Janice Harland
Lynne Garton

The Plant-based Plan

10 scientific reasons for more plant-based eating

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Design MO KA & Fulya Toper

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www.lannoocampus.be

ALPRO Foundation
Kortrijksesteenweg 1093 C
9051 Gent I Belgium
www.alprofoundation.org

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Content overview

Foreword

PROF. IAN ROWLAND
(Reading, UK)
Chair of Scientific Advisory Committee of the Alpro Foundation

We live in a time where consumers are constantly bombarded with dietary advice on how to improve their health and avoid chronic diseases such as heart disease and cancer. Some of this advice is measured and evidence-based, but much is ill-conceived and sensational, often promoting the latest trendy diet, leaving the poor consumer bemused and confused about what to eat to stay healthy. Exhorting the general public to eat so-called 'superfoods' or desist from consuming saturated fats is likely to have only minor effects if the rest of the diet is not healthful.

It is becoming increasingly clear that focusing dietary advice on single foods and nutrients - such as polyunsaturated fatty acids, sugar or dietary fibre - is counterproductive. A more effective, and scientifically more sound strategy is to look at dietary patterns and evaluate what their effects are on health outcomes. The Mediterranean and Okinawa diets, for instance, incorporate a wide range of foods and there is both epidemiological and experimental evidence for their beneficial impact on human health. These and similarly healthful dietary patterns emphasize the consumption of a diverse range of vegetables, fruits, legumes, and whole grains. It is not surprising that these plant-based foods feature strongly in dietary guidelines throughout the world.

The aim of this book is to present, in a concise, comprehensive and objective form, the extent and depth of the evidence linking a plant-based diet to human health; from its contribution to good nutrition, to its role in modifying the risk of the major chronic diseases afflicting the ageing populations of most countries in the world: cardiovascular disease, type 2 diabetes and cancer.

Introduction

In the last few years the concept of plant-based eating has grown in popularity and subsequently a number of "popular" plant-based diet books have now been published (for example [1-6]). But is there scientific evidence to support this way of eating? Is this another fad diet or is there real proof this diet can support good health? Traditional diets based on plant foods, such as the Mediterranean and East Asian diets, would seemingly endorse this, as it is this particular feature which is thought to contribute to positive health and longevity [7]. It has also been suggested that eating more plant foods while reducing animal foods, is beneficial for the planet. With a growing global population, rising incomes and urbanisation, an increased demand for meat is expected. Many believe this is neither practical nor sustainable. To explore this further, an extensive review of scientific literature was conducted in 2011. This resulted in the publication of "The Plant-based Plan©" which for the first time brought together evidence for nutritional, health and environmental benefits of plant-based eating patterns. Yet in the last few years, and since the first publication of The Plant-based Plan©, there has been a huge increase in the number of studies published in this field. As a result, an updated analysis of the scientific literature has been undertaken and the latest information is now included in this new edition of The Plant-based Plan©. This updated book provides an even greater insight into the benefits of plant-based eating.

The evidence continues to support eating a diet based on plant foods and as such many international organisations and associations still place the emphasis on plant foods in their dietary recommendations to promote good health (Table I.1).

Nearly all European countries have food-based dietary guidelines to support good health, and common to all these models is a diet that includes eating plenty of fruits, vegetables and complex carbohydrates, and choosing foods which are lower in SFA, salt and sugar. Animal foods, including meat and dairy, represent smaller segments in these models, highlighting

World Health Organisation (WHO) 2004, 2014 [8, 9]	Recommendations in the Global Strategy on Diet, Physical Activity and Health report included: 'Increase the consumption of fruits and vegetables, and legumes, whole grains and nuts.'
World Cancer Research Fund (WCRF) 2007 [10]	'Basing our diets on plant foods (like vegetables, fruits, whole grains, and pulses such as beans), which contain fibre and other nutrients, can reduce our risk of cancer.' 'To reduce your cancer risk, eat no more than 500 g (cooked weight) per week of red meats, like beef, pork and lamb, and avoid processed meats such as ham, bacon, salami, hot dogs and some sausages.'
Scientific Report of the 2015 Dietary Guidelines Advisory Committee [11]	'Common characteristics of dietary patterns associated with positive health outcomes include higher intake of vegetables, fruits, whole grains, low- or non-fat dairy, seafood, legumes, and nuts; moderate intake of alcohol (among adults); lower consumption of red and processed meat, and low intake of sugar-sweetened foods and drinks, and refined grains.' 'Moderate to strong evidence demonstrates that healthy dietary patterns that are higher in plant-based foods, such as vegetables, fruits, whole grains, legumes, nuts, and seeds, and lower in calories and animal-based foods are associated with more favourable environmental outcomes (lower greenhouse gas emissions and more favourable land, water, and energy use) than are current U.S. dietary patterns.'
American Dietetic Association 2015 [12]	'The low intake of foods containing saturated fat and cholesterol, and high intake of vegetables, fruits, whole grains, legumes, nuts, seeds and soya products that are rich in fibre and phytochemicals are components of a vegetarian diet that contribute to reduction of chronic disease.'
LiveWell for LIFE Project – defining country-specific sustainable diets across the EU [13]	'Eat more plant foods – enjoy vegetables and whole grains' 'Moderate your meat consumption, both red and white, enjoy other sources of proteins such as peas, beans and nuts'.

Table I.1: International support for plant-based eating

that only modest amounts are required as part of a healthy balanced diet. In contrast, plant-based foods represent larger segments.

Not only do recent studies continue to support plant-based diets for good health, but there is also a larger evidence base to suggest this way of eating is preferable for the environment. Plant-based foods are more advantageous as they require less land, water and energy resources, and produce fewer greenhouse gas emissions than animal-based products. In line with this the World Wildlife Fund (WWF) has recently launched the LiveWell for Low Impact Food in Europe (LiveWell for LIFE) project which uses a LiveWell plate to define country-specific sustainable diets across the EU. The LiveWell plate has now been adopted across the traditional diets of three countries – France, Spain and Sweden. The results from these three countries found that healthier eating can be aligned with environmental objectives. Also, this way of eating costs no more than the current dietary patterns, complies strictly with national nutritional requirements, and closely resembles the current dietary pattern. This was achieved by reducing the total amount of meat consumed, increasing the consumption of legumes as a source of protein, and increasing cereals and starchy foods (typically bread, pasta and potatoes). A number of other countries, e.g. the Netherlands and Norway, are now also taking sustainability into account, and at the same time address a healthy balance of nutrients in their food-based dietary guidelines [11, 14, 15].

Definition of plant-based eating

Currently there is no exact definition of a plant-based diet, yet many people associate this way of eating with being vegetarian, which is not the case. The term "vegetarian" is very broad and encompasses a variety of eating patterns - some include variable amounts of animal foods (Figure I.1).

Early studies investigating the benefits of plant-based diets tended to define this way of eating according to the relative absence of meat in the diet – from the complete avoidance of animal foods (vegans) through to individuals who consume meat on a daily basis. However, recent thinking is that the health benefits of plant-based diets are not solely due to the lack of meat in the diet but also to the increased quantity of plant-based foods. A better way to measure this is by using dietary pattern analysis. Studies using this method have found plant-based dietary patterns that include small amounts of animal products still offer nutritional and health benefits [16-18].

There are different ways of eating more plant-based foods. Plant-based eating does not automatically exclude all animal products but rather than meat being the focus of the diet, plant-based foods should be at the core.

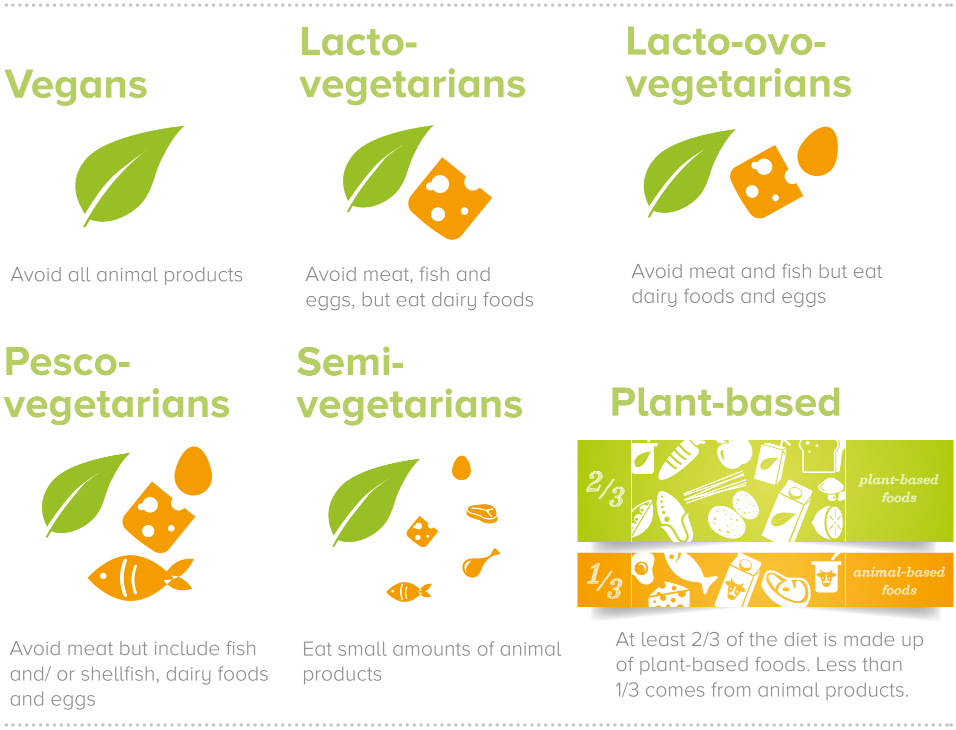

Figure I.1: Different types of vegetarians

This advice is in line with the WCRF recommendations suggesting that two-thirds of a meal should be plant-based foods and one-third animal products [10].

Introduction to the science

A number of general principles have been adopted in this latest review. To identify the recent scientific evidence, initially a search of the scientific literature was undertaken in Medline using the term “plant-based”. As the previous review was conducted up to 2011, new literature from 2011 onwards was searched. This database was supplemented by using the search term “vegetarian” and by hand-searching the reference lists in reviews and meta-analyses. Animal studies were excluded. A database containing human studies or reviews was established, which resulted in approximately 400 new references. This database was then further searched using terms relevant to each chapter. For example, for the heart health chapter the additional search terms were "heart", "CVD", "CHD", "blood pressure", "blood lipids" and "cholesterol". Once the total database had been further searched with terms appropriate to each health condition, subgroups of references were available. These, along with the earlier studies identified in the original Plant-based Plan©, resulted in a doubling of the number of references available to a total of 1008 references being used to form the core scientific evidence for each individual chapter.

The primary sources of information required were studies conducted in humans with plant-based eating patterns. However, in some cases data from vegetarian studies or studies undertaken of those adopting a Mediterranean Diet have been included, as this research can further add to our understanding of plant-based eating.

Scientific support was obtained from two main sources; observational studies and clinical studies. Evidence provided by both groups of studies is valuable; observational studies tend to be much longer term and provide information about the overall impact on health of adopting a particular lifestyle and also provide feedback on day to day practice. However, in these studies associations are measured, not cause and effect. The shorter duration clinical studies provide an insight into the change in specific risk factors. Clinical studies may also help develop an understanding of the mechanisms involved and why a particular intervention is effective. This recent review identified many more randomized clinical trials than previously; they are considered the gold standard in nutrition studies.

In the following chapters information from both clinical and observational studies is detailed (providing an insight into the overall strength of the evidence, based on both clinical disease endpoints and changes in surrogate markers, for the potential health benefits of plant-based eating) and each chapter is introduced with a guest editorial written by an expert in their respective field.

Plant-based eating in practice

Although there is universal consensus that we should be eating more plant-based foods, many people find this difficult to achieve. This may be because they do not have enough information about plant-based eating or how to put it into practice [19]. At the same time, health professionals are becoming aware of the important role they have in helping people make sustainable dietary choices. With this in mind, as well as outlining the evidence supporting the nutritional, health and environmental benefits, the 2015 update of “The Plant-based Plan” provides practical advice on how to motivate and get people started on their eating plan. It is not about transforming the diet, but by making small changes to include more plant foods and less animal products a big difference can be made to both our health and that of the planet.

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Chapter 1
Current nutritional status in Europe

PROF. STEFAAN DE HENAUW
Professor of public health and nutrition at the Department of Public Health, Ghent University (Belgium).

Introduction to Chapter 1, by invited expert Stefaan De Henauw

Over the past few decades several international initiatives were developed in Europe to set population nutrient goals as a basis for a healthy life expectancy, based on thorough review of the available evidence from nutrition research. The EURODIET's main conclusions have been disseminated and quoted widely by the scientific nutrition community and more recently EFSA have essentially confirmed this overall nutritional basis for healthy diet and healthy life.

In addition, the know-how for translating nutrient reference values into so-called food-based dietary guidelines has been improved and fine-tuned over the years. This know-how is now commonly available to all responsible public authorities. Most – if not all – countries in Europe have developed their own nutrition guidelines and many countries have adopted nutrition monitoring systems as an integrated part of their overall public health surveillance system.

Finally, one of the noteworthy efforts in the scientific nutrition community – in collaboration with other stakeholders – has been the development of nutrient profiling systems and the many variations on this theme. A series of sophisticated, yet simple to use tools and aids are available in different formats, shapes and colors, to guide consumers in their choice as they are strolling through the modern food landscape. Today's consumers are more than ever before interested in and informed about the foundations of a healthy diet.

In spite of all this knowledge and all efforts to improve the general diet, the available data on mainstream daily eating practice in Europe and most indicators of current nutritional status of the population in Europe, are far from optimal and do not allow for optimism about the further improvement of the "diet-health" nexus.

The following chapter clearly demonstrates that current data on nutritional status in Europe essentially points at a series of major nutritional problems and challenges. The key issues for the overall nutritional imbalance, so it seems, are predominantly related to overconsumption of animal products and far too low consumption of foods from vegetable origin. Nested within the latter is the general choice for refined sources of starch instead of wholegrain variants.

Interestingly, this trade-off between animal and vegetable sources plays a key role in another very important food and health related phenomenon; the issue of sustainability.

Indeed, the 21st century Western diet is not only suffering severely from imbalances vis-à-vis good health maintenance for the people, it has also cast an increasingly worrying shadow on the health of the planet. Our modern Western food production and consumption system represents a disproportionally large contribution to the global challenge of climate control and sustainability. There is an urgent call to integrate global sustainability imperatives into the processes aimed at promoting a healthy diet. However, it is far from clear how this principle should be put into practice.

Clearly, a transition is required to create a food system that will serve both the need for sustainable health at an individual level and the need for a sustainable planetary condition at a global and intergenerational level.

This indicates a need for a horizontal transition across the chain of interrelated phenomena that ultimately lead to the food choices we make. Such a transition has to rethink and reinvent the position of our food at all levels, from the food production framework – with a shift towards less animal and more vegetable – to the food environment and the way we prepare new generations of people with knowledge and skills to find the "right diet". A healthy diet, yes, for sure, but first and foremost a diet that becomes a major part of our culture, to be cherished and fostered as much as life itself.

We are facing a big challenge. Hopefully, future reports on nutritional status in Europe will bring better news than what we are dealing with today.

Chapter 1
Current nutritional status in Europe

Population nutritional goals

It is well recognized that good nutrition is one of the key factors in maintaining positive health and well-being. As such, it is important to identify the optimum range of nutrient intakes for a population that is consistent with supporting good health. In Europe the most complete population nutritional guidelines are those published by the WHO/FAO and Eurodiet [1, 2]. The Eurodiet project started in October 1998 with the aim of contributing towards a coordinated European Union (EU) health promotion programme on nutrition, diet, and healthy lifestyles. More recently EFSA has added to these with their publication of Dietary Reference Values for fats [3], protein [4], carbohydrates and dietary fibres [5], as well as a number of micronutrients [6].

In addition to these international guidelines, a number of national reference values exist to take into account local factors such as existing dietary intakes, cultural traditions, lifestyles and genetics. For example, the ‘Dietary Reference Values for Food Energy and Nutrients for the United Kingdom’ by the Department of Health, the ‘Dietary reference intakes: energy, proteins, fats, and digestible carbohydrates’ by the Health Council of the Netherlands and the ‘Food recommendations for Belgium’ by the Health Council of Belgium. As well as these national reference values, further nutrient-based guidelines for groups of countries have been developed. These are the D-A-CH Reference values for the German-speaking countries and central Europe [7] and the Nordic Nutrition Recommendations for the Nordic Countries [8].

Due to varying local nutritional guidelines, the international and European recommendations will be referred to in this chapter (Table 1.1) to be able to make meaningful comparisons between European countries.

Nutrient	WHO [1, 9-11]	FAO [12]	Eurodiet [2]	EFSA [3-5]
Dietary Fat (En%)	15-30	15-35	< 30	20-35
SFA (En%)	< 10	10	< 10	Not set, but advised to be as low as possible within a nutritionally adequate diet
PUFA (En%)	6-11	6-11 n-6: 2.5-9 n-3: 0.5-2.0	n-6 PUFA: 4-8 + 2g 18:3(n-3) + 200mg LC n-3 PUFA	18:2(n-6): 4 (AI) + 18:3(n-3): 0.5 (AI) + LC n-3 PUFA: 250mg
Cholesterol (mg/ day)	< 300			
Trans Fat (En%)	< 1	<1	< 2	Not set, but advised to be as low as possible within a nutritionally adequate diet
Total Carbohydrates (En%)	50-75		> 50	45-60
Free Sugars (En%)	< 10			
Protein (En%)	10-15			0.83g/ kg/ day (PRI) Men (ref. wt. 74.6kg) – 62g/ day Women (ref. wt. 62.1kg) –52g/ day
Fibre (g/ day)	> 25		> 25	25
Fruit and Vegetables (g/ day)	≥ 400		> 400	

AI – Adequate Intake (needed by the body for good health, but sufficient scientific data is not available to derive an average requirement, a lower threshold intake or a population reference); LC – Long Chain, ≥20 carbon atoms; PRI – Population Reference Intake; ref. wt. – Reference Weight

Table 1.1: Selected population nutrient-based guidelines for Europe

Current nutritional status in Europe

Existing data suggests there are significant gaps between these proposed nutrient goals and actual intakes in Europe.

There are three types of data collection available for comparing food and nutrients consumption patterns across Europe; nationwide surveys of individuals, household-based availability data and national food supply data. The most valuable of these comes from nationwide surveys of individuals that provide information on actual food consumption and nutrient intakes. However, caution does need to be taken when interpreting and comparing this data among countries. This is due to different methods being used to collect the information, as well as recent data not being available for all countries. Despite this, currently it is the best reflection of consumption. Using this information, a recent report on the health and nutrition status of Europe collated data by grouping different regions of the European Union and analysed the data accordingly [13]. These groups were as follows:

- North: Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Sweden
- South: Cyprus, Greece, Italy, Portugal, Spain
- Central and East: Austria, Czech Republic, Germany, Hungary, Poland, Romania, Slovenia
- West: Belgium, France, Ireland, Luxembourg, the Netherlands, United Kingdom

The findings suggested that for most of these European countries the percentage of energy coming from fat was above the recommended range set by WHO (28.4 to 45.0 En% in males and between 29.9 to 47.2 En% in females) [1]. Furthermore, the fatty acid pattern did not meet the recommendations, with SFA intakes being higher and PUFA lower than recommended in most countries [10]. Protein intakes were within or slightly above the recommended range, whereas dietary fibre intake in most countries was lower (Table 1.2).

Data for individual European countries, based on individual food consumption, was also provided in the report. A similar pattern emerged for these nutrient intakes in the adult population in the UK, the Netherlands, Belgium, Germany, Spain and Sweden, although PUFA intake did meet the minimum

Nutrient	Fat (En%)	SFAs (En%)	PUFAs (En%)	Cholesterol (mg/ day)	Protein (En%)	Fibre (g/ day)
WHO Recommendations	15-30	< 10	6-11	< 300	10-15	> 25
NORTH						
Men	31.0 – 44.9	12.0 – 14.6	4.7 – 8.9	256.0 – 477.9	13.7 – 16.8	18.0 – 25.0
Women	31.0 – 41.9	12.0 – 14.4	4.7 – 8.7	176.0 – 318.8	13.7 – 17.2	15.6 – 21.0
SOUTH						
Men	28.4 – 45.0	8.8 – 12.7	4.8 – 6.4	282.9 – 378.4	14.1 – 18.5	19.3 – 23.5
Women	29.9 – 47.2	9.4 – 13.2	4.5 – 6.9	227.6 – 310.8	14.4 – 19.3	16.9 – 23.7
CENTRAL & EAST						
Men	31.3 – 38.9	11.7 – 26.3	5.7 – 8.8	352.5 – 800.0	13.5 – 17.8	18.7 – 29.7
Women	31.2 – 39.7	11.7 – 24.8	5.6 – 9.2	277.0 – 680.0	13.1 – 17.1	19.7 – 24.7
WEST						
Men	34.8 – 36.5	13.7 – 14.6	6.7 – 7.0	250.0 – 279.0	14.7 – 16.3	12.8 – 24.4
Women	35.1 – 36.9	13.7 – 14.7	6.7	201.0 – 215.2	15.6 – 17.0	10.4 – 20.1

Table 1.2: Selected nutrient intakes (min. – max.) in adults across four European regions compared to international recommendations

Source: Elmadfa [13]

recommendations in the first three countries but not in Spain and Sweden. Figure 1.1 compares these to the recommended targets, as a percentage, for adult men, with similar findings being observed for women.

As previously highlighted, it is difficult to make direct comparisons between these countries due to differences in the dietary survey methodologies. However, the European Prospective Investigation into Cancer and Nutrition (EPIC) study uses a consistent methodology across the participating countries to collect dietary data. As a result more meaningful comparisons can be made. Information collected in this way shows similar results, in that the

Recommended targets based on WHO ranges: Dietary fat 30 En%, SFA 10 En%, PUFA 6 En% (minimum), Protein 10 En%, Fibre 25g/d (except for the UK where 18g was used to allow for the difference in fibre analysis)
Data not available: fibre intake in Belgium and PUFA in Germany.

Figure 1.1: Selected nutrient intakes for adult men as a percentage of the recommended amounts

Source: Elmadfa [13]

Netherlands, UK, Germany, Spain and Sweden are consuming too much fat and SFA, and not enough fibre or PUFA compared to the recommendations (Figures 1.2 and 1.3) [14-16]. Out of these selected countries the only group that appears to meet the recommended ranges is the UK health-conscious cohort. This group includes lacto-ovo-vegetarians, pure vegans, fish (but not meat) eaters and meat eaters. Compared to the UK general population overall, this health-conscious cohort has a lower intake of animal products and fairly high intake of legumes [17], which may account for the nutritional differences.

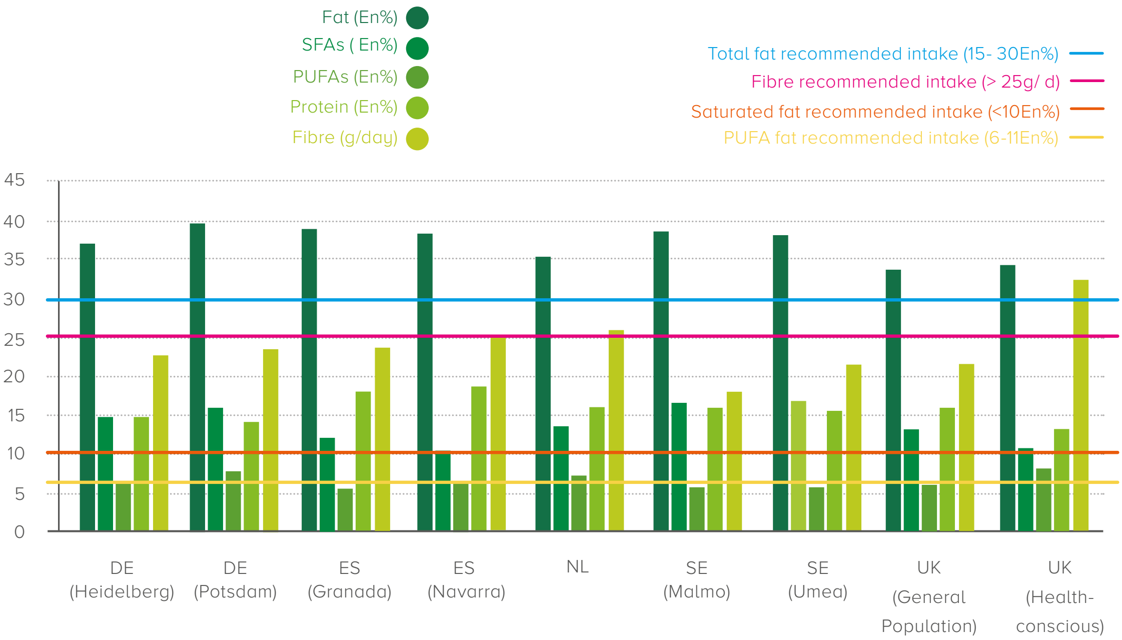


Figure 1.2: Mean selected nutrient intakes in men in the EPIC study

Source: Ocke [14] Cust [15] Linseisen [16]

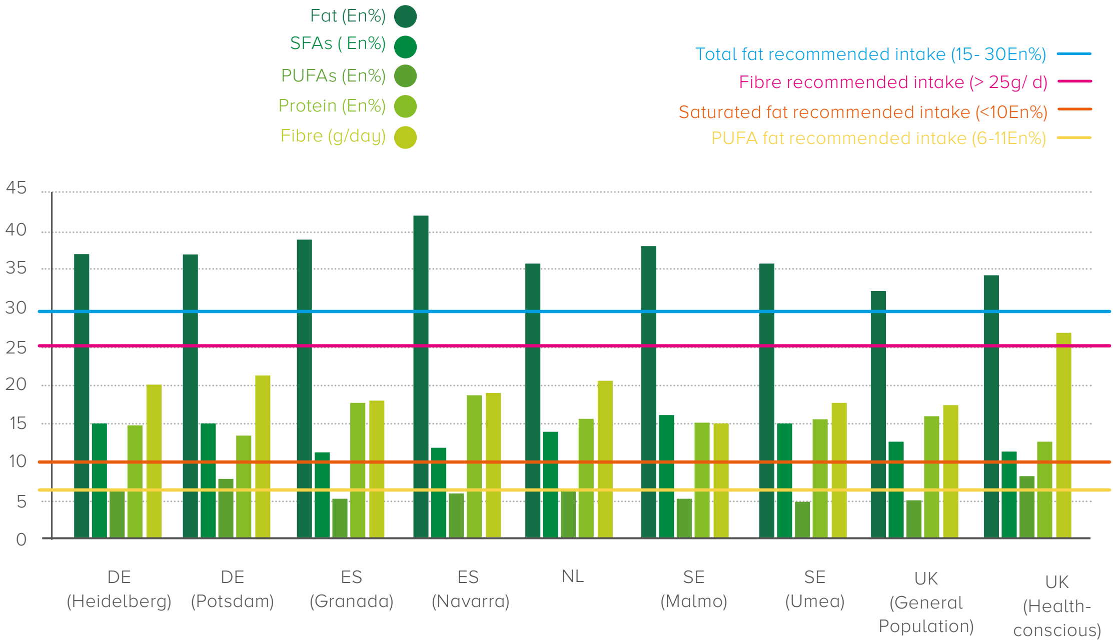


Figure 1.3: Mean selected nutrient intakes in women in the EPIC study

Source: Ocke [14] Cust [15] Linseisen [16]

Main challenges to nutrient intake

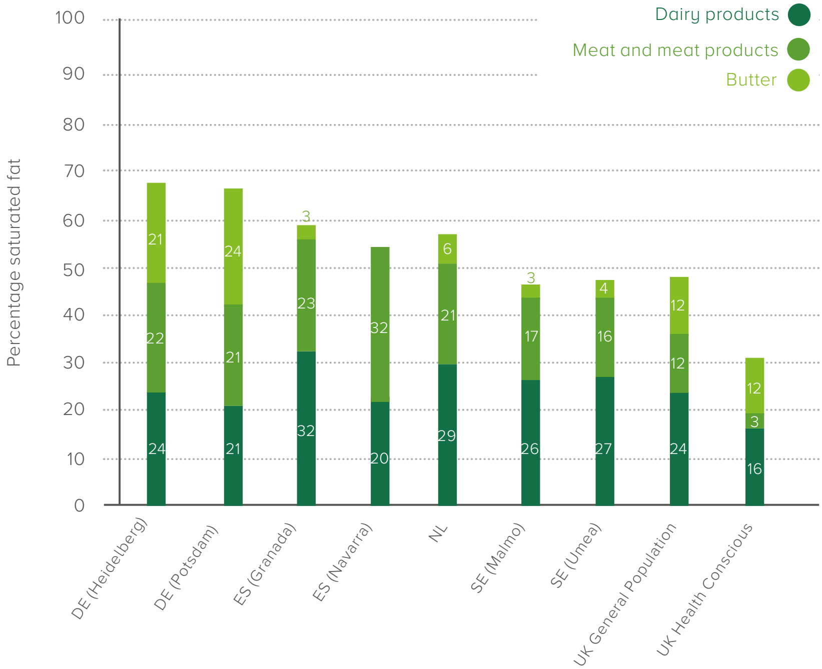
To help improve public health the key priorities for many Western European populations are to tackle the overconsumption of fat, particularly SFA, to improve fat quality, and to increase fibre in the diet. To be able to do this it is helpful to identify and quantify the main food sources of these nutrients. This in turn can help formulate food-based dietary guidelines to enable nutrient goals to be met.

Saturated fat

Data from the EPIC study suggests, in a number of European countries, a large percentage of SFA comes from animal products including dairy foods, meat, meat products and butter (Figures 1.4a and 1.4b) [16]. In Germany approximately two-thirds of the total SFA in the diet came from these foods, while in the Netherlands and Spain they provided over half, and in the UK general population and Sweden just under half of the total SFA intake. In contrast, in the UK health-conscious group these foods only provided around a third of the total SFA in the diet.

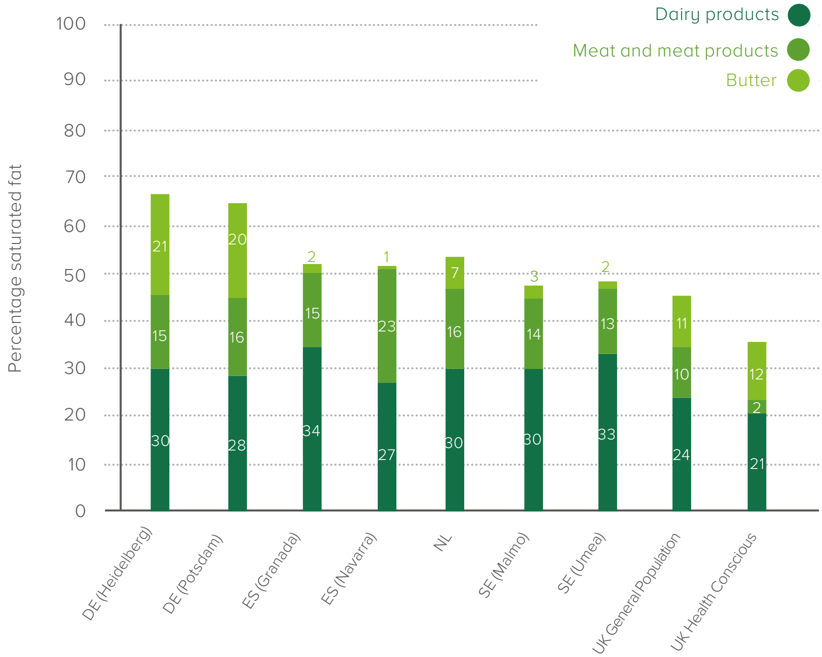
This data is now supported by more recent national dietary surveys. For example, in the UK's latest National Diet and Nutrition Survey (NDNS 2008/09 – 2011/12) meat products, dairy foods and butter provided 47% of the total SFA intake (20%, 22% and 5% respectively) [18]. Whereas the Dutch National Food Consumption Survey found dairy and meat/meat products contributed 49% of total SFA intake (30% and 19% respectively) in the Dutch population [19].

Considering these foods contribute to the majority of SFA in the diet, dietary recommendations emphasize that only modest amounts should be included as part of a healthy, balanced diet and that lower fat options such as low fat dairy foods and dairy alternatives that are low in SFA should be chosen. More plant-based foods are encouraged to make up the bulk of the diet. Shifting towards plant-based eating would subsequently reduce fat and SFA intakes, increase PUFA, while at the same time help to achieve fibre targets.



Figures 1.4a: Average contribution of major food groups to saturated fat intake in men from selected countries participating in the EPIC Study

Source: Linseisen [16]



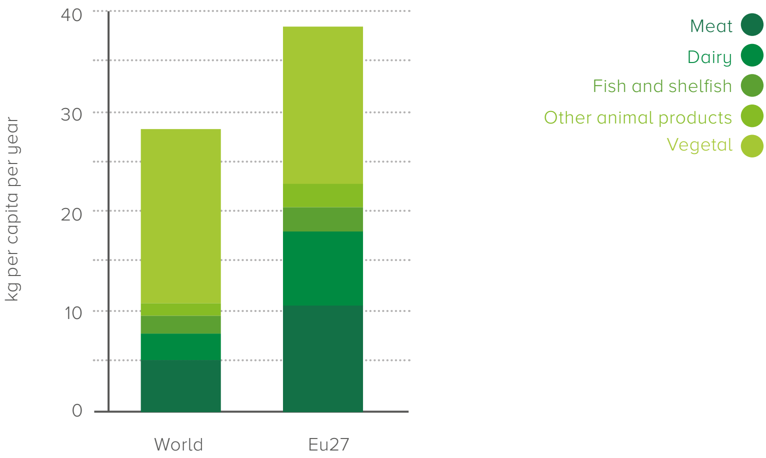
Figures 1.4b: Average contribution of major food groups to saturated fat intake in women from selected countries participating in the EPIC Study

Source: Linseisen [16]

Recommendations related to meat consumption

Although international and national recommendations suggest a reduction in animal product consumption, no exact figures have been provided as a target. However, a number of organisations have given guidance on meat intake. For example, in 2007 the World Cancer Research Fund (WCRF) recommended that red meat consumption be limited to 500 g (cooked weight) per person per week, as well as avoiding processed meats, in order to significantly reduce the risk of cancer [20]. As a population goal this should be reduced to 300 g/wk. In its review on iron and health, the UK's Scientific Advisory Committee on Nutrition (SACN) advised, as a precaution, that intakes of red and processed meat should not exceed 70 g/d [21]. Red meat usually refers to beef, pork, lamb, goat, and processed meat refers to meat (usually red) that has been preserved by smoking, curing, salting, or addition of preservatives [20].

How do these recommendations compare to current meat intakes in Europe? This is hard to measure accurately, as comparing intakes across countries is difficult due to different definitions of meat. Nevertheless, it has been attempted in a report on proteins in the diet [22]. Westhoek *et al*, calculated European protein consumption using FAO food supply data and found that the average consumption of protein per person is much higher in Europe than globally - this in particular applies to animal proteins. On average each European consumes twice as much animal protein than the global per capita average, with the majority coming from meat, followed by dairy (Figure 1.5). While this comprehensive review used FAO figures based on national food supply data (which has its limitations), various factors have been considered to allow for losses which occur from farm to fork, such as processing, retail and household losses. This attempts to provide a better reflection of actual intake.



EU per-capita consumption of proteins from animal food products is more than the double the world's average.

Figure 1.5: Global and European protein consumption per capita per year

Source: Extracted from Westhoek [22]

The average European intake of meat is 52 kg/person/yr, with varying figures per country. For example: Spain, Austria and Cyprus consume the most meat - around 65 kg/person/yr - and Bulgaria, Estonia and Slovakia the least (Figure 1.6). Using the WCRF population recommended intake of 300g of red meat/person/wk, or just under 16 kg/person/yr, Figure 1.6 highlights how in Europe on average, and in all individual European countries, these recommendations are exceeded. Typically Europeans consume about 37 kg/person/yr of pork, beef and veal; over double the recommendations.

This report also reviewed SFA intake and calculated that around 80% of the total SFA intake was from animal fats (Figure 1.7). These animal fats were from meat and dairy foods, but also animal fats used in processed foods such as biscuits, pastries, sauces, etc. A reduction of approximately 40% of animal fats was suggested by the authors in order to meet the recommended maximum amount.

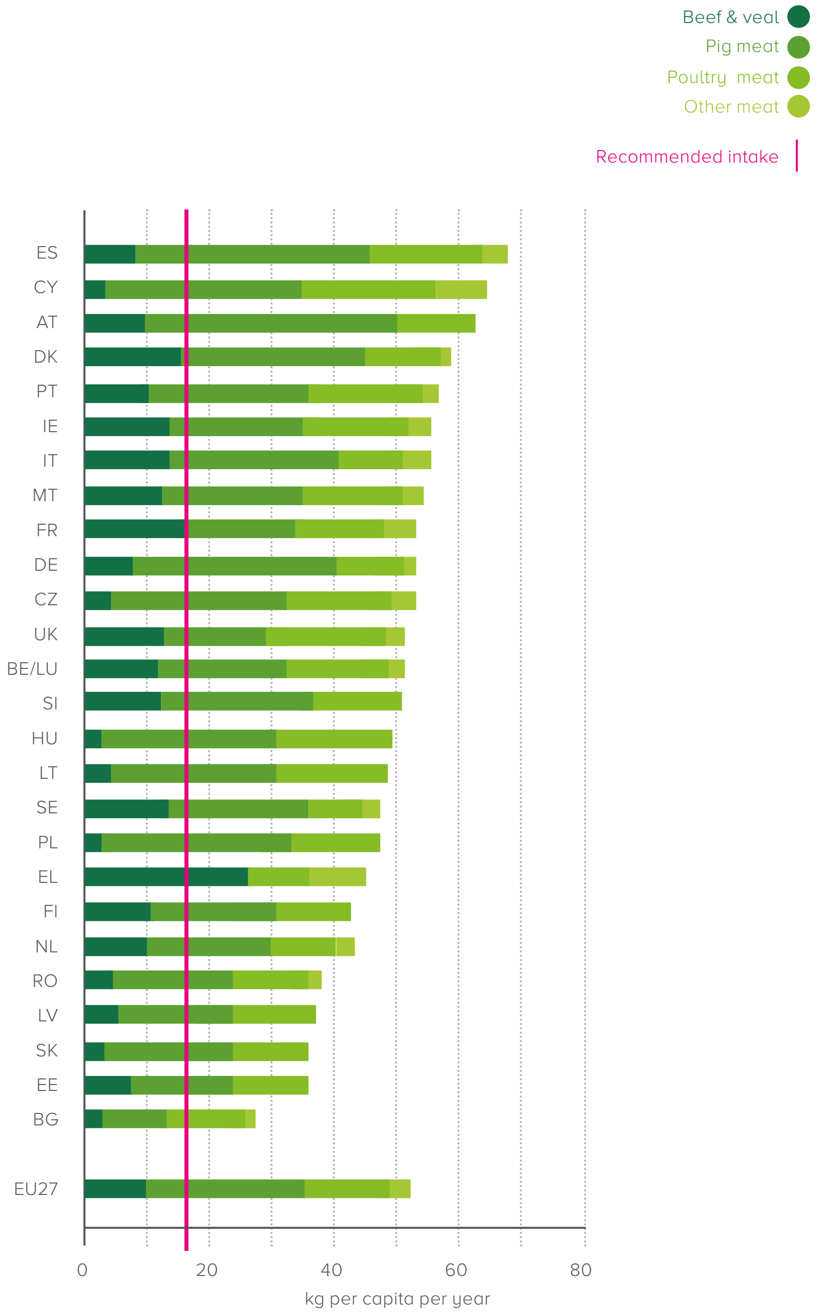


Figure 1.6: Estimated intake of meat in Europe compared to recommended amount

Source: Extracted from Westhoek [22]

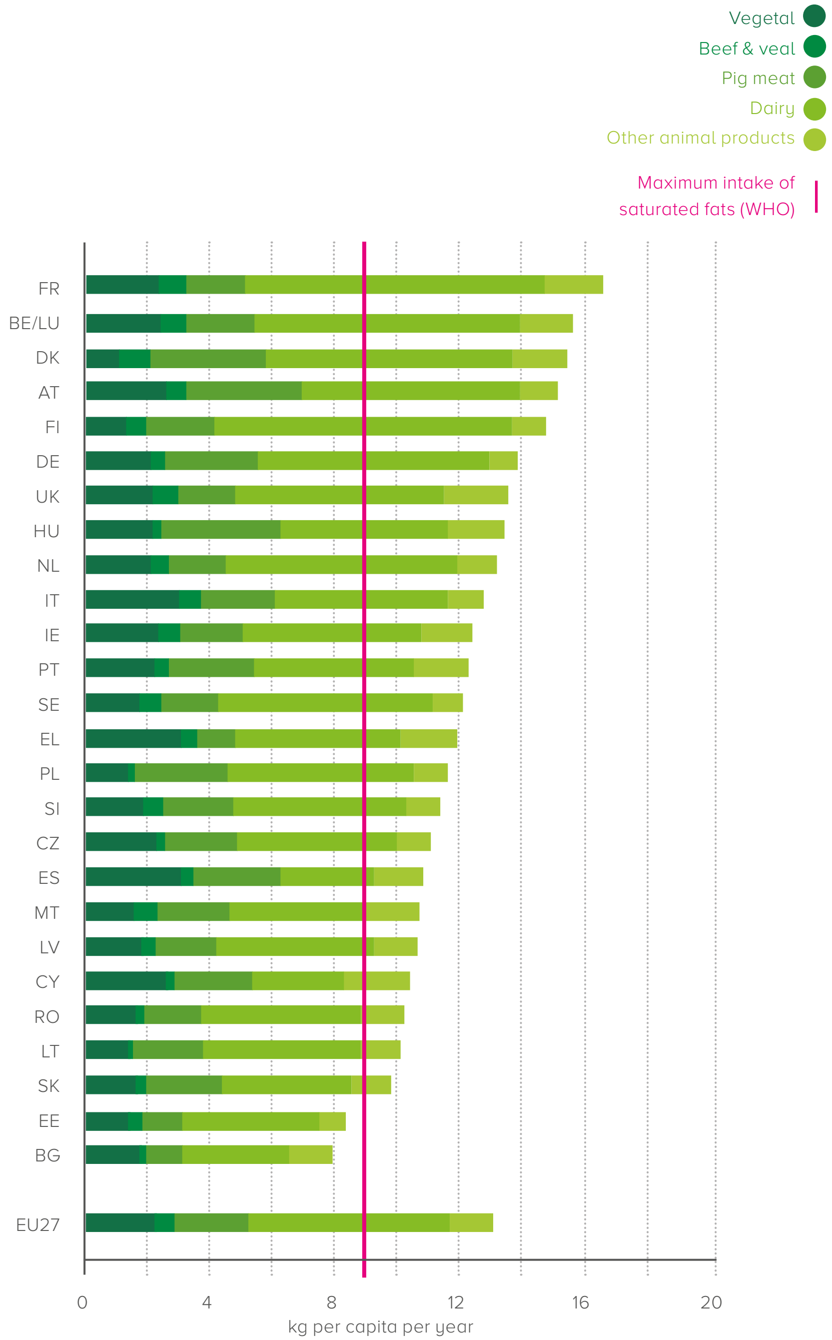


Figure 1.7: European estimated intake of saturated fat from animal products

Source: Extracted from Westhoek [22]

Another report used the EPIC results to calculate European meat intakes because of their consistent methodology (Figure 1.8) [23]. Unfortunately this is relatively old data and more up-to-date figures from EPIC are currently not available.

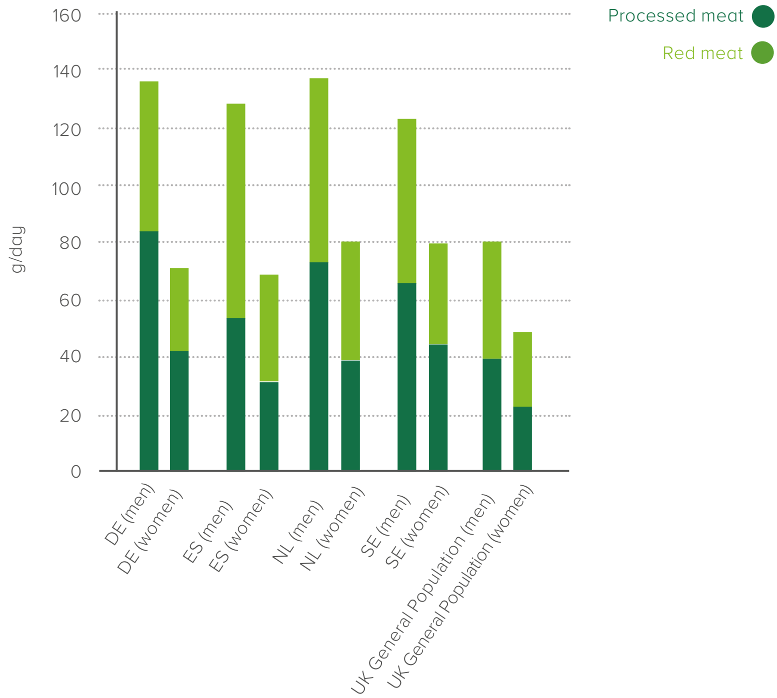


Figure 1.8: Average daily intake of red meat and processed meat in selected countries

Source: Wyness [23]

A different method for determining meat intakes is to look at the data collected in national dietary surveys, which includes individuals' food consumption. However, as mentioned previously this is problematic due to different methodologies and definitions of foods. Nevertheless, in an attempt to harmonize this, the EFSA has compiled the available data from these surveys in a way to make it as comparable as possible across Europe (EFSA Concise Database) [24]. Using this database, population intakes of meat, meat products and offal for selected countries are detailed in Figure 1.9.

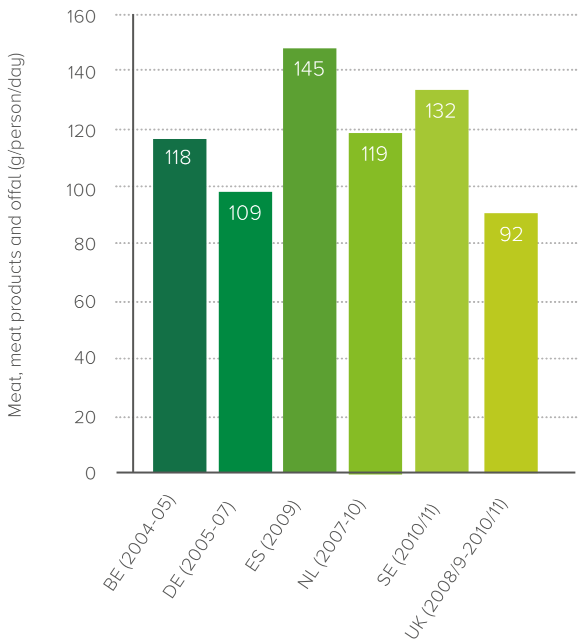


Figure 1.9: Average adult daily consumption of meat, meat products and offal (g/ day) in selected countries

Source: EFSA concise European food consumption database [24]

The most recent UK data on red meat consumption has also been calculated in the latest NDNS (2008/9 – 2011/12) [18]. Mean consumption for adults aged 19 to 64 yrs is 71 g/d (86 g for men and 56 g for women). When processed meats are also included (such as ham, bacon, sausages, burgers) this increases to 106 g/d, far in excess of the 70 g recommended by SACN [21].

Unsaturated Fats

Many Western European countries fail to reach the recommendation for PUFA intake. Furthermore, the importance of replacing SFA with UFA has been recognized as an important aspect in heart health (see Chapter 3). An analysis that compared the ratio of SFA to UFA among different countries found an unfavourable result (> 0.5) in most European countries [25]. This situation could be improved by including more foods such as nuts, seeds, vegetable oils and legumes into the diet, and less animal fats.

Fibre

Good sources of fibre include fruit, vegetables, whole grains and pulses. Consequently WHO has concluded that wholegrain cereals, fruits and vegetables should be the preferred sources of fibre in the diet [1]. This is confirmed in the WCRF report [26] which states "relatively unprocessed cereals (grains) and/or pulses (legumes), and other foods that are a natural source of dietary fibre, should contribute to a population average of at least 25 g NSP daily" and "population average consumption of non-starchy vegetables and of fruits to be at least 600 g daily" (which is more than the targets set by WHO and individual European countries).

Fruit and Vegetables

Although recommendations have been made for fruit and vegetable intakes (≥ 400 g/d), data from a number of sources highlight this is being underachieved in a number of European countries, and figures using agricultural supply data have found a decline in fruit and vegetable consumption in the majority of European countries (Figure 1.10) [27]. Although a degree of wastage has been taken into account in this data, further wastage can occur during the supply chain. For this reason consumption data should be interpreted in relative rather than in absolute terms.

This low intake of fruit and vegetables is also reflected in the EPIC study, with only Spain and the UK health-conscious cohort achieving above the recommended intake (Figure 1.11) [28].

National dietary surveys again reflect this low intake. For example, a study conducted in Belgium concluded that average fruit and vegetable consumption was only 256 g/d (118 g/d for fruit and 138 g/d for vegetables) [29]. Furthermore, in the latest UK's NDNS (2008/9 – 2011/12), average fruit and vegetable consumption (including the contribution from composite dishes) among 19 to 64 yr olds was 4.1 portions (a portion equating to 80 g) of fruit and vegetables per day. The average consumption, excluding composite dishes, was approximately 3.5 portions per day [18]. Moreover, only 30% of the population achieved the recommended 5 portions or more. Similar findings were observed in the Dutch population. According to the Dutch National Food Consumption Survey only a very low percentage of the adult population (3-14%) met the lower limit of the recommended vegetable in-

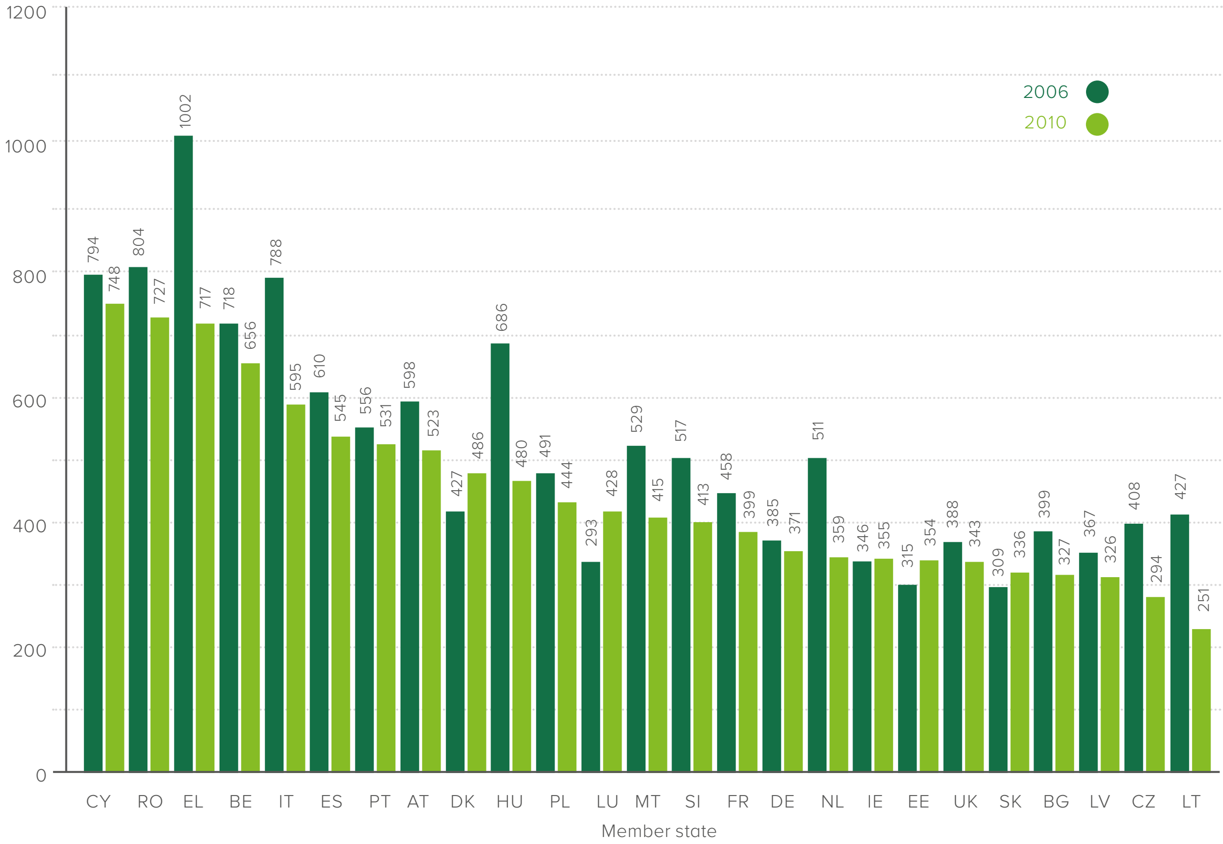


Figure 1.10: Fruit and vegetable consumption 2006 / 2010 (g/capita/d)

Source: Freshfel [2012]

take (200 g for adults). For fruit, that percentage was somewhat higher (between 3 to 26%). However, in many age groups the majority of people did not even consume one piece of fruit a day, which is half the recommended amount [19].

Using a combination of data sources, a recent study quantified the intake of fruit and vegetables across different European countries using food balance sheets, the EFSA comprehensive database and individual food consumption data from the UK NDNS [30]. Using food balance information, average fruit and vegetables intake ranged from 192 - 824 g/d across Europe. Based on EFSA data, nine out of 14 countries consumed <400 g/d. In the UK the average consumption of fruit and vegetables was 310 g/d (using earlier data than the previously described NDNS) [30].

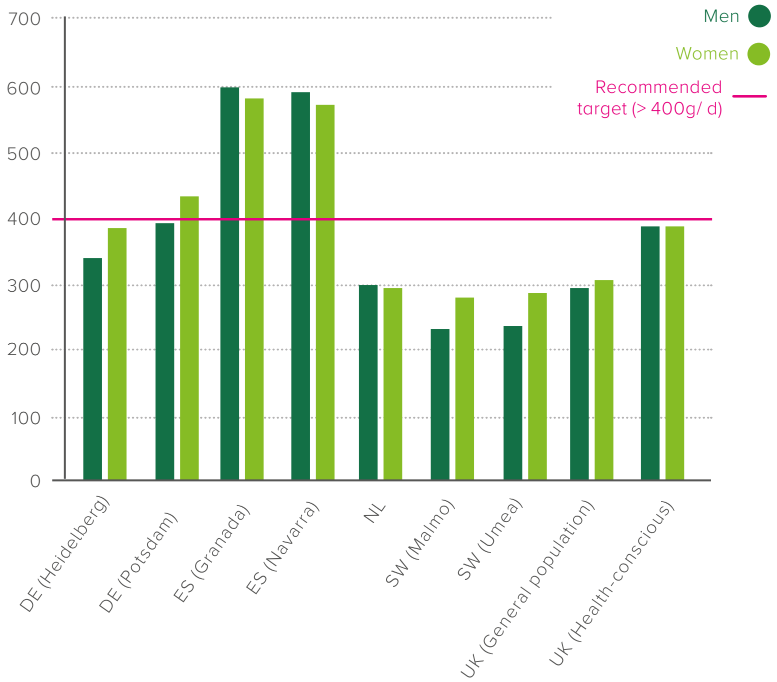


Figure 1.11: Mean consumption of fruit and vegetables (grams) per person per day in selected countries participating in the EPIC Study

Source: Extracted from Agudo [28]

Whole grains

A food is defined as a wholegrain food when the grain components (starchy endosperm, germ and bran) are present in the same relative proportions as in the original intact grain kernel [31]. Including more wholegrain foods in the diet has been found to support positive health [32], which is thought to be due to the presence of insoluble fibre and bioactive components found in the bran and germ of whole grains - including antioxidant micronutrients, carotenoids, minerals, polyphenols and vitamins, to name but a few [33]. As such, many international and national associations recommend the inclusion of more whole grains into the diet (see Introduction). However, few European countries specify exact quantities in their dietary recommendations, with the exception of Denmark, where 75 g of whole grains/2390 kcals/d is recommended [34]. In the USA the recommendation is to eat 2 to 3 daily servings (32-48 g) [35]. In Western countries this goal is generally not achieved. For example, a recent analysis of the UK dietary data has shown that the average wholegrain intake is low in both adults (20 g/d) and children (13 g/d) [36], much lower than the US and Danish recommendations. Of the total study population, 18% of adults and 15% of children/teenagers did not consume any wholegrain foods and only 17% of adults and 6% of children met the US recommendations of 3 servings a day.

