 3-5 servings per day (Department of Health, 2016). Men had a higher MDI of overall ‘cereals, grains & potatoes’ compared to women attributable to their higher MDI of ‘white bread’, ‘wholemeal & brown bread’, ‘RTEBC’, ‘high-fibre RTEBC’, ‘pizza’, ‘boiled, baked & mashed potatoes’ and ‘chipped, fried & roasted potatoes’. While there were no differences in the MDI of overall ‘cereals, grains & potatoes’ between age groups, those aged 18-35y had higher intakes of ‘convenience type foods’ such as low-fibre RTEBC’, ‘pasta’, ‘other savoury dishes & products’, ‘chipped, fried & roasted potatoes’ and ‘pizza’ compared to those aged 51-64y and 65y+. Additionally, those aged 18-35y had lower intakes of ‘boiled, baked & mashed potatoes’ compared to all other age groups and had lower intakes of ‘porridge’ compared to those aged 51-64y and 65y+. Overall, ‘cereals, grains & potatoes’ made significant contributions to the MDI of energy (32%), carbohydrate (52%), dietary fibre (53%), protein (24%), B vitamins, such as folate (32%), thiamin (27%), niacin (26%) and vitamin B6 (22%) and minerals, such as iron (40%), magnesium (35%), calcium (29%), potassium (28%) and zinc (27%) but also made significant contributions to intakes of sodium (32%) and smaller contributions to the intake of saturated fat (15%) and free sugars (7%). These findings are discussed below in the context of the available literature and in terms of the public health implications.

Intakes of ‘cereals, grains & potatoes’ and compliance with FBDG

The findings of this study showed that all adults aged 18-90y in Ireland consumed ‘cereals, grains & potatoes’, with an MDI of 358g/d. The majority of this was from ‘potatoes & potato products’ (121g/d) and ‘total breads’ (116g/d) and the remainder was evenly distributed between ‘breakfast cereals’ (62g/d) and ‘grains, rice, pasta & savouries’ (60g/d). Approximately half (184g/d) of all ‘cereals, grains & potatoes’ were from wholemeal cereals and breads, potatoes, pasta and rice, of which 53g/d was from ‘wholemeal & brown bread’, 13g/d was from ‘high-fibre RTEBC’, 39g/d was from ‘porridge & hot oat cereal’, 2g/d was from ‘brown & wholegrain rice’, 1g/d was from ‘brown & wholemeal pasta’ and 76g/d was from ‘boiled, baked & mashed potatoes’. When comparing these findings with that of the previous NSIFCS of adults (18-64y) in Ireland (1997-1999), this study found that overall intakes of cereals, grains & potatoes in adults (18-64y) (360g/d) were lower than the NSIFCS (441g/d). Within groups, the MDI of breads has remained relatively similar between the NSIFCS and the NANS (138 vs 116g/d), however the MDI of white bread has decreased (78 vs 51g/d). The MDI of breakfast cereals has almost doubled (35 vs 60g/d), primarily due to an increase in the MDI of porridge & hot oat cereals (16 vs 37g/d). The MDI of grains, rice, pasta & savouries has remained relatively similar (44 vs 62g/d), while the MDI of potatoes & potato products has halved (224 vs 122g/d) attributable to a decrease in all potato types, but particularly boiled, baked & mashed potatoes (158 vs 75g/d). Therefore, overall intake of cereals, grains & potatoes have decreased in the 10 years between national adult nutrition surveys, primarily attributable to a large reduction in the intake of ‘potatoes & potato products’.

In the current study, men had a higher intake (417g/d) of ‘cereals, grains & potatoes’ compared to women (301g/d), which was attributable to the higher intake of ‘total breads’ (men: 135g/d, women: 96g/d), ‘grains, rice, pasta & savouries’ (men: 71g/d, women: 49g/d) and ‘potatoes & potato products’ (men: 144g/d, women: 99g/d) in men. There were no differences in intakes between the age groups overall for ‘cereals, grains & potatoes’, however, those aged 18-35y had a higher intake of ‘low-fibre RTEBC’, ‘pasta’, ‘other savoury dishes & products’ and ‘chipped, fried & roasted potatoes’ compared to those aged 51-64y and 65y+ and a had higher intake of ‘pizza’ compared to all other age groups. Additionally, those aged 18-35y had lower intakes of ‘boiled, baked & mashed potatoes’ compared to all other age groups and had lower intakes of ‘porridge’ compared to those aged 51-64y and 65y+. These findings are in keeping with studies which suggest younger adults are more likely to consume convenience foods compared to older adults (Allman-Farinelli *et al.,* 2016; Sogari *et al.,* 2018; Sprake *et al.,* 2018; Livingstone *et al.,* 2022).

There is no global recommendation for the intake of ‘cereals, grains & potatoes’ in adults and recommendations vary greatly across countries within the WHO European region. The consumption of whole grains is typically recommended across countries, in line with the WHO and World Cancer Research Fund (WCRF) recommendations to reduce the risk of non-communicable diseases (World Cancer Research Fund/American Institute for Cancer Research, 2018; World Health Organisation, 2020; van der Kamp *et al.*, 2021). The Irish FBDG recommend the general population, including adults to consume 3-5 servings of wholemeal cereals and breads, potatoes, pasta and rice (Food Standards Agency, 2002a; Department of Health, 2016). Findings from this study showed that adults consumed approximately 4.5 servings of ‘cereals, grains & potatoes’, however, only 2.1 servings were from wholemeal cereals and breads, potatoes, pasta and rice which is below the recommendation for adults (Department of Health, 2016). When comparing these findings with that of the previous NSIFCS of adults (18-64y) in Ireland (1997-1999), this study found that adults consumed less servings of overall cereals, grains & potatoes (4.5) compared to the NSIFCS (5.2), however detailed disaggregated data are not available from the NSIFCS for some food groups and so it is not possible to directly compare the intake of wholemeal cereals and breads, potatoes, pasta and rice (Irish Universities Nutrition Alliance, 1999). The current study found that men consumed more servings (2.8) from wholemeal cereals and breads, potatoes, pasta and rice compared to women (1.9), likely due to an overall higher consumption of ‘cereals, grains & potatoes’, however, this was still below the recommended 3-5 servings of wholemeal cereals and breads, potatoes, pasta and rice (Department of Health, 2016). The younger age groups (18-35y and 36-50y) had fewer servings of wholemeal cereals and breads, potatoes, pasta and rice (2.2) compared to those age 51-64y and 65y+ (2.6).

Despite variations in the categorisation of cereals, grains & potatoes between studies, findings from this study can be broadly compared with nationally representative data from other countries within the WHO European region. The MDI of ‘cereals, grains & potatoes’ in adults in Ireland (358g/d) was at the higher range of intakes compared to other countries (Belgium, Denmark Finland, Italy, Portugal, Spain, the Netherlands and the UK). Mean intakes of cereals, grains & potatoes in these countries typically ranged from 276-359g/d and mean intakes of cereals & grains (excluding potatoes) was 149g/d in Spain (Leclercq *et al.*, 2009; Helldán *et al.*, 2013; Heuer *et al.*, 2015;

Pedersen *et al.*, 2015; Lopes *et al.*, 2018; Bel *et al.*, 2019; Partearroyo *et al.*, 2019; Public Health England, 2019; van Rossum, 2020).

