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Title	The role of plant-based foods and dietary fibre in school-aged children (5-12y) in Ireland
Authors	McCarthy, Róisín
Publication date	2020-05-01
Original Citation	McCarthy, R. S. 2020. The role of plant-based foods and dietary fibre in school-aged children (5-12y) in Ireland. PhD Thesis, University College Cork.
Type of publication	Doctoral thesis
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Download date	2026-11-07 00:41:26
Item downloaded from	https://hdl.handle.net/10468/10880

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Coláiste na hOllscoile Corcaigh

THE NATIONAL UNIVERSITY OF IRELAND, CORK

UNIVERSITY COLLEGE CORK

SCHOOL OF FOOD & NUTRITIONAL SCIENCES

Head of School: Professor Mairead Kiely

Supervisors: Dr Janette Walton, Dr Laura Kehoe,

Professor Albert Flynn & Professor Kevin Cashman



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Coláiste na hOllscoile Corcaigh, Éire

University College Cork, Ireland

The role of plant-based foods and dietary fibre in school-aged children (5-12y) in Ireland

THESIS

Presented by

Róisín McCarthy, B.Sc. M.Sc.

For the degree of

DOCTOR OF PHILOSOPHY

(Nutritional Sciences)

May, 2020

This thesis is dedicated to my parents. Thank you for giving me the strength and determination to pursue my dreams and ambitions.

Acknowledgements

A sincere thank you to Professor Albert Flynn and Professor Kevin Cashman for giving me the opportunity to complete my PhD with the IUNA Dietary Survey research team at University College Cork.

A massive thank you to Dr Janette Walton and Dr Laura Kehoe for your guidance and support throughout my PhD. I'm extremely grateful for everything you have taught me during my time working with the dietary survey research team. Thank you Laura for always answering my questions and queries with great patience and calm and for the coffee and wine breaks in between.

I wish to thank all the participants and families who took part in the surveys, some of whom I had the pleasure of meeting and kindly welcomed me into their homes.

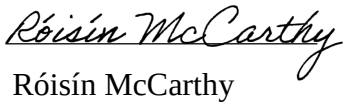
I would like to thank my Mom and Dad, Pádraig, Kate and my extended family for your constant love, understanding and reassurance over the last three years.

To my sister Kate, thank you for your good vibe, home cooked meals and sense of humour, especially in the final few months of my PhD journey. You were a comfort to come home to when I needed it the most. And to my brother Pádraig, thank you for your copious cups of tea, the laughs and words of encouragement.

To my home girls, thank you for constantly cheering me on, for being so understanding and supportive and for maintaining my very important social life during my PhD journey.

And finally thank you to all the friends I made at UCC, particularly the past and present members of the IUNA research team. To Aisling and Steph, thank you for the coffees, laughs, the hugs and chats. Wishing you all the best in your future careers. And a special thank you to Ciara, my partner from day one who has been there for me in every way possible. I'm so grateful our paths have crossed, I've made a friend for life.

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 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 concerning plagiarism.



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Personal contribution to this thesis

This thesis is based on data from two national dietary surveys carried out by the Irish Universities Nutrition Alliance (www.iuna.net) over the last 15 years. These surveys included the National Children's Food Survey (5-12y) (2003-04) and the National Children's Food Survey II (5-12y) (2017-18).

During my PhD, I worked with the Dietary Surveys Research Team in UCC as a researcher on the National Children's Food Survey II (NCFS II). In my role as recruitment coordinator for NCFS II at UCC, I was responsible for the recruitment of the primary schools surveyed by UCC fieldworkers. I also worked as a fieldworker and collected data on dietary intake, health & lifestyle, eating behaviour and anthropometric measurements in addition to collecting spot urine samples for 116 participants. I was involved in data entry including entering of dietary intake data into Nutritics and questionnaire data into DaSurvey. I was involved in the batch processing of urine samples and had overall responsibility for the purchasing of laboratory supplies and inventory. I also played a role in training and mentoring new team members.

All analyses in this thesis were performed by me. The attached work is entirely my own original work.

Róisín McCarthy

Róisín McCarthy

Publications

Conference abstracts

McCarthy, R., Kehoe, L., Walton, J., Flynn, A. (2020) Estimation of fruit and vegetable intakes in European school-aged children: current challenges and future direction. *Proceedings of the Nutrition Society* (in press).

Kent, G., Kehoe, L., **McCarthy, R.,** Walton, J., McNulty, BA., Nugent, A. P & Flynn, A. (2020) Characterising the plant based component of the Irish diet in terms of its nutritional quality. *Proceedings of the Nutrition Society* (in press).

McCarthy, R., Kehoe, L., Walton, J., McNulty, B.A., Nugent, A.P. & Flynn, A. (2018) Intakes of fruit and vegetables in Irish children (5–12 years). *Proceedings of the Nutrition Society,* 77 (OCE3), E82.

McCarthy, R., Kehoe, L., Walton, J., McNulty, B.A., Nugent, A.P. & Flynn, A. (2017) The role of yogurt in the diets of the Irish population (5–90y). *Proceedings of the Nutrition Society,* 76 (OCE3), E78.

Summary reports

Irish Universities Nutrition Alliance (2019) *National Children's Food Survey II: Summary report on Food and Nutrient Intakes, Body Weight, Physical Activity and Eating Behaviours in Children Aged 5-12 Years in Ireland* (contributing author).

Industry commissioned reports

Kehoe, L., **McCarthy, R.,** Walton, J & Flynn, A. (2017) Report on the role of yogurt in the diets of the Irish population (4 – 90y). (Report commissioned by Danone Ireland Limited).

Training/contributions during this training period

October 2019: Nutrition Society Postgraduate Student Review Competition Winner, FENS, Dublin.

September 2019: **'Odyssey Programme'** preparing academic researchers for careers in industry, UCC.

January 2019: PE6001 Analysis and Interpretation of Experimental Data with Mathematical and Statistical Tools, UCC.

January 2018: PG6001 STEPS Scientific Training for Enhanced Postgraduate Studies, UCC.

January 2018: FS6625 Current Topics in Food and Nutrition Research, UCC.

September 2017-2019: Nutrition Society Undergraduate Student Liaison Representative, UCC.

Abbreviations

Adequate Intake (AI)

AOAC (Association of Analytical Chemists)

Cork Institute of Technology (CIT)

Cardiovascular Disease (CVD)

Dietary Fibre (DF)

Dietary Folate Equivalents (DFE)

Danish National Survey of Dietary Habits and Physical Activity (DANSDA)

European Food Safety Authority (EFSA)

Food Based Dietary Guidelines (FBDG)

Irish Universities Nutrition Alliance (IUNA)

Italian National Food Consumption Survey (INRAN-SCAI)

Mean Daily Intake (MDI)

National Children's Food Survey (NCFS)

National Children's Food Survey II (NCFS II)

North/South Ireland Food Consumption Survey (NSIFCS)

National Diet and Nutrition Survey (NDNS)

National Health and Nutrition Survey (NHANES)

Nordic Nutrition Recommendation (NNR)

Ready-To-Eat Breakfast Cereal (RTEBC)

Technological University of Dublin (TUD)

The Scientific Advisory Committee on Nutrition (SACN)

University College Cork (UCC)

University College Dublin (UCD)

World Health Organisation (WHO)

Abstract

Background: On-going research suggests that changes in current dietary patterns including an increased consumption of plant-based foods will provide major health benefits and will support a more sustainable environment. Plant-based foods such as wholegrains cereals, fruit and vegetables provide high concentrations of important nutrients in the diet and are particularly promoted in food based dietary guidelines for their high dietary fibre (DF) content and the role they can play in providing sufficient intakes of DF in population groups. As the childhood years are a critical period during which eating behaviours and food preferences evolve, promoting the consumption of plant-based foods from a young age would promote healthy eating patterns that may reduce the risk of developing non-communicable diseases in later life.

Objectives: The overall aim of this thesis was to examine the role of plant-based foods such as 'cereals, grains & potatoes' and 'fruit & vegetables', and the role of DF in the diets of school-aged children (5-12y) in Ireland. A further aim was to investigate any changes in the intakes of these food groups and DF in school-aged children between 2003-04 and 2017-18 using data from two nationally representative surveys of school-aged children in Ireland, which used similar methodologies.

Methods: The analyses for this thesis are based on data from the National Children's Food Survey II (NCFS II) which was a nationally representative cross-sectional study that collected food and beverage consumption data from 600 children aged 5-12 years in the Republic of Ireland between 2017 and 2018 (www.iuna.net). Findings from the NCFS II can be compared to the previous NCFS (2003-04), which used a similar methodology. Food and beverage intakes were estimated in the NCFS II using a 4-day weighed food diary. Each food and beverage consumed was assigned a unique food code based on its food descriptor and nutritional profile and was entered into the Nutritics© data entry system. Nutrient intakes were estimated from food intakes using data from McCance & Widdowson's The Composition of Foods with modifications to include recipes of composite dishes, fortified foods, nutritional supplements, generic Irish foods and new foods on the market. Food group intakes were calculated using SPSS® Version 24.0 for Windows by summing the weight of each food consumed in the food group and dividing the total by the number of recording days (four). The usual intake (g/d) of DF was estimated using the validated National Cancer Institute (NCI)-Method using SAS Enterprise Guide© version 6.1. The percent

contribution of food groups to energy and nutrient intakes and the key dietary sources of DF were calculated by the mean proportion method. Dietary determinants of DF intake were investigated by splitting the population into low, medium and high DF intake groups and examining the food groups which contributed to the difference in intakes between the high and low intake groups and examining the patterns of consumption of these foods.

Results: 'Cereals, grains & potatoes' were consumed by 100% of Irish school-aged children with a mean daily intake (MDI) of 271g/d equating to approximately 3.7 servings per day. Of the 3.7 servings, only 1.7 servings were of the wholemeal or brown variety or from unprocessed potatoes, which is below the recommendation of 3-5 servings of wholemeal cereals & breads, potatoes, pasta and rice per day. 'Cereals, grains & potatoes' contributed an array of important nutrients to the diets of Irish children including energy (37%), carbohydrate (51%), DF (56%), B vitamins (16-51%), vitamin D (27%), iron (56%) and calcium (33%). Overall, intakes of 'cereals, grains & potatoes' were similar in the NCFS II (2017-18) (271g/d) and the NCFS (2003-04) (280g/d), however, the intake of white bread, low fibre RTEBC and potatoes was lower in the NCFS II than the NCFS and the intake of brown/wholemeal bread, high fibre RTEBC, porridges and pasta was higher.

'Fruit & vegetables' were consumed by all children in the NCFS II with a mean daily intake of 221g/d (approximately 2.8 servings per day). This is below the WHO recommendation of at least 400g of fruit & vegetables per day and the Irish food based dietary guideline of 5-7 servings of fruit & vegetables per day (with a limit of 150ml/day from unsweetened fruit juice or smoothies). At an individual level, only 9% of Irish school-aged children met the WHO recommendation and just 6% met the Irish food based dietary guidelines recommendation for fruit & vegetable consumption. This research has also shown that total vegetable intakes would have been underestimated by 54 and 52% in the NCFS II and the NCFS, respectively if vegetable intakes from composite dishes were not included in the estimates. With regard to their contribution to nutrient intake, 'fruit & vegetables' contributed a small proportion (7%) of overall energy intake but contributed significantly to intakes of DF (19%), vitamin A (28%), B vitamins (13-15%), vitamin C (50%), potassium (17%) and magnesium (12%) in Irish school-aged children. Fruit and vegetables also contributed to intakes of total sugar (25%) and free sugar (11%), primarily from the consumption of whole fruit and fruit juices, respectively. When compared to the

previous NCFS (2003-04), Irish children had similar intakes of 'fruit & vegetables' in 2017-18 (NCFS II: 221g/d, NCFS: 224g/d). However, the intake of whole fruit and smoothies was higher and the intake of fruit juice was lower in the NCFS II compared to the NCFS. Of note, there was no difference in discrete vegetable intake or vegetables in composite dishes between 2003-04 and 2017-18.

The intake of DF in Irish school-aged children in the NCFS II was 14.4g/d which is higher than that reported in the previous NCFS (2003-04) (12.4g/d) but still below the adequate intake (AI) from the European Food Safety Authority (EFSA) for normal bowel function in children. The key sources of DF were 'breads & rolls' (23%), breakfast cereals (15%), 'fruit & fruit juices' (11%), 'grains, rice, pasta & savouries' (10%), 'vegetables & vegetable dishes' (9%) and 'potatoes & potato products' (8%). The mean intake of DF among those in the high DF intake group (19g/d) was above the EFSA AI for DF while intakes in the low (9.8g/d) and medium DF intake groups (13.6g/d) were below the recommendation. The food groups that contributed to the majority of the difference in intake between the high and low DF intake groups in Irish children were wholemeal breads (22%), high fibre ready-to-eat breakfast cereals (RTEBC) (22%), vegetables & vegetable dishes (11%) and fruit (10%). For 'wholemeal & brown breads', 'high fibre RTEBC' and 'fruit', there was a higher proportion of consumers in the high DF intake group compared to the low DF intake group. Children in the high DF intake group consumed 'wholemeal & brown breads', 'high fibre RTEBC', 'vegetables & vegetable dishes' and 'fruit' more frequently than those in the low DF intake group. Children in the high DF intake group consumed greater amounts of 'wholemeal & brown breads', 'high fibre RTEBC' and 'vegetables & vegetable dishes' at each eating occasion, however this wasn't observed for fruit.

Conclusion: Overall intakes of 'cereals, grains & potatoes' were below the recommendations for children in Ireland and were mainly consumed as refined cereal products rather than the wholemeal variety. Furthermore, fruit & vegetable intakes were low with less than 10% of children meeting either national or international recommendations for fruit & vegetable consumption. Despite low intakes of both of these food-groups, 'cereals, grains & potatoes' make important contributions to intakes of energy, carbohydrate, DF, B vitamins, vitamin D, iron and calcium in the diet and 'fruit & vegetables' made important contributions to intakes of DF, vitamin A, vitamin C, B-vitamins, potassium and magnesium. Fruit and vegetables also contributed intakes of total and free sugar intakes (from fruit and fruit juice) and cereal

foods contributed to intakes of saturated fat, free sugar and sodium. While overall intakes of ‘cereals, grains & potatoes ’ and ‘fruit & vegetables’ were similar to the previous NCFS (2003-04), intakes of wholemeal breads, high fibre RTEBC, porridge, pasta, whole fruit and smoothies were higher and intakes of low fibre RTEBC, potatoes and fruit juice were lower.

Despite an increase in DF since the NCFS, intakes are still below the AI for normal bowel function in children. Determinants of a higher DF intake were wholemeal/brown breads, high fibre RTEBC, fruit and vegetables. The consumption patterns associated with a higher DF intake were a higher proportion of children consuming these foods (except for vegetables), consuming these foods more frequently and having a higher intake per eating occasion (except for fruit). Findings from this thesis may provide evidence to public health campaigns to promote the consumption of plant-based foods to increase compliance with the food based dietary guidelines and to improve DF intakes in this population group. Furthermore, results from this thesis may provide information to policy makers and the food industry to gain a more comprehensive understanding of the foods influencing high intakes of DF in school-aged children in Ireland.

Chapter 1

Literature Review

Introduction

On-going research suggests that changes in current dietary patterns including an increased consumption of plant-based foods will provide major health benefits and will support a more sustainable environment (McEvoy *et al.*, 2012, Ostfeld, 2017, Satija and Hu, 2018, Willett *et al.*, 2019). Plant-based diets typically consist of a variety of plant-based foods (such as fruits, vegetables, wholegrains, legumes, nuts and seeds), a low consumption of animal source foods (i.e. meat, poultry, fish, eggs and dairy products) and a small amount of refined grains, highly processed foods and added sugars (Ostfeld, 2017, Willett *et al.*, 2019).

Plant-based foods such as wholegrains cereals, fruit and vegetables provide high concentrations of important nutrients in the diet and are particularly promoted in food based dietary guidelines for their high dietary fibre (DF) content and the role they can play in providing sufficient intakes of DF in population groups (McKevith, 2004, Slavin and Lloyd, 2012, USDA, 2015, WCRF, 2018).

DF is required for normal bowel function in all ages and is associated with a reduced risk of chronic diseases such as obesity, cardiovascular disease, type 2 diabetes and colorectal cancer in adults (EFSA Panel on Dietetic Products and Allergies, 2010, Reynolds *et al.*, 2019). For children in particular, adequate intakes of DF are important to prevent chronic conditions such as constipation (EFSA Panel on Dietetic Products and Allergies, 2010). Furthermore, the consumption of plant-based foods as a source of DF has been associated with better diet quality in studies of both children and adults (Nicklas *et al.*, 1995, Kranz *et al.*, 2005, Finn *et al.*, 2019).

Given the recent global shift towards plant-based diets, it is timely to understand the current role of plant-based foods in the diets of population groups including children. The aim of this review is to examine the available literature on cereals, grains & potatoes and fruit & vegetables in school-aged children in Europe with respect to dietary guidance, consumption patterns and their contribution to energy and nutrient intakes. A further aim of this review is to examine the recommendations, intakes and sources of DF in school-aged children in Europe including the dietary patterns determining DF intakes.

Inclusion criteria

Data on food group and nutrient intakes are included from nationally representative dietary surveys published as reports, online web pages or peer-reviewed journal articles. For inclusion in this review, the studies must be published in English, conducted post 2000 and have collected dietary intake data via food records or 24hr recalls.

Cereal, grains & potatoes

Cereals are the edible seeds or grains in the grass family and can be cooked and eaten whole or ground into flour to make a variety of cereal foods such as bread, pasta and noodles or made into ready-to-eat breakfast cereals (RTEBC) (Bender, 2006, McSweeney and Day, 2016). Wholegrain cereal foods in particular are nutrient dense comprising of three layers of the grain; the bran, the endosperm and the germ which contain nutrients such as DF, minerals and vitamins (McKevith, 2004, Sarwar, 2013). A growing body of evidence indicates that regular consumption of wholemeal or wholegrain cereal foods plays a beneficial role in the prevention of chronic diseases such as cardiovascular diseases, type 2 diabetes and some cancers (Kushi *et al.*, 1999, Seal and Brownlee, 2015). However, cereals are commonly consumed as refined grains (e.g. white bread) where the nutrient rich bran and germ have been removed and hence may not be as rich in certain nutrients (Lafiandra *et al.*, 2014, Landberg *et al.*, 2019). Similar to cereals, potatoes are a versatile staple food providing an important source of energy and nutrients in populations worldwide (Beals, 2019). Potato dishes are prepared for consumption by boiling (with or without skin), baking or frying and can be consumed as part of a balanced diet with other vegetables and wholegrain foods (FAO, 2008, FAO, 2009).

Guidelines for cereal, grains & potato consumption in Europe

The guidelines for the consumption of cereals, grains & potatoes in European countries within the WHO region are outlined in **Table 1**. To the best of the author's knowledge, Greece is the only country that provides guidelines for children and recommend that children (4-8y) consume 4-5 portions of cereals (bread, rice, pasta) and potatoes per day (Institute of Preventive Environmental & Occupational Medicine, 2014). The World Health Organisation (WHO) recommend for the general population (including children) to consume breads, grains, pasta, rice (preferably wholegrain) or potatoes

several times a day (WHO, 2000). The majority of European countries within the WHO region have adopted this advice for the general population (including children from aged 1-5 years and over) to consume more wholemeal cereals, grains & potatoes. The general population in Germany are advised to consume between 400-550g of cereals, grains and potatoes per day while the advice in Georgia is to consume 500g-600g of cereals and grains per day with a separate guideline for potato consumption (200g-300g/d) (Ministry of Labor Health and Social Affaires, 2005, The German Nutrition Society, 2013). Other countries such as Ireland, Greece, Austria, Turkey and Finland recommend the general population to consume between 3-9 servings of cereals, grains and potatoes per day while the UK, the Netherlands and Scandinavian countries (Norway, Sweden and Denmark) provide broad guidelines for the general population to choose wholegrains over refined grains where possible but don't give a quantitative guidelines (Austrian Ministry of Health and the National Nutrition Commission, 2010, Ministry of Food Agriculture & Fisheries, 2013, Institute of Preventive Environmental & Occupational Medicine, 2014, Netherlands Nutrition Centre, 2015, Swedish National Food Agency, 2015, Norwegian Directorate of Health, 2016, Public Health England, 2016, Republic of Turkey Ministry of Health, 2016, Department of Health, 2017, National Nutrition Council Finland, 2019).

Cereal, grains & potato intakes

The mean intakes of cereals, grains & potatoes in children (3-18y) in European countries range from 168g-285g/d and are outlined in **Table 2**. Using data from national dietary surveys, the mean intakes of cereals, grains & potatoes were reported for children in Italy (285g/d), the UK (285g/d), Denmark (256g/d) and the Netherlands (250g/d) (Leclercq *et al.*, 2009, Pedersen *et al.*, 2014, Public Health England, 2014). The mean intakes of cereals & grains (excluding potatoes) were reported for children in Germany (211g/d), Turkey (187g/d) and Spain (168g/d) (Alexy, 2010, Republic of Turkey Ministry of Health, 2016, Partearroyo *et al.*, 2019). The mean intakes of wholemeal cereal foods are not typically reported separately to total cereals, however, these findings indicate that cereals, grains & potatoes were typically below the recommended 400g-600g/d for school-aged children across Europe.

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

Cereals, grains & potatoes are recognised as a source of energy, carbohydrates, protein, DF, vitamins and minerals in the diet (FAO, 2003, McKevith, 2004) and the contribution of these food groups to energy and nutrient intakes are reported for population groups (including children) in Italy (3-10y), the UK (4-10y), Spain (9-12y and 9-75y), Denmark (4-75y) and the Netherlands (7-69y) **(Table 3)**. Cereals, grains & potatoes contributed to significant proportions of energy (28-43%) and protein (18-32%) intake in European countries (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Olza *et al.*, 2017, Public Health England, 2018). Cereals, grains & potatoes contributed to significant proportions of carbohydrate (43-57%) in Denmark, the Netherlands, the UK and Spain and to a higher proportion (70%) of carbohydrate intake in Italy. This food group also made an important contribution to DF intake (44-60%) in these European countries (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018). With regard to intake of saturated fat, cereals, grains and potatoes contributed 6-14% of intake in Denmark, Italy, the Netherlands and Spain and to a higher proportion in the UK (29%) (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018). Cereals, grains & potatoes also contributed 33% of free sugar intakes in Spain and the UK. The inclusion of bakery products and puddings as cereal products in both UK and Spain may partly explain the higher saturated fat and free sugar intakes from cereals products in children in these countries (Ruiz *et al.*, 2016, Public Health England, 2018). Denmark and the UK reported similar contributions to sodium intakes (23-38%) from cereals, grains & potatoes (Pedersen *et al.*, 2014, Public Health England, 2018).

Cereals, grains & potatoes also made important contributions to micronutrients in the diet of children in Europe. For B vitamins, cereals, grains & potatoes contributed to intakes of riboflavin (11-29%), niacin (15-17%), vitamin B6 (15-33%) and thiamin (23-40%) in Italy, the UK, Spain, Denmark and the Netherlands (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Mielgo-Ayuso *et al.*, 2018, Public Health England, 2018). For vitamin D, cereals, grains & potatoes contributed 22-31% of intakes in children in Italy and the UK (Sette *et al.*, 2013, Public Health England, 2018). Studies have shown that fortified breakfast cereals in particular, have been associated with higher daily intakes of micronutrients in the diets of school children

(McNulty *et al.*, 1996, Nicklas *et al.*, 1998, van den Boom *et al.*, 2006). Similarly, breakfast cereals fortified with vitamin D have accounted for 20% of the average daily vitamin D intake in girls and 24% of intake in boys in the UK (Smithers *et al.*, 2000).

Denmark, Italy, the Netherlands, and the UK have reported that cereals, grains & potatoes contributed to intakes of calcium (9-37%), potassium (22-33%), magnesium (30-36%) and iron (31-60%) (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Public Health England, 2018), while these countries as well as Spain reported that cereals, grains & potatoes contributed 22-31% of zinc intakes (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Olza *et al.*, 2017, Public Health England, 2018).

This review so far shows that there is a broad range of dietary guidelines available on the consumption of cereal foods and potatoes in the general population in Europe however only one country provides specific guidelines for children. Intakes of wholemeal cereal foods are not typically reported separately to total cereals, however, these findings indicate that cereals, grains & potatoes were typically below the recommended 400g-600g/d for school-aged children across Europe. Despite these low intakes, cereals, grains & potatoes made significant contributions to energy, protein, carbohydrates, DF, vitamins (B vitamins and vitamin D) and minerals (potassium, magnesium, iron, calcium and zinc) in the diets of population groups (including children) in Europe but also contributed to intakes of saturated fat, free sugar and sodium.

Fruit & vegetables

Vegetables have been defined as the edible parts of the plant which include stems and stalks, roots, tubers, bulbs, leaves, flowers and fruits (IARC, 2003). Fruits are a subgroup of vegetables containing seeds and pulpy surrounding tissue and are generally consumed raw as a breakfast, snack or dessert while vegetables can be consumed raw or cooked with a main dish, in a mixed dish or in a salad (IARC, 2003). Fruit & vegetable intakes has been shown to be associated with a reduced risk of obesity and other non-communicable diseases in adults (WHO/FAO, 2004). Due to their low energy density and high concentration of vitamins, minerals and DF, fruit and vegetables are grouped together and hold an important place in food based dietary

guidelines for both adults and children (Slavin and Lloyd, 2012, USDA, 2015, Herforth *et al.*, 2019).

Guidelines for fruit & vegetable consumption in Europe

The guidelines for the consumption of fruit & vegetables in European countries within the WHO region are outlined in **Table 4**. To the best of the author's knowledge, the Netherlands, Finland, Norway, Greece and Denmark are the only countries that provide specific guidelines for fruit and vegetable consumption in school-aged children (4-13y) and recommendations range from 100-500g (Institute of Preventive Environmental & Occupational Medicine, 2014, Netherlands Nutrition Centre, 2015, Norwegian Directorate of Health, 2016, National Nutrition Council Finland, 2019). The WHO recommendation for fruit and vegetable consumption is aimed at the general population (including children) and recommends to consume a minimum of 400g of fruit & vegetables (excluding potatoes and other starchy tubers) (WHO/FAO, 2004). The majority of countries in Europe (Ireland, UK, Turkey, Sweden, France, Italy, Austria, Bulgaria and Germany) have adopted this WHO recommendation as part of their food based dietary guidelines (Bulgarian National Center of Public Health Protection, 2006, Austrian Ministry of Health and the National Nutrition Commission, 2010, The German Nutrition Society, 2013, Swedish National Food Agency, 2015, Norwegian Directorate of Health, 2016, Public Health England, 2016, Republic of Turkey Ministry of Health, 2016, Department of Health, 2017, Ministry of Solidarity and Health, 2019).

Whilst there is some variation in the quantities recommended for fruit & vegetable consumption, particularly for children, there are also differences with regards to the inclusion/exclusion of individual components such as fruit juice, potatoes, dried fruit, nuts, legumes, tinned/canned fruit or vegetables and mushrooms in country-specific guidelines **(Table 5)**.

For fruit juice, the majority of countries in Europe (except for Sweden and The Netherlands) limit fruit juice to one portion of fruit with varying quantities (100ml, 125ml, 150ml, 200ml, unlimited quantity) (WHO/FAO, 2019). Dried fruit is included as a portion of fruit with varying quantities (e.g. 25g, 30g, 1½ tbsp., ½ cup etc.) in Ireland, Bulgaria, France, Germany, Greece, The UK and The Netherlands (Bulgarian National Center of Public Health Protection, 2006, The German Nutrition Society,

2013, Institute of Preventive Environmental & Occupational Medicine, 2014, Netherlands Nutrition Centre, 2015, Department of Health, 2017, Public Health England, 2018, Ministry of Solidarity and Health, 2019). Nuts (25g) are included as a portion of fruit in Germany (The German Nutrition Society, 2013).

The majority of countries in Europe do not include pulses and legumes as part of their guideline for vegetable consumption with the exception of Austria and Germany where legumes are included in the recommendation for vegetable consumption with varying quantities (70-200g/d) (Austrian Ministry of Health and the National Nutrition Commission, 2010, The German Nutrition Society, 2013). Unlike the majority of European countries, potatoes are included in the recommendation for vegetable consumption in Turkey (WHO/FAO, 2003, Republic of Turkey Ministry of Health, 2016). Tinned/canned fruit or vegetables are included in the recommendations in Bulgaria, Denmark, Ireland, The Netherlands and Norway (Bulgarian National Center of Public Health Protection, 2006, Ministry of Food Agriculture & Fisheries, 2013, Department of Health, 2017),while Denmark do not include mushrooms as part of their guidelines for vegetable consumption (Ministry of Food Agriculture & Fisheries, 2013).

Fruit & vegetable intakes

The mean intakes of fruit & vegetables in school-aged children (3-12y) in European countries ranged from 224g-404g/d and are outlined in **Table 6**. Using data from national dietary surveys, the mean intakes of fruit & vegetables were reported in school-aged children in Ireland (224g/d), the UK (255g/d), the Netherlands (272g/d), Spain (341g/d), Italy (350g/d) and Denmark (404g/d) (Leclercq *et al.*, 2009, Pedersen *et al.*, 2014, Van Rossum *et al.*, 2016, McCarthy *et al.*, 2018, Public Health England, 2018, Partearroyo *et al.*, 2019). Despite the different classifications of fruit & vegetable intakes between countries in Europe, intakes can be broadly compared with the WHO guideline to consume a minimum of 400g of fruit & vegetables (WHO/FAO, 2004). The majority of countries in Europe reported intakes of fruit and vegetables in children to be below the WHO guideline with the exception of Denmark which reported a mean intake of 404g/d in children aged 4-9 years (Pedersen *et al.*, 2014).

Fruit and vegetables have a low energy density but provide high concentrations of DF, vitamins and minerals to the diet (Hornick and Weiss, 2011, Slavin and Lloyd, 2012) and the contribution of these foods to nutrient intakes are reported for population

groups (including children) in Italy (3-10y), the UK (4-10y), Spain (9-12y and 9-75y), Denmark (4-75y) and the Netherlands (7-69y) **(Table 7 & 8)**.

Fruit & vegetables contributed low proportions of energy intake (6-9%) in Denmark, Italy, the Netherlands, the UK and Spain and contributed 8-19% of carbohydrate intakes in these countries (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018). For DF intakes, fruit & vegetables contributed 25-37% in European countries with fruit contributing to the majority of DF intakes in Italy (20%) and vegetables contributing to the majority of DF intakes in the Netherlands, UK and Spain (14-18%) while both fruit and vegetables contributed similar proportions of DF in Denmark (18%) (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018). The available literature has also indicated that fruit & vegetables contributed 31-50% of total sugar intake in Italy and Spain with fruit contributing to the majority of this intake in Italy (16%) and both fruit (21%) and, juices & nectars (23%) contributing to the majority of intakes in Spain (Sette *et al.*, 2013, Ruiz *et al.*, 2016, Ruiz *et al.*, 2017). Fruit juice has accounted for 11% of free sugar intake in children in the UK and juices & nectars accounted for 7% of free sugar intake in Spain (Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Ruiz *et al.*, 2017, Public Health England, 2018).

