safefood

Consumer Focused Review
of Fruit and Vegetables
2013

be safe be healthy be well

Fruit and Vegetable Supply Chain

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Abbreviations

ADI	Acceptable Daily Intake
AICR	American Institute for Cancer Research
ARfD	Acute Reference Dose
BIP	Border Inspection Post
CAP	Controlled Atmosphere Packaging
CDC	Centre for Disease Control
CDSC	Communicable Disease Surveillance Centre
CFU	Colony Forming Unit
COPR	Control of Pesticides Regulations
COT	Committee on Toxicity
CSPI	Centre for Science in the Public Interest
CVD	Cardiovascular Disease
DAF	Department of Agriculture and Food
DARD	Department of Agriculture and Rural Development
DASH	Dietary Approaches to Stop Hypertension
DEFRA	Department for Environment, Food and Rural Affairs
EFSA	European Food Safety Authority
EFTA	European Free Trade Association
EHO	Environmental Health Officer
EPA	Environmental Protection Agency
EPIC	European Prospective Study of Cancer
FAO	Food and Agricultural Organisation
FDA	Food and Drug Administration

FSA	Food Standards Agency
FSAI	Food Safety Authority of Ireland
FTE	Full Time Equivalent
GAP	Good Agricultural Practice
GMP	Good Manufacturing Practice
GRAS	Generally Recognised As Safe
HACCP	Hazard Analysis Critical Control Point
HBSC	Health Behaviour in School Children
HPA	Health Protection Agency
HPSC	Health Protection Surveillance Centre
HSE	Health Service Executive
IAEA	International Atomic Energy Agency
IOI	Island of Ireland
JECFA	Joint FAO/WHO Expert Committee on Food Additives
MAP	Modified Atmosphere Packaging
MRL	Maximum Residue Level
MS	Member State(s)
MTDI	Maximum Tolerable Daily Intake
NI	Northern Ireland
NSIFCS	North-South Ireland Food Consumption Survey
NSP	Non-Starch Polysaccharides
PCS	Pesticide Control Service
PPPR	Plant Protection Products Regulations
PRC	Pesticide Residues Committee
PSD	Pesticide Safety Directorate
RASFF	Rapid Alert System for Food and Feed
ROI	Republic of Ireland

RTE	Ready-to-eat
SCF	Scientific Committee on Food
SCFA	Standing Committee on the Food Chain and Animal Health
SLAN	Survey of Lifestyle, Attitudes and Nutrition
USDA	United States Department of Agriculture
WCRF	World Cancer Research Fund
WHO	World Health Organisation

Executive summary

In 2005, ***safe*food** initiated a programme which involved two comprehensive food chain screening exercises per year over a three-year period. Each review profiled a specific food category, identifying and describing the relevant food safety issues pertaining to it at various points along the food chain, and identifying opportunities to communicate the human health benefits to various stakeholders. The primary focus of these reviews was directly pertaining to food safety and nutrition issues. However, other concerns identified by the consumer not directly related to food safety were discussed, e.g. animal welfare, etc.

As a considerable period of time has passed since these Consumer Focused Reviews were published, ***safe*food** wishes to revisit each of these in order to update their content. This will ensure consumers on the island of Ireland (IOI) are informed of any changes that have come about since 2005.

This review provides an update on the fruit and vegetable review conducted in 2007. It collates and considers the information available – academic, regulatory, public health – on the health and food safety implications of fruit and vegetables. It will focus on ready-to-eat (RTE) fresh fruit and vegetables which are consumed raw, whether whole or prepared, and includes products packaged under vacuum or in a modified atmosphere that have not undergone any treatment (chemical, physical or biological) to ensure preservation, other than chilling.

Consumer research

Fruit and vegetables are key components of a healthy diet, and a high intake of fruit and vegetables in the diet is positively associated with the prevention of cardiovascular disease, cancer, diabetes and osteoporosis. However, in spite of the strong evidence in support of health benefits and the reported awareness of these benefits, intakes of fruit and vegetables on the island of Ireland (IOI) remain below the recommended daily intakes of 400g, or five portions, per day. A number of barriers towards fruit and vegetable consumption have been identified.

Quantitative research

Recent quantitative research involving 2,046 consumers on IOI found that there was an increase in awareness of recommended daily portions of fruits and vegetables. In 2012, 75 per cent of consumers on IOI were able to identify the correct number of portions of fruit and vegetables that should be consumed on a daily basis. This represented an increase of 31 per cent from 2006 results. However it was clear that consumers' awareness did not translate into action, as just 20 per cent of respondents consumed the recommended portions (five or more) per day.

Attitudes to food safety in 2012 mainly focused on the freshness of the product, while concerns over pesticides and sprays decreased from 30 per cent in 2006 to 21 per cent in 2012. Seventeen per cent of consumers indicated that they were not concerned about the safety of their fruit and vegetables.

Factors that would most motivate increased consumption of fruit and vegetables centred on the health benefits received from increased consumption. Cost was identified as the most significant barrier affecting the purchase of fruit and vegetables in 2012. Other barriers identified by 2012 consumers were similar to those identified by 2006 consumers and included cost, shelf-life, preparation time and habit.

Qualitative research

Qualitative research was carried out among a variety of socio-economic groups and target markets on IOI to gain an insight into how consumer attitudes towards fruit and vegetables had changed since 2006. Female consumers in 2012 were just as likely as their counterparts in 2006 to consider both fruit and vegetables as important in their diets and, therefore, were more likely to report consuming increased quantities of fruit and vegetables compared to men. Similar to 2006 results, bulk buying and wastage continued to be an issue for many consumers, and the majority of consumers were unaware of any methods to prolong the shelf-life of fruit and vegetables.

Consumers identified a number of factors or 'triggers' that motivated increased consumption of fruit and vegetables including educational campaigns, lower costs and health. Educational programmes were identified as the most significant motivating factor and the *Food Dude's* campaign was most mentioned by consumers as a programme that improved knowledge and behaviour relating to fruit and vegetables in the household. Barriers discussed by consumers in 2012 were similar to those in 2006, however cost was the most significant barrier discussed in 2012, compared to inconvenience in 2006. Package size and potential waste were factors that were specific to the 2012 findings.

Consumers from the 2012 research could not identify a clear and consistent message about the possible benefits of consuming fruit and vegetables. When fruit and vegetables were put in the context of the main meal, adults failed to identify the unique benefits associated with consumption. It was also found that consumers were very aware of the 'five-a-day' message and it was found that it had the greatest impact at the point of purchase. However, it was clear that some ambiguity existed around the definition of one portion of fruit or vegetables. The 2012 research established that an important trigger for increased consumption of fruit and vegetables could be identifying key benefits that would affect consumers in their daily lives.

The supply chain

The horticultural industry on IOI is small in a European context. Nonetheless it is an important indigenous industry contributing to the economy in terms of adding value to the domestic output and employment provision.

The output for IOI was valued at approximately €282.8 million farm gate value in 2011. The key crops in the food sector include mushrooms, potatoes, field vegetables, fruit and protected crops. The main

crops grown under protective covers on IOI are tomatoes, cucumbers, peppers, lettuces and strawberries. Strawberries, the most important of these crops, comprised 50 per cent of the total value of the output from the protected edible crop sector. The mushroom sector is the largest sector of the horticulture industry and a key area of export, particularly to the UK. Due to a seasonal climate, imports of both fruit and vegetables are required for a ready supply for consumers on IOI. Imports of fruit and vegetables to IOI were valued at €496, 273 million in 2010.

The prevalence of organic produce has increased significantly since 2000 but has experienced a slow-down over the past three years. In 2010, there were 1,632 organic producers on IOI, farming a total area of 52,390 hectares, with 37 per cent of producers located in the West of Ireland. Three hundred of these producers were horticulture producers who farmed approximately 420 hectares. Organic fruit and vegetables accounted for 35 per cent of total organic food sales on IOI during 2012, approximately €31.5 million.

The retail market for fresh produce on IOI in 2012 was valued at €1.208 billion, which represented a 0.8 per cent growth compared with 2011. In 2011, increased purchase of fruit (+3% year on year) drove sales of the fresh product sector in ROI. In NI, a range of supply chains exist, with larger growers working with multiples and smaller growers supplying local stores and convenience shops.

Food safety

Fresh fruit and vegetables are key components of a healthy diet. The risk of associated infectious disease is low and mechanisms by which contamination occurs are preventable. Good hygiene and agricultural practices from farm to fork can limit contamination and microbial growth in these products, as well as increasing consumer knowledge regarding inappropriate storage, inadequate heat treatment and cross-contamination.

There has been an increase of just over five per cent in the number of all foodborne outbreaks associated with fresh produce between the 1970s and 1990s. A total of four per cent of foodborne illnesses, reported to the Health Protection Agency (HPA) in England and Wales between 1992 and 2010,

were due to fruit and vegetable consumption. *Salmonella* was identified as the aetiological agent in 39 per cent of these outbreaks, while 10 per cent were caused by foodborne viruses.

Europe has experienced a number of outbreaks since 2006. In 2010, a total of 5,262 outbreaks of foodborne illnesses were reported by EU member states. Vegetables, juices and products thereof was the third most common food category reported as the vehicle for infection, responsible for 8.7 per cent of outbreaks.

In ROI, a total of 764 fruit and vegetable samples were analysed for up to 331 pesticides and analytes, using multi-residue analytical methods, for the 2010 period. A total of 290 of the fruit and vegetables sampled contained no detectable pesticide residue, 449 contained one or more detectable residues at or below the MRL and 25 samples contained residues in excess of EU MRLs. In NI, a total of 2,048 of 3,750 samples of fruit and vegetables collected from 24 sites in the UK (including NI) were analysed for 330 pesticide active substances for the 2010 period. Residues were detected in 1,205 samples, which was almost identical to the positive rate in the ROI for the same year.

Fruit and vegetables accounted for 670 RASFF notifications to the European Commission in 2011. Examples of notifications included dimethoate and omethoate in fruit and vegetables of various origins, formenthanate in peppers from Turkey, and cucumbers from Spain. In addition, it was found that the rise in RASFF notifications for Salmonella spp. was most prominently for the product category fruits and vegetables. There were no FSAI alerts (for action or information) relating to fresh fruit and vegetables in 2011.

Nutrition

Fruit and vegetables represent one of the five major food groups in dietary guidelines and, with the exception of avocados, are low in fat and energy. The National Adult Nutrition Survey (NANS) 2011, conducted among 1,500 adults in ROI, found that the average intake of fruit and vegetable, excluding fruit juice and composite dishes was 2.4 portions per day, considerably lower than the WHO recommendation of 400g per day. The SLÁN study, 2007 (ROI) and the NI Health and Social Wellbeing Survey (HSWS) found a higher percentage of respondents in ROI ate at least one portion of fruit and vegetable per day, compared to respondents in NI. Both the NANS survey and the North-South Ireland

Food Consumption Survey (NSIFCS) found that mean intakes of fruit and vegetables increased with age.

In general, consumption of fruit and vegetables by teenagers also remains well below the recommended daily amounts. According to the National Teens' Survey (2008), the average intake of vegetables was just over half the daily allowance. Consumption of fruits was higher than vegetables, with just over two thirds coming from fruit juices. The NDNS conducted in 2011 (UK wide) found similar results to the National Teens' Survey.

Almost all children (98%) between the ages of one and four in ROI consumed fruit. Consumption of fruit increased from 196g/d at age one, to 258 g/d at age four, with a large proportion of this intake coming from fruit juices. The way children consumed fruit was very different to the way they consumed vegetables. Vegetables were primarily eaten at lunch or during the evening meal. Fruit was mostly eaten as part of a packed lunch, and as a snack throughout the day.

Health benefits

Low consumption of fruit and vegetables (less than 400 grams per day) is thought to be one of the top ten risk factors for global mortality. It is estimated that up to three per cent of deaths worldwide are attributable to low fruit and vegetable consumption. Moreover, insufficient intake of fruit and vegetables is estimated to cause about 11 per cent of ischaemic heart disease deaths, about nine per cent of stroke deaths, and around 14 per cent of gastrointestinal cancer deaths globally. In 2001, the European Prospective Study of Cancer (EPIC) estimated that an increase in fruit and vegetable intake of just 50g/d had the potential of cutting the risk of premature death from any cause by 20 per cent.

The WHO recommends an increased consumption of fruit and vegetables, as well as legumes, whole grains and nuts, to help reduce obesity at an individual level. In addition, it has also been shown that a high consumption of fruit and vegetables can have a protective role for some chronic diseases, including cardiovascular disease (CVD) and diabetes.

Recent research has found that the link between cancer risk and fruit and vegetable consumption is not as strong as previously thought. A 'probable' link between fruit and vegetable consumption, and reduced risk of cancer of the mouth and pharynx, larynx, oesophagus, stomach and colorectal cancer has been established.

Recently, studies identifying an association between fruit and vegetable consumption and bone health have been an area of focus. Some studies have shown a positive association between fruit and vegetable consumption, and improved bone mass and bone mineral content. The investigation of dietary risk factors in the prevention of cognitive decline is a relatively young field of research, and it is not yet certain whether increased fruit and vegetable consumption slows down the process of cognitive decline.

Labelling

The general labelling of fresh produce is governed by Council Directive 2000/13/EC on the Labelling, Presentation and Advertising of Foodstuffs, and by Council Regulation (EC) No. 2200/1996, which lays down marketing standards for quality and labelling of fresh fruit and vegetables.

A number of amendments have occurred since 2005 that directly impact upon the labelling of fresh fruit and vegetables. In 2008, the Commission Regulation (EC) No. 1221/2008 repealed 26 of the 36 specific marketing standards. This meant that the 36 standards which were defined by 34 regulations were replaced by a single regulation for 10 specific standards, in addition to one general marketing standard.

In ROI and NI, the EU Food Information for Consumers Regulation (No. 1169/2011) has been published in the Official Journal of the European Union. This means that the transition process has begun to replace the current food labelling regulations. The transitional arrangements mean that most of the requirements do not apply until 2014, with nutrition labelling becoming mandatory in 2016, allowing food business time to become accustomed to the new labelling requirements.