A word about micronutrients

Public health policies in Europe are focused largely on addressing the problems of overconsumption and tackling macronutrients, as previously described. Yet even in the midst of plenty, questions have been raised regarding the prevalence of sub-optimal micronutrient status in the region. A recent review of published data, performed as part of the EURopean micronutrient RECommendations Aligned (EURRECA) project, indicated a relatively high prevalence of inadequate micronutrient intakes for adults in Europe, ranging from 11 to 30% for copper, folate, selenium, iodine, vitamin B12 and vitamin C [37]. However, it has been a challenge to make meaningful comparisons of micronutrient adequacy across European countries, mainly because of different methods of, and disparities in, data analysis used in different countries, such as different age groups, different measurements for adequate intakes, and subsequently the proportion of people with intakes below the recommended nutrient intake. In an attempt to address this, a recent study collected and evaluated the prevalence of low micronutrient intakes among different European countries to provide a clearer and more accurate map of the extent of inadequate micronutrient intakes in eight selected European countries [38]. Recent nationally representative dietary survey data from Belgium, Denmark, France, Germany, the Netherlands, Poland, Spain and the United Kingdom were compared, and dietary intakes of calcium, copper, iodine, iron, magnesium, potassium, selenium, zinc and the vitamins A, B1, B2, B6, B12, C, D, E and folate compared. The percentages of those with intakes below the lower reference nutrient intake (LRNI) and the estimated average requirement (EAR) were calculated using reference intakes derived from the UK and Nordic Nutrition Recommendations. Except for vitamin D, the study found that current intakes of vitamins from foods were generally sufficient, with low proportions of individuals below the LRNI

Micronutrient	BE	DK	FR	DE	PL	ES	NL	UK
Ca	—	S	Ya	—	tCYAS	—	—	Ya
Cu	—	—	—	—	—	*	—	—
I	*	—	YAS	CYAS	tCYAS	*	*	YA
Fe	—	ya	ya	y	tcyas	—	ya	Tya
Mg	—	Y	YAs	—	YaS	—	y	YAS
K	—	yaS	YAs	ys	YaS	a	—	YAS
Se	tC	YAS	YAS	*	*	*	YAS	YAS
Zn	—	y	—	—	tCYs	—	C	TcYA†s
Vitamin A	tc	—	—	—	ta*s*	*s*	—	tcYA
Vitamin B1	—	—	—	—	—	—	—	—
Vitamin B2	—	yaS	y	y	yaS	—	ya	Ya
Vitamin B6	—	—	—	—	—	—	—	—
Folate	—	—	—	—	a	—	y	—
Vitamin B12	—	—	—	—	YaS	—	—	—
Vitamin C	—	—	—	—	—	—	—	—
Vitamin D	tC	CYAS	CYAS	CYAS	tCYAS	CYAS	CYAS	tCYAS
Vitamin E	tC	Y*as*	—	—	tc*s*	—	—	t*s*

T, toddlers (1-3 years (both sexes)); C, children (4-10 years); Y, youth (11-17 years); A, adults (18-60 years); S, seniors (>60 years); capitals, both sexes; lower case, women only; lower case italic, men only.

** No data available for any age group in country.*

† Only for women 14-50 years.

Figure 1.12: Overview of age groups with more than 5% of the population having intakes below the LRNI

Source: Extracted from Mensink [38]

in all age and gender groups. There was universal concern about vitamin D intake, as the proportions of the population with vitamin D intakes below the EAR and LRNI were exceptionally high. Vitamin D intakes are likely to vary from country to country, as more vitamin D needs to be obtained from food in those at more northern latitudes compared to those in Mediterranean countries, where vitamin D can more readily be obtained from conversion through the skin stimulated by UV radiation. For minerals, the study suggested that the risk of low intakes is likely to appear more often in specific age groups (Figure 1.12) [38].

Dietary patterns across Europe

Examining dietary patterns also provides information on a population's food, and subsequent nutrient intake. The EPIC study has examined these patterns across European countries and found that the diet in the Nordic countries, the Netherlands, Germany and the UK general population, is relatively high in potatoes and animal, processed and sweetened/ refined foods. Vegetable oils and legumes are eaten in smaller amounts. Spain, however, has a relatively high consumption of both plant foods and animal products. As highlighted previously, the UK health-conscious group have a relatively low intake of animal products and higher intakes of legumes compared to the UK general population [17].

Household-based availability data (using household budget surveys) provides a second valuable source of food availability at household level. The data food networking (DAFNE) project aims to standardize the data collected in these surveys and has created a regularly updated food databank of comparable data from a number of European countries. In the Health and Nutrition Status of Europe Report, this data was used to calculate intakes of plant and animal foods across the four European Regions previously described [13]. Figures 1.13 and 1.14 highlight how intake of vegetables, pulses and fruits are lowest in the Western countries, while dairy, meat and meat products are among the highest in this region.

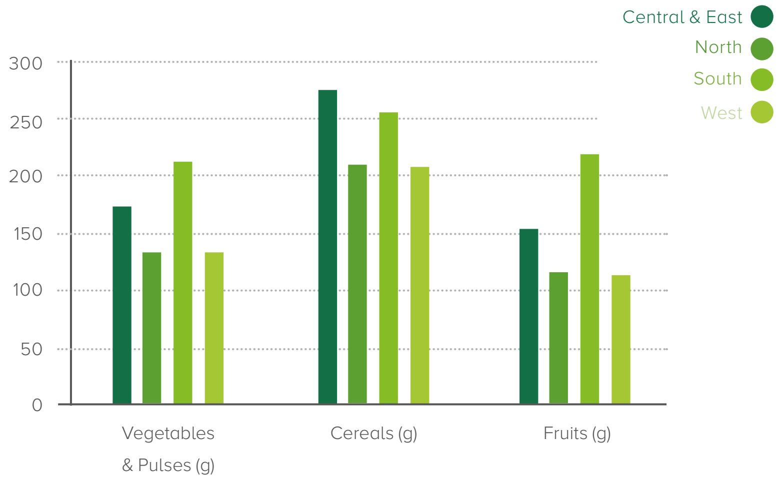


Figure 1.13: Mean availability (g/person/d) of foods of plant origin by European region. The DAFNE databank

Source: Extracted from Elmadfa [13]

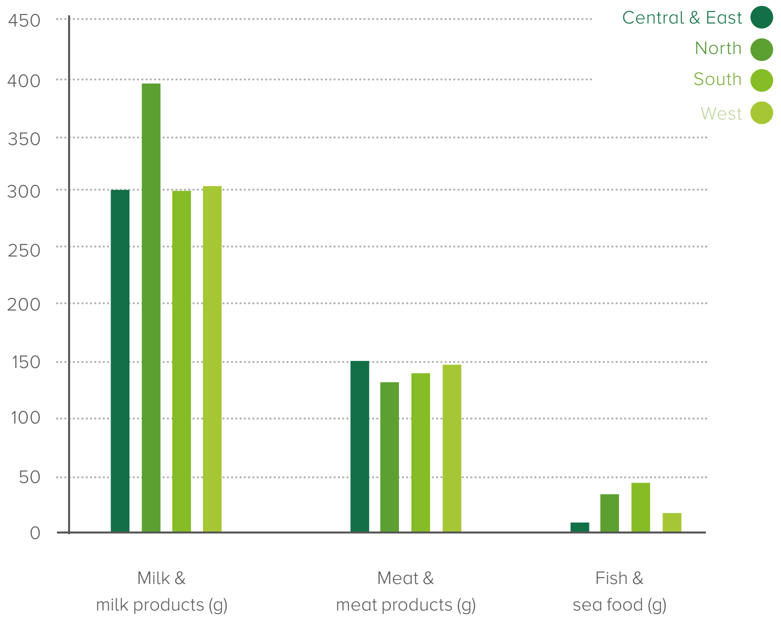


Figure 1.14: Mean availability (g/person/d) of foods of animal origin by European region. The DAFNE databank

Source: Extracted from Elmadfa [13]

Translating the science into practical dietary advice

To be understood by the public, nutrient goals need to be translated into relevant and meaningful food-based dietary guidelines. These need to include information on the contribution of different foods or food groups to an overall diet that helps to maintain good health through optimal nutrition.

EFSA has provided guidance on developing food-based dietary guidelines intended for the European population as a whole [39]. However, due to the diverse nutrient intake and public health priorities across the region, as well as differences in cultural/dietary habits, it felt it was not feasible to establish detailed and effective food-based dietary guidelines which could be used at EU level. Instead, guidelines have been provided on how an effective model can be produced [39].

Nearly all European countries have developed food-based dietary guidelines. Many countries base their guidelines on the WHO Food Pyramid (Figure 1.15) from the Countrywide Integrated Non Communicable Disease Intervention (CINDI) programme [40], for example Belgium (Figures 1.16a and 1.16b). Other countries slightly adapt this model; e.g. Germany uses a three-dimensional model (Figure 1.17). Countries such as the UK and the Netherlands use a plate model (Figure 1.18 and 1.19). Different size segments represent the proportions in which these foods should be eaten as part of a healthy balanced diet.

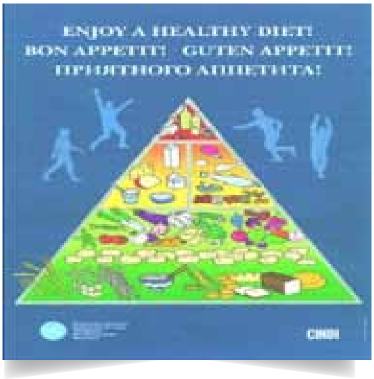


Figure 1.15: WHO Food Pyramid (published in 2000)

Figure 1.16a: Belgium: The food pyramid for the French Community (2005)

Figure 1.16a: Belgium: The active food guide pyramid for the Flemish community (2005)

(The active food guide pyramid is currently being revised)

Figure 1.17: Germany: Dreidimensionale DGE-Lebensmittelpyramide (2005)

Figure 1.18: UK: The eatwell plate (2007)

Figure 1.19: The Netherlands: The Wheel of Five (2011)

(The Wheel of Five is currently being revised)

Common recommendations in all these models include eating plenty of fruits, vegetables and complex carbohydrates, and choosing foods which are lower in SFA, salt and sugar. Animal foods, including meat and dairy, represent smaller segments in these models, highlighting that only modest amounts are required as part of a healthy balanced diet. In contrast, plant-based foods represent larger segments. Several attempts have been made to compare these guidelines with actual intakes of foods and drinks in the diet. For example, a study that evaluated the gap between usual food consumption and the guidelines in Belgium found that fruit, vegetables, dairy, and calcium enriched soya intake was less than recommended. Intakes of meat, meat-related foods and energy-rich/nutrient-poor foods, on the other hand, were in excess of recommendations. This was then depicted graphically, based on Belgium's food model (Figure 1.20) [29].

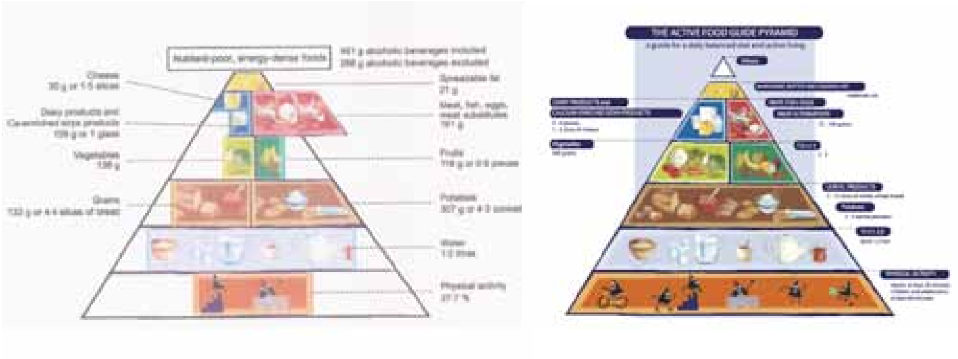


Figure 1.20: Variations in food consumption versus food recommendations in Belgium

In the development of a sustainable LiveWell diet (an eating plan that is both healthy and sustainable for the planet), the World Wildlife Fund (WWF) modelled the UK's actual food intake and compared it to the segments in the national eatwell plate. Using consumption data from the NDNS, they

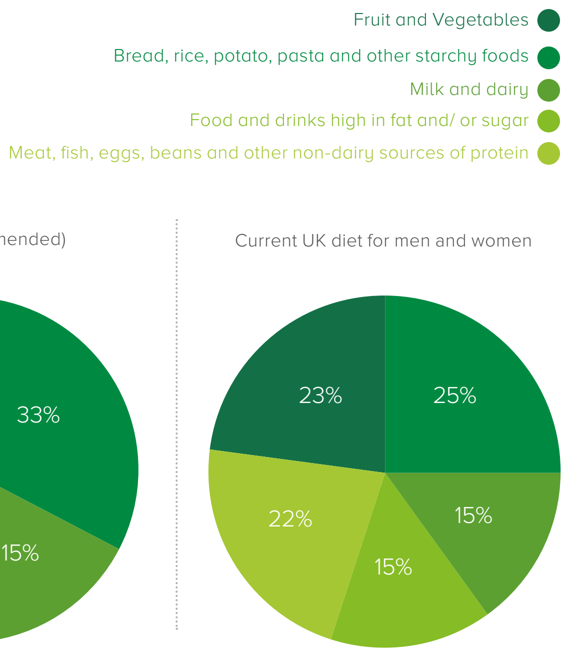


Figure 1.21 : The UK diet displayed in the eatwell plate food groups

Source: WWF [41]

concluded that the meat group as well as food and drinks high in fat and sugar were in excess of recommendations whereas fruit, vegetables and starchy foods were not sufficient (Figure 1.21) [41].

This imbalance in food groups and subsequent nutrient intakes is the focus of many public health campaigns across Europe. Driving these forward will improve the overall quality of the diet, help to achieve the ideal nutrient goals, and enable populations to enjoy positive health and well-being.

Food-based dietary guidelines and sustainability

In line with the LiveWell diet a number of countries are now taking into account sustainability, as well as addressing a healthy balance of nutrients, in their food-based dietary guidelines. For example, the Netherlands will be introducing guidelines for a diet that is both healthy and sustainable in terms of environment and biodiversity [42]. The main conclusions in the advisory report were that a healthy diet has much in common with an ecologically responsible diet and that by far the greatest ecological benefits are obtained by moving to a less animal-based, more plant-based diet [42].

The Swedish National Food Agency, together with its Nordic counterparts [8], gives evidence-based dietary recommendations every eight years and the latest, in 2014, for the first time included a chapter on environmental aspects of food consumption. These will be included in the updated Swedish dietary recommendations.

In the UK a follow-up consultation to the Green Food Project report provided clear guidance on a sustainable diet [43]. This project came about as a response to a commitment made in the Natural Environment White Paper to examine the challenges of increasing food production and improving the environment and how any tensions this raised could be reconciled. The project concluded by saying that more follow-up work was required and in July 2013 the recommendations of this follow-up provided guidance on what constitutes a healthy sustainable diet (Table 1.3). However, the next steps on implementing this are uncertain.

1	Eat a varied balanced diet to maintain a healthy body weight.
2	Eat more plant based foods, including at least five portions of fruit and vegetables per day.
3	Value your food. Ask about where it comes from and how it is produced. Don't waste it.
4	Moderate your meat consumption, and enjoy more peas, beans, nuts, and other sources of protein.
5	Choose fish sourced from sustainable stocks. Seasonality and capture methods are important here too.
6	Include milk and dairy products in your diet or seek out plant based alternatives, including those that are fortified with additional vitamins and minerals.
7	Drink tap water.
8	Eat fewer foods high in fat, sugar and salt.

Table 1.3: UK draft key principles for healthy and sustainable eating

Source: DEFRA [43]

The previously mentioned LiveWell plate was produced by WWF-UK as a first step towards investigating a more sustainable diet. Building on these results, WWF now runs the LiveWell for Low Impact Food in Europe (LiveWell for LIFE) project, using the LiveWell plate as a tool to define country-specific sustainable diets across the EU. The LiveWell plate has now been adopted across the traditional diets of three countries – France, Spain and Sweden.

The results from these three countries found healthier eating can be aligned with environmental objectives and this way of eating costs no more than the current dietary patterns, complies strictly with national nutritional requirements, and closely resembles the current dietary pattern.

This was achieved by reducing the total amount of meat consumed, increasing the consumption of legumes as a source of protein and increasing cereals and starchy foods (typically bread, pasta and potatoes). LiveWell for LIFE principles are outlined in Table 1.4.

1	Eat more plant foods. Enjoy vegetables and whole grains.
2	Eat a variety of foods. Have a colourful plate!
3	Waste less food. One third of food produced for human consumption is lost or wasted.
4	Moderate your meat consumption, both red and white. Enjoy other sources of proteins such as peas, beans and nuts.
5	Buy foods that meet a credible certified standard. Consider MSC, free-range and fair trade.
6	Eat fewer foods high in fat, salt and sugar. Keep foods such as cakes, sweets and chocolate as well as cured meat, fries and crisps to an occasional treat. Choose water, avoid sugary drinks and remember that juices only count as one of your 5-a-day however much you drink.

Table 1.4: LiveWell for Life key principles

Source: DEFRA [43]

Take-home messages

- Diets in many Western European countries are higher in total fat and SFA and lower in fibre and UFA than is recommended for good health.
- Eating smaller amounts of animal foods, which are the main sources of SFA in many of these diets, and replacing these with legumes, nuts, oils and seeds can improve the quality of the diet and help achieve current dietary recommendations.
- Dietary macro and micronutrient quality can also be enhanced by consuming more fruits, vegetables and other fibre-rich foods such as wholegrain cereals.
- As well as incorporating a healthy balance of foods to meet nutrition recommendations, a number of countries are now including sustainability in their food based dietary guidelines.
- Ensuring there are more plant foods in the diet is a simple and delicious way of improving the health of the nation.

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Chapter 2
Nutritional rationale for more plant-based eating

PROF. SANDER KERSTEN
Division of
Human Nutrition,
Wageningen University,
the Netherlands

Introduction to Chapter 2, by invited expert Sander Kersten

You may have heard the old adage, "you are what you eat". The saying implies a major link between the foods we consume and our emotional and physical well-being. Indeed, research has shown that what we eat has a major impact on overall health, both short and long term. It is therefore not surprising that health considerations have become increasingly more important in dictating people's food choices. At the same time, there is growing concern about the impact of agriculture and food production on the environment. Sustainability has become a buzzword in our contemporary society. To a growing part of the population food should not only be satisfying and provide the basis for a long and healthy life, but it should also be produced sustainably, with a minimal impact on the environment. This backdrop provides the perfect breeding ground for the growing popularity of plant-based eating. More and more people are reducing their intake of meat and other animal products in favour of a regime that puts plant foods at its centre. Their primary motivation may be animal welfare or concerns about the sustainability of our food production systems. For many people, adopting a more plant-based diet also brings along the impetus to diversify the diet and instill it with new culinary creativity.

At the same time switching to plant-based eating can be motivated by health reasons. As outlined in the following chapter, a plant-based diet generally improves the quality of the diet and brings it more in line with current health recommendations. In addition to a lower intake of SFA, plant-based eating is associated with a higher intake of UFA, fibre and numerous bioactive compounds. The field of nutritional science is rife with controversies and uncertainties, yet one association that has consistently survived the test of careful scientific scrutiny is the association between plant-based diets built around the consumption of fruits, vegetables and legumes, and a reduced risk of many chronic diseases such as metabolic disorders, e.g. obesity, diabetes, and heart disease, as well as various forms of cancer.

Personally, I switched to lacto-ovo-vegetarianism nearly twenty years ago. My three children, the eldest one now approaching thirteen years of age, have been raised as lacto-ovo-vegetarians since birth, and all three are doing very well. While it may not be necessary to dismiss meat and fish altogether to reap the benefits of plant-based eating, my family's avoidance of meat and fish has been a blessing, both in terms of culinary experience and in creating awareness about the origin of our foods. I can recommend it to anyone.

Chapter 2

Nutritional rationale for more plant-based eating

Contrary to the typical "Western" style of eating, plant-based eating patterns are associated with diets that are low in total fat and SFA, good sources of UFA (both omega-3 and omega-6 fatty acids), high in fibre, antioxidant vitamins and phytonutrients [1]. As such, these eating patterns are in line with international and national dietary recommendations (see Chapter 1).

More plant-based eating - healthy balance of nutrients

Evidence supporting the nutritional benefits of plant-based eating is provided by a number of population studies [2-12]. Early studies tended to define this way of eating according to the relative absence of meat in the diet – from the complete avoidance of animal foods (vegans) through to individuals who consume meat on a daily basis. Other vegetarian groups would fall in between this spectrum according to the amount of animal foods regularly consumed. For example, dietary characteristics were examined in the Oxford arm of the European Prospective Investigation into Cancer and Nutrition (EPIC) study [2]. Subjects included meat eaters (N=33,883), fish eaters (N=10,110), lacto-ovo-vegetarians (N=18,840) and vegans (N=2596). The nutritional contents of these diets are outlined in Figures 2.1 and 2.2. Of particular note is that the average SFA intake in vegans was approximately 5 En%, less than half that of meat eaters (10-11 En%). SFA intakes in fish eaters and vegetarians were intermediate at approximately 9 En%. In addition, PUFA intake was highest in the vegan group, followed by fish eaters and vegetarians. Meat eaters had the lowest intake of PUFA. Fibre was highest in the vegan group, followed by vegetarians and fish eaters, while meat eaters consumed the least amount of fibre.

Similar results have more recently been found in the Adventist Health Study 2 (AHS-2; 2013), which is one of the very few large cohort studies to include a high proportion of vegetarians. Nutritional intakes have been examined in a group of 71,751 AHS-2 participants according to their vegetarian status: non-vegetarians (N=33,634), semi-vegetarians (N=4042), pesco-vegetarians (N=6583), lacto-ovo-vegetarians (N=21,799) and strict vegetarians (N=5694) [10]. Figure 2.3 summarizes a selection of nutrient intakes according to dietary pattern. Total fat and SFA were highest in the non-vegetarians and lowest in the strict vegetarians, whereas PUFA and fibre were higher in the vegetarians compared to the non-vegetarians.

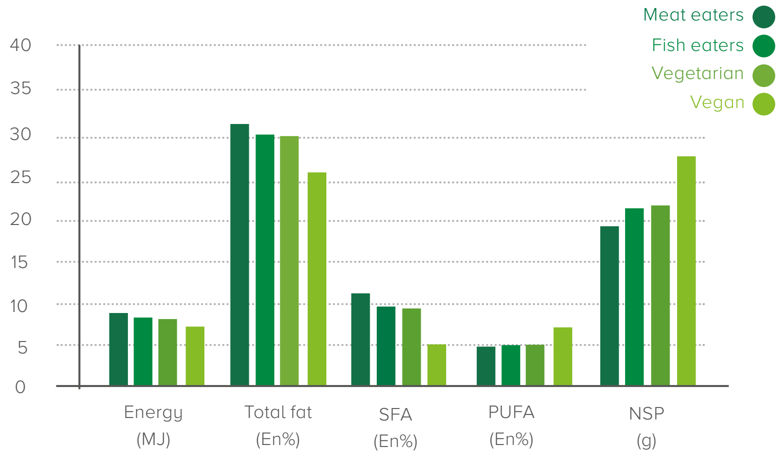


Figure 2.1: Men's average daily intake of selected nutrients by diets in the Oxford arm of the EPIC study

Source: Extracted from Davey [2]

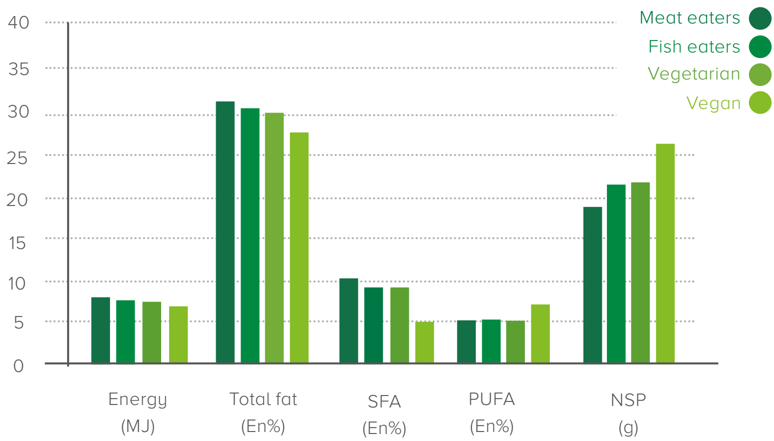


Figure 2.2: Women's average daily intake of selected nutrients by diets in the Oxford arm of the EPIC study

Source: Extracted from Davey [2]

The average percentage of energy coming from animal protein was two and a half times higher in non-vegetarians than in lacto-ovo-vegetarians. Micronutrients were also analysed in this study and vitamins associated with fruit and vegetables (e.g. vitamin C, folate and β-carotene) were lower in non-vegetarians than in the other groups.

Although the AHS-2 study categorizes vegetarian status according to the absence of certain animal products in the diet, the nutritional benefits of vegetarian diets may not exclusively be due to the absence of animal foods, but also due to the inclusion of other important plant-based foods. To explore this, food patterns of 89,000 vegetarians and non-vegetarians from the AHS-2 cohort were examined [13]. All vegetarian dietary patterns contained more plant foods including fruits, vegetables, non-fried potatoes, whole grains, legumes, soya foods, nuts and seeds than non-vegetarians. On the other hand their intake of meats, dairy products, eggs and refined grains was less than non-vegetarians. The large increase of such a broad

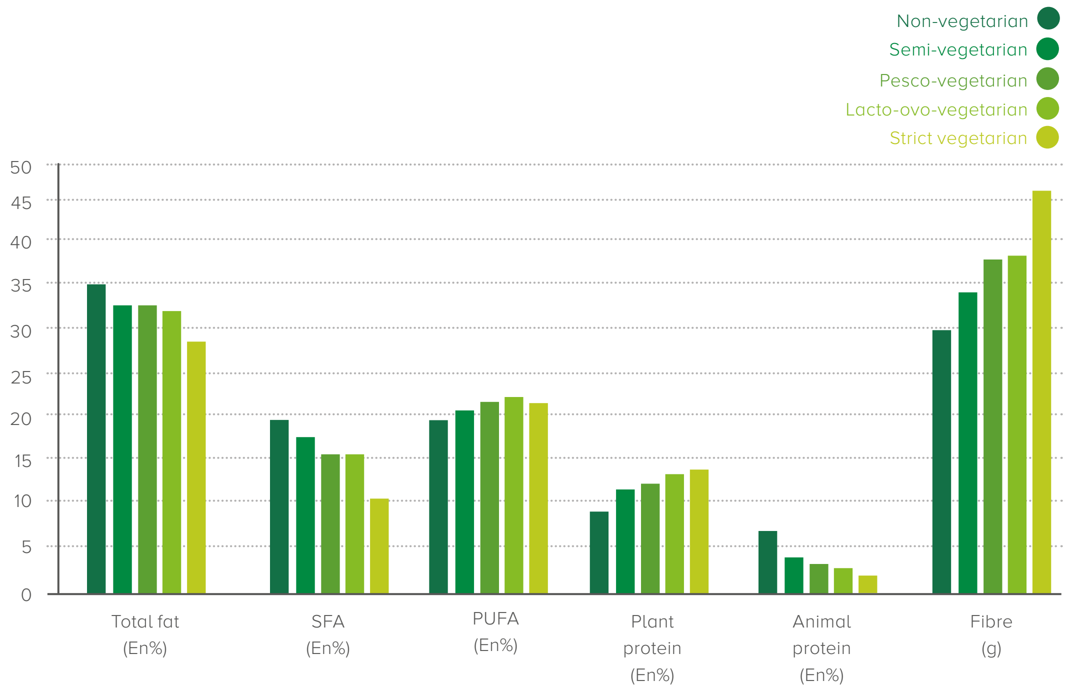


Figure 2.3: Average daily intake of selected nutrients standardized to 2000 kcals/day according to dietary pattern in the AHS-2 study

Source: Rizzo [10]

spectrum of plant-based foods, rather than a concentrated increase of just a few food groups, is likely to account for the beneficial nutrient profiles seen in plant-based eating patterns and also helps ensure nutritional adequacy.

More plant-based eating - healthy dietary patterns

In more recent studies an approach using dietary pattern analysis is being applied to better measure plant-based food intake. Dietary pattern analysis is increasingly being used alongside usual nutrient analysis to examine the effect of an overall diet. As food and nutrients are not eaten in isolation, and the "single food or nutrient" approach does not take into account the complex interactions between food and nutrients, this complimentary assessment is seen as a better method to examine overall diet quality. Using this method the PREDIMED study demonstrated how the nutritional quality of the diet improves as more plant foods are included [11]. This study is a parallel group, multicentre, RCT designed to test the effects of two Mediterranean-type diets on CVD compared with a control (low fat) diet. Approximately 7500 men and women (aged 55-80 with established risk factors for heart disease but who were all free of CVD at baseline) were assigned to one of three diets – a Mediterranean diet (high in fruits, vegetables, legumes and nuts and low in red meat, dairy and refined grains) supplemented with extra-virgin olive oil; or a Mediterranean diet supplemented with mixed nuts (approximately 30g/d); or a control diet based on the American Heart Association low fat diet. Using dietary data from 7216 participants a pro-vegetarian eating pattern was developed based on the scoring of 12 food groups. Fruit, vegetables, nuts, cereals, legumes, olive oil and potatoes were positively weighted. Added animal fats, eggs, fish, dairy products and meats or meat products were negatively weighted. Total scores ranged from 12 to 60 – higher scores reflecting higher adherence to a pro-vegetarian food pattern. Table 2.1 highlights the improvements seen in the nutritional quality of the diet as compliance to the pro-vegetarian pattern increases and the shift moves away from animal products to plant foods. Interestingly, even a very high compliance to a pro-vegetarian eating pattern includes some animal products in the diet, again suggesting total exclusion of animal foods is not required to bring about nutritional benefits.

Dietary pattern analysis has also been used to assess the overall diet quality of Belgian vegans (N=104), vegetarians (N=573), semi-vegetarians (N=498),

Pro-vegetarian food pattern category					
Food (g/day)	Very Low: <30	Low: 30-40	Moderate: 35-39	High: 40-44	Very High: >44
Vegetables	254.0	294.0	343.0	388.0	442.0
Fruits	267.0	319.0	376.0	432.0	555.0
Legumes	15.0	18.0	21.0	25.0	28.0
Cereals	105.0	129.0	144.0	164.0	205.0
Nuts	4.4	7.2	10.0	14.0	22.0
Meats/ meat products (excluding fish)	160.0	141.0	129.0	113.0	105.0
Dairy Products	495.0	419.0	371.0	314.0	259.0
Nutrients					
Total Fat (En%)	40.6	39.6	39.2	38.4	36.9
SFA (En%)	11.7	10.5	9.8	9.1	8.1
PUFA (En%)	5.8	6.1	6.3	6.5	6.8
Dietary Fibre (g/day)	19.0	22.0	26.0	30.0	36.0

Table 2.1: Average selected food and nutrient intakes of participants according to categories of the pro-vegetarian eating patterns

Source: Martínez-González [11]

pesco-vegetarians (N=145) and omnivores (N=155) [12]. In this study, Healthy Eating Index 2010 (HEI-2010) and the Mediterranean Diet Score (MDS) were calculated as indicators for diet quality as they have been related to positive health in a general population. HEI-2010 represents the degree to which a dietary pattern conforms to the official guidelines summarized in the United States Department of Agriculture Food Guide Pyramid and uses a ten or twelve component score. It also adjusts for energy, which limits the possible confounding effect of total energy intake. MDS uses ten components to express the agreement with the Mediterranean dietary pattern: seven desirable (vegetables, legumes, fruits, nuts, cereals, fish and olive oil), two undesirable (meat and dairy) and one moderation (alcohol) component. Higher scores reflect higher adherence. The vegan diet received the highest index values and the omnivore diet the lowest for both the HEI-2010 and MDS.

Other vegetarian diets scored in between these two dietary patterns. In the HEI-2010, typical aspects of vegan and vegetarian diets (fruit, vegetables intake, low sodium intake and low fat content) contributed to the high total score, whilst the omnivorous diet resulted in the lowest scores for these components. This study also examined nutrient intake and in line with previous research found the most restricted diet (vegan) had the lowest total energy intake, better fat profile, lowest protein and highest dietary fibre intake compared to the omnivorous diet; intakes of the semi-vegetarians and pesco-vegetarians were in between the vegan and omnivorous scores [12].

More plant-based eating – focus on plant foods, but not exclusively

Studies involving self-defined vegetarians who include small amounts of meat in their diets have also found nutritional benefits. A study involving 2516 US men and women, aged between 15 and 23 yrs, found that current vegetarians had healthier dietary intakes than non-vegetarians with regard to fruits, vegetables and fat [3]. Vegetarian status was self-reported and was divided into three categories – current, former and never vegetarians. Of those who identified themselves as current vegetarians: 46% reported consuming fish and 25.1% reported eating chicken. In the current vegetarian group average daily intake of fruit and vegetables was approximately 5 portions/d compared to between 3 and 4 in the former or never vegetarian group. In the younger vegetarian age group, 28.6 En% came from total fat and 10.3 En% from SFA, compared to 30.7% and 11% respectively in the never vegetarians. In the older age group, current vegetarians consumed 24.7 En% from total fat and 8.4 En% from SFA, compared to 30.9 En% and 10.7 En% respectively in the older, never vegetarian group.

Meat-eating vegetarians have also been observed in other studies [4, 14-16]. For example data from 13,313 US participants, over the age of 6 yrs, in the Continuing Survey of Food Intake by Individuals (CSFII) was used to compare self-defined vegetarian and non-vegetarian dietary patterns [4]. The vegetarian and non-vegetarian dietary classifications were further divided into groups who either ate “no meat” or “ate meat” based on results from two, 24 hour dietary recalls. Approximately two-thirds of the sample population who classified themselves as vegetarians in fact ate meat. However, these semi-vegetarians ate significantly less meat (160 g versus 216 g/d), red meat (80 g versus 137 g/d) and poultry (42 g versus 57 g/d) and more fish (38 g versus 22 g/d) than non-vegetarians. The diets of the self-defined vegetarians who included meat tended to be lower in total fat, SFA and cholesterol, and higher in fibre than the diets of non-vegetarians who ate meat (Table 2.2).

Nutrient	Self-defined meat eater	Self-defined vegetarian (ate meat)
Total fat (En%)	32.9	30.2
SFA (En%)	11.1	9.6
PUFA (En%)	6.5	7.0
Cholesterol (mg)	267.0	238.0
Fibre (g/ 2000kcals)	15.3	19.5

Table 2.2: Average daily intake of selected nutrients of diets by self-defined vegetarian status

Source: Haddad and Tanzman [4]

The authors concluded that self-defined vegetarians generally have better dietary habits than non-vegetarians – eating whole-wheat bread, brown rice, soya drink, meat substitutes, lentils, chickpeas, walnuts, and pecans more frequently [4].

Similar dietary characteristics have been found in the Netherlands Cohort Study. Within this large cohort (N=120,852) a subgroup (NLCS-Meat Investigation Cohort (NLCS-MIC)) has been designed to study the health effects of a vegetarian and low meat diet [17]. The NLCS-MIC includes all vegetarians – as confirmed by food frequency questionnaire (N=702), pescetarians (N=394), and 1 day per week meat consumers (N=1396). Dietary characteristics have been compared with a sample of regular meat consumers – 2-5 days per week and 6-7 days per week (N=2965 and 5648 respectively). Consumers who ate meat just once a week had more favourable dietary intakes compared to regular meat eaters in both sexes (Figures 2.4 and 2.5) [17].

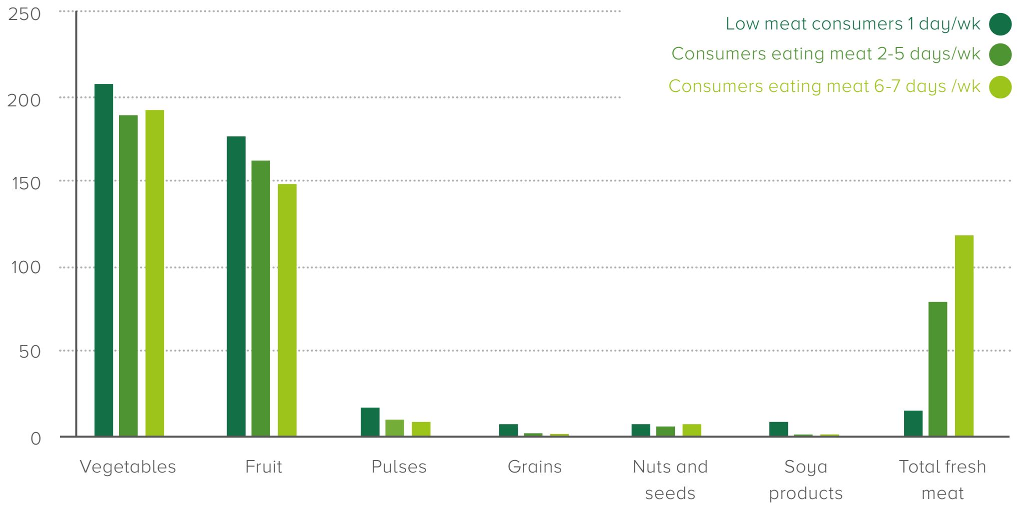


Figure 2.4: NLCS-Meat Investigation Cohort - Average daily intake of selected food groups of low meat and regular meat consumers (men; N=4781)

Source: Gilsing [17]

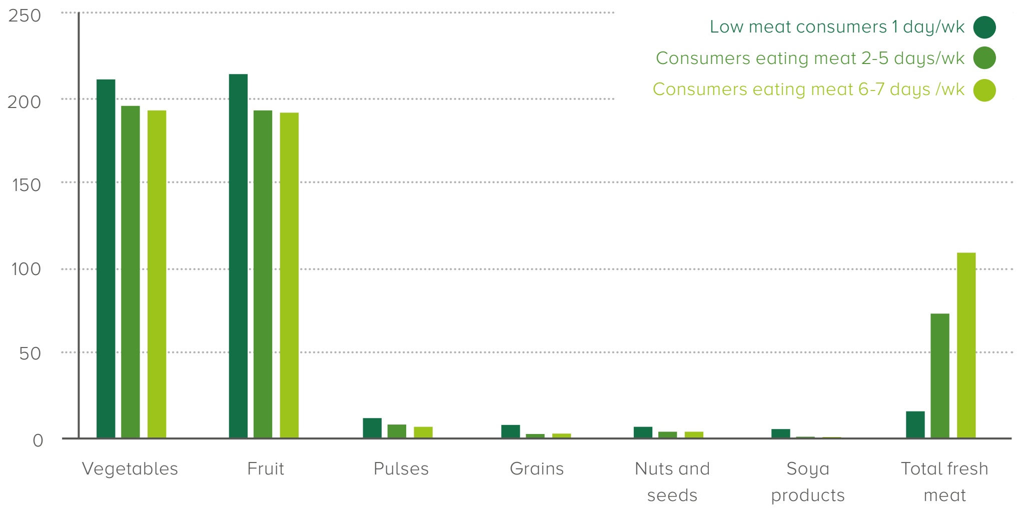


Figure 2.5: NLCS-Meat Investigation Cohort - Average daily intake of selected food groups of low meat and regular meat consumers (women; N=5229)

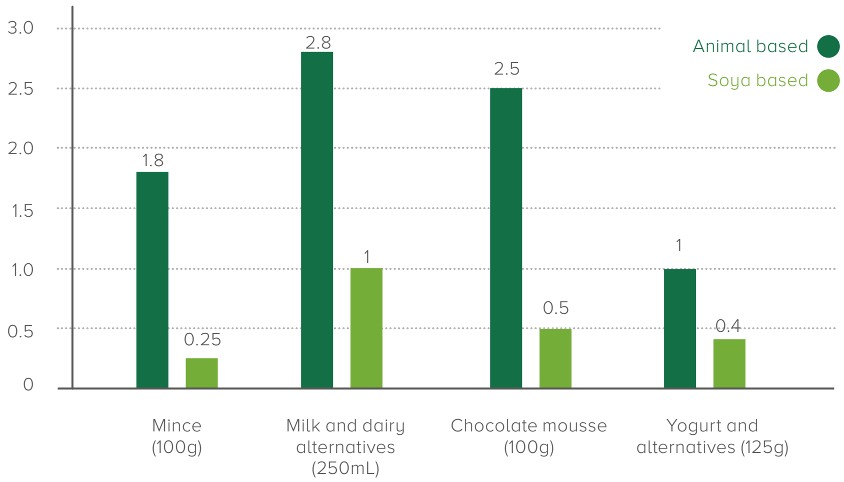
Source: Gilsing [17]

Currently many Western countries are consuming diets too high in SFA, with large amounts coming from animal based foods and drinks (see Chapter 1).

It is thought that the lower intake of SFA in plant-based eating patterns may be due to plant foods displacing other foods in the diet that are high in SFA. This was explored in a study led by Professor Jenkins from the University of Toronto [18]. He devised a diet that contained foods representative of foods typically eaten in the US diet, providing approximately 33% of calories from total fat and 11% from SFA. He then calculated the effect of substituting animal sources of protein (such as milk, yogurts, steak and bacon) with equivalent amounts of soya protein (13-58 g/d). He determined that a 13 g/d soya substitution would result in a reduction in SFA from approximately 11% of calories to 8 En%. This would be further lowered to 5.8 En% if 58 g of soya was substituted. Dietary cholesterol would also be reduced from 316 mg/d to between 205 to 267 mg/d, whereas PUFA would increase from 5.7 En% to between 7.5 and 8.0 En%.

A Dutch study also noted improvements in SFA intake when meat and dairy foods were replaced with plant-based alternatives [19]. The purpose of this study was to examine the environmental and nutritional effects when meat and dairy foods were swapped with suitable plant-based substitutes. Data was obtained from 398 Dutch females (aged 19 to 30) and a modelling scenario was used where either all, or 30% of meat and dairy foods were replaced with plant-based alternatives. In the 100% scenario SFA reduced from 13.2 En% to 9.2 En% and when 30% of these foods were replaced, SFA reduced to 12.1 En%. Although UFA intake was not analysed in this study, it is likely this improved as the foods used to replace meat and dairy included soya alternatives to dairy, beans, tofu, peas and vegetarian meat alternatives which are low in SFA and good sources of PUFA.

Figure 2.6 further highlights the reductions in SFA that could be achieved if certain foods were swapped with plant-based (soya) alternatives.



Mince – Very lean minced meat vs Linda McCartney Vegemince; Semi-skimmed milk* vs Soya, non-dairy alternative to milk, fortified*; Low fat chocolate mousse* vs Alpro silky smooth chocolate dessert; Low fat dairy yogurt* vs Soya non-dairy alternative to yogurt**

**Nutrition information from McCance and Widdowson's The Composition of Foods - 7th Edition*

Figure 2.6: Saturated fat content (g) of various animal based products compared to soya alternatives (available on the UK market)

More plant-based eating – a wide array of nutrients

As well as a reduction in animal-based products, the wide variety of nutrients (fibre, complex CHO, UFA, plant proteins, vitamins and minerals) found in plant-based foods are also thought to contribute to the potential health benefits associated with more plant-based eating.

Specific attention should be given to the fibre content of these foods (both soluble and insoluble fibre) as currently the intake of fibre in many European countries is below the recommended amounts (see Chapter 1). Including more of these fibre-rich foods can help to meet the dietary recommendations.

Studies in developed countries have found vegetarians to have greater intakes of several micronutrients, including thiamin, folate, vitamin C, carotene, potassium and vitamin E, than the general population [2, 4, 20]. As such, including more plant foods in the diet could help improve intakes of micronutrients lacking in certain population groups across Europe (see Chapter 1).

In addition to micronutrients, plant foods also contain phytochemicals. Although not nutrients in the traditional sense, they are found in a variety of different plants and include substances such as phytosterols, lignans, flavonoids, isoflavones, glucosinolates, phenols, terpenes and allium compounds. Research is suggesting that when these are eaten as part of the food (rather than an isolated supplement), these compounds may offer additional health benefits [21].

Are there any nutritional concerns to consider when adopting a plant-based eating pattern?

No, not if a wide variety of foods are included in the diet to ensure that it is nutritionally balanced. In fact, in their position paper on this issue the American Dietetic Association (ADA) say that well-designed vegetarian diets meet current nutrient recommendations and are appropriate for all stages of the life cycle [1]. They go on to say that the low intake of foods containing SFA and cholesterol, and high intake of vegetables, fruits, whole grains, legumes, nuts, seeds and soya products that are rich in fibre and phytochemicals are components of a vegetarian diet that contribute to reduction of chronic disease [1].

In the past, there was concern that moving towards a plant-based eating regime would result in deficiencies in particular nutrients, specifically protein, zinc, iron, vitamin B12, vitamin D and calcium [8, 22, 23]. However, a review that considered the evidence for this concluded that this need not be the case and suggested that, based on the evidence, meat is an optional rather than an essential constituent of human diets [24]. This is in agreement with the previously mentioned AHS-2 study which found vitamins B12 and D, calcium, iron and zinc were above the minimum requirements in strict vegetarian diets [10].

The potential risk of nutritional inadequacy depends on the extent to which animal products are being reduced and plant foods increased in the diet. Plant-based eating spans a wide spectrum of dietary practices; from vegan diets (where all animal products are excluded) to diets where small amounts of meat are included. Data from the previously mentioned CSFII study found that those who adopted a more plant-based diet had similar intakes of protein and iron, and higher intakes of omega-3 fatty acids and calcium than the non-vegetarians. While vitamin B12 and zinc intakes were slightly lower in this group compared to the non-vegetarian group, this was not significant [4]. This highlights that adopting a plant-based eating pattern does not necessarily result in lower intakes of nutrients that were thought to be at risk when cutting down on animal foods.

It is, however, important to consider the nutrients animal products generally provide when reducing these in the diet and how they can be replaced

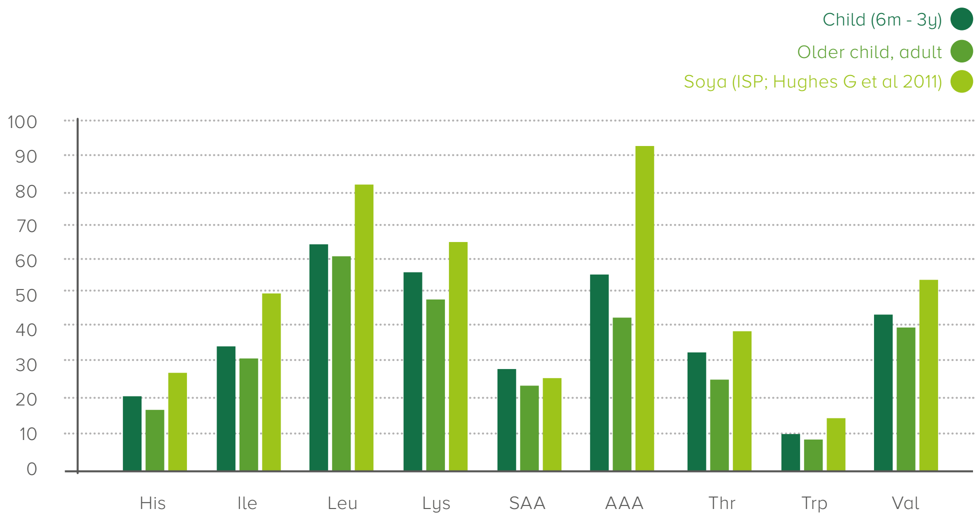
Nutrients provided by animal foods	Plant foods
Protein	Peas, beans, lentils, nuts, nut butters (peanut butter), seeds, soya alternatives to dairy, tofu, soya nuts, meat analogues such as soya mince
Zinc	Fermented soya e.g. tempeh and miso, beans (soaking dried beans and discarding the soaking water prior to cooking increases zinc bioavailability), lentils, nuts, seeds and whole grains
Iron	Beans, lentils, peas, nuts, sesame seeds, dried fruit, whole grains, fortified breakfast cereals, leafy green vegetables
Vitamin B12	Yeast extract and other fortified foods such as soya alternatives to dairy, breakfast cereals (check the label)
Calcium	Fortified soya dairy alternatives, tofu, dried fruit (e.g. apricots and figs), nuts, green leafy vegetables (especially Kale and Pak-Choi, but not spinach), sesame seeds and tahini
Vitamin D	Fortified foods such as margarines, soya dairy alternatives, some breakfast cereals (check the labels)
Omega-3 fats	Flaxseed, rapeseed, hemp seeds, walnuts, green leafy vegetables and soya oil

Table 2.3: Nutritional contribution from animal foods compared to plant foods

with suitable plant-based alternatives. For example, meat, eggs and dairy products provide protein, zinc, iron, vitamin B12, vitamin D and calcium. Fish is also a good source of long-chain omega-3 fatty acids. But these, too, can be replaced. Table 2.3 highlights good alternative plant-based sources for these particular nutrients.

Protein

Protein from animal sources contains the complete mix of essential amino acids, whereas most plant foods contain limited amounts of one or more of the essential amino acids. It was once thought that certain combinations of plant foods had to be eaten at the same meal to ensure a sufficient intake of amino acids. However, it is now known that as long as energy intake is adequate and a mixture of plant proteins are eaten over the course of the day, the requirement for essential amino acids will be met.



Abbreviations: His, Histidine; Ile, Isoleucine; Leu, Leucine; Lys, Lysine; SAA, Sulphur Amino Acids; AAA, Aromatic Amino Acids; Thr, Threonine; Trp, Tryptophan; Val, Valine

Figure 2.7: Soya protein amino acid scoring pattern (mg/g) in comparison to amino acid requirements at different ages

Source: Based on Hughes [26] and FAO 2013 [27]

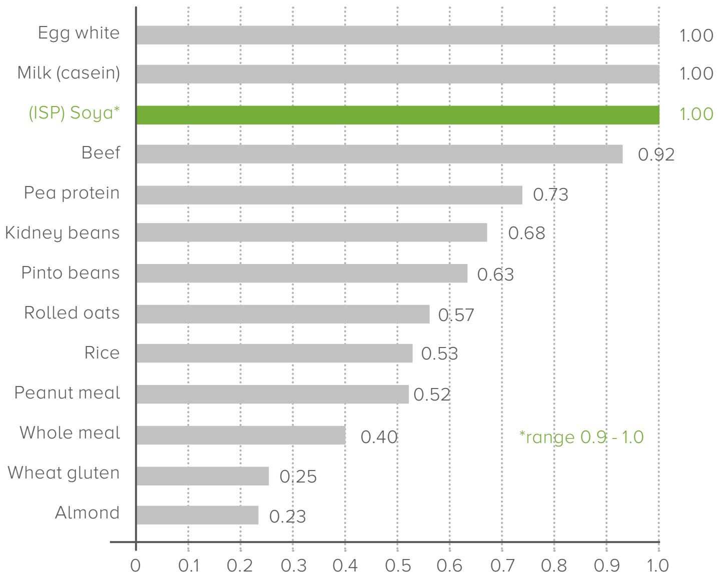


Figure 2.8: PDCAAS of different protein sources

Source: Extracted from Hughes [26]

Using the internationally recognised method to determine protein quality (Protein Digestibility Corrected Amino Acid Score (PDCAAS)) [25] soya has been identified as one of the few plant proteins that contain all the essential amino acids in amounts the body requires (Figure 2.7) [26, 27]. For this reason the quality of soya protein is comparable to meat, milk and eggs (Figure 2.8) [26].

While protein intake has been found to be slightly lower in vegetarians than meat eaters, it still meets daily requirements. Furthermore, if a vegetarian diet is planned to meet the requirements for essential micronutrients it is likely that protein needs will be exceeded.

Iron

Although iron has been considered a nutrient of concern, studies have found intakes in vegetarians to be similar, if not higher, to non-vegetarians [2, 4, 5, 12, 20] and in Western societies incidence of iron deficiency anaemia among vegetarians is similar to that of non-vegetarians, although iron stores are often lower [28]. In the Dutch study that modelled the environmental and nutritional effects of replacing all meat and dairy foods with plant-based alternatives, iron intake actually increased from 9.5 mg/d to 12 mg/d when adopting a plant-based eating pattern [19].

Nonhaem iron is present in plant foods and haem iron is found in animal foods. Nonhaem iron is not as well absorbed but its availability is enhanced by the presence of vitamin C and factors found in meat, fish and eggs. Absorption is also regulated by requirements – lower body stores result in an increased absorption of nonhaem iron. Dietary factors that may inhibit nonhaem iron include phytic acid found in whole grains and legumes and phenolic compounds found in tea and coffee. Some food preparation techniques such as soaking and sprouting beans, grains and seeds can reduce phytate levels and thereby enhance nonhaem iron absorption. Furthermore as people move towards a more plant-based diet they are likely to consume more vitamin C, which can help overcome these inhibitors of iron absorption.

In 2011 the UK's Scientific Advisory Committee on Nutrition (SACN) published its report on iron and health [29] and suggested that a healthy balanced diet, including a variety of foods containing iron, is more important in helping people to achieve adequate iron status than focusing on inhibitors and enhancers of iron absorption from foods.

Interestingly, soya contains a form of iron that is easily absorbed despite the presence of phytate. Although soya is a good source of iron, in the past it was believed that this iron, like iron from other plant foods, was poorly available. But research using improved methodologies suggests that iron absorption may be higher than previously thought because most of the iron in soya is in the form of ferritin [30, 31].

Zinc

As meat is the main source of zinc in many diets, the effect of vegetarian diets on zinc status has been examined in a recent meta-analysis [32]. Twenty-six studies compared males and/or females on vegetarian diets with non-vegetarian groups. Dietary zinc intakes and serum zinc concentrations were significantly lower (-0.9 mg/d and -0.93 µmol/l respectively) in populations that followed habitual vegetarian diets compared with non-vegetarians. However, when one of the largest studies (N=55,319) was removed from the analysis (due to its impact on effect size) the difference in intake was no longer significant. The use of serum zinc concentration as a biomarker for zinc status has also been questioned. Although it is the recommended biomarker it may not be sensitive enough to measure long term status. Furthermore, in some studies recommended collection and analytic procedures have not always been followed, making the results difficult to interpret. Zinc is tightly regulated by homeostatic mechanisms, and at lower intakes the body adapts by absorbing more zinc and excreting less. Adaptation appears to occur in vegetarians, with zinc status likely to remain stable after an initial adjustment period [33, 34].

Vitamin B12

If small amounts of animal foods are included in the diet, then getting enough vitamin B12 should not be a problem. However, if all animal products are being excluded it is important to ensure fortified food sources are eaten.

Several studies have reported lower vitamin B12 status in vegetarians, particularly vegans, when compared with omnivores. A recent review on the subject concluded that vegetarians can develop vitamin B12 depletion or deficiency regardless of demographic characteristics, age or type of vegetarian diet [35]. Well-planned diets, incorporating a wide variety of suitable plant-based foods, will help to ensure nutritional adequacy.

Vitamin D

Vitamin D deficiency is not just a concern for vegetarians (see Chapter 1). In Western societies sunlight on the skin can synthesize vitamin D during the spring and summer months, but there are other times in the year when it is important to eat foods that contain vitamin D. Because of the low sun exposure at the latitude of northern Europe there are recommendations to supplement certain age groups in some countries, e.g. the UK and the Netherlands [36, 37].

Omega-3 fats

Fish is the major source of the long chain omega-3 fatty acids (DHA and EPA) while the short version (ALA) is found in vegetable oils — particularly soya bean, flaxseed, walnut and rapeseed oils. The long chain omega-3 fatty acids are particularly important for the maintenance of health, specifically heart health, and many dietary recommendations advise incorporating fish into the diet to meet the requirement for omega-3s. The shorter omega-3 fatty acids may not have the same benefits and although the body can convert some ALA into EPA and DHA, the conversion is believed to be limited due to competition that occurs along the PUFA metabolic pathway. Despite this, studies have found that although non-fish eating meat eaters and vegetarians have much lower intakes of EPA and DHA than fish eaters their omega-3 status is higher than would be expected.

This suggests a greater conversion of ALA to circulating long chain omega-3 fatty acids in non-fish eating groups [38, 39]. One reason for this may be related to the ratio of omega-6 to omega-3 fatty acids in the diet. If very little Linoleic Acid (omega-6) is present compared to ALA, more EPA and DHA will be produced.

While long chain omega-3 fatty acids are being recommended to support heart health, studies have found no difference between ALA and EPA/DHA in relation to CVD risk [40]. Furthermore, the CV profile of vegetarians is more favourable than that of meat eaters because of lower LDL–C levels, lower BMI and moderately lower blood pressure in vegetarians. A review of this subject concluded there is currently insufficient evidence to warrant advising vegan and vegetarians to supplement their diets with EPA or DHA for CVD prevention but it is still important to ensure good sources of ALA are included in the diet [39]. Nevertheless, for those who are not eating any fish and are concerned about getting enough long chain omega-3 fatty acids in their diets, there are now supplements made from algae derived DHA.