In terms of micronutrients, fruit & vegetables contributed 71-83% of vitamin C intakes in Spain, Italy and Denmark with vegetables contributing to the majority of vitamin C intakes (34-51%) (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Olza *et al.*, 2017). Fruit & vegetables contributed lower proportions of vitamin C intakes in Netherlands (32%) due to the exclusion of fruit juice when reporting the contribution of fruit & vegetables to nutrient intakes (Van Rossum *et al.*, 2011). For vitamin A, fruit & vegetables contributed 26-46% of intakes in Denmark, the UK, Italy and Spain with vegetables also contributing to the majority of in these countries (Sette *et al.*, 2013, Pedersen *et al.*, 2014, Olza *et al.*, 2017, Public Health England, 2018). For B vitamins, fruit & vegetables made significant contributions to intakes of riboflavin (6-12%), niacin (9-10%), thiamin (9-18%), vitamin B6 (10-25%) and dietary folate equivalents (19%) in countries across Europe with the majority of intakes from vegetables (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Mielgo-Ayuso *et al.*, 2018, Public Health England, 2018). For mineral intakes,

fruit and vegetables contributed 16-29% of potassium intakes in the Netherlands, the UK, Denmark and Italy with the majority of these intakes coming from vegetables in these countries (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Public Health England, 2018). The Netherlands, UK, Denmark and Italy have reported that fruit & vegetables contributed 12-19% of magnesium intakes with both fruit and vegetables contributing to similar intakes of magnesium in these countries (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Public Health England, 2018).

Overall, fruit & vegetable intakes in European are generally below the WHO recommendations of a minimum of 400g of fruit & vegetables per day with the exception of Denmark. Despite the low intakes reported in school-aged children in Europe, countries have reported that fruit & vegetables contributed little to energy intake but make significant contributions to intakes of DF, vitamins (vitamin C, vitamin A, B vitamins) and minerals (potassium and magnesium). They also contributed to intakes of total and free sugar in the diets of population groups (including children).

Dietary Fibre (DF)

DF is a non-digestible carbohydrate found in edible plant foods (EFSA Panel on Dietetic Products and Allergies, 2010) and is required for normal bowel function in all age groups including children and is associated with a reduced risk of chronic diseases in adults (EFSA Panel on Dietetic Products and Allergies, 2010, Edwards *et al.*, 2015, Reynolds *et al.*, 2019). Adequate intakes of DF are important in childhood to prevent chronic conditions such as constipation (EFSA Panel on Dietetic Products and Allergies, 2010).

The definition for DF has been debated for many years due to the analytical methods used to analyse DF in foods and the physiological effects associated with the consumption of DF (EFSA Panel on Dietetic Products and Allergies, 2010). The definitions of DF used in Europe and the US are outlined in **Table 9.** The earliest definition of DF from Hipsley was “non-digestible constituents making up the plant cell wall” (Hipsley, 1953). More recently the Nordic Nutrition Recommendations (NNR) have defined DF as “naturally occurring in plant foods as measured by AOAC methods for total DF” and the EFSA defines DF as “non-digestible carbohydrates plus

lignin" (Becker *et al.*, 2004, EFSA Panel on Dietetic Products and Allergies, 2010). In 2015, the UK Scientific Advisory Committee on Nutrition (SACN) defined DF as "the material that is resistant to digestion and absorption in the small intestine and that has a noticeable physiological effect potentially associated with health benefits in the body" (SACN, 2015).

Guidelines for DF intake

The guidelines for DF intake for children vary between public health bodies and country-specific guidelines across Europe **(Table 10)**. The European Food Safety Authority (EFSA) recommend that a DF intake of 2g per MJ for children should be adequate for normal laxation (EFSA Panel on Dietetic Products and Allergies, 2010). This adequate intake (AI) is based on the DF intake that is considered adequate for normal laxation in adults (25g, equivalent to 2 to 3g per MJ for daily energy intakes of 8 to 12 MJ). Based on average energy intakes, the EFSA have set an AI for DF in children of different age groups; 14g/d for 4-6 years, 16g/d for 7-10 years and 19g/d for 11-14 years (EFSA Panel on Dietetic Products and Allergies, 2010).

The UK Scientific Advisory Committee on Nutrition (SACN) recommend that the average population intake of DF for children aged 5 to 11 years should be 20g/d (SACN, 2015). In Scandinavian countries (Denmark, Norway and Sweden), the Nordic Nutrition recommendations (NNR) advise that the DF intake for children should be 2-3g/MJ for children from 2 years of age. From school age, the intake should gradually increase to reach the recommended adult level during adolescence (Nordic Council of Ministers, 2014). France have adopted the DF recommendation of 'age + 5' which states that children older than 2 years of age should consume, as a minimum, the amount of DF equivalent to their age in years plus 5g/d (Williams *et al.*, 1995, Martin, 2001). In the Netherlands, it is recommended for children to increase their DF intake gradually with age from 3.0g/MJ in children aged 4-8 years to 3.2g/MJ in children aged 9-13 years (Health Council of the Netherlands, 2006).

DF intakes in school-aged children

National dietary surveys from seven countries in Europe reported DF intake in children aged 4-18 years **(Table 11)**. The mean intake of DF ranged from 11.8g-13g/d in children (5-12 years) in Spain, Ireland and Sweden. Girls had higher mean intakes of DF compared to boys in Spain while in Sweden, boys had higher mean intakes of DF compared to girls (Barbieri *et al.*, 2006, Deasy *et al.*, 2007, Ruiz *et al.*, 2016). The mean DF intake for younger children from aged 3-10 years in the UK and Italy was 14g/d while for older children (10-18y), the mean DF intake ranged from 15.3g-17.2g/d in these countries (Sette *et al.*, 2011, Public Health England, 2018). The median intake of DF in Dutch children was 16g/d in younger children (7-8 y) and 17g/d in older children (10-17y) with boys having higher median intakes compared to girls in both age groups (Van Rossum *et al.*, 2011). The mean intake of DF was 20g/d in Danish children aged 4-9 years while the mean intake of DF was 18g/d for Danish children aged 10-17 years (Pedersen *et al.*, 2014). The intakes of DF reported in school-aged children in Europe are generally below the recommended EFSA AI for DF (14-19g/d for children aged 4-14 years) with the exception of Denmark where younger children (4-9y) in particular, reported higher mean intakes of DF than the recommended AI.

Sources of DF intakes

The main food groups contributing to DF intakes in population groups (including children) were reported in Italy (3-10y), the UK (4-10y), Sweden (approx. 8 and 11y), Spain (9-12y), Denmark (4-75y) and the Netherlands (7-69y) and are outlined in **Table 11**. Data from national dietary surveys show that cereals and cereal products were the main source of DF intake in Europe and contributed 32% of DF intake in Sweden, between 43-44% in the Netherlands and the UK and between 47-54% of intakes in Spain and Denmark. Vegetables were also an important source of DF intakes and contributed 14% of DF intake in the Netherlands, the UK and Sweden and between 17-18% of DF intakes in Italy, Spain and Denmark. Fruit contributed 12-13% of DF intakes in the UK and Spain, between 11-20% of intakes in the Netherlands, Italy and Denmark and contributed 24% of intakes in Sweden. Potatoes and potato products contributed 6-10% of DF intakes in Italy, the UK and the Netherlands and contributed

24% of intakes in Sweden (Barbieri *et al.*, 2006, Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018).

Dietary patterns of DF intakes in school-aged children

In light of the low intakes of DF reported in national dietary surveys, dietary strategies are required to improve DF intakes in this population group. Understanding the dietary patterns associated with higher DF intakes can help to inform dietary strategies and initiatives to improve DF intakes (Lockyer *et al.*, 2016, Fayet-Moore *et al.*, 2018). One approach that can be used to develop dietary strategies to improve nutrient intakes in specific population groups is to identify a proportion of the population with adequate or sufficient intakes and to identify the foods and consumption patterns that contribute to the difference in intakes between those with sufficient intakes and those with lower intakes. If those with low intakes can adopt the dietary patterns of those with higher intakes, it may help to improve intakes within the overall population (Gibney and Sandström, 2008).

This approach has been used to investigate the dietary determinants of both DF and wholegrain consumption in studies of school-aged children in Australia, the US and in European. Data from an Australian nationally representative survey (2011-2012) in children aged 2-18 years found that wholegrains, fruit, and vegetables were key determinants of higher fibre intakes in school-aged children (Fayet-Moore *et al.*, 2018). Using quartile analysis, children were split into four groups based on their mean fibre intakes. The study found that children in the high fibre intake group had higher mean intakes of DF compared to those in the low fibre intake group (32.4 v 9.6g/d, respectively) with a difference of 22.8g/d between the two intake groups. This study also found that higher intakes of wholegrain foods such as wholegrain breads and high fibre RTEBC were associated with higher DF intakes in children. For example, the high fibre intake group had a higher proportion of total daily fibre from cereals and cereal products (which included grains) compared to the low fibre intake group (9.7 v 2.9g/d, respectively). The high fibre intake group were also more likely to consume RTEBC (including high fibre cereals) compared to the low fibre intake group (55 v 36%, respectively) and had double the median intake of this food group compared to the low fibre intake group (51 v 26g/d, respectively) (Fayet-Moore *et al.*, 2018). In addition, children in the high fibre intake group had a greater contribution to DF

intakes from fruit products and dishes (6.1g/d) compared to the low fibre intake group (1.3g/d), and a greater contribution to DF intakes from vegetable products and dishes compared to the low fibre intake group (4.8 v 1.3g/d, respectively) (Fayet-Moore *et al.*, 2018). Studies across Europe and the US have examined the determinants of wholegrain consumption in children (2-18y) and reported that higher intakes of wholegrain were associated with higher fibre intakes (Mann *et al.*, 2015, Albertson, 2016, Sette *et al.*, 2017). Studies in the UK, Italy and the US used tertile analysis to examine the determinants of wholegrain consumption in children. Children were divided into three groups based on their wholegrain consumption, and the mean fibre intakes for each group were reported. A study using data from The National Diet and Nutrition Survey (NDNS) (2008-11) in the UK found that children (2-17y) in the high wholegrain consumer group had higher mean intakes of DF (19.3g/d) compared to those in the low wholegrain consumer group (15.1g/d) (Mann *et al.*, 2015). Similarly, a study using data from the national dietary survey in Italy (INRAN-SCAI) (2005-06) found that children (3-17y) in the high wholegrain consumer group had a more fibre dense diet compared to those in the low consumer group (20.5 v 18.2 g/10MJ) (Sette *et al.*, 2017). A study in the US using data from the National Health and Nutrition Examination Survey (2001-12) also reported that the mean intakes of fibre were higher among children (6-18y) in the high wholegrain consumption group compared to those in the low wholegrain consumption group (18.4 v 11.3g/d, respectively) (Albertson, 2016).

Strategies to increase wholegrains, fruit and vegetable consumption

Public health campaigns to promote the consumption of wholegrains and fruit & vegetables have been implemented in countries across Europe. For example, healthy eating campaigns have been implemented in primary schools to increase the consumption of fruit and vegetables across Europe including Ireland, the UK, Denmark and Norway (Bangor Food and Activity Research Unit, 2007, Eriksen *et al.*, 2007, Bere *et al.*, 2010, DAFM, 2010). However, despite the introduction of public health initiatives to promote fruit and vegetable consumption in school-aged children, the findings of this review indicate that intakes remain below generally accepted recommendations. Public health initiatives have also been set up to promote wholegrain consumption in European countries. For example, the Bulgarian school food policy advise that wholegrain options for bread should be available at least twice

a week while the Swiss food-based standards recommend school lunches to serve 50% wholegrain bread in Switzerland (JRC, 2015). Similarly, in Germany, voluntary guidelines are set for the standardisation of school meals which require wholegrain to be served at least 4 days in a 20-day serving plan (equating to one serving per week) (WCRF, 2016). In 2009, Denmark initiated a public health campaign 'The Wholegrain Partnership' to promote the consumption of wholegrains to improve DF intakes in the Danish population. 'The Wholegrain Partnership' campaign created flyers for consumers, pictures and videos of famous wholegrain 'ambassadors' advertisements and posters to encourage consumers to buy products that have the wholegrain logo while also hosting a national wholegrain day to inform the public about wholegrains in the diet (Brinch-Nelson and Neese, 2013). Since the introduction of the public health campaign in Denmark, 43% of Danish children now eat the recommended daily intake of wholegrains compared to 7% previously reported (Greve and Neess, 2014). In addition, a voluntary labelling system known as the keyhole symbol came in to affect in Nordic countries; Denmark, Norway and Sweden in 2015. The objective of this strategy is to help consumers identify healthier food products within a product group. Foods labelled with the keyhole symbol have met the nutrient criteria to be recognised as a healthy food product such as high DF cereal foods (i.e. contain at least 6g/100g of DF) (The Norweign Ministry of Health and Care Services, 2015).

Conclusion

This review aimed to examine the current dietary guidelines for plant-based foods such as cereals, grains, potatoes and fruit & vegetables, to report the current intakes of these food groups and to investigate the contribution of these food groups to energy and nutrients in nationally representative samples of school-aged children in Europe. A further aim was to review the recommendations for DF intake for children and to report the current intakes, sources and determinants of DF in school-aged children in Europe.

Overall, mean intakes of cereals, grains & potatoes and fruit & vegetables were lower than generally accepted guidelines for these food groups for school-aged children in Europe with the exception of school-aged children in Denmark meeting the WHO guidelines for fruit & vegetable consumption. Whilst there is a broad range of dietary guidelines available for the consumption of cereal foods in the general population in

Europe, very few countries provide specific guidelines for children. Despite low intakes of both of these food groups, cereals, grains & potatoes make important contributions to intakes of energy, protein, carbohydrates, DF, B vitamins, vitamin D, potassium, calcium iron, magnesium and zinc in the diet and fruit & vegetables made important contributions to intakes of DF, vitamins (vitamin C, vitamin A, B vitamins) and minerals (potassium and magnesium). Fruit and vegetables also contributed to total and free sugar intakes (from fruit and fruit juice) and cereal foods contributed to intakes of saturated fat, free sugar and sodium mainly due to the inclusion of bakery products and puddings as cereal foods in different countries. Using data from national dietary surveys of school-aged children, the majority of countries in Europe have reported low intakes of DF (11.8g-17.2g/d) which are generally below recommendations with the notable exception of Denmark who reported a mean intake of 20g/d for children aged 4-9 years. Cereals & cereal products, potatoes and fruit & vegetables were the main contributors to intakes of DF and studies have reported wholemeal cereal foods, fruit and vegetables as the main food groups determining high DF intakes in school-aged children. Children with high DF intakes were more likely to consume these food groups in accordance with the food based dietary guidelines.

This review has indicated that higher consumption of these plant-based foods are required to increase DF intakes in children. Dietary strategies and public health initiatives have been set up in some European countries to increase the consumption of plant-based foods such as wholegrains and fruit & vegetables in school-aged children and other population groups. Such campaigns have improved wholegrain intakes in children in Denmark, however, the majority of fruit & vegetable intakes in school-aged children in Europe remain below the recommendations.

The present review provides a comprehensive overview of the role of plant-based foods such as cereal foods and fruit & vegetables in the diets of children in Europe and may be of use to stakeholders including researchers and policy makers. In light of the global shift towards providing healthy diets from sustainable food systems it is important to continue to monitor the consumption of these foods in the diets of population groups.

Table 1. Guidelines for cereals, grains & potato consumption in European countries within the WHO region

Country (Reference)	Age (years)	Guidance for cereal, grain & potato consumption
Norway (Norwegian Directorate of Health, 2016)	1+	Consume coarse cereal products every day. No specific guidelines for potato consumption.
United Kingdom (Public Health England, 2016)	2+	Base meals on potatoes, bread, rice, pasta or other starchy carbohydrates; choosing wholegrain versions where possible.
Sweden (Swedish National Food Agency, 2015)	2+	Switch to wholemeal - choose wholegrain varieties when you eat pasta, bread, grain and rice. No specific guidelines for potato consumption.
Denmark (Ministry of Food Agriculture & Fisheries, 2013)	3+	Choose wholegrains. No specific guidelines for potato consumption.
Ireland (Department of Health, 2017)	5+	Three to five servings a day of wholemeal cereal and breads, potatoes, pasta and rice group.
Greece (Institute of Preventive Environmental & Occupational Medicine, 2014)	4-8	Four to five portions of cereals (bread, rice, pasta) and potatoes per day.
The Netherlands (Netherlands Nutrition Centre, 2015)	General population	Replace refined cereal products with whole-grain products with no specific guideline for potato consumption.
Georgia (Ministry of Labor Health and Social Affaires, 2005)	General population	500-600g of breads, cereals and pasta per day, preferably whole-grain and rice with a separate guideline to consume 200-300g of potatoes per day.
Germany (The German Nutrition Society, 2013)	General population	400–550 g of bread, cereals, cereal products, potatoes, and potato products per day.
Austria (Austrian Ministry of Health and the National Nutrition Commission, 2010)	General population	Four servings of grains, breads, pasta, rice or potatoes a day (five servings for active athletes and children). Preferably wholegrain products.
Turkey (Republic of Turkey Ministry of Health, 2016)	General population	Three to seven portions of cereal group (bread, bulghar and macaroni) per day.
Finland (National Nutrition Council Finland, 2019)	General population	Six to nine portions of grain products in adult population. The number of servings for children depends on age and energy expenditure. There are no specific guidelines for potato consumption.
World Health Organisation (WHO)	General population	Consume breads, grains, pasta, rice (preferably wholegrain) or potatoes several times a day.

Table 2. Mean intake (g/d) of cereal, grains & potatoes in school-aged children in Europe using data from national nutrition surveys

Country (Reference)	Study name	Dietary assessment method	Study Years	Cereals description	Age (Years)	Total	Boys	Girls
Italy (Leclercq *et al.*, 2009)	Italian National Food Consumption Survey	3 day diary	2005-2006	Cereals, cereal products and substitutes and potatoes	3-10	285	-	-
United Kingdom (Public Health England, 2014)	National Diet and Nutrition Survey	4 day diary	2008-2012	Cereals, cereal products and potatoes	4-10	285	292	278
Denmark (Pedersen *et al.*, 2014)	Danish National Survey of Dietary Habits and Physical Activity	7 day record	2011-2013	Cereals and potatoes	4-9	256	270	242
The Netherlands (Van Rossum *et al.*, 2016)	Dutch National Food Consumption Survey	2x 24 hour recalls	2012-2016	Cereals, cereal products and potatoes	4-18	250	-	-
Germany (Alexy, 2010)	Dortmund Nutritional and Anthropometric Longitudinally Designed Study	3 day record	1997-2008	Grain based foods	6-12	211	222	200
Turkey (Republic of Turkey Ministry of Health, 2016)	Turkey Nutrition and Health Survey	24 hr recall	2010	Bread and cereals	4-10	187	-	-
Spain (Partearroyo *et al.*, 2019)	Anthropometry, Intake and Energy Balance in Spain	3 day record	2009	Cereals and derivatives	9-12	168	170	166

– data not available

Table 3. The percent contribution (%) of cereals, grains & potatoes to energy and nutrients in population groups (including children) in Europe using data from national nutrition surveys

	Denmark[1] (4-75 years)	Italy[2] (3-10 years)	The Netherlands[3] (7-69 years)	The UK[4] (4-10 years)	Spain[5,6,7] (9-12 years and 9-75 years) *
Energy	31	43	28	44	30
Protein	23	30	25	32	18
Total fat	10	16	12	31	13
Saturated fat	6	14	6	29	13
Carbohydrate	53	70	43	57	49
Total sugars	-	24	-	-	15
Free sugars	-	-	-	33	33
Dietary Fibre	60	53	53	53	44
Thiamin	34	40	23		29
Riboflavin	13	25	11	29	12
Total Niacin	15	-		-	17
Vitamin B6	23	33	21	-	15
Vitamin B12	-	5	-	-	-
DFE	-	-	29	-	-
Vitamin A	-	8	-	15	-
Vitamin D	-	22	-	31	-
Vitamin E	12	11	11	-	-
Vitamin C	-	10	14	-	-
Sodium	23	-	-	38	-
Potassium	22	27	23	33	-
Calcium	10	14	9	37	-
Iron	40	40	31	60	-
Magnesium	34	36	30	33	-
Zinc	24	28	22	31	25

* does not include potatoes, - data not available

[1] Pedersen *et al.* (2014), [2] Sette *et al.* (2013), [3] Van Rossum *et al.* (2011), [4] Public Health England (2018), [5] Ruiz *et al.* (2016), [6] Mielgo-Ayuso *et al.* (2018),[7] Olza *et al.* (2017)

Table 4. Guidelines for fruit & vegetable consumption in European countries within the WHO region

Country (Reference)	Age (years)	Guidance for fruit & vegetable consumption
UK (Public Health England, 2016)	2+	At least five portions of fruit and vegetables daily.
Sweden (Swedish National Food Agency, 2015)	2+	At least 500g vegetables and fruit per day.
Austria (Austrian Ministry of Health and the National Nutrition Commission, 2010)	2+	Five portions of vegetables, pulses and fruit per day (three portions of vegetables and/or pulses and two portions of fruit).
Ireland (Department of Health, 2017)	5+	At least 5 to 7 servings of fruit & vegetables per day.
Denmark (Ministry of Food Agriculture & Fisheries, 2013)	4-10	300-500g of fruit and vegetables per day.
Greece (Institute of Preventive Environmental & Occupational Medicine, 2014)	4-13	One to three portions of vegetables daily and one to three portions of fruit daily.
The Netherlands (Netherlands Nutrition Centre, 2015)	4-13	100g-150g/d of vegetables and 150g-200g/d of fruit.
Finland (National Nutrition Council Finland, 2019)	Children	Children should eat at least half the amount recommended for adults.
Norway (Norwegian Directorate of Health, 2016)	Children	500g of fruit and vegetables a day (250g of fruit and 250g vegetables) and 5 portions of fruit and vegetables with somewhat reduced portion size for children.
Bulgaria (Bulgarian National Center of Public Health Protection, 2006)	General population	A variety of vegetables and fruits more than 400 grams every day, preferably raw.
Turkey (Republic of Turkey Ministry of Health, 2016)	General population	Five or more portions of fruit and vegetable daily.
Italy (WHO, 2000)	General population	At least 400g of fruit and vegetables per day.
France (Ministry of Solidarity and Health, 2019)	General population	At least five portions of fruit and vegetables per day, three portions of vegetables and two portions of fruits. One portion equals 80 to 100g.
Germany (The German Nutrition Society, 2013)	General population	At least five portions of fruit and vegetables daily (three portions of vegetables and two portions of fruit). Corresponding to 400g of fruit and vegetables per day.
World Health Organisation (WHO) (WHO/FAO, 2004)	General population	A minimum of 400g of fruit & vegetables per day (excluding potatoes and other starchy tubers).

Table 5. Foods included in country specific guidelines for fruit & vegetable consumption in European countries within the WHO region

Country	Fruit juice	Dried fruit	Legumes	Potatoes	Nuts	Tinned fruit & vegetables
Austria	200ml of fruit juice as one portion	-	70g-100g (raw), 150g-200g (cooked)	-	-	-
Bulgaria	Included. Unlimited quantity	Included. No specific quantity given	-	-	-	Included. No specific quantity given
Denmark*	Included. No specific quantity given	-	-	-	-	Included. No specific quantity given
Finland	-	-	-	-	-	-
France	Included. No specific quantity given	Included. No specific quantity given		-	-	-
Germany	Included. No specific quantity given	25g as one portion	75g (raw), 125g (cooked)	-	25g included as one portion of fruit	-
Greece	125 ml of fruit juice as one portion	1½ tbsp. raisins, 4 dried fruits as one portion		-	-	-
Georgia	Included. No specific quantity given		Included. No specific quantity given	-	-	-
Ireland	150ml of unsweetened fruit juice as one portion	½ cup dried fruit as one portion		-	-	2/3 cup of tinned fruit
Norway	100ml of fruit juice as one portion	-	Encouraged to eat as vegetables	-	-	Included. No specific quantity given
The Netherlands	-	Dried fruit without added sugar as one portion. No specific quantity given.	-	-	-	Canned vegetables without added sugar. No specific quantity given
The UK	150ml of unsweetened fruit juice as one portion.	30g as one portion	-	-	-	-
Turkey	Tea glass of juice as one portion	-	-	Included. No specific quantity given	-	-
WHO/FAO	-	-	Included. No specific quantity given	-	-	-

* excludes mushrooms as part of the guidelines for vegetable consumption – data not available

Table 6. Mean intake (g/d) of fruit & vegetables in school-aged children in Europe using data from national nutrition surveys

Country (Reference)	Study name	Dietary assessment method	Study years	Age (years)	Total (g/d)	Boys (g/d)	Girls (g/d)
Denmark (Pedersen *et al.*, 2014)	Danish National Survey of Dietary Habits and Physical Activity	7 day record	2011-2013	4-9	404	407	400
Italy (Leclercq *et al.*, 2009)	Italian National Food Consumption Survey	3-day diary	2005-2006	4-9	350	-	-
Spain (Partearroyo *et al.*, 2019)	Anthropometry, Intake and Energy Balance in Spain	3 day diary	2009	9-12	341	329	359
The Netherlands (Van Rossum *et al.*, 2016)	The Dutch National Food Consumption Survey	2x 24 hour recalls	2012-2016	4-8	272	-	-
UK (Partearroyo *et al.*, 2019)	National Diet and Nutrition Survey	4 day diary	2014-2016	4-10	255	256	255
Ireland (McCarthy *et al.*, 2018)	National Children's Food Survey	7 day diary	2003-2004	5-12	224	-	-

– data not available

Table 7. The percent contribution (%) of fruit & vegetables to energy and nutrients in population groups (including children) in Europe using data from national nutrition surveys

	Denmark [1] (4-75 y)	Italy[2] (3-10 y)	The Netherlands[3] (7-69 y) *	The UK[4] (4-10 y)	Spain[5,6,7,8] (9-12 and 9-75 y)
Energy	6	8	7	9	9
Protein	6	4	5	8	4
Total fat	-	2	6	3	-
Saturated fat	4	1	0	1	-
Carbohydrate	19	12	8	13	16
Total sugars	-	31	-	-	50
Free sugars	-	-	-	12	7
Dietary Fibre	36	37	25	27	32
Thiamin	15	13	9	-	18
Riboflavin	10	12	6	8	11
Total Niacin	10	-	-	-	9
Vitamin B6	25	20	10	-	25
Vitamin B12	-	-	-	-	-
DFE**	-	-	19	-	-
Vitamin A	26	46	-	28	38
Vitamin D	-	1	-	0	-
Vitamin E	38	20	11	-	16
Vitamin C	74	83	32	-	71
Sodium	5	-	-	5	-
Potassium	27	29	16	20	-
Calcium	8	9	7	7	-
Iron	15	18	12	12	-
Magnesium	16	19	12	17	-
Zinc	7	11	7	7	9

*does not include fruit juice ** dietary folate equivalents – data not available

[1] Pedersen *et al.* (2014), [2] Sette *et al.* (2013),[3] Van Rossum *et al.* (2011),[4] Public Health England (2018),[5] Ruiz *et al.* (2016),[6] Mielgo-Ayuso *et al.* (2018),[7] Olza *et al.* (2017),[8] Ruiz *et al.* (2017)

Table 8. The percent contribution (%) of fruit, vegetables and fruit juice to energy and nutrients in Europe using data from national dietary surveys

	Denmark (4-75 y)			Italy (3-10 y)			The Netherlands (7-69 y) *		The UK (4-10 y)			Spain (9-12 and 9- 75 y)		
	Fruit	Vegetables	Juice	Fruit	Vegetables	Juice	Fruit	Vegetables	Fruit	Vegetables	Juice	Fruit	Vegetables	Juice
Energy	2	3	1	4	2	2	5	2	4	3	2	3	3	3
Protein	2	4	-	1	3	0	3	2	2	4	2	1	3	-
Total fat	-	-	-	1	1	0	5	1	1	2	-	-	-	-
Saturated fat	2	2	-	1	0	-	-	0	0	1	-	-	-	-
Carbohydrate	12	5	2	6	2	4	6	2	7	3	3	5	6	6
Total sugars	-	-	-	16	6	10	-	-	-	-	-	21	6	23
Free sugars	-	-	-	-	-	-	-	-	0	1	11	-	-	7
Dietary fibre	18	18	-	20	17	1	11	14	12	14	1	13	18	1
Thiamin	5	8	2	6	6	2	4	5	-	-	-	6	12	-
Riboflavin	4	5	1	4	6	2	2	4	3	2	3	4	7	-
Total Niacin	3	6	1	-	-	-		-	-	-	-	3	6	-
Vitamin B6	11	12	2	9	9	2	5	5	-	-	-	9	16	-
Vitamin B12	-	-	-	0	0	0	0	0	-	-	-	-	-	-
DFE**	-	-	-	-	-	-	5	14	-	-	-	-	-	-
Vitamin A	2	24	-	9	36	1	-	-	2	25	1	7	31	-
Vitamin D	-	-	-	0	1	0	-	-	0	0	-	-	-	-
Vitamin E	23	15	-	7	11	2	5	6	-	-	-	5	11	-
Vitamin C	25	37	12	23	34	26	16	16	-	-	-	20	51	-
Sodium	2	3	-	-	-	-		-	0	5		-	-	-
Potassium	11	14	2	12	15	3	7	9	9	7	4	-	-	-
Calcium	3	4	1	3	5	1	2	5	2	4	1	-	-	-
Iron	6	8	1	6	9	3	4	8	4	7	1	-	-	-
Magnesium	8	7	1	7	9	3	7	5	7	7	3	-	-	-
Zinc	3	4	-	2	8	1	3	4	2	5	-	4	5	-

* does not include fruit juice ** dietary folate equivalents – data not available

Table 9. Definitions of dietary fibre in Europe

Codex Alimentarius (WHO/FAO, 2009)	Carbohydrate polymers with ten or more monomeric units, which are not hydrolysed by the endogenous enzymes in the small intestine of humans and belong to the following categories: – *Edible carbohydrates polymers* naturally occurring in the food as consumed. – *Carbohydrates polymers* which have been obtained from food raw material by physical, enzymatic or chemical means and which have been shown to have physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities. – *Synthetic carbohydrate polymers* which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities.
European Food Safety Authority (EFSA Panel on Dietetic Products and Allergies, 2010)	Non-digestible carbohydrates plus lignin.
Scientific Advisory Committee Nutrition (SACN, 2015)	Material that is resistant to digestion and absorption in the small intestine and that has a demonstrable physiological effect potentially associated with health benefits in the body; – Increasing stool bulk. – Decreasing intestinal transit time. – Decreasing the lowering of total cholesterol and LDL-cholesterol concentrations. This includes non-starch polysaccharides. Inclusion of other components in the definition would require beneficial physiological effects to be demonstrated.
Nordic Nutrition Recommendations (Becker *et al.*, 2004)	Dietary fibre naturally occurring in plant foods as measured by AOAC methods for total DF.