Organic food constitutes a relatively small but growing part of the food supply chain on IOI. In Ireland, approximately 85 per cent of organic foods are sold via supermarkets, with the remaining 15 per cent through more direct channels such as famers markets, farm shops and box deliveries. Fruit and vegetables comprise the largest organic food type.

Key findings

Consumers

- There has been a 31 per cent increase in consumer awareness around the number of portions of fruit and vegetables that should be consumed per day. However, actual consumption of the correct portion size remains low, with only 20 per cent of consumers eating five portions or more per day.

- Market research showed that attitudes to food safety on IOI in 2012 mainly focused on the freshness of the product, while the level of concern regarding pesticides and sprays decreased from 30 per cent of those surveyed in 2006 to 21 per cent in 2012.

- In 2012, consumers identified large package sizes as a problem for unwanted wastage of fruits and vegetables. Consumers in 2006 and 2012 were unaware of methods that would prolong the shelf-life of their fruit and vegetables.

- Factors that consumers deemed most motivating for increased consumption of fruit and vegetables in 2006 and 2012 centred on health benefits and lower costs. Consumers in 2012 identified educational campaigns as an important trigger.

- Educational programmes also had an important role to play in motivating consumption of fruit and vegetables. The *Food Dude's* campaign was frequently mentioned by consumers in ROI in the 2012 research as a programme that improved general knowledge and increased consumption of fruit and vegetables in the household.

- Cost was identified as the most significant barrier to increased fruit and vegetable consumption in 2012. Other barriers identified both in 2006 and 2012 included inconvenience, shelf-life and quality.

- Consumers on IOI were aware of the five-a-day message, and it was found that the message had the greatest impact at the point of purchase.

- For the general population it was clear that some ambiguity existed around the definition of one portion size.

Producers and packers

- Many food pathogens are commonly found in soil where the edible portion of vegetables are grown either directly in soil (root vegetables) or in close proximity to the soil (leafy vegetables), thus creating potential for direct contamination during growing. While recognising that the total elimination of the risk of soilborne contamination may be impossible, thorough washing prior to packaging should serve to remove as much soil as possible.

- In addition, guidelines regarding appropriate storage, adequate heat treatment and cross-contamination should be adhered to at all time to prevent any possible outbreaks.

- Where organic material such as manure is being used as fertiliser, there are guidelines for growers which aim to minimise the risks of microbiological contamination of RTE crops. These guidelines should be followed to prevent contamination with potentially dangerous bacteria such as E.coli 0157:H7.

Processors and distributors

- The horticultural industry on IOI had an output value of approximately €282.8 million at farm gate value in 2011. Although the industry has faced a number of challenges between 2005 and 2012, the performance of the sector remains positive.
- The UK market offers fruit and vegetable producers a close export market where financial gains can be made, particularly for mushroom producers.
- The prevalence of organic produce has increased significantly since 2000, but has experienced a slow-down over the past three years. Organic fruit and vegetables accounted for 35 per cent of total organic food sales on IOI during 2012, approximately €31.5 million. However, the majority of organic food available on IOI is imported. If economies of scale can be achieved, opportunities exist for organic fruit and vegetable producers on IOI.

Retailers and caterers

- Regulation (EC) 852/2004 requires all food businesses to be registered with the competent authority. It also stipulates that food business operators should apply the principles of the system of HACCP in order to identify critical control points that need to be kept under control in order to guarantee food safety.

- Food Business Operators must ensure that where and how the food is produced is hygienic, and that the premises are kept clean and properly equipped. Staff members must observe good personal hygiene practices, and be properly supervised and trained.

- In 2010, a new EU logo was introduced on all pre-packaged organic food products produced in EU member states. A two-year transition period allowed industry to adapt product packaging before the logo became compulsory on July 1st 2012. However, the 'Euro-leaf' remains optional for non-packaged and imported organic products.

Health professionals

In spite of the claimed knowledge of the 'five-a-day' message, intakes of fruit and vegetables on IOI remain low. Therefore, there is a need to continue to promote this message, particularly amongst children, teenagers and young adults, and clarify uncertainties such as the definition of portion sizes, as well as raising awareness of the health benefits of fruit and vegetables.

- The way children consumed fruit was very different to the way they consumed vegetables. Vegetables were primarily eaten at lunch or during the evening meal. Fruit was mostly eaten as part of a packed lunch and as a snack throughout the day. Understanding the eating occasions associated with fruit and vegetables will assist in focused messages that can increase consumption of fruit and vegetables at particular times of the day.

- Much research has been conducted on the links between increased fruit and vegetable consumption and the reduction of certain chronic diseases including CVD, diabetes, overweight/obesity, osteoporosis, cancer and cognitive decline. However, consumer knowledge about particular links and health benefits remain low. Messages that target

specific links between certain fruit and vegetables and chronic disease may motivate increased consumption.

1 Introduction

Key findings

On an EU level, a recent EUFIC report found that overall consumer knowledge about health benefits associated with fruit and vegetable consumption has improved, however, confusion still exists in relation to portion size and serving size.

Seventy-five per cent of consumers on IOI were able to identify the correct number of portions of fruit and vegetables that should be consumed on a daily basis. This represented an increase of 31 per cent from 2006 results. Just 20 per cent of consumers on IOI consumed recommended portions (five or more) per day.

Consumers on IOI were aware of the five-a-day message and it was found that the message had the greatest impact at the point of purchase. However, some ambiguity existed around the definition of what one portion of fruit and vegetables consisted of. Consumers were more familiar with correct portion sizes for fruit compared to vegetables.

Attitudes to food safety on IOI in 2012 mainly focused on the freshness of the product, while the level of concern regarding pesticides and sprays decreased from 30 per cent of those surveyed in 2006 to 21 per cent in 2012.

Female consumers on IOI in 2012 were just as likely as their counterparts in 2006 to consider both fruit and vegetables as important in their diets and, therefore, were more likely to report consuming increased quantities of fruit and vegetables compared to men.

Factors that consumers deemed most motivating for increased consumption of fruit and vegetables centred on health benefits. Educational programmes also had an important role to

play in motivating consumption of fruit and vegetables. The *Food Dude's* campaign was frequently mentioned by consumers in ROI in the 2012 research as a programme that improved general knowledge and increased consumption of fruit and vegetables in the household.

Barriers identified by 2012 consumers on IOI were similar to those identified by 2006 consumers and included: "inconvenient", "expensive", "shelf-life" and "quality". Cost of fruit and vegetables was identified as the top barrier by the majority of consumers in 2012 compared to inconvenience in 2006.

Consumers from the 2012 IOI research could not identify a clear and consistent message about the possible benefits of consuming fruit and vegetables that would promote consumption. When fruit and vegetables were put in the context of the main meal, adults failed to identify the unique benefits associated with consumption.

1.1 Background to *safe*food

***safe*food** is a North-South body, responsible for the promotion of food safety on the island of Ireland. ***safe*food** advocates an environment where consumers have confidence in the food they eat. In order to create this environment, ***safe*food** works in close collaboration with its partners in food safety and nutrition.

The role of ***safe*food** is determined by its governing legislation, which sets out its functions. These functions are summarised as follows:

- Promotion of food safety
- Research into food safety
- Communication of food alerts
- Surveillance of foodborne disease

- Promotion of healthy eating
- Research into nutrition
- Promotion of scientific co-operation and linkages between laboratories
- Development of cost-effective facilities for specialised laboratory testing.

*safe*food's functions also include the provision of independent science-based assessment of the food chain, and the organisation has a role in giving advice on the nutritional aspects of foods.

1.2 Objective and terms of reference of the review

In order to address in part its function in relation to carrying out independent science-based assessment of the food chain, as well as adopting the theme of complementary working and added value, *safe*food initiated a programme in 2005 involving two comprehensive food chain screening exercises, each over three years. Each review focused on a particular food category or process with the objectives of:

- Providing consumers with the most relevant and pertinent information available to enable them to make informed choices in respect of the food they eat
- Helping consumers understand (a) how the food safety system works, (b) the efforts being taken by the regulators, producers, and industry, to reduce the inherent risks, and (c) the prudent sensible steps that can be taken to address both perceived and potential risks
- Providing opportunities to promote good practice along the food chain.

The purpose of these reviews was to profile the food category, identify and describe the relevant food safety issues pertaining to it at various points along the food chain, and to identify opportunities to communicate the human health benefits to, and influence the behaviour of, the various stakeholders.

The general terms of reference of each review were:

To report on foods in light of their impact on human health and consumer concerns, and in particular to:

1. Profile the food category, identify and describe the issues relevant to human health at various points along the food chain
2. Report on how the food safety system works across the entire food chain
3. Identify opportunities to communicate the human health benefits and potential risks of this food category to the consumer
4. Identify means to promote best practice to key stakeholders
5. Determine and communicate key issues for stakeholders with a view to influencing behaviour and practice across the food chain.

The primary purpose of these reviews was directly pertaining to food safety and nutrition issues. However, other concerns identified by the consumer not directly related to food safety will be discussed, e.g. animal welfare, environmental impact of the industry, etc. As a considerable period of time has passed since these Consumer Focused Reviews were published, ***safe***food wishes to revisit them in order to update their content. This will ensure consumers on the island of Ireland (IOI) are informed of any changes that have occurred since 2007.

1.3 Consumer focused review of fruit and vegetables

1.3.1 Introduction

Fruit and vegetables are key components of a healthy diet. They are low-fat and low energy-dense foods, relatively rich in vitamins, minerals and other bioactive compounds, as well as being a good source of fibre.

A high intake of fruit and vegetables in the diet is positively associated with the prevention of cardiovascular disease, cancer, diabetes, and osteoporosis. There is also convincing evidence that a high dietary intake of fibre (most specifically non-starch polysaccharide (NSP)) is a factor in protecting against weight gain and obesity as well as being an effective weight loss strategy. The World Health

Organisation (WHO) advocates a daily intake of 400g of fruit and vegetables for health (this is equivalent to approximately five portions based on an average weight of 80g per portion).

In spite of the strong evidence in support of the health benefits and the reported awareness of these benefits, intakes of fruit and vegetables on the island of Ireland (IOI) are low.

From a food safety perspective, the risks associated with fresh fruit and vegetables are low. However, the proportion of foodborne illness associated with this category has increased over the last number of years. Along with promoting the increased consumption of fruit and vegetables, it is important that these risks are acknowledged and managed.

This review collates and considers the information available - academic, regulatory, public health - on the health and food safety implications of fruit and vegetables. On the basis of the evidence, the review draws a number of conclusions, which may provide the basis for action for ***safe***food and other agencies on the island, as well as for stakeholders, public health professionals and consumers.

1.3.2 Scope of the review

This review of the fruit and vegetable food chain will focus only on ready-to-eat (RTE) fresh fruit and vegetables which are consumed raw, whether whole or prepared. Prepared refers to minimally processed fruits and vegetables. This means raw fresh-cut produce, which has undergone minimal processing such as peeling, slicing or shredding. This includes products packaged under vacuum or in a modified atmosphere that have not undergone any treatment (chemical, physical or biological) to ensure preservation, other than chilling. Cooked fruit and vegetables are excluded because their nutritional and microbial characteristics can be altered by cooking.

The nutrition and health benefits chapters will, however, consider fruit and vegetables as a broad food group rather than looking at them as individual fruits or vegetables. This is because it is not known which components in this category are beneficial.

The review will not include potatoes, as they are classified under ‘Breads, Cereals and Potatoes’ food group due to their high starch content, and in general are not consumed raw. In some cases, however, market statistics will include potatoes (this will be clearly stated) as it would otherwise be impossible to segregate the data.
Fruit and vegetables are very similar with respect to their compositions, methods of cultivation and harvesting, storage properties and processing. In botanical terms, fruit is the portion of a plant which

houses the seeds. Resultantly, a number of vegetables may be considered fruits. These include tomatoes, cucumbers, eggplant, and peppers. Another distinction between fruit and vegetables is based on usage. Plant items that are generally eaten with the main course of a meal are considered to be vegetables, while those commonly eaten as a dessert are considered fruits (1). Throughout this document, the latter distinction between fruit and vegetables will apply, e.g. tomatoes are considered vegetables, unless otherwise stated.

1.3.3 Consumer knowledge, attitudes and perceptions of fruit and vegetables

An element of the CFR research has been to conduct both qualitative and quantitative research with consumers on the island of Ireland. ***safe***food conducts annual market research during which it determines consumers' attitudes and behaviour in relation to particular foods and food preparation habits. In its 2006 research, 831 consumers were asked about attitudes, food safety concerns and food preparation habits with respect to fruit and vegetables. In 2012, similar research was carried out to examine any changes that may have occurred between 2006 and 2012. The main findings of this research are outlined below. Where possible, the ***safe***food results are compared to other research conducted on the island of Ireland. To put the research conducted on IOI into context, a review of positive and negative perceptions of fruit and vegetables from a European perspective is outlined below and followed by a review of international evidence on attitudes and barriers to fruit and vegetable consumption.

1.3.3.1 Perceptions of fruit and vegetables from a European perspective

Recommendations to increase consumption of fruit and vegetables to a minimum of 400g (five portions) per day are very similar across the globe (2). Although guidelines are similar, it is probable that consumer behaviours and preferences are very different. The information for this section was ascertained from a variety of European journals and reports that used both qualitative and quantitative methods to assess consumer perceptions. This section will give an overview of current perceptions to fruit and vegetables from a recent research report by EUFIC (European Food Information Council). The report showed that the mean fruit and vegetable intake across nineteen specific countries, including Ireland, was below the 400g level and only four countries from the nineteen selected, (Poland, Germany, Italy and Austria) exceeded the 400g daily target (3). In addition, it was also found that overall consumer knowledge about health benefits associated with fruit and vegetable consumption have improved, however, confusion still exists in relation to portion size and serving size

(4). A wide range of factors influence consumer attitudes to, and perceptions of, fruits and vegetables and consequent consumption. Identifying and understanding these attitudes and perceptions could aid in the development of strategies that will motivate increased consumption of fruit and vegetables (5). Key findings are discussed below.