Plant-based eating recommendations

Findings from studies to date demonstrate how **shifting to a diet based on plant foods improves the overall nutritional quality of the diet.** Furthermore, the complete avoidance of meat is not needed to bring about these nutritional benefits. Plant-based eating patterns are in line with this – based on plants, but not exclusively so. Many national and international organisations are stressing the importance of plant foods and emphasize these in their dietary recommendations (see Introduction). To help achieve this the

World Cancer Research Fund (WCRF) has suggested that at least two-thirds of a plate should be made up of plant foods (vegetables, whole grains, cereals and pulses) and foods from animals should make up less than a third [41].

Take-home messages:

- Plant-based eating is associated with a diet that is low in total fat and SFA, a good source of UFA, better UFA:SFA ratio and high in fibre.
- Eating more plant-based foods, and replacing some animal products with these, can help to improve the nutritional quality of the diet and meet current dietary recommendations.
- Plant-based eating supports normal growth and development and can meet the nutritional needs of a healthy individual throughout the lifecycle provided a wide variety of plant foods are consumed.
- Animal foods should be seen as an accompaniment, rather than as an essential component of the diet.
- At least two-thirds of a plate should be made up of plant foods (vegetables, fruits, whole grains, cereals, pulses, nuts and seeds) and foods from animals should make up less than a third.
- The wide variety of plant-based foods available provides a number of options for designing a healthy plant-based eating plan to suit all tastes and palettes.

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3

Chapter 3

More plant-based eating and cardiovascular health

PROF. BRUCE GRIFFIN
Professor of
Nutritional Metabolism,
Surrey University (UK)

PROF. JULIE LOVEGROVE
Hugh Sinclair Unit of
Human Nutrition and
Institute for Cardiovascular
and Metabolic Research
(ICMR), University
of Reading (UK)

Introduction to Chapter 3, by invited experts Bruce Griffin and Julie Lovegrove

Diet is of paramount importance in maintaining cardiovascular health by reducing risk factors for CVD such as blood cholesterol, and preventing the often fatal outcomes of CVD such as heart attack and stroke. The overconsumption of SFA has been identified as a key factor responsible for raising blood cholesterol, and its replacement represents one of the major dietary guidelines to prevent CVD. However, a lack of definitive evidence for a direct relationship between the intake of SFA and death from CVD has raised serious doubt over the validity of the health recommendation to eat less SFA. This confusion has arisen, in part, because of the complexity of the relationship between diet and CVD, which cannot be explained by the overconsumption of a single nutrient. The impact of individual nutrients on the development of CVD will be influenced by other ingredients in the food, and by other foods consumed within a whole diet. Conversely, it follows that the maintenance of cardiovascular health will require the modification of multiple dietary factors. One effective way to achieve this is by altering the overall dietary pattern and to eat more nutrient-dense, plant-based foods.

This chapter reviews the hierarchy of evidence in support of eating more plant-based food to prevent CVD. It summarizes the outcomes from a range of observational studies of prospective and cross-sectional design, and randomly controlled intervention trials on CVD risk factors and clinical end-points. What emerges is a persuasive case for the health benefits of eating plant-based diets, which have been consistently associated with a lower incidence of fatal and non-fatal cardiovascular events, and reduced risk of developing CVD. These benefits appear to be mediated largely through favourable effects on blood lipids, and chiefly by a lowering of serum LDL-C, and to a lesser extent by reductions in blood pressure. A number of plausible mechanisms have been proposed to explain these benefits which are *described in terms of both extrinsic and intrinsic properties of plant-based food and diets. Two major extrinsic effects of plant-based foods that are of immediate relevance to the maintenance of cardiovascular health are the displacement of both energy and fat (specifically SFA) from predominantly animal-based diets. These effects facilitate weight loss through energy-restriction, and the substitution of SFA with plant-derived PUFA and MUFA, both of which will lower serum LDL-C. Another potential advantage of plant-based foods is to prevent the adverse metabolic effects of a high intake of free sugars on low fat diets, which could be partly negated by the intake of a vegetable-rich diet that is higher in starch than sugar.*

From an intrinsic perspective, the components of plant-based foods that seem to produce the greatest effects on CVD risk are those with established effects in lowering serum LDL-C, including soya protein, oats and viscous soluble fibres. The review summarizes the effects and mechanisms of action of these plant-derived nutrients as part of a portfolio of dietary factors for lowering serum LDL-C. When the cholesterol-lowering effects of these factors are combined with an exchange of dietary fatty acids (SFA for MUFA and/or PUFA), together with foods fortified with plant-derived sterols (and stanols), the reductions in serum LDL-C (20-35%) can become equivalent to that of moderate statin drug therapy. While it is recognized that it may be difficult to comply with this entire portfolio of dietary factors, the individual plant components have additive effects. It is also possible that individual components of the portfolio exert multiplicative effects in lowering serum LDL-C by acting through synergistic mechanisms. These mechanisms could include limiting the absorption of cholesterol and bile acids in the gut, and stimulation of receptor-mediated uptake of LDL into cells. One of the strongest and most consistent associations to support a cardio-protective role for a dietary constituent, is between dietary fibre and CVD, in which both insoluble and soluble fibre have been implicated. This impressive finding provides firm evidence to support a new guideline to increase our intake of dietary fibre to 30 g/d, and for eating more plant-based foods to help us achieve this guideline and to improve cardiovascular health.

In comparison to the highly favourable effects of plant and vegetable-based diets on blood cholesterol, the evidence under review for the benefits of plant-based foods on blood pressure is relatively weak. Dietary *patterns that include an increased intake of vegetables, such as the DASH diet (Dietary Approaches to Stop Hypertension) and variants of the Mediterranean diet, have been shown to produce significant reductions in blood pressure, though this effect takes longer to develop than benefits on blood lipids, and may be mediated indirectly through a loss of body weight. While the latter is considered to be a confounding factor, it could also be viewed as another favourable extrinsic effect of a plant-based diet, which is lower in energy and may affect appetite, hunger and satiety in ways that promote weight loss through a restoration of energy balance. The blood pressure-lowering effects of plant-based diets have been attributed to improvements in the function of the vascular wall of blood vessels. Loss of vascular function is known to be an early pre-requisite for the development of CVD and an integrated CVD risk factor, since it develops under the influence of hyperlipidaemia, hypertension, and pro-inflammatory and thrombotic conditions. There is an increasing body of evidence to suggest that plant-based diets improve vascular function via extrinsic and intrinsic mechanisms, the latter of which may involve the specific effects of polyphenolic compounds.*

What follows is a compelling review of the evidence to support eating more plant-based food as a dietary strategy for maintaining cardiovascular health. The totality of this evidence to date suggests that plant-based foods achieve these benefits through the extrinsic displacement of energy and saturated fat, but also via the direct intrinsic effects of nutrients, the full impact of which on cardiovascular health has yet to be realized.

Chapter 3

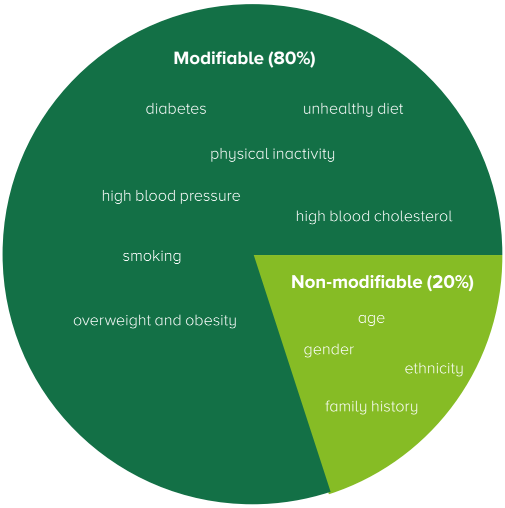
More plant-based eating and cardiovascular health

Incidence of cardiovascular disease in Europe

Coronary heart disease (CHD) and stroke together are known as CVD. It is the single most important cause of death in Europe as a whole and results in over 4 million deaths per year, representing 47% of all deaths, see Figure 3.1. CVD is the most important cause of death in women (52%) and accounts for 42% of deaths in men [1]. Heart disease leads to over 1.9 million deaths in the European Union. One of the nine voluntary WHO global non-communicable disease targets (NCD) is to globally reduce mortality from NCD, including CVD, cancer, diabetes, and chronic respiratory diseases, by 25% by 2025 [2].

Heart disease is the
#1 leading cause of
death

Risk factors



Risk factors for cardiovascular disease

Risk factors for CHD include high blood cholesterol, high BP, T2D, overweight and obesity. These are factors that can be controlled by the individual to some degree. A number of risk factors for CHD are outside of an

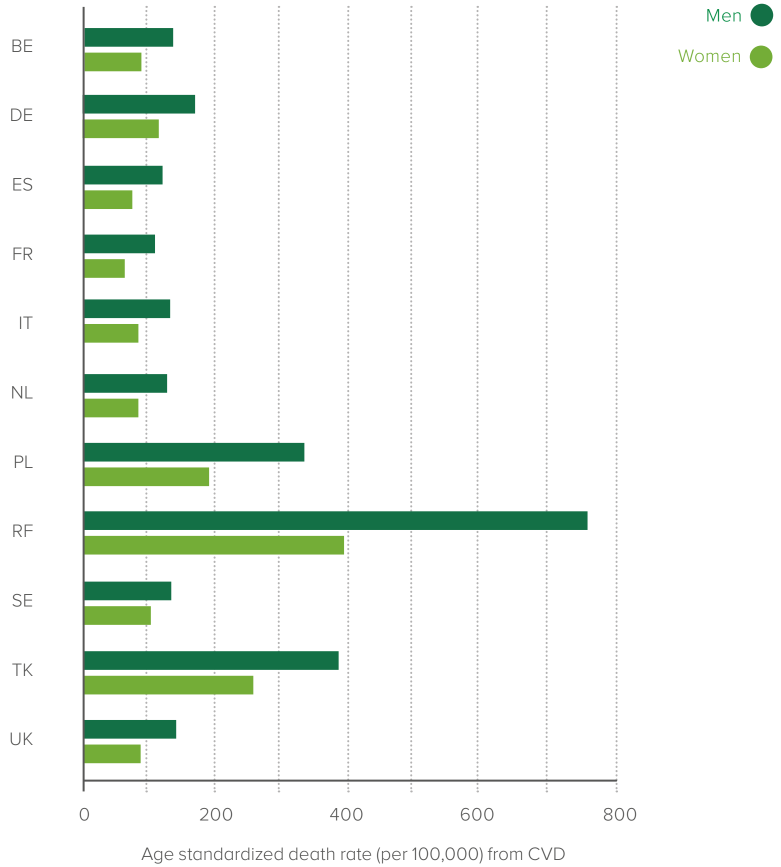


Figure 3.1: Estimated age standardized death rate (per 100,000) from CVD in certain European countries

Source: WHO 2014 [2]

individual's direct control, such as age, gender, ethnicity and family history of the disease.

The most important behavioural risk factors are **unhealthy diet, physical inactivity and tobacco use.** Together these behavioural risk factors are responsible for about 80% of CHD and stroke. One of the most important modifiable risk factors is elevated blood cholesterol [3]. The WHO estimates that over 60% of CHD and 40% of stroke in developed countries is due to total blood cholesterol levels in excess of the theoretical minimum, 3.8 mmol/L (14.7 mg/dL) [3]. This is further confirmed by reference to the INTERHEART case controlled study, which identified that 45% of heart attacks in Western Europe and 35% in Central and Eastern Europe were due to abnormal blood lipid levels [4]. Those with abnormal blood lipids (defined by elevated ApoB/ApoA1 ratio >0.8) have a three-fold greater risk of heart attack compared to those with normal levels [5]. Death from CVD is higher in men than women, although women's risk of CVD increases after the menopause and is also markedly higher in Eastern Europe compared to Western Europe [1] (see Figure 3.1).

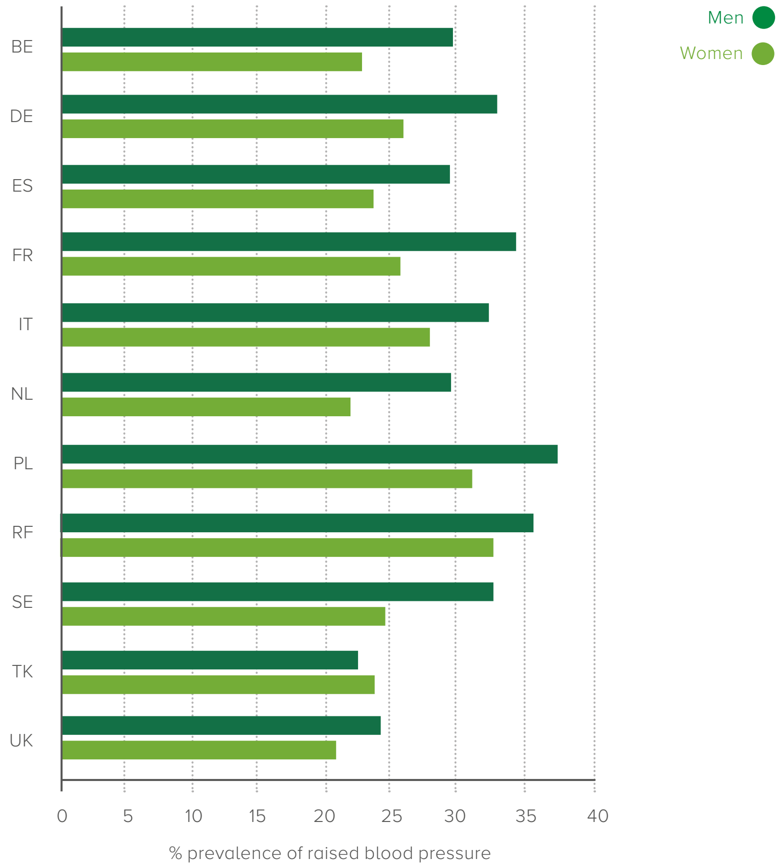


Figure 3.2: Comparable estimates of prevalence of raised blood pressure (population aged 18+ years) in certain European countries 2010

Source: WHO 2014 [2]

A second risk factor is elevated BP (hypertension). Objective Number 6 of the nine voluntary WHO global targets for the prevention and control of NCD is a 25% relative reduction in the prevalence of raised BP or to contain the prevalence of raised BP, according to national circumstances [2]. The WHO Global Health Observatory defines hypertension as a systolic blood pressure greater than 140 mmHg or a diastolic blood pressure greater than 90 mmHg. The prevalence of raised BP is typically around one third of males and a quarter of females in Europe, with Eastern European tending to have a higher prevalence, see Figure 3.2 [2]. The INTERHEART study estimates that 22% of heart attacks in Western Europe and 25% of heart attacks in Central and Eastern Europe are due to a history of hypertension [5].

Cardiovascular disease does not have a single cause; generally it is a combination of factors which increase in severity over time, leading to a heart attack or stroke. The behavioural risk factors, physical inactivity or smoking tobacco, are easily identifiable and lifestyle change can readily be undertaken to moderate these risks. For example, simply by being more active and giving up smoking. But defining healthy eating and putting it into practice has proved to be more difficult. In the past emphasis was placed on the nutrient profile of heart-healthy diets, e.g. advice was given to reduce fat, particularly SFA intake, and to increase fibre intake. Recommendations now focus on increasing the quality of the fat, replacing SFA with UFA [6]. In their global status report on NCDs, WHO have recommended the following as their best buys in terms of effectiveness [2]:

- Reduce salt intake
- Replace trans fats with unsaturated fats
- Implement public awareness programmes on diet and physical activity
- Promote and protect breastfeeding

It is also recognized that food-based recommendations are more useful and lead to better uptake and results [7]. Diets rich in fruits and vegetables have been associated with lower risk of NCDs [8], consequently recent recommendations focus on the increased consumption of plant-based foods (see Chapter 1). Important sources of plant food are fruits, vegetables, legumes, wholegrain cereals, nuts and seeds.

Evaluating heart health

Scientific evidence evaluating the benefits of plant-based eating and heart health is steadily accumulating. The risk factors for heart disease are elevated LDL-C, a low Total-C : HDL-C ratio and elevated TAG and BP, and many clinical studies measure one or more of these risk factors. Disruption of endothelial cells is an early indication of heart disease and inflammation has been shown to be contributory. The next stage in the development of CVD is the development of a thrombosis. Consequently CV studies will often measure endothelial function by using a flow-mediated dilatation (FMD) technique or changes in inflammatory and endothelial markers or molecules associated with adhesion and clot formation, such as CRP, human interleukin-6 (IL-6), human E-selectin, human intercellular adhesion molecule-1 (ICAM) and vascular cell adhesion molecule (VCAM). The combination of raised TAG, small dense LDL and reduced HDL-C comprises the atherogenic lipoprotein phenotype and is the most common lipoprotein pattern seen in patients with myocardial infarction (MI). Thus a reduction in cardiometabolic risk can also be mediated through changes in the structure, composition and metabolic properties of LDL; specifically a reduction of the small dense LDL, while reducing excess body weight and central adiposity is also important for lowering LDL-C [9]. Overweight and obesity, and T2D are independent risk factors for CVD, as well as a source of poor health in their own right. These three factors also come together in the Metabolic Syndrome, which is characterized by a cluster of clinical conditions with hyperinsulinaemia (insulin resistance) being a common factor in them all. Normally patients have one or more of the following: dyslipidemia (measured by ApoB, small LDL and elevated TAG), obesity (specifically increased waist diameter) and impaired glucose tolerance/T2D. Information in this Chapter will focus on CV effects, while information relating to overweight/obesity and T2D can be found in Chapters 4 & 5 respectively.

Potential benefits of plant-based eating

Plant-based foods or eating patterns have a number of characteristics which may contribute to their role in heart health. Specifically these are low in SFA, high in fibre (often soluble fibres that have been shown to reduce blood cholesterol) and rich sources of antioxidants and micronutrients. In addition, specific plant foods or components have been shown to reduce blood cholesterol, e.g. soya protein [10, 11], almonds [12, 13], oat/barley beta glucans [14, 15] and plant stanols and sterols [16, 17].

Observational studies

The CVD observational studies fall into two distinct groups. One group measures the number of cardiac events or deaths from CVD and are considered more convincing evidence because they measure a specific event. The second group measures risk factors such as cholesterol or BP, which provide an indication of heart health status.

Observation studies investigating CVD events or mortality

Much of this data comes from studies where subjects have been following vegetarian or semi-vegetarian diets. For example, results from five prospective cohort studies were combined to compare the death rates from common diseases of vegetarians with those of non-vegetarians with similar lifestyles. In this sample of 76,172 men and women aged 16–89 yrs, there were 8330 deaths after an average follow-up period of 10.6 yrs. Death from heart disease was almost a quarter lower in vegetarians, than in non-vegetarians. This was reported as a death rate ratio (DRR) of 0.76 and was statistically significant ($P<0.01$). This effect was more pronounced in those who had followed a vegetarian diet from a younger age and for more than 5 yrs. There was also a 7% lower death rate from stroke in the vegetarian populations, although this was not significant [18].

Two of the previously mentioned prospective studies were based on UK populations – the Healthy Food Shoppers Study and the Oxford Vegetarian Study. These have now been added to by a third, more recent, study – the European Prospective Investigation into Cancer Nutrition-Oxford (EPIC-Oxford) cohort which includes data from approximately 56,000 subjects. Together these three studies provide an insight into plant-based eating in the UK. Within each study it is possible to compare vegetarians with non-vegetarians and the resulting DRRs for heart disease, adjusted for age, sex and smoking, were 0.85 in the Health Food Shoppers Study, 0.86 in the Oxford Vegetarian Study, and 0.75 in EPIC-Oxford. The authors concluded that overall mortality of both the vegetarians and the non-vegetarians in these studies was low compared with national rates. However the non-significant reduction in mortality from heart disease was in line with previous findings, at just under 20% [19]. This data was confirmed in an update from EPIC-Oxford published in 2009. On this occasion when vegetarians were compared to meat eaters (47,254 subjects) who had no previous history of CVD or cancer, the adjusted risk factor for heart disease was 0.81 representing a reduced risk of 19% [20].

Mediterranean diet observational studies

A Mediterranean diet is another example of a plant-rich eating pattern that can be used to help understand the relationship with heart disease. In a study that assessed CHD events in five Spanish centres of the EPIC study, compliance to a Mediterranean diet was assessed relative to CHD [21]. The extent to which a Mediterranean diet was followed was based on the intake of nine key components and an overall 18-point score developed. Six components: fruit (including nuts and seeds but excluding fruit juices), vegetables (excluding potatoes), legumes, cereals (including wholegrain and refined flour, pasta, rice, other grains and bread), fresh fish (including seafood) and olive oil were viewed positively and two components viewed negatively, these were total meat (including processed meat) and dairy products. Alcohol was considered beneficial in moderation. The analysis included 41,078 participants aged 29-69 yrs, recruited in 1992-1996. They were then followed up for an average period of 10.4 yrs. Fatal and nonfatal CHD events were analysed according to subjects' Mediterranean dietary score. A high compliance to the Mediterranean diet was associated with a 40% significant reduction in risk of heart disease compared to low compliance. It was calculated that a 1-unit increase in relative Mediterranean diet score was associated with a 6% reduced risk of CHD, implying that following a regime based on plant foods and fish was associated with significantly improved heart health in Spain.

The PREDIMED study is a parallel group, multicentre, randomized clinical trial designed to evaluate the effects of two Mediterranean-type diets (Med-Diets) on various factors, in this case CVD compared with a control (low-fat) diet [22]. The 7216 participants are men or women aged 60-80 yr with no previously documented CVD but at high CV risk. They had either T2D or three or more major CV risk factors at baseline, including current smoking, hypertension (≥140/90 mmHg or treatment with antihypertensive agents), high LDL-C (≥ 4.14 mmol/L), low HDL-C (≤1.03 mmol/L), overweight/obesity [BMI (in kg/m^2) ≥25], or a family history of premature coronary artery disease

(CAD). This database was used to develop a pro-vegetarian eating pattern built from dietary data collected during the trial. Using a 137-item FFQ, components were scored to derive a dietary value with a potential range of 12–60 points [23]. Fruit, vegetables, nuts, cereals, legumes, olive oil, and potatoes were positively weighted. Added animal fats, eggs, fish, dairy products and meats or meat products were negatively weighted. Higher baseline conformity with the pro-vegetarian food pattern was associated with lower mortality; death rates decreased from 14.9/1000 person-yrs among participants with low adherence (score ≤30) to 8.7/1000 person-yrs among those with high adherence (score ≥40) [23]. When data relating to coronary deaths was examined, a similar trend was reported - HRs for 30–34, 35–39 and ≥40 points of adherence to the pro-vegetarian eating pattern were 0.48, 0.44, and 0.47 respectively and showed inverse associations (P-trend=0.039).

While this dataset of observational studies is not a perfect match for plant-based eating, there is consistency in the findings, indicating that **those who consume more plant foods and less or no meat tend to have improved heart health and a lower death rate from heart disease and possibly stroke**.

Observation studies investigating CVD risk factors

An extensive review of plant-based diets and their effect on the risk factor — blood lipids — has been undertaken by Ferdowsian [24]. In this review the authors identified 13 observational studies with a total of 4772 men and women of varying age and ethnicity, who were from six different countries, including the UK and Germany. In 12 of the 13 identified studies blood cholesterol levels were lower in those adopting plant-based eating. The authors concluded that those following a plant-based diet, particularly vegetarian and vegan diets, had lower cholesterol concentrations and were at lower risk of heart disease. Within this systematic review of studies there were four studies that related to Seventh-Day Adventists populations, who have very different lifestyles to many Western populations. Therefore care should be taken interpreting this data and its applicability to the general population. Of greater interest within this review are those studies that compared sub-populations such as vegans, vegetarians, semi-vegetarians (or fish eating vegetarians) to meat eaters. For example, in the single largest study, which was conducted in 3277 UK subjects, it was found that TC and

LDL-C were higher in meat eaters than vegans, with vegetarians and fish eaters having intermediate and similar values [25].

Clinical studies

The review of Ferdowsian also included data from RCTs that specifically measured the effect of plant-based eating on blood lipids. Of these there are two good quality studies, the first of which evaluated two low fat diets. In this study the diets were designed to be identical in total fat, SFA, protein, CHO and cholesterol content, consistent with the former American Heart Association Step I guidelines of 30 En% or less from total fat and 10 En% or less from SFA. The control "Low-Fat" diet contained foods relatively typical of a low-fat US diet, whereas the "Low-Fat Plus" diet incorporated considerably more vegetables, legumes and whole grains [26]. The study was of 4 weeks duration and included 120 adults aged 30 to 65 years of age, with initial LDL-C concentrations of 3.3 to 4.8 mmol/L (mildly elevated), who were either normal weight or overweight, but not obese. Blood lipid concentrations were measured at baseline and at the end of the study. A 7-day menu cycle was developed for the participants who consumed lunch or dinner on site at the University of Stanford's Research Center dining facility. Those in the Low-Fat Plus group, on average, consumed per day more fruit (0.8 servings), vegetables (7.6 servings), beans, legumes, nuts and seeds (3.7 servings) and whole grains (3.5 servings) and less refined grains (2.5 servings), dairy products (0.1 servings) and meat, fish and eggs (1.1 servings).

The 4-week changes in blood lipids from baseline are given in Figure 3.3. The reduction in TC and LDL-C were significantly greater in the Low-Fat Plus diet ($P<0.02$); respective values for the Low-Fat and Low-Fat Plus were -0.24 mmol/L and -0.46 mmol/L for TC and -0.18 mmol/L and -0.36 mmol/L for LDL-C. The percentage reduction in blood lipids in the Low-Fat Plus diet compared to baseline was 8% and 9% respectively for TC and LDL-C. The effects on HDL-C and TAG were similar between the groups and little changed compared to baseline.

The authors concluded that emphasis on including nutrient-dense plant-based foods, consistent with recently revised national guidelines, increased the total and LDL-C–lowering effect of a low-fat diet.

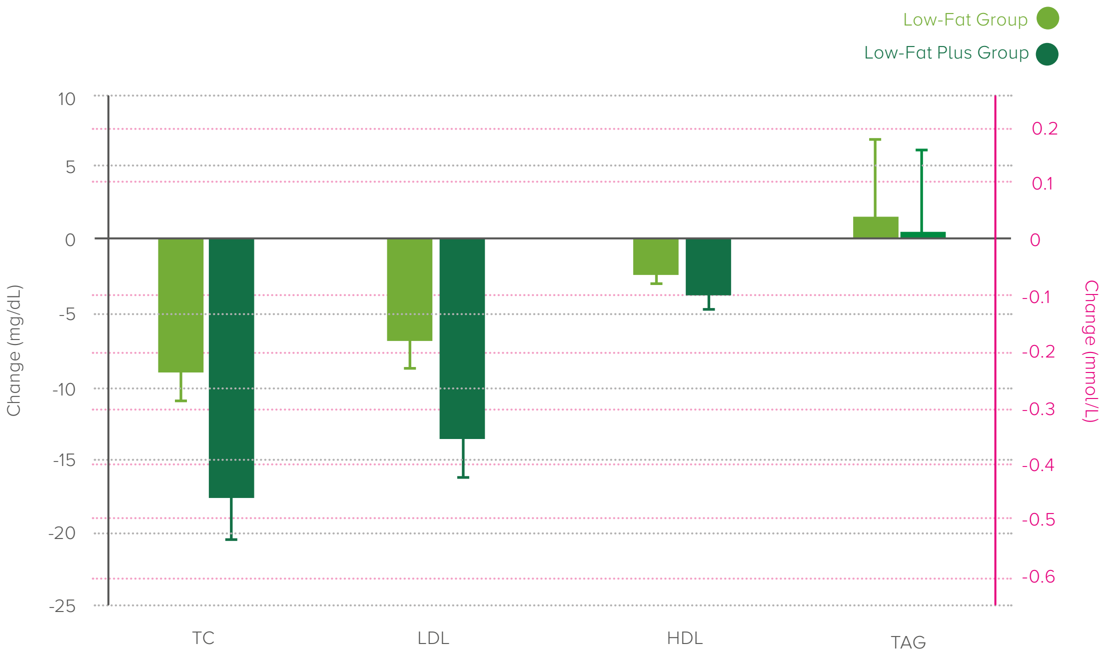


Figure 3.3: The mean change in plasma lipids after following a low fat diet

Source: Gardner [26]

In the second RCT, the Optimal Macronutrient Intake Trial to Prevent Heart Disease (Omni-Heart) was a 3-period crossover design [27]. Two clinical centres (Johns Hopkins Medical Institutions and Brigham and Women's Hospital) conducted the trial. Three healthful diets, each with reduced SFA intake (6 En%), were evaluated with respect to their effect on BP and blood lipids. The 3 dietary groups were:

- Rich in carbohydrates (CHO), similar to the DASH (Dietary Approaches to Stop Hypertension) diet [28], which emphasizes fruits, vegetables and low fat dairy products; total fat 27 En%, protein 15 En%, CHO 58 En%;
- Rich in protein, about half of which was from plant sources (PR); total fat 27 En%, protein 25 En% (half of which was from plant protein), carbohydrate 48 En%;
- Rich in UFA, predominantly MUFA; total fat 37 En% (21 En% MUFA and 10 En% PUFA), protein 15 En%, CHO 48 En%.

As this was crossover in design, one third of the subjects consumed one of the 3 diets for 6 wks, followed by a 2 wk wash-out period, before crossing over to one of the other 3 diets for 6 wks. The final diet was consumed after another 2 wk wash-out period. The 164 participants were generally healthy men and women, aged 30 years and older, either prehypertensive (SBP, 120-139 mmHg or DBP, 80-89 mmHg) or stage 1 hypertensives (SBP, 140-159 mmHg or DBP, 90-99 mmHg). Diet was well-controlled with a 7-day menu cycle developed for each diet. Throughout the study participants were provided all of their food which was prepared in research kitchens. On each weekday, participants ate their main meal on-site.

Food group targets were also established for each treatment: fruit, vegetables, legumes, nuts, seeds, other vegetable proteins and lean poultry intake were increased in the PR group, with a focus on low fat dairy products.

Data relating to blood lipids and BP was established during the run-in period, at baseline and during the treatment phase at wks 4-6. The results for blood lipids compared to baseline are shown below in Figures 3.4.

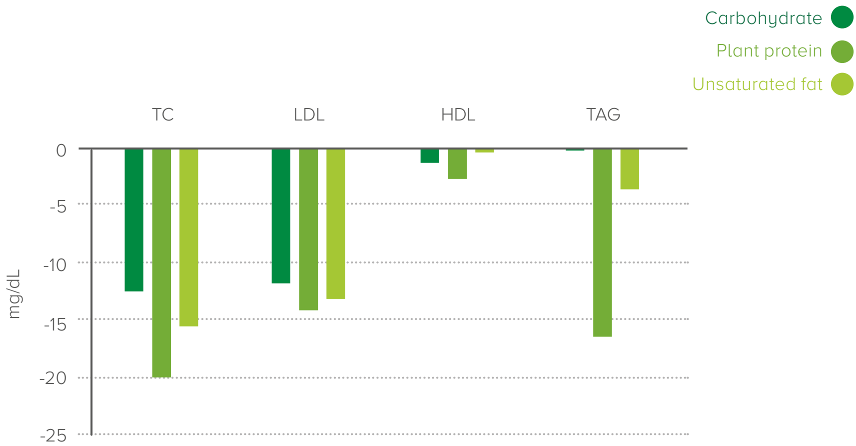


Figure 3.4: The mean change in plasma lipids after following a low fat diet rich in carbohydrate, plant protein or unsaturated fat

Source: Data extracted from Appel [27]

In all groups both TC and LDL-C was reduced significantly; in the PR group the TC reduction was significantly greater than the CHO and UFA groups (both $P<0.001$) and represented a reduction of 10% compared to baseline. The reductions for CHO and UFA groups were lower at 6% and 8% respectively. Furthermore, there was a significantly greater reduction in LDL-C in the PR group than in the CHO group ($P=0.01$) and this represented a reduction compared to baseline of 15%. There was little effect on HDL. In contrast, there was a marked reduction in TAG in the PR and UFA groups; this reduction in TAG was significantly greater in the PR group compared to the CHO group ($P<0.001$) and the UFA group ($P=0.03$).

Community-based interventions

There are four recently reported community-based interventions that have studied the effects of consuming a plant-based diet on a range of CV risk factors [29-32]. The effects on LDL-C and BP reported in these studies are summarized in Table 3.1.

It can be seen that **in all cases significant reductions in LDL-C were reported; typically these were between 7-13% compared to pre-intervention values**.

When the effects on cholesterol-modification of these community-based studies are reviewed alongside the two RCTs it can be seen that in all cases there is a reduction in LDL-C of between 7-15% compared to baseline. This is a significant benefit to heart health. There is a small effect on HDL, which is marginally lower compared to baseline. However, recently it has been suggested that the addition of MUFA to plant-based diets can help to ameliorate the negative reduction in HDL-C [33]. It has been proposed that receptors that are transcriptional regulators of lipid metabolism are activated by UFA and that the inclusion of MUFA in the diet not only results in a reduction in LDL-C concentration and enhanced clearance rate [34, 35], but, more importantly, a reduction in the proportion of the more harmful small dense LDL [35].

Plant components reported to reduce CV risk factors

There are a number of plant components that, when included in the diet reduce LDL-C, enhance HDL-C or have a beneficial effect of blood lipids.

Study description [reference]	Comparison	Study length	Subjects N	Net change LDL-C (mmol/L) or % reduction	Significance P	Net change in SBP / DBP (mmHg) or % reduction	Significance P
GEICO study, low-fat plant-based diet in a corporate setting [30]	Low fat v plant-based	18 wk	All 291	-0.19 6.7%	<0.01 NA		
			Completers 211	-0.32 11.1%	<0.001 NA		
Impact on CV Risk in Obese Children with hyper-cholesterolemia and their parents [31]	AHA low fat v plant-based	4 wk	Children parent pairs 30				
			Parents	-0.70*	<0.05	-7.96 SBP NA DBP	<0.05 <0.001
			Children	-0.34*	<0.05	-6.43 SBP NA DBP	<0.05 <0.001
Complete Health Improvement Program (CHIP) lifestyle intervention in Canadian Seventh-day Adventists [29]	Self selected intervention of plant-based eating	30 d	1003	NA 12.9%*	NA <0.001	NA -5.2% SBP NA -5.2% DBP	NA <0.001 NA <0.001
Comprehensive lifestyle intervention including diet, exercise, stress management, & group support [32]	Low-fat, whole-food, plant-based diet	3 mo	131 56 with CHD 75 high risk CHD	-0.56 -21.4%	<0.001 NA	-11 SBP -5 DBP	<0.001 <0.001

*Abbreviation: NA not available. * Difference compared to baseline, not net change in LDL-C*

Table 3.1: Community-based studies evaluating the effect of introducing plant-based eating

Table 3.2 summarizes the likely reduction in LDL-C following the inclusion of each of these components in a diet. **Typically food components reduce LDL-C by 3-5%, with higher reductions for the plant stanols and sterol (~9%)**.

Unsaturated Fatty Acids

The role that UFA can play in modifying blood lipids is largely provided by a meta-analysis of 60 RCTs [52]. It is suggested that the replacement of

Food / component	Amount	Effect on reducing LDL	Approx. estimated reduction in LDL when used at typical inclusion rate in «portfolio» diet		Reference
	g/day	%	%	mmol/L	
Replacing saturated fat	<7 En%	10.0	4.0	0.15	[36]
Plant sterol	1.5 – 1.9	8.5	8.7	0.35	[37]
Plant stanols	2.0 – 2.4	8.9			[37]
Soya protein	25	4.5 – 7.0	5.5	0.22	[10, 38-46]
Soluble fibre:					
Mixed viscous fibres	Up to 10	1.3% / g	8.0	0.35 - 0.50	[47-49]
Oats/barley beta glucan	3	3.5 – 5.0	5.0	0.20	[47]
Psyllium	9-10	0.72% / g	7.2	0.30	[36]
Tree nuts:			7.0	0.29	[50]
Almonds	25 – 168	3.75	3.75	0.15	[51]
Inclusion of MUFA	10	5.8	7.5	0.32	[52]

Table 3.2: The relative contribution that specific foods can make to blood lipid modification

Source: After Harland 2012 [53]

1% of energy from carbohydrates by PUFA, mainly as LA, reduced LDL-C levels by 0.02 mmol/l and its replacement with MUFA reduced LDL-C by 0.01 mmol/L. The estimated change in the total to HDL-cholesterol ratio was -0.032. While LA was the main source of PUFA in the studies included in the meta-analysis, smaller amounts of ALA were also used in some of the studies. Two studies of six weeks duration, one parallel design RCT conducted with an ALA-rich diet (N=29) and a second crossover design study conducted with low erucic acid rapeseed oil (N=40), demonstrate the effectiveness of ALA in this respect [54, 55].

The role of UFA in CV health is supported by the most extensive scientific consultation in recent times produced by the FAO [56]. This report on fat, fatty acids and health concluded that there is convincing evidence that replacing SFA with PUFA decreases the risk of CHD and that replacing SFA (C12:0–C16:0) with MUFA reduces LDL-C concentration and total/HDL-C ratio. In addition, replacing carbohydrates with MUFA increases HDL-C concentrations. There was possible evidence that replacing carbohydrates with MUFA improves insulin sensitivity and insufficient evidence for relationships of MUFA consumption with chronic disease end points such as CHD [56]. While there may have been controversy in the media relating to the merits of SFA reduction, in reality there has been no new original scientific trials to justify this challenge, simply a re-analysis of older data, the relevance of which to today's society is questionable.

Olive oil is a rich source of MUFA, which conventionally has been considered the beneficial component. Latterly, it has been suggested that it may be some other component that is responsible for the reported beneficial effects of Mediterranean diets, for example, the olive oil polyphenols have been found to contribute to the protection of blood lipids from oxidative stress [57]. It has also been suggested that tree nuts reduce LDL-C by an amount greater than can be explained by their fatty acid composition alone [50].

Plant Stanols/Sterols

There is extensive literature in which the effects of plant stanols/sterols on blood lipids have been evaluated. Plant sterols and stanols are naturally occurring compounds, structurally similar to cholesterol with a cellular function similar to human cholesterol. There are in excess of 200 clinical studies that have evaluated the effects of these components on blood lipids, primarily in adults with normal or elevated plasma cholesterol at baseline. There are a number of meta-analyses that have been conducted on the RCT using marginally different inclusion criteria, see for instance [58, 59] and two more recent meta-analyses [16, 17]. In 2009 the EFSA assessed the scientific evidence available up to this date and a health claim has been granted in Europe. The following statement was devised to be reflective of the evidence: "Plant stanols/sterols have been shown to lower/reduce blood cholesterol." On the basis of evidence supplied it was estimated that 1.5-1.9 g/d plant sterols and 2.0-2.4 g/d plant stanols per day reduce LDL-C by an average of 8.5% and 8.9%, respectively [37]. Typically for an intake of 1.5-2.4 g/d plant sterols/stanols a reduction in LDL-C of between 7 and 10.5% can be expected.

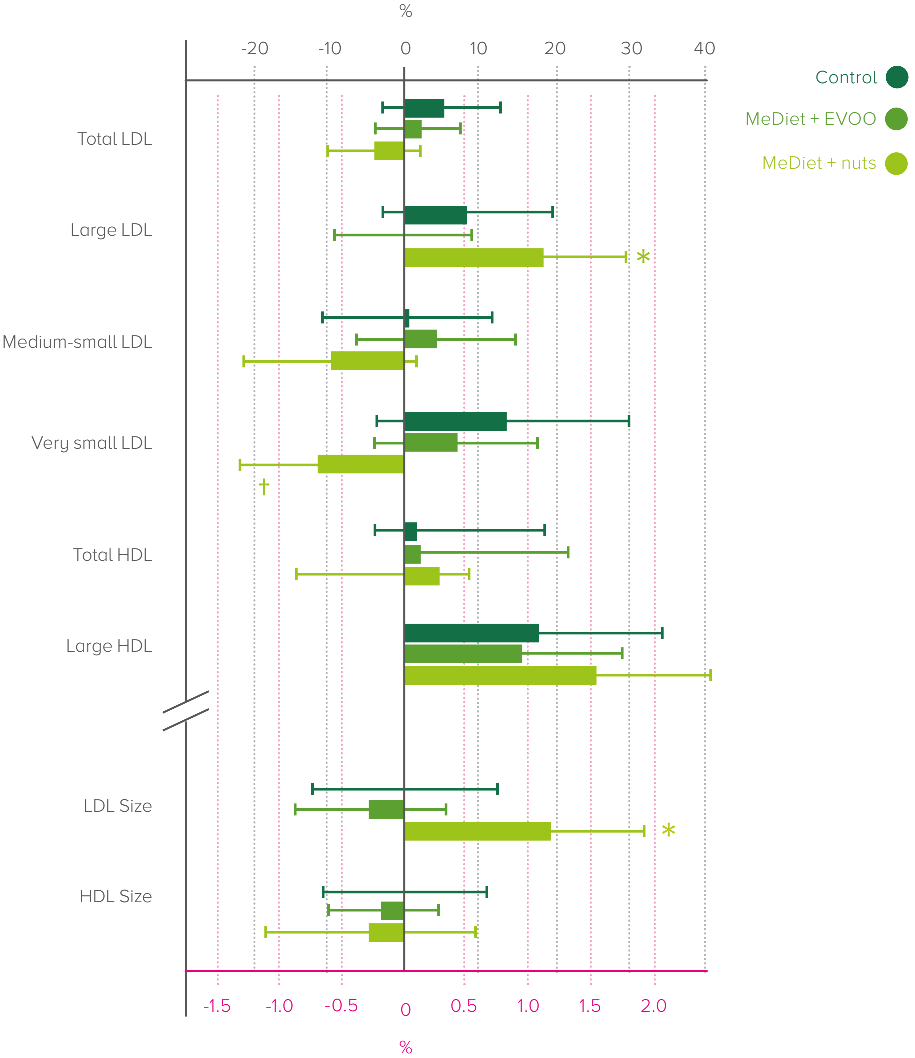
Nuts

Part of this greater benefit from consuming nuts may be due to their effect on lipoprotein subfractions, which are shifted to a less atherogenic pattern [60, 61]. In a PREDIMED sub-cohort of 169 subjects, a Mediterranean diet supplemented with nuts was compared to a similar diet supplemented with olive oil. The nut-supplemented diet showed significant reductions from baseline of concentrations of medium-small (-27 nmol/L) and very small LDL (-111 nmol/L) and an increase of large LDL concentrations (54 nmol/L), with a net increase of 0.2 nmol/L in LDL size ($P<0.05$) when compared to control diet [61] (Figure 3.5). Both Mediterranean diets (with added olive oil or nuts) increased large HDL concentrations (0.6 muM and 1.0 muM respectively).

In addition to their effect on CV risk factors, a recent systematic review of prospective studies explored the effects of nut consumption on all-cause and CVD mortality, aiming to quantify the size effect through a meta-analysis [62]. Epidemiological studies published up to June 2014 were reviewed and seven studies for all-cause mortality and six studies for CVD mortality identified, representing a total of 354,933 participants, 44,636 cumulative incident deaths, and 3,746,534 cumulative person-years. Nut consumption was associated with some baseline characteristics such as lower BMI and smoking status, as well as increased intakes of fruit, vegetables and alcohol. After adjustment for confounding factors the consumption of 1 serving of nuts/wk was associated with significant reductions in all-cause mortality or CV mortality of 4 and 7% respectively, and 1 serving of nuts/day was associated with significant reductions in all-cause mortality or CV mortality of 27% and 39% respectively. Effects were primarily driven by decreased CAD deaths.

Legumes

In recent times there has been a growing interest in the role legumes may play in cholesterol management. Two meta-analyses were published evaluating the effect of legumes (peas and beans) on heart health. The first analysis quantified associations of nut and legume consumption with heart disease, stroke and diabetes [63]. Legume consumption was inversely associated with heart disease in 5 studies; the relative risk per 4 weekly



MeDiet: Mediterranean diet; EVOO; extra-virgin olive oil; MeDiet + Nuts; Mediterranean diet with Nuts

**; † P<0.05 compared to the control group*

Figure 3.5: Mean changes (%) from baseline in selected LDL and HDL subfractions. Values are means (95% CI)

Source: Damasceno 2013 [61]

100 g servings was 0.86, equivalent to a risk reduction of 14%. There was no significant effect on stroke or diabetes. In a second meta-analysis where clinical data on dried pulses (beans, chickpeas, lentils and peas) were studied, 26 trials including 1037 subjects with a median dose of 130 g/d (about 1 serving daily), significantly lowered LDL-C compared with the control diets (mean difference -0.17 mmol/L equivalent to around 5% reduction) [64]. A further review identified dried beans reduced LDL-C [65]. Research with the legume, soya, has shown its inclusion in the diet may extend beyond LDL-C and TAG reduction, and the maintenance of HDL-C, as studies have shown that it, too, can lead to a beneficial increase LDL-particle size [66, 67].

Fibre

The classic meta-analysis of 67 RCTs that included a source of soluble fibre (oats, pectin, guar gum and psyllium) and measured the effect on blood lipids at range of 2-10 g soluble fibre/d, indicated a reduction in total-C or LDL-C of -0.045 (95 %CI -0.054, -0.035) mmol/L/g soluble fibre and -0.057 (95 %CI -0.070, -0.044) mmol/L/g soluble fibre, respectively [47]. The soluble fibre component of importance for cholesterol-reduction in oats and barley has been identified as the beta-glucans. Sub-analyses of the data, by source of soluble fibre, indicated that a dose-response relationship existed between oat soluble fibre intake and the degree of cholesterol-reduction. It could be calculated that 3 g soluble fibre from oats (3 servings of oatmeal, 28 g each) could decrease total-C and LDL-C by approx. 0.13 mmol/L [47]. In recent times, a further meta-analysis was conducted as part of the health claim application for oats [48]. In this meta-analysis data were pooled from 18 RCTs; the overall effect was a reduction of -0.34 mmol/L and -0.28 mmol/L (both $P<0.001$) for total- and LDL-C respectively. Similar effects on LDL-C are reported in meta-analyses of RCTs conducted with barley beta-glucan [68, 69].

Cereals, particularly wholegrain cereals, have been associated with a lower incidence of CHD or coronary death. The evidence is largely provided by epidemiological studies, and the mechanisms of action uncertain. Consequently it is not clear whether cholesterol-reduction is of significance, over and above the contribution made by fibre components of whole grains [70]. In a meta-analysis of seven prospective cohort studies with quantitative measures of dietary whole grains and clinical CV outcomes it was shown that a greater whole grain intake (pooled average 2.5 servings/d vs 0.2 servings/d) was associated with a 21% lower risk of CVD events; (OR, 0.79) [71].

In the main it is assumed that the effect on LDL-C of adding multiple plant derived components are additive. In a recent review of the evidence with studies including ingredient combinations, it was found that if compliance is good, to a greater or lesser extent combinations are additive, but not all ingredients combinations are completely so [53]. Nevertheless, for many people in Western Society reduction of SFA intake remains a prime nutritional objective; the intrinsic low SFA content of plant-based eating and its preferred fatty acid profile, rich in UFA makes it a good platform to achieve this objective.

Portfolio diets and blood lipids

A further number of studies that will be briefly referred to are those conducted by Professor Jenkins and colleagues from the University of Toronto, Canada. They developed the concept of a "portfolio diet". Portfolio diets are low fat diets based on plant foods, specifically those plant foods or ingredients proven to reduce blood cholesterol.

Overall there are approximately 12 "portfolio studies" reporting 725 subject values; half of whom are men and half women, mostly postmenopausal. Note there is some overlap between the studies, and a short-term clinical study may precede a longer community-based study. Study duration is from 4-80 wks. Studies have been conducted in both a metabolic setting (short term 4-6 wks duration) with virtually all foods supplied, and in community -based studies of 6-12 months duration, where free-living subjects are given dietary advice to help them adopt a portfolio diet. The studies published prior to 2012 were recently reviewed and summarized, see [53].

Typically the portfolio diets contain per 1000 kcal (4.18MJ): 1 g plant stanols or sterols, 16-23 g soya protein, 8-10 g viscous fibre generally from oats, barley, pysllium and okra, and 16-23 g nuts usually almonds or a combination of tree-nuts and peanuts. Usual total energy intake is around 2500 kcal/d except in weight loss studies, where it is 2000 kcal/d [72, 73]. Animal protein foods, particularly sources of SFA, are largely replaced in these diets by plant proteins from soya, other legumes and cereals. Canola and other vegetable oils provide UFA, thereby improving the fat quality of the diet. A single study has evaluated the effect of adding MUFA to this combination of foods [33]. The diets are generally low or very low in SFA and the emphasis is on plant foods, with many of the interventions being either vegan or vegetarian.

The portfolio studies are summarized in Table 3.3.

From Table 3.3 it can be seen that the cholesterol reduction reported in relatively short-term studies is usually highly statistically significant ($P<0.001$), with LDL-C being approximately 20-35% lower than the control diets [24]. Of interest is a long term portfolio study conducted for a year in 66 free living volunteers in Toronto, Canada [77]. On average, over the period of a year, volunteers reduced LDL-C by around 13%. This is not dissimilar to the recently reported community-based interventions shown in Table 3.1. Where compliance to the portfolio diet is better, the extent of cholesterol reduction reported is greater. In around 30% of motivated participants, LDL-C concentrations were lowered by more than 20%. This was not significantly different from their response to a first-generation statin taken under metabolically controlled conditions [77].

Effectiveness of combinations of plant-based components on blood cholesterol

The wholesale dietary changes required by the portfolio diet are not for everyone; many people would find it easy to change only one or two components in their diet, but not more. A review of the effectiveness of one or two plant food introductions into the diet, e.g. the inclusion of oats, soya protein, nuts, plant stanols and sterols, replacing SFA with UFA and viscous fibres, has recently been conducted [53]. Findings from this review suggest that when each of the plant components is included in the diet as the sole dietary change, the reduction in LDL-C is approx. 3-5%, see also Table 3.2.

When two or more of the plant components are given together, the effect is generally additive to some degree. But the extent to which these reported reductions in LDL-C are truly additive is unclear. This is because the avail-

Study description [reference]	Study length Design	Treatment N	% (net) Redn. LDL	Significance P	Total: HDL ratio	Significance P
Modified portfolio diabetics with CAD, 2014 [74]	4 wk IT	30 27M/3F	19	0.001	NA	NA
Eco-Atkins wt loss over-weight/ hyperlipidaemics, 2011 [73]	6 mo RCT	39 15M/24F	9	0.001	10.0	0.001
Portfolio + MUFA, 2010 [33] Comparison of high v low MUFA	4 wk RP	24 17M/7F	22* 1.1	NA NS	NA 5.4	0.03
Portfolio 2 levels advice, 2009 [75]	6 mo RCP	351 137M/214PF	15	≤0.05	7.8	0.006
Eco-Atkins wt loss over-weight / hyperlipidaemics, 2009 [72]	1 mo RCP	44 18M/26PF	7	0.002	5.6	0.03
Portfolio, effect of eliminating component, 2008 without plant sterol for weeks 52-62 [76]	80 wk RP	42 19M/23PF	15** 9	<0.001 <0.001	12.3 8.8	0.001 <0.001
Portfolio free-living, 2006 [77]	1 yr IT	66 31M/35PF	14	<0.0001	12.6	<0.0001
Portfolio v statin, 2005 [78]	4 wk RCX	34 20M/14PF	20	<0.001	17.0	<0.001
Portfolio, 2004 [79]	4 wk IT	12 6M/6PF	30	<0.0001	NA	NA
Portfolio v statin, 2003 [80]	1 mo RCP	46 25M/21PF	21	<0.005	17.1	<0.005
Portfolio, 2003 [81]	4 wk RCP	24 16M/9PF	23	<0.001	20.8	<0.001
Portfolio v statin, 2002 [82]	1 mo IT	13 7M/6PF	29	<0.05	20.9	<0.05

Abbreviations: IT intervention trial; RP randomized parallel trial; RCX randomized crossover study; RCP randomized controlled parallel study; M male; F female; PF post menopausal female; NS non-significant; NA not available;

** difference compared to baseline; **Plant sterols throughout study period.*

Table 3.3: Summary of the "portfolio diet" studies conducted by Professor Jenkins & colleagues

Source: After Harland 2012 [53]

able studies are of variable quality, relatively small size and limited duration. However, in practical situations reductions in LDL-C of 10-15% have been achieved in studies of 4-12 wks duration by both soya protein/plant sterol and viscous fibre/soya protein combinations [83-85]. This represents a significant reduction in coronary risk to those otherwise healthy people with mildly elevated cholesterol.

Studies evaluating effect on blood pressure

There are fewer studies investigating the association between BP and plant-based eating regimes. The DASH studies have reported reductions in BP. These studies evaluated the effect of diets rich in vegetables, fruits and low-fat dairy products in subjects with or without hypertension. For example, a DASH diet with a low sodium intake resulted in a mean SBP that was 7.1 mmHg lower in participants without hypertension, and 11.5 mmHg lower in participants with hypertension [28].

A number of the community-based studies summarized in Table 3.1 also measured BP and in these cases there was a statistically significant reduction in BP. However, as weight loss occurred in many of these studies care needs to be taken when interpreting this data.

The Omni-Heart study mentioned previously also measured BP [27]; these results are shown in Figure 3.6. From this data it can be seen that BP, both SBP and DBP, were reduced in all groups compared to baseline. There was a greater reduction in SBP and DBP in the plant protein group compared to the CHO carbohydrate group ($P=0.002$ and $P<0.001$ respectively), but they were comparable to those in the UFA group. The average reduction in SBP and DBP in the plant protein group compared to baseline was 7% in both cases. The extent of BP reduction was greater in those suffering from mild hypertension than in the prehypertensive.

Volunteers undertaking portfolio diet studies have also had their BP determined. In the long term portfolio study discussed previously, the corresponding reductions from baseline in SBP and DBP at 1 yr in 66 subjects were -4.2 mmHg ($P=0.002$) and -2.3 mmHg ($P=0.001$), respectively [86]. However, in the portfolio studies of shorter duration the changes in blood pressure are modest, with some studies reporting a significant reduction

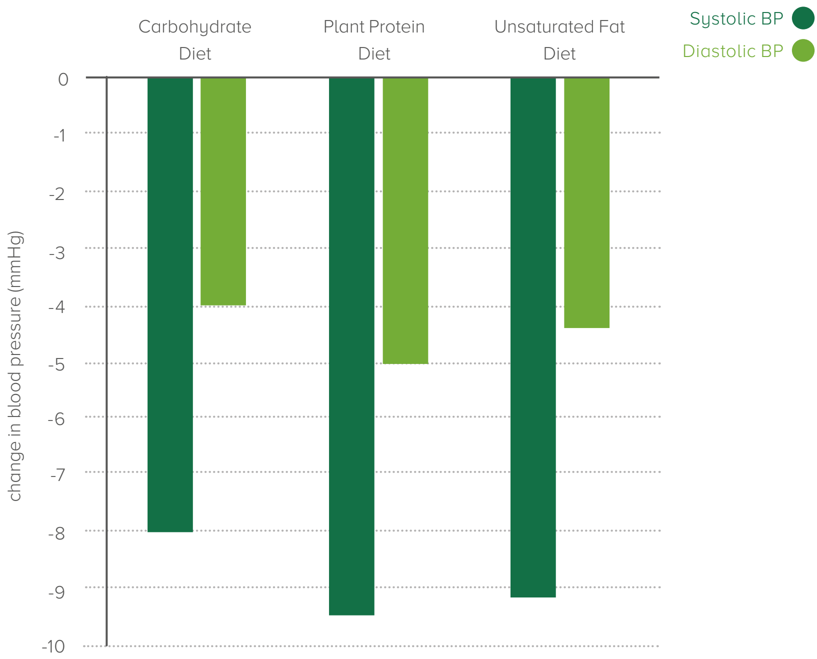


Figure 3.6: The mean change in blood pressure after following a low fat diet rich in carbohydrate, plant protein or unsaturated fat

Source: Data extracted from Appel [27]

and others reporting no change. In the case of DBP this difference may be related to a lack of an effect on bodyweight, as weight loss was significantly associated with DBP in the long-term study.

Plant components reported to reduce blood pressure

Pulses

A meta-analysis pooled data from eight trials (554 participants with and without hypertension) where dietary pulses were exchanged isocalorically for other foods to study the effect on BP [87]. The pooled data showed that including pulses significantly lowered SBP by 2.25 mmHg (P=0.03) and DBP non-significantly by 0.71 mmHg [87]. The consumption of legumes (4 servings/wk) within a hypocaloric diet not only resulted in improvements in BP and blood lipids, but also reduced pro-inflammatory markers such as CRP and complement C3 (C3), in 30 overweight/obese subjects [88]. In a meta-analysis of studies conducted with a specific legume, soya protein, data from 27 RCT were pooled and showed a mean decrease of 2.21 mmHg (P=0.02) for SBP and 1.44 mmHg (P=0.01) for DBP [89]. Reductions were related to pre-treatment BP levels of subjects and the type of control diet used as comparison.

