Plants: Diet and Health
Plants: Diet and Health

The Report of a British Nutrition Foundation Task Force

Edited by Dr Gail Goldberg

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Contents

This report is the collective work of all the members of the Task Force. Authors of the first draft of each chapter are given below.

Foreword xiv
Dedication xv
Terms of Reference xvi
Task Force Membership xvii

1 Introduction: Plant Foods and Health 1
   Dr Judith Buttriss
   1.1 Historical perspective 1
   1.2 Definitions and terminology 2
      1.2.1 Plant foods 2
      1.2.2 Categorisation of plant-derived foods and drinks adopted in this report 2
      1.2.3 Classification 4
      1.2.4 Substances in food that have an effect on health 4
   1.3 Consumption patterns of plant-derived foods and drinks 5
      1.3.1 Sources of information 5
      1.3.2 Trends in household consumption in the UK 5
      1.3.3 Intakes in different age and gender groups in the UK 9
      1.3.4 Variations in intake within and between populations 9
   1.4 Sources, intakes and properties of constituents of plant-derived foods and drinks 11
      1.4.1 Sources and intakes 11
      1.4.2 Properties of antioxidants 11
      1.4.3 Antioxidant vitamins 19
      1.4.4 Folate and other B vitamins 20
      1.4.5 Other vitamins and minerals 21
      1.4.6 Unsaturated fatty acids 21
      1.4.7 Dietary fibre 21
      1.4.8 Alcohol 22
      1.4.9 Other plant-derived bioactive substances 22
3.4 Cancer
3.4.1 Fruits and vegetables and breast cancer 58
3.4.2 Fruits and vegetables and lung cancer 58
3.4.3 Fruits and vegetables and colorectal cancer 59
3.4.4 Fruits and vegetables and gastric cancer 59
3.4.5 Fruits and vegetables and oesophageal cancer 59
3.4.6 Fruits and vegetables and other cancers 59
3.4.7 Legumes and nuts 59
3.4.8 Cereals 60
3.4.9 Fibre and cancer 60
3.4.10 Other plant-derived substances and cancer 60
3.4.11 Summary for cancer 61

3.5 Other age-related diseases
3.5.1 Type 2 diabetes 61
3.5.2 Age-related macular degeneration and cataract 61
3.5.3 Chronic obstructive pulmonary disease 62
3.5.4 Osteoporosis and bone health 63

3.6 Conclusions 63
3.7 Research recommendations 64
3.8 Key points 64

4 Potential Mechanisms of Action of Bioactive Substances Found in Foods 65
Professor Malcolm Jackson
4.1 Introduction 65
4.2 Potential mechanisms by which plant bioactive substances may help protect against cancer 66
4.2.1 The cancer process 66
4.2.2 Potential sites where plant bioactive compounds might act 68
4.2.3 Specific examples of actions of plant bioactive compounds 68
4.3 Potential mechanisms by which plant bioactive substances may protect against CVD 69
4.3.1 The process of atherosclerosis 69
4.3.3 Potential sites where plant-based bioactive compounds might act 72
4.3.4 Specific examples of actions of plant-based bioactive compounds 72
4.4 Other ageing-related disorders 74
4.4.1 Age-related macular degeneration and cataract 74
4.5 Summary 75
4.6 Research recommendations 75
4.7 Key points 75

5 Influence of the Gut Microflora 76
Professor Ian Johnson
5.1 Introduction 76
5.2 The human colon 76
5.2.1 Anatomy 76
5.2.2 Mucosal cells 77
5.2.3 Microflora 77
5.2.4 Substrates for fermentation 78
5.3 Colorectal diseases 79
5.4 Protective factors, intraluminal metabolism and health 79
5.4.1 Lactic acid bacteria 80
5.4.2 Short-chain fatty acids 80
5.4.3 Glucosinolates 81
5.4.4 Phenolic substances 82
5.5 Research recommendations 83
5.6 Key points 84