Contribution of ‘cereals, grains & potatoes’ to energy and nutrients in the diet

Cereals, grains & potatoes are recognised as a source of energy, carbohydrate, protein, dietary fibre and, vitamins and minerals, including B vitamins, iron, potassium, magnesium, calcium and zinc (McKevith, 2004; Food and Agriculture Organisation of the United Nations, 2008). This study found that ‘cereals, grains & potatoes’ contributed significantly to the MDI of energy and many other nutrients in the diets of adults aged 18-90y in Ireland. Overall, ‘cereals, grains & potatoes’ contributed to approximately one third (32%) of energy intake, with 14% of this from ‘total breads’, 8% from ‘potatoes & potato products’, 6% from ‘breakfast cereals’ and 5% from ‘grains, rice, pasta & savouries’. These findings are in line with findings from adults in other countries (Denmark, Finland, Italy, Portugal, Spain, the Netherlands and the UK), with contributions to energy from cereals, grains & potatoes ranging from 26-40% (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2015; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

‘Cereals, grains & potatoes’ contributed approximately one-quarter of protein intake (24%) in this study, with 12% from ‘total breads’ and 3-4% from each of ‘breakfast cereals’, ‘grains, rice, pasta & savouries’ and ‘potatoes & potato products’. While protein from animal-derived ingredients within this food group (e.g., milk in porridge, eggs/dairy in bread/potato dishes) may also have made some contribution, cereal grains are known to be a major source of PB protein in the diet (Poutanen *et al.*, 2022). The consumption of PB protein, as part of a PB diet, is increasingly encouraged due to its potential health and environmental benefits compared to animal-derived protein, however, there is a general concern about the adequate consumption, quality and digestibility of protein from PB sources (Davies and Jakeman, 2020; Poutanen *et al.*, 2022). Despite concerns, a well-planned PB diet, with a mixture of plant proteins (e.g., cereals and legumes) has been shown to provide a nutritionally adequate and sustainable diet (Mariotti and Gardner, 2019; Davies and Jakeman, 2020). These findings for protein contributions from cereals, grains & potatoes are broadly in line with other countries, with cereals, grains & potatoes contributing 20-30% of protein intake in adults in most countries and a lower contribution of 17% in Spain, likely due to the exclusion of potatoes when reporting contributions (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

Cereals, grains & potatoes are well-recognised as starchy foods and therefore, as expected, contributed significantly to carbohydrate intake (52%) in the diet of adults, with almost half of this (24%) coming from 'total breads'. Cereals, grains & potatoes also contributed over a half of dietary fibre intake (53%), with the majority (26%) from 'total breads' and smaller contributions from 'potatoes & potato products' (12%) and breakfast cereals (11%). While cereals, grains & potatoes contribute a significant proportion of dietary fibre, current intakes of dietary fibre (19g/d) in adults are below the recommended adequate intake of 25g/d set by the European Food Safety Authority (EFSA) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010; Irish Universities Nutrition Alliance, 2011). For this reason, Irish FBDG recommend replacing refined cereal products and grains with wholemeal and wholegrain versions to improve intakes of dietary fibre in Irish adults (Department of Health, 2016). The findings from this study for contributions to carbohydrate and dietary fibre intakes are also generally in line with other countries, with cereals, grains & potatoes contributing 43-53% of carbohydrate intake across countries within the WHO European region (with a higher contribution of 71% in Italy) and 40-60% of dietary fibre intake (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). In this study, 'cereals, grains & potatoes' also contributed a small proportion of the intake of free sugars (7%), with the majority (6%) coming from 'breakfast cereals'. While intake of free sugars in adults in Ireland is of public health concern at approximately 9% of total energy (in excess of the UK recommendations of <5% total energy), the contribution to free sugars intake from 'breakfast cereals' is moderate (and decreasing due to ongoing reformulation of RTEBC) compared to contributions from 'top shelf foods', i.e., sugars, syrups & jams, biscuits, cakes & pastries, sugar-sweetened beverages, chocolate and chilled desserts & ice cream which in total contribute almost two thirds of all free sugars intake (62%), therefore public health efforts should prioritise the reduction of sugars from these sources (Walton *et al.*, 2017). The available data from other countries showed that the contribution of cereals, grains & potatoes to free sugars intake was the same in Portugal (7%) compared to Ireland but was significantly higher in Spain (19%) and the UK (26%), potentially related to the inclusion of pastry and other bakery products in the estimation of nutrient contributions in Spain and the UK (Ruiz *et al.*, 2017; Lopes *et al.*, 2018; Public Health England, 2020).

‘Cereals, grains & potatoes’ also contributed to intakes of saturated fat (15%), with equal contributions from ‘total breads’ (5%), ‘grains, rice & savouries’ (4%) and ‘potatoes & potato products’ (5%) and a minimal contribution from ‘breakfast cereals’ (2%), with saturated fat from animal-derived ingredients within dishes making some contributions, e.g., cheese from macaroni cheese, potato chips. However, other food groups, such as ‘meat, meat products & dishes’, ‘dairy products’ and ‘top-shelf foods’ including ‘biscuits, cakes, pastries & buns’, ‘sugars, confectionery & preserves’ and ‘savoury snacks’ also contribute significantly to saturated fat intake (22%, 17% and 13%, respectively) (Li *et al.*, 2016). Therefore, while there is poor compliance with saturated fat recommendations in developed countries, including Ireland, strategies to reduce population-level intake of saturated fat are necessary and in light of the growing body of evidence suggesting that the dairy food matrix may be beneficial for cardiovascular health, these strategies should focus on the reduction of confectionery-type foods and the consumption of lean meat, meat products & dishes (Thorning *et al.*, 2017). The contribution of cereals, grains & potatoes to saturated fat intake in Ireland were generally in line with data from Italy (10%), Spain (11%) and Finland (18%), however was lower for Portugal (5%), Denmark (6%) and the Netherlands (6%), and higher for adults in the UK (24%), which may be partially explained by the inclusion of biscuits, buns, cakes, pastries and puddings in the estimation of contributions in the UK (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). ‘Cereals, grains & potatoes’ also made significant contributions to intakes of MUFA (16%) and PUFA (23%). ‘Potatoes & potato products’ contributed 7% of MUFA and 11% of PUFA intake, with the majority of this attributed to oils from ‘chipped, fried & roasted potatoes’ (6% and 8% respectively). Contributions to MUFA intake from ‘cereals, grains & potatoes’ across other countries were variable (4-24%), likely related to differences in the categorisation of cereals, grains & potatoes between countries (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). The contribution of ‘cereals, grains & potatoes’ to PUFA intake in Ireland was broadly similar in other countries (15-23%), although at the higher range (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Ruiz *et al.*, 2016; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