Price

A number of studies have found that a perception exists in certain cultures that fresh produce is more expensive than many other food products, particularly more refined carbohydrate rich product. This perception has led to more lower and middle income consumers believing that fresh fruit and vegetables are too highly priced for regular consumption (6). Although affordability of fruit and vegetables is more likely to affect those on lower incomes, Lallukka *et al.*, found that the absolute cost of healthy foods, including fruit and vegetables, was likely to have a role across all income groups (7). It was also found that quality and perceived health benefits were used as trade-offs when considering the cost of fruit and vegetables (8). Young adults on a low income associated feeling better and weight loss benefits with fruit and vegetable consumption (9).

Texture and taste

Recently, it was found that consumers placed more attention on freshness, taste and hygiene attributes when purchasing fruits and vegetables, than the price and nutritional value, although this varies by country (10). From a European perspective, a number of studies have found that children's preferences for fruit and vegetables expanded and increased in complexity as they got older. Appearance and texture were the most important determinants encouraging consumption in four to five year old children, while taste was the most important determinant influencing consumption in 11-12 year olds (11).

Health

Consumers have a generally positive perception of both fruit and vegetables, and to a large extent believed that the consumption of fruits and vegetables had a positive impact on their health status. Females reported more favourable attitudes and greater perceived behaviour control regarding fruit and vegetable intake than males (Emanuel *et al.*, 2012). Certain studies have found that overly optimistic assessment of fruit and vegetable intakes results in complacency about the need to eat more fruit and vegetables. A UK-based study that incorporated consumers who ate more than two servings of fruit per day, found that health and wellness features most associated with vegetables were “freshness”, a “source of vitamins and minerals”, and “high nutritional value”. In the mind of the consumer, these features were linked to the benefit concept “maintain energy and vitality”, which in turn was connected to the consequence “maintain an active life” (12).

Knowledge and education

A number of initiatives, such as the '*Food Dudes'* programme and grow your own campaign (GIY), have found that targeting children at an early age through interactive hands-on campaigns can create positive perceptions towards certain fruit and vegetables (13, 14). Better educated adults show higher vegetable consumption. Besides the financial aspect mentioned previously, higher education levels may also mean a greater knowledge and awareness of healthy eating and, therefore, a more positive attitude towards regular consumption (15).

Familial influences

Parents also had a significant role to play in the development of children's perceptions of fruit and vegetables. Some studies found that children's likes and dislikes were strongly correlated to their parents and, therefore, negative attitudes towards fruit and vegetables in parents were likely to result in similar attitudes towards fruit and vegetables in children (16).

Availability and convenience

A number of studies have reported on how the availability of fruit and vegetables can impact upon consumers' consumption habits. It has been found that older consumers with the lowest consumption levels of fruit were more likely to believe that the variety of fruit available in their nearest store was of a fair or poor variety. However, this was not the case for vegetable intake (17). Furthermore, consumers are more likely to turn to fruit juice when fresh fruit is not available, rather than frozen, tinned or dried fruit. This is primarily due to the belief that fruit juice is healthier and more convenient than frozen, tinned and dried varieties (9).

Convenience has been cited as a barrier to fruit and vegetable in a variety of studies, and some studies have found that where consumers perceived that convenience was an issue in preparation of fruit and vegetables, they were more likely to consume less (18).

Serving size

Although fruit and vegetables are often grouped together as one category for research purposes, it should be noted that in some cases, it is worthwhile to differentiate between the two. Some research has suggested that significant difference in consumption levels are evident when fruit and vegetables are treated as separate groups (19). It is clear that consumers differentiate between serving sizes for fruit and vegetables. A study conducted in Liverpool found that children between the ages of 9 and 10 chose larger portions sizes for fruits than vegetables. It was also found that after the 5-a-day campaign, variation in what was believed to be the correct portion size was still significant (20). Respondents' understanding of fruit and vegetable serving sizes suggests it is important to separate fruit and vegetable recommendations, using common household measures to convey serving sizes,

and using prescriptive messages. Respondents were more confident in assigning a serving size to fruit than to vegetables (21).

Fruit and vegetable format

A number of studies have uncovered that a large proportion of consumers believe that fresh fruits and vegetables are healthier than frozen or canned varieties. It has also been found that frozen fruits and vegetables are perceived to be healthier than tinned variations (22). A study conducted on Polish, French and Dutch consumers found that fresh fruits were perceived to be healthier but less convenient than dried fruits. Consumers also reported more positive feelings about the consumption of fresh fruits compared to dried fruits. This study found that consumers who were most willing to make trade-offs on their health were most likely to rate the health aspects of both fresh and dried fruits, as well as several perceptions of convenience of both fresh and dried fruits (9).

1.3.3.2 Attitudes, awareness and barriers to consumption of fruit and vegetables – international evidence

It is well recognised that there are many barriers to the consumption of five or more fruit and vegetables, and they can be broadly categorised into:

- Access to and availability of good quality, affordable fruit and vegetables locally;
- Attitudes and awareness – awareness of the fruit and vegetable message as well as people's knowledge and attitudes, motivation and skills in buying, preparing and eating fruit and vegetables.

Access and availability

Socio-demographic factors are well known to affect food choice. Lower socio-economic status and a lower education level are associated with lower consumption of fruit and vegetables. Higher social classes and those with a higher educational status are in general more health conscious and better able to conceptualise the relationship between diet and health (23).

Disposable income and the amount of money available to spend on food, influences the consumption of fruit and vegetables. In the qualitative discussion groups conducted for this review, participants also identified cost as a barrier to consumption, in particular for those who did not purchase in large quantities. Cost has been identified in research studies as a barrier to fruit and vegetable consumption across different socio-economic groups (24). This is further compounded by the perception that fruit

and vegetables are not "filling" and can have a lot of wastage, thus poorer households often opt for cheaper, energy-dense foods that are perceived as being filling and not wasteful (25). Recent research investigated the motives behind food choice in people of different socio-demographic backgrounds. They found that individuals with lower income and education placed greater emphasis on price and familiarity when purchasing food. Whereas more affluent individuals' motives for food purchase took health concerns into account due mainly to greater disposable income (26). Purdy *et al.,* found that food budgeting is often low on the list of priorities for many low-income households; as rent and fuel costs are less flexible causing inadequate resources for food (27).

The access and availability of good quality fruits and vegetables can be a key barrier to the consumption of fruits and vegetables (25). This can refer to access and availability in the home, in a catering facility or within local retail provision.

As well as income, there are other key influences on the purchase and consumption of fruit and vegetables, including area of residence, car ownership/public transport, and shopping and storage facilities. Shops in poorer areas are more likely to stock a higher proportion of processed foods which tend to be higher in saturated fats, salt and sugars, and a smaller range of fruit and vegetables than larger stores. Local shops are often more expensive than supermarkets, however, these are frequently located out of town, requiring transportation to access them; in some areas, especially rural, no public transportation is present (27). Proximity to a supermarket and number of local supermarkets is positively associated with higher fruit and vegetable intake and better dietary quality among low income households (28). Conversely, recent ROI research has found that individuals who live closer to a larger food outlet, or who live in an area with a higher density of larger food outlets, have a significantly better diet in terms of cardiovascular risk (29).

Barriers to fruit and vegetable intake reported from several studies have shown that those living in socially deprived areas may lack local sources such as good-quality, reasonably priced fruit and vegetables, resulting in a circle of poor demand and supply. Recent research has also highlighted that the built environment has an effect on food preferences. The space in which a person lives can present opportunities and barriers for adherence to dietary recommendations (30), such as 400g of fruit and vegetables per day(31).

Barriers also identified during the qualitative discussion groups included the perceived short shelf-life of certain fruit and vegetables, and the quality (and ripeness) of produce was seen to be 'hit and miss', thus discouraging consumers from purchasing these items.
With regards to children, a recent systematic review concluded that school-based interventions moderately improve fruit intake but have little impact on vegetable intake. More studies are needed

to address the barriers for success in changing dietary behaviour among this cohort, particularly in relation to vegetables (32).

Attitudes and behaviour

Children

Numerous factors influence children's food choice and eating behaviour, and attitudes towards different foods, including fruits and vegetables, can stem from various sources, including parental attitudes and eating behaviour, family meals or the child's own personal experience or food preferences. Rasmussen *et al.,* reported in a recent review that the determinants of fruit and vegetable consumption among children and adolescents most consistently supported by evidence are gender, age, socio-economic position, preferences, parental intake and home availability/accessibility (33).

At an individual level, food preferences play a major role in the consumption of fruit and vegetables. Exposure in early life can influence fruit and vegetable intakes. Research carried out by Skinner *et al.,* indicated that food-related experiences in the first two years of life predicted dietary variety in children of 6, 7 and 8 years of age (34). Similar results were reported by Mannino *et al.,* who found that fruit exposure and variety in infancy were significant predictors of fruit variety scores in school-aged children, which emphasises the importance of early experience on promoting variety in later eating patterns (35). Research has also found that repeated exposure to vegetable flavours through breast milk has been shown to increase acceptability of vegetables during childhood, compared to formula-fed infants (23).

Food neophobia refers to the rejection and or/reluctance to eat an unfamiliar food (36). Research by Galloway *et al.,* indicated that girls with neophobia and pickiness eat fewer servings of vegetables compared to girls without neophobia or pickiness (37).
Taste was also identified as a barrier to the consumption of certain fruit and vegetables in the qualitative discussion groups conducted for this review.

Familial influence

The influence of family on children's food choices is known to have a very powerful influence. Parents play an important role in the formation of food habits and preferences of children, either through the choice of infant feeding methods, foods they chose to make available or by direct modelling influences. Parental modelling and intake have been found to be consistently positively associated

with children's fruit and vegetable intake (38). Positive associations have also been found between home availability, family rules and parental encouragement and children's fruit and vegetable consumption. Cooke *et al.,* indicate that the amount of fruit and vegetables that UK parents themselves reported eating was a strong predictor of their 2 to 6 year old children's intake. The earlier the age that the children had been introduced to vegetables, the greater the child's measured intake. A similar effect was observed for fruit (39).

Regular family meals provide an opportunity for healthy eating patterns to emerge among family members. Increasing family dining has been associated with an increased intake of fruit and vegetables as well as other beneficial nutrients (40).

Kristjandottir *et al.,* recently found that determinants for fruit and vegetable intake in children include availability at home, modelling, strict rules around fruit and vegetable intakes and knowledge of recommendations (41). Father's fruit intake and eating vegetables together as a family were found to be the strongest modelling determinants for fruit and vegetable intake respectively.

Adults

For adults, skills and confidence in preparing and cooking fruits are frequently reported as factors affecting consumption, of which the perceived effort and time are most commonly cited (24, 42). For example, Horacek and colleagues found confidence in buying, preparing and eating fruit and vegetables among men as a key barrier to their consumption (43). Confidence and self-efficacy were also reported as a barrier to fruit and vegetable consumption in another large US study of adults (44).

Findings from the qualitative discussion groups supported these factors, as the inconvenience associated with the preparation of a number of fruit and vegetables, including lettuce, potatoes, cabbage and spinach were cited as a barrier to consumption.

Wardle *et al.,* investigated the relationship between knowledge and intake of fat, fruit and vegetables using a well-validated measure of nutrition knowledge. The study found knowledge was significantly associated with healthy eating (45).
Other barriers to consumption that emerged from the discussion groups included the feared presence of pesticides and other chemical sprays, and genetic modification. A lack of understanding of what constitutes a portion has been reported in the UK as a potential barrier to meeting the Five-a-Day recommendation (46).

1.3.4 IOI research

1.3.4.1 Quantitative research

Understanding of dietary guidance

In 2006, a large proportion of consumers believed that three to five portions of fruit and vegetables should be consumed per day (Table 1.1). Over the years, an increase was clearly observed in the number of consumers who believed they should aim to consume five portions of fruit and vegetables per day. In turn, this resulted in a much lower percentage of consumers who were unsure how many portions they should consume. Those consumers who believed they should consume two or less portions per day remained largely unchanged.

Table 1.1 No. of portions of fruit and vegetables consumers on IOI think a person should eat daily

No. of daily portions	% respondents 2006	% respondents 2012
1	1	1
2	3	4
3	10	7
4	16	6
5	44	75
6+	9	4
Don't know	17	3

Note: 2006 data: n = 831 (ROI-519, NI-312); 2012 data; 2012 data: n = 2046 (ROI – 1036, NI – 1010), highlighted sections indicate the correct answer.

Question: How many portions of fruit and vegetables do you think you should be eating in a typical day?

However, it is clear that knowledge of correct portion size does not translate into actual consumption of the correct number of portions. Bord Bia (2007) carried out research on consumers' attitudes towards fruit and vegetables in 2006. This research consisted of a similar numbers of adults (808) who completed surveys during face-to-face interviews in their own homes. It found that 25 per cent of consumers included five or more portions in their daily diet (47). Figures from the 2012 research conducted by ***safe***food indicated that this figure had risen, and that just over one third of adults (36%)

reported consuming five or more portions of fruit and vegetables daily (47). In addition, the 2006 research conducted by ***safefood*** found that consumers had a better understanding of the correct portion sizes for fruits compared to vegetables. This finding remained unchanged in 2010 when research conducted by Bord Bia found that consumers were still more skilled at identifying correct portion sizes for fruits compared to vegetables (48).

Consumer attitudes to food safety

While some major disease outbreaks have occurred both in Europe and America, between 2006 and 2012, it seems they have not impacted significantly upon consumers' perceptions of safety on IOI, with a large increase in the number of consumers who indicated they had no concerns regarding the production, preparation and consumption of fruit and vegetables. Fifty-one per cent of consumers indicated that the level of freshness was their primary concern, an increase of 31 per cent on the 2006 figure. The number of respondents concerned about the presence of pesticides and use of sprays decreased from 30 per cent in 2006 to 21 per cent in 2012. Notably, 17 per cent of consumers indicated that they had no concerns about the production, preparation and consumption of fruit and vegetables (Table 1.2)

Table 1.2 Unprompted issues of concern to consumers about the production, preparation and consumption of fruit and salad vegetables (Top four, unprompted)

Issue of concern	% concerned 2006	% concerned 2012
Freshness	15	51
Pesticides and sprays	30	21
I am not concerned	-	17
Bacteria e.g. E-coli	5	3

Note: 2006 data: n = 831 (ROI-519, NI-312); 2012 data n = 2046 (ROI – 1036, NI – 1010)

Question: Thinking about fruit and vegetable production, preparation and consumption, what on issue, if any, are you most concerned about?