6 Dietary Intake and Bioavailability of Plant Bioactive Compounds 86
   Dr Judith Buttriss
6.1 Introduction 86
6.1.1 Food composition databases 86
6.1.2 Total diet study 87
6.2 Methodological aspects in the assessment of bioavailability 87
6.2.1 Absolute bioavailability 87
6.2.2 Measurement in biological fluids 88
6.2.3 Methods used to assess bioavailability 88
6.3 Current intakes and bioavailability of flavonoids 90
6.3.1 Estimations of dietary intakes 90
6.3.2 Absorption of flavonoids 93
6.3.3 Metabolism 95
6.4 Current intakes and bioavailability of phytoestrogens 96
6.4.1 Absorption and metabolism of phytoestrogens 96
6.4.2 Metabolic response 97
6.5 Current intakes and bioavailability of carotenoids 98
6.5.1 Dietary sources of carotenoids 98
6.5.2 Absorption of carotenoids 99
6.5.3 Interactions between carotenoids 99
6.6 Hydroxycinnamates 100
6.7 Plant sterols 100
6.8 Glucosinolates 101
6.9 Hydroxybenzoic acid derivatives 102
6.10 Enhancement of bioavailability 104
6.11 Research recommendations 104
6.12 Key points 105

7 Fruit and Vegetables 107
   Mr Mike Saltmarsh, Professor Alan Crozier and Professor Brian Ratcliffe
7.1 Introduction 107
7.2 Bioactive compounds found in fruits and vegetables 108
7.3 Quantification 109
7.3.1 Units of measurement 109
7.3.2 Variability within and between plants 109
7.3.3 Methodologies used and analysis of data 110
7.4 Vegetables 110
7.4.1 Root crops (e.g. carrots, turnips, swedes, parsnips) 110
7.4.2 Onions and garlic 111
7.4.3 Cabbage family and greens (e.g. Brussels sprouts, broccoli, cabbage) 113
11.1.6 Bioavailability of cocoa polyphenols 214
11.1.7 Health implications of cocoa and chocolate 214
11.2 Herbs, spices and condiments 216
11.2.1 Introduction 216
11.2.2 Definitions of herbs, spices and condiments 217
11.2.3 Constituents of plants used as herbs and spices and in condiments 218
11.2.4 Essential oils and oleoresins 218
11.2.5 Bioactive compounds found in herbs, spices and condiments 220
11.2.6 Quantification of bioactive substances in herbs and spices 222
11.2.7 Potential protective effects of herbs and spices 222
11.2.8 Condiments 223
11.3 Research recommendations 224
11.4 Key points 225

12 The Effect of Agronomy, Storage, Processing and Cooking on Bioactive Substances in Food 226
Ms Claire Mac Evilly and Mrs Kirsti Peltola
12.1 Introduction 226
12.2 Terpenoids 227
12.2.1 Saponins 227
12.2.2 Carotenoids 227
12.2.3 Plant sterols 230
12.3 Phenolic compounds 231
12.3.1 Flavonoids 231
12.4 Sulphur-containing compounds 234
12.5 Protease inhibitors 234
12.6 Vitamin C 234
12.7 Vitamin E 236
12.8 Folate 236
12.9 Research recommendations 237
12.10 Key points 237
Appendix: definitions of different types of storage, processing and cooking techniques 238
(a) Factors determining the shelf-life of a product 238
(b) Storage 238
(c) Fresh storage 238
(d) Modified atmosphere storage/packaging 238
(e) Processing techniques 238

13 Implications for Public Health 240
Dr Judith Buttriss, Professor Martin Wiseman and Dr Barrie Margetts
13.1 Introduction 240
13.1.1 Approaches to changing eating behaviour 240
13.2 What is the target intake? 244
13.3 To what extent are the plant food goals being achieved in the UK? 250
13.3.1 Methodological issues 250
13.3.2 Fruit and vegetables 251
13.3.3 Other plant-derived foods 253
13.4 Evidence for the effect of interventions 254
13.4.1 Campaigns in the USA 254
13.4.2 National UK campaigns 258
13.4.3 Local initiatives in the UK 259
13.4.4 Barriers to change 260
13.5 Looking to the future 261
13.6 Safety considerations 262
13.7 Policy implications 265
  13.7.1 Addition of nutrients to foods 265
  13.7.2 Food labelling and claims 266
  13.7.3 Key players 267
13.8 Conclusions 267
13.9 Research recommendations 268
13.10 Key points 268