‘Cereals, grains & potatoes’ contributed 16% of vitamin E intake, with similar contributions from ‘total breads’, ‘breakfast cereals’, ‘grains, rice, pasta & savouries’ and ‘potatoes & potato products’ (3-5%), which is unsurprising as cereals are good sources of vitamin E. Cereals, grains & potatoes contributed to variable proportions of vitamin E intake in other countries within the WHO European region (4-26%), potentially related to differences in the categorisation of cereals, grains & potatoes between countries (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; van Rossum, 2020). ‘Cereals, grains & potatoes’ contributed 11% of vitamin C intake with the majority (8%) from ‘potatoes & potato products’, which may be expected given potatoes are a good source of vitamin C. Broadly similar findings were observed in other countries (6-18%), with the exception of Spain (1%), which excluded potatoes in the estimation of nutrient contributions (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Olza *et al.*, 2017a; Lopes *et al.*, 2018; van Rossum, 2020)

This study showed that ‘cereals, grains & potatoes’ made significant contributions to the intake of some B vitamins, such as folate (32%), thiamin (27%), niacin (26%), vitamin B6 (22%) and also contributed to the intake of riboflavin (15%). Regarding minerals, ‘cereals, grains & potatoes’ contributed significantly to the intake of iron (40%), magnesium (35%), calcium (29%) and zinc (27%) in the diets of adults in Ireland. The contribution of ‘cereals, grains & potatoes’ to these micronutrients in this study is mainly attributable to ‘breakfast cereals’ and ‘total breads’, likely related to the fortification of RTEBC and wheat flour. In Ireland, RTEBC are typically fortified with an array of B vitamins and iron (Hennessy *et al.*, 2015). ‘Breakfast cereals’ accounted for 14% of folate intake, 11% of riboflavin intake, 9% each of thiamin and niacin intakes, 8% of vitamin B6 intake and accounted for 17% of iron intake. Additionally, wheat flour is fortified with thiamin, iron and calcium to restore losses during processing (European Comission, 2006), resulting in ‘total breads’ contributing 10% of thiamin, 15% of iron and 19% of calcium in this study. In keeping with this study, cereals, grains & potatoes in other countries within the WHO European region contributed similar intakes of some B vitamins (thiamin, riboflavin, niacin, vitamin B6, folate) (13-47%), iron (27-45%), magnesium (23-35%) and zinc (21-35%) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Olza *et al.*, 2017b; Olza *et al.*, 2017a; Partearroyo *et al.*, 2017; Samaniego-Vaesken *et al.*, 2017; Lopes *et al.*, 2018; Mielgo-Ayuso *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). For calcium, while contributions from ‘cereals, grains & potatoes’ in this study (29%) were similar to the UK (32%), potentially related to the historical import of British flour to Ireland (which has changed with the departure of the UK from the EU) and similar bread consumption patterns, contributions to calcium intakes were lower in other countries (8-13% in Denmark, Finland, Italy, Portugal, Spain and the Netherlands) (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017b; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

‘Cereals, grains & potatoes’ contributed 11% of vitamin D intake, with the majority of this intake from ‘breakfast cereals’ (8%), partially related to the fortification of RTEBC. This finding was higher than findings from the Netherlands (1%), Denmark (2%), Portugal (4%), Finland (7%) and Italy (9%), but lower than findings from Spain (15%) and the UK (16%). Variations in findings may be related to differences in the classification of cereals, grains & potatoes between countries and fortification practices between countries (Helldán *et al.*, 2013; Sette *et al.*, 2013; Pedersen *et al.*, 2015; Olza *et al.*, 2017b; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020). In recent years, there has been increasing public emphasis on vitamin D intake for good health and a concomitant increase in the fortification of RTEBC with vitamin D, resulting in increased contributions from RTEBC to vitamin D intake in recent dietary surveys (National Children’s Food Survey II and National Teens’ Food Survey II) (Irish Universities Nutrition Alliance, 2018; Kellogg's Press Office, 2018; Buttriss and Lanham-New, 2020; Irish Universities Nutrition Alliance (IUNA), 2021). However, vitamin D has been identified as a nutrient of concern worldwide and despite foods fortified with vitamin D (e.g., RTEBC) making useful contributions to intake, there are calls for diverse food fortification strategies to bridge the gap between current vitamin D intakes and adequate intakes and a potential need for supplement recommendations for populations, particularly those at northerly latitudes (World Health Organisation, 2014a; Kiely and Cashman, 2018; Buttriss and Lanham-New, 2020). ‘Cereals, grains & potatoes’ contributed 6% to vitamin B12 intake, with 4% from ‘breakfast cereals’, (mainly due to fortified RTEBC) and data from other countries also showed low contributions (0-8%) to vitamin B12 intake from ‘cereals, grains & potatoes’(Helldán *et al.*, 2013; Sette *et al.*, 2013; Public Health England, 2014; Pedersen *et al.*, 2015; Partearroyo *et al.*, 2017; Lopes *et al.*, 2018; van Rossum, 2020).

‘Cereals, grains & potatoes’ contributed significantly to sodium (salt) intake (32%), with the majority of this coming from ‘total breads’ (22%). Significant reductions in the salt content of many processed and prepared foods, including bread, have been achieved over the last 20 years, through the objectives of the Salt Reduction Programme of the Food Safety Authority of Ireland (FSAI) to work in collaboration with manufacturers to gradually reduce the salt content of food groups contributing the most to salt intake (Food Safety Authority of Ireland, 2003; Food Safety Authority of Ireland, 2016). However, salt intake in adults in Ireland (10.2g/d) still exceeds the FSAI maximum population target for the Irish adult population of <6g/d (Food Safety Authority of Ireland, 2003; Food Safety Authority of Ireland, 2016; Morrissey *et al.*, 2020). These findings are similar (although at the higher range) to findings from other countries within the WHO European region, with cereals, grains & potatoes contributing 21-35% of sodium intake (Helldán *et al.*, 2013; Pedersen *et al.*, 2015; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

‘Cereals, grains & potatoes’ contributed 28% of the intake of potassium, mainly attributable to ‘potatoes & potato products’ (15%), which is at the higher range of contributions from this food group in other countries within the WHO European region (19-27%), possibly related to a higher proportion of potatoes consumed in Ireland (121g) compared to other countries (50-91g) (Helldán *et al.*, 2013; Pedersen *et al.*, 2015; Lopes *et al.*, 2018; Public Health England, 2020; van Rossum, 2020).

Overall, these findings demonstrate ‘cereals, grains & potatoes’ are important sources of energy, macronutrients and micronutrients in the diets of adults in Ireland and other countries within the WHO European region, with fortified cereal products playing a role in the contributions of micronutrients.