Changing consumption patterns

The number of people reporting consuming salads on a daily basis has decreased slightly from 73 per cent in 2006 to 67 per cent in 2012. However, this decrease may be explained by the high number of adults eating fresh fruit and vegetables. Data from the 2012 research found that fresh fruit and

vegetables were more popular than their frozen counterparts on IOI, with fresh vegetables, fruits and salads most popular 'nowadays'. These findings are very similar to 2006 findings from Bord Bia where fresh fruit and vegetables were preferred by 78 per cent and 67 per cent of consumers respectively (47). In 2012, salads and frozen vegetables were most popular with consumers aged between 35 and 49, while smoothies were most popular with consumers between the ages of 15 and 24 (Table 1.3).

Table 1.3 Preference for fruit and vegetable type

Fruit/vegetable type	% of respondents
Fresh vegetables	87
Fresh fruits	85
Salads	67
Frozen vegetables	53
Pure juices	52
Homemade/chilled soups	43
Fruit jam	39
Canned/tinned vegetables	28
Canned/tinned fruit	24
Smoothies	22
Dried fruits	19

Note: n = 2046 (ROI – 1036, NI – 1010)

Question: Which of these types of fruit and vegetables, if any, do you eat nowadays?

The 2012 research found that 57 per cent of adults reported consuming fresh vegetables on a daily basis while 60 per cent said they consumed fresh fruit on a daily basis. These figures represented an increase of approximately 16 per cent and 19 per cent respectively on 2006 figures published by Bord Bia (47).

Barriers and promoters of fruit and vegetable consumption

Cost was identified as the top barrier to fruit and vegetable consumption, with one in five adults ranking it as their number one barrier to increasing fruit and vegetable consumption. Notably, 31 per cent of adults believed they ate enough fruit and vegetables and therefore did not experience any barriers (Table 1.4).

Table 1.4 Barriers to fruit and vegetable consumption

Barrier	% of respondents
Their cost	20
The fact they go off quickly	15
They take time to prepare	15
Habit	10
They take a lot of effort to prepare	9
Poor availability in local shop	8
I don't like the taste	8
I lack the cooking skills	5
There's a lot of wastage	4
My kids won't eat them	1
Other	4
Don't know	5
Nothing-I already eat a lot	31

Note: n = 2046 (ROI – 1036, NI – 1010)

Question: What do you think prevents you from eating more fruit and vegetables as part of your diet?

A number of factors that increased motivation to consume fruit and vegetables were also identified by the 2012 research with "lower cost" and "habit" identified as the two most significant factors (Table 1.5).

Table 1.5 Promoters of fruit and vegetable consumption

Promoter	% of respondents
If they were less expensive	26
Habit	19
Greater availability in the shop	13
If they were prepared already	11
If I was more aware of the health benefits	9
If I could store them properly	6
Other	7
Don't know	5
Don't think I need to eat more	31

Note: n = 2046 (ROI – 1036, NI – 1010)

Question: What do you think would encourage you to eat more fruit and vegetables?

Cost, or more specifically "value for money", was also identified as a strong motivator for fruit and vegetable purchase in 2006, as well as "improvement in the quality of fresh produce available" (47).

1.3.4.2 Qualitative research

Qualitative research was commissioned by ***safe***food in 2006 and 2012 to examine the changes in attitudes or behaviours during that time and to elicit consumers' perceptions of the fruit and vegetable supply chain in relation to:

a. behaviour, motivations and barriers towards purchase/consumption;

b. storage, preparation, cooking and consumption; and

c. associated contamination and microbiological risk.

In 2006, six qualitative discussion groups were conducted amongst fruit and vegetable consumers in the Republic of Ireland (ROI) and Northern Ireland (NI). The groups were conducted across urban (Dublin, Mullingar and Belfast) and rural (Newry and Wexford) locations to provide a mix and allow for regional variation, if applicable. In 2012, similar discussion groups, including an additional two family

group interviews, were carried out (see Table 1.6). For both 2006 and 2012, variations in target markets were taken into account when the optimum group matrix was chosen, with emphasis placed on mothers who, in the main, were considered to take the responsibility in the family for the main grocery shop.

Table 1.6 Fruit and vegetables group schedule for 2012

Group number	Location	Lifestage	Social class	Gender
1	Belfast	Young family	BC1	Female
2	Newry	Family	C2DE	Mix
3	Athlone	Family	BC1	Mix
4	Dublin	Pre-family	BC1	Male
5	Cork	Pre-family	C2DE	Female
6	Thurles	Empty Nester	BC1F	Mix
7	Monaghan	Teen Family	C2DEF	Female
8	Aughnacloy	Empty Nester	C2DE	Female

General observations

Similarities

A number of similarities existed between the 2006 and the 2012 findings. Women were still more likely to consider both fruit and vegetables important in their diets and, therefore, were more likely to report consuming increased quantities of fruit and vegetables compared to men. In addition, parents in 2012 were just as likely to prioritise their children's needs for fruit and vegetable compared to their own as they were in 2006. Parent's lack of fruit and vegetable consumption was often justified if they believed their children had sufficient quantities.

Bulk buying and wastage continues to be an issue for many consumers. Single or two person households are most affected by this issue and

"Well if you can eat them raw then they "must be safe"

expressed a desire for smaller package sizes to avoid food waste. Similar to the 2006 findings, few consumers knew of, or used any, methods to prolong the freshness of their fruit and vegetables. The 2012 research found that there continues to be a lack of safety awareness in relation to the production, preparation and consumption of fruit and vegetables. Food safety in the home was not perceived as being an issue, as consumers believed the fruit and vegetable category was one of the healthiest and safest food categories. Many consumers believed that because fruit and vegetables could be eaten raw they did not pose a major health risk.

Disparities

The 2012 research revealed that adults were generally unconcerned about air miles, food miles and carbon footprints. In addition, availability of good quality but cheap fruit and vegetable from discounters resulted in less importance placed on the purchase of "local produce" and "country of origin" for adults. These findings are quite different to the 2006 review which found that consumers placed an emphasis on locally produced fruit and vegetables and were concerned to a certain extent about food miles.

Adults also indicated that health messages associated with fruit and vegetables were more difficult to understand in 2012 than in 2006. Simple messages such as "low fat" and "low sugar" have continued to evolve and a number of adults indicated they were more likely to be confused by the messages.

Triggers and barriers to fruit and vegetable consumption

A number of triggers identified in 2012 were similar to those identified by adults in 2006, although some variation was evident, particularly in relation to changes in education (Table 1.7) Consumers believed that educational campaigns such as *'Food Dudes'* that were implemented in primary schools since the last research was conducted, improved both knowledge and behaviour of the general household. The increased availability of fruit and vegetables at lower costs in discounter stores since 2006 also increased the likelihood that families could afford fresh produce. In addition, adults in this group mentioned how co-habitation and food preparation for more than one person significantly impacted on the likelihood that fruit and vegetables would be included in a meal.

Table 1.7 Triggers for fruit and vegetable consumption

Triggers 2006	Triggers 2012
Healthy	Educational programmes
Good for you	Lower costs

Low fat	Good for you/healthy
Variety/range	Availability/variety/range
Some are convenient	Co-habiting
Dieters are easily accommodated	
Feel good factor	
Tasty	

Barriers identified by adults in the 2012 research were very similar to those outlined in the 2006 study. However, messages around the sugar content of fruits and negative memories related to fruit and vegetables form childhood also acted as additional barriers for adults in the 2012 research (Table 1.8).

Table 1.8 Barriers to fruit and vegetable consumption

Barriers 2006	Barriers 2012
Some inconvenient to prepare	Cost
Expensive for volume/value purchasers	Package size/potential waste
Lack of longevity/shelf-life	Short shelf-life
Poor quality	Poor quality
Taste	Taste
Pesticides, sprays and genetic modifications	High sugar content
	Negative childhood memories

The impact of current and potential messaging

The promotion of a diet high in fruit and vegetables has been the corner stone of healthy eating campaigns on an international level as well as at national and local levels.

In the UK (including NI) the Five-a-Day campaign has been running for a number of years. This campaign which is run by the Department of Health has five strands which include:

- school fruit and vegetables scheme;
- local Five-a-Day initiatives;
- national/local partnerships;
- communications programmes (including the Five-a-Day logo); and
- collaboration with industry[1].

Republic of Ireland

In ROI, the Health Promotion Unit within the Department of Health and Children, in conjunction with various partners, has also promoted increased consumption of fruit and vegetables during national healthy eating campaigns. In addition, '*Food Dudes*' is a healthy eating programme run by Bord Bia aimed at increasing fruit and vegetable intake in disadvantaged school children. There are currently over 2,000 primary schools in ROI participating in the programme (49)

During the 2012 focus groups, participants were asked about their perceptions of current campaigns. Consumers could not identify a clear and consistent message about the possible benefits of consuming fruit and vegetables. When fruit and vegetables were put in the context of the main meal, adults failed to identify the unique benefits associated with consumption.

Consumers were very aware of the 'five-a-day' message, and it was found that the message had the greatest impact at the point purchase. However, this did not mean that consumers fully understood the message or that the message encouraged consumption of five-a-day. It was clear that some ambiguity existed around the definition of one portion of fruit or vegetables.

Adults in the 2012 research were asked their opinions on certain messages. Consumer opinions towards a number of suggestions are outlined in Table 1.9 below.

[1] www.5aday.nhs.uk

Table 1.9 Consumer opinions on suggested fruit and vegetable messages

Occasion	Suggested message	Consumer opinion
Five-a-day campaign	Eat one piece of fruit or veg with every meal.	Most consumers felt they were already doing this so it may have limited effect.
	Eat different coloured fruit and veg.	Consumers thought this may be a difficult task.
Specific meal occasions	One third of dinner plate should be veg.	Reminds consumers of childhood and fits less well with modern consumer tastes and meal preferences e.g. pasta dishes.
	Start the day with a piece of fruit.	Simple and clear message but limited to one occasion.
	Use two instead of one veg on your dinner plate.	Consumers indicated that this message did not stand out and was likely to be forgotten.

Summary

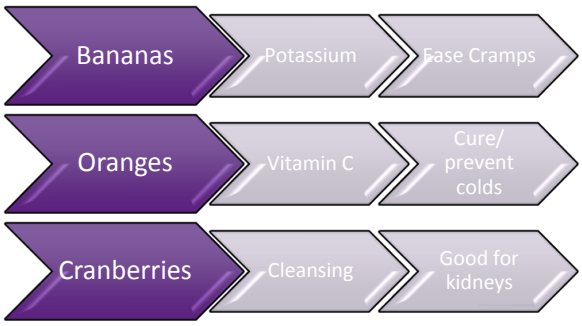
The 2012 research found that adults were likely to display one of two beliefs that significantly affected their perception of fruit and vegetables and the quantity of fruit and vegetables they consumed. The first belief was that healthy eating consisted of the inclusion of things that were healthy. Adults that fell within this group tended to display more consistent healthy behaviour with only the occasional inclusion of items that were unhealthy. This group were called the “Living within” group. The second belief was that healthy eating was the exclusion of things that were unhealthy. These adults displayed more rapid switching between healthy and unhealthy options, often on a daily basis. This group were called the “Living without” group. Understanding the beliefs that adults hold in each of these groups will contribute to the development of messages, campaigns and promotions that will be more effective in increasing motivation to purchase and consume fruit and vegetables. A more detailed list of the two categories is presented in Table 1.10.

Table 1.10 Consumer beliefs associated with general eating behaviours

"Living within" group	Reason for eating	"Living without" group
Well-balanced meals supported by healthier snacks such as fruit.	**HUNGER**	Variance between healthier options and alternatives such as fried foods and takeaways. Snacks also likely to be unhealthy.
Consistent presence of fruit, etc., for snacking help to maintain healthy options.	**BOREDOM**	Strong possibility of snacks including chocolate and crisps.
Regular healthy meals counter-balanced with eating out when appropriate and a smaller number of takeaways.	**SOCIAL**	Younger groups most likely to eat unhealthily when on nights out.
Awareness of good fuel for exercise. Strong preference for fruit and other healthy options – particularly for children at home.	**ENERGY**	Larger blocks of energy such as past were more probable. Some fruit, but also potential for sports drinks and cereal bars.
A mix of potential options including sugary, sweet options.	**COMFORT**	Strong potential for a range of snacks that is unlikely to include fruit or vegetables.

It was found that an important trigger for consumption could be identifying key benefits that would affect consumers in their daily lives. Some associations are already being made by consumers, particularly those consumers that fall into the "Living within" category (Figure 1.1).

Figure 1.1 Examples of health benefits consumers associated with fruit consumption



This type of message associates one fruit or vegetable product a healthy ingredient and a potential health benefit. The possibility of linking fruit and vegetables to particular individuals and sporting activities was also discussed. The concept of endorsement is used with a variety of other food and beverage products and has the ability to generate positive perceptions.

In an ideal world, consumers would naturally transition from the "Living without" attitude to the "Living within" attitude; however, barriers to fruit and vegetable consumption prevent this transition. The qualitative results suggest that consumers struggle to understand the specific reason for eating certain quantities of fruit and vegetables. Although messages such as five-a-day are familiar to the majority of adults, the specific details of the message are lost on the consumer. The research found that messaging at the point of purchase was most likely to be understood and impact on the purchase decision. This has worked particularly well for fruit juices and smoothies and it is worthwhile to consider this approach for other fruit and vegetable items. In addition, images to clarify what constitutes a portion of fruit and vegetables would also reduce current confusion.

2 The supply chain

Key findings

Global fresh fruit and vegetable production reached over 1.5 billion tonnes in 2011. Melons, followed by bananas, were the most frequently harvested fruits/vegetables in 2011 and together accounted for over 100 million tonnes.