14 Conclusions of the Task Force 270
  14.1 Chapter 1 270
  14.2 Chapter 2 270
  14.3 Chapter 3 271
  14.4 Chapter 4 272
  14.5 Chapter 5 272
  14.6 Chapter 6 273
  14.7 Chapter 7 274
  14.8 Chapter 8 275
  14.9 Chapter 9 276
  14.10 Chapter 10 277
  14.11 Chapter 11 278
  14.12 Chapter 12 279
  14.13 Chapter 13 280

15 Recommendations of the Task Force 282
  15.1 Priorities for future research 282
    15.1.1 Bioavailability 282
    15.1.2 Methodology including biomarkers, mechanistic studies
          and intervention studies 283
    15.1.3 Gastrointestinal influences 284
  15.2 General recommendations 284
    15.2.1 Recommendations to health professionals 284
    15.2.2 Recommendations to industry 284
    15.2.3 Recommendations to the media 285
    15.2.4 Recommendations to research funding bodies 285
    15.2.5 Recommendations to policy makers 285

16 Plant Foods: Answers to Commonly Asked Questions 286

Appendix 298
Framework Programme 4 Projects 298
Framework Programme 5 Projects 298

Glossary 300
References 302
Index 337
The important place that fruit, vegetables, grains and other plant foods have in the human diet has been recognised for a considerable time and there has been clear evidence that diets rich in these foods offer health benefits. This appears particularly true in relation to the risk of premature development of chronic diseases such as cardiovascular disease and cancer. Despite substantial investment of time, effort and resources, the factor or factors responsible for this reduction in risk and the mechanism(s) of action have remained elusive. Initially attention focused on the so-called antioxidant nutrients such as vitamins E and C and β-carotene, but more recently a large array of plant substances, sometimes referred to as phytochemicals or plant bioactive substances, have become the focus of attention. Examination of the available information about these has been the primary topic considered by the Task Force. The Task Force was charged with considering the bioactive substances in foods that are not usually considered to be nutrients and to place these in the context of what is already known about antioxidant nutrients. Whilst the overall context is the promotion of good health through appropriate diet, protection against chronic disease, particularly cancer and cardiovascular disease, has also been addressed. This Report records the findings of the group of eminent scientists listed on pages xiii–xv.

The Task Force has been completely independent. The members are experts in their fields and between them cover a range of topics from the chemistry of plant bioactive substances to public health nutrition. The Report is aimed at a wide variety of professionals who may not be familiar with all the details and so has been written in a way that recognises that some of the complex underpinning chemistry and biochemistry will not be of interest to all readers. Rather than categorising the subject by chemical grouping, a food group approach has been adopted in order to bridge between the introductory chapters on intakes of plant foods, epidemiology and mechanisms and the final chapters which discuss the public health implications and the conclusions and recommendations of the Task Force. As has become practice with recent BNF Task Force Reports, a Question and Answer Section has been included which aims to cover the main aspects discussed within the Report in a way that we hope will be helpful to journalists and other non-specialist readers who need a concise and jargon-free explanation.

I am very grateful to the members of the Task Force who have all contributed a considerable amount of their time and expertise to this Report. The support provided by the Secretariat has also been outstanding and I would like to thank them most sincerely.

Professor Malcolm J. Jackson
This book is dedicated to the memory of Professor Tony Diplock, a member of the Task Force who sadly died in February 2000. I had the pleasure and honour of being Tony’s postdoc researcher for three-and-a-half years in the early 1980s, based at Guy’s Hospital Medical School. On a personal level, he was a generous man who took every opportunity to support and encourage me in my work. On a professional level, he made an immense contribution to the field of antioxidant biochemistry, particularly in relation to vitamin E and selenium, both in Britain and internationally. He was also responsible for encouraging the then Ministry of Agriculture, Fisheries and Foods to fund a ground-breaking programme of research on antioxidant nutrients, for which he was still Programme Adviser at the time of his death. He is missed by friends and colleagues, but his contribution to science lives on.