Public health implications

Diet is one of the major risk factors for non-communicable diseases in all WHO regions including the European region (World Health Organisation, 2011). Compliance with guidelines for nutrients such as saturated fat, free sugars, dietary fibre and sodium is poor in the WHO European region, including Ireland and additionally, iron, vitamin D, potassium, calcium and folate have been identified as nutrients of concern (Irish Universities Nutrition Alliance, 2011; World health Organisation, 2014b; World Health Organisation, 2014a; Rippin *et al.*, 2017). This study found that cereals, grains & potatoes represent an important source of energy and important nutrients in the diet of adults in Ireland, but also contribute significantly to sodium intake and to smaller proportions of saturated fat and free sugars intake. The Irish FBDG emphasise the consumption of wholemeal cereals and breads, potatoes, pasta and rice, recommending 3-5 servings per day, however, this study identified that Irish adults consume about 2.1 servings of these foods (Department of Health, 2016). Recently in Ireland, the bread and bakery goods market has seen an expansion in their product range of 'better-for-you' breads, such as half brown, half white, seeded, wholegrain, multigrain, fortified with vitamin D, low glycaemic index, high protein etc., driven by health-conscious consumers (IBIS World, 2021a). Similarly, there is a reduced consumer demand for traditional sugary breakfast cereals and the industry continues to innovate by introducing 'healthier' RTEBC alternatives (IBIS World, 2021b). The reformulation of foods, particularly staple foods, such as cereal products, is an important opportunity to influence population health, such as increasing whole grains, reducing salt and free sugars and fortifying foods with vitamins and minerals, e.g., vitamin D (Department of Health, 2021).

Regarding fortification of foods, the departure of the UK from the EU has caused changes in wheat flour fortification practices which impact Ireland. Since January 2021, wheat flour fortified under UK national rules (excluding Northern Ireland) do not meet fortification regulations set out by EU rules and therefore cannot be placed on the EU market, meaning flour traditionally imported from the UK, unless fortified to significant amounts, must now be imported from elsewhere, which may impact the contribution to nutrient intakes from cereal products in Ireland (Food Safety Authority of Ireland, 2022). Additionally, in September 2021, the UK announced the mandatory fortification of flour with folic acid to help reduce the prevalence of neural tube defects (NTD), which may re-open debates around the mandatory fortification of flour in

Ireland (Department of Health & Social Care, 2021). While mandatory folic acid fortification of staple foods may reduce NTD-affected pregnancies by 8-32%, there is currently no mandatory folic acid legislation in Ireland (or Europe) (Kehoe *et al.*, 2020).

Stakeholder co-operation and collaboration is needed to educate consumers about healthful options of cereals, grains & potatoes. Reformulation and fortification of cereal products are important strategies to improve population health, however, education on the nutritional benefits of unprocessed potatoes would also help to improve intakes of high-quality cereals, grains & potatoes.

Strengths and limitations

The key strengths of this study are the nationally representative sample of adults aged 18-90y and the use of detailed dietary data collected through a 4-day semi-weighed food diary. Another important strength of this study includes the ability to account for nutrients from fortified foods and foods specific to the Irish market by using brand-level data provided from the food packaging collected during the survey, which allowed for the collection of detailed and specific food composition data. Misreporting or underreporting of food intake is a known limitation with all dietary assessment and may be a source of bias. This issue was minimised by training the participants in the use of the food diary and the high level of researcher-participant interaction (three visits over the 4-day period) by trained research nutritionists. While the NANS data are the most recently available data for dietary intake in adults in Ireland, it is important to acknowledge that data was collected in 2008-2010 and intakes may have changed in this time. Time-trend analysis using data from the NSIFCS, NANS and NANS II (currently being collected) will provide rich insight into the evolving consumption patterns of PB foods in adults in Ireland.

Conclusions

Cereals, grains & potatoes are a large and important PB component the diet. Whole grains are particularly encouraged as part of a healthful PB diet. A population-level move towards the consumption of more plant foods, including wholemeal cereals and breads, potatoes, pasta and rice may improve the nutritional quality of the diet, however despite this study showing low intakes of wholemeal cereals and breads, potatoes, pasta and rice in adults in Ireland, refined and wholemeal cereals currently make important contributions to the diets of this population group. Overall, ‘cereals, grains & potatoes’ were consumed by all adults in Ireland, with an MDI of 358g/d. This equated to approximately 4.5 servings, of which only 2.1 were from wholemeal cereals and breads, potatoes, pasta and rice, which is far below Irish FBDG recommendations (3-5 servings). Men had higher intakes of ‘cereals, grains & potatoes’ compared to women. While there were no differences in intakes of overall ‘cereals, grains & potatoes’ between the age groups, for individual subgroups, those aged 18-35y had higher intakes of convenience foods, e.g., ‘low-fibre RTEBC’, ‘pasta’, ‘other savoury dishes & products’, ‘chipped, fried & roasted potatoes’, ‘pizza’ compared to older age groups. ‘Cereals, grains & potatoes’ made significant contributions to intakes of energy, protein, carbohydrate, MUFA, PUFA, dietary fibre, vitamin E, B vitamins (folate, thiamin, niacin, vitamin B6), iron, potassium, magnesium, calcium and zinc but also made significant contributions to intake of sodium and smaller contributions to intakes of saturated fat and free sugars.

Overall, the findings of this study may benefit health professionals, policymakers and the food industry in understanding the role of cereals, grains & potatoes in the diet of adults in Ireland and may inform strategies to increase the intake of wholemeal cereals and breads, potatoes, pasta and rice, in light of the shift towards a healthful and sustainable PB diet.

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Chapter 7

General discussion

The consumption of a more plant-based (PB) diet is recommended for health and environmental sustainability (Hemler and Hu, 2019b; Willett *et al.*, 2019). PB diets have been associated with a reduced risk of type 2 diabetes, cardiovascular disease and other cardiometabolic risk factors, some cancers and all-cause mortality (Dinu *et al.*, 2017; Chiavaroli *et al.*, 2018; Toumpanakis *et al.*, 2018; Qian *et al.*, 2019; Rees *et al.*, 2019). The health benefits of PB diets for consumers may be associated with improvements in weight status, glycaemic control, blood lipid profile, inflammatory markers and the gut microbiome. (Turner-McGrievy *et al.*, 2007; David *et al.*, 2014; Yokoyama *et al.*, 2014; O'Mahony *et al.*, 2015; Sutliffe *et al.*, 2015; Dinu *et al.*, 2017; Kahleova *et al.*, 2017). However, many definitions of PB diets exist and there remains concern about the nutritional intake and adequacy of some restrictive PB diets, such as vegan diets, with respect to protein and key micronutrients, such as vitamin D and B12, which are only naturally occurring in animal-derived products (Bakaloudi *et al.*, 2020). Additionally, PB diets have also been associated with lower bone mineral density and therefore PB diets need to be carefully planned to ensure nutritional adequacy (Iguacel *et al.*, 2019; Li *et al.*, 2021; Ma *et al.*, 2021; Neufingerl and Eilander, 2021).