Table 10. Recommendations (Adequate intake) of dietary fibre for school-aged children in Europe

Source	DRV	Age (years)	Value
EFSA (EFSA Panel on Dietetic Products and Allergies, 2010)	Adequate Intake (AI)	4- 6	14g/d
		7-10	16g/d
		11-14	19g/d
The Scientific Advisory Committee on Nutrition (SACN, 2015)	Average population intake	2-5	15g/d
		5-11	20g/d
		11-16	25g/d
NNR (Nordic Council of Ministers, 2014)	Adequate intake (AI)	2+	An intake corresponding to 2-3g/MJ
France (Williams *et al.*, 1995, Martin, 2001)	Adequate intake (AI)	2+	5 + age
The Netherlands (Health Council of the Netherlands, 2006)		4-8	3.0g/MJ
		9-13	3.2g/MJ

Table 11. Mean intake (g/d) of dietary fibre in school-aged children in Europe using data from national nutrition surveys

Country (Reference)	Study name	Study years	Dietary assessment method	Age (years)	Total mean intake (g/d)	Boys mean intake (g/d)	Girls mean intake (g/d)	Sources
Denmark (Pedersen *et al.*, 2014)	Danish National Survey of Dietary Habits and Physical Activity	2011-2013	7-day record	4-9	20	21	19	Bread & cereals (54%)
				10-17	18	20	17	Vegetables (18%) Fruit (18%)
The Netherlands (Van Rossum *et al.*, 2011)	Dutch national food consumption survey	2007-2010	24-hr dietary recall	7-8	16*	16	15	Cereals & cereal products (43%)
				9-13	17*	18	16	Vegetables (14%) Potatoes (10%) Fruits (11%)
Italy (Sette *et al.*, 2011)	The third Italian national food consumption survey	2005-2006	3-day diary	3-9	14.4	-	-	Cereals & cereal products (47%)
				10-18	17.2	18.1	16.4	Vegetables (17%) Fruit (20%) Potatoes (6%)
The UK (Public Health England, 2018)	National Diet and Nutrition Survey	2014-2016	4-day food diary	4-10	14.0	14.5	13.5	Cereals & cereal products (44%)
				11-18	15.3	16.5	14.1	Vegetables (14%) Potatoes (10%) Fruit (12%)
Sweden (Barbieri *et al.*, 2006)	Swedish children's dietary survey	2003	4-day food diary	8	13	14	13	Cereals & cereal products (32%)
				11	13	13	12	Fruit (24%) Potatoes (24%) Vegetables (14%)
Ireland (Deasy *et al.*, 2007)	National Children's Food Survey	2003-2004	7-day record	5-12	12.4	-	-	-
Spain (Ruiz *et al.*, 2016)	Anthropometry, Intake and Energy Balance in Spain	2013	3-day food diary	9-12	11.8	11.5	12.2	Grains (47%) Vegetables (18%) Fruit (13%)

*median

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Aims and objectives

The overall aim of this thesis was to examine the role of plant-based foods such as 'cereals, grains & potatoes' and 'fruit & vegetables', and the role of DF in the diets of school-aged children in Ireland. This research used data from two nationally representative dietary surveys of school-aged children (5-12y) in Ireland carried out by the Irish Universities Nutrition Alliance over the past 15 years (www.iuna.net). These surveys are the National Children's Food Survey (NCFS) (2003-04) and the National Children's Food Survey II (NCFS II) (2017-18), which used similar methodologies.

Objectives:

1. To estimate the current intake of 'cereals, grains & potatoes' and the contribution of this food group to energy and nutrient intakes in school-aged children in Ireland using data from the NCFS II and to identify any changes in intakes since the NCFS.

2. To estimate the current intake of 'fruit & vegetables', compliance with food based dietary guidelines and the contribution of this food group to energy and nutrient intakes in school-aged children in Ireland and to identify any changes in intakes since the previous NCFS.

3. To estimate the current intakes and sources of DF in school-aged children in Ireland and to identify changes in intakes since the previous NCFS.

4. To identify the dietary determinants (key food groups and dietary patterns) of DF intake in school-aged children in Ireland.

Chapter 2

Methodology of the Irish National Dietary Survey

Methodology

Analyses for the present study were based on data from two nationally representative dietary surveys of school-aged children in Ireland: the National Children's Food Survey (NCFS) of 5-12 year olds (2003-04) and the National Children's Food Survey II of 5-12 year olds (NCFS II) (2017-19). The NCFS (2003-04) and the NCFS II (2017-18) used similar methodologies. The NCFS was carried out by teams in University College Cork and University College Dublin and the NCFS II was carried out by teams in University College Cork, Cork Institute of Technology, University College Dublin and Technological University Dublin, all of which form part of the Irish Universities Nutrition Alliance (IUNA) (www.iuna.net). The methods relevant to this thesis are outlined below with further information available on www.iuna.net.

Ethical approval

The two surveys were conducted in accordance with guidelines laid down in the Declaration of Helsinki. Ethical approval was obtained from St. James' Hospital and Federated Dublin Voluntary Hospitals Joint Research Ethics Committee for the NCFS and the University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospitals for the NCFS II. Written informed consent was obtained from all participants and/or parents/guardians before commencement of each survey.

Sampling and recruitment methodology

The NCFS and the NCFS II had the same method of sampling and recruitment which is summarised as follows; 594 children (293 boys, 301 girls) and 600 children (300 boys, 300 girls) aged 5 to 12 years from across the Republic of Ireland took part in the NCFS (from March 2003 to March 2004) and the NCFS II (from April 2017 to May 2018), respectively, providing a seasonal balance to the data for both surveys. In the NCFS II, 56% of children were surveyed during the winter (September – February) and 44% survey during the summer (March-August). The sample size for both surveys was chosen to deliver sufficient numbers of (at least 100) individuals in the least populated age and gender subgroups and the calculation for the sample size of the NCFS II was supported by the EFSA EU menu guidance European Food Safety Authority (2014). For both surveys, a database of primary schools in Ireland (provided by the Department of Education and Skills) was used to select schools to provide a

demographically balanced sample with respect to urban/rural location and socio-economic grouping. An introductory letter with information about the survey was sent to the principal of selected schools followed by a phone call from a researcher with 90% of schools contacted in the NCFS and 80% of schools contacted in the NCFS II agreeing to take part in the study. Information packs about the survey were provided to the school principal along with instructions to randomly select children from the school roll to receive the information packs. Those children selected at random were given an information pack consisting of an introductory letter, information brochure and a reply slip to bring home to their parent/guardian. If the selected children and parents/guardians were interested in participating in the survey, they were instructed to fill out the reply slip and return it to the school for collection by a researcher. Children who returned a reply slip were excluded if they were not between the ages of 5 and 12 years, if they belonged to an age or sex or urban/rural location for which the appropriate number of children had already been recruited or if another member of their household had already been recruited for participation in the survey. Where families opted in, a researcher visited the home to explain the survey in more detail and to obtain consent from both parents/guardians and the child. The overall response rates for the NCFS and the NCFS II were 66% and 65%, respectively. Demographic analysis of the NCFS and the NCFS II showed them to be representative of children in Ireland with respect to age, sex and urban/rural location when compared to Census 2002 and Census 2016 data, respectively (Central Statistics Office, 2003, Central Statistics Office, 2017). However, the NCFS II sample contained a higher proportion of children of professional workers and a lower proportion of children of semi-skilled and unskilled workers than the national population and all data in this thesis relating to NCFS II have been weighted to account for these differences.

Dietary data collection

An overview of the methods of dietary data collection is presented in **Table 1.** For the NCFS, 594 children aged 5-12 years completed a 7-day weighed food record with a total of four visits from the fieldworker over the recording period. For the NCFS II, 600 children aged 5-12 years completed a 4-day weighed food diary with a total of three visits during the recording period. A trained researcher visited each participant

in their home over the recording period to demonstrate how to keep the food diary, use the portable food scales that were provided, and review the diary to check for completeness. The recording period for both surveys included at least one weekend day for all participants. For each survey, participants were asked to record detailed information regarding the amount, type and brand name of all foods, beverages and dietary supplements consumed over the recording period and where applicable, the cooking method used and details of recipes and any leftovers. Data were collected on the time of each eating or drinking occasion, the participant's definition of each eating or drinking occasion (e.g. breakfast, morning snack, lunch) and the location of the preparation of the meal or snack consumed (e.g. home, work, school). To facilitate the collection of the data, participants were also asked to collect product labels for all food, beverages and dietary supplements consumed. If product labels were unavailable, the researchers sourced and photographed the packaging from local supermarkets.

Food quantification and coding

A quantification protocol that was established by the IUNA for the North/South Ireland Food Consumption Survey (NSIFCS) (Harrington *et al.*, 2001) was adapted for each survey. This protocol is summarised as follows and the percentage of each quantification method used in each survey is outlined in **Table 1:**

1) Weighed (using the digital food scales provided to each participant) or manufacturers' weights from product labels.
2) Age appropriate photographic food atlas (Nelson *et al.*, 1997, Foster *et al.*, 2010).
3) Standard food portion sizes (Food Standards Agency, 2002, Lyons *et al.*, 2013).
4) IUNA weights (Average portion weights that had been ascertained for certain foods by the IUNA survey team).
5) Household measures (measures such as teaspoon, tablespoon, pint etc.).
6) Estimated (based on the researcher's knowledge of the respondent's general eating patterns as observed during the recording period. This method was only used when no other quantification method was appropriate).

Estimation of food and nutrient intakes

Each food and beverage consumed in both surveys was assigned a unique food code depending on its nutritional profile and brand information. All foods and beverages were then entered into the data entry system WISP© (Tinuviel Software, Anglesey, UK) (NCFS) and Nutritics© (NCFS II). A total of 1945 and 2046 food codes were included in the NCFS and NCFS II databases, respectively. These foods and beverages were categorised into one of 19 food groups (Appendix 1) and were further subdivided as appropriate for estimation of food group intakes. The mean daily intake of each food group was estimated for each individual by summing the weight of each food consumed in the food group and dividing the total by the number of recording days (seven for the NCFS) and (four for the NCFS II).

WISP© and Nutritics© software (NCFS and NCFS II, respectively) were used to estimate nutrient intakes from food intakes using data from McCance & Widdowson's The Composition of Foods, seventh, sixth and fifth editions plus all nine supplemental volumes (Holland *et al.*, 1988, Holland *et al.*, 1989, Holland *et al.*, 1991, Holland *et al.*, 1992a, Holland *et al.*, 1992b, Holland *et al.*, 1993, Chan *et al.*, 1994, Chan *et al.*, 1995, Holland *et al.*, 1995, Chan *et al.*, 1996, Food Standards Agency, 2002, Food Standards Agency, 2015).

During each survey, modifications were made to the food composition database to account for recipes of composite dishes, dietary supplements, fortified foods, new foods on the market and generic Irish foods that were commonly consumed. For both surveys, the collection of food composition data at brand-level in the surveys allowed for the best possible estimates of nutrient intakes for Irish children.

Defining under-reporters of food (energy) intake

In the NCFS under-reporters were identified by predicting basal metabolic rate (BMR) for each participant from standard equations using body weight and height (Schofield, 1985), and using minimum energy intake cut-off points, calculated as multiples of BMR (Torun *et al.*, 1996) to identify URs (32% of children). In the NCFS II, under reporters were identified by evaluating reported energy intake (as a ratio of energy intake to basal metabolic rate (BMR) (EI: BMR)) against presumed age-specific energy cut offs calculated on the basis of reported levels of physical activity (19.5% of children) (Goldberg *et al.*, 1991, Black, 2000).

In various settings, under-reporting has been shown to be associated with individual factors such as sex, age, psychologic characteristics and more particularly with BMI (Black and Cole, 2001, Johnson, 2002, Maurer *et al.*, 2006). As recommended in the EU Menu methodology guidance of the European Food Safety Authority (EFSA), we have included under-reporters in our analyses (European Food Safety Authority, 2014). Excluding URs in this study investigating food groups and dietary fibre intakes and compliance may introduce additional bias by excluding some specific categories of the population more likely to be considered as under-reporters.

Quality control

Across both surveys, a number of quality procedures were put in place in an attempt to minimise error and ensure consistency throughout the collection and entry of food intake data. Researchers received training prior to commencing fieldwork which included role-play workshops where they were trained to take a natural and friendly approach to fieldwork and to avoid prompting foods. This was carried out in an attempt to make participants feel at ease and so that the most reliable data possible could be obtained. It was stressed to participants that they should not try to change or improve their diet during the recording period.

Each fieldworker was primarily responsible for the collection, quantification, coding and data entry of their own participants' food diaries in an attempt to maintain consistency. Once the data entry was completed by the fieldworker, all diaries were re-checked and a percentage of diaries were re-checked by a different fieldworker. 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. The consolidated data for each survey was then exported to SPSS and each variable exported was quality controlled for errors and outliers.

Databases

The NCFS and the NCFS II databases comprises over 72,000, and 41,780 rows of data that describe every food and drink item consumed by each of the participants, at every eating occasion, for each of the seven or four recording days, respectively. For each item consumed, each 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 food/drink consumed, the brand

information, packaging type and size, and a breakdown of the amount of food consumed for a number of nutrients. All food and drink items were allocated into one of nineteen food groups (Appendix I) and the food groups of interest were further subdivided (i.e. ‘bread & rolls’ was further categorised into ‘white breads’ and ‘brown breads’).

Table 1. Overview of each survey methodology including methods used for quantification of foods

	NCFS (2003-04)	**NCFS II (2017-18)**
Number of participants	594	600
Age group (years)	5-12	5-12
Length of data collection (days)	7	4
Number of visits from the researcher	4	3
Quantification method	Weighed	Weighed
of which	(%)	
Weighed by participant or manufacturers' weights	85	87
Food Atlas[1,2]	5	7
Standard Food Portion Sizes[,3,4]	4	3
IUNA weights	1	-
Household Measures	2	1
Estimated	3	2
Total	**100**	**100**

[1]Nelson *et al.* (1997) (NCFS)

[2]Foster *et al.* (2010)(NCFS II)

[3]Food Standards Agency (2002)

[4]Lyons *et al.* (2013)

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Chapter 3

The role of ‘cereals, grains & potatoes’ in the diets of school-aged children (5-12y) in Ireland

Introduction

'Cereals, grains & potatoes' are staple foods in the diets of all population groups (including children) and have been shown to be an important source of energy, carbohydrates, protein, dietary fibre (DF), vitamins and minerals (FAO, 2003, McKevith, 2004, Lafiandra *et al.*, 2014). Recent research has suggested a change in current dietary patterns is required to provide major health benefits and for sustainable living. The consumption of more plant-based foods (including wholegrains and 'fruit & vegetables') and less red meat, sugar, and refined grains is being advised to benefit human health (Willett *et al.*, 2019).

As healthy eating practices can be developed and fostered during the childhood years and carry in to adulthood, (Kelder *et al.*, 1994, Birch, 1999, Birch *et al.*, 2007), the consumption of cereal foods, particularly wholegrain, is encouraged in children to promote dietary patterns that will reduce the risk of developing chronic diseases in later life (Kranz *et al.*, 2012, Albertson, 2016). The Irish food based dietary guidelines (FBDG) recommend a daily intake of 3-5 servings of wholemeal cereals & breads, potatoes, pasta and rice for children aged 5 years and over. Potatoes are an important source of energy and nutrients and are grouped with the cereal food group as part of the dietary guidelines (Department of Health, 2017). One serving from the cereal food group consists of two thin slices of wholemeal soda bread, 1½ slices wholemeal bread, 1/3 cup dry porridge oats, one cup flaked breakfast cereal, one cup cooked rice, pasta or noodles and two medium or four small potatoes (Department of Health, 2017).

A number of national dietary surveys in Europe have reported the intake of 'cereals, grains & potatoes' in children ranging from 168g to 285g/d and have shown that 'cereals, grains & potatoes' make significant contributions to intakes of energy (28-43%), carbohydrate (43-70%), protein (18-32%), total fat (10-31%), DF (44-60%), B vitamins (11-40%), vitamin D (22-31%), iron (31-60%) and other minerals (calcium, zinc, potassium and magnesium) (9-41%) while also contribute to intakes of saturated fat (6-29%), total sugar (15-24%), free sugar (33%) and sodium (23-38%) (Leclercq *et al.*, 2009, Alexy, 2010, Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Public Health England, 2014, Republic of Turkey Ministry of Health, 2016, Ruiz *et al.*, 2016, Van Rossum *et al.*, 2016, Olza *et al.*, 2017, Mielgo-Ayuso *et al.*, 2018, Partearroyo *et al.*, 2019).

The recent National Children's Food Survey II (NCFS II) (2017-2018) has collected detailed dietary intake data in a nationally representative sample of children aged 5-12 years in Ireland using a similar methodology to the previous National Children's Food Survey (NCFS) (2003-2004) (www.iuna.net). The aim of this study is to examine the current intakes of 'cereals, grains & potatoes' in school-aged children in Ireland using data from the NCFS II and to examine the contribution of this food group to energy and nutrient intakes. A secondary aim is to identify any changes in the consumption of 'cereals, grains & potatoes' in school-aged children in Ireland since the NCFS (2003-2004).

Methodology

The analyses for this chapter are based on data from the National Children's Food Survey II (NCFS II) which was a nationally representative cross-sectional study that collected food and beverage consumption data from 600 children aged 5-12 years in the Republic of Ireland between 2017 and 2018. The methodology for sampling, participant recruitment, data collection and food quantification for NCFS II is described in detail in chapter 2, with methods specific to this chapter outlined below. Findings from the NCFS II can be compared to the previous NCFS (2003-04), which used a similar methodology, with the exception of the 7-day weighed food diary used in the NCFS compared to a 4-day weighed food diary used in the NCFS II. The methodology for the NCFS is outlined in detail in Chapter 2 and has also been described previously (IUNA, 2005).

Data collection and quantification

Food and beverage intake data in the NCFS II were collected using a 4-day weighed food diary. A trained researcher visited each participant in their home three times over the recording period to demonstrate how to keep the food diary, use the portable food scales that were provided, and review the diary to check for completeness. The recording period included at least one weekend day for all participants. Participants were asked to record detailed information regarding the amount, type and brand name of all foods, beverages and dietary supplements consumed over the recording period and where applicable, the cooking method used and details of recipes and any leftovers. To facilitate the collection of such data, participants were asked to collect product labels for all food, beverages and dietary supplements consumed. If product labels were unavailable, 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 NCFS II and is summarised as follows. The majority of foods and drinks (76%) were weighed directly on the portable food scales (Tanita© KD-400, 5000 x 1g) and a further 11% of weights were derived from the manufacturer's information on product labels. The remaining foods and drinks were quantified using a validated age appropriate photographic food atlas (7%) (Foster *et al.,* 2010), standard portion weights (3%) (Food Standards Agency, 2002, Lyons *et al.,* 2013), household measures (1%) and estimates based on the child's

previous eating patterns (only used when no other quantification method was appropriate) (2%).

Estimation of food intakes

Each food and beverage consumed in the NCFS II was assigned a unique food code based on its food descriptor and nutritional profile at brand level and this food code was entered into the Nutritics© data entry system. A total of 2046 food codes were included in the NCFS II food file which were then categorised into 19 food groups (Appendix 1). For the purpose of this chapter, the food groups of interest were 'grains, rice, pasta & savouries', 'bread & rolls', 'breakfast cereals' and 'potatoes & potato products'.

'Pasta, rice & savouries' was further categorised into 'pasta', 'rice', 'other cereals' (which included noodles, couscous and quinoa), 'pizza' and 'other savouries'. 'Bread & rolls' was further categorised into 'white breads' and 'brown breads' (both which included soft and crusty rolls) and 'other breads' which included other bread products such as garlic bread, fruit breads and scones. 'Breakfast cereals' were further categorised into 'ready-to-eat-breakfast cereals (RTEBC)' (dry weight) and 'porridge & hot oat cereals' (made up weight). 'RTEBCs' were then categorised further into 'high fibre' (≥6g fibre/100g) and 'low fibre' (< 6g fibre /100g) cereals. A claim that a food is high in fibre can only be made where the product contains at least 6 g of fibre per 100 g (EC, 2006). 'Potatoes & potato products' were further categorised into 'boiled, baked & mashed potatoes', 'chipped, fried & roasted potatoes' and 'processed & homemade potatoes'.

The mean daily intake of each food group was estimated for each individual by summing the weight of each food consumed in the food group and dividing the total by the number of recording days (four).

Compliance with food based dietary guidelines

The Irish food based dietary guidelines (FBDG) recommend a daily intake of 3 to 5 servings of wholemeal cereals & breads, potatoes, pasta and rice (Department of Health, 2017). For the purpose of this analysis, the intake of all 'cereal, grains & potatoes' and wholemeal and brown cereals, breads, pasta, rice and potatoes were compared with the guidelines set by the Department of Health. One serving was defined as 1 ½ slices wholemeal bread (57g), 1/3 cup dry porridge oats (40g), one cup

flaked breakfast cereal (30g), one cup cooked rice, pasta or noodles (200g) and two medium or four small potatoes (120g).

Estimation of nutrient intakes

Nutrients intakes were estimated using Nutritics© software which contains food composition data from McCance and Widdowson's The Composition of Foods, seventh edition and sixth edition (Food Standards Agency, 2002, Food Standards Agency, 2015) and was updated with the Irish food composition database (Black *et al.*, 2011). The Irish food composition database supplements the UK food composition data and includes recipes of composite dishes, dietary supplements, fortified foods, generic Irish foods and new foods on the market. The collection of food composition data at brand-level in the current study allows for the best possible estimates of nutrient intakes for school-aged children in Ireland.

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

Using descriptive frequencies, the percent contribution of 'cereals, grains & potatoes' and each sub group ('total bread', 'breakfast cereals', 'pasta, rice & savouries' and 'potatoes & potato products') to 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 for individuals in the population group as opposed to investigating the sources of a nutrient within the food supply.

Statistical analysis

The mean, standard deviation, median and interquartile range values (g/d) were calculated for 'cereals, grains & potatoes' and each sub group ('total bread', 'breakfast cereals', 'pasta, rice & savouries' and 'potatoes & potato products') using SPSS® Version 24.0 for Windows (SPSS Inc., Chicago, and IL.USA). Differences in mean daily intakes of food groups (g/d) between boys and girls, age groups (5-8y & 9-12y) and between the NCFS II (2017-18) and NCFS (2003-04) were assessed using independent sample t-tests regardless of normality (due to the large sample size). As sample size increases so does the robustness of t-tests to identify deviations from normality, thus parametric tests are recommended for large samples (Fagerland, 2012). To minimise type 1 errors (as a result of multiple testing), the Bonferoni

adjustment was used by dividing the alpha level (0.5) by the number of comparisons. Therefore, the mean intake of the food groups were considered to be significantly different from each other if $P < 0.001$. Also due to the large sample in this study, even a small difference between group means was highly statistically significant. Thus, greater emphasis was placed on a descriptive, rather than a formal statistical analysis of the data.

Results

Table 1 presents the mean daily intake (MDI) of 'cereals, grains & potatoes' in school-aged children (5-12y) in Ireland in the total population and in consumers only.

'Cereals, grains & potatoes' were consumed by all children (100%) with an MDI of 271g/d. 'Total bread' was consumed by 99% of children with an MDI of 85g/d in the total population, of which 53g was from 'white bread', 25g from 'wholemeal & brown bread' and a further 7g from 'other breads' (e.g. garlic breads, fruit breads, scones). 'Breakfast cereals' were consumed by 91% of children with an MDI of 53g/d in the total population, of which 25g was from 'porridge & hot oat cereals', 16g from 'high fibre cereals' and a further 13g from 'low fibre cereals'. 'Pasta, rice & savouries' were consumed by 89% of children with an MDI of 72g/d in the total population of which 25g was from 'pasta', 12g was from 'rice', 7g was from 'other cereals', 19g was from 'pizza' and 16g was from 'other savouries'. 'Potatoes & potato products' were consumed by 92% of children with an MDI of 61g/d in the total population, of which 32g was from 'boiled, baked & mashed potatoes', 23g from 'chipped, fried & processed potatoes' and a further 6g from 'processed & homemade potato products' **(Table 1)**.

Compliance with FBDG

The MDI of 271g/d for 'cereals, grains & potatoes' equated to approximately 3.7 servings per day of which 1.4 servings were from 'total bread', 0.9 servings from 'RTEBC', 0.6 servings from 'porridge', 0.3 servings from 'pasta, rice & savouries' and 0.5 servings from 'potatoes & potato products'. Of the 3.7 servings, only 1.7 servings were from wholemeal & brown cereal products and unprocessed potatoes (as per recommendations). This comprised of 0.4 servings from 'wholemeal bread', 0.5 servings from 'high fibre cereals', 0.6 servings from 'porridge' and 0.2 servings from unprocessed potatoes.

Table 2 presents the MDI of 'cereals, grains & potatoes' in school-aged children in Ireland split by sex.

Boys had a higher MDI of overall 'cereals, grains & potatoes' (287g/d) compared to girls (255g/d) which was attributable to the higher intake of 'total bread' (boys: 93g/d, girls: 59g/d) and 'white bread' (boys: 72g/d, girls: 47g/d) in boys . When intakes were adjusted for energy (data not shown), there were no significant differences in the MDI of overall 'cereals, grains & potatoes', 'total bread' and 'white bread' indicating that the higher intakes of these food groups in boys was due to an overall higher energy intake **(Table 2)**.

Table 3 presents the MDI of 'cereals, grains & potatoes' in school-aged children in Ireland split by age group (5-8y and 9-12y).

When compared to younger children, older children had a higher MDI of 'cereals, grains & potatoes' (9-12 y: 290g/d, 5-8 y: 251g/d) which was attributable to the higher intake of 'white bread' (9-12 y: 61g/d, 5-8 y: 45g/d) and 'pasta, rice & savouries' (9-12 y: 82g/d, 5-8 y: 61g/d) in older children (**Table 3)**. When intakes were adjusted for energy (data not shown), there were no significant differences in the MDI of overall 'cereals, grains & potatoes', 'white bread' and 'pasta, rice & savouries' indicating that the higher intakes of these food groups in older children was due to an overall higher energy intake **(Table 3).**

Table 4 presents the MDI of 'cereals, grains & potatoes' in the NCFS II (2017-18) compared to the NCFS (2003-04).

The MDI of total 'cereals, grains & potatoes' was similar in both surveys (NCFS II: 271g/d, NCFS: 280g/d), however there were some differences in the intakes of subgroups between the two surveys.

While there was no difference in the MDI of 'total bread' in the NCFS II (85g/d) compared to the NCFS (82g/d), the MDI of 'white bread' was lower (NCFS II: 53g/d, NCFS: 63g/d) and the MDI of 'wholemeal bread' was higher (NCFS II: 25g/d, NCFS: 12g/d) in the NCFS II. The overall intake of 'breakfast cereals' was higher in the NCFS II (53g/d) compared to the NCFS (42g/d) which was attributable to the higher intake of 'high fibre cereals' (NCFS II: 16g/d, NCFS: 11g/d) and 'porridge & hot oat

cereals' (NCFS II: 25g/d, NCFS:11g/d) while the MDI of 'low fibre cereals' was lower in the NCFS II (13g/d) compared to the NCFS (20g/d).

The MDI of 'pasta, rice & savouries' was higher in the NCFS II (72g/d) compared to the NCFS (58g/d) which was attributable to the higher intake of 'pasta' in the NCFSII (25g/d) compared to the NCFS (15g/d). The MDI of 'potatoes & potato products' was lower in the NCFS II (61g/d) compared to the NCFS (98g/d) with a lower intake of 'boiled, baked & mashed potatoes' (NCFS II: 32g/d, NCFS: 53g/d) and a lower intake of 'chipped, fried & roasted potatoes' (NCFS II: 23g/d, NCFS: 40g/d) **(Table 4)**.

Table 5 presents the percent contribution (%) of 'cereals, grains & potatoes' to energy and nutrient intakes in the diets of children aged 5-12 years in Ireland.

Overall 'cereals, grains & potatoes' contributed 37% of energy intake comprising of 14% from 'total bread', 9% from 'breakfast cereals', 9% from 'pasta, rice & savouries' and 6% from 'potatoes & potato products'. 'Cereals, grains & potatoes' also contributed 51% of carbohydrate intake, 30% of protein intake, 19% of total fat intake and 56% of DF intake in the diets of school-aged children in Ireland.

'Cereals, grains & potatoes' contributed 15% of saturated fat intake with 'total bread', 'breakfast cereals', 'potato and potato products' and 'pasta, rice & savouries' making similar contributions (3-5%) to these intakes in school-aged children. 'Cereals, grains & potatoes' contributed 13% of free sugar intake in school-aged children with 11% coming from 'breakfast cereals'. 'Cereals, grains & potatoes' contributed 36% of sodium intake in children with 'total bread' accounting for 22% of sodium intake and 'pasta rice & savouries' and 'breakfast cereals' contributing 5-7%.

'Cereals, grains & potatoes' contributed 16-51% of B vitamin intakes and contributed 27% of vitamin D intake. Of this, 'breakfast cereals' contributed 30% of dietary folate equivalents (DFE) intake, 23% of vitamin D intake, 22% of riboflavin intake, 18% of thiamin intake, 18% of vitamin B6 intake, 14% of niacin intake and 12% of vitamin B12 intake. 'Total bread' contributed 15% of thiamin intake, 12% of niacin intake and 12% of DFE intake.

'Cereals, grains & potatoes' contributed 56% of iron intake, 39% of magnesium intake, 33% of calcium intake, 32% of zinc intake and 30% of potassium intake.

Of this, ‘breakfast cereals’ contributed 28% of iron intake and 10% of magnesium intake. ‘Total bread’ contributed 18% of iron intake, 18% of calcium intake, 14% of magnesium intake and 12% of zinc intake. ‘Potato and potato products’ contributed 13% to potassium intake **(Table 5)**.