Dr Judy Buttriss
Science Director, BNF
The Task Force was invited by the Council of the British Nutrition Foundation to:

(1) Review the present state of knowledge of bioactive substances in foods (that are not usually considered to be nutrients) and to place this in the context of what is already known about antioxidant nutrients; the promotion of good health through appropriate diet; and protection against chronic disease, particularly cancer and cardiovascular disease.

(2) Prepare a report and, should it see fit, draw conclusions, make recommendations and identify areas for future research.
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Plants: Diet and Health
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1 Introduction: Plant Foods and Health

1.1 Historical perspective

There is now a considerable body of evidence that shows that people who follow particular dietary patterns are at reduced risk of a range of chronic diseases. Diets rich in fruits and vegetables, whole grain cereals and complex carbohydrates are generally associated with lower disease risk. It has been more difficult for researchers to identify the specific component(s) of these diets that may identify the ‘protective’ agent(s). There are at least three possible explanations (not necessarily mutually exclusive): that the key critical components have not been identified; and/or that it is only in a complex combination of substrates and cofactors that the optimal nutrient profile emerges; and/or that confounding is obscuring the findings, and that attempts to identify key components by a reductionist approach are likely to be unsuccessful.

It is clear that humans eat foods in complex patterns that cannot easily be disaggregated. What may be considered protective or beneficial in one context may not in another because other aspects of diet may also differ, or the burden of disease or other risk factors may differ. There may be a threshold of effect and, depending on what the range and shape of the distribution of intakes is within a particular population, an effect may or may not be seen. Of particular relevance, when considering an apparent protective effect of diets rich in plant foods, is the possibility that intakes of potentially harmful substances may be reduced in these diets, and that the protective effect ascribed to plant foods themselves may in fact be due to this lower level of harmful substances in the diet, rather than to components in the food per se.

Despite these difficulties in interpretation, a considerable amount of expense and effort has been invested in attempting to identify active components within plant foods and their mechanisms of action. To date much of the work has concerned animal studies and in vitro experiments, and there are recognised difficulties and limitations in the extrapolation of this type of data to the human situation.

In attempting to explore mechanisms of action, much of the focus has been on the potential of substances within plant foods to act as antioxidants. It has also been recognised for some time that living organisms have developed complex and multi-faceted defence systems to protect themselves against the harmful effects of free radicals, such as are formed from oxygen as a result of oxidative metabolism. This defence system is fundamental to the organism’s survival because free radicals can damage and affect the function of critical molecules such as DNA, proteins and lipids. The search for biomarkers of oxidative damage that might be suitable for human intervention studies has been the major thrust of the UK government’s research programme concerning antioxidants in food, formerly funded through MAFF and now under the auspices of the Food Standards Agency. A critical appraisal of this programme has recently been conducted by the British Nutrition Foundation on behalf of the Agency (Buttriss et al., 2002).
In the context of the present review, emphasis is placed on exploring the possibility that a diversity of substances found in food, particularly plant-derived foods and drinks, that are yet to be recognised as nutrients in the conventional sense but to which have been attributed a wide array of properties, including antioxidant function, may underlie the protective effect attributed to a diet high in fruits, vegetables and other plant foods. Potential mechanisms are discussed in Chapter 4.

The recently completed EU-funded concerted action EUROFEDA (European Research on Functional Effects of Dietary Antioxidants) has helped to clarify questions such as: whether or not dietary antioxidants are capable of preventing oxidative damage; what research is needed to determine meaningful dose–response relationships; and what is likely to be an optimal intake of the various bioactive compounds (Astley & Lindsay, 2002). To answer these questions, the project aimed to identify the most useful, reproducible and reliable biomarkers of oxidative damage; assess what is known about the bioavailability of dietary antioxidants (including how best to determine this, and what factors influence uptake, metabolism and tissue distribution); determine the role of dietary antioxidants in the minimisation of oxidative damage in tissues (particularly those with a high metabolic energy requirement); and ascertain the role of dietary antioxidants in gene expression (see www.ifr.bbsrc.ac.uk/EUROFEDA). A summary of what is currently known about the bioavailability of plant derived substances can be found in Chapter 6.