That being said, data from national food consumption surveys show that Western populations generally consume an omnivorous diet and the World Health Organisation (WHO) have recently highlighted a need for more research on real-world dietary patterns regarding PB foods (Bates *et al.*, 2011; Irish Universities Nutrition Alliance, 2011; Juan *et al.*, 2015; van Rossum, 2020; World Health Organisation, 2021). Hence, there is a need for studies to investigate the nutritional role of PB diet components and foods for nutritional adequacy in populations currently accustomed to consuming a primarily omnivorous diet. Therefore, the overall aim of this PhD thesis was to examine the nutritional role of PB components and PB foods in the diet of adults (18-90y) in Ireland using data from the National Adult Nutrition Survey (NANS) (2008-2010) which is a nationally representative dietary survey of adults in the Republic of Ireland.

While PB diets are receiving increasing attention, PB diet definitions vary considerably within the literature, from restrictive vegan diets to semi-vegetarian/flexitarian and other (Mediterranean-style, DASH, healthy US-style, planetary health and Nordic-style) diets, which include some animal-derived foods.

These diets have been reviewed in detail in Chapter 1 and published by Kent *et al.* (2022a). Furthermore, the contribution of PB foods to energy and nutrient intakes in a primarily omnivorous population has not been widely studied. Currently, there is no standardised approach available to identify the PB component of the diet which makes it difficult to compare findings across studies that explore the association between PB diets and markers of nutritional and health status. Many foods considered to be 'plant-based' are not necessarily healthy, take 'cake' for example, and there is a growing body of evidence that not all PB foods are 'healthy'. Therefore, there is a need to distinguish between 'healthy' PB foods (i.e., fruit, vegetables and legumes, whole grains, nuts and seeds) and 'less healthy' PB foods (i.e., sugar-sweetened beverages, confectionery and highly processed PB alternative foods) (Satija *et al.*, 2016; Kim *et al.*, 2018; Hemler and Hu, 2019a; Wickramasinghe *et al.*, 2021; World Health Organisation, 2021; Kent *et al.*, 2022a). Therefore, the first aim of this thesis was to develop a systematic methodology to identify the PB component of a diet using two extremes of PB diet definitions, i.e., plant-based (all) (PB-A) which included 'all plant-based foods' regardless of dietary quality and plant-based (healthful) (PB-H) which included 'healthful plant-based foods' only (both of which excluded all meat and fish and placed heavy restrictions on animal products, such as dairy and eggs).

A novel 23-step protocol was developed which outlines the (a) exclusion and (b) inclusion criteria under each food group (**Appendix III**) for both PB-A (all plant-based foods) and PB-H (healthful plant-based foods) diet definitions. **Figure 1** provides an overview of the food groups and sub-groups identified and their exclusion or inclusion in PB-A and/or PB-H definitions. This methodology has now been published in the *Journal of Food Composition and Analysis* outlining each of the steps in detail, in conjunction with the literature, to allow the method to be easily adapted to other food databases and newer foods on the market (Kent *et al.,* 2022b). This novel systematic methodology will help to improve cross-study comparison of the PB component of a diet and will be useful for researchers within the scientific community, health care professionals, policymakers and the food industry in understanding the role of PB foods within the diet of populations or individuals.

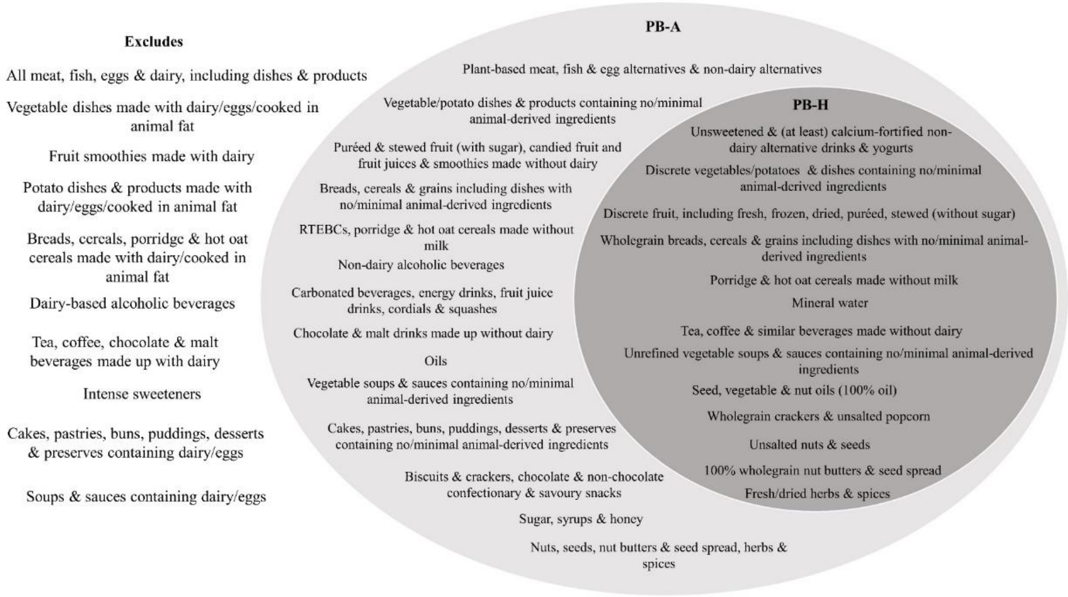

Figure 1. Categorisation of foods & beverages under plant-based (all) (PB-A) & plant-based (healthful) (PB-H) diet definitions.

The WHO have recently highlighted a need for more research on real-world dietary patterns regarding PB foods to assist policymakers with developing evidence-based dietary guidelines, food policy and general health advice (World Health Organisation, 2021). Therefore, the second aim of this thesis was to use the previously outlined systematic methodology to examine the nutritional quality of the PB component of the diet using the two definitions (PB-A and PB-H) compared to the baseline diet (the overall diet consumed by the NANS population) in adults in Ireland.

This study outlined findings from the PB components of a diet and not a PB diet per se. The nutritional quality of the PB components of an omnivorous diet cannot be directly compared to the nutritional quality of a PB diet, such as a vegan diet, however, the key findings from this study showed that the move towards a more PB diet may improve the nutritional quality of the Irish diet in terms of total and saturated fat, carbohydrate, free sugars, dietary fibre, sodium, potassium and folate. Having said that, this study also found that the move towards a more PB diet may exacerbate potential deficiencies of vitamin D, calcium, iron, vitamins B12 and iodine.

Notably, key nutrients, vitamin D and B12 were particularly low from the PB-H component of the diet (the more restrictive diet component), which excluded many refined, but fortified foods, such as ready-to-eat breakfast cereals, fat spreads and beverages. This highlights how the promotion of a ‘healthful’, unrefined and minimally processed PB diet may limit the consumption of some fortified foods, which make important contributions to micronutrient intakes on a population basis (Hennessy *et al.*, 2013; Fulgoni and Buckley, 2015; Bird *et al.*, 2022; de Jong *et al.*, 2022).