Table 1. Mean daily intake (g/d) of 'cereals, grains & potatoes' (in the total population and consumers only) in children aged 5-12 years in Ireland (n 600)

	Total population		Consumers only		
	Mean ± SD	Median (IQR)		Mean ± SD	Median (IQR)
	g/d		%	g/d	
Total intake of 'cereals, grains & potatoes'	**271 ± 97**	**261 (201-330)**	**100**	**271 ± 97**	**261 (201-330)**
Total bread	**85 ± 45**	**78 (54-108)**	**99**	**86 ± 45**	**78 (54-108)**
of which					
White bread	53 ± 42	48 (21-74)	89	60 ± 40	54 (31-81)
Wholemeal & brown bread	25 ± 36	8.5 (0.0-40)	54	47 ± 37	38 (19-65)
Other breads (e.g. garlic bread, fruit breads, scones)	7.2 ± 17	0.0 (0.0-7.5)	27	26 ± 22	20 (12-35)
Breakfast cereals	**53 ± 53**	**38 (19-70)**	**91**	**58 ± 52**	**42 (24-72)**
of which					
Ready-to-eat breakfast cereals	28 ± 23	25 (10-40)	85	33 ± 22	28 (18-44)
High fibre cereals (≥6g/100g)	16 ± 20	9.3 (0.0-25)	59	26 ± 20	20 (11-33)
Low fibre cereals (< 6g/100g)	13 ± 17	5.3 (0.0-21)	54	23 ± 18	20 (11-31)
Porridge & hot oat cereals (made up)	25 ± 51	0.0 (0.0-30)	28	90 ± 59	72 (44-130)
Pasta, rice & savouries	**72 ± 61**	**57 (27-104)**	**89**	**81 ± 59**	**64 (40-110)**
of which					
Pasta	25 ± 35	11 (0.0-41)	53	47 ± 36	38 (24-62)
Rice	12 ± 23	0.0 (0.0-17)	32	36 ± 28	29 (18-45)
Other cereals (e.g. noodles, couscous, quinoa)	6.8 ± 23	0.0 (0.0-0.0)	16	43 ± 44	29 (15-55)
Pizza	19 ± 33	0.0 (0.0-28)	37	51 ± 36	39 (26-71)
Other savouries (e.g. fried rice)	9.4 ± 23	0.0 (0.0-5.0)	26	36 ± 33	28 (13-49)
Potatoes & potato products	**61 ± 49**	**51 (26-87)**	**92**	**66 ± 47**	**56 (30-90)**
of which					
Boiled, baked & mashed potatoes	32 ± 36	23 (0.0-50)	65	49 ± 34	40 (24-64)
Chipped, fried & roasted potatoes	23 ± 29	16 (0.0-34)	65	36 ± 29	28 (16-47)
Processed & homemade potato products	6.1 ± 20	0.0 (0.0-0.0)	18	33 ± 35	24 (15-39)

Table 2. Mean daily intake (g/d) of 'cereals, grains & potatoes' in children (5-12 y) in Ireland (n 600) split by sex

	Boys (n 300)		Girls (n 300)	
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
	g/d		g/d	
Total intake of 'cereals, grains & potatoes'	**287 ± 103**	**276 (209-342)**	**255 ± 87†**	**248 (192-313)**
Total bread	**93 ± 102**	**86 (58-114)**	**78 ± 84†**	**73 (50-102)**
of which				
White bread	59 ± 47	54 (22-84)	47 ± 35†	41 (20-69)
Wholemeal & brown bread	27 ± 39	7.9 (0.0-41)	23 ± 31	8.7 (0.0-40)
Other breads (e.g. garlic bread, fruit breads, scones)	6.7 ± 15	0.0 (0.0-1.9)	7.7 ± 18	0.0 (0.0-9.5)
Breakfast cereals	**58 ± 58**	**41 (21-72)**	**49 ± 47**	**35 (18-69)**
of which				
Ready-to-eat breakfast cereals	30 ± 25	27 (10-43)	26 ± 21	22 (9.3-36)
High fibre cereals (≥6g/100g)	16 ± 21	10 (0.0-25)	15 ± 19	9.0 (0.0-23)
Low fibre cereals (< 6g/100g)	14 ± 19	5.4 (0.0-22)	11 ± 15	5.3 (0.0-19)
Porridge & hot oat cereals (made up)	28 ± 57	0.0 (0.0-26)	23 ± 43	0.0 (0.0-36)
Pasta, rice & savouries	**70 ± 61**	**56 (25-104)**	**74 ± 62**	**59 (30-104)**
of which				
Pasta	26 ± 40	0.0 (0.0-42)	24 ± 29	14 (0.0-40)
Rice	10 ± 19	0.0 (0.0-14)	14 ± 27	0.0 (0.0-19)
Other cereals (e.g. noodles, couscous, quinoa)	6.4 ± 25	0.0 (0.0-0.0)	7.2 ± 22	0.0 (0.0-0.0)
Pizza	21 ± 35	0.0 (0.0-32)	17 ± 31	0.0 (0.0-26)
Other savouries (e.g. fried rice)	7.0 ± 18	0.0 (0.0-0.0)	12 ± 27	0.0 (0.0-11)
Potatoes & potato products	**66 ± 53**	**56 (28-96)**	**55 ± 44**	**48 (23-78)**
of which				
Boiled, baked & mashed potatoes	34 ± 39	24 (0.0-57)	29 ± 32	20 (0.0-48)
Chipped, fried & roasted potatoes	26 ± 31	17 (0.0-40)	21 ± 27	13 (0.0-29)
Processed & homemade potato products	6.4 ± 23	0.0 (0.0-0.0)	5.7 ± 16	0.0 (0.0-0.0)

†Statistically different (P<0.001) from that of boys within rows via independent sample t-tests adjusted for multiple testing

Table 3. Mean daily intake (g/d) of 'cereals, grains & potatoes' in children (5-12 y) in Ireland (n 600) split by age group

	5-8 years (n 300)		9-12 years (n 300)	
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
	g/d		g/d	
Total intake of 'cereals, grains & potatoes'	**251 ± 92**	**236 (187-306)**	**290 ± 98†**	**280 (212-346)**
Total bread	**79 ± 85**	**75 (53-102)**	**91 ± 100**	**84 (55-113)**
of which				
White bread	45 ± 35	40 (18-66)	61 ± 46†	55 (27-83)
Wholemeal & brown bread	26 ± 33	13 (0.0- 40)	25 ± 38	0.0 (0.0-40)
Other breads (e.g. garlic bread, fruit breads, scones)	8.6 ± 17	0.0 (0.0-12)	5.8 ± 16	0.0 (0.0-0.0)
Breakfast cereals	**55 ± 55**	**39 (18-69)**	**52 ± 50**	**37 (20-71)**
of which				
Ready-to-eat breakfast cereals	25 ± 20	21 (8.7-37)	31 ± 25	28 (11-45)
High fibre cereals (≥6g/100g)	14 ± 18	8.2 (0.0-22)	17 ± 22	10 (0.0-26)
Low fibre cereals (< 6g/100g)	11 ± 15	5.0 (0.0-18)	14 ± 19	6.5 (0.0-24)
Porridge & hot oat cereals (made up)	30 ± 55	0.0 (0.0-43)	21 ± 47	0.0 (0.0-0.0)
Pasta, rice & savouries	**61 ± 57**	**50 (21-86)**	**82 ± 64†**	**68 (35-120)**
of which				
Pasta	23 ± 35	6.8 (0.0-34)	27 ± 35	16 (0.0-47)
Rice	11 ± 23	0.0 (0.0-17)	12 ± 24	0.0 (0.0-18)
Other cereals (e.g. noodles, couscous, quinoa)	5.3 ± 22	0.0 (0.0-0.0)	8.2 ± 24	0.0 (0.0-0.0)
Pizza	15 ± 27	0.0 (0.0-25)	23 ± 37	0.0 (0.0-35)
Other savouries (e.g. fried rice)	7.3 ± 20	0.0 (0.0-0.0)	11 ± 26	0.0 (0.0-11)
Potatoes & potato products	**56 ± 44**	**48 (25-81)**	**65 ± 53**	**56 (26-91)**
of which				
Boiled, baked & mashed potatoes	30 ± 34	21 (0.0-48)	33 ± 38	25 (0.0-52)
Chipped, fried & roasted potatoes	19 ± 24	13 (0.0-28)	27 ± 32	20 (0.0-42)
Processed & homemade potato products	6.7 ± 22	0.0 (0.0-0.0)	**5.5 ± 17**	**0.0 (0.0-0.0)**

†Statistically different (P<0.001) from that of 5-8 years within rows via independent sample t-tests adjusted for multiple testing

Table 4. Mean daily intake (g/d) of 'cereals, grains & potatoes' in children (5-12 y) in the NCFS II (2017-18) and the NCFS (2003-04) with the percent of consumers (%) in each survey

	NCFS II (n 600)			NCFS (n 594)		
	Mean ± SD	Median (IQR)	Consumer	Mean ± SD	Median (IQR)	Consumer
	(g/d)		%	(g/d)		%
Total intake of 'cereals, grains & potatoes'	**271 ± 97**	**261 (201-330)**	**100**	**280 ± 93**	**270(218-328)**	**100**
Total bread	**85 ± 45**	**78 (54-108)**	**99**	**82 ± 39**	**76 (55-102)**	**100**
of which						
White bread	53 ± 42	48 (21-74)	89	63 ± 37†	57 (36-83)	98
Wholemeal & brown bread	25 ± 36	8.5 (0.0-4.0)	54	12 ± 24†	0.0 (0.0-14)	40
Other breads (e.g. garlic bread, fruit breads, scones)	7.2 ± 17	0.0 (0.0-7.5)	27	7.2 ± 13	0.0 (0.0-10)	40
Breakfast cereals	**53 ± 53**	**38 (19-70)**	**91**	**42 ± 40†**	**32 (18-54)**	**94**
of which						
Ready-to-eat breakfast cereals	28 ± 23	25 (10-40)	85	31 ± 24	27 (13-42)	93
High fibre cereals (≥6g/100g)	16 ± 20	9.3 (0.0-25)	59	11 ± 17†	3.1(0.0-16)	54
Low fibre cereals (< 6g/100g)	13 ± 17	5.3 (0.0-21)	54	20 ± 21†	15 (3.7-30)	79
Porridge & hot oat cereals (made up)	25 ± 51	0.0 (0.0-30)	28	11 ± 36†	0.0 (0.0-0.0)	17
Pasta, rice & savouries	**72 ± 61**	**57 (27-104)**	**89**	**58 ± 50†**	**47 (21-81)**	**89**
of which						
Pasta	25 ± 35	11 (0.0-41)	53	15 ± 24†	0.0 (0.0-25)	46
Rice	12 ±23	0.0 (0.0-17)	32	10 ± 19	0.0 (0.0-14)	36
Other cereals (e.g. noodles, couscous, quinoa)	6.8 ±23	0.0 (0.0-0.0)	16	5.4 ± 17	0.0 (0.0-0.0)	16
Pizza	19 ±33	0.0 (0.0-28)	37	15 ± 23	4.1 (0.0-23)	51
Other savouries (e.g. fried rice)	9.4 ±23	0.0 (0.0-5.0)	26	12 ± 23	0.0 (0.0-17)	42
Potatoes & potato products	**61 ±49**	**51 (26-87)**	**92**	**98 ± 57†**	**88 (57-129)**	**100**
of which						
Boiled, baked & mashed potatoes	32 ± 36	23 (0.0-50)	65	53 ± 49†	41 (17-77)	88
Chipped, fried & roasted potatoes	23 ± 29	16 (0.0-34)	65	40 ± 32†	33 (16-57)	89
Processed & homemade potato products	6.1 ± 20	0.0 (0.0-0.0)	18	5.6 ± 15	0.0 (0.0-5.9)	28

†Statistically different (P<0.001) from that of NCFS II via independent sample t-tests and adjusted for multiple testing

Table 5. The percent contribution (%) of 'cereals, grains & potatoes' to energy and nutrients in the diets of children aged 5-12 years in Ireland (n 600)

	Cereals, grains & potatoes		**Bread**		**Breakfast cereals**		**Pasta, rice & savouries**		**Potato & potato products**	
	Mean	**%**	**Mean**	**%**	**Mean**	**%**	**Mean**	**%**	**Mean**	**%**
Energy (kcal)	**559**	**37.5**	215	14.3	132	8.9	129	8.7	82.7	5.5
Protein (g)	**17.5**	**30.2**	7.7	13.2	3.6	6.3	4.7	8.2	1.5	2.6
Total fat (g)	**10.6**	**19.3**	2.9	5.2	1.9	3.4	3.1	5.7	2.7	4.9
Saturated fat (g)	**3.4**	**15.0**	0.8	3.7	0.7	3.1	1.2	5.3	0.6	2.9
Carbohydrate (g)	**102**	**51.5**	42.0	21.1	24.6	12.4	21.8	11.0	13.9	7.0
Total sugars (g)	**10.0**	**14.1**	3.2	4.6	5.0	7.0	1.1	1.6	0.6	0.8
Free sugars (g)	**4.6**	**12.8**	0.4	1.1	3.9	11.0	0.3	0.7	0.0	0.0
Dietary fibre (g)	**7.9**	**56.1**	3.2	22.8	2.2	15.0	1.3	9.6	1.2	8.6
Thiamin (mg)	**0.6**	**46.0**	0.2	14.8	0.3	18.1	0.1	5.6	0.1	7.5
Riboflavin (mg)	**0.5**	**31.5**	0.1	4.9	0.4	22.1	0.0	3.0	0.0	1.5
Total Niacin (mg)	**10.3**	**36.1**	3.4	12.2	4.2	14.5	1.8	6.5	0.8	3.0
Vitamin B6 (mg)	**0.5**	**31.2**	0.1	5.9	0.3	17.9	0.0	2.4	0.1	4.9
Vitamin B12 (µg)	**0.7**	**16.4**	0.0	0.6	0.5	11.7	0.1	3.8	0.0	0.3
Total Folate (µg)	**98.7**	**47.7**	26.6	13.8	54.1	24.3	6.5	3.5	11.6	6.1
Dietary folate equivalents (µg)	**129**	**51.3**	27.3	12.4	83.5	30.4	6.5	3.1	11.6	5.4
Vitamin A (µg)	**34.1**	**7.4**	5.1	1.1	8.2	1.6	15.5	3.6	5.2	1.1
Vitamin D (µg)	**1.1**	**26.8**	0.0	1.0	1.0	23.4	0.0	2.3	0.1	0.2
Vitamin E (µg)	**1.3**	**21.2**	0.2	3.0	0.4	5.3	0.4	6.8	0.4	6.0
Vitamin C (mg)	**8.6**	**16.3**	0.1	0.2	1.8	3.2	0.5	1.0	6.1	11.9
Sodium (mg)	**606**	**36.4**	373	22.2	80.5	5.2	118	6.9	34.3	2.1
Potassium (mg)	**603**	**30.2**	149	7.7	107	5.3	73.8	4.0	274	13.3
Calcium (mg)	**251**	**32.7**	130	17.6	65.8	7.7	46.6	6.2	8.4	1.2
Iron (mg)	**5.1**	**55.6**	1.5	17.6	2.8	28.0	0.6	6.6	0.3	3.8
Magnesium (mg)	**75.8**	**39.3**	26.8	13.8	21.4	10.7	13.4	7.2	14.2	7.7
Zinc (mg)	**2.2**	**31.5**	0.8	11.7	0.7	9.1	0.5	8.0	0.2	2.7

Discussion

The aim of this study was to use data from the recent NCFS II (2017-18) to estimate the intake of 'cereals, grains & potatoes' in children aged 5-12y in Ireland and to investigate the contribution of this food group to energy and nutrient intakes in this population group. Overall, 'cereals, grains & potatoes' were consumed by 100% of school-aged children in Ireland with a mean daily intake of 271g/d. This intake equated to approximately 3.7 servings per day of all 'cereals, grains & potatoes', of which 1.7 servings were from wholemeal & brown cereal foods and unprocessed potatoes. 'Cereals, grains & potatoes' made significant contributions to intakes of energy (37%), carbohydrate (51%), protein (30%), DF (56%), B vitamins (16-51%), vitamin D (27%), iron (56%) and other minerals (calcium, zinc, potassium and magnesium) (30-39%) in this population group. Relative to the contribution to energy intake (37%), 'cereals, grains & potatoes' made relatively small contributions to intakes of total fat (19%), saturated fat (15%) and free sugar (13%) and a similar contribution to intake of sodium (36%). When compared to the previous NCFS (2003-04), the overall intake of 'cereals, grains & potatoes' was similar in both surveys. However, intakes of 'white bread', 'low fibre cereals' and 'potato and potato products' were lower in the NCFS II while the intakes of 'wholemeal & brown bread', 'high fibre cereals', 'porridge & hot oat cereals' and 'pasta, rice and savouries' were higher.

Intakes of 'cereals, grains & potatoes' and compliance with FBDG

The NCFS II showed that children aged 5-12 years in Ireland had an average intake of 271g/d of 'cereals, grains & potatoes' which included 85g/d of 'total bread', 53g/d of 'breakfast cereals' ('RTEBC' and 'porridge & hot oat cereals'), 72g/d of 'pasta, rice & savouries' and 61g/d of 'potatoes & potato products'. When compared with girls, boys had a higher intake of 'cereals, grains & potatoes' (boys: 287g/d, girls: 255g/d) and a higher amount of total bread (boys: 93g/d, girls: 78g/d) and 'white bread' (boys: 59g/d, girls: 47g/d). When compared with younger children (5-8y), older children (9-12y) had a higher intake of overall 'cereals, grains & potatoes' (9-12y: 290 g/d, 5-8y: 251g/d), 'white bread' (9-12y: 61g/d, 5-8 y: 45g/d) and 'pasta, rice & savouries' (9-12 y: 82g/d, 5-8y: 61g/d). However, when adjusted for energy intake, there were no significant differences between sex or age groups indicating that the higher intakes of hese food groups in boys and older children was due to an overall higher energy intake.

The Irish FBDG recommend a daily intake of 3 to 5 servings of wholemeal cereals and breads, potatoes, pasta and rice for children aged 5 years and over (Department of Health, 2017). Findings from the NCFS II showed that school-aged children (5-12y) in Ireland consumed approximately 3.7 servings per day of all 'cereals, grains & potatoes', however only 1.7 servings were brown & wholemeal cereals or unprocessed potatoes which is well below the recommendations set for this food group.

Despite some variations in the classification of cereals and cereal products, intakes of 'cereals, grains & potatoes' Irish school-aged children can be broadly compared with other countries. Intakes of 'cereals, grains & potatoes' in Irish children (271g/d) were similar to intakes reported in other countries such as Italy (285g/d), the UK (285g/d), Denmark (256g/d) and the Netherlands (250g/d) (Leclercq *et al.*, 2009, Van Rossum *et al.*, 2011, Pedersen *et al.*, 2014, Public Health England, 2014). While potato intakes were not reported in some countries including Spain, Turkey and Germany, intakes of cereals & grains (excluding potatoes) in Irish children (210g) was similar to intakes in children in Germany (211g/d) and Turkey (187g/d) but higher than intakes in Spanish children (168g/d) (Alexy, 2010, Republic of Turkey Ministry of Health, 2016, Partearroyo *et al.*, 2019).

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

The current study found that 'cereals, grains & potatoes' made significant contributions to energy and important nutrients in the diets of children (5-12y) in Ireland. 'Cereals, grains & potatoes' contributed 37% of energy intakes comprising of 14% from 'total bread, 9% from 'breakfast cereals', 9% from 'pasta, rice & savouries' and 6% from 'potatoes & potato products'. In keeping with these findings, 'cereals, grains & potatoes' contributed to similar proportions of energy in the Netherlands (28%), Spain (30%), Denmark (31%), Italy (43%) and the UK (44%) (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018). The NCFS II also showed that 'cereals, grains & potatoes' contributed 51% of carbohydrate, 30% of protein, 19% of total fat and 56% of DF intake. In keeping with our findings, 'cereals, grains & potatoes' contributed between 43-57% of carbohydrate intakes in Denmark, the Netherlands, the UK and Spain and up to 70% of carbohydrate intakes in Italy. 'Cereals, grains & potatoes' also contributed to 18-

32% of protein, 10-31% of total fat intakes and 44-60% of DF intakes in these European countries (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018). These findings demonstrate the role of 'cereals, grains and potatoes' as a key energy and macronutrient source in children, hence the importance of the nutritional quality of this food group and the varieties chosen within it.

In the current study, 'cereals, grains & potatoes' made relatively small contributions to intakes of saturated fat (15%) and free sugar (13%) yet a higher contribution to intake of sodium (36%) in Irish children. For saturated fat, 'total bread', 'breakfast cereals', 'potatoes & potato products' and 'pasta, rice & savouries' made similar contributions to overall intake from this food group while previous findings from the NCFS II showed that other food groups such as 'meat & meat products', milks and 'top shelf' foods ('biscuits, cakes & pastries', and 'sugars, confectionery, preserves & savoury snacks') contributed 18, 15 and 21% of saturated fat intake in this cohort, respectively (IUNA, 2019).

While 'RTEBC' contributed 11% of free sugar intake in this study, previous findings from the NCFS II showed that 53% of free sugar intake in Irish children was provided by 'top shelf' foods (IUNA, 2019).

In comparison to our study, 'cereals, grains & potatoes' contributed to similar intakes of saturated fat in Italy and Spain (13-14%) (Sette *et al.*, 2013, Ruiz *et al.*, 2016), lower intakes of saturated fat in Denmark and the Netherlands (6%) (Van Rossum *et al.*, 2011, Pedersen *et al.*, 2014) and contributed to higher intakes of saturated fat in the UK (29%) (Public Health England, 2018).

In contrast to our study, 'cereals, grains & potatoes' contributed much higher intakes of free sugar (33%) in Spain and the UK (Ruiz *et al.*, 2016, Public Health England, 2018). The inclusion of bakery products and puddings as cereal products in both the UK and Spain may partly explain the higher saturated fat and free sugar intakes from cereals products in children in these countries. In the current study, 22% of sodium intake came from 'total bread'. When compared to our study, Denmark and the UK reported a similar contribution to salt intakes (23-38%) from 'cereals, grains & potatoes'(Pedersen *et al.*, 2014, Public Health England, 2018). Despite the introduction and success of the salt reduction programme to decrease the sodium

content in food products in Ireland (FSAI, 2003), bread still contributed 22% of sodium intakes in Irish children, similar to fifteen years ago (IUNA, 2005).

In terms of micronutrient intakes, this study showed that 'cereals, grains & potatoes' made significant contributions to intakes of B vitamins (16-51%), vitamin D (27%), iron (56%) and other minerals (calcium, zinc, magnesium and potassium) (30-39%) in the diets of school-aged children in Ireland. The contribution of 'cereals, grains & potatoes' to these micronutrients in this study is mainly attributable to fortified RTEBCs and wheat products made from fortified flour. RTEBCs in Ireland are typically fortified with an array of B-vitamins, vitamin D and iron accounting for 12-30% of B-vitamin intake, 23% of vitamin D intake and 28% of iron intakes in this study. Additionally, wheat flour is mandatorily fortified with iron, thiamin and calcium to restore losses during the milling process (Foods Standard Agency, 1998), resulting in 'total bread' contributing to 15% of thiamin, 18% of iron and 18% of calcium intakes in Irish children. In comparison to our findings, 'cereals grains & potatoes' contributed to lower intakes of B vitamins (11-40%) in Denmark, Italy, the Netherlands, the UK and Spain (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Mielgo-Ayuso *et al.*, 2017, Public Health England, 2018) but made similar contributions to intakes of vitamin D (22-31%) in Italy and the UK (Sette *et al.*, 2013, Public Health England, 2018). In keeping with our study, 'cereals, grains & potatoes' made similar contributions to intakes of iron (31-60%), calcium (9-37%), potassium (22-33%) and magnesium (30-36%) in Denmark, Italy, the Netherlands and the UK (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Mielgo-Ayuso *et al.*, 2018, Public Health England, 2018) and similar contributions to intakes of zinc (22-31%) in Denmark, Italy, the Netherlands, the UK and Spain (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Olza *et al.*, 2017, Public Health England, 2018). Findings from our study indicate that fortified cereal products are an important source of energy and micronutrients in the diets of school-aged children. However, refined cereal products also contributed to intakes of saturated fat, free sugar and sodium in this population group. The food industry have an important role in ensuring that benefits of the fortified cereal products are not outweighed by poorer dietary quality in terms of their of saturated fat, free sugar and sodium content.

Changes in intakes of 'cereals grains & potatoes' between NCFS II and NCFS

When compared to the previous NCFS (2003-04), Irish children had similar intakes of 'cereals, grains & potatoes' in 2017-18 (NCFS II: 271g/d, NCFS: 280g/d), however, there were some changes within subcategories between the two surveys. Irish children still mainly consume refined cereal products but the intake of wholemeal cereal foods has increased over time. While overall bread intakes remained the same (85g/d for both surveys), the intake of 'white bread' was lower in the NCFS II (53g/d) compared to the NCFS (63g/d) and the intake of 'wholemeal bread' was higher than in the NCFS (NCFS II: 25g/d, NCFS: 12g/d). Overall 'breakfast cereal' intake was higher in the NCFS II (53g/d) compared to the NCFS (42g/d) which was attributable to the higher intake of 'high fibre cereals' (NCFS II: 16g/d, NCFS: 11g/d) and 'porridge & hot oat cereals' (NCFS II: 25g/d: NCFS: 11g/d) while the intake of of 'low fibre cereals' was lower than previously reported (NCFS II: 13g/d, NCFS: 20g/d). The intake of 'pasta, rice & savouries' was higher in the NCFS II (72g/d) compared to the NCFS (58g/d), in particular the intake of 'pasta' (NCFS II: 25g/d: NCFS: 15g/d), and the intake of 'potatoes & potato products' was lower than reported fifteen years ago (NCFS II: 61g/d, NCFS: 98g/d). Whilst there has been a positive shift in the intake of wholemeal and brown cereal products over the last fifteen years, Irish children are still consuming mainly refined cereal products.

Strengths and limitations

The key strengths of this study are the nationally representative sample of children aged 5-12 years in Ireland included in the NCFS II and the detailed dietary intake data collected through a 4-day weighed food diary. Another important strength of this study includes the detailed food composition data, in particular 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. Misreporting or under reporting of energy intake is a known limitation with all dietary assessment and may be a source of bias. This issue was minimised by extensive training and the high level of researcher-participant interaction (three visits over the 4-day period) by trained research nutritionists.

Conclusion

In summary, 'cereals, grains & potatoes' were consumed by 100% of school-aged children in Ireland with a mean intake of 271g/d equating to approximately 3.7 servings per day. Of the 3.7 servings, only 1.7 were of the wholemeal or brown variety or unprocessed potatoes, which is below the recommendation set for this food group of 3-5 servings of wholemeal cereals & breads, potatoes, pasta and rice. This highlights that refined cereal products such as white bread, white pasta, rice & other savouries are more widely consumed than the wholemeal varieties in Irish children and there is a need to increase the consumption of wholemeal cereal foods to comply with the FBDG.

Findings from this analysis show that overall 'cereals, grains & potatoes' contributed an array of important nutrients such as DF, B vitamins, vitamin D, iron and calcium in the diets of school-aged children in Ireland. When compared to intakes reported in the previous NCFS (2003-2004), the current data indicate that despite a higher intake of wholemeal cereal foods over time, Irish children still mainly consume refined cereal products.

This is the first study to examine the intakes and changes of cereal food consumption in children aged 5-12 years in Ireland, and may provide evidence to support public health campaigns to increase the intake of wholemeal cereal foods in this population group. Such campaigns to increase intakes of wholemeal cereal foods could include the reformulation of cereal products in the food industry, the implementation of public health campaigns to increase awareness and availability and educational programmes on the importance of wholemeal cereal foods in the diet.

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Chapter 4

The role of ‘fruit & vegetables’ in the diets of school-aged children (5-12y) in Ireland

Introduction

Fruit & vegetable intake has been shown to be associated with a reduced risk of obesity and other non-communicable diseases (WHO/FAO, 2004). Due to their low energy density and high concentration of vitamins, minerals and dietary fibre (DF), fruit and vegetables are grouped together and hold an important place in food based dietary guidelines (FBDG) across the world (Slavin and Lloyd, 2012, USDA, 2015). Vegetables have been defined as the edible parts of the plant which include stems and stalks, roots, tubers, bulbs, leaves, flowers and fruits (IARC, 2003). Fruits are a subgroup of vegetables containing seeds and pulpy surrounding tissue and are generally consumed raw as a breakfast, snack or dessert while vegetables can be consumed raw or cooked with a main dish, in a mixed dish or in a salad (IARC, 2003).

The World Health Organisation (WHO) recommend to consume a minimum of 400g of fruit & vegetables (excluding potatoes and other starchy tubers) per day for the prevention of chronic diseases such as heart disease, cancer, diabetes and obesity, as well as for the prevention and alleviation of several micronutrient deficiencies, especially in less developed countries (WHO/FAO, 2004). As the childhood years are an important period during which eating behaviours and food preferences evolve (Kelder *et al.*, 1994, Birch *et al.*, 2007), the consumption of fruit & vegetables from a young age would help develop and foster healthy eating practices for later life which may reduce the risk of developing chronic diseases.

The Irish food based dietary guidelines recommend that children over 5 years of age consume 5 to 7 servings of fruit & vegetables per day, including no more than 150ml of unsweetened fruit juice or smoothies (Department of Health, 2017). One serving of fruit consists of one medium apple, ½ cup of dried fruit or $^{2}/_{3}$ cup of tinned fruit while one serving of vegetable includes ½ cup of broccoli, ½ cup of carrots or a bowl of homemade vegetable soup (Department of Health, 2017).

Five national dietary surveys in Europe have reported intakes of fruit & vegetables in children and despite differences in the categorisation of fruit & vegetables within individual studies, intakes typically ranged from 255g to 404g/d. It is important to note that each of these studies included fruit and vegetables from composite dishes in estimates of intakes, which is particularly important as it has previously been shown that failing to account for intake from composite dishes can underestimate vegetable

intakes by 52% in children and up to 26% in adults (O'Brien *et al.*, 2003, McCarthy *et al.*, 2018). Furthermore data from these studies of European children has shown that fruit & vegetables made low contributions to energy (6-9%) yet significant contributions to intakes of carbohydrates (8-19%), total sugar (31-50%), DF (25-37%), vitamin A (26-46%), vitamin C (32-83%), B vitamins (6-25%), potassium (16-29%) and magnesium (12-19%) while also contributing to intakes of free sugar where examined (7-12%) (Leclercq *et al.*, 2009, Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Van Rossum *et al.*, 2016, Olza *et al.*, 2017, Mielgo-Ayuso *et al.*, 2018, Public Health England, 2018, Partearroyo *et al.*, 2019).

The recent National Children's Food Survey II (NCFS II) (2017-18) in Ireland has collected detailed dietary intake data in a nationally representative sample of children aged 5-12 years. The aim of this study is to use data from the NCFS II to estimate the intake of fruit & vegetables, compliance with food based dietary guidelines and to examine the contribution of fruit & vegetables to overall energy and nutrient intakes in school-aged children (5-12 y) in Ireland. A further aim is to identify any changes in the intake of fruit & vegetables in children (5-12y) in Ireland since the previous NCFS (2003-04) which used a similar methodology.

Methodology

The analyses for this chapter are based on data from the National Children's Food Survey II (NCFS II) which was a nationally representative cross-sectional study that collected food and beverage consumption data from 600 children aged 5-12 years in the Republic of Ireland between 2017 and 2018. The methodology for sampling, participant recruitment, data collection and food quantification for NCFS II is described in detail in chapter 2, with methods specific to this chapter outlined below. Findings from the NCFS II can be compared to the previous NCFS (2003-04), which used a similar methodology, with the exception of the 7-day weighed food diary used in the NCFS compared to a 4-day weighed food diary used in the NCFS II. The methodology for the NCFS is outlined in detail in Chapter 2 and has also been described previously (IUNA, 2005).

Data collection and quantification

Food and beverage intake data in the NCFS II were collected using a 4-day weighed food diary. A trained researcher visited each participant in their home three times over the recording period to demonstrate how to keep the food diary, use the portable food scales that were provided, and review the diary to check for completeness. The recording period included at least one weekend day for all participants. Participants were asked to record detailed information regarding the amount, type and brand name of all foods, beverages and dietary supplements consumed over the recording period and where applicable, the cooking method used and details of recipes and any leftovers. To facilitate the collection of such data, participants were asked to collect product labels for all food, beverages and dietary supplements consumed. If product labels were unavailable, 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 NCFS II and is summarised as follows. The majority of foods and drinks (76%) were weighed directly on the portable food scales (Tanita© KD-400, 5000 x 1g) and a further 11% of weights were derived from the manufacturer's information on product labels. The remaining foods and drinks were quantified using a validated age appropriate photographic food atlas (7%) (Foster *et al.*, 2010), standard portion weights (3%) (Food Standards Agency, 2002,

Lyons *et al.*, 2013), household measures (1%) and estimates based on the child's previous eating patterns (only used when no other quantification method was appropriate) (2%).

Estimation of food group intakes

Each food and beverage consumed in the NCFS II was assigned a unique food code based on its food descriptor and nutritional profile at brand level and this food code was entered into the Nutritics© data entry system. A total of 2046 food codes were included in the NCFS II food file which were then categorised into 19 food groups and further categorised for some foods (Appendix 1).

For the purpose of this analysis, the food groups of interest were fruit and vegetables which included 'vegetables & vegetable dishes' and 'fruit & fruit juices'. Other foods were also examined to identify fruit and vegetable components which would make important contributions to intake. The fruit or vegetable component for all composite dishes was estimated using participants' recipes and ingredient lists on retail products. Examples of fruit and vegetables in composite dishes included fruit in fruit yogurt and vegetables in spaghetti bolognese. Furthermore, when estimating intakes of fruit and vegetables, adjustments were made to the total weight of the food to remove inedible or unconsumed portions such as cores and uneaten peel of fruit. 'Fruit & fruit juices' was categorised into 'discrete fruit','100% fruit juice', 'smoothies' and 'fruit in composite dishes'. 'Vegetables' was categorised into 'discrete vegetables' and 'vegetables in composite dishes.

The mean daily intake of 'fruit & vegetables' and their sub-groups was estimated for each individual by summing the weight of each food consumed in the food group and dividing the total by the number of recording days (four).

Compliance with food based dietary guidelines

The World Health Organisation (WHO) recommend that all population groups including children consume a minimum of 400g of fruit and vegetables per day (which equates to approximately five 80g servings) (WHO/FAO, 2004) while the Irish food based dietary guidelines advise the general population to consume 5 to 7 servings of fruit & vegetables per day, including no more than 150ml of unsweetened fruit juice or smoothies (Department of Health, 2017). In this study, the proportion of children

(5-12y) in Ireland meeting the WHO recommendation of a minimum of 400g (80g servings) of 'fruit & vegetables' per day and the proportion of children meeting the Irish food based dietary guidelines of ≥ 5 servings of 'fruit & vegetables' per day (limited to no more than 150ml/day of unsweetened fruit juice or smoothies) were determined (WHO/FAO, 2004). The proportion of children with ≥ 4 servings of 'fruit & vegetables' per day, ≥ 3 servings/d, ≥ 2 servings/d and ≥ 1 serving/d were also determined for both the WHO recommendations and Irish FBDG.