1.2 Definitions and terminology

1.2.1 Plant foods

In this report we consider the health effects of plant foods. We include under this definition:

• fruits, vegetables, cereals, pulses, nuts, seeds, herbs and spices
• plants which have been processed in some way to yield foods and drinks whose origin is primarily plant-based (e.g. oils and other substances derived from cereals and seeds, hot and cold beverages, chocolate, condiments).

1.2.2 Categorisation of plant-derived foods and drinks adopted in this report

The categories adopted in this report and examples of foods and drinks are illustrated in Table 1.1 and summarised below. The different food groups and their constituents are discussed in detail in Chapters 7 (fruit and vegetables), 8 (cereals, nuts and pulses), 9 (beverages), 10 (plant lipids) and 11 (miscellaneous: chocolate and herbs, spices and condiments).

(i) Fruit and vegetables

The COMA report on cancer (Department of Health, 1998b) makes the point that the term ‘fruit and vegetables’ is used in most studies in a culinary rather than a botanical sense, and covers a wide variety of plants and parts of plants. In many studies, it is often not clear which are included or excluded in the analysis. However, it is generally assumed that potatoes are excluded and regarded as starchy foods. It is often unclear whether or not pulses are included in the studies’ categorisation. In this report, the term fruit and vegetables (see Chapter 7) excludes cereals and grains, seeds and nuts, and pulses.

(ii) Cereals and grains

This category covers all cereal grains eaten as food, e.g. wheat, oats, barley, rice, maize (corn). Foods derived from these plants are generally consumed as staple items within the diet. The terms ‘wholegrain’ and ‘wholemeal’ are commonly used to describe minimally processed grains. It should be noted that although these terms are useful for comparative purposes, in reality virtually all grains undergo some processing to make them palatable, e.g. removal of the husk from brown rice (see Chapters 8 and 12).

(iii) Nuts

This category includes all forms of nuts, with the
exception of peanuts, which, despite their name, are in fact a legume (see Chapter 8).

(iv) Pulses

The term pulses is used to describe the seeds of legumes, e.g. beans and lentils, that are typically dried (to allow storage) and then rehydrated and soaked and cooked before use (see Chapters 8 and 12).

(v) Beverages

The hot beverages commonly consumed in the UK are tea, coffee, cocoa and herbal teas (see Chapters 9 and 11). Cold beverages commonly consumed in the UK are fruit juice, wines, spirits and beers (see Chapters 7 and 9).

(vi) Oils and other plant lipids

Seeds and nuts and some pulses, e.g. soya, are rich sources of unsaturated oils, as are olives (see Chapter 10). This report also includes reference to plant sterols and stanols, and other dietary lipids with proposed health benefits which are derived from plant sources but found in foods of animal origin, namely conjugated linolenic acid (CLA) and sphingolipids (Chapter 10).

(vii) Miscellaneous (chocolate, herbs, spices and condiments)

In Chapter 11, information can be found about chocolate, derived from cocoa and hence rich in polyphenols. The category herbs, spices and condiments (Chapter 11) includes terpenoids,
particularly aromatic compounds, and sulphur-containing compounds.

**(viii) Composite dishes**

Many plant foods discussed in this report are neither eaten on their own nor eaten raw. Many are consumed in combination with others, for example eaten as soups, sauces and pies, in the case of fruit, vegetables and cereals; as baked products (e.g. pies, cakes, bread, pizzas and biscuits); consumed with milk in the case of breakfast cereals and hot beverages. Composite dishes are included in survey data and are sometimes categorised separately or included together with other foods. There are known and potential interactions, both positive and negative, between different constituents. These may affect their properties and functions (see Sections 1.5.1 and Table 1.9) and bioavailability (see Chapter 6). Furthermore, the effects of preparation, cooking and processing of foods on the properties of the constituents discussed in Chapters 6–11 have to be considered (see Chapter 12).