Total EU consumption of fresh fruit and vegetables amounted to 94 million tonnes in 2010. The main types of fruit produced were grapes, apples, oranges and peaches/nectarines. The main types of vegetables produced were tomatoes, onions, carrots, lettuce and chicory.

Approximately 50 per cent of the fruit and vegetables produced each year in Europe is wasted. These losses occur throughout the entire food chain, but the predominant losses are linked to the production phase.

The horticultural industry on IOI had an output value of approximately €282.8 million at farm gate value in 2011. The key crops in the food sector included mushrooms, potatoes, field vegetables, fruit and protected crops.

The mushroom sector is the largest sector of the horticulture industry and a key area of export, particularly to the UK. Due a seasonal climate, imports of both fruit and vegetables are required for a ready supply for consumers on IOI. Imports of fruit and vegetables to IOI were valued at €496, 273 million in 2010.

The prevalence of organic produce has increased significantly since 2000, but has experienced a slow down over the past three years. In 2010 there were 1,632 organic producers on IOI,

farming a total area of 52,390 hectares, with 37 per cent of producers located in the West of Ireland. Three hundred of these producers were horticulture producers who farmed approximately 420 hectares. Organic fruit and vegetables accounted for 35 per cent of total organic food sales on IOI during 2012, approximately €31.5 million.

The retail market for fresh product on IOI in 2012 was valued at €1.208 billion, which represented a 0.8 per cent growth compared with 2011. In 2011, increased purchase of fruit (+3% year on year) drove sales of the fresh product sector in ROI. In NI, a range of supply chains exist with larger growers working with multiples and smaller growers supplying local stores and convenience shops.

2.1 Introduction

The horticultural industry on IOI is small in a European context. Nonetheless it is an important indigenous industry contributing to the economy in terms of adding value to the domestic output and employment provision.

There is widespread domestic production of certain fruit and vegetables on the island, for example mushrooms and strawberries. However, the climate limits the production of a range of fruit and vegetables, which are grown in hotter climates, such as bananas and citrus fruits (see Appendix A). Thus allied with seasonality, importation from other EU Member States (MS) and Third Countries is, and has always been, necessary to supply the demand for fruit and vegetables. Improved growing, storage and distribution, however, have enabled producers to reduce the negative influence of the seasons.

In order to explain the supply chain on IOI, it is first necessary to put it into context within the global and European fruit and vegetable supply chains.

2.2 The global supply chain

Global fresh fruit and vegetable production reached over 1.5 billion tonnes in 2011. Melons were the most frequently harvested fruit followed by bananas. Together these accounted for over 100 million tonnes. Equally important were apples, grapes and oranges with an aggregate harvest of approximately 70 million tonnes in 2011. These five fruits made up 60 per cent of total fruit production for the 2011 period. China, India and Brazil are the leading global producers of fruit and vegetables respectively (Ibis 2012).

The EU dominates the import market for fresh fruit. For fresh vegetables this is only the case if trade between EU countries is taken into account. If trade between EU countries is not included, then the US dominates the import market for fresh vegetables (50).

2.3 The European context

Total EU consumption of fresh fruit and vegetables declined from 533.9g/capita/day in 2005 to 457.6g/capita/day in 2010 (51). This aggregate figure is higher than the World Health Organisation's 400g/day minimum recommendation, but is still below the threshold in a number of member states (52).

2.3.1 Production

In 2010, production of fresh fruit amounted to 36 million tonnes, while production of fresh vegetables amounted to 58 million tonnes (53). The main types of fruit produced in 2010 were grapes, apples, oranges, and peaches/nectarines. The main types of vegetables produced were tomatoes, onions, carrots, lettuce and chicory (53). Italy and Spain were the leading producers of both fruit and vegetables for the 2011 period (Table 2.1) (52). Although production of fruit and vegetables in the EU is high, a recent FAO report found that of the total amount of fruit and vegetables produced each year, close to 50 per cent goes to waste. These losses occur throughout the entire food chain, from "farm to fork," but the predominant losses are linked to the production phase. Accidental damage during threshing or fruit picking, damage by insects, mechanical damage and spillage during harvest, and crops filtered out post-harvest by quality requirements of supermarkets and food companies, are some of the reasons for this loss (55).

Table 2.1 EU production of fruit and vegetables

Fresh fruit		Fresh vegetables	
Production	**Million tonnes**	**Production**	**Million tonnes**
Total	**36.0**	**Total**	**58.0**
Italy	16.6	Italy	14.0
Spain	16.5	Spain	9.9
Main types		**Main types**	
Apples	10.5	Tomatoes	16.8
Oranges	6.3	Onions	5.4
Peaches	2.8	Carrots	5.3

Source: (53)

2.3.2 EU imports

Total fruit and vegetable imports (excluding potatoes) reached €11.7 billion in 2011(56). Most fresh vegetables were imported from four Mediterranean countries – Morocco, Israel, Turkey and Egypt. Imports from this region are gradually increasing due to improved market access to the EU under preferential trade agreements. The leading supplier, Morocco, covers about 30 per cent (€534.4 million) of EU fresh vegetable imports, half of which are accounted for by tomatoes.

EU imports of fresh vegetables were valued at €2 billion in 2011, a 40 per cent increase in value since 1999. Two thirds of the import gains were from tomatoes, beans and sweet peppers. Tomatoes constituted the biggest share of imported fresh vegetables in 2011, and made up approximately 20 per cent of imports. In value terms, over the past decade, imports of tomatoes have increased two-fold (both in value and volume) to reach €349 million in 2011, beans increased four-fold to reach €345 million and sweet peppers increased six-fold to reach €274 million. Other products such as asparagus, cucumbers, garlic, onion and shallots also experienced large increases in value (56).

In 2010, imports of vegetables originating in third countries continued to decrease. The total import volume amounted to 1.8 million tonnes, a decrease of 2.2% compared to 2009, but an overall increase of 7.2 per cent compared to the average of the previous five years (52). The largest import gains for fruits were bananas, pineapples, oranges, table grapes, and sultanas. Other fruit which showed quite a significant growth, although their individual share was small, included mandarins, melons, watermelons, and strawberries (57) . Imports of fruit originating in third countries remained stable in 2010 and reached a total of 11.2 million tonnes. This figure is 1.3 per cent below the average import volume for the previous five years (52).

2.3.3 EU exports

Total exports for fruit and vegetables (excluding potatoes) reached €4.2 billion in 2011. The top destinations for EU exports of fresh fruits and vegetables were Russia and the EFTA countries (Norway, Switzerland). Russia purchased one third of all EU fresh fruit and vegetables in 2011 – a total of one billion euro worth of fresh fruit and €682 million worth of fresh vegetables. The US and Japan are also important export destinations, both primarily for processed fruit and vegetables, however increased competition from geographically closer countries has affected exports to these two countries.

The EU exports of fresh vegetables are currently dominated by potatoes (28 per cent of total vegetable exports). Since 1999, the value of vegetable exports has more than doubled and in 2011, EU fresh vegetable exports reached around €2.1 billion (including potatoes). Although exports were dominated by potatoes (28 per cent of vegetable exports), large gains were also recorded for tomatoes (exports rose two-fold to €241 million), onions (exports rose three-fold to €197 million) and sweet peppers (exports rose two-fold to €235 million) for the same time period. Other fast growing exports of vegetables included mushrooms, cauliflower, cabbage, lettuce, carrots and aubergines (56).

Total vegetable exports destined for third countries increased by 10.4 per cent reaching a total of 1.7 million tonnes and 20 per cent above the average for the previous five years (52).

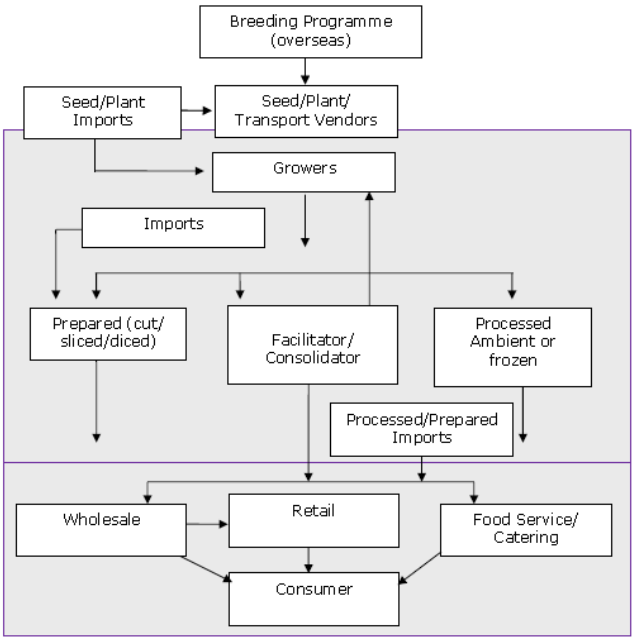
Apples and pears were the major fruit exported by the EU in 2011. In value terms, since 1999, apple exports increased five-fold to €706 million and pears seven-fold to €277.2 million (56). Exports of fruit destined for third countries increased in 2010 to reach a total of 3.2 million tonnes, 31.6 per cent above the average export volume for the previous five years (52).

2.4 Island of Ireland

2.4.1 Introduction

The horticultural food sector on ROI had a farm gate value of approximately €293 million in 2010, while NI had a value of £40.3 million for the same period. The fruit and vegetable category on IOI can be subdivided into fruit, field vegetables, protected crops and mushrooms. The fruit sector in Ireland was valued at €50 million per annum in 2010. Soft fruit accounted for €40 million, while top fruit accounted for €10 million (58). Estimates from 2010 found there were approximately 1,100 horticultural food growers involved in a range of farm enterprises including mushrooms, potatoes, field vegetables, protected crops and outdoor fruit and honey in ROI with a further 900 individuals employed in the sector in NI (59, 60). The fruit and vegetable supply chain on IOI is outlined in Figure 2.1.

Figure 2.1 Fruit and vegetable supply chain on IOI



Adapted from Bord Glas (61)

A range of factors (including climate and soil type) influence the location of growers. However, the movement of supermarket multiples to centralised distribution systems has led to a clustering of producers within range of the major centralised distribution centres, most of which are close to the large urban areas (Table 2.2).

Table 2.2 Horticulture clusters on IOI

Sector	Locations
Mushrooms	Monaghan/Cavan/Tipperary/Mayo
Field vegetables	Dublin/Meath
	Down/Armagh/Londonderry/Antrim
	Cork
	Wexford
Fruit	Dublin/Tipperary
	Waterford/Killarney
Protected crops	Dublin/Louth/Wexford/Armagh

Adapted from:(59, 62)

2.4.2 Production

The horticultural industry on IOI had an output valued at approximately €292.8 million at farm gate value in 2011. The key crops in the food sector include mushrooms, potatoes, field vegetables, fruit and protected crops, each of which are outlined below. In NI, the production horticulture sector is highly valued and provides the inputs for approximately 50 businesses, employing almost 1,770 people with a gross turnover estimated at £195 million. The production horticulture specific to food had a farm gate value of £40.3 million in 2010 (60).

2.4.2.1 Protected crops

There were 120 protected crop growers in ROI in 2010, primarily located in north Dublin, Louth and Wexford. The main food crops grown under protective covers in ROI included tomatoes, cucumbers, peppers and strawberries. Due to high capital requirement and running costs, as well as increased competition, the areas and values of output overall have decreased since 2007 in both ROI and NI (62,

63). The two main protected crops grown in NI are lettuce and strawberries (60). Protected strawberries accounted for 28 per cent of all soft fruit crops grown in Northern Ireland in 2010 (62).

2.4.2.2 Field vegetables

In the 2009 National Field Vegetable Consensus, a total production area of 4,590 hectares and a farm gate value of €69.7 million was recorded for the 2008 period. There were 212 field vegetable growers in 2008 (including 21 organic growers), which was an 11 per cent decline from the previous 2005 census. In addition, the sector provided 911 full-time equivalent jobs in 2008 (63).

2.4.2.3 Soft fruits

More than 70 growers were involved in soft fruit production in the ROI in 2010. The main crops grown were strawberries, raspberries and blackcurrants. Strawberries, the most important of these crops, comprised 50 per cent of the total value of the output from the protected edible crop sector. (59). Protected crops account for just under 30 per cent of the total soft fruit industry in NI. Average production was just over 200 tonnes with a value of approximately £720,000 in 2010. Production is dominated by strawberries, raspberries, gooseberries and blackberries (60, 62)

2.4.2.4 Top fruits

The apple sector in ROI achieved strong yields in 2010, resulting in an increase in production of approximately 25 per cent compared to 2009, when production was severely hit by an apple scab epidemic. There were approximately 40 apple growers who produced culinary, dessert and cider apples in an area of 579 hectares in 2010. Of the three apple types, culinary apples accounted for 46 per cent of production, cider apples for 27 per cent and dessert apples for 26 per cent. Dublin, Tipperary, Waterford and Kilkenny are the principal counties for apple production (64).

Production in NI is dominated by top fruit production with an estimated output of 47,000 tonnes of apples from an area of 12,000 ha per year. Yield in NI varies considerably, but is largely based on the Bramley variety. Much of the apples products are used for processing, with an estimated 41 per cent used for juice/cider production and 46 per cent into products such as pie filling or sliced apple (60).

2.4.2.5 Mushrooms

The mushroom sector is the largest sector of the horticulture industry on the IOI. There were approximately 80 growers located in the ROI, primarily in Monaghan, Tipperary, Cavan and Mayo in 2010. These growers produced 41,000 tonnes in 2010 with a farm gate value of approximately €100 million. In NI, approximately 43 growers produced 17,000 tonnes for the same period with a farm gate value of €32 million (62, 65). At least 70 per cent of this production was exported to the UK where Irish mushrooms accounted for 50 per cent of all mushroom retail sales (59).

2.4.3 Imports

The climate on IOI naturally restricts the growing of certain fruits and, as such, is heavily dependent on imports (e.g. citrus fruits and bananas, grapes, etc.).