Estimation of nutrient intakes

Nutrients intakes were estimated using Nutritics© software which contains food composition data from McCance and Widdowson's The Composition of Foods, seventh edition and sixth edition (Food Standards Agency, 2002, Food Standards Agency, 2015) and was updated with the Irish food composition database (Black *et al.*, 2011). The Irish food composition database supplements the UK food composition data and includes recipes of composite dishes, dietary supplements, fortified foods, generic Irish foods and new foods on the market. The collection of food composition data at brand level in the current study allows for the best possible estimates of nutrient intakes for children in Ireland.

The percent contribution of 'fruit & vegetables' to energy and nutrient intakes

Using descriptive frequencies, the percent contribution of 'total fruit & vegetables' (and each sub group) to the mean daily intake of energy and nutrients were 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 for individuals in the population group as opposed to investigating the sources of a nutrient within the food supply. The contribution of 'fruit & vegetables' to energy and nutrient intakes was estimated based on intake from discrete fruit and vegetables, fruit juices and vegetable dishes (including the non-vegetable components). However, fruit and vegetables from composite dishes in other categories (e.g. meat dishes) were not included in the contribution of fruit & vegetables to energy and nutrient intakes.

Statistical analysis

The mean, standard deviation, median and interquartile range values (g/d) were calculated for 'total fruit & vegetables' and each sub group ('fruit & fruit juices', 'discrete fruit, 'fruit in composite dishes',' '100% fruit juice', 'smoothies', 'vegetables', 'discrete vegetables' and 'vegetables in composite dishes') using SPSS® Version 24.0 for Windows (SPSS Inc., Chicago, and IL.USA). Differences in mean daily intakes of food groups (g/d) between boys and girls, age groups (5-8y & 9-12y) and between the NCFS II (2017-18) and NCFS (2003-04) were assessed using independent sample t-tests regardless of normality (due to the large sample size). As sample size increases so does the robustness of t-tests to identify deviations from normality, thus parametric tests are recommended for large samples (Fagerland, 2012). To minimise type 1 errors (as a result of multiple testing), the Bonferoni adjustment was used by dividing the alpha level (0.5) by the number of comparisons. Therefore, the mean intake of the food groups were considered to be significantly different from each other if $P< 0.001$. Also due to the large sample in this study, even a small difference between group means was highly statistically significant. Thus, greater emphasis was placed on a descriptive, rather than a formal statistical analysis of the data.

Results

Table 1 presents the mean daily intake (MDI) of 'fruit & vegetables' in children (5-12y) in Ireland in the total population and in consumers only. 'Fruit & vegetables' was consumed by all children (100%) with an MDI of 221g/d. Of this, 'fruit & fruit juices' was consumed by 97% of children with an MDI of 147g/d and 'vegetables' (including those from composite dishes) was consumed by 99% of Irish children with an MDI of 74g/d.

Of the 'fruit & fruit juices' intake, the MDI of 'discrete fruit'(in the total population) was 90g/d 'fruit in composite dishes' was 9g/d, '100% fruit juice' was 38g/d and 'smoothies' was 11g/d.

Of 'vegetables' intake, the MDI of 'discrete vegetables' (in the total population) was 40g/d and 'vegetables in composite dishes' was 34g/d **(Table 1)**.

Tables 2 & 3 present the MDI intake of 'fruit & vegetables' in children (5-12y) in Ireland split by sex and age group. There were no significant differences in the MDI of 'fruit & vegetables' (or any subgroup examined) between boys and girls or between younger (5-8y) and older (9-12y) children **(Table 2 & 3)**.

Table 4 presents the MDI of 'fruit & vegetables' in the NCFS II (2017-18) compared to the NCFS (2003-04). The MDI of overall 'fruit & vegetables' was similar in both surveys (NCFS II: 221g/d, NCFS: 224g/d) however some differences were noted in the intakes of subgroups between the two surveys. The MDI of 'discrete fruit' was higher in the NCFS II (90g/d) compared to the NCFS (59g/d). The MDI of '100% fruit juice' was lower in the NCFS II (38g/d) compared to the NCFS (86g/d) while the MDI of 'smoothies' was higher in the NCFS II (11g/d) compared to the NCFS (0.6g/d). There were no significant differences in the MDI of 'vegetables' in the NCFS II (74g/d) compared to the NCFS (69g/d) or 'vegetables in composite dishes' between the two surveys (NCFS II: 34g/d, NCFS: 30g/d) **(Table 4)**.

Compliance with food based dietary guidelines

Table 5 presents the proportion (%) of children (5-12y) in Ireland meeting the recommendations for 'fruit & vegetable' consumption recommended by the (WHO) (WHO/FAO, 2004) and the Irish food based dietary guidelines (Department of Health, 2017).

The MDI of 'fruit & vegetables' (with unlimited fruit juice and smoothies) was 221g/d which equates to approximately 2.8 servings. When intake of fruit juice was limited to 150ml/d, the MDI of 'fruit and vegetables' was 212g/d (approx. 2.7 servings).This intake is below both the WHO recommendation of at least 400g of fruit and vegetables per day (WHO/FAO, 2004) and the Irish food based dietary guidelines of 5-7 servings of fruit and vegetables per day (Department of Health, 2017).

When investigating compliance at an individual level, 9% of school-aged children in Ireland met the WHO recommendation of at least 400g of fruit & vegetables per day. A total of 18% of Irish children had ≥ 4 servings of fruit & vegetables per day, 38% had ≥ 3 servings/day, 65% had ≥ 2 servings/day and 90% had ≥ 1 serving/day. When compared with the Irish food based dietary guidelines, 6% of children in Ireland had ≥ 5 servings of fruit & vegetables per day, 14% had ≥ 4 servings of fruit & vegetables per day, 37% had ≥ 3 servings/day, 60% had ≥ 2 servings/day and 90% had ≥ 1 serving/day.

Current intakes of 'fruit and vegetables' (2017-18) can be compared with the previous NCFS (2003-04) where 11% of Irish children met the WHO recommendation of at least 400g of fruit & vegetables per day with 21% having intakes ≥ 320g/d, 40% ≥ 240g/d, 62% ≥ 160g/d and 87% ≥ 80g /d. When comparing to the Irish food based dietary guidelines, 4% of Irish children in the NCFS (2003-04) had intakes of ≥ 5 servings of 'fruit & vegetables' per day, 15% had ≥ 4 servings per day, 36% ≥ 3 servings/day, 62% ≥ 2 servings/day and 87% ≥ 1 serving/day **(Table 5)**.

Table 6 presents the percent contribution (%) of 'fruit & vegetables' to energy and nutrient intakes in the diets of children aged 5-12 years in Ireland. Overall, 'fruit & vegetables' contributed 7% of energy intake with 5% from 'fruit & fruit juices' and 2% from 'vegetables including vegetable dishes'. 'Fruit & vegetables' contributed 11% of carbohydrate intake with 'fruit & fruit juices' contributing 9% and 'vegetables including vegetable dishes' contributing 2% of carbohydrate intake. 'Fruit &

vegetables' contributed 19% of DF intake with 'fruit & fruit juice' contributing 11% (9% from 'fruit') and 'vegetables including vegetables dishes' contributed 9% (8% from 'vegetables').

'Fruit & vegetables' contributed 25% of total sugar intake with 'fruit & fruit juices' contributing 22% (16% from 'fruit' and 6% from '100% fruit juice & smoothies') and 3% from 'vegetables including vegetable dishes'. For free sugar intake, 'fruit & vegetables' contributed 11% of intakes with 10% from '100% fruit juice & smoothies' and 1% from 'vegetables including vegetable dishes'.

'Fruit & vegetables' contributed 50% of vitamin C intakes with 'fruit & fruit juices' contributing 39% (23% from 'fruit' and 15% from 'fruit & fruit juices') and 'vegetables including vegetable dishes' contributing 12% of vitamin C intake. 'Fruit & vegetables' 'contributed 28% of vitamin A intakes with 'vegetables including vegetable dishes' contributing 26% and 'fruit & fruit juices' contributing 2% of vitamin A intakes. 'Fruit & vegetables' also contributed to intakes of thiamin (15%), vitamin B6 (13%) and DFE (14%) with 'fruit & fruit juices' contributing 10% of thiamin, 10% of vitamin B6 and 8% of DFE intakes. 'Vegetables including vegetable dishes' accounted for 5% of thiamin, 3% of vitamin B6 and 6% of DFE intakes.

'Fruit & vegetables' contributed 17% of potassium intake with 12% from 'fruit & fruit juices' and 5% from 'vegetable and vegetable dishes'. 'Fruit & vegetables' contributed 12% of magnesium intakes with 8% from 'fruit & fruit juices' and 4% from 'vegetable & vegetable dishes'. 'Fruit & vegetables' contributed smaller proportions of vitamin E (9%), iron (7%) protein (4%), riboflavin (5%), niacin (4%), calcium (4%), and zinc (4%) (**Table 6).**

Table 1. Mean daily intake (g/d) of 'fruit & vegetables' in children (5-12 y) in Ireland (n 600) in the NCFS II (in the total population and consumers only)

	Total population			Consumers only	
	Mean ± SD	Median (IQR)		Mean ± SD	Median (IQR)
	(g/d)		%	(g/d)	
Total fruit & vegetables	**221 ± 129**	**201 (133-291)**	**100**	**221 ± 129**	**201 (133-291)**
Fruit & fruit juices	**147 ± 115**	**125 (65-203)**	**97**	**151 ± 114**	**128 (70-207)**
Discrete Fruit	**90 ± 70**	**78 (37-122)**	**92**	**98 ± 68**	**85 (50-126)**
of which					
Apples	27 ± 30	20 (0.0-46)	63	43 ± 28	35 (22-59)
Bananas	20 ± 29	0.0 (0.0-32)	47	43 ± 29	36 (22-58)
Citrus fruits	11 ± 23	0.0 (0.0-14)	32	35 ± 29	24 (15-42)
Other fruits*	32 ± 43	16 (0.0-48)	64	50 ± 44	35 (19-70)
Fruit in composite dishes	**8.9 ± 14**	**4.7 (1.2-11)**	**84**	**11 ± 14**	**6.2 (2.7-13)**
100% fruit juice	**38 ± 75**	**0.0 (0.0-57)**	**40**	**94 ± 94**	**75 (42-110)**
Smoothies	**11 ± 36**	**0.0 (0.0-0.0)**	**12**	**94 ± 55**	**84 (50-135)**
Vegetables	**74 ± 49**	**67 (38-99)**	**99**	**75 ± 49**	**68 (38-99)**
Discrete vegetables	**40 ± 38**	**30 (10-62)**	**85**	**47 ± 37**	**39 (20-70)**
of which					
Peas, beans & lentils	11 ± 21	0.0 (0.0-15)	45	24 ± 26	17 (8.5-31)
Baked beans	*6.7 ± 19*	*0.0 (0.0-0.0)*	*20*	*33 ± 29*	*25 (15-42)*
Carrots	9.3 ± 14	2.5 (0.0-13)	52	18 ± 15	13 (7.2-24)
Green vegetables	6.0 ± 11	0.0 (0.0-10)	38	16 ± 12	13 (7.5-21)
Other vegetables **	14 ± 20	5.3 (0.0-21)	59	24 ± 21	17 (9.0-34)
Vegetables in composite dishes	**34 ± 32**	**25 (10-49)**	**95**	**36 ± 32**	**27 (12-50)**

*Includes avocados, blackberries, nectarines, grapefruit, kiwi, mangoes, melon, olives, peaches, pears, pineapple, plums, dried fruit etc. (≤10g)
**Includes cauliflower, celery, courgette, garlic, lettuce, mushrooms, onions, parsnip, pepper, sweetcorn, tomatoes, turnips, tinned & jarred vegetables etc. (< 6g)

Table 2. Mean daily intake (g/d) of 'fruit & vegetables' in children (5-12 y) in Ireland split by sex in the NCFS II

	Boys (n 300)		Girls (n 300)	
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
	(g/d)		(g/d)	
Total fruit & vegetables	**228 ± 141**	**204 (131-294)**	**215 ± 114**	**194 (136-288)**
Fruit & fruit juices	**152 ± 123**	**123 (67-208)**	**143 ± 106**	**128 (64-199)**
Discrete Fruit	**92 ± 73**	**78 (37-123)**	**87 ± 67**	**76 (39-119)**
of which				
Apples	29 ± 32	22 (0.0-50)	25 ± 29	18 (0.0-40)
Bananas	24 ± 32	8.0 (0.0-42)	16 ± 25	0.0 (0.0-25)
Citrus fruits	10 ± 23	0.0 (0.0-13)	11 ± 23	0.0 (0.0-16)
Other fruits*	29 ± 41	12 (0.0-44)	35 ± 44	18 (0.0-53)
Fruit in composite dishes	**9.2 ± 13**	**5.2 (1.5-12)**	**8.5 ± 14**	**4.4 (1.0-10)**
100% fruit juice	**39 ± 84**	**0.0 (0.0-63)**	**36 ± 65**	**0.0 (0.0-56)**
Smoothies	**11 ± 36**	**0.0 (0.0-0.0)**	**11 ± 35**	**0.0 (0.0-0.0)**
Vegetables	**76 ± 51**	**69 (38-100)**	**72 ± 48**	**65 (37-97)**
Discrete vegetables	**42 ± 39**	**31 (9.4-68)**	**39 ± 36**	**30 (11-59)**
of which				
Peas, beans & lentils	12 ± 19	0.0 (0.0-17)	10 ± 22	0.0 (0.0-12)
Baked beans	*7.1 ± 17*	*0.0 (0.0-0.0)*	*6.3 ± 20*	*0.0 (0.0-0.0)*
Carrots	9.2 ± 15	0.0 (0.0-13)	9.5 ± 13	4.4 (0.0-14)
Green vegetables	6.0 ± 12	0.0 (0.0-8.7)	5.9 ± 9.3	0.0 (0.0-10)
Other vegetables **	15 ± 22	4.3 (0.0-22)	13 ± 18	6.1 (0.0-21)
Vegetables in composite dishes	**35 ± 32**	**26 (10-49)**	**33 ± 31**	**25 (10-45)**

*Includes avocados, blackberries, nectarines, grapefruit, kiwi, mangoes, melon, olives, peaches, pears, pineapple, plums, dried fruit etc. (≤10g)
**Includes cauliflower, celery, courgette, garlic, lettuce, mushrooms, onions, pepper, sweetcorn, tomatoes, turnips, tinned & jarred vegetables etc. (< 6g)
No statistical differences were observed (P<0.001) from that of boys within the rows via independent t test adjusted for multiple testing

Table 3. Mean daily intake (g/d) of 'fruit & vegetables' in children (5-12 y) in Ireland split by age group in the NCFS II

	5-8 years (n 300)		9-12 years (n 300)	
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
	(g/d)		(g/d)	
Total fruit & vegetables	**219 ± 133**	**196 (134-279)**	**224 ± 124**	**205 (132-300)**
Fruit & fruit juices	**150 ± 119**	**128 (66-196)**	**145 ± 111**	**122 (65-207)**
Discrete Fruit	**95 ± 73**	**78 (43-124)**	**85 ± 67**	**78 (32-119)**
of which				
Apples	30 ± 31	23 (0.0-52)	24 ± 29	18 (0.0-43)
Bananas	20 ± 30	0.0 (0.0-30)	20 ± 29	0.0 (0.0-35)
Citrus fruits	9.5 ± 17	0.0 (0.0-14)	12 ± 27	0.0 (0.0-13)
Other fruits*	35 ± 43	22 (0.0-57)	29 ± 42	10.0 (0.0-43)
Fruit in composite dishes	**10 ± 16**	**4.8 (1.3-11)**	**7.8 ± 11**	**4.6 (4.6-10)**
100% fruit juice	**35 ± 84**	**0.0 (0.0-50)**	**41 ± 66**	**0.0 (0.0-64)**
Smoothies	**10 ± 32**	**0.0 (0.0-0.0)**	**12 ± 39**	**0.0 (0.0-0.0)**
Vegetables	**69 ± 45**	**64 (36-92)**	**78 ± 52**	**73 (73-103)**
Discrete vegetables	**39 ± 32**	**33 (12-57)**	**42 ± 42**	**29 (29-69)**
of which				
Peas, beans & lentils	9.8 ± 16	0.0 (0.0-15)	12 ± 25	0.0 (0.0-15)
Baked beans	*5.4 ± 12*	*0.0 (0.0-0.0)*	*7.8 ± 23*	*0.0 (0.0-0.0)*
Carrots	9.6 ± 13	4.7 (0.0-14)	9.1 ± 15	0.0 (0.0-0.0)
Green vegetables	6.9 ± 12	0.0 (0.0-11)	5.1 ± 9.0	0.0 (0.0-0.0)
Other vegetables**	12 ± 18	5.6 (0.0-17)	16 ± 22	5.3 (5.3-5.3)
Vegetables in composite dishes	**31 ± 31**	**22 (7.9-44)**	**36 ± 32**	**28 (28-28)**

*Includes avocados, blackberries, nectarines, grapefruit, kiwi, mangoes, melon, olives, peaches, pears, pineapple, plums, dried fruit etc. (≤10g)
**Includes cauliflower, celery, courgette, garlic, lettuce, mushrooms, onions, pepper, sweetcorn, tomatoes, turnips, tinned & jarred vegetables etc. (< 6g)
No statistical differences were observed (P<0.001) from that of 5-8 years within the rows via independent t test adjusted for multiple testing

Table 4. Mean daily intake (g/d) of 'fruit & vegetables' in Irish children (5-12 y) in the NCFS II (2017-18) and the NCFS (2003-04) and the proportion of consumers (%) in each survey

	NCFS II (2017-18) (n 600)			NCFS (2003-04) (n 594)		
	Mean ± SD	Median (IQR)	Consumer	Mean ± SD	Median (IQR)	Consumer
	(g/d)		%	g/d		%
Total fruit & vegetables	**221 ± 129**	**201 (133-291)**	**100**	**224 ± 153**	**186 (117-296)**	**100**
Fruit & fruit juices	**147 ± 115**	**125 (65-203)**	**97**	**155 ± 133**	**123 (60-213)**	**98**
Discrete Fruit	**90 ± 70**	**78 (37-122)**	**92**	**59 ± 53†**	**46 (14-92)**	**85**
of which						
Apples	27 ± 30	20 (0.0-46)	63	24 ± 32	14 (0.0-38)	59
Bananas	20 ± 29	0.0 (0.0-32)	47	12 ± 19 †	0.0 (0.0-20)	44
Citrus fruits	11 ± 23	0.0 (0.0-14)	32	7.3 ± 15	0.0 (0.0-7.3)	31
Other fruits*	32 ± 43	16 (0.0-48)	64	15 ± 27 †	0.0 (0.0-21)	46
Fruit in composite dishes	**8.9 ± 14**	**4.7 (1.2-11)**	**84**	**9.1 ± 11**	**6.1 (2.3-12)**	**94**
100% fruit juice	**38 ± 75**	**0.0 (0.0-57)**	**40**	**86 ± 113 †**	**46 (0.0-128)**	**67**
Smoothies	**11 ± 36**	**0.0 (0.0-0.0)**	**12**	**0.6 ± 6.0 †**	**0.0 (0.0-0.0)**	**2**
Vegetables	**74 ± 49**	**67 (38-99)**	**99**	**69 ± 52**	**58 (31-97)**	**98**
Discrete vegetables	**40 ± 38**	**30 (10-62)**	**85**	**39 ± 35**	**31 (12-55)**	**92**
of which						
Peas, beans & lentils	11 ± 21	0.0 (0.0-15)	45	12 ± 18	5.7 (0.0-17)	60
Baked beans	*6.7 ± 19*	*0.0 (0.0-0.0)*	*20*	*8.3 ± 16*	*0.0 (0.0-12)*	*38*
Carrots	9.3 ± 14	2.5 (0.0-13)	52	9.0 ± 12	4.2 (0.0-14)	60
Green vegetables	6.0 ± 11	0.0 (0.0-10)	38	6.0 ± 9.9	0.0 (0.0-9.1)	45
Other vegetables **	14 ± 20	5.3 (0.0-21)	59	12 ± 18	4.5 (0.0-17)	61
Vegetables in composite dishes	**34 ± 32**	**25 (10-49)**	**95**	**30 ± 28**	**23 (12-42)**	**97**

*Includes avocados, blackberries, nectarines, grapefruit, kiwi, mangoes, melon, olives, peaches, pears, pineapple, plums, dried fruit etc. (≤10g)
**Includes cauliflower, celery, courgette, garlic, lettuce, mushrooms, onions, pepper, sweetcorn, tomatoes, turnips, tinned & jarred vegetables etc. (< 6g)
†Statistically different (P<0.001) from that of NCFS II via independent sample t-tests and adjusted for multiple testing

Table 5. The proportion (%) of children (5-12y) in Ireland achieving daily intakes of 1-5 servings of 'fruit & vegetables'

	NCFS II (2017-18)		NCFS (2003-04)	
	% meeting the WHO guidelines	% meeting the Irish FBDG	% meeting the WHO guidelines	% meeting the Irish FBDG
5 servings/d (400g) [1, 2]	9	6	11	4
4 servings/d (320g)	18	14	21	15
3 servings/d (240g)	38	37	40	36
2 servings/d (160g)	65	60	62	62
1 serving/d (80g)	90	90	87	87

1. WHO advise to consume a minimum of 400g of 'fruit & vegetables' per day (WHO/FAO, 2004)
2. Irish food based dietary guidelines recommend at least 5-7 servings of fruit & vegetables per day, including no more than 150ml of unsweetened fruit juice or smoothies (Department of Health, 2017)

Table 6. Percent contribution (%) of 'fruit & vegetables' to energy and nutrients in the diets of children (5-12 y) in Ireland (n 600) in the NCFS II

	Total fruit & vegetables		**Fruit & fruit juices**		*Fruit*		*100% fruit juice & smoothies*		**Vegetables incl. vegetable dishes**		*Vegetables*		*Vegetable dishes*	
	Mean	**%**	**Mean**	**%**	Mean	%	Mean	%	**Mean**	**%**	Mean	%	Mean	%
Energy (kcal)	**98.3**	**6.7**	73.3	5.0	51.8	3.6	21.5	1.4	25.1	1.7	18.3	1.3	6.8	0.5
Protein (g)	**2.3**	**4.0**	1.0	1.8	0.7	1.3	0.3	0.5	1.3	2.2	1.0	1.8	0.2	0.4
Total fat (g)	**1.0**	**1.9**	0.4	0.7	0.3	0.6	0.1	0.2	0.6	1.2	0.3	0.5	0.4	0.6
Saturated fat (g)	**0.3**	**1.2**	0.1	0.5	0.1	0.3	0.0	0.1	0.1	0.7	0.1	0.3	0.1	0.4
Carbohydrate (g)	**21.3**	**10.8**	17.4	8.8	12.3	6.3	5.2	2.5	3.8	2.0	3.1	1.6	0.7	0.4
Total sugars (g)	**18.7**	**24.8**	16.8	22.0	11.8	16.1	5.0	6.0	1.9	2.8	1.7	2.5	0.2	0.3
Free sugars (g)	**5.0**	**10.7**	4.7	10.0	0.1	0.2	4.6	9.8	0.2	0.7	0.2	0.6	0.0	0.1
Dietary fibre (g)	**2.7**	**19.4**	1.5	10.6	1.3	9.3	0.2	1.3	1.3	8.9	1.2	8.3	0.1	0.6
Thiamin (mg)	**0.2**	**15.2**	0.1	10.3	0.1	5.6	0.1	4.8	0.1	4.9	0.1	4.4	0.0	0.5
Riboflavin (mg)	**0.1**	**4.9**	0.0	3.2	0.0	2.3	0.0	0.9	0.0	1.7	0.0	1.3	0.0	0.4
Total Niacin (mg)	**1.2**	**4.4**	0.7	2.4	0.5	1.8	0.2	0.7	0.5	2.0	0.5	1.7	0.1	0.3
Vitamin B6 (mg)	**0.2**	**12.6**	0.1	9.5	0.1	7.6	0.0	1.9	0.0	3.1	0.0	2.6	0.0	0.4
Vitamin B12 (µg)	**0.0**	**0.3**	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.1
Dietary folate equivalents(µg)	**31.3**	**14.0**	18.0	7.9	11.4	5.1	6.5	2.7	13.4	6.2	12.2	5.6	1.1	0.5
Vitamin A (µg)	**226**	**27.9**	11.6	2.0	6.4	1.3	5.2	0.7	214	25.9	206	24.9	8.0	1.0
Vitamin D (µg)	**0.0**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Vitamin E (mg)	**0.5**	**9.1**	0.3	4.5	0.2	3.6	0.1	0.9	0.3	4.6	0.2	3.7	0.1	0.9
Vitamin C (mg)	**37.6**	**50.5**	30.2	38.6	15.6	23.2	14.6	15.4	7.4	11.9	6.9	11.0	0.5	0.9
Sodium (mg)	**40.7**	**2.4**	5.7	0.4	3.3	0.2	2.4	0.2	35.0	2.1	24.6	1.4	10.4	0.6
Potassium (mg)	**344**	**17.0**	235	11.6	173	8.7	61.8	2.9	109	5.4	97.1	4.8	12.1	0.6
Calcium (mg)	**31.1**	**4.5**	15.3	2.2	10.2	1.5	5.1	0.7	15.8	2.3	13.2	1.9	2.5	0.4
Iron (mg)	**0.6**	**7.4**	0.3	3.2	0.2	2.7	0.0	0.5	0.4	4.2	0.3	3.6	0.1	0.6
Magnesium (mg)	**22.9**	**11.9**	14.5	7.5	10.9	5.7	3.6	1.9	8.4	4.4	7.3	3.8	1.0	0.5
Zinc (mg)	**0.3**	**4.0**	0.1	1.2	0.1	1.0	0.0	0.2	0.2	2.8	0.2	2.2	0.0	0.6

Discussion

The aim of this study was to use data from the recent NCFS II (2017-18) to estimate the current intake of fruit & vegetables including those from composite foods, in children (5-12 y) in Ireland, to assess compliance with food based dietary guidelines for fruit and vegetables and to investigate their contribution to energy and nutrient intakes. A further aim was to identify any changes in the intake of 'fruit & vegetables' children (5-12y) in Ireland since the previous NCFS carried out in 2003-04. Overall, 'fruit & vegetables' was consumed by 100% of school-aged children in Ireland with an MDI of 221g/d equating to approximately 2.8 servings/day, which is well below the recommended intake for this food group. 'Fruit & vegetables' contributed a small proportion of energy (7%) in the overall diet but made significant contributions to intakes of vitamin C (50%), vitamin A (28%), B vitamins (thiamin, vitamin B6, DFE) (13-15%) and minerals (magnesium and potassium) (12-17%) while also contributing to intakes of carbohydrates (11%) and DF (19%). 'Fruit & vegetables' also contributed to intakes of total sugar (25%) and free sugar (11%) in the diets of Irish school-aged children. When compared to the previous NCFS (2003-04), the overall intake of 'fruit & vegetables' was similar in both surveys (NCFS II: 221g/d, NCFS: 224g/d) however intakes of discrete fruit were higher in the NCFS II and intakes of fruit juices were lower. There were no differences in intakes of vegetables between the two surveys.

'Fruit & vegetable' intakes

The current study showed that children aged 5-12 years in Ireland had a mean daily intake of 221g/d of 'fruit & vegetables', which included 147g/d of 'fruit & fruit juices' and 74g/d of 'vegetables'. Of the 'fruit & fruit juices', 90g was from 'discrete fruit', 9g from 'fruit in composite dishes', 38g from '100% fruit juice' and a further 11g from 'smoothies'. For 'vegetables', 40g came from 'discrete vegetables' while 34g came from 'vegetables in composite dishes' highlighting the important contribution composite dishes make to total vegetable intakes in Irish school-aged children. Failing to account for vegetables in composite dishes may underestimate intake by as much as 54 % in this age group. This is in keeping with findings from the previous NCFS (2003-04) and findings in Irish pre-school children where vegetables in composite dishes were shown to contribute to 52 and 45% of vegetable intakes, respectively. There were no differences in the MDI of 'fruit & vegetables' (or any subgroup

examined) between boys and girls or between younger (5-8y) and older children (9-12y) in this study.

Despite the small number of studies reporting fruit & vegetables intakes in children in Europe and the variations in the categorisation of this food group between studies, the intake of 'fruit & vegetables' in school-aged children in Ireland can be broadly compared with five other countries. Intakes of 'fruit & vegetables' in Irish children (221g/d) were similar to intakes reported in children in the UK (225g/d) and in the Netherlands (272g/d), (Van Rossum *et al.*, 2016, Public Health England, 2018), while intakes were higher in children in Italy (350g/d), Spain (341g/d) and Denmark (404g/d) which may be partly attributable to the higher intakes of fruit in Danish children (188g/d) compared to Irish children (90g/d) and the higher intake of juice in Italian children (80g/d) and Spanish children (112g/d) compared to Irish children (38g/d) (Leclercq *et al.*, 2009, Pedersen *et al.*, 2014, Partearroyo *et al.*, 2019). However, there are large variations in the categorisation of 'fruit & vegetables' in each country and there is a need to harmonise the dietary guidelines to ensure an accurate comparison of intakes.

Compliance with food based dietary guidelines

In the current study, children (5-12y) in Ireland had an MDI of 221g of 'fruit & vegetables' per day (approximately 2.8 servings per day) which was well below the WHO recommendation of a minimum of 400g of fruit and vegetables per day (WHO/FAO, 2004). When fruit juice and smoothies intake was limited to no more than 150ml/day, the MDI of 'fruit & vegetables' was 212g/d per day (approx. 2.7 servings per day) which was below the Irish food based dietary guidelines of 5-7 servings of fruit and vegetables per day (Department of Health, 2017). In addition, only 9% of Irish children in the NCFS II met the WHO guideline of greater than 400g of fruit & vegetables per day and just 6% of children met the Irish food based dietary guidelines recommendation of greater than 5 servings (limiting fruit juice or smoothies to no more than 150ml/day).

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

This study found that 'fruit & vegetables' contributed to a small proportion of overall energy intake while making significant contributions to many other nutrients in the diets of children aged 5-12 years in Ireland. Overall, fruit & vegetables contributed 7% of energy intake comprising of 5% from 'fruit & fruit juices' and 2% from 'vegetables including vegetable dishes'. In keeping with our study, 'fruit & vegetables' contributed 6-9% of energy intakes in Denmark, Italy, the Netherlands, the UK and Spain with fruit contributing to the majority of these intakes. Fruit contributed 3% of energy intakes in Spain, 4% in Italy and the UK, 5% in the Netherlands and 2% in Denmark while vegetables contributed 2% of energy intakes in Italy and the Netherlands and 3% of intakes in the UK, Denmark and Spain (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018).

The present study also showed that 'fruit & vegetables' contributed 11% of carbohydrate intakes in Irish children with 'fruit & fruit juices' accounting for 9% and 'vegetables including vegetable dishes' accounting for 2% of intake. Similarly, fruit & vegetables contributed 8-19% of carbohydrate intakes in Denmark, Italy, the Netherlands, the UK and Spain with the majority of these intakes from fruit rather than vegetables. Fruit contributed 5% to carbohydrate intake in Spain, 6% in Italy and the Netherlands, 7% in the UK and 12% in Denmark while vegetables contributed 2% of carbohydrate intakes in Italy and the Netherlands, 3% in the UK, 5% in Denmark and 6% of intakes in Spain (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018).