1.2.3 Classification

The botanical (Latin) names and classes of the plants and other organisms discussed in this report can be found in the relevant chapters (see Chapters 5 and 7–11). The bioactive compounds discussed in this report are members of a number of families of compounds defined on the basis of their structure and biochemistry. In turn, most of these families are comprised of many sub-classes and derivatives. The terminology adopted in this report can be found in Chapter 2.

1.2.4 Substances in food that have an effect on health

*Benders’ Dictionary of Nutrition and Food Technology* (Bender & Bender, 1999) defines nutrients as *essential dietary factors such as vitamins, minerals, amino acids and fatty acids*. Essentiality is a common theme of most conventional definitions. Nutrients have traditionally been viewed as food components that either cannot be synthesised in the body (e.g. vitamin C, ascorbic acid), or whose synthesis requires a specific factor that may in certain circumstances be absent or inadequate (e.g. sunlight exposure in the case of vitamin D). Therefore, they need to be supplied in the diet. For example, if the supply of vitamin C in the diet is inadequate, the deficiency disease scurvy results.

Nutrients have also been regarded as necessary for normal structure and function, beyond the avoidance of clinical deficiency disease, and hence contributors to healthy growth and development. However, in contrast to their essential functions, these properties may be shared by a number of other substances in foods and drinks that have not been conventionally regarded as ‘nutrients’. Consequently, there is now recognition that many other components of food, particularly plant foods, may have a biological activity that may influence structure and/or function. In general, absorption into the bloodstream in a bioavailable form will be a prerequisite (see Chapter 6), although dietary fibre is an example where benefits are accrued (e.g. helps prevent constipation) in the absence of absorption of the fibre itself.

In this report, we have not attempted to redefine the term ‘nutrient’. However, we do believe it is useful to take into account that whilst a ‘nutrient’ is essential in order to prevent a life-threatening deficiency disease (e.g. scurvy, beriberi or pellagra), the same nutrients may have other health effects, perhaps via different mechanisms. Furthermore, similar effects may also be derived from consumption of other biologically active substances in food, which do not meet the traditional definition of a nutrient. In other words, food components may be categorised as being either specific to a particular deficiency disease (i.e. a condition that is only caused by inadequate provision of the relevant substance) or non-specific (the biological functions affected may be influenced by a number of factors via the same or different mechanisms). Vitamin C, for example, would have both specific activity (in relation to scurvy) and non-specific activity (in relation to its antioxidant functions). Other nutrients may have only specific (e.g. thiamin) or non-specific activity (e.g. non-provitamin A carotenoids or flavonoids).
To elaborate this, again using vitamin C as an example, prolonged absence from the diet over a period of 3–6 months results in scurvy (Department of Health, 1991). Clinical disease can be prevented by regular consumption of small amounts (10 mg/day or less) of the vitamin, which permits collagen synthesis and the maintenance of the integrity of connective tissue. The UK Reference Nutrient Intake (RNI) is 40 mg/day in adults, which further allows for detectable plasma levels to act as an effective means of transfer between body pools. Plasma levels approach a plateau at daily intakes of between 70 and 100 mg (Department of Health, 1991); however, tissue levels are not saturated until daily intakes reach 200 mg/day or more. At intakes above the RNI, interest has grown in the potential for vitamin C to have positive health effects beyond its traditionally recognised functions. Vitamin C also acts as an antioxidant, a facet not directly related to its function in collagen synthesis, and the suggestion is that this function may be responsible for its putative effects at higher intakes (see Section 1.4.2). Equally plausible is the potential of other antioxidant substances in foods to contribute to the body’s overall antioxidant defences. The recent review of vitamin C recommendations in the USA (National Academy of Sciences Food and Nutrition Board, 2000) has attempted to take into account the available evidence for ‘optimising’ intakes, although the relation to health of the criteria used to define ‘optimum’ are not clear. It is also important to recognise that these same nutrients may be detrimental in excess. Upper safe levels for a range of nutrients have now been established by the Scientific Committee for Foods and values have been reported by the UK’s Expert Vitamins and Minerals Group (www.foodstandards.gov.uk, Oldreive, 2003).