In discussing the move towards a more PB diet in adults in Ireland, this study additionally highlights the need to acknowledge the lower bioavailability of some nutrients from PB foods compared to animal-derived products. For example, since many PB diets lack the main sources of high biological value protein (found in animal-derived foods), protein intake from PB diets should be carefully planned to ensure that not only an adequate amount of protein is consumed, but that the variety of protein sources provides a full complement of essential amino acids (Mariotti and Gardner, 2019). Furthermore, in those consuming a PB diet, PUFA intake should be carefully considered given the lower bioavailability of omega-3 fatty acids from PB sources, such as seed oils, compared to marine sources (Lane *et al.*, 2014; Trautwein and McKay, 2020). Additionally, the lower bioavailability of non-haem iron and zinc from PB foods should be acknowledged, with the US Institute of Medicine recommending intakes of iron and zinc 1.8 and 1.5 times higher, respectively, for those consuming a vegetarian diet compared to an omnivorous diet due to the lower bioavailability of iron from PB foods compared to animal-derived foods and due to the presence of zinc inhibitors, such as phytate, in PB foods (Trumbo *et al.*, 2001).

In all, while the promotion of a more PB diet is undoubtedly beneficial, the restrictiveness of the diet definition impacts negatively on nutritional intake. PB diets need to be carefully considered to ensure foods omitted from the diet, e.g., meat, dairy, refined foods etc., are appropriately substituted to meet nutritional needs.

Another approach to investigating the role of PB components or foods within a population, is to examine current intakes with regard to FBDG and their contributions to overall nutrient intakes. ‘Fruit & vegetables’ and ‘cereals, grains & potatoes’ are the foundations of a PB diet and central components of FBDG worldwide (Herforth *et al.*, 2019; Kent *et al.*, 2022a) due to their importance in providing essential micronutrients, dietary fibre and health-promoting bioactive compounds to the diet (Slavin and Lloyd, 2012; Herforth *et al.*, 2019; Rocha *et al.*, 2019; Wallace *et al.*, 2020; Rong *et al.*, 2021). Therefore, the final aims of this thesis were to estimate the current intake of ‘fruit & vegetables’ and ‘cereals, grains & potatoes’ in adults (18-90y) in Ireland, to assess compliance with recommendations and to determine their contribution to overall energy and nutrient intakes.

The key findings of these chapters highlighted that while ‘fruit & vegetables’ were consumed by all adults in Ireland, with a mean daily intake (MDI) of 285g/d (approximately 3.6 servings), only one fifth of adults are meeting the WHO or the Irish FBDG recommendations for fruit & vegetable intake (World Health Organisation, 2005; Department of Health, 2016). ‘Cereals, grains & potatoes’ were also consumed by all adults, with an MDI of approximately 4.5 servings, however, only 2.1 servings were from wholemeal cereals and breads, potatoes, pasta and rice, which is below the Irish FBDG recommendation of 3-5 servings per day (Department of Health, 2016).

Understanding differences between demographic groups can help in the development of targeted public health strategies. This study found few differences between PB food intake between men and women (that were not related to overall energy intake), however differences were observed between younger and older adults which may be useful for targeted strategies. Generally, the younger age groups (18-35y and 36-50y) had lower intakes of ‘fruit & vegetables’ compared to those aged 51-64y and 65y+, with the exception of ‘vegetables in composite dishes’ and those aged 18-35y had higher intakes of convenience foods, e.g., ‘low-fibre RTEBC’, ‘pasta’, ‘other savoury dishes & products’, ‘chipped, fried & roasted potatoes’ and ‘pizza’ compared to older age groups. These findings are in keeping with studies which suggest younger adults are more likely to consume convenience foods compared to older adults (Allman-Farinelli *et al.*, 2016; Sogari *et al.*, 2018; Sprake *et al.*, 2018; Livingstone *et al.*, 2022).

In terms of their contribution to the overall diet, this study found that both ‘fruit & vegetables’ and ‘cereals, grains & potatoes’ made important contributions to intakes of many nutrients for adults in Ireland. With regard to overall energy intake, while ‘fruit & vegetables’ only made a small contribution to energy intake (7%), ‘cereals, grains & potatoes’ contributed almost one third of overall intake (32%). ‘Cereals, grains & potatoes’ and ‘fruit & vegetables’ together, contributed 63% of carbohydrate intake and 82% of dietary fibre intake in adults in Ireland, with ‘cereals, grains & potatoes’ contributing the majority (52% of carbohydrate intake and 53% of dietary fibre intake), however the current MDI of dietary fibre in adults in Ireland (19g/d) is still below adequate intakes (25g/d) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010; Irish Universities Nutrition Alliance, 2011).

Fruit & vegetables are typically low in protein and fat and therefore, as expected, this study found that ‘fruit & vegetables’ contributed minimal proportions of protein (4%) and total fat (5%). On the other hand, ‘cereals, grains & potatoes’ made notable contributions to protein (24%) and total fat (18%) intake. The consumption of PB protein, as part of a PB diet, is increasingly encouraged due to its potential health and environmental benefits compared to animal-derived protein, however, there is a general concern about the adequate consumption, quality and digestibility of protein from PB sources (Davies and Jakeman, 2020; Poutanen *et al.*, 2022). Despite concerns, a well-planned PB diet, with a mixture of plant proteins (e.g., cereals and legumes) has been shown to provide a nutritionally adequate and sustainable diet (Mariotti and Gardner, 2019; Davies and Jakeman, 2020).

Regarding fatty acid quality, these PB food groups contributed 17% of saturated fat intake, 20% of MUFA intake and 33% of PUFA intake, with ‘cereals, grains & potatoes’ contributing the majority for each fatty acid (15%, 16% and 23%, respectively). The contribution of ‘cereals, grains & potatoes’ to MUFA and PUFA intake can be largely attributed to the oils used to cook ‘vegetables & vegetable dishes’ and ‘chipped, fried & roasted potatoes’ while saturated fat was contributed equally from ‘total breads, ‘grains, rice & savouries’ and ‘potatoes & potato products’, with saturated fat from animal-derived ingredients within dishes making some contributions.

Overall, the contribution of free sugars from PB foods was quite low with ‘fruit juice & smoothies’ contributing 10% and RTEBC contributing 6% of free sugars intake. With ‘top shelf foods’ contributing almost two-thirds of all free sugars intake (62%) for adults in Ireland, public health efforts should prioritise the reduction of sugars from these sources (Walton *et al.*, 2017). With regard to salt intake, ‘cereals, grains & potatoes’ contributed almost one-third of salt intake (32%), with the majority of this coming from ‘total breads’ (22%). In Ireland, the Food Safety Authority of Ireland (FSAI) and the food industry have been working closely together to meet the objectives of the Salt Reduction Programme (2003) and while some significant reductions in the salt content of processed products, including breads and breakfast cereals have been noted over time, further reductions are necessary to meet the maximum population target of <6g of salt per day (Food Safety Authority of Ireland, 2003; Food Safety Authority of Ireland, 2016; Department of Health, 2021b).