For intakes of DF in Irish children, 'fruit & vegetables' contributed 19%, comprising of 9% from 'fruit' and 8% from 'vegetables'. In contrast to our study, fruit & vegetables contributed to slightly higher intakes of DF (25-37%) in Denmark, the Netherlands, the UK, Italy and Spain with vegetables accounting for the majority of intakes in the Netherlands (14%), the UK (14%) and Spain (18%) and fruit accounting for the majority of intakes in Italy (20%), while fruit and vegetables made an equal contribution to DF intakes in Denmark (18% respectively) (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018). The higher contribution of fruit & vegetables to DF intakes in Italy, Denmark

and Spain may be attributable to the higher intakes of fruit & vegetables in children in these countries (Leclercq *et al.*, 2009, Pedersen *et al.*, 2014, Partearroyo *et al.*, 2019). In terms of micronutrient intakes, this study showed that 'fruit & vegetables' made significant contributions to intake of vitamin C (50%), vitamin A (28%), B vitamins (thiamin, vitamin B6 and DFE) (13-15%) and other minerals (magnesium and potassium) (12-17%) in the diets of Irish children. For vitamin C, 'fruit & vegetables' contributed 50% to intakes in Irish children with fruit (23%) and'100% fruit juice & smoothies' (15%) the main contributors to these intakes. In comparison to our study, Spain, Italy and Denmark reported that fruit & vegetables contributed to higher intakes of vitamin C (71-83%) with vegetables contributing to the majority of vitamin C intakes in these countries (34% in Italy, 37% in Denmark and 51% in Spain) (Sette *et al.*, 2013, Pedersen *et al.*, 2014, Olza *et al.*, 2017). This may be partly explained by the higher intake of vegetables in children in Spain (125g/d), Italy (134g/d) and Denmark (157g/d) compared to Irish children (74g/d) (Leclercq *et al.*, 2009, Pedersen *et al.*, 2014, Partearroyo *et al.*, 2019). The Netherlands reported that fruit & vegetables contributed to lower intakes of vitamin C (32%) with fruit (16%) and vegetables (16%) contributing equal amounts to intakes. In contrast to our study, the lower contribution to vitamin C intakes reported in the Netherlands may be attributable to the exclusion of fruit juice when reporting the contribution of fruit & vegetables to nutrients (Van Rossum *et al.*, 2011). The food group '100% fruit juice' made a significant contribution to vitamin C intakes in Irish children and the exclusion of this food group in our study would result in a lower contribution to vitamin C intakes (35%), similar to the Netherlands.

For vitamin A, 'fruit & vegetables' contributed 28% of intakes in the present study with 'vegetables' the main contributor (25%). In keeping with our study, Denmark and the UK have reported that fruit & vegetables contributed 26-28% of vitamin A intakes with vegetables also contributing to the majority of intakes compared to fruit in these countries (Pedersen *et al.*, 2014, Public Health England, 2018), while Italy and Spain reported that fruit & vegetables contributed to higher intakes of vitamin A (38-46%) (Sette *et al.*, 2013, Olza *et al.*, 2017). The higher contribution of fruit & vegetables to vitamin A intakes in Italy and Spain may be due to the higher intake of vegetables in Italian and Spanish children compared to Irish children (Leclercq *et al.*, 2009, Partearroyo *et al.*, 2019).

‘Fruit & vegetables’ contributed 15% of thiamin intakes, 13% of vitamin B6 intakes and 14% of DFE intakes in Irish children school-aged children with ‘fruit’ the main contributor to these intakes in this age group. In comparison to our study, fruit & vegetables contributed to lower intakes of thiamin in Italy and the Netherlands (9-13%), similar intakes in Denmark (15%) and higher intakes in Spain (18%) with vegetables mainly contributing to thiamin intakes in Denmark (8%), the Netherlands (5%) and Spain (12%) while fruit and vegetables contributed to equal amounts (6%) of thiamin intakes in Italy (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Mielgo-Ayuso *et al.*, 2018, Public Health England, 2018). In comparison to our study, fruit & vegetables contributed to lower intakes of vitamin B6 in the Netherlands (10%) (Van Rossum *et al.*, 2011) and higher intakes in Denmark, Italy and Spain (20-25%) (Sette *et al.*, 2011, Pedersen *et al.*, 2014, Mielgo-Ayuso *et al.*, 2018) with fruit & vegetables contributing equal amounts of vitamin B6 intakes in these countries, except for Spain, where vegetables (16%) contributed to the majority of vitamin B6 intakes compared to fruit (9%). Fruit & vegetables contributed 19% of DFE intakes in the Netherlands and vegetables (14%) were also primarily the main source of intakes compared to fruit (5%) (Van Rossum *et al.*, 2011).

‘Fruit & vegetables’ contributed 17% of potassium intakes in Irish children with 12% from ‘fruit & fruit juices’ (9% from ‘fruit’) and 5% from ‘vegetables including vegetable dishes’. A similar contribution to potassium intakes was reported in the Netherlands and the UK (16-20%) (Van Rossum *et al.*, 2011, Public Health England, 2018) while Denmark and Italy reported that fruit & vegetables contributed 27% and 29% of potassium intakes, respectively, with the majority of intakes from vegetables in these countries (14% in Denmark and 15% in Italy) (Sette *et al.*, 2013, Pedersen *et al.*, 2014). For magnesium intakes in Irish children, ‘fruit & vegetables’ contributed 12% of which ‘fruit & fruit juices’ accounted for 8% and ‘vegetables including vegetable dishes’ accounting for 4% of intakes. Similar to our study, the Netherlands have reported fruit & vegetables contributed 12% of magnesium intakes (Van Rossum *et al.*, 2011) while the UK, Denmark and Italy have reported that fruit & vegetables contributed 16-19% of magnesium intakes with fruit and vegetables contributing to similar intakes of magnesium in these countries (Sette *et al.*, 2013, Pedersen *et al.*, 2014, Public Health England, 2018).

Fruit & vegetables' contributed 25% of total sugar intake in Irish children comprising of 22% from 'fruit & fruit juices' with the majority of intakes from fruit (16%), and 3% from 'vegetables including vegetable dishes'. In contrast to our study, Italy and Spain reported that fruit & vegetables contributed 31-50% of total sugar intake with fruit contributing to the majority of intakes in Italy (16%) and fruit and juices & nectars contributing to the majority of intakes in Spain (21 and 23%, respectively) (Sette *et al.*, 2013, Ruiz *et al.*, 2017).

While there are currently no guidelines for total sugar intake, the WHO recommend adults and children to reduce their daily intake of free sugars to less than 10% of their total energy intake (WHO, 2015). Free sugars refers to all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and fruit juices (WHO/FAO, 2003). Of free sugar intakes in Irish children, 'fruit & vegetables' contributed 11% of intakes with '100% fruit juice & smoothies' accounting for 10% of these intakes. In keeping with our study, fruit & vegetables contributed 12% of free sugar intakes in the UK with fruit juice accounting for 11% of free sugar intakes and juices and nectars accounting for 7% of free sugar intake in Spain (Pedersen *et al.*, 2014, Ruiz *et al.*, 2017, Public Health England, 2018).

Changes in intake of 'fruit & vegetables' between NCFS II and NCFS

When compared to the previous NCFS (2003-04), Irish children aged 5-12 years in 2017-18 had similar intakes of 'total fruit & vegetables' (NCFS II: 221g/d, NCFS: 224g/d) with similar intakes of 'fruit & fruit juices' (NCFS II: 147g, NCFS: 155g/d) and 'vegetables' (including those from composite dishes) (NCFS II: 74g, NCFS: 69g/d) observed also. There were some differences in intakes noted within subcategories between the two surveys. The intake of 'discrete fruit' was higher in the NCFS II (90g/d) compared to the NCFS (59g/d). The intake of 'smoothies' was higher in the NCFS II (11g/d) compared to the NCFS (0.6g/d) and the intake of '100% fruit juice' was lower than reported fifteen years ago (NCFS II: 38g, NCFS: 86g/d). The intake of 'fruit in composite dishes' was similar in the NCFS II (9g/d) and the NCFS (9g/d), as was the intake of 'vegetables in composite dishes (NCFS II: 34g, NCFS: 30g/d).

When compliance with dietary guidelines was examined in the NCFS II and the NCFS, 9% of school-aged children in Ireland met the WHO dietary guidelines in the present study compared to 11% in 2003-04 (WHO/FAO, 2004) and when limiting fruit juice to 150 ml/d, 6% of children met this guideline in 2017-18 while 4% met it in the 2003-04 (Department of Health, 2017). While compliance with both recommendations is still extremely low, the slight decrease in compliance with the WHO guidelines and increase in compliance with the Irish FBDG can be partly explained by the decrease in fruit juice consumption and increase in discrete fruit in Irish children despite no change in the overall intake of total 'fruit & vegetables'. Despite the introduction of strategies such as the 'Food Dudes Healthy Eating programme' which have reported a positive effect in educating children and families on the importance of fruit & vegetables in primary school-aged children (Horne *et al.*, 2009, DAFM, 2010), no improvement in fruit and vegetable intakes has been noted over the last 14 years. Further strategies or public health initiatives are needed to increase the intake of this food group among Irish children.

Strengths and limitations

The key strengths of this study are the nationally representative sample of children aged 5-12 years in Ireland included in the NCFS II and the detailed dietary intake data collected through a 4-day weighed food diary. Further strengths of our study was the inclusion of fruit & vegetable intake from composite dishes in this analysis to avoid underestimating total fruit & vegetable intake in this population group. In addition, calculations were used to remove inedible or unconsumed portions of fruit (cores and uneaten peel) when estimating fruit intakes for this age group. Misreporting or under reporting of energy intake is a known limitation with all dietary assessment and may be a source of bias. This issue was minimised by extensive training and the high level of researcher-participant interaction (three visits over the 4-day period) by trained research nutritionists.

Conclusion

Overall, 'total fruit & vegetables' were consumed by all school-aged children in Ireland with a mean intake of 221g/d (approximately 2.8 servings per day), which is well below generally accepted guidelines for fruit and vegetable intake. Furthermore, at an individual level, only 9% of Irish school-aged children met the WHO

recommendation and 6% of Irish children met the Irish food based dietary guidelines for fruit & vegetables consumption. This study has also further highlighted the importance of including composite dishes in assessing vegetable intakes. Failing to account for intakes from this important source, would underestimate vegetable intakes by 54% in Irish school-aged children. 'Fruit & vegetables' contributed a small proportion (7%) of overall energy intake but contributed significantly to beneficial nutrients such as DF, vitamin C, vitamin A, B vitamins, potassium and magnesium. It also contributed to total and free sugar intake primarily from whole fruit and juices respectively. When compared to intakes reported in the previous NCFS (2003-2004), the current data indicate that school-aged children (5-12 y) in Ireland have higher intakes of whole fruit and smoothies, lower intakes of 100% fruit juice while the intake of vegetables has remained the same.

This is the first study to examine the intakes and changes of 'fruit & vegetable' consumption in children aged 5-12 years in Ireland and could serve as useful evidence for public health strategies to promote the intake of 'fruit & vegetables' in this population group. Such public health strategies could include continued educational and promotional programmes and the implementation of school policies for healthy eating.

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Chapter 5

Dietary fibre in school-aged children (5-12 years) in Ireland; intakes, sources and changes since the previous National Children's Food Survey (NCFS 2003-2004)

Introduction

Dietary fibre (DF) plays a key role in normal bowel function for all ages and is associated with a reduced risk of chronic diseases such as obesity, cardiovascular disease, type 2 diabetes and colorectal cancer in adults (EFSA Panel on Dietetic Products and Allergies, 2010, Reynolds *et al.*, 2019). A diet high in fibre is considered to have relatively low energy density and is beneficial to promote satiety and weight maintenance (Edwards *et al.*, 2015). Adequate intakes of DF are important in childhood to prevent chronic conditions such as constipation (EFSA Panel on Dietetic Products and Allergies, 2010). Furthermore, the childhood years are a critical period during which eating behaviours and food preferences evolve, providing an opportunity to develop and foster healthy eating practices, which carry into adulthood (Kelder *et al.*, 1994, Birch, 1999, Birch *et al.*, 2007). Therefore, adequate DF intake in children is not only important for current health but also to promote dietary patterns that will reduce the risk of developing chronic diseases in later life (Anderson *et al.*, 2009, Kranz *et al.*, 2012).

The European Food Safety Authority (EFSA) has proposed an adequate intake (AI) of 2g/ MJ to be considered adequate for normal laxation in children from the age of one year, which based on average energy intakes relates to 14g/d for 4-6 years, 16g/d for 7-10 years and 19g/d for 11-14 years (EFSA Panel on Dietetic Products and Allergies, 2010). The UK Scientific Advisory Committee on Nutrition (SACN) recommend that the average population intake of DF should approximate 20g/d for children aged 5 to 11 years and 25g/d for children aged 11-16 years (SACN, 2015). These recommendations have been extrapolated from adult data and were based on the available evidence of DF having a beneficial effect on constipation and also its association with a lower incidence of cardiovascular disease, coronary events, type 2 diabetes and colorectal cancer in adult populations (EFSA Panel on Dietetic Products and Allergies, 2010, SACN, 2015). In keeping with the SACN recommendations, the Nordic Nutrition Recommendations (NNR) have set recommendations for DF in the Nordic countries based on the rationale to reduce the risk of constipation and to contribute to the protection of colon cancer in later life. The NNR recommend an adequate intake of DF in children corresponding to 2-3g/MJ from 2 years of age. It is recommended that from school age, DF intake should gradually increase during adolescence to reach the recommended adult level (Nordic Council of Ministers,

2014). The available literature has highlighted low intakes of DF in children across Europe. Spanish children aged 9-12 years had a mean intake of 11.8 g/d, while the mean intake of DF for Swedish children aged 8 years and 11 years was 13g/d (Barbieri *et al.*, 2006, Ruiz *et al.*, 2016). The mean DF intake for children aged 3-18 years in the UK and Italy ranged between 14 -17.2g/d, while the median intake of DF for children aged 7-13 years in The Netherlands ranged from 16g-17 g/d. The mean DF intakes for Danish children aged 4-17 years were 18-20g/d (Sette *et al.*, 2011, Van Rossum *et al.*, 2011, Pedersen *et al.*, 2014, Public Health England, 2018). The key sources of DF intakes in European population groups (including children) were breads, grains and cereals (32-54%), fruit (11-24%), vegetables (14-18%) and potatoes and tubers (6-24%) (Barbieri *et al.*, 2006, Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018)

Low intakes of DF (12.4 g/d) have previously been reported in Irish children aged 5-12 years in the National Children's Food Survey (NCFS) (2003-2004) (Deasy *et al.*, 2007). New dietary intake data have become available to examine the current DF intakes and sources in children aged 5-12 years in the National Children's Food Survey II (NCFS II) (2017-2018) in Ireland. This chapter aims to estimate the current intakes and sources of DF in school-aged children in Ireland and a further aim is to identify changes in DF intakes since the NCFS (2003-2004).

Methodology

The analysis for this chapter was based on data from the National Children's Food Survey II NCFSII (2017-2018). The methodology for sampling, selection, recruitment, data collection and food quantification is described in Chapter 2, and a brief methodology relating to this chapter is outlined below.

Energy and DF composition of foods and estimation of DF intake

Food and beverage intake data were collected using a 4-day weighed food record. Energy and DF intakes were analysed using Nutritcs© software which contains data from The Composition of Foods, Seventh edition (Foods Standard Agency, 2015). Where a small number of foods were not available in the Seventh edition, the Sixth edition (Food Standards Agency, 2002) was used. *McCance and Widdowson's The Composition of Foods: Seventh Summary Edition* provides analytical values for DF measured by the American Association of Analytical Chemists (AOAC) (Helrich. K, 1990, Foods Standard Agency, 2015, Public Health England, 2018). During the NCFS II, details of foods consumed were collected at brand level and modifications were made to the food composition database to ensure that the DF content in food was accurately reflected e.g. for foods such as high fibre bread and high fibre breakfast cereals.

Compliance with DF recommendations

Mean intakes of DF were compared with the adequate intake for children proposed by the European Food Safety Authority for normal laxation in children from the age of one year; 14g/d; 4-6 years, 16g/d; 7-10 years and 19g/d; 11-14 years (EFSA Panel on Dietetic Products and Allergies, 2010).

Contribution of food groups to intakes of DF

The NCFS II database included one line of data (including full nutrient composition) for each food and drink item consumed on the survey. All foods and drinks were then allocated into one of nineteen food groups and then further subdivided (Appendix I). In the context of DF for this analysis, ready-to-eat-breakfast cereals (RTEBC) were further categorised into low fibre breakfast cereals (< 6g fibre) and high fibre breakfast cereals (≥6g fibre). A claim that a food is high in fibre can only be made where the product contains at least 6 g of fibre per 100g (EC, 2006).

The key dietary sources of DF were estimated using SPSS© for Windows Version 24.0 (SPSS, Inc. IBM, Chicago, IL, USA). Using descriptive frequencies, the percent contribution of each food group to mean daily intakes of DF were calculated by the mean proportion method (Krebs-Smith *et al.*, 1989) and the key contributor to each nutrient were established in order of importance for the total population and by sex and age-group. 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 for individuals in the population group as opposed to investigating the sources of a nutrient within the food supply.

Statistical analysis

The usual intakes (g/d) of DF were estimated using the validated National Cancer Institute (NCI)-Method (Tooze *et al.*, 2010) using SAS Enterprise Guide© version 6.1 (SAS Institute Inc., Cary, NC, USA). Differences in intakes of food groups (g/d) between boys and girls, age groups (5-8y & 9-12y) and between the NCFS II (2017-18) and NCFS (2003-04) were assessed using independent sample t-tests regardless of normality (due to the large sample size). As sample size increases so does the robustness of t-tests to identify deviations from normality, thus parametric tests are recommended for large samples (Fagerland, 2012). To minimise type 1 errors (as a result of multiple testing), the Bonferoni adjustment was used by dividing the alpha level (0.5) by the number of comparisons. Therefore, the mean intake of the food groups were considered to be significantly different from each other if $P < 0.01$. Also due to the large sample in this study, even a small difference between group means was highly statistically significant. Thus, greater emphasis was placed on a descriptive, rather than a formal statistical analysis of the data.

Results

Table 1 presents the mean intake (g/d) and energy-adjusted intake (g/10MJ) of DF in children aged 5-12 years in Ireland split by sex and age group.

The mean intake of DF in children aged 5-12 years was 14.4g/d. Boys had significantly higher intakes (15.5g/d) compared to girls (13.4g/d) and DF intakes were higher in those aged 9-12 years (15.1 g/d) compared to those aged 5-8 years (13.8g/d). When intakes were adjusted for energy (g/10MJ), the fibre density was higher in boys (23.8g/10MJ) compared to girls (23.2 g/10MJ) and in children aged 5-8 years (24.1g/10MJ) compared to children aged 9-12 years (22.8g/10MJ), indicating boys and younger children had higher intakes of DF compared to girls and older children **(Table 1)**.

Table 2 presents the mean intake (g/d) of DF in 5-6, 7-10 and 11-12 year old children in Ireland for comparison with the adequate intake for these age groups proposed by the EFSA of 14g/d, 16 g/d and 19g/d, respectively. In the present study, the mean intakes of DF were 13.8g/d,14.4g/d and 15.1g/d in children aged 5-6, 7-10 and 11-12 years, respectively. Intakes were below the EFSA adequate intake in all age groups examined **(Table 2)**.

Tables 3 presents the contribution (g & %) of food groups to DF intake in children aged 5-12 years in Ireland.

The key sources of DF for this age-group were ‘bread & rolls’ (23%), ‘breakfast cereals’ (15%), ‘fruit & fruit juice’ (11%), ‘grains, rice, pasta and savouries’ (10%), ‘vegetables & vegetable dishes’ (9%), ‘potatoes & potato products’ (8%), ‘sugars, confectionary, preserves & savoury snacks’ (6%) and ‘biscuits, cake & pastries’ (6%).

Within the bread & rolls food group (23%), white sliced bread and rolls contributed 10% and wholemeal, brown bread and rolls accounted for 11%, while other breads contributed to 2% to DF intake. ‘Breakfast cereals’ contributed to 15% of DF intake with RTEBCs contributing 13% and other breakfast cereals such as porridge contributing 3%.Within the RTEBC group, high fibre breakfast cereals contributed 10%, while low fibre breakfast cereals contributed 2%. ‘Fruit and fruit juices’ contributed 11 % of DF intakes in children with fruits such as apples, pears, grapes, berries (including dried fruits) contributing 6%, bananas contributed 2% and fruit

juices & smoothies contributed 1% to DF intakes. 'Grains, rice, pasta and savouries' contributed 10% to DF intakes with pasta contributing the highest out of this food group (5%) followed by pizza (3%). 'Vegetables and vegetable dishes' contributed 9% to the DF intake with peas, beans and lentils contributing the highest (3%), followed by carrots (2%) and green vegetables contributing 1% to DF intakes. 'Potatoes and potato products' contributed 8% to DF intakes in children with chipped, fried & roasted potatoes contributing 4% and processed & homemade potato products contributing 3% of DF intakes. Other contributors to DF intakes included 'meat and meat products' (7%) and 'sugars, confectionary, preserves and savoury snacks' (6%). Dietary sources of fibre were similar across sex and age groups **(Table 3 & 4)**.

Changes in DF intakes between NCFS and NCFS II

Table 5 presents the mean intake (g/d) of DF in children aged 5-12 years in Ireland in the NCFS II (2017-18) compared to the NCFS (2003-04).

When mean DF intakes were compared to previous intakes reported in the NCFS (2003-04), it was found that the intake of DF was higher in the NCFS II (2017-18) compared to the NCFS (14.4 g vs 12.4g/d) When adjusted for energy intake (g/10MJ), the fibre density of the diet remained higher for the NCFS II compared to the NCFS (23.5g vs 17.9g/10MJ). In both surveys, boys had higher DF intakes compared to girls (NCFS II; 15.5 vs 13.4g/d, NCFS; 13.2 vs 11.7g/d). While intakes of DF have increased over the 15-year period, mean intakes still remain below the adequate intake proposed by EFSA for children aged 5-12 years **(Table 5)**.

Table 6 presents the contribution (g & %) of food groups to DF intakes in children aged 5-12 years in Ireland in the NCFS II (2017-18) compared to the NCFS (2003-04).

'Bread & rolls' were the main contributor to DF intakes in both surveys (21% vs 23%). White sliced bread & rolls contributed a high amount to DF intakes in both the NCFS II and the NCFS (10% vs 15%) with wholemeal bread contributing more to DF intakes than white bread in the NCFS II compared to the NCFS (11% vs 5%). Within the 'breakfast cereals' category, there was a higher contribution from high fibre RTEBC compared to low fibre RTEBC in the NCFS II (10% vs 2%) and in the NCFS (8% vs 5%). There was a lower contribution from 'potato and potato products' in this study compared to the NCFS (8% vs 16%). There was a relatively similar contribution from

‘fruit and fruit juices’ in the NCFS II compared to the NCFS (11% vs 10%) and also from ‘vegetable and vegetable dishes’ (9% vs 11%). There was a higher contribution to DF intakes from ‘grains, rice, pasta and savouries’ (10% vs 8%) and ‘sugars, confectionary, preserves & savoury snacks’ (6% vs 8%).‘Meat & meat dishes’ contributed a higher proportion to DF intakes in NCFS II compared to the NCFS (8% vs 4%) **(Table 6)**.

Table 1. Mean and *SD* values for dietary fibre intake in children aged 5-12 years in Ireland for the total population (n 600) by sex and age-group

		All			Boys			Girls		
		n	Mean	*SD*	n	Mean	*SD*	N	Mean	*SD*
DF (g/d)	5-12 y	600	14.4	3.5	300	15.5	3.6	300	13.4†	3.1
	5-8y	300	13.8	3.3	149	14.5	3.3	151	13.1†	3.1
	9-12y	300	15.1*	3.6	151	16.6*	3.6	149	13.7†	3.1
DF (g/10MJ)	5-12y	600	23.5	4.3	300	23.8	4.3	300	23.2†	4.2
	5-8y	300	24.1	4.3	149	24.2	4.3	151	24.0†	4.3
	9-12y	300	22.8*	4.1	151	23.3*	4.2	149	22.3†	4.0

†Statistically different (P<0.01) from that of boys within rows via independent sample t-tests adjusted for multiple testing

* Statistically different (*P*<0.01) from that of 5-8 years within the columns via independent sample t-tests adjusted for multiple testing

Table 2. Mean and *SD* values for dietary fibre intake in Irish children based on the EFSA age-groups for the adequate intake of DF split by sex

		All (n 600)			Boys (n 300)			Girls (n 300)		
		N	Mean	*SD*	n	Mean	*SD*	n	Mean	*SD*
DF (g/d)	5-6y	151	13.8	3.2	75	14.5	3.3	76	13.1	3.1
	7-10y	299	14.4	3.5	149	15.6	3.6	150	13.4	3.1
	11-12y	150	15.1	3.6	76	16.7	3.6	74	13.7	3.1

EFSA (2010) adequate intake recommendation: 4-6y:14g/d, 7-10y: 16g/d, 9-14y:19g/d

Table 3. Contribution (g & %) of food groups to mean daily intake of dietary fibre intake in children (5-12 years) in Ireland (n 600) split by sex in the NCFS II

	All (n 600)		Boys (n 300)		Girls (n 300)	
	g	%	g	%	g	%
Bread & Rolls	3.4	23.0	3.8	23.8	3.0	22.3
White sliced bread & rolls	1.4	10.4	1.5	10.5	1.3	10.3
Wholemeal & brown bread & rolls	1.7	11.1	2.0	11.8	1.5	10.5
Other breads(e.g. scones, rye bread, garlic bread)	0.2	1.5	0.2	1.5	0.2	1.5
Breakfast cereals	2.3	15.2	2.6	16.2	2.0	14.3
RTEBC (Ready-to-eat breakfast cereal)	2.0	12.8	2.2	13.4	1.7	12.1
High fibre RTEBC	1.6	10.4	1.8	11.0	1.5	9.9
Low fibre RTEBC	0.3	2.3	0.3	2.5	0.3	2.2
Other breakfast cereals (e.g. porridge and ready brek)	0.3	2.5	0.4	2.8	0.3	2.2
Fruit & fruit juices	1.6	11.0	1.6	10.2	1.6	11.7
Apples,pears,grapes,berries etc.*	0.9	6.4	0.9	5.7	1.0	7.1
Bananas	0.3	2.0	0.3	2.2	0.2	1.8
Fruit juices & smoothies	0.2	1.4	0.2	1.2	0.2	1.6
Other fruit (e.g. citrus & tinned fruit)	0.2	1.2	0.2	1.0	0.2	1.4
Grains, rice , pasta and savouries	1.3	9.7	1.3	8.8	1.4	10.6
Pasta	0.7	4.8	0.7	4.2	0.7	5.3
Pizza	0.3	2.5	0.4	2.8	0.3	2.3
Rice	0.1	0.6	0.1	0.5	0.1	0.7
Noodles	0.1	0.7	0.1	0.6	0.1	0.8
Savouries	0.1	1.1	0.1	0.7	0.2	1.4
Vegetables & vegetable dishes	1.4	9.3	1.5	9.3	1.2	9.2
Peas, beans & lentils	0.5	3.3	0.5	3.4	0.4	3.2
Carrots	0.3	2.3	0.3	2.1	0.3	2.4
Green vegetables	0.2	1.3	0.2	1.2	0.2	1.4
Turnips,peppers,parsnips, onions etc. †	0.2	1.1	0.2	1.3	0.1	0.9
Vegetables & pulse dishes	0.1	0.7	0.1	0.8	0.1	0.7
Other(salad, tinned and jarred vegetables)	0.1	0.6	0.1	0.6	0.1	0.6
Potatoes & potato products	1.2	8.4	1.3	8.5	1.1	8.3
Chipped, fried & roasted potatoes	0.6	4.1	0.7	4.3	0.5	3.9
Boiled, baked & mashed potatoes	0.4	3.1	0.5	3.2	0.4	3.0
Processed & homemade potato products	0.2	1.1	0.1	0.9	0.2	1.3
Meat & meat products	1.0	7.7	1.1	7.1	0.9	6.8
Sugars, confectionery, preserves & savoury snacks	0.8	5.9	0.9	5.9	0.8	5.9
Biscuits, cakes & pastries	0.8	5.7	0.8	5.5	0.7	5.8
Other foods	0.7	4.9	0.7	4.8	0.7	5.1
Total	**14.4**	**100**	**15.5**	**100**	**13.4**	**100**

*Includes peaches, melon ,mangoes, nectarines, plums, pineapples etc.

†Includes sweetcorn, mushrooms, garlic, ,cauliflower etc.

Table 4. Contribution (g & %) of food groups to mean daily intake of dietary fibre intake in children (5-12 years) in Ireland (n 600) split by sex and age group in the NCFS II

	5-8 y (n 300)				9-12 y (n 300)			
	Boys (n 149)		Girls (n 151)		Boys (n 151)		Girls (n 149)	
	g	%	g	%	g	%	g	%
Bread & Rolls	3.5	23.4	2.9	21.5	4.0	24.2	3.2	23.0
White sliced bread & rolls	1.2	8.8	1.1	9.4	1.9	12.4	1.5	10.4
Wholemeal & brown bread & rolls	2.1	12.9	1.5	10.7	1.9	10.6	1.5	11.1
Other breads(e.g. scones, rye bread, garlic bread)	0.3	1.8	0.2	1.5	0.2	1.2	0.2	1.5
Breakfast cereals	2.5	17.3	2.2	16	2.6	15	1.9	15.2
RTEBC (Ready-to-eat breakfast cereal)	2.1	13.9	1.8	13	2.3	12.9	1.7	12.8
High fibre RTEBC	*1.8*	*11.9*	*1.5*	*11.1*	*1.8*	*9.9*	*1.4*	*10.4*
Low fibre RTEBC	*0.2*	*2.0*	*0.3*	*2.0*	*0.5*	*3.0*	*0.3*	*2.3*
Other breakfast cereals (e.g. porridge and ready brek)	0.5	3.4	0.4	2.9	0.3	2.1	0.2	2.5
Fruit & fruit juices	1.7	11.9	1.6	12.1	1.4	8.3	1.6	11
Apples,pears,grapes,berries etc.	1.0	7.1	1.0	7.8	0.7	4.2	0.9	6.4
Bananas	0.4	2.6	0.2	1.9	0.3	1.7	0.2	2.0
Fruit juices & smoothies	0.1	1.1	0.2	1.3	0.2	1.4	0.3	1.4
Other fruit (e.g. citrus & tinned fruit)	0.2	1.1	0.1	1.1	0.1	1.0	0.2	1.2
Grains, rice , pasta and savouries	1.2	8.0	1.2	9.8	1.5	9.6	1.5	9.7
Pasta	0.6	3.9	0.7	5.1	0.8	4.7	0.7	4.8
Pizza	0.4	2.7	0.3	2.2	0.4	3.0	0.3	2.5
Rice	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.6
Noodles	0.1	0.5	0.1	0.6	0.1	0.6	0.1	0.7
Savouries	0.1	0.5	0.2	1.4	0.1	0.9	0.2	1.1
Vegetables & vegetable dishes	1.4	9.0	1.2	9.3	1.6	9.6	1.3	9.3
Peas, beans & lentils	0.5	3.1	0.5	3.5	0.6	3.6	0.4	3.3
Carrots	0.3	2.2	0.3	2.5	0.3	1.9	0.3	2.3
Green vegetables	0.3	1.6	0.2	1.5	0.1	0.7	0.2	1.3
Turnips,peppers,parsnips, onions etc.	0.2	1.1	0.1	0.7	0.3	1.5	0.1	1.1
Vegetables & pulse dishes	0.1	0.3	0.1	0.6	0.2	1.3	0.1	0.7
Other(salad, tinned and jarred vegetables)	0.1	0.6	0.1	0.5	0.1	0.6	0.1	0.6
Potatoes & potato products	1.1	7.6	1.0	7.9	1.5	9.4	1.2	8.4
Chipped, fried & roasted potatoes	0.5	3.4	0.4	3.0	0.8	5.3	0.6	4.1
Boiled, baked & mashed potatoes	0.5	3.1	0.4	3.4	0.5	3.4	0.3	3.1
Processed & homemade potato products	0.2	1.0	0.2	1.5	0.1	0.8	0.2	1.1
Meat & meat products	0.8	6.3	0.9	7.1	1.3	8.0	0.9	6.5
Sugars, confectionery, preserves & savoury snacks	0.7	5.1	0.6	5.0	1.1	6.7	0.9	5.9
Biscuits, cakes & pastries	0.8	6.1	0.7	5.5	0.8	4.9	0.8	5.7
Other foods	0.7	4.8	0.7	4.4	0.5	3.3	0.3	2.9
Total	**14.5**	**100**	**13.1**	**100**	**16.6**	**100**	**13.7**	**100**

*Includes peaches, melon ,mangoes, nectarines, plums, pineapples etc.
†Includes sweetcorn, mushrooms, garlic, ,cauliflower etc.