The fruit crops grown on IOI are seasonal and hence importation is necessary at certain times of the year to maintain continuity of supply (strawberries, apples). Imports of fresh fruit and vegetables into ROI for the years 2008-2010 are presented in Table 2.3. It should be noted that in the case of fruit, the values include fresh/dried fruit. In the case of vegetables the values include fresh/chilled vegetables (66). Values for NI only are not available.

Table 2.3 Imports of fruit and vegetables on ROI 2008-2010

	2008		2009		2010	
Product	**Value €m**	**Tonnage 000s**	**Value €m**	**Tonnage 000s**	**Value €m**	**Tonnage 000s**
Apples	54,547	65,413	48,914	58,871	47,934	53,271
Soft fruit	20,594	4,812	19,348	5,148	13,128	2,621
Total other Fruit	184,833	195,356	167,708	186,688	176,042	190,448
Potatoes	25,848	52,212	22,840	58,021	27,134	66,072
Carrots	13,082	19,072	16,849	25,283	14,451	23,474
Cabbage	18,935	19,629	20,736	20,932	22,356	21,952
Tomatoes	41,646	36,216	37,449	34,968	39,955	29,969
Onions	27,212	53,577	17,939	37,024	23,699	40,333
Total other Vegetables	72,935	51,768	99,102	70,469	131,574	83,003
Total Fruit & Vegetable Imports	459,632	498,055	450,885	497,404	496,273	511,143

Source: (66)

Comment [AM1]: Sara – would you mind checking this against the original CSO figures. AS far as I can see these commas should be decimal points (although they are commas in the Dail report

2.4.4 Exports

The Irish horticulture industry (both ROI and NI) is primarily targeted towards supplying the domestic market. However, one key area of export within the fruit and vegetable sector for IOI are mushrooms. The key market for Irish mushrooms is the UK, where exports are valued at over €115 million at retail level annually. Approximately 50 per cent of the UK market is supplied both from IOI and by IOI owned mushroom production companies based in the UK (67).

2.4.5 The organic market

The total area under organic production on IOI has doubled during the past decade. Organic production in Ireland is located mainly in the west, mid-west and the south-west, with over two-thirds of producers located in Connaught and Munster. In 2010 there were 1,632 organic producers on IOI, farming a total area of 52,390 hectares, with 37 per cent of producers located in the West of Ireland (68, 69). Three hundred of these producers were horticulture producers who farmed approximately 420 hectares. Individual farming areas for horticultural producers was relatively small with only 20 farms larger than six hectares (70).

2.4.6 Retail

In 2012, the retail market for fresh produce on IOI was valued at €1.208 billion, which was a 0.8 per cent growth compared with 2011. This market was made up of sales of fruit (45.1%), vegetables (43.3%) and potatoes (11.6%). The other notable outlet for produce is the food service (i.e. catering) sector (59). The most important market for fresh produce in ROI is the retail market, in particular the major retail multiples. Recent data from Kantar Worldpanel on the prepared fruit and vegetable category in retail outlets in ROI has shown that convenience is still an important factor for consumers when shopping for fresh produce. In 2010, while the value of the ROI retail prepared fruit and vegetable market fell by 3 per cent on a year earlier, the volume purchased was up by 2.5 per cent (Table 2.4) (71). During 2011 increased purchases of fruit (+3% year on year) drove sales of the fresh produce sector on ROI (72). In NI, a range of supply chains exist with larger growers working with multiples and smaller growers are tending to supply local convenience stores and farm shops. However, the power of the multiples to

dictate terms and price has reduced margins for fresh vegetables to very low and possibly unsustainable levels. Most producers in NI are not capable of producing the quantity required by multiples and therefore use alternate supply chains such as farmers markets and convenience stores (60).

Table 2.4 Percentage sector share by volume 2009/2010

Vegetables	2009 %	2010 %
Fruit	5.7	5.0
Chilled salad	41.9	40.5
Mixed tray salad	1.5	0.9
Leafy salad	23.9	21.4
Vegetables	26.9	32.2

2.4.6.1 Organic

Organic fruit and vegetables accounted for 35 per cent of total organic food sales on IOI during 2010, approximately €31.5 million. The majority of organic fruit and vegetables available in IOI retail outlets are imported produce. In 2011 imported fruit and vegetable products accounted for 70 per cent of sales of organic fruit and vegetables (73).

2.4.7 Food service

Despite the size of the food service sector, there is limited information on the value of fruit and vegetables purchases in both NI and ROI by this sector, however, many studies have acknowledged the difficulties faced by the food service in Ireland over the past number of years. In 2011, there were 125 fruit and vegetable SMEs based in NI and the UK (74).

3 Food safety

Key findings

The proportion of all foodborne outbreaks associated with fresh produce increased from 0.7 per cent in the 1970s to 6 per cent in the 1990s. Between 1999 and 2008, fresh fruits and vegetables were responsible for 4 per cent of cases of foodborne illnesses in the U.S.

Four per cent of foodborne illnesses reported to the Health Protection Agency (HPA) in England and Wales between 1992 and 2010, were due to fruit and vegetable consumption. *Salmonella* was identified as the aetiological agent in 39 per cent of these outbreaks, while 10 per cent were caused by foodborne viruses. Other pathogens most frequently reported include *Campylobacter* (5.5%), *Bacillus* (5.5%) and VTEC O157 (3%) (75).

Inappropriate storage, inadequate heat treatment and cross-contamination were the major factors facilitating outbreaks.

Europe has experienced a number of outbreaks since 2006. In 2010, a total of 5,262 outbreaks of foodborne illnesses were reported by EU member states. Vegetables, juices and products thereof was the third most common food category reported as the vehicle for infection, responsible for 8.7 per cent of outbreaks.

An outbreak of *Salmonella* Newport infection in late 2011 and early 2012 was reported in England, Wales and NI, ROI, Scotland and Germany. Between the beginning of May 2011 and July 2011, more than 770 cases of haemolytic uremic syndrome (HUS) and 3,100 cases of VTEC

were reported across the EU. In 2011 an outbreak of *E. coli* O157:H7 infection in Great Britain admitted 80 people to hospital and claimed the life of one person. And in 2010, an outbreak of *Salmonella* Bareilly infection in the UK was associated with consumption of bean sprouts. Over 200 cases of illness were reported throughout the UK, with at least three cases in NI.

Within the EU, pesticide authorisation and use is regulated by two main pieces of legislation; the Plant Protection Products Regulation (EC) No. 1107/2009 and the Biocides Directive (98/8/EC), as amended. The Regulation was transposed into ROI law as Statutory Instrument No. 159 of 2013 and into UK (NI) law as the Plant Protection Products Regulations (PPPR) of 2011.

In ROI, a total of 764 fruit and vegetable samples were analysed for up to 331 pesticides and analytes, using multi-residue analytical methods, for the 2010 period. A total of 290 of the fruit and vegetables sampled contained no detectable pesticide residue, 449 contained one or more detectable residues at or below the MRL and 25 samples contained residues in excess of EU MRLs.

In NI, a total of 2,048 of 3,750 samples of fruit and vegetables collected from 24 sites in the UK (including NI) were analysed for 330 pesticide active substances for the 2010 period. Residues were detected in 1,205 samples. This was almost identical to the positive rate in the ROI for the same year.

Fruit and vegetables accounted for 670 RASFF notifications to the European Commission in 2011. Examples of notifications included dimethoate and omethoate in fruit and vegetables of various origins, formenthanate in peppers from Turkey and cucumbers from Spain. In addition, it was found that the rise in RASFF notifications for Salmonella spp. was most prominently for the product category fruits and vegetables. There were no FSAI alerts (for action or information) relating to fresh fruit and vegetables in 2011.

3.1 Introduction

Fresh fruit and vegetables are key components of a healthy diet. The risk of associated infectious disease is low and mechanisms by which contamination occurs are preventable. Good hygiene and agricultural practices from farm to fork can limit contamination and microbial growth in these products. The public health challenge is clear - to promote and increase the consumption of fruit and vegetables, while also promoting and enforcing strict hygiene measures and agricultural practices that ensure safe, fresh produce for the consumer.

This chapter will look at the microbiological and toxicological aspects of the fruit and vegetable supply chain. This will include the hazards and risks associated with fresh fruit and vegetables, and the controls in place to minimise any associated risk. The controls on produce imported from Third Countries will also be discussed at the end of this chapter.

3.2 Microbiology

3.2.1 Introduction

Microorganisms form part of the epiphytic flora of fruits and vegetables. This means that they grow on plants but are not parasitic to them, and thus many will be present at the time of consumption. The numbers of bacteria present will vary depending on seasonal and climatic variation with populations of 10^5 to 10^7 CFU (colony forming units) g^{-1} being frequently present (76). The majority of bacteria found on the surface of plants are usually Gram negative and belong to the *Pseudomonas* group or to the family Enterobacteriaceae. Many of these organisms are normally non-pathogenic for humans with intact immune systems (77).

There are many points during production of fruits and vegetables at which microbiological contamination can occur. These include:

- Growing (seeds, soil, water, manure, insects, animals)
- Harvesting (faeces, handling, equipment, transport)
- Post-harvest handling (washing, packing, vehicles, cross-contamination) (78).

From a human health perspective, contamination of pathogens from human or animal sources is likely to present the greatest risk. As fruit and vegetables are often eaten raw, this increases the risk that consumers may be exposed to such pathogens.

The natural structures covering the outside of fruit and vegetables provide excellent protection against the entry and subsequent damage by spoilage organisms (79). The inner tissues of fruit and vegetables are usually regarded as sterile (77), but the application of processing technologies such as cutting, slicing, skinning and shredding will disrupt the natural protective barriers of the intact plant and open the possibility for a suitable medium for the growth of contaminating microorganisms (80). Internalisation of microorganisms may also be facilitated by root or stomata uptake, and also by damage sustained in the field, or during harvesting and post-harvest stages. The range of microorganisms capable of growing on such products and their growth rates will be determined by the intrinsic parameters and the storage conditions.

Intrinsic factors are those parameters that are inherent characteristics of plant tissues. These include the natural pH value, moisture content, oxidation-reduction (Eh) potential, nutrient content, antimicrobial constituents, and biological structures.

In general, the high water content of fruit and vegetables, the favourable Eh value, and ready supply of nutrients make such products suitable substrates for microbial growth. The low pH value of fruits, however, favours the growth of yeasts and moulds that are more acid tolerant than bacteria, while the low B vitamin content of fruits favour the growth of Gram negative bacteria and moulds (79).

The presence of natural antimicrobial constituents in some fruit and vegetables has been reported. The hydroxycinnamic acid derivatives (*p*-coumaric, ferulic, caffeic, and chlorogenic acids) found in fruit, vegetables, tea, molasses and other plant sources all show antibacterial and some antifungal activity (79). Moreover, cranberries are a natural source of benzoic acid which is an antimicrobial.

3.2.2 Foodborne human infections associated with fresh produce

Fruit and vegetables (also termed 'fresh produce') are increasingly being recognised as an emerging vehicle for foodborne illness in humans. Traditionally meat, milk and egg products were the 'usual suspects'. The consumption of fresh produce has now been linked, both epidemiologically and microbiologically to infectious intestinal disease. However, illness as a result of consumption of this category represents only a small proportion of the total number of reported cases. For example, only 1.4 to three per cent of outbreaks were associated with fruit and vegetables in the US between 1993

and 1997 (81). Nevertheless, outbreaks associated with uncooked produce in the US are increasing in absolute numbers and as a proportion of all reported foodborne outbreaks. The proportion of all foodborne outbreaks associated with fresh produce increased from 0.7 per cent in the 1970s to 6 per cent in the 1990s (82). Between 1999 and 2008, fresh fruits and vegetables were responsible for 4 per cent of cases of foodborne illness in the US(83).

3.2.2.1 Epidemiological and microbiological information limitations

Tracing individual episodes of human infection to a particular food is inherently difficult. Estimating the risks associated with consuming different foods is a complex epidemiological process. Disease risks from foods can only be derived from the analysis and interpretation of a large body of evidence. This evidence includes laboratory infectious disease surveillance data, hospital episode statistics, food intake surveys, outbreak surveillance data, death statistics, and special studies related to infectious disease outbreak investigations. It should be noted that caution must be exercised in attributing infections to specific foods.

There are some important features associated with the role of fresh produce acting as vehicles of intestinal infection. Contamination often occurs early in the production process, e.g., via animal manure or contaminated water used during growth or harvesting. Ingredients from many countries may be combined in a single dish making the specific source of contamination difficult to trace. Fresh produce foods typically have fewer barriers to microbial growth such as preservatives, therefore, simple errors can make the food unsafe.

Definitively tracing back the produce source of an outbreak may be impossible because this food usually has a short shelf-life and may have exited the food chain by the time the outbreak is recognised (84). Also, consumers may not remember eating produce in the form of garnishes, e.g., parsley (85).

The widespread geographic distribution of these minimally processed RTE foods results in outbreaks that are very difficult to detect. Only a few sporadic cases may be detected in any given jurisdiction. The identification of multi-country outbreaks is facilitated if the causative organism is of an unusual serotype, and the epidemiologic and laboratory authorities collaborate at the relevant international level.

This phenomenon is well illustrated by simultaneous outbreaks of *Shigella sonnei* and Enterotoxigenic *E. coli* O157:H7 infections associated with parsley in the US and Canada in 1998 (86). A 1,600 acre farm in Mexico was the likely source of the parsley sourced in the six of the seven *Shigella* outbreaks. The farm was also identified as a possible source in the two *E. coli* O157:H7 outbreaks.

3.2.2.2 Human outbreaks associated with fresh produce

Data from population-based studies and surveillance systems have been analysed to estimate the burden of disease associated with fresh produce consumption.