Nuts

A systematic review and meta-analysis of RCTs was used to estimate the effect of nut consumption on BP [90]. Studies conducted up to October 2013, that reported the effect of consuming single or mixed nuts (including walnuts, almonds, pistachios, cashews, hazelnuts, macadamia nuts, pecans, peanuts, and soya nuts) on SBP or DBP as primary or secondary outcomes in adult populations, were retained for further analyses. Twenty-one RCTs met the inclusion criteria, and after pooling the data the primary findings were that nut consumption leads to a significant reduction in SBP in participants without T2D (mean difference, -1.29, P=0.02) but not in the total population. Subgroup analyses of different nut types suggest that pistachios, but not other nuts, significantly reduce SBP (mean difference, -1.82, P=0.002). Mixed nuts and pistachios have a significant reducing effect on DBP; mean difference -1.19, (P=0.04) and -0.80, (P=0.01), respectively.

Oils

In a recent double-blinded crossover design RCT a number of different treatment oils (60 g/3000 kcal) were accessed over a 4-wk period. Of these, a high-oleic acid canola oil with docosahexaenoic acid (CanolaDHA; omega-9 and omega-3 rich) proved to have the greatest effect on a range of cardiovascular markers [91]. Systolic BP was reduced by 3.3% ± 0.8% compared to baseline (P<0.001) and significantly reduced compared to other diets (P<0.05). CanolaDHA was the only diet that increased HDL-C from baseline (3.5% ± 1.8%; P<0.05) and produced the greatest reduction in TAG (-20.7% ± 3.8%; P<0.001). The calculated reductions in Framingham 10-yr CHD risk scores (FRS) from baseline were greatest after CanolaDHA at -19.0% (P<0.001).

Overall it appears there may be a small beneficial effect on BP from the inclusion of plant foods in the diet; at this stage the information is most convincing for plant proteins (legumes and nuts) and UFA, but the data does not allow specific quantification of the benefit.

Intervention studies on other markers of heart disease

Plant-based eating and lifestyle changes have been shown to play a role in the regression of atherosclerosis, improvement of CV risk profiles, and decreased cardiac events in subjects suffering from heart disease [92]. The Multisite Cardiac Lifestyle Intervention Program measured endothelial function and inflammatory markers of atherosclerosis in 27 volunteers with CAD and/or risk factors for CAD. The volunteers were asked to make changes in their diet to achieve a plant-based diet with 10% of calories from fat, participate in moderate exercise (3 hrs/wk), and practice stress management (1 hr/d). At baseline endothelium-dependent brachial artery flow-mediated dilatation (FMD) was performed in the control and intervention groups. After 12 wks FMD had improved in the experimental group from a baseline of 4.23mm to 4.65mm, compared to the control group where it decreased from 4.62mm to 4.48mm ($P<0.0001$). Also, significant decreases occurred in C-reactive protein (from 2.07 to 1.6 mg/L, $P=0.03$) and interleukin-6 (from 2.52 to 1.23 pg/mL, $P=0.02$) after 12 wks. The authors concluded that the significant improvement in FMD, C-reactive protein, and interleukin-6 in the experimental group suggests one or more potential mechanisms underlying the clinical CV benefits of plant-based eating.

A Bayesian meta-analysis was used to study the effect of isoflavone-containing soya products on endothelial function as measured by FMD [93]. Data from 17 RCTs were pooled and the mean absolute change in FMD (95% Bayesian CI) for isoflavone-containing soya interventions was 1.15%. When the effects of separate interventions were considered, the treatment effect for isolated isoflavones was 1.98% compared to 0.72% for isoflavone-containing soya protein. The authors concluded that isoflavones in soya can modestly, but significantly, improve endothelial function as measured by FMD, and may beneficially influence vascular health [93].

The role of the portfolio diet in secondary prevention was investigated in 30 T2D patients with CAD, 6-wks post bypass surgery [74]. Twenty-three patients received dietary counselling on a modified portfolio diet and seven patients with no diet therapy served as time controls. Over a 4-wk period, LDL-C levels fell in the intervention group, see Table 3.3, and other CV risk factors also reduced. Homocysteine levels dropped significantly, 10.1

umol/L compared to 7.9 umol/L in the control group, (P=0.006), while FMD increased significantly in treated patients from 3.8 to 6.5 umol/L (P=0.004) and remained constant in controls.

Overview and conclusions

Both plant-based foods and eating patterns tend to be lower in fat, specifically SFA, and have a better MUFA:SFA or UFA:SFA ratio. This nutrient profile has been associated with lower blood LDL-C and recent evidence seems to suggest that the inclusion of MUFA has a beneficial effect on HDL-C levels [33]. There is wide acceptance among scientists that one of the important ways plant-based eating improves heart health is by its action on blood lipids [53]. Professor Jenkins and colleagues recently explored the extent to which the displacement of fatty foods from the diet with a plant food (soya) was responsible for the cholesterol lowering properties of soya foods. Using data from 11 RCTs, it was calculated that when comparable amounts of animal proteins were replaced with soya proteins there would be **a 3.6-6.0% reduction in LDL-C due to the displacement of SFA and cholesterol from the diet**. This he called the extrinsic effect. Overall the total reported **LDL-C reductions for soya protein have been estimated to be between 7.9-10.3%** and the difference between this total and the extrinsic effect, has been called the intrinsic effect [45]. It is highly likely that plant foods as a whole have a similar extrinsic effect on the diet and part of their beneficial effect on health is related to an overall healthier nutrient composition. However, there are intrinsic benefits of plant foods, too. Some of the intrinsic effects may be the result of direct blood lipid-lowering effects such as seen with soya, almonds, oats, and soluble fibres. Evidence for a role of improved blood lipid profile is also provided by observational studies with vegetarians, or those following a prudent dietary regime [24], and evidence of reduced incidence of CHD from observational studies with vegetarians or a Mediterranean diet.

The significance of reducing blood cholesterol has been expressed in public health terms by the WHO; they suggested that each 1% reduction in LDL-C in the population could lead to a 2%–4% reduction in CVD [94]. From the intervention studies identified, it can be seen that **plant-based eating is associated with a LDL-C reduction of between 7–15%**. Using this data as a basis for calculating CVD-risk reduction, this would be equivalent to a decrease in CVD risk of 14–30%. This extent of risk reduction is confirmed by reference to the observational studies; those following vegetarian or plant-rich prudent eating patterns have been shown to have a lower incidence of cardiovascular death of around 20%.

In addition to the effect on blood lipids, there appears to be some evidence of an effect on BP. Blood pressure reduction is significant for public health, where it has been suggested that a 1% reduction in DBP in the UK population could prevent around 1500 deaths from CHD each year. Currently, however, insufficient evidence exists to quantity a benefit in public health terms of plant-based eating. Nevertheless, **a modest benefit in terms of 3–5% reduction in DBP could have a significant benefit to CV health.** As such, BP normalisation may be another contributing factor to the improved heart health reported in the observational studies. In addition, with plant-based eating vascular benefits may derive from improved health of the epithelium, but further research is required in this area.

Plant foods intrinsically contain many beneficial compounds that, by acting through multiple mechanisms, provide protection against heart disease. Of these, it is likely that the rich supply of antioxidants found in many plant foods is important. Yet there is controversy as to how well the antioxidant properties of foods relate to their ability to have an antioxidant function in the body. However, whether or not plant foods do act as antioxidants, they do seem to have important signalling and regulatory functions that enhance cell function [95]. In addition, polyphenol components such as isoflavones, flavonols and flavones may also inhibit platelet aggregation and reduce inflammation [24, 96].

Plant-based eating is associated with a nutrient rich diet. Of the micronutrients found in plants foods, potassium is important as it tends to displace sodium, which as seen from the DASH diets, is beneficial in BP control [28]. Selenium is also present at good levels in certain plants foods. As well as being a co-factor for enzymes, selenium is strongly associated with antioxidant functions in the cell. Furthermore, plant-based diets tend to be higher in fibre. Both soluble and insoluble fibre result in a lower energy density diet and can improve satiety and enhance the feeling of fullness. Not surprisingly, **plant-based eating is associated with lower body weight and less weight gain over time**. As overweight and obesity are key modifiable risk factors for heart disease, this effect may further contribute to a role in promoting heart health [97].

Take-home messages:

- Heart disease and stroke together are the most important cause of death in Europe.
- Good quality scientific studies demonstrate that plant-based eating is associated with a reduced risk of heart disease.
- Evidence from observational studies indicates that typically the incidence of heart disease is around 20% lower in those following a plant-based eating pattern.
- Plant-based foods and eating patterns are typically low in SFA, high in UFA and fibre and have a better SFA:UFA ratio. This is important in maintaining healthy blood cholesterol levels and subsequently a healthy heart.
- Evidence is accumulating to suggest that BP may also be lower in those following a plant-based eating regime; in addition specific components found intrinsically in plant foods may also work together to bring further heart health benefits.
- Overall, plant-based eating - eating more fruit, vegetables, legumes, whole grains, nuts and seeds - promotes a healthy heart and should be recommended in dietary advice.

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4

Chapter 4

More plant-based eating and weight control

Introduction to Chapter 4, by invited experts Jason Halford, Jayne Pickering and Janice Harland

PROF. JASON HALFORD
Head of Department, Reader in Appetite and Obesity, Institute of Psychology, Health and Society, University of Liverpool (UK)

JAYNE PICKERING
Institute of Psychology, Health and Society, University of Liverpool (UK)

DR. JANICE HARLAND
University of Bath, Spa (UK)

Maintaining a healthy weight is a major public health challenge. The basic concept of energy balance remains important in understanding weight gain, and the causes and consequences of obesity lie within it [1]. If an individual consumes excess energy in relation to their body's needs, they will be in a state of positive energy balance storing excess energy in the form of adipose tissue. However, the energy balance equation is often taken to suggest that "easy" behavioural adjustments in exercise and diet would clearly reverse weight gain. The implication that losing weight or not gaining weight over a lifetime is not a demanding activity sits at odds with personal experience. While the energy balance concept may emphasize the role of behaviour in weight control, it fails to recognize that behaviour results from lifelong learning and habit formation and thus is difficult to change, Secondly, behaviour is shaped by the external environment, and if that environment promotes reduced activity and excessive consumption, individual efforts to control their behaviour will be compromized. Individual behaviour is shaped by biological and psychological factors, which in turn are influenced by the wider physical, food and social environment. If this environment is obesogenic (full of cheap, readily-available, energy dense foods and energy-saving devices such as cars and escalators) then the individual's behaviour change within it is difficult to sustain. The concept of energy balance in its simplest form also fails to consider the dynamic changes in energy demand that result from weight loss; dieting not only requires a quite radical initial reduction in energy intake, but further incremental reductions in energy intake are required if weight loss is to continue.

This chapter reviews the hierarchy of evidence in support of eating more plant-based food to enhance weight control. It summarizes the outcomes from a range of observational studies and randomly controlled intervention studies that have looked at weight loss regimes, energy metabolism and *satiety. In it a persuasive case for the weight management benefits of plant-based eating is made; plant-based eating patterns have been consistently associated with a lower BMI, less weight gain over time and more healthful diets that are higher in fibre and lower in SFA.*

A number of plausible mechanisms have been proposed to explain these benefits which are described in terms of both extrinsic and intrinsic properties of plant-based food and diets. One of the major extrinsic effects of plant-based eating that may be of relevance is the higher fibre content of plant-based diets and their lower energy density (while retaining their nutrient density) [2]. Physical distension of the stomach, along with the early detection and absorption of nutrients, are major components of satiation that generate the negative feedback leading to meal termination (within-meal inhibition). The detection of nutrients has a powerful effect on the passage of food through the gastrointestinal tract and within a meal it delays gastric emptying, thereby prolonging gastric distension. Cognitive factors such as prior expectations and previous experiences also play a significant role. Experiences tell us what is likely to be filling and importantly satisfy hunger and influence our experience of the eating event. Satiety is the end state of satisfaction in which the drive to consume is suppressed after a meal, delaying the onset of the next eating episode (between meal-inhibition). Satiety is generated through the passage of nutrients through the gut, their detection by pre-absorptive chemoreceptors and hormones. The effects of nutrients on gut microbiota and the post-absorptive metabolic effects also appear important in generating and sustaining satiety.

In terms of satiety, food form and structure have a powerful influence on appetite as measured by subsequent ad libitum intake and changes in subjective experience [3]. Protein is generally held to be the most satiating nutrient, followed by carbohydrate and then fat [4]. However, whether there is a difference between plant and animal protein has not been convincingly shown. As many animal protein foods are associated with higher SFA content and, as much of the epidemiological evidence fails to fully correct for this, any differences may be related to SFA intake or energy density of the diet rather than protein source per se. Nevertheless dietary patterns rich in vegetable, nut and fish proteins such as the Mediterranean diet or Adventist vegetarians appear to be associated with better weight management.

The macronutrient hierarchy disguises the great variability of effects within each macronutrient category. For instance, simple carbohydrates have relatively transient effects on appetite compared to more complex forms. Those resistant to digestion, like dietary fibres, may produce sustained reductions in appetite. Fibre is believed to increase satiety through increasing mastication, slowing down gastric emptying and increasing food bulk due to water swelling. Dietary fibre is also a heterogeneous group and despite fibre's role in satiety being widely accepted, systematic examination of the literature demonstrates that only a few fibres affect appetite robustly [5]. Similarly, the effects of fat on appetite vary and much depends on form (triglycerides or free fatty acids), chain length and degree of saturation. Thus the physical and chemical structure of food can produce quite distinct effects on appetite. Understanding these effects can help us understand the potential for foods to moderate hunger and help individuals control their appetite, as well as how certain foods may fail to produce lasting inhibition permitting later overconsumption (inadequate caloric compensation) [1]. In this context it may be more helpful to look at food patterns rather than individual foods per se.

The displacement of both energy and fat (specifically SFA) from predominantly animal-based diet may facilitate weight management through energy-restriction, and the substitution of SFA with plant-derived PUFA and MUFA will also have CV benefits. A further potential advantage of plant-based foods is to prevent the adverse metabolic effects of what could be seen as a "high carbohydrate low fat diet" as the higher intake of sugars are intrinsic to fruits bound up in the matrix of the food, as are the starches in wholegrain and vegetable-rich diets. Given that the effects of sugar on post consumptive appetite tends to be transient, and the satiating properties of fat per se are regarded as relatively weak, adequate caloric compensation for energy dense foods, at least at the next meal, would be less likely with this pattern of eating.

With regard to weight control, two potentially useful weight management tools for those with functional appetite control may be 1) to enhance satiation through reducing the energy density of meals, and 2) to promote post meal satiety through the incorporation of satiating ingredients into the diet. Both of these aspects can be achieved with plant-based eating. However, *whether this approach restores normal appetite control in individuals with weaker regulatory control of appetite and whose intake is driven by the external food environment is less clear.*

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Chapter 4

More plant-based eating and weight control

Challenge of weight management in Europe

Maintaining a healthy weight is a major public health challenge and the lack of weight management frequently catches the headlines, with continuing concern about both the number of people that are heavier than the ideal weight range and the ever increasing number of people who are over-weight. Such is the concern that Health ministers in Europe have signed a European Charter committing to halt the rise in obesity, particularly in children and adolescents by 2015 [1]. Still, the rates of childhood obesity are continuing to rise in many countries, and the number of overweight and obese children aged under five yrs is predicted to increase from more than 42 million in 2013 to 70 million by 2025. In an effort to better inform a

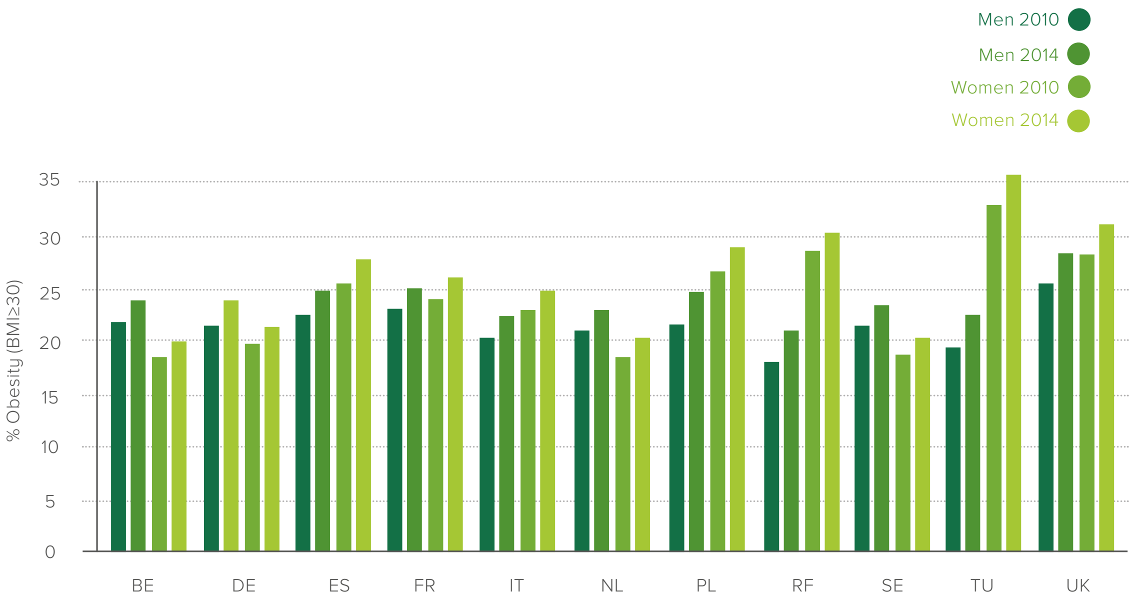

Figure 4.1: Comparable estimates of obesity, (BMI ≥ 30 kg/m²) in adults 18+ years, in 2010 and 2014 in certain European countries

Source: WHO 2014 [3]

comprehensive response to childhood obesity, in 2014 a WHO-led initiative established a Commission on Ending Childhood Obesity. The aim of the Commission is to raise awareness and build momentum for action to address childhood obesity while recognising the need to identify effective approaches for diverse geographical and socioeconomic contexts to respond to the global epidemic of childhood obesity.

Target 7 of the nine voluntary WHO global non-communicable disease targets is to halt the rise of obesity and diabetes; the implementation of the non-communicable disease action plan will be through monitoring and reporting on the attainment of the global targets in 2015-2020. In the WHO European Region, overweight and obesity are recognized as serious public health challenges. The worldwide prevalence of obesity nearly doubled between 1980 and 2008. According to country estimates for 2014, over 50% of both men and women in the WHO European Region were overweight, and approximately 25% of women and 22% of men were obese, see Figure 4.1 [2]. For the majority of European Countries, both the proportion of men and women that are obese and average BMI has continued to increase between 2010 and 2014, and at the present time there is no evidence that the European Charter target to halt the increase by 2015 is likely to be achieved, Figures 4.1 and 4.2.

Overweight affects 30–70% of adults in the countries of the WHO European Region. About 20% of children and adolescents are overweight, and a third of these are obese.

In the WHO
European Region

1 in 3
11-year-olds is

overweight or obese

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The trend in obesity is especially of concern in children and adolescents. Over 60% of children who are overweight before puberty will be overweight in early adulthood. Childhood obesity is strongly associated with risk factors for CVD, T2D, orthopaedic problems, mental disorders, underachievement in school and lower self-esteem. Prevalence of childhood obesity has been growing steadily, see Figure 4.3.

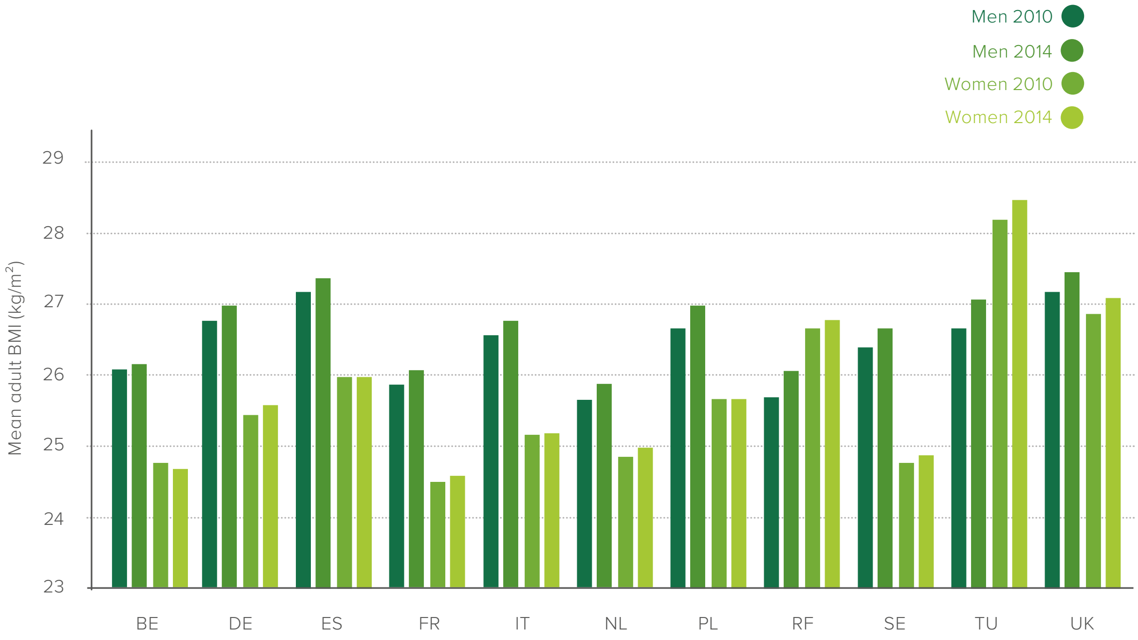
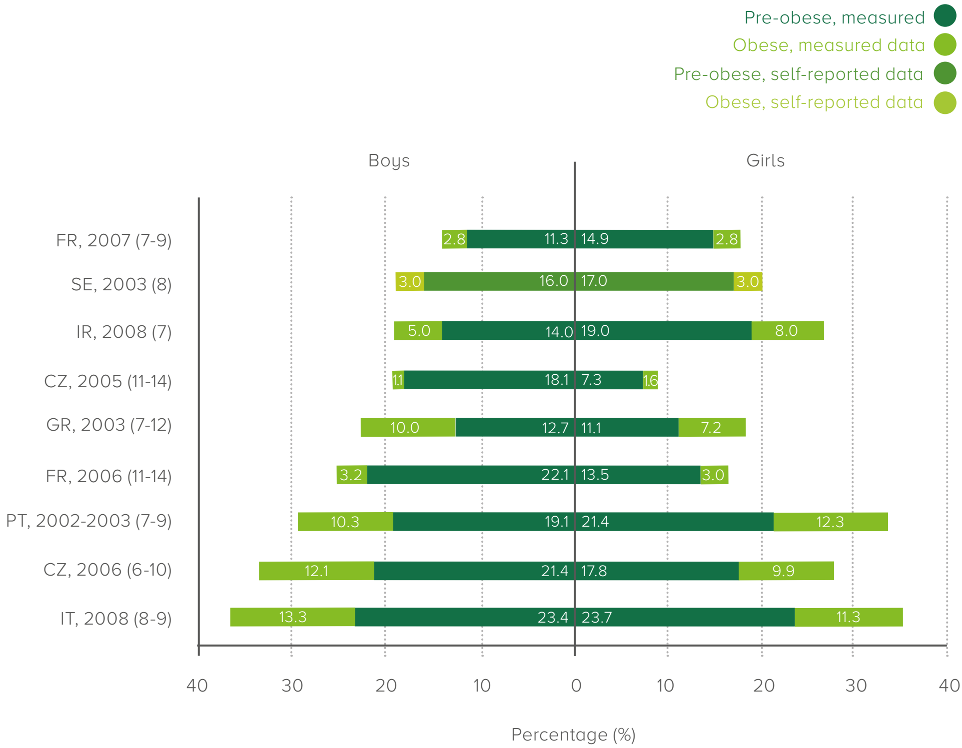


Figure 4.2: Comparable estimates of mean body mass index (kg/m²) in adults 18+ years, in 2010 and 2014 in certain European countries

Source: WHO 2014 [3]

Particularly targeted at children. WHO urge the establishment of strong measures, at a national level, to reduce the overall impact on children of all forms of marketing of foods high in energy, SFA, trans-fats, sugar or salt [4].

It is recognized that obesity is a societal problem caused by both lifestyle factors — including diet, eating habits, levels of physical activity — and genetic factors. Not only is it a health risk in its own right, but it is also associated with an increased risk of diabetes, CVD and certain cancers. Obesity and overweight create an enormous burden of disability and mortality and is estimated to be responsible for 10-15% life-years lost in the EU [4].



Survey characteristics: country, year, age range (year)

Figure 4.3: Prevalence of overweight and obesity among school age children in selected EU countries based on surveys with an ending year of 2003 or later

Source: WHO 2015 [4]

Monitoring healthy weight

A key measure when assessing weight management within a population is to establish the proportion with a healthy weight. The usual measure is BMI; between 18.5 to 24.9 kg/m^2 is normal weight, $\geq$ 25-30 kg/m^2 is overweight and BMI of 30 or more is obese. Waist to hip ratio provides an indication of central adiposity, considered to be a greater risk to health than those who carry their weight around the hips. A better and now frequently used measure of adiposity is waist circumference (WC). It has also been proposed that measuring waist to height ratio, which is simple to measure in practice, may be the most accurate predictor of the risk posed by abdominal obesity [5, 6]. Measuring the weight gain in kg over a relatively long period, say a year or five yrs, allows the identification of eating patterns more conducive to weight maintenance.

Maintaining healthy weight

WHO guidelines for promoting healthy behaviours to encourage, motivate and enable individuals to lose weight, recommend eating more fruit and vegetables, as well as nuts and whole grains [7]. These recommendations are based on a review of the strength of evidence of factors that might promote or protect against weight gain and obesity. Factors were classified as being supported by convincing, probable, possible and insufficient evidence.

The factors for which there was strongest evidence, identified as convincing, were regular physical activity and high intake of dietary fibre, which were protective, whereas sedentary lifestyles and high dietary intake of energy-dense, micronutrient-poor foods increase the risk of weight gain.

The factors that probably related to weight maintenance were home and school environments that support healthy food choices for children and breastfeeding. Heavy marketing of energy-dense foods and fast-food outlets, high intake of sugars-sweetened soft drinks and fruit juices, and in developed countries adverse socioeconomic conditions (especially for women) increased risk.

A number of other factors were identified, but as yet there is either possible or insufficient evidence to draw conclusions. These factors include large portion size, a high proportion of food consumed outside the home and alcohol, which present a risk to weight maintenance. Low GI foods may be protective.

In the UK, the National Institute for Clinical Excellence (NICE) published guidance in November 2014 on the prevention, identification, assessment and management of overweight and obesity in adults and children. The first two NICE dietary guidelines for healthy weight maintenance make the following recommendations [8]:

- **Base meals on starchy foods**: Starchy foods should make up around one third of the foods you eat. Starchy foods include potatoes, cereals, pasta, rice and bread. Choose wholegrain varieties (or eat potatoes with their skins on) when you can: they contain more fibre, and can help you feel full. Try to include at least one starchy food with each main meal. Some people think starchy foods are fattening, but gram for gram the carbohydrate they contain provides fewer than half the calories of fat (4 kcal vs 9 kcal/g).
- **Eat lots of fruit and vegetables**: It is recommended that we eat at least five (400 g) portions of different types of fruit and vegetables a day including fresh, frozen, canned (without added sugar) fruits, vegetables, legumes (e.g. lentils, beans), nuts and whole grains.

Potential benefits of plant-based eating

Plant-based eating tends to lead to intakes that are of lower energy density and higher in fibre and as such follows the WHO dietary recommendations for weight management. Lower energy density is a result of both lower fat, particularly SFA intake, and higher fibre intake. The higher fibre content of plant-based eating patterns may be of direct benefit in weight management, as well as contributing to the lower energy density. Fibre, particularly soluble fibres, have been shown to contribute to feelings of fullness and improved satiety, which may be central to the role they play in weight management [9]. In addition most fibres are low GI, which is important in glucose and particularly insulin management. Moderating insulin production or improving insulin sensitivity will tend to promote less fat storage and hence less obesity [10].

Satiation occurs during an eating episode and brings it to an end. Satiety is the decrease in motivation to eat after consuming food and varies in extent and duration. It may also result in a reduction in subsequent energy intake. Enhancing satiation and satiety derived from foodstuffs is perceived as a means to facilitate weight control [11]. It is also recognized that proteins are more satiating than either CHO or fat [12]. There is little comparative work that has studied the effect of animal vs plant protein on satiety, nevertheless it has been identified that diets that contain whole grains, fruits and vegetables, that are relatively high in fibre and low in energy density, tend to promote satisfaction and satiety [12]. It has also been identified that higher protein diets may spare lean body mass during weight loss, promote weight management, enhance glycaemic regulation, and increase intestinal calcium absorption, which may result in long-term improvements in bone health [13] and there appears no difference between animal and plant proteins in this context [14].

Scientific evidence

Observational studies provide information about dietary patterns and weight maintenance over time or can indicate the proportion of the population that is normal weight, overweight or obese. Short or medium term RCTs and occasionally year-long studies demonstrate the effectiveness of weight loss regimes or maintenance of weight after weight loss. Shorter term RCTs may also be used to try and understand why particular eating patterns are effective in helping to maintain weight, for example, by measuring the satiation or satiety characteristics of a food or eating pattern or other psychological sensations such as mood, hunger, fullness and desire to eat [12].

Observational studies

During the last year or two, observational studies have evaluated the effect of protein source on a number of markers of obesity both in Europe and the USA.

Observational studies investigating protein source

In the first of these studies animal and plant protein intakes were compared in 3083 Belgians and their relationship with overweight and obesity was examined [15]. Participants in the Belgian National Food Consumption Survey conducted in 2004 and aged ≥ 15y; (1546M, 1537F) assessed food consumption by using two 24-h dietary recalls. Animal protein intake (47 g/d) contributed 65% to total protein intakes (72 g/d), while plant protein intake was only 35% or 25 g/d. Meat and meat products were the main contributors to total animal protein intakes (53 %), while cereals and their products contributed most to plant protein intake (54 %). Men had significantly higher animal and plant protein intakes than females ($P<0.001$). Legume and soya protein intakes were low in the whole population (0.101 and 0.174 g/d, respectively). In men, animal protein intake was positively associated with

BMI and WC (P≤0.002) and in both men and women plant protein intake was inversely associated with BMI (P<0.001) and WC (men, P<0.001; women, P=0.024) [15].

Total, animal and plant protein intakes were assessed in 1804 European adolescents participating in the HELENA study (conducted in 2006-2007) by two 24-h dietary recalls. Participants aged 12.5-17.5 yr (47% boys) were stratified by gender and age and associations with cardio-metabolic indicators determined [16]. Average total protein intake exceeded WHO and EFSA recommendations at 96 g/d of which 59% was derived from animal protein. Total, animal and plant protein intakes (g/d) were significantly lower in girls than in boys and total and plant protein intakes were lower in younger participants (12.5-14.9 yr). Protein intake was significantly lower in underweight subjects and higher in obese ones; the direction of the relationship was reversed after adjustments for body weight. The inverse association of plant protein intakes was stronger with BMI z-score and body fat % compared to animal protein intakes. Additionally, BMI and body fat % were positively associated with energy percentage of animal protein [16].

In three prospective US cohorts (Nurses' Health Study, Nurses' Health Study II, and Health Professionals Follow-Up Study) comprising 120,784 men and women free of chronic disease or obesity at baseline, the association between 4-yr changes in consumption of protein foods, glycaemic load (GL), and their interaction with 4-yr weight change over a 16- to 24-yr follow-up were assessed [17]. After adjusting for other lifestyle changes (smoking, physical activity, television watching, sleep duration), BMI, and all dietary factors simultaneously, it was reported that protein foods were not interchanged with each other but with carbohydrate (P<0.05). Protein foods had different relations with long-term weight gain; positive associations for meat, chicken with skin, and regular cheese (0.13-1.17 kg per increased serving/d, P≤0.02 in all cases); no association for milk, legumes, peanuts, or eggs (P>0.40 for each); and relative weight loss for yogurt, peanut butter, walnuts, other nuts, chicken without skin, low-fat cheese, and seafood (-0.14 to -0.71 kg; P≤0.01). Increases in GL were independently associated with a 0.42 kg greater weight gain per 50-unit increase (P<0.001). Significant interactions (P-interaction < 0.05) between changes in protein foods and GL were identified; for example, increased cheese intake was associated with weight gain when GL increased, with weight stability when GL did not change, and with weight loss when GL decreased [17].

The association of protein intake from either plant or animal sources in early and mid-childhood was associated with the ages at take-off of the pubertal growth spurt (ATO), peak height velocity, menarche in girls and voice break in boys, using data from the Dortmund Nutritional and Anthropometric Longitudinally Designed Study in Germany [18]. A higher total and animal protein intake at age 5-6 yrs was related to an earlier ATO. In those in the highest third of animal protein intake at age 5-6 yrs, ATO occurred 0.6 yrs earlier than those in the lowest (P-trend=0.003). Similar findings were seen for peak height velocity (P-trend=0.001) and the timing of menarche/voice break (P-trend=0.02). Conversely, a higher vegetable protein intake at ages 3-4 and 5-6 yrs was related to later ATO, peak height velocity and menarche/voice break (P-trend =0.02-0.04). These results suggest that animal and vegetable protein intake in mid-childhood might be differentially related to pubertal timing.

Observational studies investigating vegetarian/Mediterranean diets

Data related to vegetarian diets also provides an insight to the benefits of plant-based eating while not exactly replicating it.

In a systematic review of cross sectional evidence it was consistently shown that an inverse relation also exists between vegetarian diets and BMI in both adults and children [19]. In a meta-analysis of 36 early studies conducted with adults, vegetarians had significantly lower weight (-7.7 kg for men and -3.3 kg for women; P<0.001) and 2-points lower BMI. There was no significant difference in height between vegetarians and non-vegetarians [19]. Data from European vegetarians is provided by the Oxford Vegetarian Study [20]. Dietary pattern data from 1914 men and 3378 women, aged 20 to 89 yrs, were compared to BMI. Lower BMI was observed in vegetarians compared with non-vegetarians, by 1.1 kg/m^2 in men and 1.0 kg/m^2 in women both highly statistically significant (P<0.001). These findings are supported by the Oxford cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC) study [21]. In 21,966 men and women, aged 20-69, participating in EPIC, the mean annual weight gain was 389g in men and 398g in women. When adjusted for a number of lifestyle factors, mean weight gain was less in vegans (284g in men and 303g in women, P<0.05) and fish eaters (338g, women only, P<0.001) compared with meat eaters. In Germany, an inverse relation between BMI and vegetarian status (strict vegetarian compared with occasional meat eater) was observed in a cohort of 20,000 vegetarians [22].

Information from the Adventist studies provides an insight into weight management as people progress from, a vegan diet to mixed diet [19]. The data shown in Figure 4.4 indicates there is a gradual increase in BMI as people progress to a mixed diet.

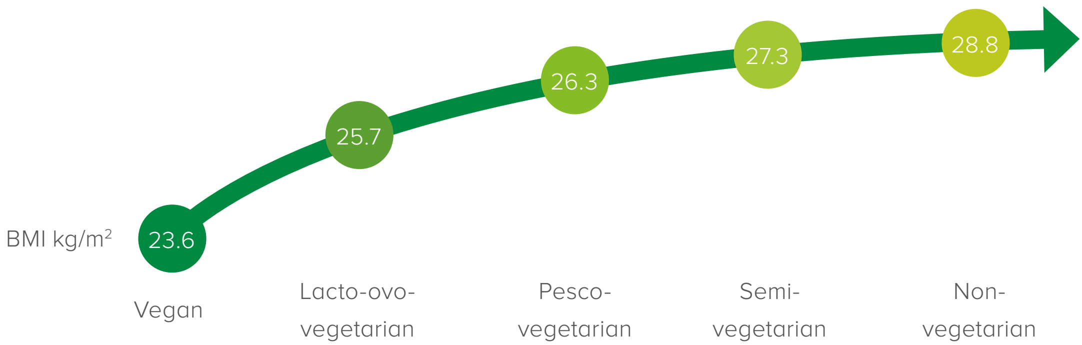


Figure 4.4: BMI according to vegetarian status in the Adventist Health Study

Source: Sabate and Wien [19]

Adherence to the Mediterranean dietary pattern was assessed relative to weight change and the incidence of overweight or obesity in 10 European countries [23]. The EPIC-Physical Activity, Nutrition, Alcohol Consumption, Cessation of Smoking, Eating Out of Home, and Obesity (EPIC-PANACEA) project] was conducted in 373,803 individuals (103,455 men and 270,348 women), aged 25-70 yrs. Measurements were obtained at recruitment and after a median follow-up time of 5 yrs. A Mediterranean Diet Score (range: 0-18) was developed to assess adherence to the Mediterranean diet. The association between the Mediterranean Diet Score and weight change over 5 yrs was modeled. Individuals with a high adherence to the Mediterranean Diet (11-18 points) showed a modest 5-yr weight loss of -0.16 kg and were 10% less likely to become overweight or develop obesity than were individuals with a low score (0-6 points).

High adherence to the Mediterranean Diet was also associated with a lower change in WC and BMI in a case-cohort study comprising data from five European countries (11,048 subjects) with a median follow-up of 6.8 yrs [24]. This study also demonstrated that the change in WC and BMI was independent of allele for the obesity risk alleles (FTO and TCF7L2), indicating the effect relating to Mediterranean Diet was not associated with genetic predisposition.

The evidence from observational studies indicates that those who follow plant-based eating and eat more protein as plant proteins, tend to have a lower BMI and gain less weight over time.

Studies investigating weight management and high fibre Intakes

It is recognized that plant-based eating results in a higher fibre intake [25]. This aspect of plant-based diets can be explored by reference to studies that have investigated the impact of higher fibre intakes.

A systematic review and analysis of observational studies reporting wholegrain consumption and measures of BW and adiposity, including the effect on macronutrient intakes and lifestyle factors has been undertaken [26]. Higher intake of whole grains led to a significantly increased dietary fibre intake (9 g, P<0.01), while total and SFA intakes decreased by 11 g and 3.9 g, respectively. The combined and weighted mean difference in BMI from 15 studies representing 20 treatment groups (N=119,829) was 0.630 kg/m^2 lower when high versus low wholegrain intake was compared (P<0.0001). In high consumers, adiposity assessed as WC was reduced by 2.7 cm, (P=0.03) or as waist:hip ratio by 0.023 (P<0.0001) [26].

Wholegrain and high fibre intake were assessed in relation to T2D, CVD, weight gain, and metabolic risk factors in a systematic review of 45 prospective cohort studies and 21 RCT [27]. The data relevant to weight gain indicated that consistently less weight gain occurred during 8-13 yr (1.27 vs 1.64 kg; P=0.001) of follow-up in those consuming more fibre (3-5 servings of whole grains/d).

In an earlier review, it was concluded that increasing consumption of dietary fibre with fruits, vegetables, whole grains, and legumes across the life cycle is a critical step in stemming the epidemic of obesity found in developed countries. The addition of functional fibre to weight-loss diets should also be considered as a tool to improve success [28].

An extensive systematic review of 1517 papers relating macronutrient intake to long term weight gain, concluded that there was "**probable evidence for high intake of dietary fibre predicting less weight gain**" [29].

The issue of energy density was addressed in an evidence-based systematic review conducted by the 2010 Dietary Guidelines Advisory Committee. It reviewed the findings of 17 studies (seven RCT, one non-RCT, and nine cohort studies) in adults and six cohort studies in children and adolescents [30]. Based on this evidence, it concluded that strong and consistent evidence in adults indicates that dietary patterns relatively low in energy density improve weight loss and weight maintenance. In addition, the committee concluded that there was moderately strong evidence from methodologically rigorous longitudinal cohort studies in children and adolescents to suggest that there is a positive association between dietary energy density and increased adiposity [30].

Clinical Studies

The objective of short term clinical studies is often to establish the effectiveness of various weight loss regimes rather than to look at weight management over time.

ECO-Atkins studies

Two studies report weight loss interventions when following a plant-based so-called "Eco-Atkins" diet and compare this to a more conventional low-carbohydrate, high-animal protein weight-reducing diet [31, 32]. The "Eco-Atkins" diet comprises low-carbohydrate (26% of total calories), high-vegetable protein (31% from gluten, soya, nuts, fruit, vegetables, and cereals) and vegetable oil (43%) plant-based diet and was derived in response to the suggestion that low-carbohydrate, high-animal protein diets, are beneficial for weight loss. The control diet was a high-carbohydrate lacto-ovo-vegetarian diet (58% carbohydrate, 16% protein, and 25% fat). Results from the study are summarized in Table 4.1.

Study description [reference]	Study length Design	Treatment	N	Weight loss kg P	Difference in % body fat P	Difference in Attrition P
Eco-Atkins wt loss overweight / hyperlipidaemics [32]	6 mo RCT	Ad lib low-carbohydrate vegan diet vs high-carbohydrate lacto-ovo-vegetarian	39 15M/ 24F	-6.9 v -5.8 P=0.047	-1.7% NS	50% v 32% NS
				Weight loss kg (%) P	Satiety P	Difference in compliance P
Eco-Atkins wt loss overweight / hyperlipidaemics [31]	1 mo RCP	Low-CHO (26 En%) high-vegetable protein (31% from gluten, soya, nuts, fruit, vegetables & cereals), and vegetable oil (43%) vs high-carbohydrate lacto-ovo-vegetarian diet (58% CHO, 16% protein & 25% fat)	44 18M/ 26PF	-3.9 v 4.2 (4.8% BWT) NS	1.5 v 0.8 P=0.003	94% v 93% NS

Table 4.1: Summary of the Eco-Atkins studies conducted by Professor Jenkins & colleagues

While weight loss was significantly less in the long-term study a major difference between treatments was the improved blood lipid profile and reduced BP with the Eco-Atkins diet, both of which were significantly improved. The calculated 10-year CHD risk on Eco-Atkins low-CHO diet relative to the high-CHO diet was significantly reduced by 2% (P=0.001), [32].

Intervention studies comparing protein source

In one of the few intervention studies that compared protein sources, 20 obese men (BMI 34.8 kg/m^2) were provided in a crossover design with either a vegetarian high protein weight loss diet based on soya protein (Soya-HPWL) or a meat-based HPWL (Meat-HPWL) diet for 2 wk [33]. Both diets comprised 30% protein, 30% fat, and 40% CHO. Over the 2 wk period, the men lost an average, 2.41 and 2.27 kg with consumption of the Soya- and Meat-HPWL diets, respectively, which was not significantly different.

Subjectively rated hunger, fullness, desire to eat, preservation of lean body mass and loss of percentage fat mass did not differ significantly between the two diets. There were differences in absolute concentrations of ghrelin and peptide YY between the two diets, although the response as net area under the curve was not different. The authors concluded that from this very short term intervention, appetite control and weight loss were similar for both types of high protein diets. Gut hormone profile was similar between the diets, which suggests that vegetarian diets can be as effective as meat-based diets for appetite control during weight loss.

Around 10 RCTs were identified that compared different protein sources, usually animal protein compared to soya protein [34]. There are a number of imperfections in these studies, but when the findings from eight studies conducted with soya protein were pooled, the weight loss in 4-wk periods was 2.7 kg with soya protein and 2.4 kg with the control protein. See Figure 4.5.

In three weight loss studies that have compared lacto-ovo-vegetarian diets with diets based on meat, weight loss was similar but, where measured, blood lipid profiles improved [35, 36].

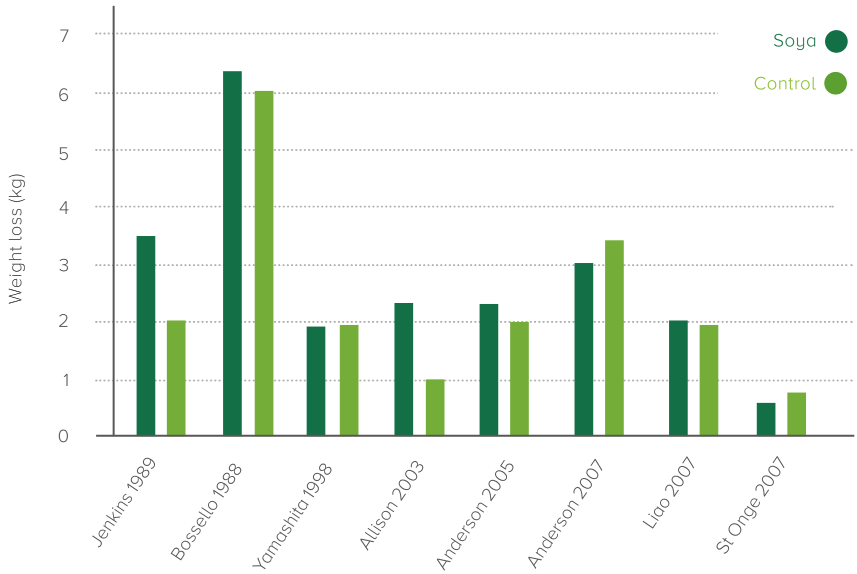


Figure 4.5: Four-week weight loss in RCT with soya and control treatments

Source: Harland [34]

A systematic review of RCT evidence evaluated the effect of enhanced fruit and vegetable intake on BW [37]. Two studies met all criteria and five further studies met all criteria but one. When fruit and vegetables were included in a weight management regime, the standard mean difference in BW was -0.16 and 0.04, both NS, for two or all seven studies respectively [37].

A systematic review and meta-analysis of changes in BW in RCTs of vegetarian diets has recently been undertaken [38]. Studies were included if interventions included vegetarian diets of ≥4 wks' duration without energy intake limitations, and BW effects reported. Fifteen trials (17 intervention groups) where vegetarian diets were introduced, were associated with a mean weight change of -3.4 kg (95% CI -4.4 to -2.4; $P<0.001$), with an intention-to-treat analysis of -4.6 kg BW. Greater weight loss was reported in studies with higher baseline weights, smaller proportions of women and older participants, longer durations and where weight loss was a specific goal [38].

In a recent review of high protein diets it was concluded that high protein diets, either ad libitum or energy controlled, increase the loss of fat mass relative to lean mass in many studies and that high protein diets are associated with greater satiety [14]. In the main this review did not differentiate between plant and animal sources of protein, but the author did conclude that red meat intake was frequently associated with the development of CHD and T2D, while vegetable protein was associated with protection from these diseases. Clifton suggested it was not clear whether this was related to the protein per se or to the increased PUFA or higher fibre levels associated with more vegetarian diets [14].

The effects of three energy matched diets on 24-h energy expenditure have been compared [39]. The diets were based on meat protein (pork: 29 En% as fat and 29 En% as protein, mainly from pork meat), a vegetable protein (soya: 29 En% as fat and 28 En% as protein), and carbohydrate (28 En% as fat and 11 En% as protein). Substitution of carbohydrate with 17-18 En% as either pork-meat or soya protein produced a 3% higher 24-h energy expenditure. Diet induced thermogenesis (heat production) and basic metabolic rate also tended to be higher in the protein diets indicating that these factors may contribute to weight loss (Table 4.2).

Measure	Pork	Soya	Carb	Baseline
Diet-induced thermogenesis (kJ/min)	9.08[a]	8.77[a]	8.61[b]	8.75[ab]
Basal metabolic rate (kJ/min)	6.90[a]	6.73[ab]	6.60[b]	6.57[b]
24-h Energy expenditure (MJ/d)	13.11[a]	12.86[b]	12.62[c]	12.52[bc]

Values with different superscript letters are significantly different (P<0.05)

Table 4.2: The effect of protein source compared to carbohydrate on 24-hour energy expenditure

Source: Mikkelsen [39]

Satiety has been identified as a key factor in both weight loss and in weight maintenance after weight loss [35]. Proteins are considered to play a key role in this respect, but the relative effectiveness of plant-based or animal-based dietary pattern on appetite regulation and satiety is not well-researched [40]. Generally it is believed that protein is more satiating, leads to a higher rate of thermogenesis and helps to maintain fat-free body weight [41]. The overall nutrient composition of food and energy density also influence appetite regulation. Particular sensory and nutrient combinations (for example, SFA and salt in meat pies and pastries; SFA and sugar in cakes and confectionary) in foods can lead to passive overconsumption, while overriding the physiological satiety signals can lead to a positive energy balance and weight gain. The relative importance of these factors has yet to be established in medium or long term studies of plant-based eating, although early indications from the previously reported short-term (2-wk) study demonstrate no significant difference between subjective rated hunger, fullness, desire to eat, preservation of lean body mass and loss of percentage fat mass between meat and soya-based diets [33].

Overview and conclusions

From the evidence reviewed in this chapter it appears that long-term consumption of diets based on plant proteins appear to be associated with lower body weight; this may also be due to a lower SFA intake and better UFA:SFA. It has been suggested that the high SFA:UFA ratio of Western omnivore diets tends to impair muscle insulin sensitivity, leading to a compensatory up-regulation of insulin secretion [42]. Since insulin signals adipocytes to take up and retain fatty acids, a high dietary SFA:UFA ratio would be expected to promote obesity. However the benefits of improved blood lipid profile, BP and reduced CVD risk also need to be taken into consideration.

WHO identify that lower energy density is beneficial in weight management, as did the 2010 Dietary Guidelines Advisory Committee following their systematic review of the evidence available to 2012 [30]. It may well be that the lower fat and higher in fibre plant-based diets are important factors. However, whether the benefit is from the fibre itself or an indirect effect due to energy density is an area that requires further research [43]. In addition it should be recalled that certain soluble fibres have been shown to contribute to feelings of fullness and improved satiety [9] and insoluble fibres may contribute to satiation [44].

It may also be the ratio of essential to non-essential amino acids that are beneficial, and these happen to be found in plant-based diets [42].

Secondly, plant-based eating tends to be associated with other beneficial lifestyle factors that may influence body weight, including less smoking, greater physical activity and higher education level. It may well be that the combination of all of these factors are important rather than a single factor [26].

Thirdly, the variety of plant foods that are included in a plant-based eating pattern may have a significant influence preventing overweight or obesity and on weight maintenance through the action of specific factors (protein, fibres and others) present in plant foods that possibly promote appetite regulation and satiety.

It is interesting to note then when plant proteins replace animal proteins in short-term clinical weight loss studies there is little difference in reported weight loss, and when fruit and vegetables are introduced as the main dietary intervention for weight loss, again there is little difference between the control and treatment. The evidence, albeit limited, seems to suggest that it is the totality of the plant-based eating regime that is important rather than the individual component parts.

Take-home messages:

- Maintaining a healthy weight is a major public health challenge.
- Overweight affects 30 – 70% of adults in the countries of WHO European Region and over 20% of adults are obese.
- About 20% of children and adolescents are overweight and about one third of these are obese.
- Plant-based eating is associated with lower body weight and less weight gain over time.
- Plant-based foods and eating patterns are typically low in SFA, high in UFA and fibre, and are of a lower energy density. This appears important in maintaining long-term body weight.
- Specific components found intrinsically in plant foods may work together to help with appetite regulation and promoting satiety.
- Eating more fruit, vegetables, legumes, whole grains, nuts and seeds and reducing the amount of energy-rich foods, is a simple and easy way to help manage weight.

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Chapter 5

More plant-based eating and managing blood glucose

PROF. DAVID JA JENKINS
Department of Nutritional Sciences, University of Toronto, Canada

PROF. CYRIL WC KENDALL
Departments of Nutritional Sciences, University of Toronto, Canada

DR. ARASH MIRRAHIMI
Departments of Nutritional Sciences, University of Toronto, Canada

Introduction to Chapter 5, by invited experts David Jenkins, Cyril Kendall and Arash Mirrahimi

This chapter documents the positive impact of plant foods, their components, and diets containing these foods, including vegan diets, on diabetes prevention and treatment. The background is set with the statistic of an 8% diabetes incidence rate in Europe, despite it being one of the world's regions with a comparatively low incidence rate.

The argument is developed that cohort studies such as the EPIC, and the Nurses and Health Professionals studies from both sides of the Atlantic, have implicated animal proteins and red meat with subsequent development of diabetes, while plant foods and whole grains appear protective. Indeed data from the Nurses Health Studies and the Health Professionals Studies suggest that in contrast to animal fats and proteins, diets high in plant fats and proteins offer protection for both diabetes and CVD [1, 2].

Individual foods and food components, from viscous fibres to legumes, nuts, and vegetable oils, may all favourably affect glycaemia in single meal studies or in longer term feeding trials in study participants with diabetes. These interventions have demonstrated not only improved blood glucose control in T2D, but also reductions in serum cholesterol.

Furthermore studies of Barnard and colleagues in T2D, as documented in Chapter 5 [3, 4], have demonstrated in RCTs the ability of vegan dietary advice to improve HbA1C, BW and blood lipid risk factors for heart disease.

The evidence is therefore mounting for the use of plant-based diets to reduce the risk factors for chronic disease. Many agencies concerned with disease are recommending less red meat consumption. The Canadian Diabetes Association acknowledges a vegetarian diet as one of the preferred dietary patterns for diabetes [5]. Most recently even the US Dietary Guide-

lines Committee also, for the first time, recommended the use of vegetarian diets as a healthy eating pattern for US citizens [6].

The current chapter is therefore timely and in accord with current practice internationally for the prevention and treatment of chronic disease, of which diabetes is a major part.

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Chapter 5

More plant-based eating and managing blood glucose

Challenge of diabetes in Europe

One of the nine voluntary WHO global non-communicable disease targets is to halt the rise of obesity and diabetes; the target is to globally reduce mortality from non-communicable diseases, including diabetes, by 25% by 2025 [1]. The global prevalence of diabetes in 2014 was estimated to be 9%, while the prevalence of diabetes was highest in the WHO Region of the Eastern Mediterranean (14% for both sexes) and lowest in the European Region (8% for both sexes). In general, low-income countries showed the lowest prevalence and upper-middle-income countries had the highest prevalence of diabetes for both sexes. In the European Region of the WHO around 4% of deaths from non-communicable disease were directly as a result of diabetes. The WHO projects diabetes deaths will double between 2005 and

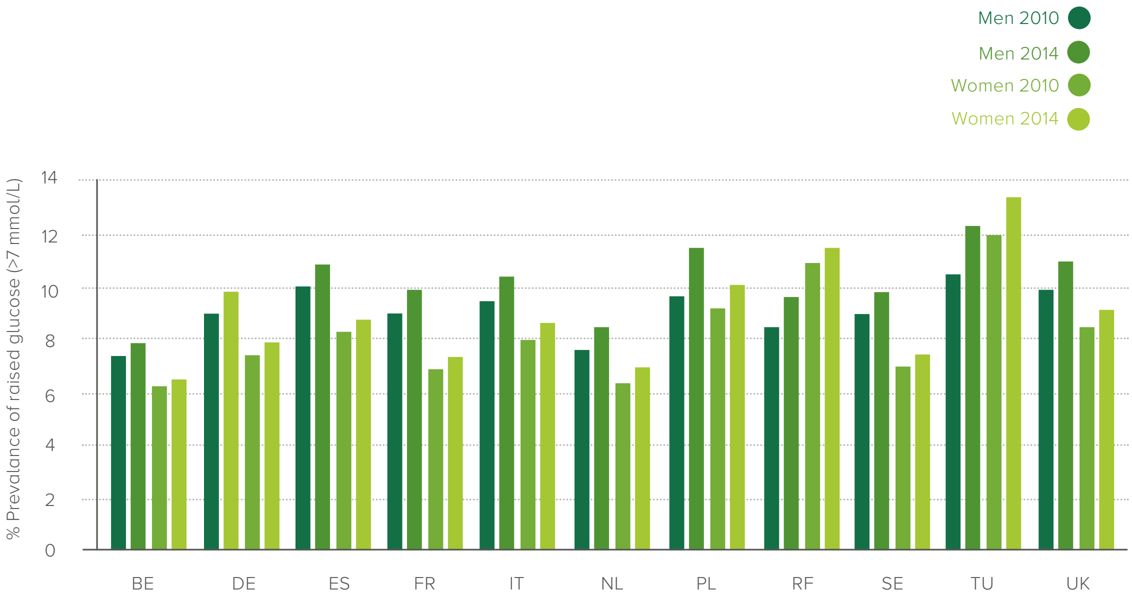

Figure 5.1: Prevalence of raised blood glucose (>7 mmol/L) in certain European countries in 2010 and 2014

Source: WHO 2014 [1]

2030 and is extremely concerned by the rate of increase [2]. The prime early indication of diabetes is poor blood glucose management. The prevalence of elevated blood glucose (>7mmol/L) in European populations was reported in comparable datasets from 2010 and 2014 and this data is shown for certain countries in Figure 5.1. As can be seen, in all European Countries cited, the incidence of diabetes has increased over this 4-yr period.