Table 5. Comparison of mean and SD values of intakes of DF (g/d) and (g/10MJ) in children (5-12 years) in Ireland in the NCFS (2003-2004) and the NCFS II (2017-2018), split by sex

	NCFS (2003-2004)						NCFS II (2017-2018)					
	Total (n 594)		Boys (n 291)		Girls (n 303)		Total (n 600)		Boys (n 300)		Girls (n 300)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DF (g/d)	12.4	3.5	13.2	3.6	11.7	3.2	14.4*	*3.5*	15.5	*3.6*	13.4†	*3.1*
DF (g/10MJ)	17.9	3.7	18.1	3.7	17.7	3.6	23.5	*4.3*	23.8	*4.3*	23.2	*4.2*

†Statistically different (P<0.01) from that of boys within rows via independent sample t-tests adjusted for multiple testing
*Statistically different (P<0.01) from that of the NCFS II within rows via independent sample t-tests and adjusted for multiple testing

Table 6. Contribution of food groups (%) to mean daily intake of DF in children (5-12y) in Ireland in the NCFS and the NCFS II

	NCFS (2003-2004) (n 594)		NCFS II (2017-2019) (n 600)	
	g	%	g	%
Bread & rolls	2.6	21.1	3.4	23.0
White bread	1.7	14.7	1.4	10.4
Brown/wholemeal bread	0.7	4.7	1.7	11.1
Other breads (e.g.scones,rye bread, garlic bread)	0.2	1.6	0.2	1.5
Breakfast cereals	1.8	13.5	2.3	15.2
Ready-to-eat breakfast cereals	1.6	12.4	2.0	12.8
High fibre RTEBC	*1.0*	*7.5*	*1.6*	*10.4*
Low fibre RTEBC	*0.6*	*4.9*	*0.3*	*2.3*
Other breakfast cereals (e.g. porridge and ready brek)	0.1	1.1	0.3	2.5
Fruit & fruit juices	1.3	10	1.6	11.0
Apples, pears,grapes,berries etc.*	0.7	5.1	0.9	6.4
Bananas	0.4	2.9	0.3	2.0
Fruit juices & smoothies	0.1	0.7	0.2	1.4
Other (e.g. citrus & tinned fruit)	0.2	1.3	0.2	1.2
Grains, rice , pasta and savouries	1.0	8.2	1.3	9.7
Vegetable & vegetable dishes	1.5	10.9	1.4	9.3
Peas/beans/lentils	0.8	6.0	0.5	3.3
Carrots	0.3	2.0	0.3	2.3
Green vegetables	0.1	0.4	0.2	1.3
Turnip, peppers, parsnips, onions etc. †	0.2	1.4	0.2	1.1
Vegetable & pulse dishes	0.1	0.7	0.1	0.7
Other (e.g. salad and tinned or jarred vegetables)	0.0	0.3	0.1	0.6
Potatoes & potato products	1.9	15.9	1.2	8.4
Chipped, fried & roasted potatoes	1.1	9.7	0.6	4.1
Processed & homemade potato products	0.0	0.2	0.4	3.1
Potatoes (e.g. boiled, mashed, baked)	0.7	6.0	0.2	1.1
Meat & meat dishes	0.5	4.1	1.0	7.7
Sugars, confectionery, preserves & savoury snacks	1.0	8.4	0.8	5.9
Biscuits, cakes & pastries	0.6	5.5	0.8	5.7
Other foods	0.3	2.6	0.7	4.9
Total	**12.4**	**100**	**14.4**	**100**

*Includes peaches, melon ,mangoes, nectarines, plums, pineapples etc.
†Includes sweetcorn, mushrooms, garlic, ,cauliflower etc.

Discusion

This study examined the intakes of DF in a nationally representative sample of children aged 5-12 years in Ireland using data from the recent National Children's Food Survey II (2017-2018). The key dietary sources that contributed to the intake of DF for this age group were also identified in this study. A further aim was to identify changes in DF intakes in Irish school-aged children since the previous National Children's Food Survey (2003-2004).

The mean intake of DF in school-aged children in Ireland was 14.4 g/d with boys having significantly higher intakes compared to girls (15.5g/d vs 13.4g/d). The intakes of DF were also higher in those aged 9-12 years compared to those aged 5-8years (15.1 vs 13.8g/d). When DF intakes were adjusted for energy, the fibre density of the diet was higher in boys and younger children, indicating that the differences in intakes was a result of boys and younger children consuming more DF compared to girls and older children and not just due to an overall greater energy intake. To assess compliance with DF recommendations, the mean intakes of DF in the present study were compared with the most recent adequate intake set for children proposed by EFSA (EFSA Panel on Dietetic Products and Allergies, 2010). EFSA advised an AI of 14g/d, 16g/d and 19g/d for children aged 4-6 years, 7-10 years and 11-14 years, respectively. Irish school-aged children were below this recommendation with intakes of 13.8g/d for children aged 5-6 years, 14.4 g/d for children aged 7-10 years and 15.1g/d for children aged 11-12 years. Similarly, DF intakes for children aged 5-12 years (14.4g/d) were below the SACN average population intake of 20g/d for children aged 5-11 years and were at the lower end of the NNR adequate intake of 2-3g/MJ for children from 2 years of age (Nordic Council of Ministers, 2014, SACN, 2015).

DF intakes reported for children in other European countries varied from 11.8g to 20g/d and intakes were compared to DF intakes in school-aged children in Ireland (14.4g/d). The Spanish national dietary survey (Anthropometry, Intake and Energy Balance in Spain) used a 3-day food diary to collect data on DF intakes in Spanish children aged 9-12 years. DF intakes were 11.8g/d for this age groups and lower than intakes in Irish children aged 9-12 years (15.1g/d). In contrast to our study, Spanish girls reported higher intakes of DF (12.2g/d) than Spanish boys (11.5g/d) (Ruiz *et al.*, 2016). The Swedish National Children's Food Survey (2003) reported DF intakes

using a 4-day food diary. DF intakes were 13g/d for Swedish children aged 8 and 11 years. Similar to our study of school-aged children in Ireland, boys in Sweden had higher intakes of DF compared to girls. For children aged 8 years old, Swedish boys and girls had intakes of 14g/d and 13g/d, respectively. In children aged 11 years, DF intakes were 13g/d for Swedish boys and 12g/d for girls (Barbieri *et al.*, 2006). The National Diet and Nutrition Survey (NDNS) (2014-2016) used a 4-day food diary to report DF intakes in children in the UK. DF intakes were 14g/d in children aged 4-10 years, which were similar to intakes in Irish children aged 5-12 years (14.4g/d). Boys in the UK had higher intakes compared to girls in this age group (boys: 14.5g/d; girls: 13.5 g/d). For children aged 11-18 years, the DF intakes were 15.3g/d (boys: 16.5g/d; girls:14.1 g/d) (Public Health England, 2018). The Italian National Food Consumption Survey (INRAN-SCAI 2005-06) used a 3-day food diary reporting DF intakes of 14.4g/d in Italian children aged 3-9 years (Sette *et al.*, 2011). These intakes were higher than DF intakes (12.4g/d) in the NCFS (2003-04). As the Italian consumption data is relatively old, there is a need for continuous monitoring of dietary survey data to make accurate comparisons of intakes between countries.

The Dutch National Food Consumption Survey (2007-2010) used a 24-hour recall to report the median intake of DF. Dutch children reported higher median intakes of DF compared to Irish children. Intakes were 16g/d for children aged 7-8 years (boys: 16g/d; girls: 15g/d) and 17g/d for children aged 10-17 years (boys: 18g/d; girls: 16 g/d). For both age groups, boys had higher DF intakes compared to girls (Van Rossum *et al.*, 2011). Similar to Ireland, intakes of DF increased with age in the Netherlands, Italy and the UK (Sette *et al.*, 2011, Van Rossum *et al.*, 2011, Public Health England, 2018). The Danish National Survey of Dietary Habits and Physical Activity (2011-2013) (DANSDA) used a 7-day record to report DF intakes of 20g/d and 18g/d in Danish children aged 4-9 years 10-17 years, respectively. Similar to DF data in children from other European countries, boys had higher intakes of DF compared to girls. For children aged 4- 9 years, DF intakes were 21g/d and 19g/d for boys and girls, respectively. Likewise, for children aged 10-17 years, boys had DF intakes of 20g/d, while girls had intakes of 17g/d (Pedersen *et al.*, 2014).

The key dietary sources that contributed to DF intakes in Irish children (5-12 years) were examined and are compared with data in other European countries. In the current study, the key food groups contributing to intakes of DF were 'breads & rolls', 'breakfast cereals', 'fruit & fruit juices', 'grains, rice, pasta and savouries' and 'vegetables & vegetable dishes'. 'Breads & rolls' (23.0%) were the main contributor to DF intakes with a similar contribution from 'white breads' and 'wholemeal breads' (1.4g/d vs 1.7g/d). Within the 'breakfast cereal' food group which contributed 15% to DF intakes, 'high fibre RTEBC' contributed a higher amount to DF intakes compared to 'low fibre RTEBC' (1.6g vs 0.3g). Similarly, in European countries, breads, grains and cereals (32-54%) were the main dietary sources of DF intakes in the population. In Ireland, vegetables contributed 9% and fruit contributed 11% to DF intakes in Irish children while vegetables contributed 14-18% and fruit contributed 11-24% to DF intakes in European countries (Barbieri *et al.*, 2006, Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018). In Ireland, potatoes & potato products contributed 9% to DF intakes in children while potatoes and tubers contributed 6-24% to intakes in European countries (Barbieri *et al.*, 2006, Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018).

The new data available from the NCFS II (2017-2018) has allowed us to monitor and compare current DF intakes in children aged 5-12 years in Ireland with the previous NCFS (2003-2004). The current study showed that the average DF intake of 14.4 g/d is higher than the intake of 12.4g/d previously reported. However, DF intakes are still below the EFSA recommended AI (Deasy *et al.*, 2007, EFSA Panel on Dietetic Products and Allergies, 2010). Similar to the NCFS, 'breads & rolls' were still the main contributor to DF intakes in children aged 5-12 years in Ireland. The contribution of wholemeal breads to DF intakes in the diets of Irish children is now higher than previously reported in the NCFS (1.7g/d vs 0.7g/d). This is attributable to the higher consumption of wholemeal bread in the NCFS II compared to the NCFS (25g/d vs 12 g/d) as the DF composition in wholemeal breads has remained similar. Breakfast cereals also contributed a significant proportion (15%) to DF intakes in children in Ireland. In both surveys, high fibre RTEBC contributed a higher amount than low fibre RTEBC to DF intakes. This is explained by the higher consumption of high fibre RTEBC in the NCFSII compared to the NCFS (16g/d vs 11g/d) and the lower

consumption of low fibre RTEBC in the NCFSII compared to the NCFS (13g/d vs 20g/d).

Strengths and Limitations

The main strength of the current study was the high quality dietary data used to estimate DF intakes. Detailed dietary intake data were collected at brand level supported by the food packaging collected during the survey. Modifications were made to the food composition database to include the DF content of recipes, composite dishes, fortified foods and the generic Irish foods that were consumed (i.e. high fibre bread and high fibre breakfast cereals). Misreporting or under reporting of energy intake is a known limitation with all dietary assessment and may be a source of bias. This issue was minimised by extensive training and the high level of researcher-participant interaction (three visits over the 4-day period) by trained research nutritionists.

Conclusion

In summary, findings from this analysis have shown that children aged 5-12 years in Ireland have low intakes of DF and are below the recommendations set by the European Food Safety Authority. Low intakes of DF in children may increase the risk of constipation in childhood and chronic disease in later life. When compared to intakes reported in the previous NCFS (2003-2004), this new dietary intake data indicated that DF in school-aged children has increased over time but still remains low compared to recommendations. Breads & rolls and breakfast cereals are the key dietary sources of DF intakes in children. These findings are similar to that found in children in other European countries. Information about the contributions of specific foods to DF intakes will be useful in the development of dietary strategies to increase the intake of DF in the diets of school-aged children in Ireland.

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Chapter 6

Dietary determinants of dietary fibre intakes in school-aged children (5-12y) in Ireland

Introduction

Low intakes of dietary fibre (DF) have previously been identified in school-aged children in Ireland, with mean intakes (14.4g/d) below the adequate intake (AI) proposed by the European Food Safety Authority (EFSA) for normal laxation, indicating a need to improve DF intakes in this population group (EFSA Panel on Dietetic Products and Allergies, 2010). Understanding the dietary patterns associated with DF intakes may help to inform dietary strategies and initiatives to improve intakes in this population group (Lockyer *et al.*, 2016, Fayet-Moore *et al.*, 2018). One approach that can be used to develop dietary strategies to improve nutrient intakes in specific population groups is to identify a proportion of the population with adequate or sufficient intakes and to identify the foods and consumption patterns that contribute to the difference in intakes between those with sufficient intakes and those with lower intakes. If those with low intakes can adopt the dietary patterns of those with higher intakes, it may help to improve intakes within the overall population (Gibney and Sandström, 2008).

This approach has been used to investigate the dietary determinants of both DF and wholegrain consumption in studies of school-aged children. Data from a nationally representative survey in Australian children found that wholegrains, fruit, and vegetables were key determinants of higher fibre intakes in school-aged children (Fayet-Moore *et al.*, 2018). Similarly, the nationally representative National Children's Food Survey (NCFS) (2003-04) in Ireland identified that wholemeal & brown breads, high fibre ready-to-eat breakfast cereals (RTEBC), fruit, and vegetables were the key foods that contributed to the difference in high and low intakes of DF in Irish school-aged children (Bannon, 2011). Studies across Europe and the US have examined the determinants of whole grain consumption in children (2-18y) and reported that higher intakes of wholegrain were associated with higher fibre intakes (Mann *et al.*, 2015, Albertson, 2016, Sette *et al.*, 2017).

The recent Irish National Children's Food Survey II (NCFS II) (2017-18) has identified dietary changes since the previous NCFS (2003-04) including an increased intake of fruit and wholemeal & brown breads resulting in an increase in the intake of important nutrients such as DF (Chapters 3-5). This chapter aims to use the new dietary

data from the NCFS II (2017-18) to identify the dietary determinants (key food groups and dietary patterns) of DF intake in school-aged children (5-12y) in Ireland.

Methodology

The analyses for this chapter are based on data from the National Children's Food Survey II (NCFS II) which was a nationally representative cross-sectional study that collected food and beverage consumption data from 600 children aged 5-12 years in the Republic of Ireland between 2017 and 2018. The methodology for sampling, selection, recruitment, data collection, food quantification and nutrient composition is described in detail in Chapter 2. The methodology for the estimation of DF intake and the contribution of food groups to DF intakes is described in Chapter 5. A brief methodology relating to this chapter is outlined below.

Dietary determinants of DF intake

All data manipulation and analysis were carried out using SPSS© for Windows™ Version 24.0 (SPSS, Inc., IBM, Chicago, IL, USA). The dietary determinants of DF intake were investigated using tertile analysis. Participants were split into three groups based on their mean daily intake (MDI) of DF, stratified by sex and age group (5-8y & 9-12y). This provided low, medium and high DF intake groups in the total population. The MDI of DF (g/d) in the low, medium and high intake groups was determined and the difference in intake between the high and low intake groups was examined. The MDI of DF in each intake group was compared with the adequate intake (AI) for fibre proposed by the European Food Safety Authority for normal laxation in children; 14g/d (4-6y), 16 g/d (7-10y) and 19g/d (11-14y**)** (EFSA Panel on Dietetic Products and Allergies, 2010).

The contribution of food groups to DF intake in each intake group (low, medium and high) was determined and the food groups accounting for the difference in intakes between the high and low DF intake groups were identified. The food groups that contributed the greatest difference to DF intakes between the high and low intake groups were identified as determinants of DF intake. As previously outlined, for dietary fibre analysis 'RTEBCs' were categorised into 'high fibre' (≥6g fibre/100g) and 'low fibre' (< 6g fibre /100g) cereals. A claim that a food is high in fibre can only be made where the product contains at least 6 g of fibre per 100 g (EC, 2006).

The MDI of the food groups identified as dietary determinants were reported in the total population and the patterns of consumption of these food groups were investigated in consumers only, to understand the dietary patterns of those with higher

DF intakes. For each food group, the percentage of consumers, the MDI, the frequency of intake (over the four-day recording period) and the mean intake (grams) at each eating occasion were compared between consumers only in the high and low DF intake groups. A consumer of a food group was defined as a participant who consumed this food at least once over the 4-day recording period. The frequency of intake of a food group was determined by identifying each eating occasion at which the participant consumed this food group over the 4-day recording period. The mean intake per eating occasion was determined by calculating the total intake (g) of this food group divided by the frequency of consumption for each participant.

Statistical Analysis

Differences in the MDI of food groups, the frequency of intake of food groups and the mean intake (g) per eating occasion between low and high DF intake groups were assessed using independent sample t-tests regardless of normality (due to the large sample size). As sample size increases so does the robustness of t-tests to identify deviations from normality, thus parametric tests are recommended for large samples (Fagerland, 2012). The difference in the percentage of consumers between low and high DF intake groups was assessed using the Chi-Square test for independence. To minimise type 1 errors (as a result of multiple testing), the Bonferoni adjustment was used by dividing the alpha level (0.5) by the number of comparisons. Therefore, values were considered to be significantly different from each other if $P< 0.01$. Also due to the large sample in this study even a small difference between group means was highly statistically significant. Thus greater emphasis was placed on a descriptive, rather than a formal statistical analysis of the data.

Results

Table 1 presents the mean daily intake (MDI) of DF (g/d) in the low, medium and high DF intake groups and the difference in intakes between the high and low DF intake groups (in the total population) in children (5-12 y) in Ireland.

The MDI of DF was 9.8, 13.6 and 19.0g/d in the low, medium and high intake groups respectively. There was a significant increase in DF intake between the three DF intake groups. The difference in the MDI of DF between the high and low intake groups was 9.3g/d **(Table 1)**.

The MDI of DF in each intake group was compared to the AI proposed by the European Food Safety Authority (EFSA) of 14g/d (4-6 y), 16 g/d (7-10y) and 19g/d (11-14y) **(Table 1)**. The MDI of DF in both the low and medium DF intake groups was below the EFSA recommended AI, while the MDI in the high intake group was above the AI from the EFSA (EFSA Panel on Dietetic Products and Allergies, 2010).

Table 2 presents the contribution of food groups to the difference in DF intake between high and low DF intake groups (in the total population) in children (5-12y) in Ireland.

'Breads & rolls' contributed 27% of the difference in DF intake between high and low DF intake groups with 'wholemeal & brown bread' contributing 22% of this difference. 'Breakfast cereals' contributed 23% of the difference in DF intakes of which 'high fibre RTEBC' contributed 22% of the difference between high and low DF intake groups. 'Vegetables & vegetable dishes' contributed 11% and 'fruit' contributed 10% of the difference between high and low DF intake groups **(Table 2)**.

The dietary patterns of 'wholemeal & brown bread' and 'high fibre RTEBC' are presented together in **Table 3** as these food groups are part of the wholemeal cereals & breads, potatoes, pasta and rice food group in the Irish food based dietary guidelines (Department of Health, 2017).

The MDI of 'wholemeal & brown bread' was significantly higher among those in the high DF intake group compared to the low DF intake group in both the total population (43 v 12g/d, respectively) and in consumers only (62 v 29g/d, respectively).

There were more consumers of 'wholemeal & brown bread' in the high DF intake group compared to the low DF intake group (69 v 40%). Among consumers, those in the high DF intake consumed 'wholemeal & brown breads' more often over the four days than those in the low DF intake group (3.9 v 2.2 times), and also consumed more 'wholemeal & brown breads' at each eating occasion (65g) compared to those in the low DF intake group (54g).

The MDI of 'high fibre RTEBC' was significantly higher among those in the high DF intake group compared to the low DF intake group in both the total population (25 v 7g/d, respectively) and in consumers only (34 v 16g/d, respectively). There were more consumers of 'high fibre RTEBC' in the high DF intake group compared to the low DF intake group (73 v 47%). Among consumers, those in the high DF intake group consumed 'high fibre RTEBC' more often over the four days than those in the low DF intake group (2.8 v 1.9 times) and also consumed more 'high fibre RTEBC' at each eating occasion (51 v 36g) compared to those in the low DF intake group **(Table 3)**.

The dietary patterns of 'fruit' and 'vegetables & vegetable dishes' are presented together in **Table 4** as these food groups are part of the vegetables, salad and fruit food group in the Irish food based dietary guidelines (Department of Health, 2017).

The MDI of 'fruit' was significantly higher among those in the high DF intake group compared to the low DF group in both the total population (124 v 64g/d, respectively) and in consumers only (127 v 76g/d, respectively). There were more consumers of 'fruit' in the high DF intake group compared to the low DF intake group (97 v 84%). Among consumers, those in the high DF intake group consumed 'fruit' more often over the four days than those in the low DF intake group (5.4 v 3.6 times) and consumed a similar amount of 'fruit' at each eating occasion (113 v 112g).

The MDI of 'vegetables & vegetable dishes' was significantly higher among those in the high DF intake group compared to the low DF intake group in both the total population (65 v 33g/d, respectively) and in consumers only (72 v 40g/d, respectively). There was a similar number of consumers of 'vegetables & vegetable dishes' in the high DF intake group compared to the low DF intake group (91 v 82%). Among consumers, those in the high DF intake group consumed 'vegetables & vegetable dishes' more often over the four days than those in the low DF intake group (3.4 v 2.6 times) and also consumed more at each eating occasion (89 v 58g) **(Table 4)**.

Table 1. Mean daily intake (g/d) of dietary fibre in low, medium and high fibre intake groups and the difference in intakes in children (5-12 y) in Ireland (n 600) in the NCFS II.

Age group	Low intake group (*n* 198)	Medium intake group (*n* 202)	High intake group (*n* 200)	Difference between the high and low DF intake groups
	g/d			
5-12y	9.8 [a]	13.6 [b]	19.0 [c]	9.3
5-6 y	9.1 [a]	12.8 [b]	17.0 [c]	7.9
7-10 y	9.9 [a]	13.6 [b]	19.5 [c]	9.6
11-12y	10.3 [a]	14.1 [b]	19.8 [c]	9.6

Statistically significant differences (P<0.01) between intake groups within the rows are denoted by different superscript lowercase letters
EFSA adequate intake for D age groups: 14g/d (4-6 y), 16 g/d (7-10y), 19g/d (11-14y); Scientific Opinion on Dietary Reference Values for carbohydrates and dietary fibre. European Food Safety Authority. (2010).

Table 2. Percent contribution (%) of food groups to the difference in dietary fibre intakes between high and low fibre intake groups in children (5-12y) in Ireland (n 600) in the NCFS II.

Food Group	Low intake group (*n* 198)		Medium intake group (*n* 202)		High intake group (*n* 200)		Difference between the high and low DF intake groups	
	g/d	%	g/d	%	g/d	%	g/d	%
Breads & rolls	2.2	22.2	3.0	22.1	4.6	24.4	2.5	26.6
Wholemeal & brown bread	0.6	6.6	1.3	9.3	2.7	14.0	2.0	21.8
White bread	1.4	14.3	1.6	11.6	1.6	8.3	0.2	2.0
Other breads (e.g. garlic bread, fruit breads, scones)	0.1	1.3	0.2	1.1	0.4	2.1	0.3	2.9
Breakfast cereals	1.2	12.7	2.1	15.9	3.3	17.5	2.1	22.5
RTEBC (Ready-to-eat breakfast cereal)	1.0	10.7	1.9	13.8	3.0	15.5	1.9	20.7
High fibre RTEBC (≥ 6g / 100g)	*0.7*	*6.7*	*1.5*	*10.7*	*2.7*	*14.1*	*2.0*	*21.9*
Low fibre RTEBC (< 6g / 100g)	*0.4*	*4.0*	*0.4*	*3.1*	*0.3*	*1.4*	*-0.1*	*-1.3*
Other breakfast cereals	0.2	2.0	0.3	2.0	0.4	1.9	0.2	1.9
Vegetables & vegetable dishes	0.8	7.8	1.3	9.5	1.8	9.5	1.0	11.3
Fruit	0.9	9.0	1.2	9.3	1.8	9.6	0.9	9.9
Grains, rice, pasta & savouries	1.0	10.4	1.3	9.5	1.6	8.5	0.6	6.5
Sugars, confectionery, preserves & savoury snacks	0.6	6.5	0.8	6.2	1.2	6.2	0.5	5.9
Potatoes & potato products	0.9	9.4	1.2	8.6	1.4	7.6	0.5	5.7
Meat & meat products	0.9	9.0	1.0	7.1	1.2	6.5	0.4	3.9
Fruit juices & smoothies	0.1	1.3	0.2	1.6	0.2	1.1	0.1	0.8
Other food groups	1.1	11.7	1.4	10.3	1.8	9.3	0.6	6.9
Total	**9.8**	**100**	**13.6**	**100**	**19.0**	**100**	**9.3**	**100**

Table 3. The consumption patterns of 'wholemeal & brown bread' and 'high fibre RTEBC' in the low and high dietary fibre intake groups in children (5-12 y) in Ireland in the NCFS II.

	Wholemeal & brown bread		High fibre RTEBC	
	Low *n* 198	High *n* 200	Low *n* 198	High *n* 200
MDI in the total population (g)	12	43†	7	25†
Consumers (%)	40	69*	47	73*
MDI in consumers (g)	29	62†	16	34†
Frequency of intake over 4 days	2.2	3.9†	1.9	2.8†
Mean amount per eating occasion (g)	54	65†	36	51†

*Statistically different ($P<0.01$) from that in the low intake group via Chi Square test for independence

†Statistically different ($P<0.01$) from that in the low intake group via independent samples t-tests

Table 4. The consumption patterns of 'vegetables & vegetable dishes' and 'fruit' in the low and high dietary fibre intake groups in children (5-12 y) in Ireland in the NCFS II.

	Vegetables & vegetable dishes		Fruit	
	Low *n* 198	High *n* 200	Low *n* 198	High *n* 200
MDI in the total population (g)	33	65†	64	124†
Consumers (%)	82	91	84	97*
MDI in consumers (g)	40	72†	76	127†
Frequency of intake over 4 days	2.6	3.4†	3.6	5.4†
Mean amount per eating occasion (g)	58	89†	112	113

*Statistically different (P<0.01) from that in the low intake group via Chi Square test for independence

†Statistically different (P<0.01) from that in the low intake group via independent samples t-tests

Discussion

Low intakes of DF have previously been identified in school-aged children in Ireland with mean intakes (14 g/d) below the AI proposed by EFSA for normal laxation (EFSA Panel on Dietetic Products and Allergies, 2010). The aim of the current chapter was to identify the dietary determinants of DF intake in those children with high DF intakes compared to those with lower intakes. Children were divided into three groups based on their intake of DF. Children in the low and medium DF intake group had an MDI of 9.8g/d and 13.6g/d, respectively, while those in the high DF intake group had an MDI 19.0g/d. The mean intake of DF among children in the low and medium intake group was below the EFSA AI while the mean intake in the high intake group was above the AI (EFSA Panel on Dietetic Products and Allergies, 2010). The main food groups contributing to the difference in DF intakes (9.3g) between the high and low intake groups were 'wholemeal & brown breads' (22%), 'high fibre RTEBC' (22%), 'vegetables & vegetable dishes' (11%) and 'fruit' (10%). For 'wholemeal & brown breads', 'high fibre RTEBC' and 'fruit', there was a higher proportion of consumers in the high DF intake group compared to the low DF intake group. Children in the high DF intake group consumed 'wholemeal & brown breads', 'high fibre RTEBC', 'vegetables & vegetable dishes' and 'fruit' more frequently than those in the low DF intake group. For 'wholemeal & brown breads', 'high fibre RTEBC' and 'vegetables & vegetable dishes', those in the higher DF intake group consumed greater amounts at each eating occasion however this wasn't observed for fruit.

Dietary determinants of DF intakes

The low DF intakes previously identified in school-aged children in Ireland highlights a need to develop dietary strategies to improve DF intakes in this population group. As previously outlined, one approach that can be used to develop dietary strategies to improve nutrient intakes in specific population groups is to identify a proportion of the population with adequate or sufficient intakes and to identify the foods and consumption patterns that contribute to the difference in intakes between those with sufficient intakes and those with lower intakes. If those with low intakes can adopt the dietary patterns of those with higher intakes it may help to improve intakes within the

overall population (Gibney and Sandström, 2008). Using this approach, the cohort was divided into thirds based on their intake of DF (low, medium & high). When compared to the AI for DF intake proposed by the EFSA; 14g/d (4-6 y), 16 g/d (7-10y) and 19g/d (11-14y**)**, the mean intake of DF among children in the low and medium DF intake groups (9.8g/d and 13.6g/d, respectively) were below the EFSA AI, while the mean intake in the high intake group (19g/d) was above the AI (EFSA Panel on Dietetic Products and Allergies, 2010) with a difference of 9.3g/d reported between the high and low DF intake group. Over two thirds of the difference in intakes between high and low DF intake groups was attributable to just four food groups; 'wholemeal & brown breads' (22%) 'high fibre RTEBC' (22%), 'vegetables & vegetable dishes' (11%) and 'fruit' (10%) suggesting that focussing on the patterns of intake of these four food groups could help identify strategies to improve DF intake for children in Ireland.

Of the 9.3g/d difference in DF intakes between the high DF intake group and the low DF intake group, 'wholemeal & brown breads' and 'high fibre RTEBC' accounted for 44% of this difference. While 'white breads' and 'wholemeal & brown breads' have previously been shown to make equal contributions to overall DF intakes (10-11%), 'wholemeal & brown breads' made a greater contribution to the difference (22%) in DF intakes between the high and low DF intake groups compared to white breads (2%), reflective of the widespread consumption of white bread in both the high and low DF intake groups.

The current study showed that the large contribution of 'wholemeal & brown breads' and 'high fibre RTEBC' to the difference in intake between the high and low DF intake groups can be explained by a number of consumption patterns. Children with a higher DF intake were more likely to be consumers of both 'wholemeal & brown bread' and 'high fibre RTBC', consume these foods more frequently and in greater amounts per eating occasion compared to those with low intakes of DF. In this study, children in the high DF intake group had a combined average intake of 138g of 'wholemeal & brown breads' and 'high fibre RTEBC' (equating to approx. 2.7 servings) while those in the low DF intake group had an average intake of 68g (approx. 1.0 serving). These findings are in keeping with the Irish food based dietary guidelines to choose three to

five servings of wholemeal breads, cereals and rice per day (Department of Health, 2017), indicating that a higher compliance with the food based dietary guidelines to consume 'wholemeal & brown breads' and 'high fibre RTEBC' will improve DF intakes in children. These findings are similar to that previously observed in Irish children in the previous NCFS (2003-04) (Bannon, 2011). While there was an increased consumption of both 'wholemeal & brown breads' and 'high fibre RTEBC' the increased intake of these foods was distributed across low, medium and high DF intake groups.