Outbreak data from England and Wales

One hundred and thirty five (7.7%) of the outbreaks of infectious intestinal disease reported to the Communicable Disease Surveillance Centre (CDSC) in England and Wales during the years 1992 to 2003 were associated with the consumption of salad, vegetables or fruit (87). The pathogens most frequently reported in these outbreaks were *Salmonella* (21%), Norovirus (17%), *Shigella* (6%), *Campylobacter* (5%), *E. coli* O157 (3%). No organism was identified in 33 per cent of these outbreaks. A marked seasonal variation in these outbreaks was also evident with over half (56%) occurring during the summer months of May to August. Ninety (4%) of the 2,321 outbreaks of foodborne illness associated with known food categories, reported to the Health Protection Agency in England and Wales between 1992 and 2010, were attributed to the consumption of vegetables and fruit. *Salmonella* was identified as the aetiological agent in 39 per cent of these outbreaks, while 10 per cent were caused by foodborne viruses. Other pathogens most frequently reported include *Campylobacter (*5.5%), *Bacillus* (5.5%) and VTEC O157 (3%) (75).

Most outbreaks were linked to catering premises (73%). Cross-contamination (38%) and infected food handlers (25%) were identified as the two major factors facilitating produce-related outbreaks. When this is compared to all foodborne outbreaks a different ranking of contributing factors emerges, with inappropriate storage (27%), inadequate heat treatment (27%) and cross-contamination (25%) featuring as the major factors.

Cross-contamination is understandably a major contributing factor in outbreaks involving fresh produce as these foods are usually eaten raw.

A major study (88) conducted in England and Wales during the period 1996 to 2000 demonstrated that only three per cent of cases of indigenous foodborne disease were attributed to fruit and vegetable consumption (Table 3.1).

Table 3.1 Estimated annual impact of indigenous foodborne disease, by selected food group and type, England and Wales

Food Group/Type	Cases (%)	Death (%)	Case-Fatality Rate*
Poultry	502,634 (29)	191 (28)	38
Chicken	398,420 (23)	141 (21)	35
Eggs	103,740 (6)	46 (7)	44
Red Meat	287,485 (17)	164 (24)	57
Seafood	116,603 (7)	30 (4)	26
Shellfish	77,019 (4)	16 (2)	21
Milk	108,043 (6)	37 (5)	34
Vegetable/Fruit	49,642 (3)	14 (2)	29
Salad Vegetables	37,496 (2)	11 (2)	28
Cooked Vegetables	6,870 (0)	2 (0)	35
Fruit	5,275 (0)	1 (0)	25

n = 1,724,315 *Deaths/100,000 cases Source: (88)

When severity of illness measures, such as hospitalisation and deaths, were taken into consideration, a low level of risk was associated with the consumption of fresh produce. Within this category, salad vegetables constituted the majority of the risk (76%), with cooked vegetables (14%) and fruit (10%). Nevertheless, the healthcare impact arising from fresh produce was low (Table 3.2).

Table 3.2 Estimated annual healthcare impact of indigenous foodborne disease, by selected food group and type, England and Wales

Food Group/Type	General Practitioner Cases (%)	Hospital cases (%)	Hospital Days (%)
Poultry	159,433 (35)	9,952 (45)	41,645 (41)
Chicken	129,271 (28)	9,005 (41)	36,425 (36)
Eggs	19,554 (4)	552 (3)	3,410 (3)
Red Meat	80,805 (18)	1,231 (6)	10,935 (11)
Seafood	23,998 (5)	828 (4)	3,690 (4)
Shellfish	12,861 (3)	134 (1)	752 (1)
Milk	40,755 (9)	3,681 (17)	14,176 (14)
Vegetable/Fruit	11,912 (3)	702 (3)	2,932 (3)
Salad Vegetables	9,874 (2)	660 (3)	2,671 (3)
Cooked Vegetables	1,184 (0)	27 (0)	168 (0)
Fruit	853 (0)	15 (0)	93 (0)

* Totals given are calculated on the basis of rounding to whole numbers. Source: (88)

Between 2008 and 2010 seven foodborne outbreaks associated with the consumption of fresh produce were reported to the Health Protection Agency (89). All seven outbreaks were linked to the consumption of vegetables, three of which were lettuce. In five of the seven outbreaks, more than 30 people were affected and the most common aetiological agent was *Salmonella.*

In 2011, an outbreak of *E. coli* O157:H7 infection in Great Britain was the subject of an extensive multi-agency investigation (90). During the course of the outbreak 252 laboratory confirmed cases were reported to the relevant public health agencies in England, Scotland and Wales, 80 people were admitted to hospital and one person died. Investigators established that, although the organism was not isolated from any food samples, infection was epidemiologically linked to the handling of leeks and potatoes in domestic kitchens.

In 2010, an outbreak of *Salmonella* Bareilly infection in the UK was associated with consumption of bean sprouts. Over 200 cases of illness were reported throughout the UK, with at least three cases in Northern Ireland (91).

Analysis by food group (Table 3.3) demonstrated that vegetables and fruit had the lowest disease and hospitalisation risks, while chicken had the highest. Within this category, there is a distinction between the 'extremely low risk' posed by fruit and cooked vegetables, and the 'very low risk' attributable to salad vegetables. The estimated risk of foodborne infection associated with the category vegetable/fruit was one case per million servings in England and Wales during the period reviewed.

Table 3.3 Estimated risks associated with food groups and type, England and Wales

Food Group/Type	Disease Risk*	Risk Ratio	Hospitalisation Risk†	Risk Ratio
Poultry	104	947	2,063	4,584
Chicken	111	1,013	2,518	5,595
Eggs	49	448	262	583
Red Meat	24	217	102	227
Seafood	41	374	293	650
Shellfish	646	5,869	1,121	2,490
Milk	4	35	133	295
Vegetable/Fruit	1	NA	8	NA
Salad Vegetables	6	53	103	229
Cooked Vegetables	0	1	0	1
Fruit	0	2	1	1

* Cases/1 million servings

† Hospitalisations/1 billion servings

NA: not applicable

Source: (88)

Outbreak data from the EU

The number of outbreaks reported in some jurisdictions is more likely to reflect the comprehensiveness of surveillance than the scale of true problems with fresh produce in that country.

A risk profile of raw vegetables and fruit conducted by the European Commission's Scientific Committee on Food (SCF) (81) found that the majority of the attributed outbreaks were associated with intact products grown in contact with the soil or water. Fewer outbreaks have been associated with cut/sliced/skinned or shredded products, while a significant number have been linked with sprouted seeds and fruit juices. All of the outbreaks linked to sprouted seeds and fruit juices (with the exception of one fruit juice outbreak) have involved bacteria, in particular *Salmonella*.

In 2010, a total of 5,262 outbreaks of foodborne illness were reported by EU member states. Vegetables, juices and products thereof was the third most common food category reported as the vehicle for infection, responsible for 8.7 per cent of outbreaks (92). The number of outbreaks caused by this category of foods increased from 2 in 2009 to 61 in 2010, primarily due to lettuce contaminated with norovirus. Fruit, berries and juices, and other products thereof, were responsible for 1.3 per cent of reported outbreaks.

In 2011, Germany reported a large outbreak of VTEC *E. coli* O104:H4 (93). Between the beginning of May 2011 and July 2011, more than 770 cases of haemolytic uremic syndrome (HUS) and 3,100 cases of VTEC were reported across the EU following the outbreak that was first recognised in Germany. There were 47 confirmed deaths. Initial case control studies, conducted by the Robert Koch Institute, demonstrated a statistically significant association with the consumption of fresh salad vegetables. Later, a detailed cohort study demonstrated an association with sprouted seeds.

On 24 June 2011, the French authorities reported a cluster of cases of patients suffering from bloody diarrhoea, following participation in an event near Bordeaux. Characterisation of the *E. coli* O104:H4 isolated from the patients showed that it was indistinguishable from the German outbreak strain, leading authorities to conclude that a common source was responsible. Epidemiological studies in France also identified sprouted seeds as the outbreak vehicle. Further investigations revealed the likely source to be a batch of contaminated fenugreek seeds imported from Egypt. This outbreak was characterised by an unusually high rate of HUS notable in that the majority of the reported HUS cases were in adults, rather than young children (94).

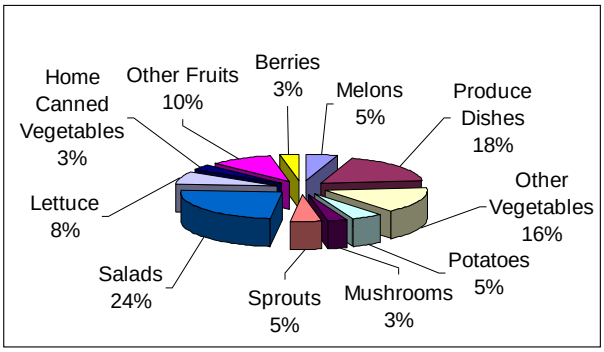
Sprouted seeds have also been linked to outbreaks of *Salmonella* and *E. coli* O157 infections (95, 96). Many of these outbreaks have been attributed to contaminated seeds, which are often distributed across a wide geographic area.

Outbreak data from the US

In the US, the Centre for Science in the Public Interest (CSPI) maintains its own database of foodborne illness outbreaks, compiled largely from data from the Centre for Disease Control (CDC) in Atlanta, the state health department and peer reviewed articles.

A total of 554 foodborne illness outbreaks involving 28,315 cases linked to fresh produce and fresh produce dishes were reported by the CSPI during the period 1990 to 2003 (97). The produce category had an average of 51 cases per outbreak; vegetables were linked to 205 outbreaks with 10,358 cases, while fruits were identified as the vehicle in 93 outbreaks with 7,799 cases. Of the 93 fruit associated outbreaks, 15 were linked to berries and 25 were linked to melon. Fresh produce dishes were implicated in 256 outbreaks involving 10,158 cases. In produce-linked outbreaks, *Salmonella* spp., Noroviruses, and *Cyclospora* spp. accounted for the majority of cases of foodborne illness. See Figure 3.1 for an overview of produce-related outbreaks in the US.

Figure 3.1 USA vehicles of produce-related outbreaks, 1990 to 2003 Source: (97)



Using data reported by the states and compiled by the CDC, the Centre for Science in the Public Interest (CSPI) identified and analysed 4,742 outbreaks that occurred between 1999 and 2008, which together caused 120,570 cases of illness (83). There was a sharp increase in produce-related outbreaks in 2008, due to a large multi-state outbreak from peppers that sickened over 1,500 people, discussed below. The produce category was linked to the largest number of foodborne illnesses associated with outbreaks, constituting 23 per cent of all illnesses in the database between 1999 and 2008.

Several large-scale, multi-state outbreaks in the US have been associated with fresh produce. In September 2006, an outbreak *E. coli* O157 infection occurred across 26 states. The outbreak was

associated with the consumption of pre-packaged spinach and resulted in 183 confirmed infections and three deaths (98). Investigations determined that one ranch in California's Salinas valley was the likely source of the outbreak. Analysis of genotyping patterns showed that the strains involved in the outbreak were indistinguishable from isolates recovered from local feral swine and cattle faeces (99). However, the manner in which the spinach became contaminated was not established. In 2008 jalapeno and serrano peppers were vehicles for a large multi-state outbreak of *Salmonella* serovar Saintpaul infections (100).

Outbreak data from IOI

Northern Ireland

Two outbreaks in NI have been associated with eating lettuce. An outbreak of *Salmonella* Newport in England, Scotland and NI occurred during the period of September to October 2004. Over 350 people in England, NI, Scotland and the Isle of Man were affected, with 20 people being hospitalised. The NI cases comprised 113 of the 372 reported cases. Food histories implicated fast-food premises and a case-control study undertaken in NI, in agreement with one conducted in Lincolnshire, demonstrated an association with 'Iceberg' lettuce consumption in restaurants, fast food and take-away premises. It appeared that the lettuce had only been supplied to catering premises and not to retail traders. There were no confirmed cases of the illness in ROI, however, surveillance was increased as there was one case of *S.* Newport in Co. Donegal which may have been associated with the UK outbreak. Further investigation linked the outbreaks with adverse weather conditions in Spain where the lettuce had been grown that had resulted in run-off and contamination of the crop (101).

Prior to this in May 1997, a *Campylobacter* outbreak was notified to CDSC NI and the suspect vehicle was seasonal leaves/tomatoes (102).

Republic of Ireland

Salad was identified as a potential source of five linked cases of *Salmonella* Infantis in 1998. The evidence was based on epidemiological rather than microbiological data (103).

The UK HPA reported an outbreak of *Salmonella* Newport infection in late 2011 and early 2012 (104). There were 30 confirmed cases in England, Wales and Northern Ireland (1 case), with further cases of illness caused by the same strain reported in Scotland, Germany and ROI (4 cases). Epidemiological evidence alone suggested watermelon as a possible vehicle for infection.

3.2.2.3 Pathogens associated with RTE fruit and vegetables

A wide range of fruit and vegetables have been implicated in foodborne illness, as demonstrated in the previous section. With global distribution systems providing a continuous supply of seasonal produce, it is likely that the diverse locations from which fruit and vegetables are sourced will result in exposure to pathogens far removed from the point of contamination.

The pathogens most commonly associated with fruit and raw vegetables are grouped in Table 3.4.

Table 3.4 Pathogens transmitted via fruit and vegetables

Bacterial	*Aeromonas*
	Bacillus cereus
	Campylobacter
	Clostridium botulinum
	Clostridium perfringens
	Escherichia coli O157
	Listeria monocytogenes
	Salmonella
	Shigella
	Staphylococcus aureus
	Vibrio cholerae
Viral	Hepatitis A
	Norovirus
Protozoan	*Cryptosporidium parvum*
	Cyclospora cayetanesis
	Giardia

Adapted from (78, 81)

Pathogens associated with infectious disease outbreaks

(a) Salmonella

There have been a number of reports of international outbreaks of salmonellosis linked with the consumption of fresh fruit and vegetables. Both watermelons and cantaloupe melons have been associated with *Salmonella* infections. Examples include watermelons in 1979 and 1993, cantaloupes in 1990, and pre-sliced cantaloupes linked to *S.* Poona infections in 1991 (105). The rapid growth of *Salmonella* on cantaloupe, honeydew and watermelons has been reported, with the recorded pH

values of the melons involved (5.9 to 6.7) not exerting any antimicrobial effect (78). Cantaloupes were also linked to a large outbreak of *Salmonella* Saintpaul in Australia (106). As mentioned above, watermelons were also linked to a recent outbreak of *Salmonella* Newport in the UK, ROI and Germany.