Around the world

Source: International Diabetes Federation

Diabetes and effect on health

The challenge of diabetes is not only related to the condition itself, but also to associated complications that can result in damage to the heart, blood vessels, eyes, kidneys, and nerves [2]. Specifically diabetes:

- increases the risk of heart disease and stroke, with half of the people with diabetes dying of CVD (primarily heart disease and stroke);
- combined with reduced blood flow, nerve damage increases the chance of foot ulcers and eventual limb amputation;
- is an important cause of blindness (around 1% of blindness globally), which occurs as a result of long-term accumulated damage to the small blood vessels in the retina in the eye;
- is among the leading causes of kidney failure;
- can result in damage to the nerves which affects up to half the people with diabetes;
- increases the overall risk of dying which is at least double the risk of those without diabetes.

Consequently, not only is it important to maintain healthy blood glucose levels to reduce the risk of developing diabetes, but also to help avoid the risk of developing ill health and a wide range of chronic diseases.

Identifying diabetes

There are a number of types of diabetes including:

- **Type 1 diabetes (T1D)** – around 5% prevalence
- **Type 2 diabetes (T2D)** – globally accounts for 90% of all diabetes
- **Gestational diabetes**
- **Prediabetes**, also known as impaired glucose tolerance (IGT) or impaired fasting glycaemia (IFG).

The WHO criteria used to define diabetes, impaired glucose tolerance and the metabolic syndrome are given in Table 5.1.

Condition	2 hour glucose* mmol/L	Fasting glucose mmol/L
Normal	<7.8	<6.1
Impaired fasting glycaemia (IFG)	<7.8	6.1 - 6.9
Impaired glucose tolerance (IGT)	≥7.8 - <11.1	<7.0
Diabetes mellitus	≥11.1	≥7.0

* Two hours after a 75g oral glucose load in a glucose tolerance test

Table 5.1: 2006 WHO diabetes criteria

Source: WHO, http://www.who.int/diabetes/publications/diagnosis_diabetes2006/en/

Maintaining healthy glucose levels

Lifestyle measures have been shown to be effective in preventing or delaying the onset of T2D. To help prevent T2D and its complications WHO have recommended (http://www.who.int/mediacentre/factsheets/fs312/en/) that people should:

- achieve and maintain a healthy body weight;
- be physically active – at least 30 minutes of regular, moderate-intensity activity on most days – a greater level of activity is required for weight control;

- eat a healthy diet of between 3 and 5 servings of fruit and vegetables a day and reduce sugar and SFA intake (for details see below);
- avoid tobacco use – smoking increases the risk of cardiovascular diseases.

The WHO Global Status Report on non-communicable diseases 2014 complements WHO's diabetes work by focusing on population-wide approaches to maintain a healthy weight, promote regular physical activity and eat a healthy diet [1, 3]. It states a healthy diet includes:

- at least 400 g (5 portions) of fruit and vegetables a day, including fruits, vegetables, legumes (e.g. lentils, beans), nuts and whole grains (e.g. unprocessed maize, millet, oats, wheat, brown rice);
- less than 10% of total energy intake from free sugars (equivalent to 50 g a day for a person with a healthy body weight consuming approximately 2000 calories per day) but ideally less than 5% of total energy intake for additional health benefits;
- less than 30% of total energy intake from fats. UFA (e.g. those found in fish, avocado, nuts, sunflower, canola and olive oils) are preferable to SFA and industrial trans fats (found in processed food, fast food, etc.);
- less than 5 g a day of all salt and when used choose iodized salt.

Potential benefits of plant-based eating

The main macronutrient benefits of plant-based eating are a lower SFA content and better SFA:UFA ratio in the diet and a higher fibre intake, all of which match well with the guidance given by WHO for a healthy diet. Individually each of these factors, and possibly the inter-relationship between all, may contribute to the beneficial role reported in those following a plant-based diet. In addition it appears there are benefits associated with the consumption of plant polyphenols and other phyto-chemicals.

Examining these factors in detail, it may well be the higher fibre content of plant-based eating patterns are of direct benefit in glucose management [4]. Fibre, particularly soluble fibres, may result in more desirable post prandial glucose concentrations and improved glucose tolerance curve or insulin response [5, 6]. Low glycaemic index carbohydrates produce only small fluctuations in blood glucose and insulin levels and as such are beneficial in helping to manage diabetes and also reducing the risk of heart disease [7].

Fibres tend to have both a low glycaemic index and a low glycaemic load and, as such, will tend to moderate insulin production, thereby improving insulin sensitivity and tending to promote less fat storage and so help reduce the risk of both T2D and obesity.

Conditions which predispose to developing T2D include overweight (and obesity), reduced insulin sensitivity and inflammation. Consequently any aspect of plant-based eating that can help improve these will help to avoid the progression to diabetes. Plant-based eating patterns tend to be lower in energy density and promote fibre intake as discussed in Chapter 2 and, as such, follow the WHO dietary recommendations for weight management, see Chapter 4. Fibre intake also alters the microbial population in the gut. It has been suggested that certain bacteria present in the gut of leaner individuals lead to inefficient use of dietary fat and thus promote weight maintenance. Encouraging such microbial populations in the gut may therefore play a role in the avoidance of metabolic consequences that promote T2D.

It is believed that eating large amounts of calorie-dense foods causes abnormal surges in blood glucose and TAG levels [8]. After a meal high levels of certain fats in the blood including TAG, chylomicrons and remnant lipoproteins, cause oxidative stress and inflammation. This can also have a negative impact on blood glucose levels [8]. Consequently eating patterns that blunt the post meal glucose and TAG response are beneficial in maintaining healthy glucose tolerance [9].

Scientific evidence

Observational studies can provide information about dietary patterns and development of T2D over time. Or, by measuring insulin sensitivity, glucose tolerance or some other factor, dietary patterns can indicate the risk of developing T2D. RCTs are often used to demonstrate the effectiveness of specific dietary components on glucose levels or insulin sensitivity.

Observational studies

There are few observational studies that have specifically looked at the relationship between plant-based eating and T2D. In the main, data comes from studies where subjects have been following vegetarian or vegan diets, or dietary intake is reviewed relative to the intake of fibre, wholegrain cereals or meat. Data comes from three main sources; the European Prospective Investigation into Cancer and Nutrition (EPIC) cohorts, a number of long-standing US cohorts and the Adventist studies. While there are other cohorts around the world to which reference could be made, often the diet and lifestyle are not closely related to Western Society and attention will be focused on the three sources of data highlighted.

Findings from EPIC cohorts

The Dutch EPIC cohort comprises of 38,094 subjects, aged 21-70 yrs at baseline, who have been followed for 10 yrs. It has been used to demonstrate that T2D risk increases with higher total protein intake (hazard ratio (HR) 2.15 for the highest vs lowest quartile) and animal protein intake (HR, 2.18), whereas vegetable protein was not related to diabetes [10]. The authors calculated that consuming 5 En% from total or animal protein at the expense of 5 En% from carbohydrates or fat increased T2D risk. In the same cohort, it was established that dietary fibre intake was associated with an 8% reduced T2D risk (HR, 0.92; $P<0.05$), but increasing glycaemic load and glycaemic index of the diet resulted in a greater risk of T2D, (HR, 1.32; $P<0.001$ and 1.08; $P=0.05$ respectively) [11].

The association between isotopic biomarkers with incident T2D was assessed using a case-cohort design (N=476 diabetes cases; N=718 subcohort) within the EPIC Norfolk cohort [12]. The stable-isotope ratios of carbon, expressed as delta(13)C) and nitrogen expressed as delta(15)N) were used as potential nutritional biomarkers to distinguish between meat, fish, and plant-based foods. Animal protein was significantly ($P\leq0.013$) correlated with delta(15)N, specifically dairy protein correlation (r=0.11); meat protein (r=0.09) and terrestrial animal protein (r=0.12). Animal protein was not correlated with delta(13)C. Delta(13)C relates largely to plant proteins. Delta(13)C was significantly inversely associated with diabetes in adjusted analyses; HR per tertile was 0.74 (P-trend<0.001). Delta(15)N (marker of animal proteins) was positively associated with T2D, where the HR was 1.23 (P-trend=0.001). In this cohort a positive association of delta(15)N (animal proteins) was linked with incident T2D [12].

Also using data from the EPIC cohorts the association between the risk of developing T2D and dietary flavonoid and lignan intakes were assessed

[13]. EPICAct is a case-cohort study that included 12,403 incident T2D cases and a stratified sub-cohort of 16,154 participants from among 340,234 participants with 3.99 million person-yrs of follow-up in eight European countries. A diet rich in flavonoids is considered to be a dietary pattern based on plant-based foods. Using multivariable models, a trend for an inverse association between total flavonoid intake and T2D was reported; HR for the highest vs the lowest quintile, 0.90 (P-trend=0.04), but not with lignans (HR, 0.88). When the flavonoid subclasses were examined there were significant associations between flavonols (HR, 0.80, P-trend=0.020), flavanols (HR, 0.82, P-trend=0.012), and flavan-3-ol monomers (HR, 0.73, P-trend=0.029) and a reduced risk of diabetes.

Findings from American Cohorts

The association between changes in red meat intake and subsequent T2D were studied in three US cohorts [14]. Data from 26,357 men in the Health Professionals Follow-up Study (1986-2006), 48,709 women in the Nurses' Health Study (1986-2006), and 74,077 women in the Nurses' Health Study II (1991-2007) were assessed. Diet was measured by validated FFQ and updated every 4 yrs. Incident T2D cases were validated by supplementary questionnaires. During 1,965,824 person-yrs of follow-up, 7540 incident T2D cases were documented. Using multivariate-adjusted models, increasing red meat intake during a 4-yr interval was associated with an elevated risk of T2D in each cohort (all P-trend<0.001). Compared with the reference group of no change in red meat intake, increasing red meat intake by more than 0.50 servings/d was associated with a 48% greater risk of T2D in the subsequent 4-yr period, while reducing red meat consumption by more than 0.50 servings/d from baseline to the first 4 yrs of follow-up was associated with a 14% lower risk.

Other studies have identified that higher red meat consumption is associated with an increased risk of developing diabetes. For example, in middle-aged women in The Women's Health Study [15].

In a further analysis of the Health Professionals Follow-Up Study; men who were initially free of T2D, CV disease, or cancer (N=41,615), were followed for ≤ 20 yrs [16]. The diets were then scored using one of five dietary scores. The Healthy Eating Index (HEI) 2005 score, (a 100-point score awards points for diet diversity; higher intakes of grains, vegetables fruit, and milk and lower intakes of meat total fat, SFA, cholesterol and sodium); the alternative HEI (aHEI) (as HEI, but combines fruit and vegetable categories and eliminates others, e.g., total grains and adds foods associated with chronic disease reduction e.g. nuts, cereal and fibre); the Recommended Food Score (awards points for weekly intake of 51 foods, e.g., fruit, vegetables, whole grains, lean meats, and low-fat dairy), the alternative Mediterranean Diet (aMED) score, (awards one point for above median intakes of vegetables (not potatoes), legumes, whole grains, fruits, nuts and fish; ratio of MUFA:SFA; moderate intakes of alcohol and below-median intakes of red and processed meat) and the Dietary Approaches to Stop Hypertension (DASH) score [a 40-point score awards points for higher intakes of foods related to a lower risk of hypertension - fruits, vegetables, low-fat dairy, nuts, legumes, and whole grains - and lower intakes of harmful foods (sodium, red and processed meats, and sweetened beverages)] were calculated from FFQs.

There were 2795 incident cases of T2D. After multivariate adjustment, the higher aHEI, aMED, and DASH scores were significantly associated with reduced risk. A 1-standard deviation increase was associated with 9-13% reduced risk (P<0.01), and the DASH score was associated with lower risk, independent of other scores (Figure 5.2).

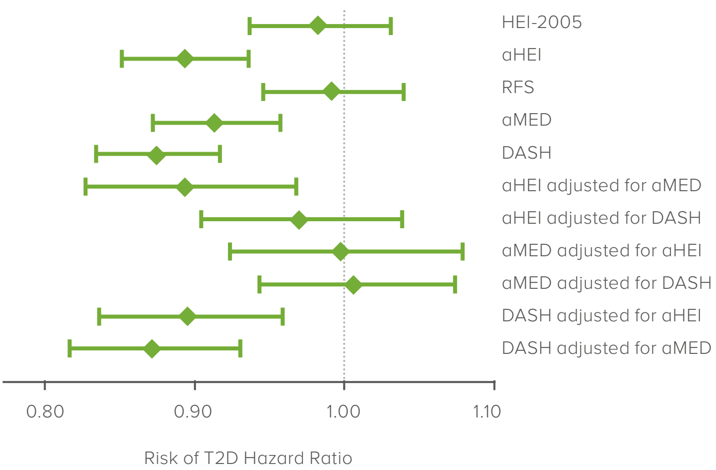

Figure 5.2: Standardized and adjusted diet quality scores and the risk of T2D

Source: de Koning [16]

All scores were associated with lower absolute risk among those who were overweight or obese compared with normal weight (P-interaction<0.01). The authors concluded that these diet-quality scores were associated with a lower risk of T2D and reflect a common dietary pattern characterized by high intakes of plant-based foods such as whole grains, moderate alcohol and low intakes of red and processed meat, sodium, sugar-sweetened beverages, and trans fat.

Findings from Adventist cohorts

The Seventh-day Adventist Study-2, contains data from 22,434 men and 38,469 women, approximately half of whom are omnivores and half vegetarians. Participants were grouped as vegan, lacto-ovo-vegetarian, pesco-vegetarian, semi-vegetarian or non-vegetarian (reference group). It has been shown that for the range of diet-types, as the consumption of meat and animal products increase, there is an increasing prevalence of diabetes [17], see Figure 5.3.

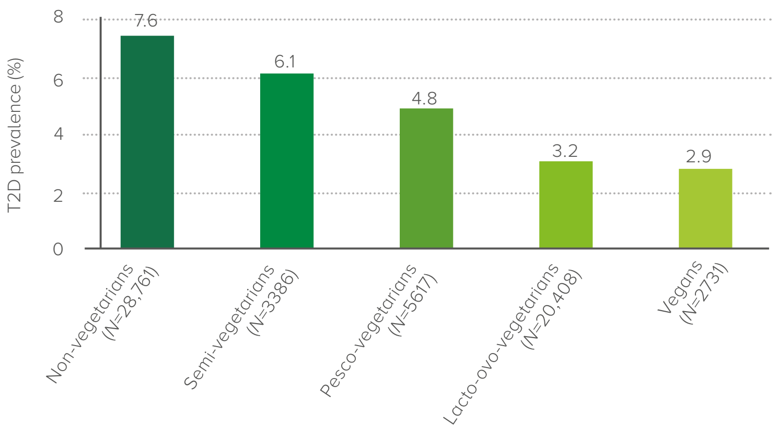

Figure 5.3: The effect of eating pattern on T2D prevalence in the Adventist Healthy Study-2

Source: Trapp and Barnard 2010 [18]

In a further analysis of the Adventist Health Study-2, the relationship of diet to incident T2D among non-Black and Black participants who were initially free of T2D was assessed [19]. Data from 15,200 men and 26,187 women (17.3% Blacks) across the US and Canada was collected and participants grouped into the diet-types detailed above. A follow-up questionnaire after two yrs collected information on the development of T2D. Cases of T2D developed in 0.54% of vegans, 1.08% of lacto-ovo-vegetarians, 1.29% of pesco-vegetarians, 0.92% of semi-vegetarians and 2.12% of non-vegetarians, see Figure 5.4.

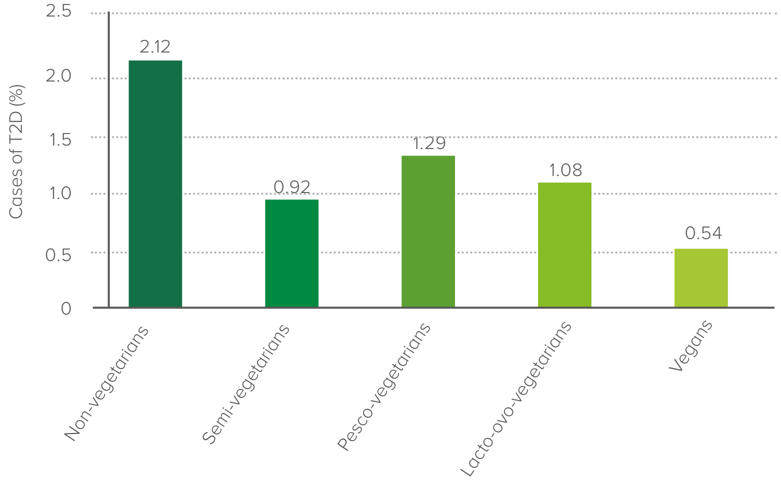

Figure 5.4: The effect of eating pattern on T2D prevalence in the Adventist Health Study-2

Blacks had an increased risk compared to non-Blacks (OR, 1.36), Figure 5.5. In multiple logistic regression analysis controlling for BMI and other lifestyle factors, vegans (OR, 0.38), lacto-ovo-vegetarians (OR, 0.62) and semi-vegetarians (OR, 0.496) had a lower risk of T2D than non-vegetarians. In non-Blacks vegan, lacto-ovo- and semi-vegetarian diets were protective against diabetes (OR, 0.43, 0.69 and 0.50, respectively); among Blacks vegan (OR, 0.30), and lacto-ovo-vegetarian diets (OR, 0.47) were protective. In this study the associations were strengthened when BMI was removed from the analyses.

In a recent review of the findings from Adventist Health Study-2 [20], it was concluded that vegetarian dietary patterns were associated with lower BMI, lower prevalence and incidence of T2D, lower prevalence of the metabolic syndrome and its component factors, lower prevalence of hypertension, lower all-cause mortality, and in some instances lower risk of cancer, suggesting important links between vegetarian dietary patterns and improved health.

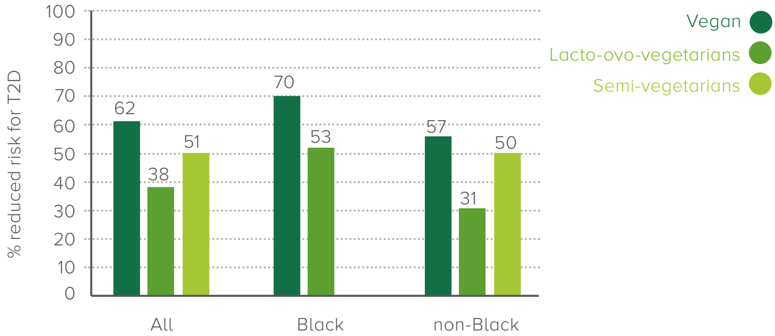

Figure 5.5: The effect of eating pattern and colour on T2D prevalence in the Adventist Health Study-2

Meta-analyses of observational studies

Associations between dietary fibre and magnesium intake and risk of T2D were examined by means of meta-analysis [4]. Nine cohort studies that measured fibre intake were assessed and an overall relative risk calculated. Meta-analyses showed a 33% reduced risk of T2D with higher cereal fibre intake. Fruit and vegetable fibre intakes were not significantly associated with diabetes risk.

Eating patterns rich in wholegrain foods have also been shown to be associated with a lower risk of developing diabetes [21]. Using data from three prospective studies, including 160,000 men and women, it was identified that the risk of developing T2D was 21-27% lower for those in the highest quintile of wholegrain intake (typically those consuming two or more servings of wholegrain foods/d compared to those consuming little or none), and 30-36% lower in the highest quintile of cereal-fibre intake, each compared with the lowest quintile.

In a systematic review of 12 cohort studies, including those already detailed, it has been estimated that the relative risk of developing diabetes was 17% higher when comparing high or low intake of red meat [22]. Or expressed another way, for each 120 g increase in red meat intake/d (equivalent to a small piece of steak), the risk of developing diabetes was 20% higher. A similar comparison evaluating the risk of developing diabetes compared to total meat intake, indicated a 21% greater risk at higher intakes [22].

The relation between nut intake and T2D incidence was assessed by reference to 31 reports from 18 prospective studies in which there were 12,655 T2D cases. The RR of T2D for each incremental serving per day of nut intake was 0.80 (without adjustment for BMI); with adjustment, the association was attenuated (RR 1.03) [23].

A review of “Mediterranean Diets” found at least five large prospective studies that reported a substantially lower risk of developing T2D in healthy people or at risk patients with the highest adherence to a Mediterranean diet [24]. The authors conclude that accumulated evidence suggests that adopting a Mediterranean diet may not only help prevent T2D, but also that a lower carbohydrate, Mediterranean-style diet seems good for HbA1c reduction in people with established diabetes.

Systematic reviews and meta-analyses of clinical studies

In the most recent systematic review and meta-analyses, the association between vegetarian diets and glycaemic control in T2D was examined [25]. Of 477 studies identified, six met the inclusion criteria (N=255, mean age 42.5 yrs). The analyses revealed that vegetarian diets was associated with a significant reduction in HbA1c (-0.39 % point (P=0.001)) and a non-significant reduction in fasting blood glucose concentration of -0.36 mmol/L compared with comparator diets. The authors concluded that consumption of vegetarian diets is associated with improved glycaemic control in T2D.

In an earlier systematic review, 13 RCTs were identified but in fact the majority reported a relationship between either insoluble or soluble fibre and some measure of diabetes risk [6]. Only four studies, all of which were conducted in people with established diabetes, specifically studied plant-based diets. Of these, three RCTs related to vegan diets, rather than the broader definition of plant-based (refer to Introduction).

Clinical studies of people with diabetes

The RCTs that have been conducted in this area of research primarily focus on dietary interventions that reduce glycaemic index or add fibre in the diet of T2D rather than the benefits of plant-based eating per se in people without diabetes.

In the first of three studies identified in the meta-analysis above [6], a pilot study with 11 overweight T2D men and women, a low fat plant-based diet (<10 En% fat and 26g fibre) was compared to a control diet that met the American Diabetes Association 2003 guidelines (15-20 En% protein, <7 En% SFA, 60-70 En% carbohydrate and 20g fibre) [26]. The diets were not designed to be isocaloric and as a result weight loss was markedly different between the two groups, with the control group losing 3.8 kg and the experimental group 7.2 kg ($P<0.005$). The vegan diet also resulted in a 28% mean reduction in fasting serum glucose from 10.7 to 7.75 mmol/L, which was significantly greater than the 12% decrease, from 9.86 to 8.64 mmol/L, in the control group ($P<0.05$). No other measures of glycaemic control were significantly altered, although blood lipid profile improved.

In a second study with 99 overweight T2D, the macronutrient targets of the control and experimental diets were the same as described above, except the vegan and control diets resulted in fibre intakes of 36.3 g and 19 g respectively [27]. Volunteers were evaluated at baseline and after 22 weeks. At the end of study, 43% of subjects (21 of 49) in the vegan group and 26% (13 of 50) of the control group reduced their diabetes medications. Glycated haemoglobin decreased non-significantly by 0.96 and 0.56% points in the vegan and control groups respectively ($P=0.089$). When those people with T2D who had changed medications were excluded, HbA1c fell 1.23 points in the vegan group compared with 0.38 points in the control group ($P=0.01$). Urine albumin was also significantly reduced in the vegan group. As in the previous study, body weight loss was greater in the vegan group than in the control group (6.5 kg compared to 3.1 kg), ($P<0.001$). In a further report of this study, after volunteers had been on their respective diets for 74 weeks [28], changes in HbA1c from baseline to 74 weeks (or last available value), or last value before any medication adjustment, were -0.40 and 0.01 for vegan and control groups, respectively ($P=0.03$). Weight loss was sustained over the 74 week period, but was not significantly different between groups (-4.4 kg in the vegan group and -3.0 kg in the control group). Significant reductions in both Total-C and LDL-C were also reported in the vegan group. After controlling for medication changes the authors concluded that a low-fat vegan diet appeared to improve glycaemia and plasma lipids more than the conventional diabetes dietary recommendations.

In the third RCT a plant-based, high carbohydrate/high fibre diet (52 En% carbohydrate and 28 g fibre) was compared to a low carbohydrate/high MUFA diet (45 En% carbohydrate, 23 En% MUFA and 8 g fibre) in a 4-week crossover design study using 18 marginally overweight men and women with T2D [29]. During the plant-based period there were significant decreases in after meal plasma glucose levels and insulin responses. The plant-based diet also significantly improved markers of inflammation and coronary health, as well as improved glycaemic control, suggesting that plant-based eating may be beneficial for people with diabetes.

Two further studies have been conducted by Jenkins et al [30, 31]. In the first of these, legumes were included as part of a low glycaemic index diet and effects on glycaemic control and CV risk factors were assessed in people with T2D [30]. Subjects (N=121) were randomized to either a low-glycaemic index legume diet that encouraged participants to increase legume intake by at least 1 cup per day, or to increase insoluble fibre by consumption of whole wheat products, for 3 months. The primary outcome was change in HbA1c values. The low-glycaemic index legume diet and the high wheat fibre diet reduced HbA1c values by -0.5% and -0.3% respectively, with the relative reduction in HbA1c values after the low-glycaemic index legume diet being greater by -0.2% (P<0.001). The respective CHD risk reduction on the low-glycaemic index legume diet was also lower (-0.8%, P=0.003).

In the second of these studies, the effect of lowering the glycaemic load with canola oil on glycaemic control and cardiovascular risk factors was assessed in 141 subjects with T2D [31]. Subjects were provided with dietary advice on either a low-glycaemic load diet with ALA and MUFA given as a canola oil-enriched bread supplement (31 g canola oil per 2000 kcal) or a wholegrain diet with a whole wheat bread supplement. The primary outcome was HbA1c change. Seventy-nine and 90% of the low-glycaemic load group and wholegrain group respectively completed the trial with respective reductions in HbA1c units of -0.47% (-5.15 mmol/mol) and -0.31% (-3.44 mmol/mol) that were significantly different (P=0.002).

Dietary intake, including protein amount and type, seems to affect the progression of renal disease; an important consideration for those with diabetes. A pilot study tested the hypothesis that substituting a vegetable protein for animal protein in the diets of diabetics would help correct kidney filtration function in terms of glomerular hyperfiltration. In this small study of 12 young adults (aged 29.9 yr) with T1D, glomerular filtration rate was found to improve after eight weeks, both compared to baseline and compared to a control based on animal protein, demonstrating an overall improved clinical profile in these diabetics [32].

In addition various studies suggest that low fat vegan or vegetarian diets can be effective for the treatment and management of T2D specifically by improving body weight, CV risk factors, and insulin sensitivity [33-35] and reducing the need for diabetic medications [27, 28, 36].

Community studies

One of the few studies that evaluated the effect of plant-based eating was a community-based intervention studying the effects of consuming a plant-based diet on a range of CV risk factors. Employees from 10 sites of a major US company with BMI ≥ 25 kg/m^2 and/or previous diagnosis of T2D were randomized to either follow a low-fat vegan diet, with weekly group support and work cafeteria options available, or make no diet changes for 18 wks [37]. Mean body weight fell 2.9 kg and 0.06 kg in the intervention and control groups, respectively (P<0.001). HbA1c fell 0.6 and 0.08% points in the intervention and control group, respectively (P<0.01). In addition changes in Total-C and LDL-C were significantly greater in the intervention group (P<0.001). Among study completers, mean changes in body weight were -4.3 kg and -0.08 kg in the intervention and control groups, respectively (P<0.001). HbA1c levels decreased 0.7 and 0.1% points in the intervention and control group, respectively (P<0.01). This shows a beneficial effect of a low-fat vegan diet on parameters for T2D.

In a second community study the awareness and perception of plant-based diets for the treatment and management of T2D was assessed [38]. Few respondents (9%) currently followed a plant-based diet, but 66% indicated willingness to follow one for three weeks. Family eating preferences and meal planning skills were common barriers to diet change. 72% of health-care providers reported knowledge of plant-based diets for diabetes management but low levels of practice.

Clinical studies of people without diabetes

In one of the few plant-based eating interventions conducted in people without diabetes the effect of soya consumption on insulin resistance, glucose homeostasis, and other characteristics of the metabolic syndrome (MetS) was investigated in a 4-wk, crossover design RCT [39]. Postmenopausal women with abdominal obesity (N=15) were used to evaluate the effects of test diets comprising 22 En% from protein, 27 En% from fat, and 50 En% from carbohydrate. One diet contained protein of mixed origin (mainly meat, dairy, and bread), and in the other diet, meat was partly replaced with soya meat analogues and soya nuts containing 30 g/d soya protein. The primary outcome was a frequently sampled intravenous glucose tolerance test (FSIGT) performed at the end of each 4-wk period. Compared with the mixed-protein diet, the soya-protein diet resulted in greater insulin sensitivity after 4-wks ($P=0.038$). Blood lipid profiles were also improved. The authors concluded that partly replacing meat with soya in a moderately high-protein diet has clear advantages regarding insulin sensitivity and could be important in preventing MetS.

In addition to the RCT detailed above, a number of RCTs have found improvements on measures of glycaemic control following the introduction of fibre or whole grains into the diet [6]. For example, when overweight women without diabetes consumed additional insoluble fibre (total intake 31.2 g/d), insulin sensitivity improved by 8% and there was a 12% increase in insulin action compared to the control group [40]. The addition of soluble fibre in the form of beta-glucan led to improved post-meal glucose tolerance and resulted in a lower insulin response (33% less) when introduced into the diet of overweight non-diabetic women. Two studies assessed the addition of wholegrain cereals on insulin resistance score [41, 42]. In men with coronary artery disease with or without diabetes, and in obese men and women, the score was significantly improved indicating that insulin was performing at a more optimal efficiency level.

Overview and conclusions

With the shift in the medical arena towards looking for evidence based on clinical disease endpoints (such as provided from prospective cohorts) rather than changes in surrogate markers (e.g. risk factors such as glucose tolerance and insulin sensitivity), the weight of evidence related to plant-based diets deserves attention.
Cohort studies indicate:

- diabetes prevalence is lower in those following a plant-based diet [11, 12, 16];
- consuming more meat and animal products tends to result in a higher incidence of T2D [14, 15, 22];
- a higher intake of plant polyphenols is associated with lower incidence of T2D [13] and
- diets rich in wholegrain cereals also tend to lead to a reduced incidence of T2D [21, 43].

Meat can be a significant source of SFA in the diet and it is not absolutely clear whether it is this characteristic that leads it to be associated with T2D or whether it is some other property of meat per se, or in fact other properties associated with a meat-rich diet. For example, it has been suggested that substituting vegetable proteins for animal protein may also decrease the long term risk of developing kidney disease in T2D [44].

Based on what is known of the components of plant-based diets and the findings from clinical studies in the literature, it appears there is sufficient evidence to indicate that **those following plant-based eating patterns have improved glycaemia and insulin sensitivity, improvements in markers of inflammation and CVD**. In addition, the information presented in Chapter 4 indicates that plant-based eating is associated with better weight management. As obesity is one of the key risk factors in the development of T2D it may be this aspect that is of importance.

The combination of all these aspects of plant-based eating patterns is of value to those wishing to maintain healthy glucose levels and avoid the progression to T2D.

Take-home messages:

- In the WHO EU region in 2014, it was estimated that the prevalence of T2D is around 8%.
- Incidence of diabetes is increasing and is associated with an increased risk of heart conditions, renal failure and other chronic diseases.
- Plant-based eating is associated with a reduced incidence of T2D.
- Plant-based eating results in better blood glucose control, better weight management and improved blood lipid profile – all risk factors for the development of T2D.
- Plant-based foods and eating patterns are typically low in SFA and rich in fibre. Fibre is important as it helps glycaemic control, may improve satiety and is useful in maintaining body weight.
- Limited evidence suggests that plant proteins, such as legumes, may also be beneficial in enhancing glycaemic control; plant polyphenols could also be protective.
- Eating more fruit, vegetables, legumes, whole grains, nuts and seeds and reducing the amount of energy-rich foods is a simple and easy way to improve blood glucose control and helps manage some of the risks associated with diabetes.

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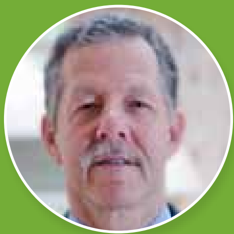
6

Chapter 6

More plant-based eating and cancer



PROF. MARK MESSINA,
Adjunct associated
professor, Dept. Nutrition
School of Public Health,
Loma Linda University
Loma Linda, CA (USA)

PROF. VIRGINIA MESSINA,
Adjunct assistant
professor, Dept. Nutrition
School of Public Health,
Loma Linda University
Loma Linda, CA (USA)

Introduction to Chapter 6, by invited experts Mark and Virginia Messina

"It is abundantly clear that the incidence of all the common cancers in humans is determined by various potentially controllable external factors. This is surely the most comforting fact to come out of cancer research, for it means that cancer is, in large part, a preventable disease."
National Research Council. Diet, Nutrition and Cancer. Washington DC: National Academy of Sciences, 1982.

Lifestyle is believed to have a significant effect on risk for most cancers. Observations from migration studies, changes in cancer rates over time within a population, and differences in cancer rates within the same genetic population living in different geographical regions, all lend support to the link between lifestyle and cancer risk. Within the past 35 yrs there has been a focus on diet as one part of lifestyle that may affect as much as 35% of cancer risk. As such, dietary guidelines issued by cancer organisations have generally focused on plant-based dietary patterns for the prevention of cancer.

However, a precise understanding of the impact of diet and individual foods on the risk of specific cancers has not been as forthcoming as hoped. For example, the World Cancer Research Fund/American Institute for Cancer Research acknowledged that the evidence in support of the cancer-protective effects of fruits and vegetables, previously believed to provide significant protection, was less robust in 2007 than it was 1997.

Furthermore, in comparison to other chronic diseases such as CHD and diabetes, the health advantages of plant-based diets are not nearly as evident when it comes to cancer. This may be due in part to the fact that cancer is not a single disease; it is actually different cancer types with different *etiologies. But a number of factors also contribute to the relatively poorer understanding of the link between diet and cancer.*

It is, for instance, possible that the impact of diet on cancer risk occurs early in life. For example, there is evidence that soya foods reduce risk of breast cancer only if exposure occurs during childhood and/or adolescence. This early exposure hypothesis may be particularly relevant to vegetarians, many of whom adopted their plant-based diet as adults. Most female vegetarians may not have introduced soya foods to their diets until adulthood and therefore may not reap the proposed cancer-protective benefits of soya foods.

Early dietary habits may be especially relevant since the transformation of a normal cell into a cancer cell and eventually a tumor is believed to usually take decades. While diet may impact this process at many different stages, this also means that only long-term vegetarians are likely to benefit from the protective effects of a plant-based diet. Epidemiologic studies often do not take early dietary habits into account.

The cancer process may also respond less robustly to dietary changes compared to other chronic diseases. For example, even minor weight loss markedly improves glucose control, which helps in the management and prevention of diabetes. Similarly, diets such as the Dietary Alternatives to Stop Hypertension have been shown to markedly lower BP, at least in some subsets of the population, which can dramatically reduce risk of stroke and myocardial infarction. There is now even clinical data showing that adoption of a Mediterranean diet reduces risk of stroke.

It is much more difficult to point to such dramatic examples of diet affecting cancer risk. In part, this is because of the lack of established biomarkers for cancer. Nevertheless, in many instances clinical trials that have included a dietary component have not affected the existing cancer biomarkers or even the progression of a pre-cancerous condition to cancer. This may simply mean that the vegetarian and plant-based diets consumed by these subjects are not different enough from the general population (or at least different enough from the non-vegetarian subjects in these studies, many of whom are healthier than the general population) to see robust effects.

Consider, for example, the relative modest difference in blood lipid levels between vegans and non-vegetarians in the European Prospective Investigation into Cancer-Oxford. The ratio of total cholesterol to HDL-C was only about 5% higher in non-vegetarians compared to vegans (3.52 vs 3.33). In contrast, the vegan portfolio diet was shown to lower LDL-C levels by 30%. Similarly, comprehensive lifestyle programs using very low-fat near-vegan diets have been shown to increase telomere length in a relatively short period of time.

Therefore, despite the uncertainty surrounding the relationship of diet to cancer and the somewhat disappointing evidence in support of plant-based diets, it is not unreasonable to continue to promote vegetarian and near-vegetarian diets for reducing cancer risk. This is particularly true since the benefits of plant-based diets for a number of other chronic diseases such as heart disease, diabetes, and obesity, are very well established. Furthermore, it is well established that vegans and vegetarians are leaner than their meat-eating counterparts and that obesity increases risk of several cancers. Also, red meat intake is associated with certain cancers.

Finally, the best available evidence suggests that plant-based diets are potentially advantageous for cancer survivors. The World Cancer Research Fund International recently concluded that there may be links between better survival of breast cancer patients and 1) healthy body weight 2) being physically active 3) eating foods containing fibre 4) eating foods containing soya and 5) a lower intake of total fat, especially SFA.

Chapter 6

More plant-based eating and cancer

The relationship between diet and cancer has been the subject of rigorous investigation for nearly forty years. Although much has been learned, progress has been slow in understanding this relationship and there is much that remains unknown. It is clear, however, that diets based on plant foods tend to be more beneficial for reducing cancer risk compared to typical Western diets.

Evidence for a role of diet in cancer risk

In 2012 there were an estimated 14.1 million cancer cases worldwide and that number is expected to increase to 24 million by 2035. Although the highest per capita rates are seen in Western countries such as Denmark,

Rank	Country	Rate	Rank	Country	Rate
1	Denmark	338.1	41	Montenegro	238.3
2	France (Metropolitan)	324.6	42	Kazakhstan	236.5
3	Australia	323.0	43	Bulgaria	234.8
4	Belgium	321.1	44	Poland	229.6
5	Norway	318.3	45	Romania	224.2
6	United States	318.0	46	Belarus	218.7
7	Ireland	307.9	47	Cuba	218.0
8	Korea	307.8	48	Japan	217.1
9	The Netherlands	304.8	49	Argentina	216.7
10	New Caledonia	297.9	50	Puerto Rico	211.1

Table 6.1: Age-standardized all cancer incidence per 100,000 for selected countries

Source: GLOBOCAN 2012 [1]

Australia and the United States (Table 6.1), 57% of all cancer cases occur in less developed countries.

The international variation in rates of specific cancers provide initial clues about the role that lifestyle plays in the development of this disease. Rates of breast cancer, the most common cancer in women worldwide, with nearly 1.7 million new cases diagnosed in 2012, are particularly revealing (Table 6.2). The low breast cancer rates in Japan, a country with a socioeconomic status comparable to Northern Europe, suggested early on that lifestyle factors played a role in the development of this cancer [2].

Country	Rate	Country	Rate
Belgium	109.40	Austria	69.90
France (Metropolitan)	99.70	Spain	61.00
The Netherlands	96.80	Singapore	59.90
Israel	96.80	Croatia	56.80
Ireland	93.90	Chinese Taipei	52.80
Denmark	89.10	Greece	44.80
United Kingdom	87.90	Japan	42.70
Italy	86.30	Chile	40.10
Sweden	82.70	India	22.90
Germany	81.80	Honduras	19.90
United States	76.00	Swaziland	9.90

Table 6.2: Age-adjusted breast cancer incidence rates per 100,000 women for selected countries for year 2008

Source: GLOBOCAN 2012 [1]

However, the more impressive initial epidemiologic evidence favouring environment over genetics, came from migration studies. Such studies show that rates of some of the most common cancers, including those of the stomach, colo-rectal, breast and prostate, can change over just one or two generations as people move to areas with different rates of cancer. For example, one study found Asian-American women born in the West had a breast cancer risk that was 60% higher than Asian-American women born in the East [3]. Furthermore, among those born in the West, risk was determined by whether their grandparents, especially grandmothers, were born in the East or the West. Asian-American women with three or four grandparents born in the West had a risk 50% higher than those with all grandparents born in the East.

Differences in cancer rates among the same genetic population living within different geographic regions of a country are also revealing. For example, breast cancer risk is approximately one-third lower among women who live their first 20 yrs of life in rural India compared to those living in urban areas [4]. Similarly, the age-adjusted breast cancer incidence rate is nearly twice as high in women living in urban compared to rural China [5].

Finally, changes in cancer rates within a country over relatively short time periods, much too short for genetic changes to have occurred, emphasize the importance of lifestyle. The rates of breast cancer in the Miyagi region of Japan increased more than three-fold over a recent forty year period [6]. Even more striking is the change in rates among Japanese-Americans. Age-adjusted incident rates of invasive breast cancer among this group increased from 69.5 to 114.3 per 100,000 women between 1988 and 1997 [7].

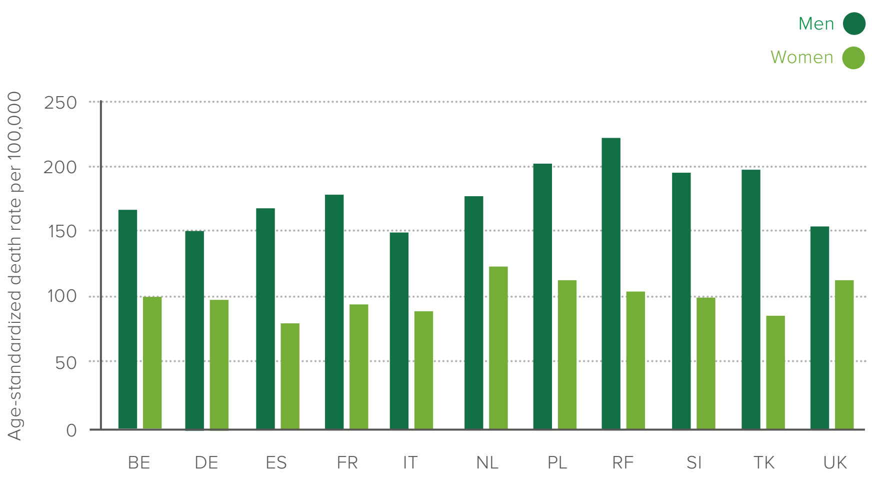


Figure 6.1: Age-standardized all cancer death rate per 100,000 for certain European countries

Source: WHO 2014 [8]

Cancer remains one of the main causes of non-communicable disease in Europe and is included in the first of the nine voluntary WHO non-communicable disease targets. The objective is to globally reduce mortality from non-communicable disease, including CVD, cancer, diabetes or chronic respiratory diseases, by 25% by 2025 [8]. In European countries typically 30 - 40% of deaths from non-communicable disease are from cancers; for age standardized death rates for certain European Countries (see Figure 6.1).

Historical perspective on the role of diet in cancer prevention

For more than a century, scientists have proposed that diet influences cancer risk, but the connection between diet and cancer did not gain widespread acceptance within the medical and scientific communities until the 1980s. It was at this time that a landmark review of factors believed to affect cancer risk was published [9]. This soon became a reference standard for assessing relative roles of lifestyle, environment and host factors as causes of cancer in the US population [9]. The report identified diet as the leading cause of cancer deaths, responsible for 35% of all cancers. Within just a few years it was commonly accepted that one-third of cancer cases was diet-related.

In 1997 the World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) produced their landmark report which estimated that 30 to 40% of cancer — or three to four million cancer cases per year worldwide — is preventable over time by appropriate diet, regular physical activity, and avoidance of obesity [10].

The estimates established in the 1980s have held up well according to a 2015 review [11]. However, the authors of this review also emphasized the considerable uncertainty associated with the contribution of diet to cancer risk, as the range associated with the 35% estimate was 10 to 70% [11]. Furthermore, they noted that while there have been many epidemiologic studies on diet and cancer over the past decades, the evidence for estimating the percentage of cancer associated with diet largely remains, as reported in 1981, “a chronic source of frustration and excitement to epidemiologists.”

Nevertheless, there is little dispute that environmental factors (diet, reproduction habits, lifestyle) are intimately involved in the development of cancer. In fact, since only 5 to 10% of all cancer cases can be attributed to genetic defects, it was concluded that 90 to 95% of cancer have their roots in the environment and lifestyle, and therefore can be prevented [13]. Diet appears to play a role even in risk for cancers stemming from inherited genetic mutations. This may be the case with mutations in the BRCA1 and BRCA2 genes, which raise risk for breast and ovarian cancer. Epidemiologic data indicate that women who carry these mutations have a lower risk of developing cancer if they consume soya foods [12, 13]. Dietary recommendations from the WCRF/AICR are to eat mostly foods of plant origin, limit intake of red meat and avoid processed meat [14].

Determining cancer risk

Part of the difficulty in understanding the connection between diet and cancer is the lack of well-established biomarkers. The US National Cancer Institute defines a biomarker as: "A biological molecule found in blood, other body fluids or tissues that is a sign of a normal or abnormal process, or of a condition or disease. A biomarker may be used to evaluate how well the body responds to a treatment for cancer as well as for establishing risk of developing cancer." Additional criteria for biomarkers include the following:

- Changes in biomarker should correlate with changes in the disease.
- Levels of biomarkers should be high enough that they can be measured easily and reliably.
- Levels or presence of biomarker should readily distinguish between normal, cancerous, and precancerous tissue.
- Effective treatment of the cancer should change the level of the biomarker.
- Level of the biomarker should not change spontaneously or in response to other factors not related to the successful treatment of the cancer.

Good biomarkers exist for a number of chronic diseases. Examples are blood cholesterol levels for CHD and bone mineral density for osteoporosis. Intervention trials that target these biomarkers can reasonably assess the effects of different treatments on disease risk. Furthermore, some biomarkers, such as BP and bone mineral density, are assessed non-invasively, an important attribute when conducting large scale clinical or epidemiologic studies. Both BP and cholesterol levels are also biomarkers that respond relatively quickly to dietary changes, which allows for short-term clinical trials using these parameters as outcomes.

Cancer is more difficult to assess, although biomarkers of this disease do exist. For example, mammographic density is a biomarker of breast cancer risk [15], and prostate specific antigen is a biomarker of prostate cancer risk [16], but each have important limitations.

Finally, markers of genomic stability and DNA methylation, damage and repair are also potential candidates as cancer biomarkers [17-19], and there is limited evidence these markers are favourably affected by vegetarian diets. In a small study, lacto-ovo-vegetarians showed slightly lower levels of oxidative DNA damage in lymphocytes, although genomic stability was unaffected [20, 21]. The effect of a vegetarian diet was also investigated in regard to DNA methylation, which is involved in gene regulation. No difference was found between 48 lacto-ovo-vegetarians and 23 vegans in one study [19], but buccal cells from 40 young vegetarians showed decreased promoter methylation and a 3-fold increase in expression of superoxide dismutase in comparison to 40 age-matched omnivores [22].

Components of vegetarian diets that may affect cancer risk

Assessing the relationship of vegetarian diets to cancer risk can be challenging. While different types of vegetarian diets share some common characteristics — namely the absence of animal flesh foods — there is considerable heterogeneity among plant-based dietary patterns. For example, even among lacto-ovo-vegetarians, the amount of dairy products and eggs consumed varies widely. The difficulty of accurately assessing dietary intake, regardless of the type of diet, is also increasingly being recognized. In fact, one team of researchers recently concluded that self-reports of energy intake and physical activity energy expenditure are so poor that they are wholly unacceptable for scientific research [23]. The length of time individuals have been following a vegetarian diet is also likely to affect cancer risk, a factor often not considered in epidemiologic studies.

Health authorities and organisations increasingly focus on understanding the relationship between "dietary patterns" and disease risk rather than singling out specific foods, food groups or dietary constituents [24]. So for example, greater emphasis is placed on the connection between the traditional Asian diet rather than soya foods, even though there is considerable support for a role of soya in reducing breast cancer risk [25, 26]. Nevertheless, there are certain specific aspects common to vegetarian diets that may be protective against cancer.

Antioxidants

Benefits of plant-based diets are often ascribed to the high antioxidant content of plant foods [27, 28]. A high antioxidant intake is believed to ameliorate oxidative stress, which may be a common factor in several chronic diseases [29]. Reactive oxygen species generated through normal oxidative metabolism have the potential to cause extensive DNA damage. The body has several mechanisms to prevent such damage occurring, or to block the effects.

Repair of damaged DNA results in urinary excretion of oxidized bases. Levels of urinary 8-hydroxy-2'-deoxyguanosine, an oxidative DNA damage adduct, can be used as an indicator of oxidative DNA damage in humans [30] and rodents. There is evidence that a Mediterranean diet reduces levels of oxidative DNA damage [31, 32] and that a plant-based diet might as well [33]. Evidence also suggests that the general oxidative status of vegetarians is better than that of meat eaters [34].

There are hundreds of antioxidants in foods, although much focus has been on vitamins C and E. In the Oxford arm of the European Prospective Investigation into Cancer and Nutrition (EPIC-Oxford), vegan vitamin C and E intake was approximately 30 and 36% higher, respectively, than that of meat eaters [35]. In contrast, in the Adventist Health Study2 (AHS-2), vitamin C and E intakes of vegans were similar to those of the non-vegetarians, which reflects the fact that the non-vegetarians in this cohort consumed a healthier diet than the general US population. On the other hand, in the AHS-2 intake of another antioxidant nutrient, beta-carotene was 50% higher in vegans compared to non-vegetarians [36].

Despite the benefits ascribed to antioxidants, many supplementation trials with isolated antioxidants have not shown improved clinical outcome [37-39]. This lack of benefit may be due in part to the complex nature of whole foods and the fact that supplementation with isolated antioxidants cannot reproduce the varied action of antioxidants in foods [40, 41]. Finally, it has been suggested that the benefits of antioxidants extend beyond simple increased radical scavenging [42]. For example, a variety of plant constituents can activate the signaling pathways that lead to activation of the antioxidant response element and upregulation of the expression of detoxifying enzymes [43].

Phytochemicals

While phytochemicals are not nutrients, it has been widely believed that the health benefits of diets high in fruits and vegetables are likely due in part to the presence of these compounds. However, in recent years evidence for the role of phytochemicals in promoting health and reducing disease risk has not been as robust as was anticipated when this field emerged in the 1980s.

For simplicity's sake, phytochemicals can be divided into three categories which include most of the phytochemicals. These are phenolic compounds, isoprenoids, and protein-amino acid based and/or sulphur containing compounds. The vast majority of phytochemicals are phenolics.

Phytochemicals exert biological effects through a number of mechanisms. Five of these mechanisms appear to be most important in relation to chronic diseases. These are:

1. antioxidant effects;
2. effects on xenobiotic metabolism;
3. hormonal-like effects (oestrogenic and anti-oestrogenic);
4. effects on signal transduction (proliferation and apoptosis) pathways;
5. anti-inflammatory and immune-stimulatory effects.

There are likely additive and synergistic effects of combinations of different phytochemicals and also between phytochemicals and nutrients. The effects of these interactions are not easy to predict from studies using isolated compounds. One reason it is difficult to accurately quantify phytochemical intake is that the phytochemical content of a food may differ according to plant variety and the environmental conditions under which the plant is grown. For example, there is a fourfold difference in flavonoid and phenolic acid content among different varieties of apples [44] and a comparable range for quercetin content between red and yellow onions [45]. Similarly, the isoflavone content of soya beans can vary fourfold [46]. Unfortunately, there is relatively little data on the phytochemical intake of vegetarians. Nevertheless, since people consuming plant-based diets are likely to consume more grains and beans in place of meat and possibly dairy, vegetarian phytochemical intake can be expected to be higher than that of omnivores.

Fibre

Much of the initial enthusiasm for the role of fibre in preventing colon cancer can be dated back to Dr. Denis P. Burkitt's work in Africa. Based on his experience as a medical missionary he suggested that many Western diseases which were rare in Africa were the result of diet and lifestyle. In 1974, he concluded that "In view of the evidence, it seems justifiable to issue a warning against the removal of so much of the unabsorbable fibre from our food, and the associated over-ingestion of refined carbohydrates" [47].

Soon thereafter dietary guidelines aimed at reducing cancer risk included a focus on fibre consumption. For example, in 1984 the US National Cancer Institute recommended that diets provide 25 to 35 g fibre/d [48]. At that time, fibre was believed to reduce the risk of not only colon cancer but also breast cancer, possibly by increasing faecal oestrogen excretion [49]. Currently, the WCRF/AICR recommends consuming relatively unprocessed grains and/or legumes, and other foods that are natural sources of dietary fibre, in order to achieve a population average of at least 25 g NSP [14]. While few Westerners meet this goal, people eating plant-based diets, typically have high fibre intakes (see Chapters 1 and 2).

Fibre and colorectal cancer

While higher fibre intakes may have a number of health benefits, the extent to which fibre protects against cancer remains unclear. A case in point are the results of an analysis that included 13 prospective cohort studies involving 725,628 men and women who were followed for 6 to 20 yrs during which time 8081 colorectal cancer cases were identified. While those in the highest fibre intake quintile had a 16% lower risk for colorectal cancer compared to those in the lowest quintile (pooled relative risk (RR), 0.84; 95% CI (0.77, 0.92)), the association was attenuated and was no longer statistically significant after adjusting for other risk factors (pooled multivariate RR, 0.94; 95% CI: 0.86, 1.03). Fibre intake from cereals, fruits, and vegetables was not associated with risk of colorectal cancer [50].

Two points are worth noting in regard to fibre and colon cancer. First, the Africans that Dr. Burkitt studied likely consumed more fibre than even Western vegans. In fact, he found that stool weight in Ugandan villagers was twice that of British vegetarians [51]. Second, it has been postulated that the low prevalence of colon cancer in black Africans cannot be explained by dietary "protective" factors such as fibre, Ca, vitamins A, C and folic acid, but instead is likely influenced by the absence of "aggressive" factors such as excess animal protein and fat, and by differences in colonic bacterial fermentation [52].

Fibre and breast cancer

A meta-analysis of 16 prospective studies found, when comparing the highest with lowest fibre intake, that the summary RR of breast cancer was 0.93; 95% CI (0.89, 0.98) for dietary fibre, 0.95 (0.86, 1.06) for fruit fibre, 0.99 (0.92, 1.07) for vegetable fibre, 0.96 (0.90, 1.02) for cereal fibre, 0.91 (0.84, 0.99) for soluble fibre and 0.95 (0.89, 1.02) for insoluble fibre. However, it is noteworthy that in stratified analyses an inverse association was observed among studies with a large range (≥13 g/d) or high level of intake (≥25 g/d) [53].

Fruits and vegetables

Plant-based diets are commonly perceived as being rich in fruits and vegetables and research shows that vegetarians do frequently have higher intakes of these foods than non-vegetarians (see Chapter 2). For example, in the AHS-2, vegans consumed approximately 50% more fruit (483.1 vs 298.8 g/d) and vegetables (424.1 vs 319.9 g/d) than non-vegetarians (Table 6.3). However, evidence for the protective effect of fruits and vegetables against cancer has weakened over the years.

According to the 2007 WCRF/AICR report on cancer, findings from cohort studies conducted since the mid-1990s have made the overall evidence

Food group	Type of vegetarians				Non-vegetarians	All participants[1]
	Vegan	Lacto-ovo-	Pesco-	Semi-		
Fruit	483.1	357.0	400.3	343.0	298.8	330.2
Vegetables	424.1	347.2	386.0	337.0	319.0	327.1
Legumes	84.4	73.4	75.2	65.5	52.5	62.0
Soya foods	202.9	166.4	172.6	136.2	88.1	125.2
Whole grains	292.8	214.0	210.6	197.8	157.9	187.3
Nuts and seeds	36.0	27.5	25.0	23.4	18.8	23.6

[1]Unadjusted values

Table 6.3: Mean values (g/d) adjusted for age, sex and race (black v. non-black) and standardized to a 8,368 kJ/d (2000 kcal/d) diet among participants in the Adventist Health Study-2

Source: Orlich [54]

that vegetables or fruits protect against cancer somewhat less impressive, and evidence of protection is not judged to be convincing [14]. It is possible, however, that certain types of vegetables, and that fruits in general, protect against a number of specific cancers.

The WCRF/AICR report suggests that non-starchy vegetables probably protect against cancers of the mouth, pharynx, and larynx, and those of the esophagus and stomach. Allium vegetables may protect against stomach cancer and garlic probably protects against colorectal cancer. Fruits in general probably protect against cancers of the mouth, pharynx, and larynx, and of the esophagus, lung, and stomach. In contrast, there is only limited evidence suggesting that fruits also protect against cancers of the nasopharynx, pancreas, liver and colorectum.

It is worthwhile to consider evidence published subsequent to the WCRF/AICR report. For example, a meta-analysis of 15 prospective epidemiologic studies found that fruits and vegetables combined and fruits alone were associated with lower breast cancer risk, but there was no statistically significant association for vegetables alone [53]. Summary RRs (95% CI) for the highest versus the lowest intake was 0.89 (0.80, 0.99) for fruits and vegetables combined, 0.92 (0.86, 0.98) for fruits, and 0.99 (0.92, 1.06) for vegetables. In dose-response analyses the summary RR (95% CI) per 200 g/d was 0.96 (0.93, 1.00) for fruits and vegetables combined, 0.94 (0.89, 1.00) for fruits, and 1.00 (0.95, 1.06) for vegetables [53].