Our findings are similar to that observed in a nationally representative dietary survey of children in Australia (2011-2012) which used quartile analysis to split children aged 2-18 years into four groups based on their fibre intakes. The study found that children in the high fibre intake group had higher intakes of DF compared to those in the low fibre intake group (32.4 v 9.6g/d, respectively) with a difference of 22.8g/d between the two intake groups. This study also found that higher intakes of wholegrain foods such as whole grain breads and high fibre RTEBC were associated with higher DF intakes in children. For example, the high fibre intake group had a higher proportion of total daily fibre from cereals and cereal products (which included grains) compared to the low fibre intake group (9.7 v 2.9g/d, respectively). The high fibre intake group were also more likely to consume RTEBC (including high fibre cereals) compared to the low fibre intake group (55 v 36%, respectively) and had double the median intake of this food group compared to the low fibre intake group (51 v 26g/d, respectively) (Fayet-Moore *et al.*, 2018).

Studies in the UK, Italy and the US used tertile analysis to examine the determinants of whole grain consumption in children. Children were divided into three groups based on their whole grain consumption, and the fibre intakes for each group were reported. A study using data from The National Diet and Nutrition Survey (NDNS) (2008-11) in the UK found that children (2-17y) in the high whole grain consumer group had higher intakes of DF (19.3g/d) compared to those in the low whole grain consumer group (15.1g/d) (Mann *et al.*, 2015). Similarly, a study using data from the national dietary survey in Italy (INRAN-SCAI) (2005-06) found that children (3-17y) in the high wholegrain consumer group had a more fibre dense diet compared to those in the

low consumer group (20.5 v 18.2 g/10MJ) (Sette *et al.*, 2017). A study in the US using data from the National Health and Nutrition Examination Survey (2001-12) also reported that fibre intakes were higher among children (6-18y) in the high whole grain consumption group compared to those in the low whole grain consumption group (18.4 v 11.3g/d, respectively) (Albertson, 2016).

Fruit & vegetables including vegetable dishes collectively accounted for 21% of the difference in DF intakes between the high and low DF intake groups in our study of Irish school-aged children. 'Fruit' accounted for 10% of the difference while 'vegetables & vegetable dishes' accounted for 11% of this difference.

Children in the high DF intake group were more likely to be consumers of 'fruit' and also to consume it more frequently (5.4 v 3.6 times) compared to children in the low DF intake group however there was no difference in the amount of 'fruit' consumed at an eating occasion (112-113g) which may suggest that fruit is consumed in standard portion sizes. Children in the high DF intake group consumed 'vegetables & vegetable dishes' more frequently (3.4 v 2.6 times) and in greater amounts per eating occasion (89g v 58g) compared to the low DF intake group. The Irish food based dietary guidelines advise to consume 5 to 7 servings of 'fruit & vegetables' per day (Department of Health, 2017). In the current study, children in the high DF intake group consumed an average intake of 260g/d of 'fruit & vegetables' (equating to approx. 3.2 servings) while those in the low DF intake group consumed an average intake of 158g/d (approx.1.9 servings). While those in the high DF intake group appear to be meeting the DF recommendations with current fruit & vegetable intake (in combination with other dietary sources), it is important to note that no group were meeting the food based dietary guidelines for fruit & vegetables which may infer other health benefits. Fruit & vegetables were also identified as determinants of DF intake in the previous NCFS (2003-04). However the contribution of vegetables & vegetable dishes to the difference in intakes is lower due to the increased intake in the low DF intake group (Bannon, 2011). These findings are similar to findings from a study in Australian children (2-18y). Using quartile analysis, children in the high fibre intake group had a greater contribution to DF intakes from fruit products and dishes (6.1g/d) compared to the low fibre intake group (1.3g/d), and a greater contribution to DF

intakes from vegetable products and dishes compared to the low fibre intake group (4.8 v 1.3g/d, respectively) (Fayet-Moore *et al.*, 2018).

Strategies to increase fibre intakes

Public health campaigns have been implemented in countries across Europe to improve DF intakes in children. For example, the Bulgarian school food policy advise that whole grain options for bread should be available at least twice a week while the Swiss food-based standards recommend school lunches to serve 50% whole grain bread in Switzerland (JRC, 2015). Similarly, in Germany, voluntary guidelines are set for the standardisation of school meals which require whole grain to be served at least 4 days in a 20-day serving plan (equating to one serving per week) (WCRF, 2016). In 2009, Denmark initiated a public health campaign 'The Whole Grain Partnership' to promote the consumption of wholegrains to improve DF intakes in the Danish population. 'The Whole Grain Partnership' campaign created flyers for consumers, pictures and videos of famous whole grain 'ambassadors' advertisements and posters to encourage consumers to buy products that have the whole grain logo while also hosting a national whole grain day to inform the public about whole grains in the diet (Brinch-Nelson and Neese, 2013). Since the introduction of the public health campaign in Denmark, 43% of Danish children now eat the recommended daily intake of wholegrains compared to 7% previously reported (Greve and Neess, 2014). In addition, a voluntary labelling system known as the keyhole symbol came in to affect in Nordic countries; Denmark, Norway and Sweden in 2015. The objective of this strategy is to help consumers identify healthier food products within a product group. Foods labelled with the keyhole symbol have met the nutrient criteria to be recognised as a healthy food product such as high fibre cereal foods (i.e. contain at least 6g/100g of DF) (The Norweign Ministry of Health and Care Services, 2015).

In Ireland, the food industry have responded to the low DF intake in the population and have reformulated products to increase their DF content. Data from the NCFS II has shown availability of 'half and half' breads with an increased fibre content (3.5-6.5g/100g) since the previous NCFS (2003-04) (e.g. 'Hovis Best of Both Sliced Pan,'Brennan's Brown & White In One Bite' and 'Irish Pride Hi-Fibre Plus') however these were not widely consumed by Irish children (<5% consumers). The DF content

has also increased in commonly consumed RTEBC such as Cheerios (6.2 to 8.9g DF per 100g) and Special K (2.7 to 5.3 DF per 100g) in the last fifteen years which highlights the steps the food industry are making to improve DF intake in population groups.

Public health campaigns to increase the intake of fruit and vegetables have also been implemented across Europe. In Ireland and the UK, the Food Dudes Healthy Eating programme (2010) has been implemented in primary schools reporting a positive effect in educating children and families on the importance of fruit & vegetables in primary school-aged children (Bangor Food and Activity Research Unit, 2007, DAFM, 2010). Denmark and Norway have also successfully implemented public health campaigns in schools to promote the consumption of fruit and vegetables in children (Eriksen *et al.*, 2007, Bere *et al.*, 2010). However despite the introduction of public health initiatives to promote fruit and vegetable consumption in school-aged children, a review of the literature (Chapter 1) and recent findings in Irish children (Chapter 4) indicate that the intake of fruit & vegetables in children are still below the recommendations in Ireland and other European countries.

Strengths & limitations

A key strength of this study is the detailed dietary intake data collected which provided information on every food and drink item consumed by each of the participants, at every eating occasion, for each of the four recording days. Food packaging was obtained where possible to ensure a high level of accuracy of dietary data and to provide DF composition at brand level (i.e. information on high fibre bread and high fibre breakfast cereals). The robust methodology used in this study is also a key strength as this approach has been suggested as part of a framework for developing food based dietary guidelines in the European Union (Gibney and Sandström, 2001). Misreporting or under reporting of energy intake is a known limitation with all dietary assessment and may be a source of bias. This issue was minimised by extensive training and the high level of researcher-participant interaction (three visits over the 4-day period) by trained research nutritionists.

Conclusion

In summary, findings from this analysis have indicated that the mean intake of DF among those in the high DF intake group was above the recommended AI for DF while children in the low and medium DF intake groups were below the EFSA recommendations. The food groups that contributed to the majority of the difference in intake between the high and low DF intake groups in Irish children were wholemeal breads, high fibre RTEBC, vegetables & vegetable dishes and fruit. For 'wholemeal & brown breads', 'high fibre RTEBC' and 'fruit', there was a higher proportion of consumers in the high DF intake group compared to the low DF intake group. Children in the high DF intake group consumed 'wholemeal & brown breads', 'high fibre RTEBC', 'vegetables & vegetable dishes' and 'fruit' more frequently than those in the low DF intake group. For 'wholemeal & brown breads', 'high fibre RTEBC' and 'vegetables & vegetable dishes', those in the higher DF intake group consumed greater amounts at each eating occasion. These findings are in line with dietary guidelines to consume wholemeal breads, high fibre RTEBC and fruit and vegetables

It could be advised for children with low DF intakes to adopt the dietary patterns of children with high DF intakes to improve the intake of DF in this population group. Similar to public health strategies in other countries, these findings suggest that the promotion of wholemeal cereal foods and fruit and vegetable consumption in school-aged children is required to improve DF intakes in this population group. Overall, findings from this study may provide information to policy makers and the food industry to gain a more comprehensive understanding of the foods influencing high intakes of fibre in school-aged children in Ireland.

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Chapter 7

General Discussion

On-going research suggests that changes in current dietary patterns including an increased consumption of plant-based foods will provide major health benefits and will support a more sustainable environment (Ostfeld, 2017, Satija and Hu, 2018, Willett *et al.*, 2019).

The important contribution of plant-based foods such as wholemeal cereals, fruits and vegetables to dietary fibre (DF) and an array of micronutrients places these food groups as central components of dietary guidelines worldwide (WHO, 2000, Herforth *et al.*, 2019, WHO/FAO, 2019). Studies have reported that plant-based diets have been associated with a reduction in the risk of developing many non-communicable diseases (Appleby *et al.*, 2002, Boeing *et al.*, 2006, Ferdowsian and Barnard, 2009, Tonstad *et al.*, 2009, Wien and Sabaté, 2010, Boeing *et al.*, 2012, Romaguera *et al.*, 2012, Viguiliouk *et al.*, 2015, Albertson, 2016, McMacken and Shah, 2017). As the childhood years are a critical period during which eating behaviours and food preferences evolve, (Kelder *et al.*, 1994, Birch, 1999, Birch *et al.*, 2007), promoting the consumption of plant-based foods from a young age would promote healthy eating patterns that may reduce the risk of developing non-communicable diseases in later life.

This PhD thesis aimed to use data from the recent National Children's Food Survey II (NCFS II) (2017-18) to examine the current intakes of 'cereals, grains & potatoes', 'fruit & vegetables' and DF in a nationally representative sample of children aged 5-12 years in the Republic of Ireland and to investigate the dietary determinants of DF intake in this population group. A further aim was to investigate any changes in the intakes of 'cereals, grains & potatoes', 'fruit & vegetables' and DF in school-aged children between the current study (2017-18) and the previous NCFS (2003-04) which used a similar methodology.

Cereals, grains & potatoes are staple foods in the human diet providing a major proportion of energy and nutrients to all population groups (including children) (FAO, 2003, McKevith, 2004, Lafiandra *et al.*, 2014). The consumption of cereal foods, particularly wholegrain, is encouraged in children to promote dietary patterns that will reduce the risk of developing chronic diseases in later life (Kranz *et al.*, 2004, Kranz *et al.*, 2017). The first aim of this thesis was to estimate the intake of 'cereals, grains & potatoes' and the contribution of this food group to energy and nutrient intakes in

school-aged children (5-12y) in the Republic of Ireland using data from the NCFS II (2017-18), and to identify any changes in the consumption of this food group since the previous NCFS (2003-04). Findings from the current study indicate that 'cereals, grains & potatoes' were consumed by 100% of Irish school-aged children with a mean daily intake of 271g/d equating to approximately 3.7 servings per day. Of the 3.7 servings, only 1.7 servings were of the wholemeal or brown variety or from unprocessed potatoes, which is below the recommendation of 3-5 servings of wholemeal cereals & breads, potatoes, pasta and rice per day (Department of Health, 2017). Findings from this study highlight that refined cereal products such as white bread, white pasta, rice & other savouries are more widely consumed than the wholemeal varieties in children in Ireland and there is a need to increase the consumption of wholemeal cereal foods to comply with the food based dietary guidelines.

Despite some variations in the classification of cereals and cereal products across countries, the intake of 'cereals, grains & potatoes' reported in Irish children (271g/d) was similar to intakes reported in other countries across Europe such as Italy (285g/d), the UK, Denmark and the Netherlands (250g-285g/d) (Leclercq *et al.*, 2009, Pedersen *et al.*, 2014, Public Health England, 2014, Van Rossum *et al.*, 2016). For countries that don't include potatoes in their estimates of intakes, the intake of cereals & grains (excluding potatoes) in Irish children (210g) was similar to intakes in Turkey and Germany (187g-211g/d) but higher than intakes in Spain (168g/d) (Alexy *et al.*, 2010, Republic of Turkey Ministry of Health, 2016, Partearroyo *et al.*, 2019). Findings from this study also showed that, 'cereals, grains & potatoes' contributed an array of important nutrients to the diets of children in Ireland including DF (56%), B vitamins (16-51%), vitamin D (27%), iron (56%) and calcium (33%). For most nutrients, these findings were in keeping with other European countries. However, for B-vitamins, 'cereals grains & potatoes' made smaller contributions (11-40%) in Denmark, Italy, the Netherlands, the UK and Spain compared to our study (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Mielgo-Ayuso *et al.*, 2017, Public Health England, 2018). The contribution of 'cereals, grains & potatoes' to micronutrients such as B-vitamins, vitamin D and iron in our study is mainly attributable to fortified ready-to-eat breakfast cereals (RTEBCs) and wheat products produced from fortified flour. In Ireland, RTEBCs are typically fortified with an array of B-vitamins, vitamin

D and iron and, wheat flour is mandatorily fortified with thiamin, calcium and iron to restore losses during the milling process (Foods Standard Agency, 1998). In the current study, 'cereals, grains & potatoes' made relatively small contributions to intakes of saturated fat (15%) and free sugar (13%). However, 'cereals, grains & potatoes' contributed to higher intakes of saturated fat in the UK (29%) and higher intakes of free sugar in Spain (33%) and the UK (33%) compared to our study which may be attributable to the inclusion of bakery products and puddings in the estimation of cereal intake in these countries (Ruiz *et al.*, 2016, Public Health England, 2018).

Overall, intakes of 'cereals, grains & potatoes' were similar in the NCFS II (2017-18) (271g/d) and the NCFS (2003-04) (280g/d), however, the intake of white bread, low fibre RTEBC and potatoes was lower in the current study than the previous NCFS and the intake of brown/wholemeal bread, high fibre RTEBC, porridges and pasta was higher. Despite a higher intake of wholemeal cereal foods over time, children still in Ireland mainly consume refined cereal products and intakes are below the recommendations. The National Teens' Food Survey (NTFS) (2005-06) found that Irish teenagers (13-17y) had an intake of 364g/d of 'cereals, grains & potatoes' (IUNA, 2007) but consumed less wholemeal varieties. Although this age group had higher intakes, they still did not meet the recommendation of 3-5 servings of wholemeal cereals & breads, potatoes, pasta and rice per day (Department of Health, 2017). The ongoing NTFS II (2019-20) will offer new insights to observe if a similar trend between Irish children and teenagers has occurred since the previous surveys.

Fruit and vegetables hold an important place in food based dietary guidelines due to their low energy density and high concentration of vitamins, minerals and DF in the diet (Slavin and Lloyd, 2012, USDA, 2015). As the childhood years are an important period during which food preferences evolve (Kelder *et al.*, 1994, Birch *et al.*, 2007), the consumption of fruit & vegetables from a young age would help foster healthy eating practices which may reduce the risk of developing chronic diseases such as obesity and non-communicable diseases in later life (Kranz *et al.*, 2004, WHO/FAO, 2004). The next aim of this thesis was to use data from the NCFS II to estimate the intake of fruit & vegetables, compliance with recommendations for fruit & vegetable consumption and the contribution of this food group to energy and nutrient intakes in school-aged children (5-12y) in the Republic of Ireland. A further aim was to identify

any changes in the consumption of fruit and vegetables in children in Ireland since the previous NCFS (2003-04). Findings from the current study indicated that 'fruit & vegetables' were consumed by all children in the NCFS II with a mean daily intake of 221g/d (approximately 2.8 servings per day). This is below the WHO recommendation of at least 400g of fruit & vegetables per day (WHO/FAO, 2004) and the Irish food based dietary guideline of 5-7 servings of fruit & vegetables per day (with a limit of 150ml/day from unsweetened fruit juice or smoothies) (Department of Health, 2017). At an individual level, only 9% of Irish school-aged children met the WHO recommendation and just 6% met the Irish food based dietary guidelines recommendation for fruit & vegetable consumption (WHO/FAO, 2004, Department of Health, 2017). Findings from this study have also highlighted the importance of including composite dishes in estimates of vegetable intakes. Total vegetable intakes would have been underestimated by 54% in this study if vegetable intakes from composite dishes were not included in the estimates. This is consistent with previous studies which showed that failing to account for intake from composite dishes can underestimate vegetable intakes by 45% in pre-school children, 52% in school-aged children and up to 26% in adults (O'Brien *et al.*, 2003, O'Connor *et al.*, 2016, McCarthy *et al.*, 2018).

The low intake of 'fruit & vegetables' found in Irish children (221g/d) was similar to intakes reported in the UK and the Netherlands (255g-272g/d) (Van Rossum *et al.*, 2016, Public Health England, 2018) but lower than that reported in in Italy and Spain (341g-350g/d) (Leclercq *et al.*, 2009, Partearroyo *et al.*, 2019). Of note, Danish children had a higher fruit and vegetable intake of 404g/d which is line with the WHO recommendation (WHO/FAO, 2004, Pedersen *et al.*, 2014). These higher intakes may be partly attributable to the higher intakes of fruit in Danish children (188g/d) compared to Irish children (90g/d).

The current study found that 'fruit & vegetables' contributed a small proportion (7%) of overall energy intake but contributed significantly to intakes of DF (19%), vitamin A (28%), B vitamins (13-15%), vitamin C (50%), potassium (17%) and magnesium (12%) in Irish school-aged children. Fruit and vegetables also contributed to intakes of total sugar (25%) and free sugar (11%), primarily from the consumption of whole fruit and fruit juices, respectively. For most nutrients, fruit and vegetables made similar contributions to dietary intakes in other European countries such as Denmark,

the Netherlands, the UK, Italy and Spain (Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Olza *et al.*, 2017, Mielgo-Ayuso *et al.*, 2018, Public Health England, 2018). Fruit and vegetables made greater contributions to intakes of DF (25-37%), vitamin C (71-83%) and vitamin A (38-46%) in some European countries such as Denmark, Italy, Spain, the Netherlands and the UK which may be attributable to the overall higher intakes and different classification of fruit & vegetables in these countries (Leclercq *et al.*, 2009, Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018, Partearroyo *et al.*, 2019).

When compared to the previous NCFS (2003-04), children (5-12y) in Ireland had similar intakes of 'fruit & vegetables' in 2017-18 (NCFS II: 221g/d, NCFS: 224g/d). However, the intake of whole fruit and smoothies was higher and the intake of fruit juice was lower in the NCFS II (2017-18) compared to the NCFS (2003-04). Of note, there was no difference in discrete vegetable intake or vegetables in composite dishes between 2003-04 and 2017-18. Children in the NCFS (2003-04) consumed relatively similar amounts of 'fruit & vegetables' per day compared to Irish teenagers (13-17y) in the NTFS (2005-06) (NTFS: 210g/d, NCFS 224g/d) (IUNA, 2005, IUNA, 2007). Irish teenagers consumed higher amounts of fruit juice compared to Irish children (NTFS: 86g/d, NCFS 38g/d) (IUNA, 2005, IUNA, 2007). However, both age groups did not meet the Irish food based dietary guideline of 5-7 servings of fruit & vegetables per day (Department of Health, 2017). Ongoing research in the NTFS II (2019-20) will provide insights into the current consumption patterns of this food group from childhood to teenage years in Ireland.

As previously outlined, plant-based foods such as wholemeal cereal foods and fruits and vegetables hold an important place in food based dietary guidelines due to their important contribution to DF and other nutrients in the diet. As intakes of these food groups in Irish children are below recommendations, the next aim of this thesis was to estimate the current intakes and sources of DF in school-aged children (5-12y) in the Republic of Ireland and to identify any changes in DF intakes since the previous NCFS (2003-04). DF plays a key role in normal bowel function for all ages and is associated with a reduced risk of chronic diseases such as obesity, cardiovascular disease, type 2 diabetes and colorectal cancer in adults (EFSA Panel on Dietetic Products and Allergies, 2010, Reynolds *et al.*, 2019). Therefore, adequate DF intake in childhood is

important for current bowel health and also to promote dietary patterns that will reduce the risk of developing chronic diseases in later life (Anderson *et al.*, 2009, Kranz *et al.*, 2012).

This study found that while the intake of DF in Irish school-aged children (14.4g/d) has increased since the previous NCFS (2003-04) (12.4g/d), intakes still remain lower than the adequate intake (AI) set by the EFSA for normal bowel function (Deasy *et al.*, 2007, EFSA Panel on Dietetic Products and Allergies, 2010). Furthermore, the previous NTFS (2005-06) found that DF intakes decreased from Irish children to teenagers (NCFS : 12.4g/d, NTFS: 11.6g/d) (Deasy *et al.*, 2007, IUNA, 2007) not meeting the AI set by EFSA (EFSA Panel on Dietetic Products and Allergies, 2010). The ongoing NTFS II (2019-20) will provide current nutrient intake data to observe if a similar trend between Irish children and teenagers has occurred since the previous surveys. These findings are in keeping with the low intake of DF reported in children in the UK, Spain, Italy, Sweden and the Netherlands (11.8g- 17g/d) (Barbieri *et al.*, 2006, Sette *et al.*, 2011, Ruiz *et al.*, 2016, Public Health England, 2018), however intakes of DF were higher in Danish children (18-20g/d) (Pedersen *et al.*, 2014) and met the EFSA AI recommendation (EFSA Panel on Dietetic Products and Allergies, 2010). The key sources of DF in children in Ireland were 'breads & rolls' (23%), breakfast cereals (15%), 'fruit & fruit juices' (11%), 'grains, rice, pasta & savouries' (10%), 'vegetables & vegetable dishes' (9%) and 'potatoes & potato products' (8%). These findings were similar to the main sources of DF intakes reported in other European population groups (including children) which were grains and cereals (30-54%), fruit (11-24%), vegetables (4-18%) and potatoes and potato products (6-24%) (Barbieri *et al.*, 2006, Van Rossum *et al.*, 2011, Sette *et al.*, 2013, Pedersen *et al.*, 2014, Ruiz *et al.*, 2016, Public Health England, 2018).

Having identified low intakes of DF in children in Ireland, a further aim of this study was to investigate the dietary determinants of DF intakes, which may help to inform dietary strategies to increase intakes of DF in in this population group. One approach that can be used to develop dietary strategies to improve nutrient intakes in specific population groups is to identify a proportion of the population with adequate or sufficient intakes and to identify the foods and consumption patterns that contribute to the difference in intakes between those with sufficient intakes and those with lower intakes. If those with low intakes can adopt the dietary patterns of those with higher

intakes it may help to improve intakes within the overall population (Gibney and Sandström, 2008). Using this approach, this study highlighted that the mean intake of DF among those in the high DF intake group (19g/d) was above the recommended AI for DF while intakes in the low (9.8g/d) and medium DF intake groups (13.6g/d) were below the EFSA recommendation.

The food groups that contributed to the majority of the difference in intake between the high and low DF intake groups in Irish children were wholemeal breads (22%), high fibre ready-to-eat breakfast cereals (RTEBC) (22%), vegetables & vegetable dishes (11%) and fruit (10%). For 'wholemeal & brown breads', 'high fibre RTEBC' and 'fruit', there was a higher proportion of consumers in the high DF intake group compared to the low DF intake group. Children in the high DF intake group consumed 'wholemeal & brown breads', 'high fibre RTEBC', 'vegetables & vegetable dishes' and 'fruit' more frequently than those in the low DF intake group. Children in the high DF intake group consumed greater amounts of 'wholemeal & brown breads', 'high fibre RTEBC' and 'vegetables & vegetable dishes' at each eating occasion, however this wasn't observed for fruit. These findings are in line with dietary guidelines to consume wholemeal cereals and fruit and vegetables (Department of Health, 2017). It could be advised for children with low DF intakes to adopt the dietary patterns of children with high DF intakes to improve the intake of DF in this population group. Our findings are similar to results from studies in Europe, the US and Australia that used the above approach to investigate the dietary determinants of both DF and wholegrain consumption in school-aged children. Similar to our study, these studies suggest that increasing intakes of whole grains, fruits and vegetables in compliance with the dietary guidelines would help to improve DF intakes in school-aged children (Mann *et al.*, 2015, Albertson, 2016, Sette *et al.*, 2017, Fayet-Moore *et al.*, 2018). Such public health strategies have been implemented in some European countries. For example, healthy eating campaigns have been implemented in primary schools to increase the consumption of fruit and vegetables across Europe including Ireland, the UK, Denmark and Norway (Bangor Food and Activity Research Unit, 2007, Eriksen *et al.*, 2007, Bere *et al.*, 2010, DAFM, 2010). In addition, dietary strategies have been implemented in primary schools in Bulgaria, Switzerland and Germany to increase the consumption of wholegrains in children (JRC, 2015, WCRF, 2016). There has also been public health initiatives set up to promote wholegrain consumption in Denmark

and since the introduction of the initiative, 43% of Danish children now eat the recommended daily intake of wholegrains compared to 7% previously reported (Brinch-Nelson and Neese, 2013, Greve and Neess, 2014). Furthermore, Nordic countries (Denmark, Norway and Sweden) have introduced the voluntary labelling of healthy food products to promote the consumption of healthy foods such as whole grains, fruit & vegetables (The Norweign Ministry of Health and Care Services, 2015).

The present thesis has a number of strengths. This is the first study to report the intake of 'cereal, grains & potatoes' and 'fruit & vegetables' in a nationally representative sample of Irish school-aged children (including changes since 2003-04). Another main strength of the study is the use of high quality dietary data (including brand level detail and recipes of composite dishes) for estimating intakes of plant-based foods and DF in school-aged children in Ireland. A further strength of this study is the detailed methodology used to estimate fruit & vegetable intake from composite dishes. The robust methodology used to estimate the dietary determinants of DF intakes in this study is another strength as this method has been suggested as part of a framework for developing food based dietary guidelines in the European Union (Gibney and Sandström, 2001). Whist under reporting of energy intake is a known limitation with dietary assessment, this issue was minimised by high levels of researcher-participant interaction across the NCFS II and the NCFS (three visits over the 4-day recording period for the NCFS II and 4 visits over the 7-day recording period for the NCFS).

Future analysis could examine the effect of socio-economic status (SES) and urban/ rural location on plant-based foods and DF intake in school-aged children. Previous studies have found that whole grain intakes in the UK increased with higher socio-economic status (Mann *et al.*, 2015) and in Spain, children and young people from a lower socioeconomic background showed to have lower intake of vegetables (Aranceta *et al.*, 2003). In addition, those of lower socio-economic status in Australia were also less likely to meet the recommendations for DF (Fayet-Moore *et al.*, 2018). A study in Canadian school-aged children (14-15y) also observed links between food intakes, SES and urban/rural location of schools. This study identified that regional demographics may be useful in tailoring healthy eating programs to schools (Minaker *et al.*, 2006). The impact of food consumption patterns in different food environments (at school or at home) could also be examined in future analysis as studies have suggested that food environments at home and at school may be associated with

children's diet or obesity-related outcomes, including influence on BMI (Caspi *et al.*, 2012, Williams *et al.*, 2014).

To conclude, this is the first study to examine the intakes and changes of 'cereal, grains & potatoes' and 'fruit & vegetable' consumption in nationally representative samples of school-aged children (5-12y) in the Republic of Ireland. This study also estimated the current intakes, sources and dietary determinants of DF intake in Irish school-aged children and identified changes since the previous NCFS (2003-04).

Overall intakes of 'cereals, grains & potatoes' were below the recommendations for children in Ireland and were mainly consumed as refined cereal products rather than the wholemeal variety. Furthermore, fruit & vegetable intakes were low with less than 10% of children meeting either national or international recommendations for fruit & vegetable consumption. While overall intakes of 'cereals, grains & potatoes ' and 'fruit & vegetables' were similar to the previous NCFS (2003-04), intakes of wholemeal breads, high fibre RTEBC, porridge, pasta, whole fruit and smoothies were higher and intakes of low fibre RTEBC, potatoes and fruit juice were lower.

Despite an increase in DF since the previous NCFS (2003-04) intakes are still below the AI for normal bowel function in children. Determinants of a higher DF intake were wholemeal/brown breads, high fibre RTEBC, fruit and vegetables. The consumption patterns associated with a higher DF intake were a higher proportion of children consuming these foods (except for vegetables), consuming these foods more frequently and having a higher intake per eating occasion (except for fruit).

The current study indicates that school-aged children in Ireland are not meeting the dietary guidelines with no major changes over the last fifteen years. A multidisciplinary approach is required to improve the diets of children in order to prevent chronic disease in later life. Such stratgeies could include investigating and understanding the factors influending the dietary patterns and the barriers to complying with dietary guidelines from a young age to adulthood. The availability and the reformulation of foods in the food industry, as well as a labelling system to help identify healthy food products could help to educate and support healthy food choices in all population groups. Continued educational and promotional campaigns as well as the implementation of school policies for healthy eating is required to communicate the importance of a healthy diet to the younger age group. Finally, continuous

engagement between policy makers, the food industry, non-government organisations, academia and the general public is required to prevent chronic disease in the population.

In order to harmonise national dietary surveys, the EFSA FoodEx system has been developed to standardise the classification and description of food consumption data in dietary surveys in order to compare data from different sources (European Food Safety Authority, 2011). In addition, the EU Menu Methodology guidance document was created to facilitate the collection of more harmonised food consumption data from all European Union Member States by the year 2020 (European Food Safety Authority, 2014). However, this study indicates that there is a need to further standardise the methodologies used in each dietary survey to ensure accurate comparison of food and nutrient intakes between countries.

Findings from this thesis may provide evidence to public health campaigns to promote the consumption of plant-based foods to increase compliance with the FBDG and to improve DF intakes in this population group. Furthermore, results from this thesis may provide information to policy makers and the food industry to gain a more comprehensive understanding of the foods influencing high intakes of DF in school-aged children in Ireland.

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Appendix I 19 Food Groups

1. Grains, rice, pasta & savouries
    - Pasta
    - Rice
    - Other cereals (e.g. noodles, couscous, quinoa)
    - Pizza
    - Other savouries (e.g. fried rice)
2. Bread & rolls
    - White bread
    - Wholemeal & brown bread
    - Other breads (e.g. garlic bread, fruit breads, scones)
3. Breakfast cereals
    - Ready-to-eat breakfast cereals
        - *High fibre cereals (≥6g/100)*
        - *Low fibre cereals (< 6g/100)*
    - Porridge & hot oat cereals (made up)
4. Biscuits, cakes & pastries
5. Milk & yogurt
6. Creams, ice-creams & chilled desserts
7. Cheeses
8. Butter, spreading fats & oils
9. Eggs & egg dishes
10. Potatoes & potato products
    - Boiled, baked & mashed potatoes
    - Chipped, fried & roasted potatoes
    - Processed & homemade potato products
11. Vegetables & vegetable dishes
    - Discrete vegetables
        - *Peas, beans & lentils*
            - *Baked beans*
        - *Carrots*
        - *Green vegetables*
        - *Other vegetables*
    - Vegetables in composite dishes

12. Fruit & fruit juices
    - Discrete fruit
        - *Apples*
        - *Bananas*
        - *Citrus fruits*
        - *Other fruits*
    - Fruit in composite dishes
    - Fruit juice (100% fruit)
    - Smoothies
13. Fish & fish dishes
14. Meat & meat products
15. Beverages
16. Sugars, confectionery, preserves & savoury snacks
17. Soups, sauces & miscellaneous foods
18. Nutritional supplements
19. Nuts, seeds, herbs & spices