This study also highlighted the key role of PB foods with regard to micronutrient intakes, either due to their naturally rich content or in the case of some micronutrients, due to the mandatory or voluntary fortification of cereals and cereal products. PB foods contributed 52% of vitamin C intake (26% from 'fruit & fruit juices', 12% from 'discrete vegetables', 8% from 'potatoes & potato products') and 45% of potassium intake (17% from 'fruit and vegetables' and 15% from 'potatoes & potato products'). Additionally, 'fruit & vegetables' contributed 39% of vitamin A intake (34% from 'discrete vegetables') and also contributed to intakes of total folate (13%) and 'cereals, grains & potatoes' contributed 16% of vitamin E intake.

'Cereals, grains & potatoes' also contributed significantly to the intake of many B vitamins, such as folate (32%), thiamin (27%), niacin (26%) and vitamin B6 (22%) and some minerals, such as iron (40%), magnesium (35%), calcium (29%) and zinc (27%). The contribution of 'cereals, grains & potatoes' to these micronutrients in this study is mainly attributable to the wide consumption of breakfast cereals and breads, mainly explained by the addition of these micronutrients to RTEBC and wheat flour. In Ireland, RTEBC are typically fortified with an array of B vitamins and iron (Hennessy *et al.*, 2015) and in this study 'breakfast cereals' accounted for 14% of folate intake, 9% each of thiamin and niacin intakes, 8% of vitamin B6 intake and accounted for 17% of iron intake. Additionally, wheat flour in Ireland is fortified with thiamin, iron and calcium to restore losses during processing (European Comission, 2006), resulting in 'total breads' contributing 10% of thiamin intake, 15% of iron intake and 19% of calcium intake in adults in Ireland.

It is important to acknowledge that, although the data used in this thesis are the most up-to-date dietary data for adults in Ireland, data were collected from 2008-2010 and therefore may not reflect current intakes and nutrient contributions, as dietary patterns change and as food products are continuously being reformulated. Continued monitoring of the contribution of PB foods to the diets of population groups is therefore important in light of changing dietary patterns and the changing landscape of the food environment. Findings from this study can be compared to the previous study of adults in Ireland; the North/South Ireland Food Consumption Survey (NSIFCS). The intake of ‘fruit & vegetables’ in adults (18-64y) in this study (286g/d) was similar to findings from the NSIFCS (274g/d), indicating that the intake of fruit & vegetables had not improved in adults in Ireland over approximately 10 years (Irish Universities Nutrition Alliance, 1999). Furthermore, the intake of ‘cereals, grains & potatoes’ in adults (18-64y) (360g/d) has decreased since the NSIFCS (441g/d), primarily attributable to a large reduction in the intake of ‘potatoes & potato products’ (122 vs 224g/d), particularly in ‘boiled, baked & mashed potatoes’ (75 vs 158g/d) over the 10 year period (Irish Universities Nutrition Alliance, 1999). Current dietary intake data for this population group are now being collected (National Adult Nutrition Survey II, www.iuna.net) and it will be useful to compare the intake of PB foods among adults in Ireland over the three timepoints to understand the changing patterns of consumption and role of PB foods in the diets of this population group.

Overall, the findings of this thesis highlight a poor intake of fruit & vegetables and wholemeal cereals and breads, potatoes, pasta and rice and therefore, the need for multilevel strategies to improve the intake of these PB foods in adults in Ireland to comply with FBDG. Strategies that address the food environment, accessibility of healthful PB foods and personal determinants of PB food intake will be important (Centers for Disease Control and Prevention, 2011; Shahid and Bishop, 2019; World Cancer Research Fund, 2022). For example, the workplace has been identified as an advantageous setting to implement nutrition education and support healthful dietary changes in adults and systematic reviews report workplace interventions improve intakes of fruit & vegetables and whole grains (Ní Mhurchú *et al.*, 2010; Geaney *et al.*, 2013; World Health Organisation, 2017; Naicker *et al.*, 2021). In Ireland, there are resources freely available online to employers to encourage a healthful eating environment (Health Service Executive, 2022; Irish Heart Foundation, 2022). Additionally, the government of Ireland will provide resources to workplaces seeking to engage in workplace wellbeing programmes, as part of the Healthy Ireland at Work National Framework for Healthy Workplaces in Ireland (Department of Health, 2021a). However, studies are needed which identify firstly, whether workplaces are engaging with such nutrition resources and secondly, whether workplace wellbeing programmes have improved outcomes in Ireland, e.g., improvements in intakes of fruit and vegetables and whole grains.

Modelling studies and interventions also suggest the subsidisation of fruit & vegetables improve intakes in general populations and may offer a strategy to increase the accessibility of fruit & vegetables (Black *et al.*, 2012; Choi *et al.*, 2017; Blakely *et al.*, 2020; Pancrazi *et al.*, 2022; Relton *et al.*, 2022). For example, government subsidised schemes and grants to support urban/suburban growing and other community garden initiatives, such as rooftop/balcony gardens, school raised bed gardens and community farmer’s markets may improve access to fruit, vegetables and grains in local communities (Mead *et al.*, 2021).

The reformulation of foods is another important strategy to improve the nutritional quality of products and therefore influence public health (Department of Health, 2021b; Gressier *et al.*, 2021). Ireland’s Roadmap for Food Product Reformulation (2021-2025) has set targets for the reduction of calories, saturated fat, sugar and salt in the Irish diet including among commonly eaten foods, such as breads and breakfast cereals, which may positively influence the nutritional contribution from these foods (Department of Health, 2021b). Furthermore, the food industry continues its voluntary fortification practices of various food groups which make important contributions to micronutrient intakes among populations (Hennessy *et al.*, 2013; Fulgoni and Buckley, 2015; Bird *et al.*, 2022; de Jong *et al.*, 2022).

The key strengths of this study are the nationally representative sample of adults aged 18-90y included in the NANS and the use of detailed dietary data collected through a 4-day semi-weighed food diary. This is the first study to describe a methodological approach to identify PB foods/components within an omnivorous diet based on actual food consumption data from an omnivorous population group. Furthermore, this is the first study to examine the nutritional quality of the PB component of a diet, using real food consumption data from an omnivorous population group. Another main strength of the study is the use of high-quality dietary data, such as the inclusion of fruit & vegetables from composite dishes and accounting for inedible or unconsumed portions of fruit & vegetables (cores and uneaten peel) in the estimation of fruit & vegetable intakes. This study used brand-level data provided from the food packaging collected during the survey, which allowed for the collection of detailed and specific food composition data, including nutrients from fortified foods and foods specific to the Irish market. Misreporting or underreporting of food intake is a known limitation with all dietary assessment. This issue was minimised by training the participants in the use of the food diary and the high level of researcher-participant interaction (three visits over the 4-day period) by trained research nutritionists.