In another large analysis, which involved 756,217 men and women who were followed for between 6 and 20 yrs, associations between fruit and vegetable intake and colon cancer risk were in most instances not statistically significant [55]. Pooled multivariable RRs (95% CIs) for colon cancer for the highest versus lowest intake quintiles were 0.91 (0.82, 1.01) for total fruits and vegetables, 0.93 (0.85, 1.02) for total fruits, and 0.94 (0.86, 1.02) for total vegetables [55]. During the follow up period, 5838 participants were diagnosed with colon cancer. When analysed by colon site, the pooled multivariable RRs (95% CIs) comparing total fruit and vegetable intakes of 800 g or more versus less than 200 g/d were 0.74 (0.57, 0.95) for distal colon cancers and 1.02 (0.82, 1.27) for proximal colon cancers. Similar site-specific associations were observed for total fruits and total vegetables.

There also appears to be no relationship between fruit and vegetable intake and risk of prostate cancer. In the EPIC study, after an average follow up of 4.8 yrs, during which time 1104 incident cases of prostate cancer were identified, no significant associations between fruit and vegetable consumption and prostate cancer risk were observed [56]. RRs (95% CI) in the top fifth of the distribution of consumption, compared to the bottom fifth, were 1.06 (0.84, 1.34) for total fruits, 1.00 (0.81, 1.22) for total vegetables and 1.00 (0.79, 1.26) for total fruits and vegetables combined and intake of cruciferous vegetables was not associated with risk [56]. There was a wide range in consumption of fruits and vegetables: mean intakes (g/d) in the bottom and top fifths of the distribution, as estimated from 24-hr recalls in a subsample of participants, were 53.2 and 410.7 for fruits, 97.1 and 242.1 for vegetables and 169.0 and 633.7 for fruits and vegetables combined. These results agree with a large prospective study from Japan [57].

Meat and cancer risk

The connection between meat and cancer risk is also not as strong as once thought. According to the 2007 WCRF/AICR report there is convincing evidence that red and processed meat increases risk of cancer of the colorectum, but there is only limited evidence that both increase risk of cancer of the esophagus and lung, and only limited evidence that red meat increases risk of pancreatic and endometrial cancer and that processed meat increases risk of stomach and prostate cancer [14].

Furthermore, despite the convincing conclusion reached by the WCRF/ AICR in 2007, a 2010 meta-analysis concluded that “the currently available epidemiologic evidence is not sufficient to support a clear and unequivocal independent positive association between processed meat consumption and colorectal cancer” [58]. Summary RR (95% CI) estimates for high versus low processed meat intake for men were 1.23 (1.07, 1.42) and for women 1.05 (0.94, 1.16), based on nine and 13 studies, respectively. A meta-analysis published in that same year did find that consuming over 50 g of red meat/d increased risk of colon (RR, 1.21; 95% CI: 1.07, 1.37) but not rectal (RR, 1.30; 95% CI: 0.90, 1.89) cancer [59]. However, red meat intake more frequently than once a day increased risk of both colon and rectal cancer (RR, 1.37; 95% CI: 1.09, 1.71). Other recent meta-analyses have failed to find associations between red or processed meat intake and risk of prostate [60] and breast cancer [61]. Finally, a meta-analysis which included seven studies found that processed but not red meat increased risk of ovarian cancer [62].

Obesity and Cancer

According to the US National Cancer Institute obesity is associated with increased risks of cancers of the oesophagus, breast (postmenopausal), endometrium (the lining of the uterus), colon and rectum, kidney, pancreas, thyroid, gall bladder, and possibly other cancer types. One study, using National Cancer Institute Surveillance, Epidemiology, and End Results (SEER) data, estimated that in 2007 in the United States about 34,000 new cases of cancer in men (4%) and 50,500 in women (7%) were due to obesity. The percentage of cases attributed to obesity varied widely for different cancer types but was as high as 40% for some cancers, particularly endometrial cancer and oesophageal adenocarcinoma [63].

The WCRF/AICR in 2007 concluded that there was convincing evidence for an association of obesity with cancers of the pancreas and rectum (as well as colon), and a probable association with cancers of the gall bladder [14]. It now appears that liver cancer can also be added to the list. An analysis by the WCRF/AICR Continuous Update Project (CUP) found "strong evidence" linking higher BMI to increased risk for liver cancer [64].

Cancer Research UK concludes that 1 in 20 cancers in the UK are linked to weight [65]. More specifically, an estimated 17,294 excess cancer cases occurring in 2010 were due to overweight and obesity (5.5% of all cancers). The sites contributing most to this excess are large bowel (5172) and breast (4194) [66].

Most studies have linked plant-based diets with a lower risk for obesity and overweight and with better weight management and lower average BMI compared to non-vegetarians (see Chapter 4).

Cancer rates and mortality in vegetarians

In North America the only large scale studies of vegetarians have involved members of the Seventh-day Adventist (SDA) church. Adventists are less likely to use tobacco or alcohol and are more likely to be vegetarian or to eat less meat compared to the general population. As a result, there has been considerable interest in their health and risk for chronic disease.

Adventist Health Studies

The first major study of SDAs in 1958 was the Adventist Mortality Study, a prospective study of 22,940 California SDAs. It entailed an intensive 5-yr follow-up and a more informal 25-yr follow-up period [67]. During the first period a similar study was being conducted by the American Cancer Society (ACS) which also focused on participants who were generally healthier and, like SDAs, better educated on average than the general population. Cancer mortality rates were lower for SDA men and women compared to their ACS counterparts. SDAs had a much lower risk of death from lung cancer which remained after adjusting for smoking. They were also less likely to die from colorectal, breast cancer, or prostate cancer [68].

In 1974, the Adventist Health Study-1 (AHS-1) began as an effort to determine which components of the Adventist lifestyle were responsible for protection from disease [69]. This study included a much more detailed investigation of diet and began as a cancer investigation. This prospective study included 34,198 non-Hispanic whites who were members of the Adventist church and whose average age was 51 yrs for men and 53 yrs for women. Diet was an important part of the investigation since it was believed that the lower meat intake of Adventists might account in part for the lower cancer mortality found in the Adventist Mortality Study.

Findings from the AHS-1 have shown certain fairly clear indications of associations between diet and cancer, mainly for cancers of the lung, stomach, pancreas, colon and bladder. For example, those who consumed fruit more than once per day were about 25% less likely to develop lung cancer compared to those who ate fruit less than three times per week. Risk for stomach cancer was also lower among frequent fruit consumers [69]. Pancreatic cancer mortality was strikingly lower among frequent consumers of legumes, vegetarian protein products and dried fruits [70]. Both red and white meat intake was associated with higher risk for colon cancer [71]. Compared to meat eaters, vegetarians had a 47% lower risk for colon cancer (RR, 0.53; 95% CI: 0.35, 0.81) and a 35% lower risk of prostate cancer (RR, 0.65; 95% CI: 0.44, 0.95) [72].

Efforts to better understand effects of vegetarian diets on disease risk, including cancer, were undertaken with establishment in 2002 of the much larger AHS-2. This prospective cohort study enrolled 96,354 adult Adventists from Canada and from every state in the United States. Participants filled out a validated self-administered food frequency questionnaire that contained a list of more than 200 food items. Based on the findings, participants were classified into five dietary groups: non-vegetarian, semi-vegetarian, pesco-vegetarian, lacto-ovo-vegetarian and vegan [72].

Data from 69,120 of the AHS-2 participants from 38 states found a statistically significant lower risk for all cancers combined in vegetarians compared to non-vegetarians [73]. Over an average follow-up of 4.14 yrs, 2939 cancer cases were identified. The multivariate hazard ratio (HR) for overall cancer risk among all vegetarians, which included lacto-ovo-vegetarians, vegans, pesco-vegetarians and semi-vegetarians, compared with non-vegetarians was statistically significant (HR, 0.92; 95% CI: 0.85, 0.99) for both genders combined when adjusted for race, family history of cancer, education, smoking, alcohol, age at menarche, pregnancies, breastfeeding, use of oral contraceptives, hormone replacement therapy, and menopause status. When sub-analyzing the data to determine risk associated with specific dietary patterns, vegan diets showed even greater reductions in overall cancer incidence (HR, 0.84; 95% CI: 0.72, 0.99) in both genders combined and for female-specific cancers (HR, 0.66; 95% CI: 0.47, 0.92).

With regard to cancer sites, a statistically significant association was found between vegetarian diet (all types combined) and cancers of the gastrointestinal tract (HR, 0.76; 95% CI: 0.63, 0.90). In the analysis of specific types of vegetarian diets, only lacto-ovo-vegetarian diets were associated with decreased risk of cancers of the gastrointestinal system (HR, 0.75; 95% CI, 0.60, 0.92).

A longer follow-up of 7.3 yrs involving 77,659 participants enrolled in the AHS-2 found a lower risk for colon cancer among vegetarians when all four of the vegetarian patterns were combined [74]. The adjusted HRs (95% CI) among vegetarians versus non-vegetarians were 0.78 (0.64, 0.95) for colorectal cancer and 0.81 (0.65, 1.00) for colon cancer. A lower risk for rectal cancer was also found, but the finding was not statistically significant. Of the different vegetarian groups only the pesco-vegetarians had a statistically significant lower risk for colorectal cancer (HR, 0.57; 95% CI: 0.40, 0.82) in comparison with non-vegetarians. In an investigation of all-cause mortality which included 73,308 participants in the AHS-2, mortality was lower in vegetarians compared to non-vegetarians, but there was no clear reduction in risk of death from cancer after a mean follow-up of 5.79 yrs [75].

European studies

While the AHSs have been the only large scale research to look at disease rates in North American vegetarians, a number of studies have examined cancer rates in British vegetarians. Of these, the largest is the EPIC-Oxford. The EPIC-Oxford includes 65,000 subjects who were enrolled between 1993 and 1999 and was designed to recruit as many vegetarians and vegans as possible. The first results from EPIC-Oxford found no significant difference in breast cancer risk between vegetarians (defined as those women who ate no meat or fish) and non-vegetarians and found a surprisingly higher risk for colon cancer in the vegetarians [76].

An earlier study of cancer rates in vegetarians was The Oxford Vegetarian Study, a cohort of 11,045 individuals recruited between 1980 and 1984 through the Vegetarian Society of the UK and the news media. Non-vegetarians were recruited by the vegetarian participants from among their friends and relatives. Approximately 42% (4674) of the participants were vegetarian. After a mean follow-up of 17.6 yrs, rates of death from cancer were similar in the vegetarians and non-vegetarians [77]. A later study of this population found moderately lower rates of colon cancer in vegetarians but the findings were not statistically significant and the association became weaker after adjusting for smoking and alcohol consumption [78]. However, pooled data from EPIC-Oxford and the Oxford Vegetarian Study with a follow-up of nearly 15 yrs found that both lacto-ovo-vegetarians and vegans had lower rates of cancer. Lacto-ovo-vegetarians had an 11% lower risk of cancer compared to non-vegetarians (RR, 0.89; 95% CI: 0.83, 0.96) and vegans had a 19% lower risk (RR, 0.81; 95% CI: 0.66, 0.98) [79]. There were no statistically significant differences in any one type of cancer.

Prior to the AHS and the EPIC-Oxford, a number of smaller studies had investigated the relationship of vegetarian diet to cancer. For example, findings from a small study of members of a vegetarian society were published in 1983. The researchers compared cancer mortality in 759 individuals who had joined vegetarian societies before 1950 and compared rates to expected numbers calculated from mortality rates for England and Wales. Breast cancer rates were higher among the vegetarian society members than in the general population (24 vs 10.79, $P<0.001$) while rates of bladder cancer were lower (1 vs 4.05, $P<0.05$). Surprisingly, overall cancer rates were higher among the vegetarians (146 compared to 122.2, expected $P<0.05$). One explanation may be that some individuals with cancer became vegetarian after a diagnosis of their disease. However, it was also not clear that all members of the vegetarian society were vegetarian in practice [80].

The Health Food Shoppers Study recruited participants between 1973 and 1979 from customers of health food shops, members of vegetarian societies and readers of health-related magazines. The study included 10,736 subjects of whom 4600 (43%) were vegetarian. Mean follow-up was 18.7 yrs. Although overall mortality was lower compared to the general population, there was little difference in cancer death rates between the vegetarians and non-vegetarians probably because both groups engaged in overall healthy habits. After adjustments for smoking and excluding the first five years of follow-up, vegetarians had a statistically significant higher risk of death from breast cancer (RR 1.62; 95% CI: 1.01, 2.60) [77].

A study in Germany also compared vegetarians to health conscious non-vegetarians. The Heidelberg Study began in 1978 and participants were followed for 21 yrs to compare mortality between the groups. Of the 1904 participants, 3% were vegan and slightly more than 60% were lacto-ovo-vegetarians. Although the rest were non-vegetarian, they were actually referred to as "moderate vegetarians," since their meat intake was low. Given the healthy lifestyles of all of the participants in this study, it is not surprising that there was no difference in cancer mortality between the vegetarians and non-vegetarians [81].

Syntheses and meta-analyes of studies

Cancer mortality was also assessed through a collaborative analysis of five studies: Adventist Mortality, AHS-1, The Heidelberg Study, The Health Food Shoppers Study, and the Oxford Vegetarian Study. The investigators found no evidence of a protective effect of vegetarian diets against any of the cancers studied which included cancers of the stomach, colorectum, breast, prostate, and lung [82].

Finally, there are the results of a recent meta-analysis which included a total of 124,706 participants and seven studies: EPIC-Oxford, AHS-1, the Heidelberg Study, a study of Dutch Seventh-day Adventists, the Health Food Shoppers Study, the Oxford Vegetarian Study, and a study of Japanese male Zen priests. Vegetarians had a statistically significant 18% lower risk of cancer incidence compared to non-vegetarians (RR, 0.82; 95% CI: 0.67, 0.97) [83]. A weakness of this meta-analysis was that semi-vegetarians were included as "vegetarians" in some of the studies and as "non-vegetarians" in others.

Conclusions

There is general agreement that lifestyle, including diet, impacts risk of cancer, although the extent to which this is true varies greatly among specific types of cancer. However, it is also clear that a precise understanding of the relationship between diet and risk of specific cancers remains elusive. In part, this uncertainty results from the lack of convenient, well-established biomarkers. Nevertheless, it is clear that plant-based dietary patterns conform more closely to dietary recommendations aimed at reducing cancer risk in comparison to typical Western diets. On the other hand, so far epidemiologic studies have not shown impressive differences in cancer rates between vegetarians and non-vegetarians. Still, since plant-based diets are associated with overall health benefits, the lack of robust data in support of cancer-protective effects should not dissuade health-conscious individuals from following a plant-based dietary pattern.

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Take-home messages:

- Cancer remains one of the main causes of non-communicable disease in Europe, typically 30 - 40% of death from non-communicable disease are from cancers.
- Lifestyle, including diet, impacts risk of cancer, although the extent to which this is true varies greatly among specific types of cancer.
- Plant-based dietary patterns conform more closely to dietary recommendations aimed at reducing cancer risk in comparison to typical Western diets.
- People following plant-based eating tend to be less obese and have better weight management, of importance as obesity has been positively associated with a number of cancers.
- A varied diet with increased consumption of fruits, vegetables, legumes, whole grains and nuts, and adequate intakes of calcium, vitamin B12 and D, as well as regular and physical activity are important components of a healthy lifestyle.

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7

Chapter 7

More plant-based eating and healthy bones

PROF. AMY JOY LANOU
Department of Health and Wellness, University of North Carolina Asheville, USA

Introduction to Chapter 7, by invited expert Amy Joy Lanou

In Chapter 07 Harland and Garton provide a thorough review of the current literature on plant-based diets and bone health. They come to the clear and helpful conclusions that 1) achieving optimal bone health in childhood and adolescence is important to keep bones healthy throughout life (WHO also supports this); 2) healthy plant-based eating patterns support normal bone growth; 3) increasing fruit and vegetable consumption may make a positive contribution to bone health; and 4) specific plant foods such as those containing soya isoflavones may help to reduce bone loss in later life.

Readers are cautioned against using typical omnivorous dietary patterns (high in calories from animal sources and low in calories from plant sources) as a standard to which we compare plant-based, vegetarian and vegan diets with respect to bone health. Current and traditional diets in countries of moderate to high wealth, such as countries in the European Union, Australia and the United States, are very rich in foods from animal sources and also have some of the highest incidence of osteoporosis [1]. Epidemiological studies provide evidence that diets richer in protein from animal sources are associated with increased risk of fracture in later life suggesting vegetarian, vegan or other plant-based diets limited in foods containing animal protein may be protective. Consistent with the evidence offered in the chapter, diets richer in protein from plant sources are associated with decreased risk of hip fracture in later life [2]. As the authors state, meeting protein needs (0.8 to 1.0 g/kg BW) is necessary for the maintenance of healthy bones. Keep in mind though, that additional dietary protein, especially from animal sources, is not likely to offer additional benefit and may even be deleterious to bones and other body systems, especially at intakes more than twice the recommended amount [3].

What seems clear is that the important focus for studies investigating dietary patterns and bone health should be to find the nutritional factors that support bone strength and reduce bone loss for individuals across all dietary habits. We would do well to turn our attention to overall nutrient density rather than focus on specific nutrients found in highest amounts in the dietary patterns of meat and dairy consuming countries.

As recommended by the authors, individuals need to consume sufficient Ca, but the amount that is considered sufficient is still an important question. Certainly, at least 525 mg for adults, as indicated in the EPIC-Oxford cohort, is recommended. However, twice this amount as suggested in the US guidelines (1000 mg/d for most population groups) is potentially problematic. The Recommended Nutrient Intake of 700 mg/d as in the UK guidelines, and the recent EFSA adult recommendation of 750 mg/d [4], may be a bit high, but is reasonable based on the literature.

The source of the Ca, or the dietary pattern in which the Ca is consumed, may influence the amount "needed" and so there are potential risks of setting Ca requirements too high. For example, RCT doubling Ca intake from cow's milk in youths (pre-teenagers through to young adults) have demonstrated limited or no benefit of increasing Ca consumption above intakes of 500-600 mg/d [5]. Furthermore Ca absorption from beans and other legumes, as well as cruciferous vegetables, are considerably higher than that from dairy products or supplemental Ca.

It would be prudent to set a modest range for healthy Ca values. Supplemental intakes of 1000 mg and higher (as has been typically recommended for postmenopausal women) has been associated with an increased risk of cardiac events in postmenopausal women [6]. Also, high intake of Ca from cow's milk (2.5 or more cups/d (i.e. >600 mL/d); the equivalent to about 700 or more mg/d) is associated with an increased risk of prostate cancer among adult men [7].

Evidence for modest levels of weight-bearing exercise and the promotion of bone health is unequivocal: well over 80% of studies addressing the relationship between exercise and bone health demonstrate a positive benefit. While 60 minutes (as recommended by the authors and many *governments) may be necessary for CV health and maintaining a healthy body weight, numerous studies indicate that 30 min daily of regular physical activity (walking, dancing, gardening, jogging, working on one's feet, etc.) are sufficient to stimulate new bone formation or bone cell regeneration [8]. Two types of activities that do not demonstrate these bone strengthening benefits are cycling (stationary and on-road) and swimming, neither of which stress the bones of the spine and hips sufficiently for the prevention of bone loss in these areas.*

Evidence for the mechanisms of increased Ca excretion with acid-forming dietary patterns (those high in animal protein and low in fruits and vegetables) is considered controversial. Yet it remains paradoxical that populations consuming the highest intakes of animal protein also have the highest rates of hip fracture in later life. It is possible that the absence of the additive benefits of plant foods (alkaline-forming, rich in important nutrients and phytochemicals) and the replacement of foods that tend to increase Ca loss from the body (especially protein from animal sources) taken together explain this paradox.

Vegan, vegetarian and other plant-based diets are health promoting, and just as with omnivorous dietary patterns they must be nutrient-dense (i.e. nutritionally adequate) and consumed near to calorie requirements in order to support bone growth in early life, and to mitigate bone loss and resulting fractures later in life. It is also important to acknowledge other nutrients found in abundance in foods from plant sources (less well studied) are likely to be of importance for optimal bone health throughout life, including vitamin K, vitamin C, potassium, magnesium and boron [8]. Replacing meat and dairy products with soya foods and other legumes, and focusing on plant-based sources of Ca (especially, legumes and cruciferous vegetables) will go a long way to supporting bone health throughout life. Adding in some time in the sunshine, or a dietary or supplemental source of vitamin D to maintain a healthy vitamin D status, as well as walking or participating in other activities lasting at least 30 min/d, would solve the Ca paradox and maintain skeletal health.

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Chapter 7

More plant-based eating and healthy bones

Challenge of bone health in Europe

Poor bone health in Western Society does not usually manifest itself until later life (unless there are nutrient deficiencies or extreme malnutrition) when the number of fractures, particularly osteoporotic fractures, increases in adults over 50. Osteoporosis, or brittle bone disease, is defined as a metabolic bone disease that has two principal characteristics: low bone mass (BM) and deterioration in the architecture of bone tissue. Both factors lead to enhanced bone fragility and a consequent increase in fracture risk. Onset of osteoporosis generally occurs in women after the menopause and men over 50 yrs, although it can also affect the younger.

Worldwide variation in the incidence and prevalence of osteoporosis is difficult to determine because of problems with definition and diagnosis. The most useful way of comparing osteoporosis prevalence between populations is to use fracture rates in older people. However, because osteoporosis is usually not life-threatening, quantitative data from developing countries are scarce. The current consensus is that in Western society at least one in three women and one in five men will suffer an osteoporotic fracture in their life. Worldwide this equates to 1.66 million hip fractures each yr (80% of which will be in women) and the incidence of fracture is set to increase four-fold by 2050 due to the increasing number of older people in society [1]. Also, the age-adjusted incidence rates are many times higher in affluent developed countries than in less developed regions of the world. In the year 2000, it was estimated that in the WHO European region there were over 3 million osteoporotic fractures, representing over one third of the total worldwide [1].

About bone

Bone is a dynamic living tissue which is constantly being renewed by two types of cells: osteoblasts (build up new bone) and osteoclasts (break down old bone). Osteoblasts make a protein mixture, osteoid, which mineralizes to become bone. Osteoblasts also produce hormones, the prostaglandins, which act on the bone itself. Osteoclasts are the cells that break down bone and are responsible for bone resorption. Bone formation and bone loss takes place throughout life, although at different rates and at different times. Up to the age of about 30, new bone is made faster than old bone is broken down resulting in an increase in BM. Thereafter, healthy men and premenopausal women lose 0.3-0.4% bone/yr.

Bone mass is an important indicator of bone strength. While BM is not the only indicator of strength, the relationship between mass, density and strength of bones is important for all ages [2]. Many factors are known to affect BM accumulated during growth, with genetic and inherited factors of major importance, accounting for approximately 75% of the variation between individuals. Gender, dietary components, hormonal factors, physical activity and body weight also play an important role and account for approx 25% of the variation.

Peak bone mass (PBM) or optimal bone mass is when the full genetic potential for bone strength is achieved. It is essential that this is attained in childhood and adolescence, see Figure 7.1. Storing plenty of bone during these years puts the skeleton in a better position to withstand the bone loss that occurs in later years. A number of reviews have made clear associations between PBM attained prior to adulthood and PBM in later life. Higher PBM is associated with a reduced risk of osteoporosis and osteoporotic fractures in later life [2, 3]. Hence two critical times for bone health are identified, during early life through to the attainment of PBM and in later life when the emphasis is to maintain BM.

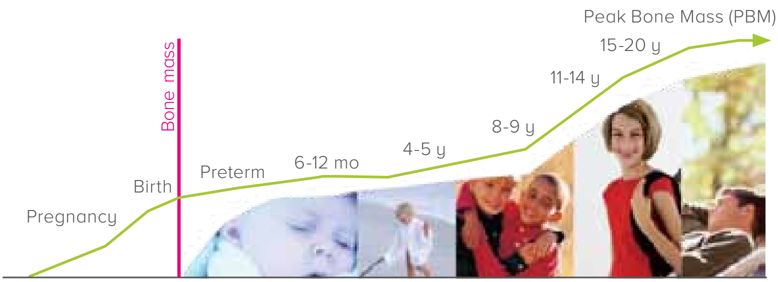

Figure 7.1: Peak bone mass achievement throughout life

Source: Based on Atkinson, McMaster University 2005

Maintaining healthy bones

In order to maximize bone health throughout life WHO have identified it is important to:

1. achieve the highest possible bone mass during the time of growth - childhood through to early adulthood;
2. maintain bone health in early adulthood; and
3. reduce the rate of bone loss in later life [4].

Bone health throughout life is highly dependent on PBM status achieved in young adulthood; 90% of PBM occurs by the age of 18 in girls and 20 yrs in boys (when growth ceases). Bone density continues to increase slowly until people are in their mid to late 20s. At this point the balance between bone loss and bone formation stays stable, see Figure 7.1.

Nutrients important for bone health

Adequate calcium (Ca) intake and vitamin D status [assessed by serum 25 hydroxy vitamin D (25-OHD)] in children and adolescents, is required for optimal bone health throughout the lifecycle [5].

Calcium

All living cells require Ca to survive, but the majority (99%) of Ca is found in bones and teeth with the remainder in soft tissues and body fluids. Intakes of Ca are a concern among certain groups of the population, e.g. a high proportion of teenage boys and girls (12%) in the UK fail to meet the lower reference nutrient intake (LRNI) for Ca [6]. While more recent UK data indicates that 17% of 11-24 yr-old females fail to meet the LRNI [7], see Chapter 1 for further detail. Chronic Ca deficiency, resulting from inadequate intake or poor intestinal absorption, is one of several important causes of reduced BM and osteoporosis. It is vital, therefore, that adequate dietary Ca is consumed at all stages of life, with both the amount of Ca in the diet and its bioavailability being important.

Vitamin D

Vitamin D, either in the form of ergocalciferol (vitamin D2) derived by ultraviolet (UV) irradiation of ergosterol, which is distributed in plants and fungi, or cholecalciferol (vitamin D3) which is formed from the effect of UV irradiation on the skin, is essential for bone health. Its principal role is to maintain Ca ion homeostasis and it is closely related to the actions of parathyroid hormone (PTH). In adults, low 25-OHD status can result in secondary hyperparathyroidism with increased circulating PTH. Elevated PTH levels accelerate bone resorption leading to an increased risk of osteoporosis and fractures. Optimal 25-OHD status is reached when PTH values plateau at 25-OHD concentration at $\geq$75 nmol/L for adults. In children and adolescents it has been suggested that serum 25(OH)D <25 nmol/l and <50 nmol/L are regarded as subclinical vitamin D deficiency and insufficiency respectively, and that in excess of 70 nmol/L is required for adequacy. Target level in children and adolescents is 50 nmol/L.

There is increasing evidence of vitamin D inadequacy in certain sectors of the population, including those who do not expose their skin to sunlight either for religious or cultural reasons, or concerns about skin health. For example, an increased risk of vitamin D deficiency in all age/sex groups in first four years (2008 - 2011) of the NDNS Rolling programme was reported [7]; year-round, the proportion of children with a serum 25-OHD concentration below 25nmol/L ranged from 7.5% for children aged 1.5-3 yrs to 24.4% for girls aged 11-18 yrs and for adults this ranged from 16.9% and 24.1% for men and women aged 65 yrs, respectively. A recently conducted review of standardized European Dietary Surveys also reached similar conclusions [8], see Chapter 1.

Protein

Modifiable dietary and lifestyle factors will influence whether the genetic potential for PBM is achieved. As well as physical activity, Ca intake and vitamin D status [2, 9], adequate protein intake and an appropriate energy intake are also important factors. Whether more protein is advantageous or detrimental remains controversial. Excess dietary protein increases urinary Ca excretion and has the potential to cause negative Ca balance, leading to bone loss and osteoporosis. Furthermore high protein diets produce acid residues which create an acidic environment. Osteoclasts are stimulated by acidic environment and so break down bone in order to correct pH levels. Overall results from studies are inconsistent as to whether high (or excess) protein intake is protective or detrimental to bone health. However, protein adequacy has been shown to be beneficial to bone health. This is also illustrated by the approved EFSA health claims: “Protein is needed for normal growth and development of bone in children" and "Protein contributes to the maintenance of normal bones".

The strength of evidence linking diet to osteoporotic fractures, see Table 7.1 [10].

Evidence	Decreased risk	No relationship	Increased risk
Convincing Older People[a]	Vitamin D Calcium Physical activity		High alcohol intake Low body weight
Probable Older People[a]		Fluoride[b]	
Possible	Fruits and vegetables[c] Moderate alcohol intake Soya products	Phosphorus	High sodium intake Low protein intake (in older people) High protein intake

a: In populations with high fracture incidence only. Applies to men and women older than 50-60 yrs, with a low calcium intake and/or poor vitamin D status.

b: At levels used to fluoridate water supplies. High fluoride intake causes fluorosis and may also alter bone matrix.

c: Several components of fruits and vegetables are associated with a decreased risk at levels of intake within the normal range of consumption (e.g. alkalinity, vitamin K, phytoestrogens, potassium, magnesium, boron). Vitamin C deficiency (scurvy) results in osteopenic bone disease.

Table 7.1: Summary of strength of evidence linking diet to osteoporotic fractures

Source: Prentice 2004 [10]

Recommendations for promoting bone health

Dietary recommendations for promoting bone health are based on the 2004 WHO Report updated in 2014 [11, 12]. These recommend that at a population and individual level the target should be to:

- achieve energy balance and a healthy weight (physical activity is a key determinant of energy expenditure, and thus is fundamental to energy balance and weight control);

- limit energy intake from total fats and shift fat consumption away from SFA to UFA and towards the elimination of trans fatty acids;
- increase consumption of fruits and vegetables, and legumes, whole grains and nuts;
- limit the intake of sugars and limit salt (sodium) consumption from all sources and ensure that salt is iodized.

Other nutrients and dietary factors have been identified as being important for long-term bone health and the prevention of osteoporosis. Specifically many of the essential micronutrients suggested to be involved with skeletal health including, zinc, magnesium, copper, manganese, boron, vitamin A, vitamin C, vitamin K, the B vitamins, potassium and sodium [13]. However, evidence from physiological and clinical studies is largely lacking and the data is often difficult to interpret.

WHO have identified physical activity as also being important for bone health (www.who.int/mediacentre/factsheets/fs385/en/) and they suggest that:

1. children and youths aged 5–17 should undertake at least 60 min of moderate-to vigorous-intensity physical activity daily;
2. physical activity greater than 60 mins provides additional health benefits;
3. most of the daily physical activity should be aerobic. Vigorous-intensity activities should also be incorporated, including those that strengthen muscle and bone, at least 3 times per wk.

It has been further suggested that the benefits of being physically active outweigh any potential harms. Any existing risk can be reduced by gradually increasing activity level, especially in children and young people who are inactive. Many of the food based dietary guidelines, such as the WHO Food Pyramid, include reference to physical activity, see Chapter 1.

Plant-based eating in relation to bone health

There are possible benefits of fruit and vegetable consumption for bone health as identified in Table 7.1. More broadly, consuming plant-based or vegetarian diets may be important for bone health, as characteristics associated with plant-based diets are a healthy body weight and active lifestyle (see Chapter 4), both of which are also beneficial for bone health.

Nevertheless, there has been concern expressed that moving towards a plant-based eating regime would result in deficiencies in particular nutrients, specifically protein, zinc, iron, vitamin B12, vitamin D and Ca [14-16]. However, evidence that this need not be the case, and the proposal that meat is an optional rather than an essential constituent of human diets, is provided by an extensive review [17] and American Dietetic Association (ADA) recommendations for vegetarian diets [18] (see Chapter 2). Despite these opinions, there is no doubt that many people are concerned about the ability of plant-based eating to provide sufficient Ca, due to the strong link between Ca and dairy foods. While the nutrient adequacy of plant-based eating has been discussed in detail in Chapter 2, the findings related to Ca intake and bone health will also be included in the following sections.

Scientific evidence

Generally observational studies provide information about dietary patterns, rather than plant-based eating *per se,* and BMD or bone mineral content (BMC). Furthermore, because bone growth and development occur over a long period of time, this type of study provides the majority of evidence relating to diet and bone health. Short term RCTs are relatively few in number and can often only address aspects of diet and markers of bone growth, turnover, or loss of bone. Longer term RCT's are generally conducted in postmenopausal women and may, by using dual-energy x-ray techniques (DXA), measure bone loss over time. Ideally these studies should be a minimum of two years duration and, as such, are expensive to conduct and consequently are again few in number.

Observational studies

Most of the observational studies identified, measure an association between a marker of bone health, usually BMD or resorption markers, and plant-based eating, often defined by use of a surrogate marker to determine status, e.g. silicon (Si) or flavonoids, or will define the diets as lacto-vegetarian, vegetarian or vegan diets. An additional complication is that bone health is measured at a number of sites, e.g. BMD or BMC are generally measured in bones from the spine, hip or leg, but it may also be in the arm or wrist bones. As the various bones grow and turnover at different rates, it is only valid to make comparisons between measurements taken at the same site.

EPIC cohort data

In the EPIC-Oxford cohort [19], data was obtained from 7947 men and 26,749 women aged 20-89 yr, including 19,249 meat eaters, 4901 fish eaters, 9420 vegetarians and 1126 vegans, who were followed for an average of 5.2 yrs [19]. During this time 343 men and 1555 women reported one or more fractures. Compared with meat eaters, fracture incidence rate ratios in men and women, adjusted for sex, age and non-dietary factors, were 1.01 for fish eaters, 1.00 for vegetarians and 1.30 for vegans. These results suggest that only the vegans had a 30% greater risk of fracture (although this was non-significant). This was halved to 15% after adjustment for dietary energy and Ca intake. Among subjects consuming at least 525 mg Ca/d the corresponding incidence rate ratios were 1.05 for fish eaters, 1.02 for vegetarians and 1.00 for vegans, indicating that the higher fracture risk in the vegans appeared to be a consequence of their considerably lower mean Ca intake. **An adequate Ca intake is essential for bone health, irrespective of dietary preferences.**

Differences in **vitamin D intake** and serum concentrations of 25-OHD among meat eaters, fish eaters, vegetarians and vegans were assessed in a cross-sectional sub-sample taken from the EPIC Oxford cohort [20]. Using data from 2107 men and women (1388 meat eaters, 210 fish eaters, 420 vegetarians and 89 vegans), aged 20-76 yr, it was established that serum 25-OHD concentrations reflected the degree of animal product exclusion. Meat eaters had the highest mean dietary intake of vitamin D (3.1 µg/d) and serum 25-OHD concentrations (77.0 nmol/L) and vegans the lowest (0.7 µg/d and 55.8 nmol/L, respectively), although mean 25-OHD status was above target levels of 50 nmol/L. The magnitude of difference in 25-OHD concentrations between meat eaters and vegans was smaller (20%) among those participants who had a blood sample collected during the summer months (July-September) compared with the winter months (38% in January-March). The prevalence of low plasma concentrations of 25-OHD (<25 nmol/L) during the winter and spring ranged from <1 % to 8 % across all the diet groups.

Adventist Health Studies

Additional data relating to bone health is provided by the first and second Adventist Health Studies (AHS). In AHS, 1865 peri- and postmenopausal women, of which a significant proportion consumed a meat-free diet, completed two lifestyle surveys 25 years apart. This was used to evaluate the effects of foods high in protein on the risk of wrist fracture [21]. The study found there was a significant interaction between meat consumption and foods high in vegetable protein on the risk of wrist fracture. Among vegetarians, those who consumed the least vegetable protein were at highest risk of fracture. However, increasing levels of plant-based high-protein foods decreased wrist fracture risk, with a 68% reduction in risk in the highest intake group. Conversely among those with lowest vegetable protein consumption, increasing meat intake decreased the risk of wrist fracture, with the highest consumption decreasing risk by 80%. **Overall, consuming foods rich in protein more frequently was associated with reduced wrist fracture and provides evidence to support the importance of adequate protein for bone health.** The similarity in risk reduction by vegetable protein foods compared with meat intake suggests that adequate protein intake is attainable in a vegetarian diet.

Cross-sectional evaluation of the effect of dietary habit on bone

A cross-sectional study was used to evaluate the effect of dietary habits on bone [22]. Based on self-reported diet habits, participants were grouped into three diet groups: omnivore (N=27), lacto-ovo-vegetarian (N=27), and vegan (N=28). Individuals adhering to a vegan diet were significantly older than individuals adhering to a meat-based diet (33.9 ± 8.6 yr v 27.2 ± 6.7 yr respectively); while the mean age of lacto-ovo-vegetarians was 31.1 ± 9.1 yr. Anthropometric measures and physical activity levels did not differ significantly between diet groups, but BMI tended to be higher for individuals adhering to a meat-based diet. Protein intake was reduced around 30% in individuals consuming lacto-ovo and vegan diets as compared to those consuming meat-based diets (68 ± 24, 69 ± 29, and 97 ± 47 g/d respectively, P=0.006); BMD did not differ significantly between groups, Figure 7.2. Dietary protein was only associated with BMD for those following vegan diets. Urinary pH was more alkaline in the lacto-ovo and vegan groups compared to the omnivores (6.5 ± 0.4, 6.7 ± 0.4, and 6.2 ± 0.4 respectively, P=0.003). However urinary pH was associated with BMD in omnivores only. The authors concluded that the data suggests that plant-based diets are not detrimental to bone in young adults.

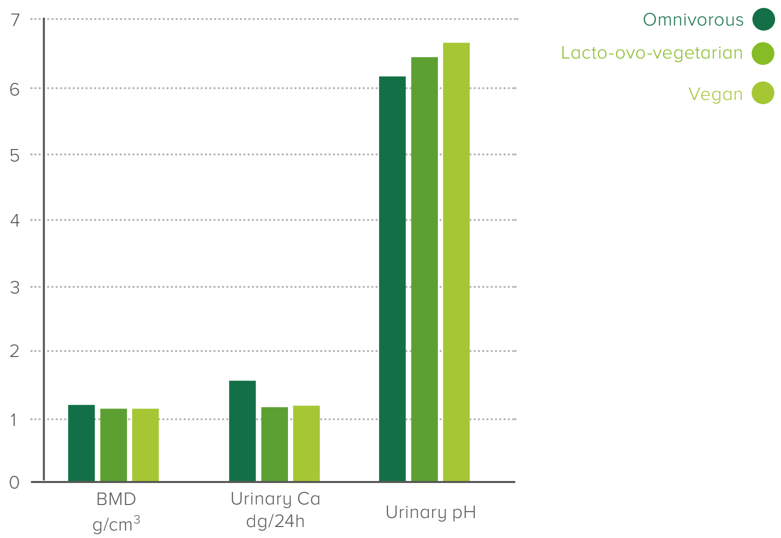

Figure 7.2: Bone mineral density and urinary measures by diet group (omnivorous, lacto-ovo-vegetarian, and vegan)

Source: Extracted from Knurick [22]

Observational studies assessing a marker of plant-based eating and bone health

Silicon (Si) levels tend to be higher in foods derived from plants than in foods from animal sources. Average daily intakes of Si probably range from about 20 to 50 mg/d with the lower values for animal-based diets and the higher values for plant-based diets [23]. Thus Si is considered a marker of predominantly plant-based diets; it has been associated with BMD in premenopausal but not postmenopausal women [24]. In a recent review of Si consumption and bone metabolism, 45 articles were highlighted, but only 38 were specifically focused on Si studies [25]. The authors of this review concluded a positive relationship between dietary Si intake and bone regeneration existed [25]. This suggestion was also confirmed by reference to the Aberdeen Prospective Osteoporosis Screening Study [24]. In this cohort the association between Si intake and markers of bone health was examined in 3198 women, aged 50-62 yr, of which 1170 were current HRT users, and 1018 had never used. Femoral neck and lumbar spine BMD, urinary markers of bone resorption (free pyridinoline and deoxypyridinoline cross-links relative to creatinine, fPYD/Cr and fDPYD/Cr) and serum markers of bone formation (N-terminal propeptide of type 1 collagen, P1NP) were measured. Dietary Si, bio-available Si and dietary confounders were estimated by FFQ. Mean femoral neck BMD was 2% lower ($P<0.005$) in the lowest quartile (Q1, 16 mg/d) compared to the top quartile of energy-adjusted Si intake (Q4, 31.5 mg/d). Energy-adjusted Si intake was positively associated with femoral neck BMD for oestrogen-replete women only, e.g., in late premenopausal women ($r=+0.21$, $P=0.03$) and in women on HRT ($r=+0.09$, $P<0.001$). Quartiles of energy-adjusted dietary Si intake was negatively associated with markers of bone resorption (fDPYD/Cr and fPYD/Cr ($P<0.001$)) and positively with the marker of bone formation (P1NP ($P<0.05$)) suggesting Si as a marker of plant-based foods is associated with higher BMD and bone formation.

Flavonoids have also been used as a measure of plant-based eating. The association between plant-based eating as determined by daily intake of flavonoids (and flavonoid subclasses) and BMD (measured by DXA) was assessed in a cohort of female twins [26]. A total of 3160 women from the TwinsUK adult twin registry participated in the study. Habitual intakes of flavonoids and subclasses (flavanones, anthocyanins, flavan-3-ols, polymers, flavonols, and flavones) were calculated from semi-quantitative FFQ. Total flavonoid intake was positively associated with higher BMD at the spine but not at the hip, see Figure 7.3. For the subclasses, the magnitude of effect on BMD was greatest for anthocyanins (main sources: grapes, pears, wine, berries, and fruit yogurt), with 0.034 g/cm^2 (+3.4%) and 0.029 g/cm^2 (+3.1%) higher BMD at the spine and hip, respectively, for women in the highest intake quintile compared to those in the lowest. Women in Q5 of flavone intake (main sources: peppers, oranges, and wine) had a higher BMD at both sites; 0.021 g/cm^2 and 0.026 g/cm^2 spine and hip, respectively. At the spine, a greater intake of flavonols (main sources: tea and onions) and polymers (from tea) was associated with a higher BMD (0.021 and 0.024 g/cm^2, respectively), while a higher flavanone intake (main sources: oranges, grapefruit, and juices) was positively associated with hip BMD (0.008 g/cm^2).

Figure 7.3: Mean spine bone density (g/cm²) in 3160 female twins aged 18 to 79 years according to quintile of total flavonoid intake

Source: Extracted from Welch [26]

The authors concluded that total flavonoid intake was positively associated with BMD, with effects observed for anthocyanins and flavones at both the hip and spine, supporting a role for flavonoids present in plant-based foods on bone health [26].

In a further Scottish study, the association of dietary flavonoids on BMD and bone resorption was investigated in over 3000 perimenopausal women [27]. Flavonoid intake was assessed using a FFQ and BMD was measured at the femoral neck and lumbar spine by DXA. Bone resorption was measured using fPYD and DPYD. The mean flavonoid intake of the diet was 307 ± 99 mg/d. The catechin family contributed the most to flavonoid intakes (55%) (primarily from tea), and the flavones the least (<1%). Positive associations were found between energy-adjusted total flavonoid intakes and BMD at the femoral neck and lumbar spine (r=0.054 and r=0.036 respectively, both P≤0.05). Annual % change in BMD was associated with intakes of procyanidins and catechins (P≤0.05), and flavanones were negatively associated with bone-resorption markers (fPYD r=-0.049, DPYD r=-0.057, P≤0.001).

Reviews of the literature

In a review of the literature the association between vegetarian diets and BMD was assessed; data from nine observational studies were pooled and subjected to a Bayesian-type meta-analysis [28]. This analysis looks at the probability of treatment effect and as such does not provide "conclusive" evidence. The reviewed studies all measured BMD at either the lumbar spine or femoral neck, or at both these sites. A weakness of this analysis is that it contained data from five studies where the subjects were Asian and only four studies relating to white populations (one of which was the EPIC Oxford study detailed above). Overall subject numbers were low with 2749 subjects included in the analysis, of which 1880 were women and 869 were men, with a mean age of between 27 to 79 yr. The median sample size of the studies was 152 and these were split equally between omnivores and vegetarians. Of the 9 eligible studies, 6 studies were conducted in lacto-ovo-vegetarians, and 3 in vegans. Overall BMD, at both the femoral neck and the lumbar spine, was 4% lower in vegetarians than in omnivores. Compared with omnivores, vegans had a significantly lower lumbar spine BMD (6% lower) and this was more pronounced than in lacto-ovo-vegetarians, where lumbar spine BMD was 2% lower. In vegetarians, compared to omnivores, the probability that BMD was 5% or more lower, was 42% for the femoral neck and 32% for the lumbar spine. The authors concluded that these associations were clinically insignificant [28]; a view supported by Dr Lanham-New in an editorial that reviewed the analysis [13]. She concluded that this meta-analysis, as well as the findings of the 5-yr prospective study of changes in radial bone density in elderly white American women (which showed no differences in bone loss rates between vegetarians and omnivores [29]), demonstrate that vegetarianism is not a serious risk factor for osteoporotic fracture. In addition she also pointed to additional weaknesses in the analysis, specifically that the results did not fully adjust for key confounding factors such as differences in body weight (indeed in half of the studies body weight was significantly lower in the vegetarian group compared with the omnivore group). This is important as it is well established that body weight is a key determinant of BMD. Physical activity levels and smoking, as well as the considerable differences in genetic-ethnic backgrounds in the population studied (Asian compared with white) were also not fully adjusted.

An earlier review of the literature relating to vegetarian diets and bone mass included evidence related to observational, clinical and intervention studies [30]. Studies were reviewed by date of publication pre-1984 and post-1984. From the seven identified studies published pre-1984 it was concluded that BMD was higher in those following a vegetarian diet, although many of the identified studies were conducted in Seventh Day Adventists who have many lifestyle features that differ from the population at large. There were fewer post-1984 observational studies — five were identified — and these showed no real consistent effect of a vegetarian diet on BMD. **Overall, the key findings were that there was no difference in bone health indices between lacto-ovo-vegetarians and omnivores, and that vegetarians appear to have a normal bone mass.** There was conflicting data for protein effects on bone, and growing support for a beneficial effect of fruit and vegetable intake on bone health [30]. In addition, the review identified the complexities of evaluating the role of vegetarian diets on bone health due to the interaction of various dietary components such as Ca, protein, acid/alkali-balance, vitamins D and K, as well as specific functional components such as isoflavones from soya foods.

Evidence related to the acid-base load of the diet

An aspect that can be investigated as a marker of bone health is the acid-base load of the diet. Evidence exists that a diet which increases the acidity of blood and other body fluids may result in minerals, including Ca, being leached out of bones which would be detrimental to bone health. An early review of intervention studies investigating the effects of a more alkaline diets, with higher in fruit and vegetables and lower in meat intakes, reported support for the hypothesis of a positive link between fruit and vegetable intake and bone health [31]. A more recent review of observational studies and RCTs concluded there is no evidence that an alkaline diet is protective of bone health or a causal association between dietary acid load and osteoporotic bone disease [32]. Recently the relationship between urine pH and dietary acid-base load and its contributory food groups (fruit and vegetables, meats, cereal and dairy foods) was investigated in 22,034 men and women, aged 39-78 yr, in the EPIC-Norfolk cohort [33]. From this study, data from 363 volunteers was used to compare urinary pH and 24 hour urine output with dietary intakes from a 7-day diary and a FFQ. A more alkaline diet, which had a high fruit and vegetable intake and lower consumption of meat, was significantly associated with a more alkaline urine pH. This was both before and after adjustment for age, BMI, physical activity and smoking habit and also after excluding for urinary protein, glucose, ketones, diagnosed high BP and diuretic medication. The effect of net acid load was determined in the German Vegan Study [34]. This cross-sectional study was conducted in 67 healthy men and 87 women aged 21-75 yrs [34]. The potential renal acid load and the estimated diet-dependent net acid load (net endogenous acid production, NEAP) was related to intake of bone health-related nutrients. NEAP values were calculated from diet composition using two models: one based on the protein/potassium quotient and another taking into account an anthropometry-based loss of urinary organic anions. Only the consumption of fruits decreased constantly across the increasing quartiles of NEAP, leading the authors to suggest that vegan diets *per se* do not affect acid-base homeostasis.

The most recent study that has determined a measure of acid/alkalinity reported that urinary pH was more alkaline in the lacto-ovo and vegan groups compared to omnivores (P=0.003) [22]. However, urinary pH was associated with BMD in omnivores only. The authors suggested that diet prescriptions for bone health may vary among diet groups: increased fruit and vegetable intake for individuals with high meat intakes and increased plant protein intake for individuals who follow a vegetarian diet plan [22].

It can be seen that there are several shortcomings and inconsistencies in the literature and the relevance of differences in acid/base status has yet to be clarified; there is clearly a need for further research in this area.

Evidence relating to components of plant-based eating

Soya intake

Of the specific plant foods that may have a beneficial effect on bone health in later life, soya has been extensively researched. There is a large group of intervention studies that have evaluated the role of soya isoflavones on reducing bone loss in postmenopausal women and this data has been reviewed [35]. Data from ten eligible RCTs conducted in 896 women for at least a year, were pooled and a meta-analysis conducted. A mean dose of 87 mg soya isoflavones for at least one year did not significantly affect BMD changes. The mean differences in BMD changes were 4.1 mg/cm^2 per yr equivalent to 0.4% difference at the lumbar spine, -1.5 mg/cm^2 or -0.3% at the femoral neck and 2.5 mg/cm^2 or 0.2% at the total hip, see Table 7.2. The results were similar when the analysis was conducted according to source of isoflavones either as soya protein containing foods or isoflavone extract. At higher rates of inclusion (≥80 mg isoflavones/d compared to <80 mg/d) there was a beneficial, but non-significant effect on BMD (P=0.08) [35].

In a second meta-analysis, conducted with 18 studies and a total of 978 subjects, followed for a minimum of 6 mo, spine BMD in subjects who consumed isoflavones increased significantly by 20.6 mg/cm^2 in comparison to subjects who did not consume isoflavones [36]; see Table 7.2. In this analysis BMC also increased by 0.93 g, which was of borderline significance. The authors concluded that the addition of isoflavones to the diet significantly attenuates bone loss of the spine in menopausal women and that these favourable effects become more significant when intakes of isoflavones are more than 90 mg/d. This effect can become apparent after 6 mo consumption [36].

More recently a further meta-analysis of RCT was undertaken [37], Table 7.2. Nineteen RCTs, including three studies with soya foods, were included in the analysis of peri- and/or postmenopausal women. Soya isoflavones significantly increased the BMD by 54% and decreased the bone resorption marker, urinary DPYD, by 23% compared to baseline in women. Greater changes were found in postmenopausal women consuming isoflavones in excess of 75 mg/d. There was no significant effect on bone formation markers including serum bone alkaline phosphatase. The authors concluded that the significant effect of soya isoflavones on BMD and urinary DPYD is relative to menopausal status, supplement type, amounts of isoflavones and intervention duration.

Author	No of studies	Mean Isoflavones (mg)	LUMBAR BMD effect (mg/cm²)	LUMBAR BMD effect %	FEMORAL NECK BMD effect (mg/cm²)	FEMORAL NECK BMD effect %	Significance P	Comment
Liu [35]	10 N=896	87 >80	4.1 6.0	0.40	1.5	0.3	NS P=0.08	Minimum study duration 1yr Effect on BMD at Hip 2.5 mg/cm² (P=0.25 NS)
Ma [36]	18 N=978	<90 >90	ND		20.6 28.6		P<0.05	Minimum study duration 6mo BMC increase by 0.93g (P=0.05) BAP increase 1.48 μg/L DPYR -2.08 nmol/mmol
Wei [37]	19 N=1376	75	ND	0.54*	ND		P=0.009	Study duration 4mo-2yr *Net effect BAP net effect 0.0 μg/L (P=0.06)

Abbreviations: BAP Blood alkaline phosphatase; DPYR deoxypyridinoline; ND not determined.

Table 7.2: Meta-analyses reporting the effect of soya isoflavone inclusion on a measure of bone

Plant-based eating intervention studies

Intervention studies are often used to assess bone turnover by measuring a number of different markers. A slight variation on this approach assessed Ca balance of individuals on a vegan diet in comparison with a lacto-vegetarian diet [38]. Seven women and one man, aged 19 to 24 yrs, received a vegan diet based on plant foods and Ca-rich mineral water for the first 10 days and a lacto-vegetarian diet during the following 10 days. Ca status was assessed by means of Ca intake in food and Ca output in faeces and urine. DPYR was measured in urine as a marker of bone resorption. The results showed a significantly lower average daily Ca intake in the vegan phase (843 ± 140 mg) compared to 1322 ± 303 mg in the lacto-vegetarian phase. Apparent Ca absorption rates were calculated as 26% ± 15% and 24% ± 8% in the vegan and lacto-vegetarian phases respectively. The Ca balance was positive and not significantly different in the vegan (119 ± 113 mg/d) and lacto-vegetarian phase (211 ± 136 mg/d). DPYR excretion was also not significantly different between the two diet phases. This short term study indicates that calcium balance and a marker of bone turnover are not significantly affected when Ca is provided either solely by plant foods and Ca enriched water, or by a diet including dairy products, despite the significantly different Ca intake levels. This study also highlights how a well-selected vegan diet maintains Ca status, at least for a short-term period.

Overview and conclusions

The data, primarily from observational studies, indicates that there appears to be nothing inherent in plant-based eating patterns that may have an adverse effect on bone health. Alkaline diet interventions are suggested to be beneficial, but there is a need for long term studies which measure bone health end points, including fracture risk. In this respect it has been suggested that flavonoids may protect against bone loss by upregulating signalling pathways that promote osteoblast function, by reducing the effects of oxidative stress or chronic low-grade inflammation rather than a specific acid/base effect [39].

There is no doubting the importance of Ca, Vitamin D and physical activity for the development and maintenance of bone health.

Dietary factors in plant-based diets that support the development and maintenance of BM include Ca, vitamin D, protein, potassium, and soya isoflavones [40]. While other factors present in plant-based diets, such as oxalic acid and phytic acid, could potentially interfere with absorption and retention of Ca this does not appear to be of practical significance. The issue of impaired vitamin B12 status which could also negatively affect BMD is raised [40]. In an extensive systematic review of the literature that identified 17 studies (3230 participants) where vegetarian status, serum vitamin B12 and plasma total homocysteine (tHcy) were measured, it was reported that in two studies vegan concentrations of plasma tHcy and serum vitamin B12 did not differ from omnivores [41]. However, in the majority of studies vitamin B12 status was lower. The analysis also confirmed that an inverse relationship exists between plasma tHcy and serum vitamin B12. But the significance of this lower vitamin B12 status requires further investigation.

The role of protein in bone health and Ca balance is multifaceted. Overall, current recommendations are that Ca and protein intakes in line with dietary reference intakes are recommended for vegetarians, including vegans. In this respect fortified foods are often helpful in meeting recommendations for Ca, vitamin D and vitamin B12.

There appears to be little difference in BM between omnivore and vegetarian populations, particularly those who consume some dairy and fish. However, it appears that for those consuming vegan-type diets, care should be taken to preserve protein and calcium intake, particularly during adolescence and young adulthood when peak bone mass is attained.

Overall, it appears that plant-based diets can provide adequate amounts of key nutrients for bone health. In addition plant-based eating tends to be associated with other beneficial lifestyle factors, including greater physical activity, less smoking and overall a lower energy dense and nutrient-rich diet, all of which contribute to good bone health.

Take-home messages:

- Achieving optimum bone health during childhood and adolescence is not only important during this period, but it is also key in keeping bones healthy throughout life.

- To ensure bone health throughout life, WHO recommend that it is important to: achieve the highest possible bone mass during the time of growth, maintain bone health in early adulthood and reduce the rate of bone loss in later life.

- A varied and adequate diet with increased consumption of fruits, vegetables, legumes, whole grains and nuts, and regular weight bearing physical activity are important components of this healthy lifestyle.

- Plant-based eating supports normal bone growth and development throughout life, provided a wide variety of plant foods is consumed and adequate intakes of protein, Ca and vitamin B12 and vitamin D status are maintained.

- Plant-based eating is associated with other lifestyle factors known to be beneficial to bone health, such as greater physical activity and being less overweight.

- Greater fruit and vegetable consumption may make a positive contribution to good bone health.

- Specific plant foods, such as those containing soya isoflavones, may help to reduce bone loss in later life.

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Chapter 8

More plant-based eating and ageing

PROF. IAN ROWLAND
Emeritus Professor of Human Nutrition, University of Reading (UK)

Introduction to Chapter 8, by invited expert Ian Rowland

Over the past hundred years there has been a seemingly inexorable rise in life expectancy throughout the world, indeed in some countries it has almost doubled during this time. For example, in the UK life expectancy in 1901 for males and females was 45 and 49 yrs respectively. By 2012, this had risen to 78.9 and 82.7 yrs [1]. Such figures are reflective of most developed countries. Unfortunately, this increased longevity has brought with it increased number of years of ill health, because age is the main risk factor for the majority of chronic non-communicable diseases and conditions such as heart disease, stroke and cancer, which are the main causes of morbidity and mortality in the developed world. Consequently, although life expectancy at birth in European countries in 2013 was 73 and 80 yrs for males and females respectively, healthy life expectancy was only 64 and 70 yrs [2]. Furthermore, not only does the prevalence of these long term conditions increase with age, but also the severity of the disability rises [3].