1.3 Consumption patterns of plant-derived foods and drinks

1.3.1 Sources of information

At a national level, information on consumption of foods, including plant foods, comes from a variety of sources. The principal surveys are conducted for Government:

- The National Food Survey (now the Expenditure and Food Survey, EFS)
- The National Diet and Nutrition Survey
- Health Survey for England.

The National Food Survey (NFS) (which has recently merged with the Family Expenditure Survey to become the Expenditure and Food Survey) has been conducted annually for the population of Great Britain as a whole since 1950. Some 7000 households record food purchases. More recently, information on food eaten outside the home has also been collected. Although not a direct measure of consumption by individuals, data from the NFS provide valuable information about trends, and regional and socio-economic variations. The National Diet and Nutrition Survey (NDNS) is a rolling programme of cross-sectional surveys of 1500–2000 individuals in one of four age groups selected for simplicity of access (see Section 1.3.3). The Health Survey for England is a rolling annual survey of health status and reported behaviours in around 17 000 individuals and intermittently collects qualitative information in relation to dietary habits [e.g. cardiovascular disease (Department of Health, 1999a)]. Within this series, additional surveys of diet and/or nutrition status have also been performed in various population groups, e.g. ethnic minorities, young people (Department of Health, 1998a, 2001a). All such sources can provide useful information.

Not all countries conduct such detailed population surveys. Nevertheless, data are available from other countries that enable comparisons to be made (see Section 1.3.4 and Table 1.5), e.g. food supply statistics, sometimes referred to as ‘food balance sheets’ or ‘food disappearance statistics’, such as those produced by the Food and Agriculture Organisation.

1.3.2 Trends in household consumption in the UK

Information on trends in consumption of fruit, vegetables and other plant-derived foods in the home in the UK can be found in the annual NFS/EFS reports. Some data collected during the
**Fig. 1.1**  Trends in consumption of fruit and vegetables.

**Fig. 1.2**  Trends in fresh fruit consumption.
**Introduction: Plant Foods and Health**

Fig. 1.3  Trends in fresh vegetable consumption.

Fig. 1.4  Trends in household consumption of tea and coffee.
period 1974–99 are presented in Figs 1.1–1.5. Figure 1.1 illustrates overall trends in household consumption of different categories of plant foods in Britain. Although in food grouping systems, such as the *Balance of Good Health* (Food Standards Agency, 2001), potatoes are classed as starchy foods (such as bread), and do not count towards the recommended five servings a day of fruit and vegetables, they are included in Fig. 1.1 for information. This figure shows that the biggest change is the fall in potato consumption that has not been compensated by a rise in consumption of processed potato products. There has also been a substantial rise in household fruit juice consumption. This began to rise in the 1970s and by 1980 had increased to 87 g/person/week. By 1990 the average intake was 202 g/person/week and in 2000 was 303 g/person/week.

Figures 1.2 and 1.3 illustrate the changes in the consumption of individual fruits and vegetables during 1974–99. A notable change has been the rise in banana consumption from around 100 g/person/week during the period 1974–85 to over 200 g in 1999. There has been a substantial decline in consumption of vegetables such as Brussels sprouts and cabbage and a rise in leafy salad vegetables and carrots. The contribution made to total household vegetable consumption by frozen vegetables in 1974 was 6.5% (63 g/person/week); intake peaked in 1991 at 117 g/week (12%), falling again and reaching 9% (87 g/week) by 1999.

Table 1.2 illustrates trends in consumption of vegetables (fresh and frozen, but excluding potatoes and pulses), fruit (fresh, frozen, canned and dried) and fruit juice. Data are presented for 5-yearly intervals between 1974 and 1999. It is also interesting to note the changes that have occurred in dietary staple consumption during this period, with reductions in potatoes and bread and increases in rice and breakfast cereals, although the total amount of starchy staple food has fallen progressively. It is likely that pasta consumption has risen too, although specific consumption data have only very recently been collected and reported separately. During this period there has been little change in total vegetable consumption, with per capita average daily consumption (excluding potatoes and pulses) in 1999, within the home, being just 142 g/day. Fruit consumption has risen slightly during the 25-year period, with average household daily consump-