To conclude, this is the first study to provide a standardised methodology to identify the PB component of a diet and to examine the nutritional quality of the PB component of the diet of adults (18-90y) in Ireland compared to a baseline (omnivorous) diet. This novel systematic methodology will help to improve cross-study comparison of the PB component of a diet and will be useful for researchers within the scientific community, health care professionals, policymakers and the food industry to understand the role of PB foods within the diet of populations or individuals. Considering most populations consume an omnivorous diet, future research should focus on adapting and using this methodology and comparing the PB components of omnivorous diets between countries. This study can be used to study trends in PB consumptions, for example, in comparing PB alternative foods between countries.

This study has found that the consumption of a more PB diet may improve the nutritional quality of the diet of adults in Ireland, in terms of many nutrients, such as total fat, saturated fat, carbohydrate, free sugar, dietary fibre, sodium, potassium and folate, but may exacerbate potential deficiencies of other nutrients, such as vitamin D, vitamin B12, calcium and iodine. When assessing nutrient intakes from PB diets, it is important to acknowledge the lower bioavailability of some nutrients such as protein, PUFA, iron and zinc from PB foods compared to animal-derived products, with some government authorities already recommending higher intakes of some of these nutrients for those consuming vegetarian diets. The general population should continue to be encouraged to consume a more PB diet, however, public health and nutrition professionals should be aware that not all PB diets are the same and the level of restrictiveness of the diet can impact greatly on nutritional intake. This awareness can help to inform how data on PB diet intake is collected within national and other surveys, for example, considering an open question when asking about type of PB diet.

Additionally, this study identified the current intakes and nutrient contributions of ‘fruit & vegetables’ and ‘cereals, grains & potatoes’ in the diets of adults in Ireland

and compared these to existing recommendations and intakes and nutrient contributions in countries within the WHO European region. Overall, there is a poor intake of fruit & vegetables and wholemeal cereals and breads, potatoes, pasta and rice among adults in Ireland. This data, as well as future research of the temporal changes between NSIFCS, NANS and NANS II (currently being collected) will highlight trends in consumption and can inform policy changes to improve intakes, such as product reformulation, and can also inform other research areas. For example, additional research into strategies which target the food environment (workplace initiatives), accessibility of healthful PB foods (government subsidisations and incentives) and personal determinants (education and choice) of PB food intake are needed in adults in Ireland.

This study may benefit the scientific community, health professionals, policymakers and the food industry in understanding the nutritional role of PB foods in the diet of adults in Ireland and may inform strategies to increase the intake of high-quality plant foods in light of the shift towards a more PB diet for health and environmental benefits.

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Appendix I

NANS 19 food groups

1. Grains, rice, pasta and savouries
2. Bread & rolls
3. Breakfast cereals
4. Biscuits, cakes & pastries
5. Milk & yogurt
6. Creams, ice-creams & chilled desserts
7. Cheeses
8. Butter, spreading fats & oils
9. Egg & Egg dishes
10. Potato and potato products
11. Vegetables & vegetable dishes
12. Fruit & fruit juices
13. Fish & fish dishes
14. Meat & meat products
15. Beverages
16. Sugars, confectionary, preserves & savoury snacks
17. Soups, sauces & miscellaneous foods
18. Nutritional Supplements
19. Nuts, seeds, herbs & spices

Appendix II

NANS 68 food groups

1. Rice & pasta, flours grains & starch
2. Savouries
3. White sliced bread & rolls
4. Wholemeal & brown bread & rolls
5. Other breads
6. RTEBC
7. Other breakfast cereals
8. Biscuits including crackers
9. Cakes, pastries & buns
10. Whole milk
11. Low fat, skimmed & fortified milks
12. Other milks & milk-based beverages
13. Creams
14. Cheeses
15. Yogurts
16. Ice-creams
17. Desserts
18. Rice puddings & custard
19. Eggs & egg dishes
20. Butter (over 80% fat)
21. Low fat spreads (under 40% fat)
22. Other fat spreads (40-80% fat)
23. Oils (not including those used in recipes)
24. Hard cooking fats
25. Potatoes (boiled/baked/mashed
26. Processed & homemade potato products
27. Chipped, fried & roasted potatoes
28. Vegetable & pulse dishes
29. Peas, beans & lentils
30. Green vegetables
31. Carrots
32. Salad vegetable
33. Other vegetables
34. Tinned or jarred vegetables
35. Fruit juices & smoothies
36. Bananas
37. Other fruits
38. Citrus fruits
39. Tinned fruits
40. Nuts & seeds, herbs & spices
41. Fish & fish products
42. Fish dishes
43. Bacon & ham
44. Beef & Veal
45. Lamb
46. Pork
47. Chicken, turkey & game
48. Offal & offal dishes
49. Beef & veal dishes
50. Lamb, pork & bacon dishes
51. Poultry & game dishes
52. Burgers
53. Sausages
54. Meat pies & pastries
55. Meat products
56. Alcoholic Beverages
57. Sugars, syrups, preserves & sweeteners
58. Chocolate confectionary
59. Non-chocolate confectionary
60. Savoury snacks
61. Soups, sauces & miscellaneous foods
62. Nutritional supplements
63. Teas
64. Coffees
65. Other beverages
66. Carbonated beverages
67. Diet carbonated beverages
68. Squashes, cordials & fruit juice drinks

Appendix III

11 food groups and subgroups adapted from the 19 and 68 food groups

Non-food items
Nutritional supplements and other non-food items
Meat, fish, eggs & dairy
Meat, meat dishes & products
Fish & seafood, dishes & products
Eggs & egg dishes
Dairy & dairy products (including milk, cream, cheese, yogurt, butter & their products)
Non-dairy alternatives
Non-dairy alternative drinks
Non-dairy alternative yogurts
Non-dairy alternative cheeses
Non-dairy alternative fat spreads
Vegetables & vegetable dishes
Vegetables (including discrete vegetables & vegetables cooked in animal fat)
Vegetable dishes & products
Fruit & fruit juices
Fruit (including discrete fruit, tinned fruit & candied fruit)
Fruit juices & smoothies
Potatoes & potato dishes
Potatoes (including discrete potatoes & potatoes cooked in animal fats)
Potato dishes & products
Cereals & cereal products
Breads
Breakfast cereals
Rice, pasta, flours, grains & starches (including their dishes & products)
Beverages
Alcohol (including dairy-based & other)
Tea & coffee (including made up with/without dairy)
Chocolate & malt beverages (including made up with/without dairy)
Other beverages (including carbonated, beverages, fruit juice drinks, cordials, squashes & other beverages)
Soups & sauces
Dairy & egg-based soups & sauces
Other vegetable soups & sauces
Foods high in fat, salt & sugar
Oils (including 100% oils & spray oils)
Biscuits & crackers (including wholegrain crackers)
Cakes, pastries & buns (including dairy & custard-based cakes, pastries & buns)
Puddings & desserts (including dairy, meringue & custard-based puddings & desserts)
Sugar, sweeteners, syrups & preserves
Chocolate confectionery
Non-chocolate confectionery
Savoury snacks
Nuts, seeds, herbs & spices
Nuts & seeds (including unsalted & salted)
Nut/seed spreads (including 100% wholegrain & other)
Herbs & spices