In addition to the increased risk of major chronic diseases, older age is also associated with other conditions which, although not life-threatening, can have an impact on quality of life of older subjects such as cognitive decline, arthritis, osteoporosis, immunosenescence and gastrointestinal disorders.

There is increasing evidence that diet and nutrition are key factors influencing ageing by impacting molecular and cellular events such as inflammation and oxidative stress, underlying the impaired function and increased frailty characteristic of the ageing process. Consequently, nutrition can be considered an important contributor to healthy ageing.

So, three major questions have been addressed in this chapter: Firstly, can plant-based eating help people meet the changing energy, protein and micronutrient requirements during ageing. Secondly, are plant-rich diets *associated with lower mortality/increased life expectancy and finally, but equally importantly, do such diets improve the health status and quality of life in older age?*

Under the first heading it is clear that older people are especially vulnerable to malnutrition. Particular concerns are ensuring adequate protein intake to reduce risk of sarcopenia, and sufficient calcium to maintain bone health. In addition, intake of other micronutrients e.g. vitamins E and K, and potassium, may be compromized in older people, as can intake of fibre. Finally, there is concern about both under- and overconsumption of energy, leading to marked deviations from optimal body weight in ageing subjects. The United States have been very proactive in developing dietary guidelines for older people, initially with a modified food pyramid and more recently, in 2011, with its modified 'MyPlate' for older adults. It is noteworthy that both emphasize the importance of a wide range of fruits, vegetables, whole grains, low- and non fat dairy products, legumes, fish, and lean meats. Indeed half of MyPlate comprises fruit and vegetable icons, a wide range of fruit and vegetables.

In terms of the association of plant-based diets with lower mortality, it is probably no coincidence that the two dietary patterns most closely linked to longevity – the Mediterranean diet and the Okinawa diet from Japan – are both characterized by an abundance of plant foods: fruits, low to moderate amounts of fish and lean meats. Indeed, close adherence to the Mediterranean diet has been associated with a significant reduction in total mortality and mortality from CVD and cancer, in both Mediterranean and non-Mediterranean populations. It is important to remember, however, that these types of diet are part of a lifestyle that incorporates other health promoting factors such as exercise, and social eating.

Finally, can consuming plant-rich diets impact health status and quality of life in older age by reducing the risk of developing cardiovascular disease, T2D and possibly cancer? This topic is addressed at length in this chapter (and others in this book) and the evidence for a role for plant foods in reducing the risk of the major non-communicable diseases and ameliorating the impact of other conditions such as cognitive decline and menopausal symptoms is critically assessed here. Overall, epidemiological studies indi-

cate that plant-based diets such as the Mediterranean diet are associated with reduced risk of CHD and T2D. Furthermore, such plant-rich diets, particularly when combined with other lifestyle factors (healthy body weight, not smoking and exercise), resulted in a lower disease burden and about two years longer in good health as quantified by Disability-Adjusted Life Years (DALYs).

It has to be remembered that although diseases and disorders such as CVD, cancer, T2D, osteoporosis and cognitive impairment become much more important as age progresses, the risks in old age are influenced by factors acting throughout the lifespan, from the foetus, through infancy and adolescence to adulthood. Thus it is critical to take a holistic approach and ensure good dietary practices at these early stages, to promote healthier life trajectories and optimize healthy life expectancy for future older cohorts.

To summarize:

- *There is increasing evidence that consumption of plant-based diets may make a positive contribution to the health status and quality of life of older people.*
- *Achieving energy balance is important in older people where overweight or obesity may be prevalent; plant-based eating patterns, which tend to be lower in energy and nutrient-rich, can help maintain a healthy weight.*
- *Vegetarian diets and certain traditional plant-rich dietary patterns such as the Mediterranean diet, are associated with a reduced incidence of overall mortality and death from CHD, stroke and T2D.*
- *Older people can be especially vulnerable to malnutrition. Dietary guidelines developed by the United States specifically for older subjects emphasize the contribution of fruits, vegetables, whole grains and other plant-based foods.*

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Chapter 8

More plant-based eating and ageing

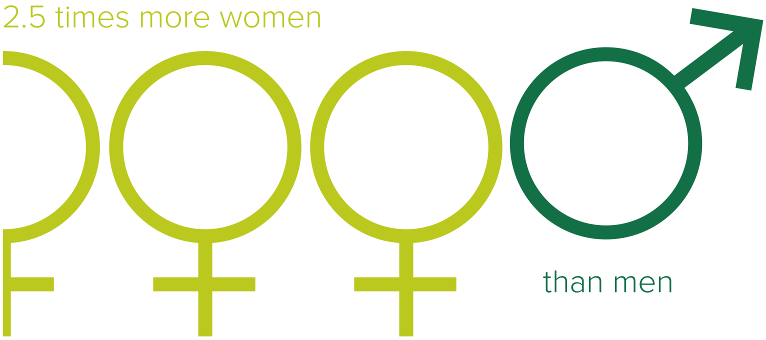
An ageing population

Persons aged 60 yrs or over are now the world's fastest growing age group. Their proportion of the global population is ever increasing, from 12% in 2015 and it is predicted to be 16% in 2030 [1], with the fastest growth taking place in Europe and Northern America. World population has increased by 2 billion people over the past 25 yrs, from 5.3 billion in 1990 to 7.3 billion in 2015. Although growth rates have slowed, the world's population is still increasing by an additional 81 million people per year. The situation in Europe is different, as its total population is projected to decrease slightly, by less than 1% by 2030.

By 2030, the target year to achieve the UN's post-2015 development agenda, the global economy will need to support approximately 8.4 billion people, of which 1.5 billion will be older than 60 yrs. In addition, the UN is addressing the issue of integrating population issues into sustainable development [1].

There are currently

2.5 times more women



among people aged 85 years and over in the WHO European Region

Source: www.euro.who.int/ageing

In the European Region of WHO 20.5% of the population is already aged 60 yrs or older, with Germany and Italy having the highest proportion of older people (approx. 27% in 2013) (Figure 8.1) [2]. Furthermore it is predicted that the population aged 80 yrs or older will more than triple by 2050, while the number of centurions is expected to increase 15-fold during this time. In virtually all countries women comprise the majority of the older population, largely because globally women live longer than men [2].

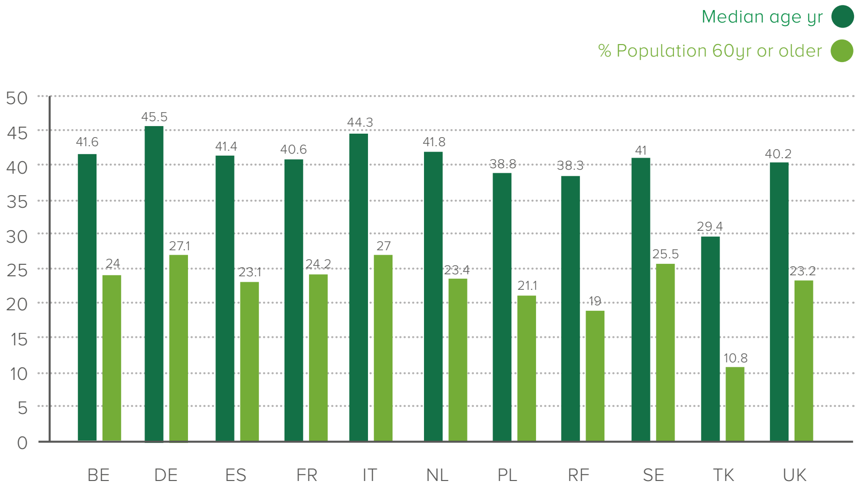


Figure 8.1: Median age (yr) and proportion of the population aged 60 yr or more in 2013 in certain European countries

Source: http://www.who.int/gho/countries/

The implications of these demographic changes are significant. **Good health must lie at the core of any successful response to ageing, ensuring that people are living longer in good health**. In the long term this will provide greater opportunities both to the individual and to society as a whole, and in addition will reduce the overall cost to society [3]. Healthy lifestyles, which include physical activity and nutritious diets while avoiding smoking, have great potential to promote a long and healthy life.

Health and dietary challenges of ageing

Specific issues facing the older population are:

- a main health challenge from non-communicable diseases, with the most prevalent cause of death in this population being CVD;

- ensuring bone health, particularly as the majority of the population are women, who after the menopause are more likely to suffer an osteoporotic fracture;
- maintaining weight within the desirable range;
- disability, mainly due to visual impairment, dementia, hearing loss and osteoarthritis.

Many of the diseases suffered by older people are the result of dietary factors, some of which have been operating since infancy. These factors are often compounded by changes that naturally occur with the ageing process.

Degenerative diseases such as CVD and stroke, diabetes, osteoporosis and cancer, the most common diseases in older people, are all affected by diet. The role micronutrients play in promoting health and preventing non-communicable disease is receiving more and more attention in the diet/disease debate. Micronutrient deficiencies are common in elderly people due to a number of factors, e.g. reduced food intake and lack of variety in the food consumed.

The higher cost of micronutrient-rich foods can discourage their consumption. In addition, older people often suffer from decreased immune function, which can contribute to increased morbidity and mortality in this age group. Other significant age-related changes include the loss of cognitive function and deteriorating vision, all of which hinder good health and dietary habits.

Elevated blood cholesterol, a risk factor for CHD, is common in older people and this continues into very old age. Modifying the diet to reduce LDL-C and BP by relatively modest reductions in SFA and salt can have significant benefits. For example, intervention trials have shown that reduction of BP by 6 mmHg reduces the risk of stroke by 40% and of heart attack by 15%, and that a 10% reduction in blood cholesterol concentration will reduce the risk of CHD by 30%, while increasing consumption of fruit and vegetables by one to two servings a day could cut CV risk by 30% [3].

Nutritional needs

Older people are particularly vulnerable to malnutrition and have unique nutrient needs. In the United States the dietary reference intakes (DRI) recognizes two categories of older people with the "greater than age 50 yr" split into the 51–70 yr olds and >70 yrs. This older age group is particularly vulnerable to poor nutrient status [4]. Traditionally, food intake tends to decrease with advancing age to compensate for the diminished energy needs associated with lower energy expended in physical activity and basal metabolic rate. However vitamin and mineral needs either remain constant or increase.

Nutritional concerns for older adults are related to both under- and over-consumption of energy and nutrients. Attempts to provide adequate nutrition encounter practical problems. Firstly, nutritional requirements are not well defined and secondly, reduced food intake and lack of variety of foods in the diet can lead to micronutrient deficiencies. For others excess energy intake, either in old age or during their life time, increases the risk of becoming obese.

The United States have led the way in producing advice targeted specifically at older people and in 1995 developed the Modified Food Guide Pyramid for adults aged 70+ yrs [4]. In 2007 this was developed further, although it continues to be based on the principles of the US Dietary Guidelines for Americans and those of other health organisations, such as WHO. The Modified **MyPyramid for older adults** continues to **emphasize nutrient-dense food choices and the importance of fluid balance**, but has added additional guidance about forms of foods that could best meet the unique needs of older adults, as well as the importance of regular physical activity, Figure 8.2. It emphasizes that diets should be high in fruits, vegetables, whole grains, low- and non-fat dairy products, legumes, fish, and lean meats (Figure 8.2) [4]. In addition, the Pyramid makes reference to the need to promote fluid intake in older people by reference to the row of glasses, which acts as a reminder of the need for regular fluid intake. A second row depicts a variety of physical activities to emphasize the importance of regular physical activity for this age group. The flag at the top refers to vitamins B12 and D and Ca – the nutrients most likely to be compromized in the over 70 yr olds – and highlights the need to consider an appropriate supplement. At the same time it has been recognized that these people are among the highest supplement takers in the population and risk overconsumption of other micronutrients, specifically folate and sodium [4]·.

MyPlate for older adults, developed in 2011, incorporates the updated 2010 Dietary Guidelines for Americans and focuses on the unique nutritional and physical activity needs associated with advancing years (Figure 8.3). It provides examples of foods that contain high levels of vitamins and minerals per serving, and recommends limiting foods high in trans and SFA, salt and added sugars. It also emphasizes the importance of whole grains and, as half of the MyPlate are fruit and vegetable icons, a wide range of fruit and vegetables. It includes protein sources with plant-based options such as beans and tofu, as well as fish and lean meat and recommends vegetable oils and soft spreads as alternatives to foods high in animal fats.

Finland is another country with specific dietary guidelines for older people, that were approved by the National Nutritional Council in Finland [5].

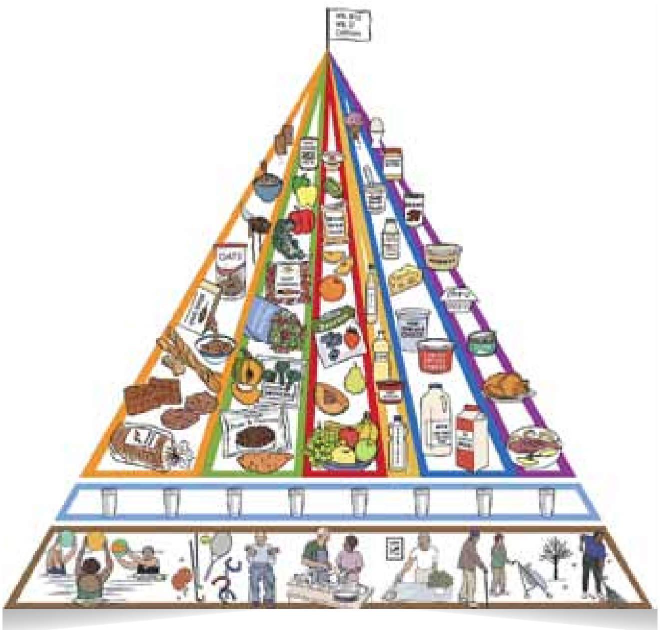


Figure 8.2: My pyramid for older adults 2007

Source: /www.nutrition.tufts.edu/documents/ModifiedMyPyramid.pdf

A multidisciplinary expert panel drafted guidelines based on an extensive review of literature. These were then revised based on comments from expert organisations to form the final guidance.

The five key guidelines are:

1. The nutritional needs in different age and disability groups should be considered.
2. The nutritional status and food intake of older individuals should be assessed regularly.
3. An adequate intake of energy, protein, fibre, other nutrients, and fluids should be guaranteed.
4. The use of a vitamin D supplement (20 µg/d) is recommended.
5. The importance of physical activity is emphasized. In addition, weight changes, oral health, constipation, obesity and implementing nutritional care are highlighted.

This guidance, along with that produced in the United States, highlights how nutrition recommendations for older people are basically the same as for

Figure 8.3: MyPlate for older adults 2011

Source: http://www.nutrition.tufts.edu/research/myplate-older-adults the general population, but with **particular focus on micronutrient intake, consuming a variety of foods, and ensuring hydration and weight maintenance.**

Other than the US recommendations, food-based dietary guidelines for the elderly are limited; those produced by WHO are detailed below [6]:

- Emphasize healthy traditional vegetable and legume-based dishes.
- Limit traditional dishes/foods that are heavily preserved/pickled in salt, and encourage the use of herbs and spices.
- Introduce healthy traditional foods or dishes from other cuisines (e.g. tofu in Europe and tomatoes in Asia).
- Select nutrient-dense foods such as fish, lean meat, liver, eggs, soya products (e.g. tofu and tempeh) and low-fat dairy products, yeast-based products (e.g. spreads), fruits and vegetables, herbs and spices, wholegrain cereals, nuts and seeds.
- Consume fat from whole foods such as nuts, seeds, beans, olives and fatty fish. Where refined fats are necessary for cooking, select from a variety of liquid oils, including those high in omega-3 and omega-9 fats. Avoid fatty spreads.
- Enjoy food and eating in the company of others. Avoid the regular use of celebratory foods (e.g. ice cream, cakes and pastries in western culture).
- Eat several (5–6) small non-fatty meals. This pattern appears to be associated with greater food variety and lower body fat, blood glucose and lipid levels, especially if larger meals are eaten early in the day.
- Avoid dehydration by regularly consuming, especially in warm climates, fluids and foods with a high water content.
- Be physically active on a regular basis and include exercises that strengthen muscles and improve balance.

Other WHO advice includes transferring as much as possible of one's food culture, health knowledge and related skills to one's children, grandchildren and the wider community, and encouraging the food industry and fast-food chains to produce ready-made meals that are low in animal fats.

Potential nutritional benefits of plant-based eating

It can be seen from the WHO guidance there is an emphasis on meeting nutritional needs from plant foods and the trial and consumption of a wider range of plant foods is encouraged. The importance of eating a wide range of foods is particularly relevant in older people consuming plant-based eating patterns, as care should be taken to ensure adequate Ca, vitamin B12 and vitamin D intake in later life.

In respect of **vitamin D** the Finnish guidance specifically suggests a supplement of 20 µg/d, as exposure to sunlight may be less and the efficiency of the skin to synthesize vitamin D declines with age. Other European countries recommend Vitamin D supplementation for the elderly, e.g., UK recommendations are 10 µg/d in the over 65s [7]. In addition, with increasing rates of overweight and obesity in the older population, there is concern for vitamin D inadequacy due to its deposition in body fat compartments, leading to reduced bioavailability.

Ensuring adequate **Ca intake** in plant-based eating patterns has been discussed in detail in Chapter 2, where mention is made of the wide range of available plant foods that contain Ca and can meet Ca needs without increasing SFA intake. Examples include fortified soya dairy alternatives, tofu, dried fruit (e.g. apricots and figs), nuts, green leafy vegetables (especially kale and pak-choi, but not spinach), sesame seeds and tahini. Other micronutrients of which the intake may be compromized in older people are **vitamins E and K, and potassium**. Vegetables and fruits are good sources of these nutrients and consequently plant-based eating can help ensure their intake.

It has previously been identified that plant-based eating patterns tend to be lower in SFA and rich in fibre (see Chapter 2). **Fibre** intake is an important consideration as it aids laxation and reduces the likelihood of constipation. However, in this age group fibre intake is typically lower than desirable. Data from the first 4 yrs of the UK National Diet and Nutrition Survey Rolling programme 2008 - 2011 indicates that fibre intake in men aged 65 yrs and over is typically only 70% of the current recommended population intake, and in women it is even less [8]. A recent review of carbohydrates and health has suggested an increase in recommended fibre intake to 30 g/d for adults; if this level of recommended intake is assumed, current levels of intake in 65 yr-olds would be just over half the proposed recommendations [9]. Average intakes of fibre are also low in older adults in France, Denmark, Italy, Spain and Ireland [10], where clearly many adults would benefit from the inclusion of more fibre-rich plant foods in the diet [11].

A further beneficial effect related to fibre-rich plant foods in the diet is the effect they have on the gut microbiota [12]. In adults, diets that have a high proportion of fruit and vegetables and a low consumption of meat are associated with a highly diverse microbiota. It has been proposed that dietary modulation to manipulate specific gut microbial species, or groups of species, may offer new therapeutic approaches to functional gastrointestinal disorders, obesity and age-related under-nutrition [12].

Potential health benefits of plant-based eating

Cardiovascular health

It has been identified that the main health challenge for older people is from non-communicable diseases, with **the leading cause of death being CVD** [3]. It has clearly been shown in Chapter 3 that plant-based eating is beneficial for CV health. In addition, weight management is essential in this age group where weight is both a direct cause of ill health and a major risk factor for CVD, diabetes and cancer. In many societies obesity is most prevalent in the 45-75 yr-olds, e.g. in England it affects around 30-34% of this age-group [13]. As discussed in Chapter 4, plant-based eating is associated with lower body weight and leaner body mass. Consequently, in an ageing population this way of eating has major benefits, both in helping maintain a healthy body weight and reducing the risk of non-communicable diseases.

Bone health

Another challenge for older people is **maintaining bone health**. The inclusion of fruit, vegetables, Ca, vitamin D and soya foods that contain isoflavones, all appear to be beneficial (Table 8.1 and Chapter 7) [14]. In addition, women suffering from menopausal symptoms such as hot flushes, may benefit from including soya isoflavones into their diet [15-17].

Evidence	Decreased risk	No relationship	Increased risk
Convincing Older people[a]	Vitamin D Calcium Physical activity		High alcohol intake Low body weight
Probable Older people[a]		Fluoride[b]	
Possible	Fruits and vegetables[c] Moderate alcohol intake Soya products	Phosphorus	High sodium intake Low protein intake (in older people) High protein intake

Abbreviations:

[a] *In populations with high fracture incidence only. Applies to men and women older than 50-60 yrs, with a low calcium intake and/or poor vitamin D status.*

[b] *At levels used to fluoridate water supplies. High fluoride intake causes fluorosis and may also alter bone matrix.*

[c] *Several components of fruits and vegetables are associated with a decreased risk at levels of intake within the normal range of consumption (e.g. alkalinity, vitamin K, phytoestrogens, potassium, magnesium, boron). Vitamin C deficiency (scurvy) results in osteopenic bone disease.*

Table 8.1: Summary of strength of evidence linking diet to osteoporotic fractures

Source: Prentice [14]

Sarcopenia

The challenge of mobility is not only related to bone health but also muscle health. **Sarcopenia** (muscle weakness) is common among older adults, resulting in serious consequences such as disability, increased mortality, and negative effects on co-morbid conditions. However, it is currently unrecognized as a disease state within the healthcare community, mainly because there is a lack of uniform criteria for its diagnosis and severity. In all probability it is a group of conditions which is generally understood to mean: the age-related loss of lean muscle mass, strength, and functionality that can prevent elderly people from performing the most basic tasks of daily living and greatly increases their risk of suffering falls and other serious accidents. **Between the ages of 40 and 80 yrs around 30 to 50% of muscle mass can be lost.** After the age of 50 muscle function is estimated to be reduced by 1 to 2% each yr, and as much as 3% a yr after the age of 60.

Although there is no specific level of muscle mass and function used to diagnose sarcopenia, a critical loss has serious consequences. Not only can loss of lean muscle mass and strength prevent older people from undertaking the most basic day-to-day tasks, more serious implications include an increased risk of falls, frailty, immobility and loss of independence. **Worldwide it is estimated that up to 25% of older adults are affected by sarcopenia**, with this figure likely to rise with the growing ageing population. The health implications of this, both to the individual and to wider society, are considerable. The European Working Group on Sarcopenia in Older People (EWGSOP) has proposed cut-off values for sarcopenia status based on muscle mass, muscle strength and physical performance. In the prospective BELFRAIL study, which took place in 567 subjects aged 80 yrs and older in Belgium [18], sarcopenia status was determined according to the EWGSOP guidelines. The skeletal muscle mass index was assessed according to bioelectrical impedance. Muscle strength and muscle performance were evaluated according to grip strength and the modified short physical performance battery (SPPBm). Using the combined EWGSOP guidelines, 12.5% of the participants were classified in the sarcopenia group. By reference to the specific elements it was identified that 60% of the women had muscle strength values below the cut-off and 70% had low SPPBm values. In men the prevalence values were 49.5% for grip strength and 39.7% for SPPBm.

Sarcopenia is a multifactorial disease process that may result from sub-optimal hormone levels, inadequate dietary protein, other nutritional imbalances, lack of exercise, oxidative stress, and inflammation (Figure 8.4).

Age-related sarcopenia does not just happen; it is a slow, progressive condition. Fortunately a number of lifestyle steps have been found to be effective in preventing, delaying and managing this condition. **An integrated approach that incorporates dietary strategies, hormone replacement, nutritional supplementation and exercise is required.**

From a dietary perspective older adults should strive to ensure an adequate intake of high-quality protein and an abundant consumption of fruits and vegetables. Being physically active can help reduce age-related muscle loss and maintain muscle strength and function. These actions combined over the years can help to build and maintain good levels of muscle mass and reduce the risk of sarcopenia in later life.

Muscle is made up of proteins, so getting adequate amounts in the diet is important for building and maintaining muscle mass, strength and function. The daily protein intake recommendation for adults is currently 0.8g protein/kg BW. However research has shown older adults may need more protein to maintain proper levels of muscle mass and function [20].

Abbreviations: GH growth hormone; IGF-1 insulin-like growth factor

Figure 8.4: Sarcopenia pathways and inter-relationships

Source: After Beasley [19]

This is to help compensate for the age related decline in the body's ability to synthesize protein and build lean muscle, as well as to meet the increased requirements due to diseases that commonly occur in ageing. A further consideration is that a significant proportion of older people may fail to meet this daily protein intake recommendation and hence their protein status may be compromized. As important as the amount of protein is the timing of protein intake throughout the day; it is recommended that dividing protein intake evenly across the day, ideally with a third of the daily intake consumed at breakfast, lunch and dinner in order to maximize the building of muscle.

In older people who are losing weight there may also be the need to adjust both protein and energy intake to ensure weight and muscle maintenance. Several micronutrients including Ca, vitamin D, and creatine and whey proteins, have shown promise in minimising the symptoms of sarcopenia. The evidence is not available to be specific, but a healthy diet with adequate good quality protein, fruit and vegetables, Ca and vitamin D is a good starting point. In those consuming little meat attention also needs to focus on adequate vitamin B12 intake.

Cognition

A further challenge to an ageing population is cognition. It has been suggested that diet may be protective against mild and advanced cognitive impairment, including Alzheimer's disease [21]; this is a fast-developing area of research, and evidence to support a potential benefit from diet has been identified.

Scientific evidence

In respect to ageing, observational studies provide information about dietary patterns and their impact on the incidence of chronic disease or cause of death, and such studies can also help to identify dietary patterns that are associated with better health. Observational data relating to specific plant foods, or categories of plant foods, can be difficult to interpret as there are many other variables in people's overall diet and lifestyle. It is not always possible to adjust for all these factors, particularly in long term studies where dietary changes may have been made many years before the end-points are measured.

Clinical studies provide short and medium term data that usually relate the consumption of a specific plant food to some aspect of ageing, e.g. bone health, menopausal symptoms, cognitive function and disease risk factors. These have largely have been reviewed in Chapters 3-7.

Observational studies

Studies investigating CV and all cause mortality

The evidence relating to the health effects of vegetarian diets was reviewed by Fraser [22]. Although data outside of the various Adventist cohorts was limited, the author nevertheless concluded there is convincing evidence that vegetarians have:

- lower rates of CHD, largely as a result of lower LDL-C;
- probably lower rates of hypertension and T2D;
- lower prevalence of obesity,

as described in Table 8.2 [22]. In this dataset the non-vegetarian group is used to establish the baseline risk for hypertension and T2D, which is given a risk of 1. The risk of these chronic diseases reduces in all those adopting more plant-based diets, with the lowest risk being observed among vegans. In this group the risk for hypertension or diabetes respectively is 75 or 78% lower than that of a non-vegetarian.

Mediterranean diets have been described as being healthy ageing diets [21, 23]. This dietary pattern is characterized by the abundance of plant foods: fruits, vegetables, bread and other forms of cereals, legumes, nuts, and seeds. Olive oil is the principal source of fat. Mediterranean diets also includes moderate amounts of dairy products (principally cheese and yogurt), low to moderate amounts of fish and poultry, red meat in low amounts and wine, consumed modestly. The review of the last five years of research has shown that greater adherence to the Mediterranean diet is associated with longevity and a lower prevalence of several chronic diseases [24]. Specifically, greater adherence to the Mediterranean diet has been associated with a significant reduction in total mortality, mortality from CVD and cancer, both in Mediterranean and non-Mediterranean populations [24, 25]. It has been proposed that the mechanisms underlying the health benefits are the anti-inflammatory and anti-oxidative properties of this diet. However, the properties of the whole pattern seem to be well

Diet Group	BMI (kg/m^2)	Hypertension	T2D
Non-vegetarian	28.3	1.00	1.00
Semi-vegetarian	27.0	0.77	0.72
Pesco-vegetarian	25.7	0.62	0.49
Lacto-ovo-vegetarian	25.5	0.45	0.39
Vegan	23.1	0.25	0.22
Statistical significance (P)	0.0001	0.0001	0.0001

Number in study = 89,224
Normal weight is classified as BMI <25kg/m^2

Table 8.2: Mean difference in BMI and the prevalence of hypertension and diabetes in different types of vegetarians compared with non-vegetarians in California Seventh-day Adventists

Source: Fraser 2009 [22]

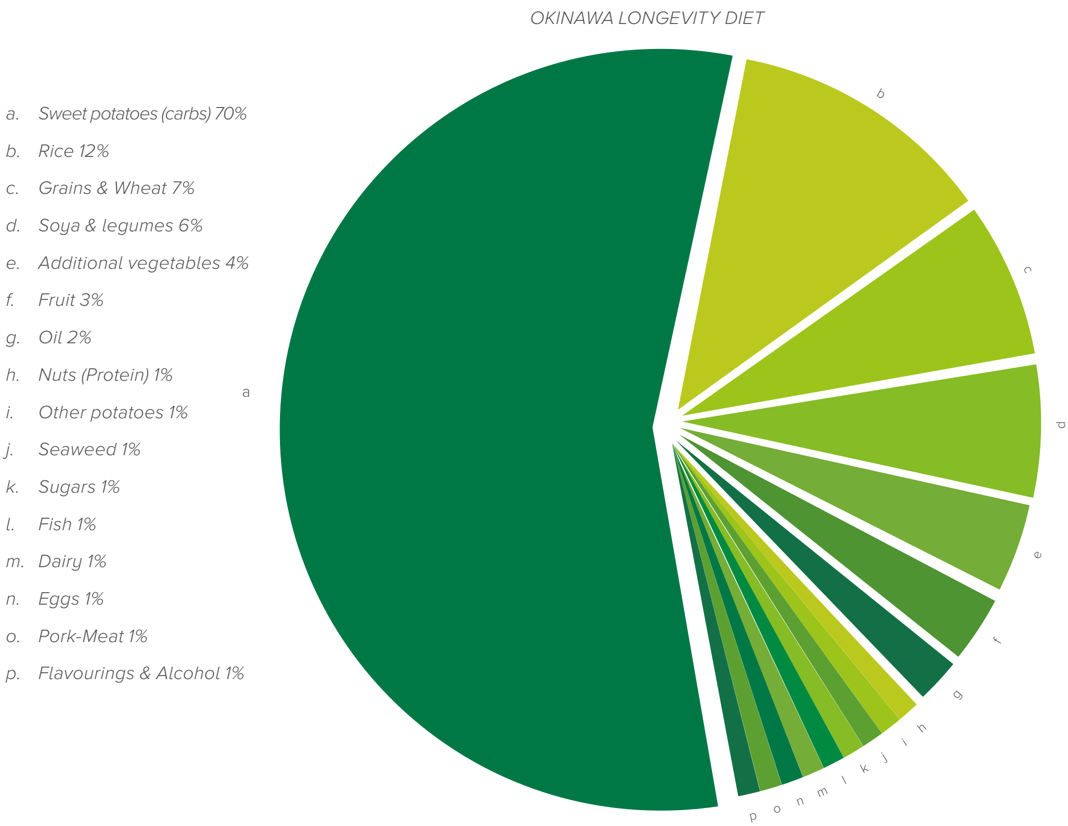
beyond the individual effects of nutrients and it has been stressed that it is important to focus on the impact of a holistic dietary approach rather than on single nutrients.

The role of energy balance in successful ageing was investigated in 2663 older adults living in the Mediterranean basin. During 2005 to 2011, older (aged 65-100 yrs) adults from 21 Mediterranean islands and the rural Mani region (Peloponnesus) of Greece were voluntarily enrolled in the study [26]. Dietary habits, energy intake, expenditure, and energy balance were derived throughout, using standard procedures, and a successful ageing index (range: 0-10) was devised. After adjustment, high energy intake (>1700 kcal/d), as well as positive energy balance, were inversely associated with successful ageing.

Is the evidence related to plant-based eating confined to Mediterranean diet? No, a small number of other cohorts have studied vegetarians and the risk of chronic diseases. These include the UK Health Food Shoppers' Study, the Oxford Vegetarian Study (UK) and the Heidelberg Vegetarian

Study in Germany. These cohorts recorded deaths only and, whilst numbers are small, they indicate a reduction in coronary death, although the position was not as clear cut for cancers. The mortality data of vegetarians and non-vegetarians was collected from the EPIC-Oxford cohort which included 64,234 subjects, aged 20-89 yrs, and for whom diet group was known. During follow-up, 2965 subjects had died before the age of 90. The death rates of participants were much lower than the United Kingdom average and were identical in vegetarians and in non-vegetarians. The authors concluded that this was because the study was not large enough to exclude small or moderate differences for specific causes of death. In a sub-set of 47,254 people who did not have CVD or cancer at recruitment, when vegetarians were compared with meat eaters the adjusted death rate was 19% lower for heart disease and no different for all causes of death [27]. The incidence rate for colorectal cancer in vegetarians compared with meat eaters was 39% higher, although within the study the incidence of all cancers combined was lower among vegetarians than among meat eaters [28].

The island of Okinawa is known to have one of the longest-living populations in the world; there are 34 centenarians per 100,000 people. The, **traditional Okinawan diet** is characterized by root vegetables (principally sweet potatoes), green and yellow vegetables, soya bean-based foods, and medicinal plants [29]. Marine foods, lean meats, fruit, medicinal garnishes and spices, tea and alcohol are also moderately consumed (Figure 8.5). It has much in common with other healthy dietary patterns such as the Mediterranean diet, DASH diet, and Portfolio diet. Indeed, all these dietary patterns are associated with a reduced risk for CVD, as well as other age-associated diseases. It has been suggested that the shared healthy fat profile of these diets may be a mechanism for reducing inflammation, optimising blood lipids and other potential risk factors [23]. Additionally, it has been proposed that the lower energy density of plant-rich diets results in a lower calorie intake, with a concomitant high intake of phytonutrients and antioxidants. Other shared features include low glycaemic load, less inflammation and oxidative stress, and possibly the modulation of aging-related biological pathways which may reduce the risk for chronic age-associated diseases and promote healthy ageing and longevity [23].



1785	*Calories :*	*96%*	*Vegan*	*1%*	*Fish*
85%	*Carbs*	*98%*	*Vegetarian*	*1%*	*Red Meat*
9%	*Protein*	*99%*	*Pesco-vegetarian*	*1%*	*Pork*
6%	*Fat*	*4%*	*Animal Prod*		

Figure 8.5: The diet of the world's longest-lived people

Source: Wilcox [29]

The independent roles of SFA intake and fruit and vegetable intake on total and CHD mortality was assessed among 501 initially healthy men in the Baltimore Longitudinal Study of Aging [30]. Over an average of 18 yrs follow-up, diet records were collected on 1-7 occasions. From these, both fruit and vegetable intake and SFA intakes were individually associated with lower all-cause and CHD mortality ($P<0.05$). Men consuming a combination of ≥ 5 servings of fruit and vegetables/day and ≤12 En% from SFA were

31% less likely to die of any cause (P<0.05), and 76% less likely to die from CHD (P<0.001), relative to those consuming less than 5 servings of fruit and vegetables and >12 En% SFA. Men consuming either a low SFA or a high fruit and vegetables intake, but not both, did not have a significantly lower risk of total mortality; but did have 64-67% lower risk of CHD mortality (P<0.05) relative to those doing neither.

Higher fruit and vegetable consumption has previously been reported to protect against all cause mortality, see for example the EPIC Elderly Study in Europe [31]. However, the suggestion that SFA modification and greater consumption of fruit and vegetables act independently in reducing the risk of CHD is an interesting development of the data [30]. Lending weight to the proposal that plant-based or vegetarian diets are beneficial with regard to CHD mortality not only because they comprise more fruit and vegetables, but also because of the lower SFA intakes associated with these diets [2].

Studies determining diet, lifestyle and chronic disease burden expressed in Disability-Adjusted Life Years

Disease burden is often expressed in Disability-Adjusted Life Years (DALYs). DALYs are the sum of Years Lost due to Disability and the Years of Life Lost due to premature mortality. The advantage of this summary health measure is that the outcome morbidity as well as mortality of several diseases are combined. The measure can help to identify lifestyle factors that have minor effects on several diseases, and by summarizing these, make it easier to identify factors that are important for public health [32].

The association between lifestyle and disease burden was studied among 33,066 healthy participants of the EPIC-NL cohort [33, 34]. In this cohort lifestyle data was collected between 1993-7 and participants were followed for disease occurrence until the end of 2007. Diet, BMI, physical activity and smoking were studied individually and combined into a health behaviour score. Diet was studied in more detail by comparing self-reported adherence to 5 different dietary patterns: 1. the Dutch guidelines for a healthy diet from the Dutch Health Council (Dutch Healthy Diet-index), 2. the dietary guidelines proposed by the WHO (Healthy Diet Indicator), 3. a Mediterranean-Style Diet (modified Mediterranean Diet Score), and the a posteriori defined 4. prudent and 5. Western-type dietary pattern.

Consuming a healthy diet, never smoking, a BMI lower than 25 and being physically active all result in a lower disease burden. Persons who adhere to all four lifestyle factors lived approximately two years longer in good health (DALYs: -2.13; 95% CI: -2.65, -1.62) compared to those without any of the beneficial lifestyle behaviours [34]. Each additional lifestyle behaviour contributed to a longer life in good health, independent of the starting adherence score.

Higher adherence to any of the studied dietary patterns, with the exception of the Western dietary pattern, is related to a lower disease burden. Higher adherence to the modified Mediterranean Diet Score or prudent dietary pattern was associated with on average 2 mo longer life in good health (per standard deviation increase in score). Adherence to dietary guidelines from the WHO and Dutch Health Council were to a lesser extent associated with disease burden, showing on average approximately 1 additional healthy month (per standard deviation increase in score). Due to the underestimation of DALYs, which were measured over 12.4 yrs of follow-up, the estimates should be considered the minimal benefit [33].

It was concluded that in addition to non-smoking, maintaining a healthy body weight, and being physically active a healthy diet is also important for a longer life in good health. The results show a beneficial association with total disease burden when adhering to a healthy diet, specifically when adhering to a Mediterranean-style diet, including limited meat and meat products, plenty of fruit, nuts, fibre, fish and UFA and a moderate amount of alcohol.

Studies investigating cognitive health

A recent review identified that good adherence to the Mediterranean diet was associated with reduced cognitive decline [24, 35]. A recent meta-analysis examined the association between adherence to a Mediterranean diet and cognitive impairment, Parkinson disease and depression [36]. Twenty-two eligible studies were included (11 evaluated stroke, 9 evaluated depression, 8 evaluated cognitive impairment and one Parkinson's disease). High adherence to Mediterranean diet was consistently associated with reduced risk for stroke (RR, 0.71, 95% CI: 0.57-0.89), depression

(RR, 0.68, 95% CI: 0.54-0.86) and cognitive impairment (RR, 0.60, 95% CI: 0.43-0.83). A high adherence to the Mediterranean diet also protected against depression independent of age, but the benefits of moderate adherence tended to diminish with advancing age. Similar findings relating to cognitive function were reported in the PREDIMED-NAVARRA randomized trial [37].

Dietary pattern analysis and cognitive function were examined in the older segment of the Australian Diabetes, Obesity and Lifestyle Study (AusDiab) sample (age 60+ yr) [38]. Subjects completed FFQ in 1999/2000 and the mini-mental state examination and tests of memory, verbal ability and processing speed in 2012. Three dietary patterns were found to be associated with decreased odds of cognitive impairment. Dietary patterns derived from 101 individual food items showed that for every one unit increase in Fruit and Vegetable Pattern: OR, 1.06, (95%CI: 1.006-1.118, P=0.030); Fish, Legumes and Vegetable Pattern: OR 1.032, (95% CI: 1.001-1.064, P=0.040); Dairy, Cereal and Eggs Pattern: OR 1.020, (95%CI: 1.007-1.033, P=0.003), the odds of cognitive impairment decreased. Complex patterns of associations between dietary factors and cognition were evident, with the most consistent finding being the protective effects of high vegetable and plant-based food item consumption and negative effects of “Western” patterns on cognition [38].

A recent review highlighted the vascular component of Alzheimer’s disease and suggested that treatment of vascular risk factors could eventually lead to primary prevention of Alzheimer’s disease [39], while a recent study concluded that arterial ageing seems to affect cognitive function [40]. The association of Alzheimer’s disease with T2D, hypertension and dyslipidemia were the most prominent and serve to provide an insight into the mechanisms by which plant-based and Mediterranean diets appear to be beneficial in maintaining cognitive health, as all these conditions have been shown to be positively affected in those following them.

With regard to cognitive function in postmenopausal women the effect of soya isoflavones inclusion in the diet has been examined in a number of RCT. A meta-analysis of 10 of these placebo-controlled RCTs of soya isoflavone supplementation has recently been conducted [41]. The studies included had a treatment duration of 6 wk to 30 mo, and involved 1024 subject values. Both summary cognitive function test scores and visual memory scores were assessed and found to be statistically significant in favour of isoflavone supplementation. Subgroup analyses (location, age and duration of treatment) found favourable effects for non-US countries (vs US) younger than 60 yrs (vs older than 60 yrs) and duration less than 12 mo. The authors concluded that soya isoflavone supplementation seems to have a positive effect on improving summary cognitive function and visual memory in postmenopausal women. There may be a critical window of opportunity in initiating soya isoflavone use at an earlier age in postmenopausal women, and geography and treatment duration seem to be factors influencing the effects.

Studies investigating menopausal symptoms

It has been suggested that specific plant foods may have a beneficial effect on ageing. Of these, soya is the most extensively researched. In the postmenopausal female population where concern about bone health (see Chapter 7), cognitive decline and menopausal symptoms such as hot flushes is prevalent, a wide range of studies have been undertaken.

With regards to menopausal symptoms and the use of soya isoflavones there are several meta- analyses of RCT conducted to date. Some of the older studies included in these analyses suffer from poor characterisation of the supplement, inadequate study duration and do not adequately take account of placebo effect. Specific attention was given to characterisation of the supplement in one analysis, and in this, studies were compared on the basis of the quantity of free genistein (the predominant isoflavone found in soya) consumed [42]. All five studies investigating intakes of 15 mg genistein per treatment in healthy menopausal and breast cancer sufferers, consistently reported a statistically significant decrease in hot flush symptoms [42]. The consensus view of the EU-funded project Phytohealth was also positive, concluding that soya bean isoflavone extracts could be effective in reducing hot flushes, but the effect is about half that observed with HRT and similar to that of other non-hormonal pharmacological therapies [17].

Recent data show that typically hot flushes are reduced by approximately 20-30%, provided a minimum level of around 40-60 mg isoflavones/d is included in the diet. This is equivalent to around 2-3 servings of soya products such as soya alternative to milk and yogurt, soya nuts or tofu [42].

Meta-analysis also revealed that extracted or synthesized soya bean isoflavones can significantly reduce hot flash severity by 26.2% (P=0.001) compared with placebo [43]. This analysis of 17 studies also reported a significantly reduced frequency of hot flashes by 20.6% (P<0.0001) compared with placebo. Isoflavone supplements providing more than 18.8 mg of genistein were more than twice as potent at reducing hot flash frequency than lower genistein supplements.

In the most recent review, attention was focused accounting for the placebo effect [15]. In this analysis 16 soya isoflavones studies, including 1710 subjects, examined the average effect of soya isoflavones, compared to placebo, on hot flush reduction [15]. Soya isoflavones reduced hot flushes by a maximum of 25.2% after the placebo effect was taken into account. The effect with isoflavones was just over half (57%) that reported for oestradiol. However 13.4 wks was needed for soya isoflavones to achieve half of its maximal effects, much longer than oestradiol, which only required 3.09 wks. These results suggest that treatment intervals of 12 wks are too short for soya isoflavones, which require at least 48 wks to achieve 80% of their maximum effects, which may explain some of the inconsistent results reported in early soya isoflavone studies which were of short duration.

Overview and conclusions

Western populations are living longer with a significant increase in the proportion of older people in society. Currently, in most Western European countries, over 20% of the population is aged 60 yrs or older and this is predicted to increase further. Of particular note are the population demographics in Greece, Italy and Spain, where there is proportionately a greater consumption of a Mediterranean diet. Plant-based eating is just as relevant, if not more so, to the ageing population as it is to the population at large. It is associated with a lower incidence of obesity, which is beneficial in its own right, but also as it reduces the risk of developing CVD, T2D and cancer — the main non-communicable diseases — and causes of premature mortality. Recent research appears to indicate there is an association between vascular disease, dyslipidaemia and cognitive decline, and that following a dietary pattern which benefits CV health also appears to have cognitive health benefits, too.

Plant-based eating patterns also tend to be rich in fibre, often limited in the diet of older people, which can aid laxation and help encourage gut microbiotic diversity. Micronutrients can be inadequate in the diets of older people and care should be taken to ensure a sufficient intake of Ca, vitamins B12 and vitamin D by consuming a wide range of plant foods, if necessary choosing foods fortified with these nutrients.

In this ageing population CVD is the main cause of death. Plant-based eating tends to be associated with a lower risk of CVD and also a lower incidence of death from CVD (as discussed in Chapter 3).

A varied and adequate diet with increased consumption of fruits, vegetables, legumes, whole grains and nuts, and regular physical activity, are important components of a healthy lifestyle for older people.

Take-home messages:

- Western populations are living longer with a significant increase in the proportion of older people, who wish to live longer in good health, presenting a challenge to society.
- Achieving energy balance is important in older people where overweight or obesity may be prevalent; plant-based eating patterns, which tend to be lower in energy and nutrient-rich, can help maintain a healthy weight.
- The diet of older people is often low in fibre, which can be found in plant foods.
- Plant-based eating is associated with a reduced incidence of death from CHD, stroke and diabetes and a lower prevalence of obesity.
- Those consuming a Mediterranean diet appear to have improved cognitive function into old age and it appears other plant-based eating patterns may also be beneficial.
- Greater fruit and vegetable consumption may make a positive contribution to the health of older people, as may soya foods that can improve bone health and moderate symptoms of the menopause.
- Attention needs to be focussed on ensuring adequate intakes of Ca, vitamin B12 and D, which in older people may be below the recommended amounts.
- A varied diet with increased consumption of fruits, vegetables, legumes, whole grains and nuts, and adequate intakes of Ca, vitamin B12 and D, as well as regular and physical activity are important components of a healthy lifestyle for older people.

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9

Chapter 9

More plant-based eating for the planet

PROF. HARRY AIKING
Emeritus Professor
Chemistry and Food at
VU University Amsterdam
(The Netherlands)

Introduction to Chapter 9, by invited expert Harry Aiking

In 1987 the Brundtland Commission defined sustainable development as follows: "To ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs." Subsequently, the three pillars of sustainability are taken to be ecology, economy and society, also known as "people, planet, profit". However, individual definitions do not always address issues such as human health, equity, and animal welfare. At any rate, sustainability is not a static notion, but a rapidly moving target, which should be understood as a challenge to preserve the adaptability and resilience of the natural (biotic and abiotic) systems that form the basis of social and economic development.

In order to explain sustainability in terms of the "carrying capacity" of planet Earth, Rockström et al. [1] identified in 2009 and quantified the most important environmental issues caused by human activity (Table I9.1). Further analysis shows that a) food production is an important driver underlying all of these impacts, b) the top three environmental impacts, i.e. biodiversity loss, nitrogen cycle disruption and climate change, are strongly interlinked, and c) protein is the linking pin, as described below.

Food production already uses up 33% of all ice-free land, 70% of freshwater and 20% of all energy production. In the next few decades we will face an additional dual challenge of global food security and global food sustainability, in spite of dwindling resources. By 2050, a world with 2.3 billion more people will need 60-100% more food. Simultaneously, the environmental impacts of food production must be reduced. Taken together, this outlines the daunting task of roughly quartering the environmental impacts per tonne of food within a period of merely 35 yrs.

Dietary protein is nutritionally crucial, since it is our primary source of nitrogen, which is an indispensable constituent of DNA, RNA and protein. In fact, before large-scale application of fertilizers, world population was capped at approximately 3 billion people by nitrogen limitation. The tremendous

Rank	Environmental impact	Current status*
1	Rate of biodiversity loss	>10
2	Nitrogen cycle disruption	3.4
3	Climate change (Carbon cycle disruption)	1.1-1.5
4	Phosphate cycle disruption	0.77-0.86
5	Ocean acidification	0.81
6	Land-use change	0.78
7	Freshwater use	0.65
8	Stratospheric ozone depletion	0.50

Table I9.1: Ranking environmental impacts (boundary value for sustainability = 1).

*Source: Aiking 2014 [2] * in terms of the "carrying capacity" of our planet.*

energy input in nitrogen fertilizer alone is responsible for 37% of all energy expenditure in US agriculture, linking our disruption of the nitrogen cycle to our disruption of the carbon cycle, leading to climate change.

Invariably, a large proportion of fertilizer nitrogen is lost to the environment. Much of this "reactive nitrogen" is transported by air to be deposited in nitrogen-limited ecosystems. There it leads to unintended fertilization of ecosystems unable to cope with this nutrient inflow (such as several types of forest), making it one of the leading causes of biodiversity loss [3]. Thus, our disruption of the nitrogen cycle is strongly linked to biodiversity loss, as well.

Besides, human contributions to the natural carbon cycle are 1-2% (by mineral fuel combustion), but to the natural nitrogen cycle 100-200% (by production of artificial fertilizer). Since nitrogen cycle disruption has strong impacts both on biodiversity and on the carbon cycle, protein production was shown to be the pivotal link between the top three environmental issues in the Rockström ranking [2].

Conversion of plant protein into animal protein is a metabolic process optimized for animal metabolism and survival. However, turning protein from feed crops into animal protein for human consumption is inherently resource-inefficient. Since 6 kg plant protein is required to yield 1 kg meat protein, on average, a mere 15% of the protein and energy in these crops will ever reach a human mouth (indirectly), 85% wasted and, moreover, turned into reactive nitrogen emissions (such as from manure), subsequently resulting in tremendous biodiversity loss.

Currently, over 38% of the world grain harvest and approximately 75% of soya is fed to livestock, with resource losses of about 85%. In light of doubling food production, such wasteful practice will need to be discontinued. Besides, it is clear that the continued upward pressure on food prices can be significantly reduced by replacing animal proteins with plant proteins, abolishing the inherently huge conversion losses. The good news is that a primarily plant-based diet is not just more sustainable than a primarily animal-based diet, but also healthier (Health Council of the Netherlands, 2011; US Dietary Guidelines, 2015).

Whether for environmental reasons, exploding prices, health, or - more likely - a combination of these, a trend reversal towards diets containing less animal protein in Western countries seems not just strongly recommendable, but inevitable. At any rate, plant foods can clearly play a large part in this transition towards diets that are both healthier and more sustainable. Food security, equity, health, biodiversity, and animal welfare may all benefit.

In essence:

- *Animal-based foods generally require more resources (land, water, energy) than plant-based foods, and result in more greenhouse gas emissions and more biodiversity loss.*
- *Shifting towards more plant-based eating can make a big difference to improve both human health and ecological health.*

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Chapter 9

More plant-based eating for the planet

Introduction

Over the last two to three decades it has been recognized that the planet cannot continue to be treated as it has been over the last millennium or there simply will not be sufficient food to feed the rising world population. UN Secretary General, Ban Ki-Moon, stated that, "for world food security, food production needs to increase by 50% by 2030 to meet rising demands", while the Director-General of the FAO, Jacques Diouf, stated that food production would need to double by 2050 to feed a world population of 9 billion [1]. In addition, it has been reported that the number of people suffering from chronic hunger increased from under 800 million in 1996 to over 1 billion in 2009, and in 2010, 925 million people were estimated to be undernourished [2].

This global food demand is neither sustainable nor feasible. It will place even greater stress on an already limited supply of land and natural resources such as energy and water. Furthermore it will have a noticeable impact on climate change and biodiversity. All of these factors pose major challenges for food provision and security.

For many years dietary messages have mainly focused on the benefits a nutritious diet provides to health. However, it is now recognized that what a person chooses to eat can make a big difference to the environment. The good news is that plant-based eating is not only good for health, but is also healthy for the planet [3]. This chapter discusses the environmental benefits of plant-based eating, along with the various recommendations that have been proposed to achieve a sustainable diet.

Sustainability

The Foresight Programme defines sustainability as, "a system or state where the needs of the present and local population can be met without diminishing the ability of future generations or populations in other locations to meet their needs and without causing harm to the environment & natural assets" [1, 4].

It comprises 3 "pillars" of importance, alternatively known as people, planet and profit [5], each of which contains a number of elements:

- **People:** social *(health and welfare, ethics, social dynamics)*
- **Planet:** environmental *(global warming potential, land use, water use, biodiversity)*
- **Profit:** economic *(value of output, employment, trade)*

What does this mean in practice in the context of food production?

- The need to radically reduce greenhouse gas emissions produced by the food system;
- The need to reduce the dependency of the food chain on fossil fuels (given climate change and expectations of higher energy costs in the decades ahead); and
- The need to address the depletion of the natural resources and ecosystem services on which food production depends (e.g. soil and water); without compromising the ability of future generations to meet their needs [6].

Food's impact on the environment

Food production is extrinsically linked to the environment. However, measuring the environmental impact of food production is complex, with many factors needing to be considered. Life-cycle analysis (LCA) is a method that has been identified to address this. LCA takes into account all stages of food production from farm to fork and includes:

- Agricultural inputs (feed, fertilizer)
- Agriculture itself (food production)
- Food processing/ manufacturing
- Packaging
- Distribution and retail
- Storage
- Consumption
- Land use change arising from agriculture production

The contribution of these different stages to the total environmental impact will depend on the food product, the method used to do the calculations and the impact that is being measured, e.g. greenhouse gas emissions (GHGe), water requirements, energy needs, etc. Although LCA is considered the best method for assessing environmental impacts, LCA takes time to complete and is currently not available for all foods. In the UK a study commissioned by the Department for Environment, Food and Rural Affairs (DEFRA) aimed to identify the extent of the LCA information available; it concluded that a much greater volume and depth of robust evidence appears to be available with respect to environmental sustainability than for economic and social sustainability [7]. However, even in respect of the environmental measures there was a great deal of variation between the sources of information and within the method of production used, e.g. there is great variability in the values for tomatoes depending whether or not the crop is produced in a hothouse and irrigated.

The current focus of environmental impact is GHGe, measured in terms of CO_2e. Most assessments related to food production use this measure, but may unintentionally overlook other very important impacts, both positive and negative. For example, this measure neglects the resource, which many believe is most under threat: water supply.

The relationship between food and the environment is intertwined, so that environmental changes will in turn effect food production. Figure 9.1 describes this relationship.

Food production and climate change

Global warming is caused primarily by GHGe such as carbon dioxide (CO_2), methane and nitrous oxide. Each of the GHG's has a different global warming potential (GWP); CO_2 is the reference point and so 1; nitrous oxide is 310 and methane is 21, thus both considerably higher than CO_2 [9].

These gases act like the glass in a greenhouse, trapping heat from the sun to warm up the earth. Although most of these gases occur naturally and are vital to ensure the planet stays warm enough to sustain life, the balance is very delicate. Current lifestyles are resulting in an increase in GHGe and if this continues the planet's temperature will rise higher and higher. This global warming could increase the risk of flooding, droughts, hurricanes, tropical storms as well as a loss in biodiversity. This in turn could damage sectors such as agriculture and ultimately threaten human health. Between 1970 and 2004 global emissions of these three GHG's increased by a colossal 70% [10].

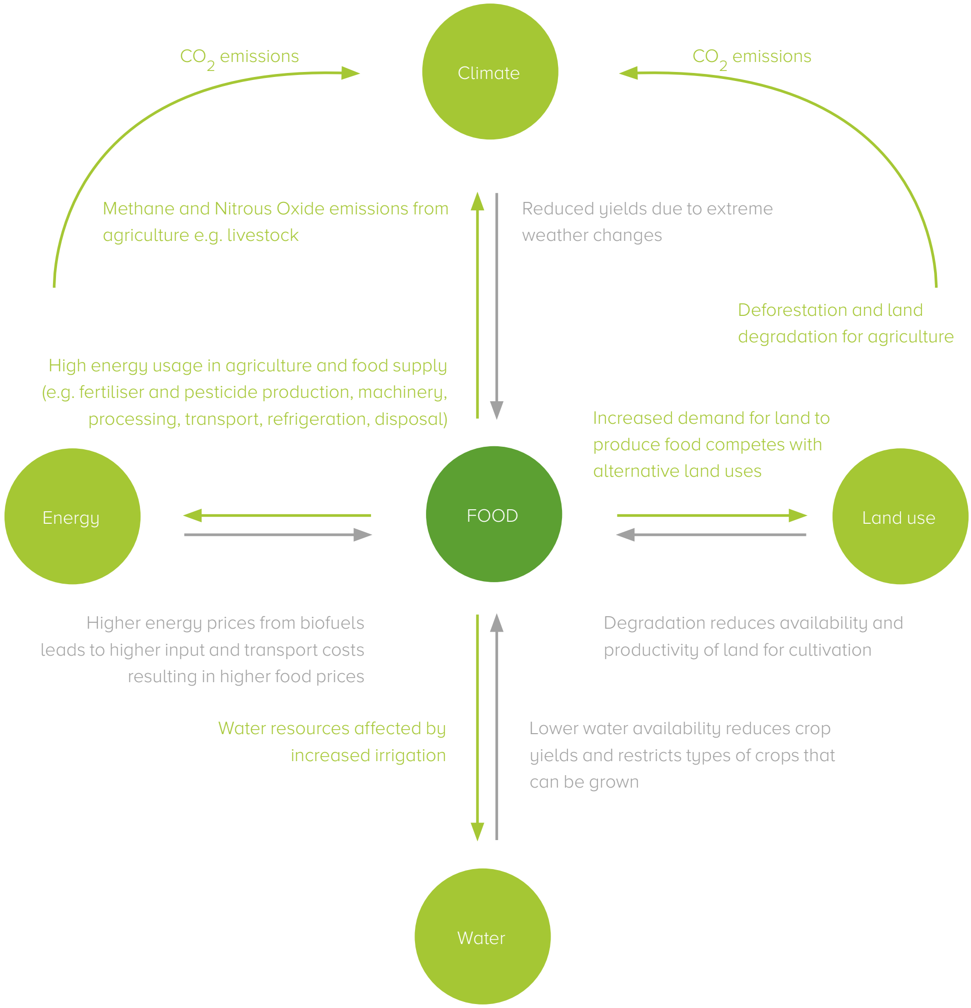

Figure 9.1: Food's relationship with the environment

Source: Adapted from Oxfam GB Briefing Paper [8]

Many experts believe that climate change is the most serious issue facing the human race. As a result various policies (such as the United Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol) have been agreed. In terms of Europe:

- 27 countries of the European Union have agreed to a 20% cut in GHGe by 2020 (taking 1990 as the base).
- WWF-UK has also set out targets to reduce GHGe by at least 25% by 2020 (based on 1990 levels) and 70% by 2050 as part of its One Planet Food Programme [11].

Estimates suggest that modest climate change could result in a global mean temperature rise of around 2°C, but this could be up to 3°C. As a result of this change there would be a reduction in agricultural production in places already hot and dry, a shortened growing season and increased frequency of extreme weather events, with water becoming an even more precious commodity. Worldwide the likely impact of climate change has been assessed and is shown in Figure 9.2. Of particular note is the reduced output in areas of the world such as Africa and Indian continents, where food supplies are already limited. Europe, Northern USA and Canada become increasingly important as food producers, so that agricultural practice and systems adopted need to maximize efficiency to ensure these Regions produce as much food as possible.

Food production and GHGe

The **food system** is believed to be a very significant contributor to global GHGe, **accounting for approximately 30% of the European Union's total GHGe** [12, 13]. While calculating GHGe is difficult (due to the complexities of measuring GHGe at the different stages of the LCA), it has been estimated that agriculture, including fertilizer application and production, contributes 12-14% of GHGe.

On a global scale, nitrous oxide from soils and methane from enteric fermentation and manure are the largest sources of GHGe from agriculture. In fact, livestock production globally accounts for 18% of the total GHGe, more than the entire transport system (approx. 14% of global GHGe) [14]. However,

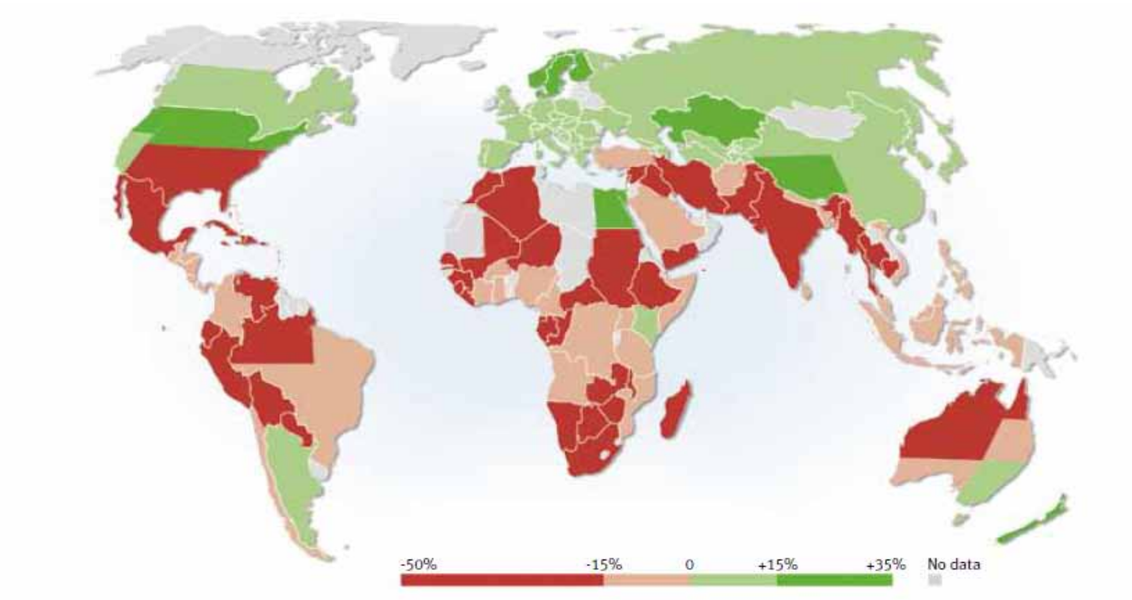

Figure 9.2: Projected changes in agricultural production in 2080 due to climate change

Source: Cline 2007, cited in [6]. Note projections assume a 15% increase in yield due to fertilization effect of rising CO_2 in the atmosphere on some plant species.

this varies from region to region and also depends on the livestock system used (e.g. pastoral versus intensive, as well as the type of livestock).

Food system considerations:

- Demography, development and diets
- Climate change impacts on agriculture
- Food production, supply chains and the environment
- Investment, trade and food price volatility

Various studies have attempted to calculate the GHGe from different food products. A summary of values for key agricultural products is given in Table 9.1; also shown is the impact on water footprint and fossil fuel requirements. It can be seen that GHGe from milk, eggs and poultry are lower than beef, lamb and pork, but these can increase with processing. In contrast, plant foods have been estimated to produce far fewer GHGe.

Foodstuff	GHG emissions ($kgCO_2e$)	Water footprint (L/kg)	Fossil fuel input (MJ)
Beef	6.3 - 37	15,500	15 - 56
Sheep meat	7.6 - 17	6100	17 - 19.3
Pig meat	3.6 - 6.4	4460 - 5900	17 - 21.06
Eggs	2.2 - 5.5	3900	14 - 22.2
Poultry	1.1 - 4.6	2390 - 4500	12 - 25
Cow's milk	0.4 - 1.4	1000	2.5 - 3.6
Soya beans	0.9	1800	5.9
Rice	0.4	3400	8.8
Wheat	0.3	1300	2.1 - 2.8
Oranges	0.25	500	2.96
Apples	0.24	500 - 700	2.87
Potatoes	0.17 - 0.24	105 - 500	1.17 - 1.4
Tomatoes	0.1 - 10	0.04	3.4 - 37.7

Table 9.1 : Global livestock emissions as GHGs ($kgCO_2e$), water footprint (L/kg) and fossil fuel input (MJ)

Source: European Parliament STOA (2009) [9]

A Swedish study which compared the total GHGe for 22 food items sold in Sweden, found comparable results. In this study plant foods based on vegetables, cereals and legumes generally produced the lowest GHGe (with the exception of those shipped by aeroplane). While, animal products were generally associated with higher GHGe than plant-based products, with the highest emissions occurring in meats from ruminants [15].

A comparison between soya-based foods and animal products found that cow's milk (1.3 kg CO_2e/L) created on average five times more CO_2e/L than soya drink (0.28 kg CO_2e/L), while beef generated 10 times more /kg than tofu [16].

Studies have also investigated the climatic effect of producing protein from different food sources and concluded that it is more "climate friendly" to produce protein from vegetable sources than from animal sources (although some animal products are fairly climate efficient). For example, the Swedish study described previously found that wheat, local herring and soya beans (cooked and shipped by boat) were the top three most climate efficient protein producing foods [15].

As studies use different methods to calculate these GHGe, caution does need to be taken when interpreting this information. However, it is generally agreed that on average meat and dairy products are the most GHG-intensive relative to other food groups, with most emissions coming from the agricultural stage of the LCA, see Figure 9.3 for a graphical summary of livestock product emissions [17].

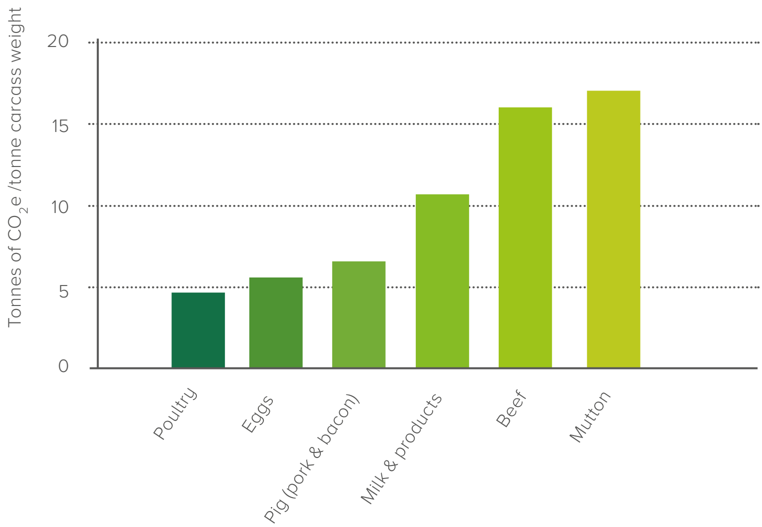

Figure 9.3: Estimates of total livestock emissions for livestock products produced in the UK

Source: Extracted from Friel 2009 [17]

Food production and land use

Land is a valuable commodity and it is important to consider the best way to use it, e.g. how to ensure adequate sustenance for the population while minimising any environmental damage. Currently 25-30% of the earth's entire land surface (65-70% of all agricultural land) is used for rearing farmed animals. Much of this is used as grazing land, however, crops are also grown for animal feed. **One third of all land that is suitable for growing crops is used to produce feed for farmed animals** [14].

Animals such as poultry and pigs consume only grains, whereas cattle and sheep consume both forage and grains. However, livestock animals are relatively inefficient at converting grains to meat, with large amounts of the grain's energy and protein not being used to make animal protein or fat. Consequently large amounts of grain are needed to produce 1 kg of meat (Table 9.2). Nevertheless, in certain parts of the world, where the land is only suitable for growing grass, it can be argued that there is no alternative but to have ruminants graze on this land to preserve the local eco-system.

Poultry	Pork, bacon and ham	Beef	Mutton
2 – 4 kg	2.64 kg – 5.9 kg	7 – 13 kg	7 – 21 kg

Table 9.2: Ranges of grain feed required to produce 1kg meat

Source: European Parliament STOA (2009) [9]

Rather than growing grains to feed animals it has been suggested that some of these grains would be better used to feed the world's growing population. **In fact, in the United States, the amount of grains fed to US livestock is sufficient to feed approximately 840 million people who eat a plant-based diet** [18]. Soya beans are a major source of protein in animal feed and currently 75% of the world's soya is used in this way. Soya-based feed plays a significant contribution towards land-use change in other parts of the world. However, again this link could be broken if soya was directly consumed by humans. Its excellent nutritional properties and high quality protein make it an ideal food for health and the environment.

One estimate has suggested that a **typical meat-based diet requires two and half times more land compared to a vegetarian diet** [19].

Food production and energy resources

Although food provides energy, at the same time it requires energy to produce. Key energy inputs for agriculture are fossil fuel for fertilizer production, agricultural machinery, fuel, irrigation and pesticides. Fossil fuel estimates for different food productions have been made and a summary of this data is given in Table 9.1. When energy requirements are considered in relation to the protein and energy content of the food, grains and some legumes, e.g. soya beans, are produced more efficiently than vegetables, fruit and animal products. One study calculated that, on average, to produce 1 kcal plant protein requires 2.2 kcal fossil energy. In contrast, producing **animal protein is more energy intensive**, requiring 25 kcal fossil fuel to produce 1 kcal meat protein, **more than 11 times that of plant protein** [18]. However, energy requirements will depend on the type of livestock, the type of feed (grain vs pasture) and the geographic location. The two livestock systems that depend most heavily on forage, but also rely on significant amounts of grain, are beef and lamb. As a result they require the highest amount of energy to produce 1 kcal of protein. If these animals were fed on only good quality pasture, the energy inputs could be reduced by about half [18].

Food production and water

More fresh water is used for agriculture than for any other human activity. It has been suggested that if current trends for water continue, by **2030 47% of the world's population will live in areas of water stress** [9].

The water required to produce various foods and feed crops ranges from 500 to 3000 litres of water per kilogram of crop produced. If irrigation systems are needed, this amount can increase considerably. Producing 1 kg animal protein requires about 100 times more water than producing 1 kg grain protein. The actual amount of water that is drunk directly by livestock is very small (1.3% of the total water used in agriculture). However, when the water to make the feed and forage is taken into account this volume increases dramatically [18].

Different animals vary in the amount of water required for their production. Other factors that will determine how much water is required include geographic location (how much rainfall there is), as well their type of feed and where this is grown. Estimates of the amount of water required for different foods are summarized in Table 9.1.

A further issue of agricultural practices is the potential risk of water pollution. Animal waste, pesticides and fertilizers, at high concentrations, can act as pollutants and should they enter waterways can have a damaging effect on aquatic life and may be partly responsible for "dead zones" in oceans and rivers where plant and animal life cannot exist.

Food production and the economic and social aspects of sustainability

Assessments of the impact of food production on the economic and social aspects of sustainability are less frequently reported [7]. As these are the people and profit aspect of sustainability, and have less relevance to the planet, further reference will not be made to this area, other than to note that data availability with regard to economic impact of food production is concentrated at the production end of the chain; e.g. storage, transport and distribution. However, there is no doubt that one of the key economic impacts of climate change is greater variability and volatility in food prices.

Information on social sustainability indicators is lacking. An important dimension in this context is health, e.g. supplying the population with safe, health–promoting nutrition and the ethical dimension, which includes aspects such as animal welfare and the impact of biotechnology, e.g. GM for both plant- and animal-based foods.

What is a sustainable diet?

The FAO defined sustainable diets as being, "those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" [1].

Over the last decade there has been a much greater interest in sustainable eating. The reasons for this are two-fold; firstly, the growing worldwide population. Secondly, global dietary patterns are changing – as societies are becoming more affluent there is a shift towards a more "Western" style of eating with a focus on animal products. Due to this there is an increased demand for these animal foods. As a result, it has been estimated that global meat demand could double from 251 million tonnes in 2005 to 563 million tonnes by 2050 [9]. Currently meat and seafood are the two most rapidly growing ingredients in the global diet – four times as much meat is now being produced compared to 1961 [20].

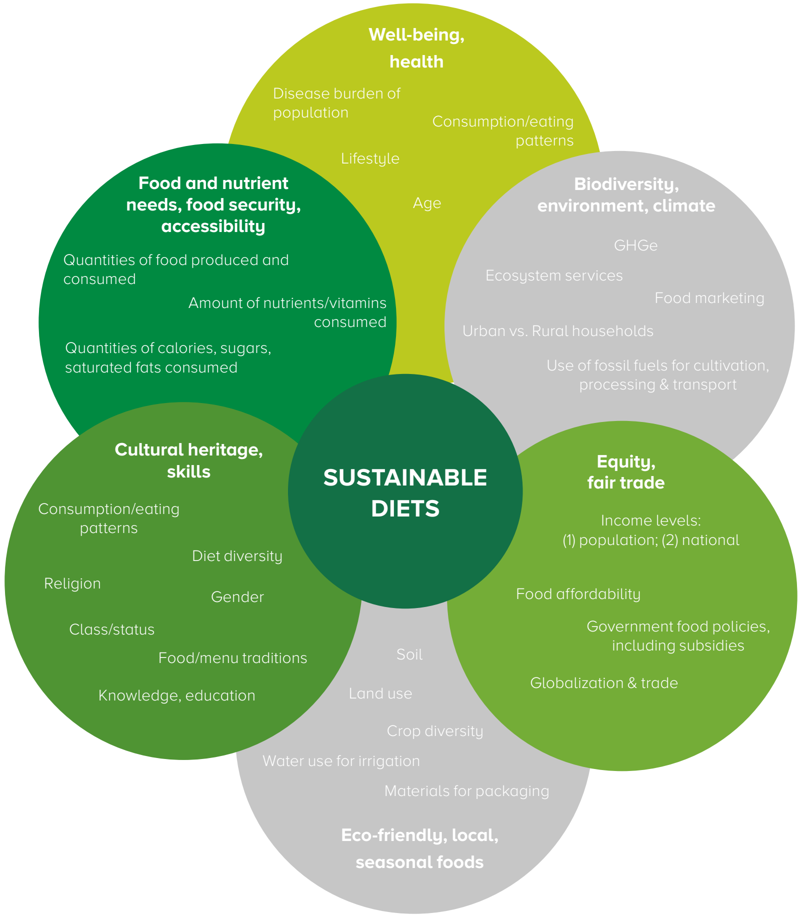

Figure 9.4: Sustainable diets' relationship with the environment

Source: Johnston 2014 [24]

Consequently not only is the demand for meat growing, but it requires more resources to produce it and potentially has a greater impact on the environment. As a result recommendations are already in place in several European countries that high meat intakes should be limited [17] (Swedish National Food Administration [21]; New Nordic Diet [22], the Netherlands [23]).

In addition, a number of research groups have started to assess the effect on both nutrient intake and health outcomes of changing to a more environmentally aware diet. The complexity of diets' relationship with the environment is shown in Figure 9.4.

Defining sustainable diets in practice

It is generally considered that if general healthy eating guidelines be followed there would be a reduction in dietary GHGe [25-27]. However, in an analysis of UK National Diet and Nutrition Survey (NDNS) data (405 males + 408 females aged 19–64yrs) compliance to a healthy diet (comprising of a fat intake of 35 En%, SFA intake of 11 En% and 5 fruit and vegetables a day) indicated little effect on sustainability [28]. There was little difference in overall meat and dairy intake in those achieving the healthy eating guidelines; they had simply selected lower fat options. High fat and high sugar foods were in excess of recommendations and while fat and SFA had reduced, carbohydrate intake had not increased nor protein intake reduced. Overall, those meeting the dietary guidelines consumed significantly more skimmed milk, soya, almond and rice drinks, cream, chicken and turkey dishes, white fish, shellfish and fish dishes and wholemeal bread ($P<0.05$).

A similar finding was reported in French adults [29]. High nutritional quality was not associated with low GHGe in self-selected diets which contained more plant-based foods, notably fruit and vegetables, and fewer sweets and salted snacks than did low-quality diets. After adjustment for age, sex and energy intake, the consumption of sweets and salted snacks was negatively correlated with diet-related GHGe, while consumption of animal products and of fruit and vegetables was positively associated with GHGe. Overall, the high-nutritional-quality diets had significantly higher GHGe (+9% for men and +22% for women) than did low nutritional-quality diets. However, the quantities of the ruminant meat, pork, poultry, and eggs groups did not differ between nutritional-quality classes and the authors conclude that animal-based products (ruminant meat, fish, dairy products, and pork, poultry, and eggs) have higher GHGEs than do plant-based products (fruit and vegetables and starchy food) on a weight basis. Among the food groups, ruminant meat, mixed dishes (because of animal-based mixed dishes), and pork, poultry, and eggs were the main contributors to diet-related GHGEs and were the most strongly and positively associated with them.

Nevertheless, **there is considerable evidence that a healthy and sustainable diet could be devised to reduce GHGe** [3, 25, 27, 30-33]. While most healthy diets focus on SFA reduction, it has been documented that reducing the consumption of edible fats and oils appears to have little environmental impact [34], but as shown previously, the environmental impact of foods containing animal protein is much higher than that of plant proteins [5, 9, 15, 35-37]. For example, approx. 6 kg of plant protein as animal feed is required to generate 1 kg animal protein [5]. Consequently, suggestions for healthy and sustainable diets include minimising the consumption of energy-dense and highly processed and packaged foods, including less animal-derived foods and more plant-based foods and encouraging people not to exceed the recommended daily energy intake [38].

Research studies evaluating the impact of consuming a sustainable diet on the environment

In a recent systematic review of the literature, 31 studies that examined impacts of dietary patterns on at least one environmental indicator were identified [39]. Interestingly, more than two-thirds of the studies were published between 2010 and 2014 and 21 were from Europe, (see, for example, Finland [40]; Denmark [41]; France [29]; Austria [42]; the Netherlands [43]; UK [26]; Italy [44]; Germany [45]; EU [46]). The European studies generally included an assessment of GHGe by reference to eating patterns. Impacts of dietary patterns on other indicators of sustainability were reported less frequently, with land capacity examined in 12 studies, energy/fossil fuel use in 4 studies, water use in 7 studies, and environmental impacts to human health in 2 studies. The authors concluded that it is difficult to assimilate all of the disparate approaches, and that the limitations and inconsistencies of research in this emerging area underscore the need to standardize methodology [39].

Research studies evaluating the impact of consuming a plant-based sustainable diet on the environment

A number of studies in the literature used published data from cohorts and modelled the environmental impact of various sub-groups in the cohort that follow different dietary patterns. For example, subjects in the EPIC-Oxford UK cohort study were divided by dietary habit; self-selected meat eaters, fish eaters, vegetarians and vegans [36]. The differences in estimates of dietary GHGe were calculated using dietary records (assessed using a validated food frequency questionnaire) from 2041 vegans, 15,751 vegetarians, 8123 fish eaters and 29,589 meat eaters aged 20-79. Comparable GHGe parameters were developed using a dataset of GHGe for 94 food commodities in the UK. The average GHGe associated with a standard 2000 kcal diet were estimated for all subjects. The age-and-sex-adjusted average GHGe in kgCO_2e/d were 7.19 for high meat eaters (≥100 g/d), 5.63 for medium meat eaters (50-99 g/d), 4.67 for low meat eaters (<50 g/d), 3.91 for fish eaters, 3.81 for vegetarians and 2.89 for vegans, Figure 9.5. The authors concluded that dietary GHGe in self-selected meat eaters are approximately twice as high as those in vegans, and hence it is likely that reductions in meat consumption would lead to reductions in dietary GHGe.

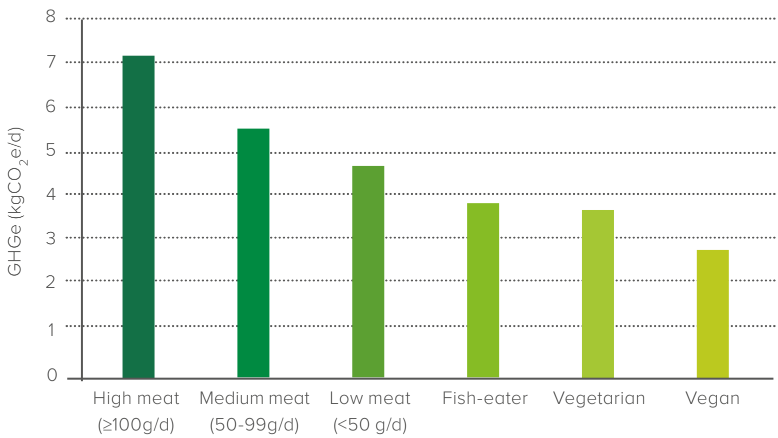

Figure 9.5: Dietary GHGe (kgCO_2e/d) for subjects following different dietary patterns in the EPIC Oxford Cohort

Source: Scarborough [36]

One study has attempted to examine the environmental impact of whole diets rather than individual foods. Data from Seventh Day Adventists in California was used to compare vegetarian and non-vegetarian diets. Among the 34,000 Californian Adventists participating in the Adventist Health Study I cohort, around 50% were vegetarians and 50% were non-vegetarians. Dietary information, collected from the study questionnaire, found that non-vegetarians ate substantially more animal foods than the vegetarians, whereas the vegetarians ate slightly more plant foods. Using environmental information from state agricultural data it was found that the non-vegetarian diet required 2.5 times more energy, 13 times more fertilizer and 1.4 times more pesticides than the vegetarian diet [47].

A further paper used what the authors termed as an environmentally extended input-output model of the economy, to estimate GHGe for different food sectors [27]. This model estimated GHGe by reference to the GHGe outputs in the finished food products in each food sector, counterbalanced by GHGe input during production and processing of different food sectors. Food intake estimates were from the 1995 Australian National Nutrition Survey. The average Australian diet was estimated to produce 14.5 kg CO_2e/person/d. If a dietary pattern was followed that met the Australian guidelines, which focus on eating more fruit, vegetables and legumes and dairy and less food and drinks high in SFA, added sugar, salt, or alcohol (referred to as non-core foods), as well as being more nutrient-rich, it was calculated the diet would produce approximately 25% GHGe less than the average diet. In the average Australian diet, greatest contributions to diet-related GHGe were red meat (8.0 kg CO_2e/person/d) and energy-dense, nutrient poor "non-core" foods (3.9 kg CO_2e). Energy dense non-core foods accounted for 27% of emissions and the authors suggested that intake of these foods should be kept to a minimum [27].

In a study of the environmental impact of diets of different population groups (omnivorous, vegetarian and vegan) data from 61 different categories of foods were examined to calculate GHGe in the different dietary scenarios [48]. Compared with habitual UK diet, vegetarians had 18-25% lower GHGe and diets were 9-15% cheaper, and vegans had 23-31% lower GHGe and their diets were 4-14% cheaper. The vegetarian and vegan diets had lower protein intakes and none of these theoretical diets had higher sodium than the average UK diet.

In a further UK study linear programming was used to model a diet that met the dietary requirements of an adult woman (19-50 yr), while minimizing GHGes [26]. Acceptability constraints were added to the model to include foods commonly consumed in the UK in sensible quantities. A sample menu was created to ensure that the quantities and types of food generated from the model could be combined into a realistic 7-d diet. Reductions in GHGes of the diets were set against 1990 emission values. In the first-devised model, without any acceptability constraints, a 90% reduction in GHGes was identified but it only included only 7 food items, all in unrealistic quantities. The addition of acceptability constraints gave a more realistic diet with 52 foods but reduced GHGes by a lesser amount of 36%. This diet, termed the Livewell 2020, included meat products but in smaller amounts than in the current diet. An interesting dimension of this study was that the retail cost of the Livewell 2020 diet was estimated to be more than 10% cheaper/ person/wk when compared with an average household spend (2009 prices). Adoption of the Livewell diet or Livewell Plate – which is essentially based on two-thirds or more plant foods and one third or less animal based foods – has been piloted in three European countries although progression to full-scale adoption has not taken place to date [49].

Research studies evaluating the impact of consuming a sustainable diet on health and the environment

Fewer studies have looked at the combined effects of a sustainable diet, health and the environmental impact.

In a recently reported study the health effects associated with adopting low GHGe diets were quantified in the UK Design Epidemiological modelling study [25]. Using data from 1571 UK adults that participated in the NDNS, the adoption of diets optimized to achieve the 2003 WHO nutritional recommendations [50], while remaining as close as possible to existing dietary patterns, to reduce GHGe was assessed. GHGe associated with each food group were estimated using a Life Cycle Inventory (LCI) compiled from the published literature and, where possible, included information on food losses from production, handling, sales, cooking and consumer waste. Average dietary intake patterns were optimized primarily by increasing the consumption of fruit and non-starchy vegetables and reducing the amount of red and processed meat, to achieve target reductions in dietary GHGe of 10%, 20%, 30%, 40%, 50% and 60% while meeting the WHO recommendations.

The health benefits derived from this assessment are shown in Figure 9.6.

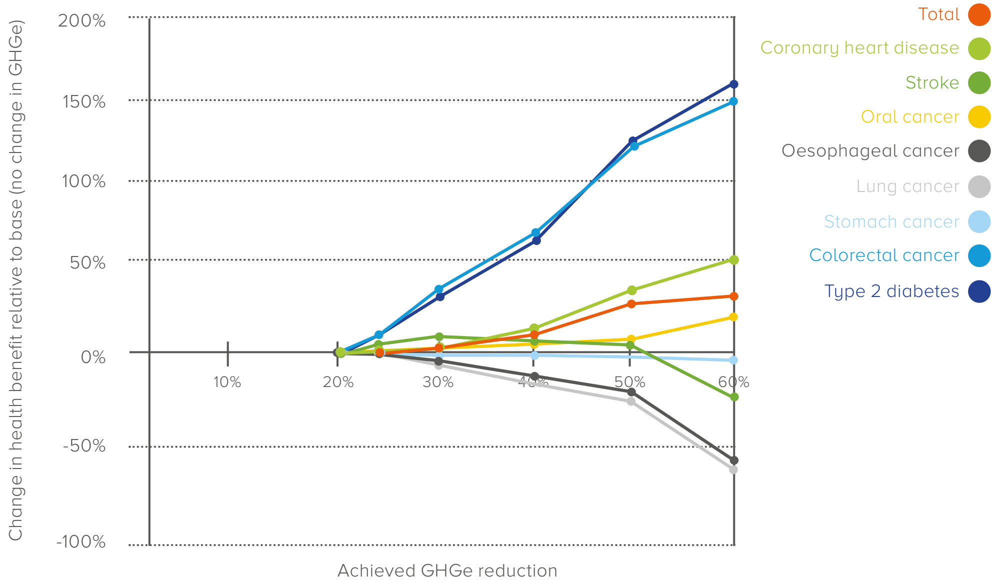

Figure 9.6: Relative changes in modelled health impacts for incremental increases in GHGe reduction target of 10 - 60%

Source: Milner [25]

The authors state that if the average UK dietary intake were optimized to comply with the WHO recommendations, it would result in a 17% reduction in GHGe, save almost 7 million yrs of lives lost prematurely in the UK over the next 30 yrs, and average life expectancy would increase by over 8 months. This dietary pattern would be broadly similar to the current UK average. However, if emission reductions were greater than 40% improvements in some health outcomes may decrease, e.g. oesophageal cancer and lung cancer, due to acceptability and aspects of diet quality that will diminish.

Data from other identified studies from the literature are summarized in Table 9.3. A further study modelled the effect of potential strategies for the agricultural sector to meet the target recommended by the UK Committee on Climate Change to reduce UK emissions from the concentrations recorded in 1990 by 80% by 2050, which would require a 50% reduction

Study	Outline	Health / nutrient factor	Health / nutrient outcome	UK saving in CO_2e
Scarborough 2012 [51] (Uses NDNS 2001)	UK CCC – Dietron: Scenario 1 - 50%↓ in all animal foods (2/3 meat ↓, replaced with plant foods)	Deaths ↓ SFA (g) F&V (g)	↓ 36,910 29.7 473	15 M tonnes/yr (19%)
	Scenario 2 - 75%↓ beef and sheep meat, replaced with pork and poultry	Deaths ↓ SFA (g) F&V (g)	↓ 1,999 32.5 294	6.3 M tonnes/yr (9%)
	Scenario 3 - 50%↓ in pork and poultry, re-placed with plant foods	Deaths ↓ SFA (g) F&V (g)	↓ 9,297 33.5 328	2.1 M tonnes/yr (3%)
Aston 2012 [52] (Uses NDNS 2001)	Estimated health & climate benefits if high red and processed meat consumers adopt a pat-tern of low consumers	CHD (M) (F) Diabetes (M) (F) Colorectal C (M) (F)	-20.6% -11.1% -24.1% -15.9% -24.4% -16.2%	0.45 tonnes/person/yr (3%)
				Saving compared to base 3.05 $kgCO_2e/d$ or 1.14 tonnes/yr
Soret 2014 [53] Adventist Health Study 2	Non-vegetarian Semi-vegetarian Vegetarian	Death rate/1000 person/yr	6.66 5.53 5.56	0.00 -21.6% ↓ -29.2% ↓
	Non-vegetarian Semi-vegetarian Vegetarian	RR All cause mortality	1.00 0.86 0.91	

Table 9.3: Summary of studies reporting the impact of consuming a sustainable diet on health and the environment

by 2030 [17]. Using the UK as a case study, it was identified that a 30% reduction in livestock production would be needed to meet this target. The potential benefits of reducing livestock consumption would also result in a decreased burden of ischaemic heart disease by about 15% in the UK (equivalent to 2850 disability-adjusted life-yrs [DALYs] per million population in 1 yr).

More recently a study used an econometric model (finance and tax-based) and comparative risk assessment to examine the impact on chronic disease if GHGe were taken into account in the price of food [54]. Two tax scenarios were modelled: (1) a tax of £2.72/tonne (tCO_2e)/100 g product to all food and drink groups with above average GHGe and (2) as with scenario (1) but food groups with emissions below average subsidized to create a tax neutral scenario. Scenario (1) resulted in 7770 deaths being avoided and a reduction in GHGe of 18,683 (95%CI, 14,665-22,889) $ktCO_2e$/yr, with an estimated annual revenue of £2.02 billion. Scenario (2) resulted in 2685 extra deaths and a reduction in GHG emissions of 15,228 (95%CI, 11,245-19,492) $ktCO_2e$/yr.

Sustainable diets in practice

Bringing health and environmental sustainability together is now becoming an important priority for both the scientific community and policy makers. Some countries, such as Germany and Sweden, have drawn up official guidelines. The UK Sustainable Development Commission (UK SDC) has drawn up recommendations which consider both public health nutrition as well as environmental sustainability. One of the highest priority changes in this guidance was to reduce the consumption of meat and dairy foods [55]. Recommendations by other organizations reinforce this advice (Table 9.4).

Organization	Report	Recommendations
UK SDC [55, 56]	Setting The Table; Advice to Government on priority elements of sustainable diets The Principles of Healthy and Sustainable Eating Patterns	Reduce meat and dairy consumption
Oxfam [8]	Oxfam GB Briefing Paper – 4-a-week. Changing food consumption in the UK to benefit people and planet	Reduce consumption of meat and dairy products
Food Climate Research Network [35]	Cooking up a storm: Food, green-house gas emissions and our changing climate.	'Eating fewer meat and dairy products and consuming more plant foods in their place is probably the single most helpful behaviour shift one can make.'
WWF-UK [57]	LiveWell plate	Eat more fruit, vegetables and cereals (especially regionally grown, in season) Eat less meat (meat of all kinds – red and white – are a "hotspot" in terms of environmental impact)
WWW Livewell LIFE [49] Adopted in Spain, France and Sweden.	LiveWell diet is a healthy, low-carbon diet that takes account of cultural preferences. Its focus is on mitigating greenhouse gas emissions, and it incorporates health, socio-cultural, economic and qualitative elements.	• Eat more plant foods • Enjoy vegetables and whole grains • Eat a variety of foods • Have a colourful plate! • Waste less food (one third of food produced for human consumption is lost or wasted) • Moderate your meat consumption, both red and white • Enjoy other sources of proteins such as peas, beans and nuts • Buy foods that meet a credible certified standard. Consider MSC, free-range and fair trade • Eat fewer foods high in fat, salt and sugar. Keep foods such as cakes, sweets and chocolate as well as cured meat, fries and crisps to an occasional treat. Choose water, avoid sugary drinks and remember that juices only count as one of your 5-a-day however much you drink.
American Dietetic Association (ADA) [58]	Position of the ADA: Food and nutrition professionals can implement practices to conserve natural resources and support ecological sustainability	Encourage consumption of protein from plant sources
New Nordic Diet [22, 32]	Working Group on Food, Diet and Toxicology under the auspices of the Nordic Committee of Senior Officials for Food Issues	Eat more calories from plant foods and fewer from meat; more foods from the sea and lakes; more foods from the wild countryside.
Health Council of the Netherlands [23]	Guidelines for a healthy diet: the ecological perspective.	Eat a less animal-based and more plant-based diet, containing fewer meat and dairy products and more wholegrain products, legumes, vegetables, fruit, and plant-derived meat substitutes.

Table 9.4: Recommendations by various organizations to achieve a more sustainable diet

Conclusions

If the planet is to be protected a number of changes are needed, including technological improvements in the growth, manufacture, distribution, storage and preparation of food. However, if targets such as GHGe are to be met this will not be enough. For this reason a number of experts are also recommending different eating patterns that will enhance nutrient intake, improve health and be beneficial for the environment too. Eating a more plant-based diet that contains more plant foods and reduces meat and dairy foods, while minimizing the consumption of energy-dense and highly processed and packaged foods, as well as ensuring energy intakes are not exceeded, are small changes that will have a big impact on our planet.

Take-home messages:

- A growing global population, increasing urbanization and economic growth are placing a huge demand on worldwide food supplies, especially animal products.
- This global demand, based on current food consumption patterns, is neither sustainable nor feasible as it puts tremendous pressure on the environment.
- Eating plant-based foods rather than animal-based foods can contribute to a healthier planet.
- Animal-derived foods generally require more resources than plant-based foods, typically resulting in 15-fold more GHGe and requiring 10-fold more water and 5- fold more fossil fuel input.
- Shifting towards plant-based eating, while cutting down on animal foods, can make a big difference to both our health and that of the planet.
- There are now a number of healthy and sustainable dietary recommendations; all focus on increasing the intake of plant foods and reducing animal foods, while also reducing the amount of energy-dense, highly processed and packaged foods and encouraging people not to eat more than their energy requirements.

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10

Chapter 10

More plant-based eating in practice

LYNNE GARTON
Registered Dietitian, UK

Introduction to Chapter 10, by invited expert Lynne Garton

There is now overwhelming evidence that eating more plant-based foods, while at the same time cutting down on animal products, is a real solution to the growing health and environmental issues currently being faced. Not only is this way of eating in line with international and national dietary guidelines, but it is also more sustainable, requiring less land, water and energy resources, and producing fewer GHGe than a diet based on animal foods.

The challenge, however, is how to encourage people to shift towards a more plant-based diet. Studies investigating this have found a number of barriers that need to be overcome before people will adopt this way of eating. These include:

- *A lack of awareness of what plant-based eating involves;*
- *Fears about the nutritional adequacy;*
- *Concerns that it is too expensive;*
- *Concerns about radically changing existing eating habits;*
- *Lack of meal planning skills.*

Yet most people are willing to try to make the change once they understand the potential benefits.

One of the main barriers identified to adopting a plant-based eating plan is not being aware of what it entails. It is important to stress that this is not about giving up animal foods, but about putting plant foods first. It is likely that the health benefits seen in plant-based eating patterns are associated with the increased quantity of plant foods eaten rather than the lack of meat consumption. Plant foods on which to focus include whole grains, legumes, fruits, vegetables, seeds and nuts. These should make up two-thirds of the diet, with the remaining one-third coming from animal foods. Choosing a *wide variety of plant foods helps ensure nutritional adequacy, which in turn can help overcome concerns related to the nutritional content of the diet.*

Another barrier highlighted is cost. However, modelling studies examining the financial implications have found a plant-based diet to be no more expensive, and in some cases cheaper, than the typical diet. This has been demonstrated in a number of countries including the UK, France, Sweden and Spain. Many plant proteins such as pulses, beans, tofu, and soya mince are often cheaper than animal proteins, which tend to be the most expensive item in a meal. Including more plant proteins, at the expense of animal proteins, as well as careful planning and shopping, makes plant-based eating financially beneficial.

Plant-based eating is not about transforming the diet but about making small changes to put plant-based foods first. It is not a "one-diet-fits-all", as there is more than one way to include extra plant foods into the diet. A step-by-step approach helps to gradually shift towards this way of eating. For example, start by looking at the balance of foods on the plate, next consider swapping animal products for plant foods in the diet, then try and replace some ingredients in a recipe for suitable plant-based alternatives. Building on this, and doing it gradually, is more likely to result in a permanent shift towards plant-based eating.

Nutrition professionals are in an ideal position to help people adopt a plant-based eating pattern. They have the skills to translate the science into meaningful and understandable information; they are able to discuss potential barriers and provide solutions to overcome these difficulties; and they can provide practical suggestions with regard to shopping, preparing and cooking ideas. All in all, they can help people change their eating habits for good, enabling plant-based eating to become a permanent feature of the diet.

Chapter 10

More plant-based eating in practice

Throughout this book the health and environmental benefits of plant-based eating have been clearly identified. This way of eating is not another fad diet but a solution to the growing health and environmental challenges now being faced. Plant-based eating is not about transforming the diet but about making small changes to put plant-based foods first.

Despite the quite clear advantages of eating more plant-based foods, studies have found that people perceive this to be difficult to achieve in practice. In one Australian study the main barriers identified included:

- Lack of information – both on the definition of plant-based eating and on the potential benefits of this way of eating, especially in relation to the environment.
- Not wanting to alter eating habits – as well as eating habits of individuals, there were also concerns that family members would not want to eat a plant-based regime.
- Lack of availability of plant-based options when eating out.

It is important to address these barriers if plant foods are to be increased in the diet. Yet in this study there was higher agreement with the benefits of plant-based eating than there was with the potential barriers of such a diet. Furthermore, 62% of respondents were interested in learning more about plant-based eating [1]. These findings were similar to a Canadian pilot study examining the awareness, barriers and promoters of plant-based diets for use in the management of T2D [2]. In this study of 98 patients, only 9% were currently following a plant-based diet, but 66% indicated they were willing to follow one for three weeks if they were given the appropriate support. Family eating preferences, meal planning skills and cost were common barriers to change [2]. The majority of staff (72%) were aware of the use of plant-based diets for treatment of T2D, but only 32% were currently recommending this dietary pattern to patients. Common reasons for not promoting this way of eating included a perception that it was too difficult for patients to follow (despite two-thirds of participants expressing an interest to try it) and lack of clear clinical practical guidelines and diet-specific educational support [2].

The following guide helps to overcome this by providing nutrition professionals practical suggestions to help promote plant-based eating. The aim of a plant-based eating plan is to be flexible so that people can include more plant foods based on their likes and dislikes and taking into account their lifestyles.

What is plant-based eating?

One of the main barriers to adopting a plant-based eating plan is not being aware of what this way of eating entails. It is important to stress that this is not about giving up animal foods, but about putting plant foods first. To help people understand the concept of plant-based eating it is useful to discuss the main plant food groups, e.g. whole grains, legumes (including soya), vegetables, fruits, nuts and seeds, along with common food sources these are found in.

The main principles of plant-based eating include [3]:

- Eat more plants foods, e.g. fruits, vegetables, whole grains, legumes, nuts and seeds
- Eat a variety of foods
- Waste less food
- Moderate your animal food consumption, e.g. meat and dairy
- Buy foods that meet a credible standard
- Eat fewer highly processed foods and foods high in fat, salt and sugar

Benefits of more plant-based eating

When considering a change in any eating habit it is important for an individual to identify the benefits they would gain by making dietary changes. Some of the benefits highlighted in the previously described Australian study included well-being benefits; weight and health benefits; ethical benefits; and convenience and financial benefits (Table 10.1) [4]. Using this as a guide, people can consider the personal advantages they would gain by moving towards plant-based eating.

Well-being benefits	• Staying fit and healthy • Having a tasty diet which includes a greater variety of foods with lots of nutrients • Eating a diet that is in-line with dietary recommendations
Weight and health benefits	• Helps to manage a healthy weight • Reduces the risk of developing certain lifestyle diseases e.g. CVD, T2D, certain types of cancer, etc. and helps manage existing health conditions • Improves digestion because of the fibre content of the diet • Focuses on the right balance of foods to support positive health
Ethical benefits	• Helps the environment • Helps promote animal welfare/rights • Promotes more efficient food production
Convenience and financial benefits	• Saves time and money • Fewer food storage problems

Table 10.1: Perceived benefits of eating a plant-based diet

Source: Based on Lea [4]

At the same time, it is also essential to help individuals identify any potential difficulties they foresee in including more plant foods into their diet. Strategies for overcoming these will need to be discussed, as the benefits of change need to outweigh the perceived barriers if plant-based eating is to become a permanent feature in the diet. Table 10.2 describes some of the potential barriers to plant-based eating highlighted in the Australian study [4], along with suggestions on how these can be overcome.

More plant-based eating in practice

Once plant-based eating has been described and personal advantages have been identified, the next stage is to consider what dietary changes need to be made. However, not knowing how to practically incorporate these foods into the diet is another barrier given to plant-based eating. A study examining how such challenges could be overcome suggested promoting smaller portions of meat (“less”), smaller portions using meat raised in a more sustainable manner (“less but better”), smaller portions and eating more vegetable protein (“less and more varied”), and meatless meals with or without meat substitutes (“veggie-days”) [5]. This study sampled 1083 Dutch

Lack of awareness of plant foods	• Provide information on the different plant food groups that should form the bulk of the diet • Highlight typical products that contain these plant foods • Discuss the plant proteins that can be used to replace animal proteins
Not knowing how to prepare plant-based meals	• Provide the relevant information (as described below) to help improve cooking skills and meal choices • Explain this way of eating can be enjoyed by the whole family
Concerns over the nutritional adequacy	• Describe the nutrients found in different plant foods • Highlight how nutrients in animal products can be replaced with the relevant plant foods • Explain this way of eating is associated with a better nutritional profile than animal-based diets and is in line with national and international dietary recommendations
Fears this way of eating is more expensive	• Highlight the studies which have found this way of eating is no more expensive, and often cheaper, than diets heavily based on animal foods • Suggest focussing on fruit and vegetables that are in season as these are generally cheaper and provide year round variety to the diet • Explain that meat is often the most expensive item in a meal and compare costs of animal protein with plant protein • Provide practical tips on meal planning, shopping, storage and preparation to help save money • Suggest ways to minimize wastage e.g. portion control, coo-king only the right amount of food required, freezing leftovers, or using them in soups

Table 10.2: Potential barriers and solutions to plant-based eating

Source: Based on Lea [4]

consumers and the findings suggested these strategies appeared to have different strengths and weaknesses; which one to apply would depend on individual preferences. As such it should be stressed that a plant-based eating plan is not a rigid diet. Instead personalized, practical advice needs to be tailored around the individual. For this reason there is more than one way to adopt a plant-based eating plan, and depending on the individual they may decide to try one or more of these suggestions. For example:

1. **Re-shaping the plate**

Often meat tends to be the main focus of meals, yet by addressing the balance on a plate, more room can be made for plant foods. The World Cancer Research Fund (WCRF) and American Institute for Cancer Research (AICR) have suggested that at least two-thirds of a plate should be made up of plant foods (vegetables, whole grains, cereals and pulses) and foods from animals should make up less than a third (Figure 10.1) [6, 7].

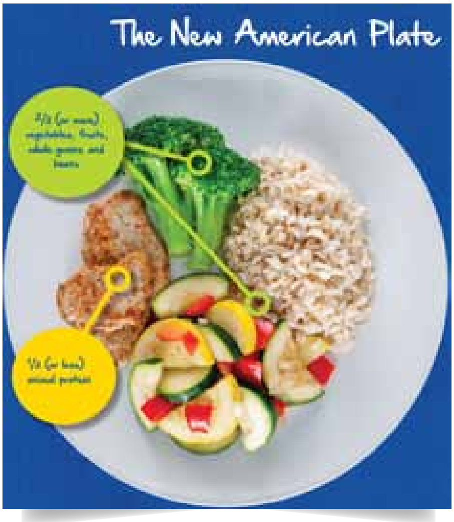

Figure 10.1: The New American Plate

Source: AICR [7] ; Reprinted with permission from the American Institute for Cancer Research

PRACTICAL SUGGESTIONS
• Explain it's NOT about giving up meat and animal-based foods, but it IS about putting plant-based foods first.
• Address the balance of foods on the plate: Suggest visualising the plate - at least two-thirds of this plate should be made up of plant foods (vegetables, whole grains, cereals, pulses, nuts/seeds) and foods from animals should make up less than a third.
• When planning meals consider plant foods e.g. whole grains, vegetables and pulses, and then think how meat can be served as an accompaniment around these foods.
• Serve up plant foods first so there is less room on the plate for animal foods.

2. Introducing more plant-based foods into the diet

With the wide variety of plant-based foods available there are plenty of opportunities to include more plant-based alternatives into the diet.

PRACTICAL SUGGESTIONS	
Food groups	Plant-based alternatives
Dairy products e.g. milk, yogurts, milkshakes, etc.	Fortified plant-based alternatives to dairy e.g. soya alternative to milk; soya alternatives to yogurts. Fortified almond milk, coconut drink, hazelnut drink
Snacks such as crisps, sweets, chocolates and biscuits	Snacks such as fresh or dried fruit; fruit smoothie; soya shakes; soya nuts; other unsalted nuts; seeds; wholegrain cereal bars; rice cakes; pitta/vegetable sticks/oatcakes with hummus or salsa; plain popcorn; wholegrain crackers with nut butter; wholemeal scones and currant buns; malt loaf; soya desserts
White bread, pasta and rice	Wholemeal bread, wholegrain pasta and brown rice
Refined breakfast cereals	Wholegrain cereals
Butter	Margarines made from vegetable oils
Lard	Vegetable oils such as olive oil, rapeseed oil, sunflower oil
Creamy meat-based pasta sauce	Tomato and vegetable-based pasta sauce
Mince, burgers, sausages, etc	Meat analogs such as soya mince, Quorn, veggie burgers and sausages
Meat/chicken-based curries or Chinese dishes	Vegetable curries, dhal, edamame/tofu stir fries and noodle dishes

Desserts/Puddings	Soya alternatives to yogurts; soya desserts; fruit crumble (topping made with wholemeal flour and oats) served with soya custard; stewed fruit topped with soya cream alternative; meringues with berries and soya alternative to cream; fresh fruit; fruit sorbet

3. Meal makeovers

Many familiar meals can easily be based around plant-based foods. Discussing ways in which traditional meals can be based around more plant-based foods will allow the whole family to enjoy plant-based eating.

PRACTICAL SUGGESTIONS
Plant powered breakfasts
• Wholegrain cereal, topped with fruit (fresh or dried) and served with a plant-based alternative to milk or yogurt (try and choose varieties which are fortified with added vitamins and minerals) • Blend together oats, berries (fresh or frozen), banana and a plant-based alternative to milk or yogurt to make a home-made smoothie • Instead of granola and Greek yogurt try sugar-free muesli with soya alternative to yogurt and mixed berries • Swap fried bacon and eggs in a cooked breakfast for a rasher of lean grilled bacon (fat removed), poached eggs, plenty of grilled tomatoes and mushrooms and serve with a slice of wholemeal toast
Plant powered main meals
• Use more plant foods such as lentils, beans and vegetables, and cut down on meat in dishes, e.g. chilli con carne, stir fries, spaghetti Bolognese, shepherd's pie, curries, stews, pasta sauces, etc. Serve with wholemeal pasta, brown rice or jacket potato • Try vegetable and bean salads that include pasta, rice, noodles, couscous or potatoes • Pile a shop bought cheese and tomato pizza with extra vegetables and serve with a side salad • For a change try vegetarian alternatives to sausages, burgers, soya mince or Quorn and serve with plenty of vegetables and a jacket potato • Add extra grains to stews or soups e.g. Bulghur/cracked wheat or pearl barley
Plant powered snack meals
• Wholegrain starchy foods, such as bread, rolls, bagels, pittas, wraps and chapattis filled with foods based on plant proteins e.g. hummus, falafel, beans, bean pate or nut butter • Chunky bean and vegetable soup served with a wholegrain roll • Jacket potato filled with hummus, baked beans or tuna and sweetcorn, accompanied by a side salad • Wholemeal toast topped with scrambled eggs or baked beans in tomato sauce

4. **Meat-free days**

Initiatives in several European countries are now actively encouraging a meat-free day. For example, “Thursday Veggie day” in the Flanders and Germany, and “Meat-free Mondays” in the UK, Norway, Sweden and the Netherlands. While this is another strategy for cutting down on animal foods, people should be advised on suitable plant alternatives during these meat-free times, to ensure the meals are nutritionally adequate.

Conclusions

Nutrition professionals are in an ideal position to educate people on plant-based eating and support them in making permanent changes to their dietary habits. By providing tailored dietary advice and continued support, they can help people shift towards a more plant-based diet. By using the methodical approach outlined above, so that changes are made slowly and gradually, plant-based foods are more likely to become a permanent feature of the everyday diet.

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In conclusion...

For centuries many people's traditional diets have been based on plant foods and it is this particular feature which is thought to contribute to their markedly good health and long life.

Many international and national dietary recommendations emphasize plant foods to promote good health as experts believe that increasing the amount of plant foods and eating smaller amounts of animal foods, would be beneficial.

Diets in many Western European countries are higher in total fat and SFA and lower in fibre and UFA than is recommended for good health.

Plant-based eating patterns tend to be low in total fat and SFA, include a good level of UFA leading to better overall fat quality, and are high in fibre – all in line with international and national dietary recommendations.

Dietary micronutrient quality can also be enhanced by consuming more fruits, vegetables and other fibre-rich foods such as whole grain cereals – important for good health – these plant-based foods are also rich in polyphenols.

Specific plant foods, or ingredients, such as soya protein, nuts, oat/barley beta-glucan may further provide additional health benefits.

Currently there is no precise definition of a plant-based diet but this way of eating does not necessarily exclude all animal products, instead it places the emphasis on plant foods.

The five major plant-based food groups that comprise plant-based eating are wholegrains, legumes, including soya, fruit, vegetables, nuts and seeds; diets based on these food groups are healthy and a sound basis for meeting nutritional requirements throughout life.

The nutritional characteristics of plant-based eating are thought to be responsible for the healthier hearts, body weights and blood sugar levels observed in people whose diets are mainly based on plant foods. Other specific components found intrinsically in plant foods may also work together to bring further heart health benefits.

As a result there's evidence that plant-based eaters have a lower prevalence of obesity, lower rates of CHD, hypertension and T2D. Furthermore, specific plant foods, such as those containing soya isoflavones, may have a beneficial effect on symptoms of the menopause in women and help to maintain bone health in later life.

The lower prevalence of obesity, as well as the nutritional characteristics of plant-based dietary patterns, are in line with recommendations aimed at reducing cancer risk.

Plant-based eating supports normal bone growth and development throughout life provided a wide variety of plant foods are consumed and adequate intakes of protein, Ca and vitamin B12 and vitamin D status are maintained.

As well as incorporating a healthy balance of foods to meet nutrition recommendations, a number of countries are now including sustainability in their food-based dietary guidelines.

Recent evidence continues to support plant-based foods being preferable for the environment as they requires less land, water and energy resources and produce fewer GHGe than animal-based products.

Nutrition professionals are in an ideal position to educate people on plant-based eating and support them in making permanent changes to their dietary habits.

The wide variety of plant-based foods available provides a number of options for designing a healthy plant-based eating plan to suit all tastes and palettes.

There's more than one way to include more plant-based foods into the diet including reshaping what's on the plate, making simple dietary swaps, giving meals a plant make-over and opting for meat free days.

To encourage more plant-based foods in the diet it's been suggested that at least two-thirds of a plate should be made up of plant foods and foods from animals should make up less than a third.

Moving towards plant-based eating by building the diet around plant foods and eating less animal foods can make a difference to both our health and the planet's.

Glossary

commonly used abbreviations

AHS	Adventist Health Studies
ALA	Alpha Linolenic Acid
AT	Austria
BE	Belgium
BG	Bulgaria
BMI	Body Mass Index
BP	Blood Pressure
BW	Bodyweight
Ca	Calcium
CHD	Coronary Heart Disease
CHO	Carbohydrate
CV	Cardiovascular
CVD	Cardiovascular Disease
CY	Cyprus
CZ	Czech Republic
d	Day
DBP	Diastolic Blood Pressure
DE	Germany
DHA	Docosahexaenoic acid
DK	Denmark
EE	Estonia
EFSA	European Food Safety Authority
EL	Greece
En%	Percentage of Energy
EPA	Eicosapentaenoic acid
EPIC	European Prospective Investigation into Cancer
ES	Spain
FAO	Food and Agriculture Organization of the United Nations
FI	Finland
FR	France
GI	Glycaemic Index
HDL-C	High Density Lipoprotein Cholesterol
HU	Hungary

IE	Ireland
IT	Italy
LDL-C	Low Density Lipoprotein Cholesterol
LT	Lithuania
LU	Luxembourg
LV	Latvia
mo	Month
MUFA	Monounsaturated Fatty Acids
MT	Malta
NL	Netherlands
NSP	Non-Starch Polysaccharides
PUFA	Polyunsaturated Fatty Acids
PL	Poland
PT	Portugal
RCT	Randomized Controlled Trial
RO	Romania
RF	Russian Federation
SBP	Systolic Blood Pressure
SE	Sweden
SFA	Saturated Fatty Acids
SI	Slovenia
SK	Slovakia
T1D	Type I Diabetes
T2D	Type II Diabetes
TAG	Triglycerides
TU	Turkey
UFA	Unsaturated fatty acids
UK	United Kingdom
WHO	World Health Organization
wk	Week
yr	Year