Salmonella has also been shown to survive in a variety of products including more acidic fruits such as apples and tomatoes during refrigerated storage for prolonged periods, with growth being observed at ambient temperatures. In two outbreaks of *S.* Javiana and *S.* Montevideo associated with the consumption of fresh tomatoes in the early 1990s in the US, water baths used by tomato packers were the most likely sources of contamination (107, 108).

The survival of *Salmonella* for 12 days on shredded lettuce has been reported and growth on minimally processed cabbage recorded during storage at mild temperature abuse conditions (78). As mentioned previously in relation to outbreaks on IOI, over 350 people in England, NI, Scotland and the Isle of Man, were affected by the relatively rare strain of *S.* Newport in 2004, as a result of the consumption of contaminated 'Iceberg' lettuce. An outbreak of *Salmonella* Thompson infections in Scandinavia and the UK was linked to the consumption of rocket leaves (109).

Bean sprouts have also been implicated in outbreaks of *Salmonella* Saint-Paul in the UK and Sweden (110). During the 1990s, outbreaks of a range of *Salmonella* serotypes (Stanley, Newport, Infantis and Anatum) in the US, Finland and Canada were associated with contaminated alfalfa sprouts (110). As described previously, sprouted seeds have been responsible for a number of large-scale infections in recent years, including the outbreak of *Salmonella* Bareilly in the UK in 2010.

Salmonella enterica serovars have been shown to colonise seeds, leaves and fruit of a variety of plant species (111). The mechanism of adhesion to plant surfaces appears to vary, depending on the serovar involved. *Salmonella* Montenegro internalised into bean sprout seed has been detected inside the growing plant after germination, suggesting that *Salmonella* strains can 'invade' plant tissues as well as adhering to surfaces (112).

(b) Shigella

The primary spread of *Shigella sonnei* is by the person-to-person route, although food and waterborne transmission are reported. Outbreaks of shigellosis have been attributed to the consumption of raw vegetables (105). In 1994 a number of cases of *S. sonnei* occurred in European countries (Norway, Sweden and the UK). These were linked to 'Iceberg' lettuce from Spain (113, 114).

In 1994 an outbreak in the US was epidemiologically linked to contaminated scallions of Mexican and US origin (115). Contamination at harvesting or packing stages was considered a potential factor. The growth of this pathogen on watermelon has also been recorded (116).

(c) VTEC E. coli

The world's largest ever reported outbreak of *E. coli* O157:H7 to date occurred in Japan in 1996 and was linked to the consumption of raw radish sprouts served in school lunches. In total 6,000 people were affected and three deaths resulted (81).

A number of *E. coli* O157:H7 infections in the US have been epidemiologically linked to the consumption of lettuce. In 1995, contamination with irrigation water or unsanitary handling of lettuce were the likely causes of an outbreak associated with lettuce, and cross- contamination from meat products was linked with another outbreak involving iceberg lettuce. Bovine and avian faecal contamination was also considered a potential factor in two outbreaks in 1996 involving 'mesclun mix' lettuce (105). Lettuce was also identified as the vehicle for infection in an outbreak of *E. coli* O157 in Sweden in 2005, during which a total of 135 cases were reported (117). Other outbreaks of *E. coli* O157 infection involving fresh fruit and vegetables, include the 2011 outbreak in Great Britain, linked to domestic handling of leeks and potatoes, as well as the multi-state outbreak linked to contaminated spinach in the US, both described above.

E.coli has been shown to survive on salad vegetables at refrigeration temperatures and grow at temperatures indicative of temperature abuse. The survival and growth on fruits such as watermelons, cantaloupe melons, apples and oranges has also been reported (78). Lettuce plants sprayed with water contaminated with *E. coli* O157 remained positive for the pathogen on their foliage 30 days later (118).

Plants may become contaminated with bacteria through attachment to the surface of the plant, internalisation via the leaves, or internalisation via the roots. Three different leaf attachment mechanisms have been described in VTEC O157. Laboratory studies have also reported internalisation of O157 through the leaves of growing plants (119, 120). In the field, plant injury can influence colonisation of lettuce plants by *E. coli* (Critzer 2010). Root inoculation can lead to contamination of the entire plant. VTEC O157 in contaminated water can enter the vascular system of lettuce and reach the edible parts of the plant. It appears from these studies that *E. coli* O157 employ multiple mechanisms to colonise plants and are well adapted to this biosphere (121).

(d) Listeria

The growth of *Listeria monocytogenes* on a wide variety of vegetables including broccoli, cabbage, lettuce and cauliflower has been reported both under MAP conditions and at refrigeration temperatures (76). The ability of the pathogen to survive on more acidic products, such as chopped tomatoes, appears to be lower than that reported for *E. coli* or *Salmonella (78).*

In 2011 a large outbreak of listeriosis in the US was linked to cantaloupe from a farm in Colorado. A total of 147 persons infected with any of the five outbreak-associated subtypes of *Listeria monocytogenes* were reported to CDC from 28 states and there were 33 deaths (122).

(e) Spore-forming bacteria

Psychrotophic strains of *Bacillus* and *Clostridium* are a potential hazard associated with chilled products. The main source of contamination is the soil. Cases of botulism that have been linked to fresh produce are very rare (123). However, outbreaks involving cooked/processed vegetable products (e.g. garlic in oil, mushrooms) have been reported (84).

(f) Protozoa

The protozoan pathogens most commonly associated with outbreaks involving fresh produce are *Cryptosporidium*, *Cyclospora* and *Giardia.* The oocysts of these organisms survive well in the environment and are resistant to chlorination in water supplies. The main routes of contamination are through exposure from irrigation water and poor hygienic practices.

The parasite *Cyclospora cayetanensis* was linked to numerous outbreaks of cyclosporidiosis associated with soft fruits and leaves in the late 1990s in Canada and the US (81).

However, in relative terms cyclosporidiosis is a rare infection. It is estimated to be responsible for 0.1 per cent of total foodborne infections (124).

Giardia lamblia was epidemiologically linked with an asymptomatic food handler in an outbreak involving sliced vegetables in a cafeteria in a corporate office building (76).

(g) Viruses

Foodborne infection with viruses is generally mediated through the faecal-oral route, direct contact or via consumption of contaminated food or water. Hepatitis A and Norovirus are the most commonly reported viral agents in food (105).

Limited data are available describing the survival of virus particles on fresh produce (76), however, research funded by the FSA has demonstrated the potential for the prolonged survival on fresh fruit and vegetable produce. At least 11 outbreaks of gastroenteritis in Denmark in 2010 were caused by Norovirus and Enterotoxigenic *Escherichia coli* ETEC. Investigators identified lettuce of the Lollo Bionda type grown in France, as the vehicle for infection (125).

Frozen raspberries have been linked to Hepatitis A infections in the UK (105). In 1998, 202 cases of Hepatitis A in Kentucky were linked to lettuce that was widely distributed commercially (126).

(h) Campylobacter

Although animals and birds are natural reservoirs for human pathogenic *Campylobacter,* and the organism is also associated with water supplies, the potential for cross-contamination from meat and poultry during food preparation has also been recognised (81).

C. jejuni has been shown to survive on a variety of fruit and vegetables for sufficient periods to cause food poisoning (78).

At retail level, a large survey of over 3,000 samples of RTE organic vegetables failed to detect the pathogen (127), suggesting that contamination through the food supply chain is not a significant issue. In a retrospective cohort study of sporadic cases of campylobacteriosis, the consumption of salad vegetables was found to be a risk factor, which was most likely attributed to cross-contamination during food preparation (128).

A case-control study to determine risk factors for sporadic *Campylobacter* infections on the island of Ireland identified lettuce as an important risk factor, with cross-contamination in the kitchen, possibly from raw chicken, suggested as the most likely source of contamination (129).

Microbiological surveys of fresh produce

In the US, the Food and Drug Administration (FDA) domestic survey found that one per cent of fresh produce samples (11 out of 1,028) were contaminated with either *Salmonella* or *Shigella* (*E. coli* O157 was not detected). In the same survey, four per cent of 1,003 samples of imported produce were contaminated with a pathogen, with 80 per cent (35 samples) testing positive for *Salmonella* and 20 per cent (nine samples) positive for *Shigella* (78).

In the UK, 99.5 per cent (3,185 of 3,200 samples) of RTE organic vegetables from retail outlets were found to be of satisfactory and acceptable quality (127). Unsatisfactory results were recorded from 15 samples, where *E. coli* and *Listeria* spp. were in excess of 10^2 CFU g^{-1}. The study concluded that overall agricultural, hygiene, harvesting and production practices were good.

A similar study was conducted a year later in 2001, that involved the testing of bagged prepared RTE salad vegetables (130). The vast majority (3,826 of 3,852; 99.3%) were of satisfactory or acceptable microbiological quality, whilst 20 (0.5%) of the samples were of unsatisfactory microbiological quality, because of *E. coli* or *Listeria* spp. counts in excess of 10^2 CFU g^{-1}. More importantly, six samples (0.2%) were of an unacceptable microbiological quality because of the presence of *Salmonella* (five samples, one of which was *S.* Newport PT33 that was subsequently linked with 19 cases of human infection, where strains had a unique plasmid profile identical to that isolated from the salad) or *L. monocytogenes* (where the level was 660 CFU g^{-1}). The authors concluded that these results

highlighted the necessity for good hygienic practices from farm to fork, to prevent contamination and/or bacterial growth in such salad products.

An in-depth analysis of data on microbiological contaminants in foodstuffs in the EU was conducted for the years 2004-2009 (131). Eleven Member States reported data on non-ready to eat (RTE) fruits, vegetables, spices and herbs, mushrooms and sprouted seeds and the majority of investigations revealed no positive findings. The highest proportion of positive samples was reported for spices and herbs, with Hungary and the Netherlands reporting one per cent and three per cent positive, respectively. Nine Member States reported data on *Salmonella* in ready-to-eat fruits, vegetables, nuts and juices. The Netherlands and ROI reported 0.6 per cent and 3.4 per cent of sprouted seeds positive, respectively, and ROI reported 1.4 per cent of nuts and nut products positive. Eight Member States reported data on the occurrence of *L. monocytogenes* was generally low, with 0-1.3 per cent positive for fruits, and 1-3.7 per cent positive for vegetables on retail sale.

The study reported data from 1,938 single food samples and 64 batches which tested negative for the presence of VTEC. In 2008, the Netherlands reported the detection of VTEC *E. coli* in 2 studies. Spain reported contamination levels of 8.7 per cent of unspecified VTEC in vegetables, and Sweden reported VTEC O157 in 5.3 per cent of 57 samples of vegetables.

3.2.3 Preventing microbial contamination along the food chain

There are a number of sources of contamination, all of which must be controlled to prevent or minimise microbial contamination of fresh produce. The key areas where microbial contamination can occur are in the field, during harvesting and processing, and in the home. Each of these areas is outlined below.

3.2.3.1 Preventing microbial contamination in the field

Soil

Many food pathogens are commonly found in soil where the edible portion of vegetables are grown either directly in soil (root vegetables) or in close proximity to the soil (leafy vegetables) and where there is the potential for direct contamination during growing.

The contamination rate and survival of bacteria in soil appears to be dependent on several factors including soil type, moisture content, UV light exposure, temperature, and presence or absence of a ground crop. It is difficult to eliminate the risk of soil-borne contamination from vegetables, however, thorough washing prior to packaging should serve to remove as much soil as possible.

With respect to fruit products, these can be contaminated via soil if the fruit has dropped from trees. Therefore, the practice of using dropped or fallen fruit should be avoided, as additionally the product may have become bruised or the skin may have been broken, thus facilitating the internalisation of pathogens.

Animals, insects and birds

Transmission of pathogens can occur directly from animals, birds and insects. Many animals can act as reservoirs for human pathogens, and if these animals come into contact with fresh produce, contamination can occur. The UK Fresh Produce Consortium Guideline (132) has recommended that animals should be prevented from entering fields, and that measures should be taken to prevent animal waste contaminating crop fields or water supplies during heavy rainfall. Insects may also be a source of contamination. In laboratory conditions, contaminated flies have been shown to directly transfer bacteria to plant leaves (133).

Animal waste and sewage use

Animal waste is added as a fertiliser to soil to provide a nutrient source required for plant development. In some instances, such as organic farming, animal waste may provide the primary source of nitrogen (134). The Food Standards Agency (FSA) has produced draft guidelines for growers to minimise the risks of microbiological contamination of RTE crops (135). The guidelines points out a range of measures that can help kill pathogens that are present in manures and slurries including:

- exposure to sunlight and ultra-violet rays;
- high temperatures (above 55°C);
- low acid or high alkaline conditions (use of quick lime or slaked lime to raise pH levels);
- drying; and
- the passage of time (though bacteria such as *E. coli* can survive in soil for several months).

The draft guidance recommends a package of measures before, during and after the growing season including:

- careful selection of site of fields;
- lay-off periods between application of manures and slurries before harvest;

- not allowing livestock to roam on land where crops will soon be grown or harvested;
- recommendations for storing manures and slurries; and
- the use of potable water for washing produce.

The FSAI has also issued guidance on the use of farmyard manure, compost and faecal material in the fresh produce supply chain in ROI (136).

Water

Within crop production, many practices require the use of water including irrigation, pesticide application, produce washing and cooling systems (137). Water can be a potential source of pathogen contamination, and there are many organisms that can be transmitted via water, including viruses. These organisms can be shed in faeces and can contaminate water courses from animals directly or from sewage that has run off into water courses. The important issues relating to irrigation and pathogen contamination of RTE produce are:

- amount of water applied (this will affect bacterial levels applied);
- interval between application and harvest (this will influence pathogen survival rate); and
- microbiological quality of the water.

It is recommended that growers should identify the sources of water used for a particular purpose and minimise contamination from livestock, run-off, heavy rainfall and excess irrigation. It is also recommended that the microbial and chemical quality of the water is tested at appropriate intervals.

The FSAI have issued guidance on the use of water in the fresh produce supply chain and, in particular, on how to minimise the contamination of water used (136).

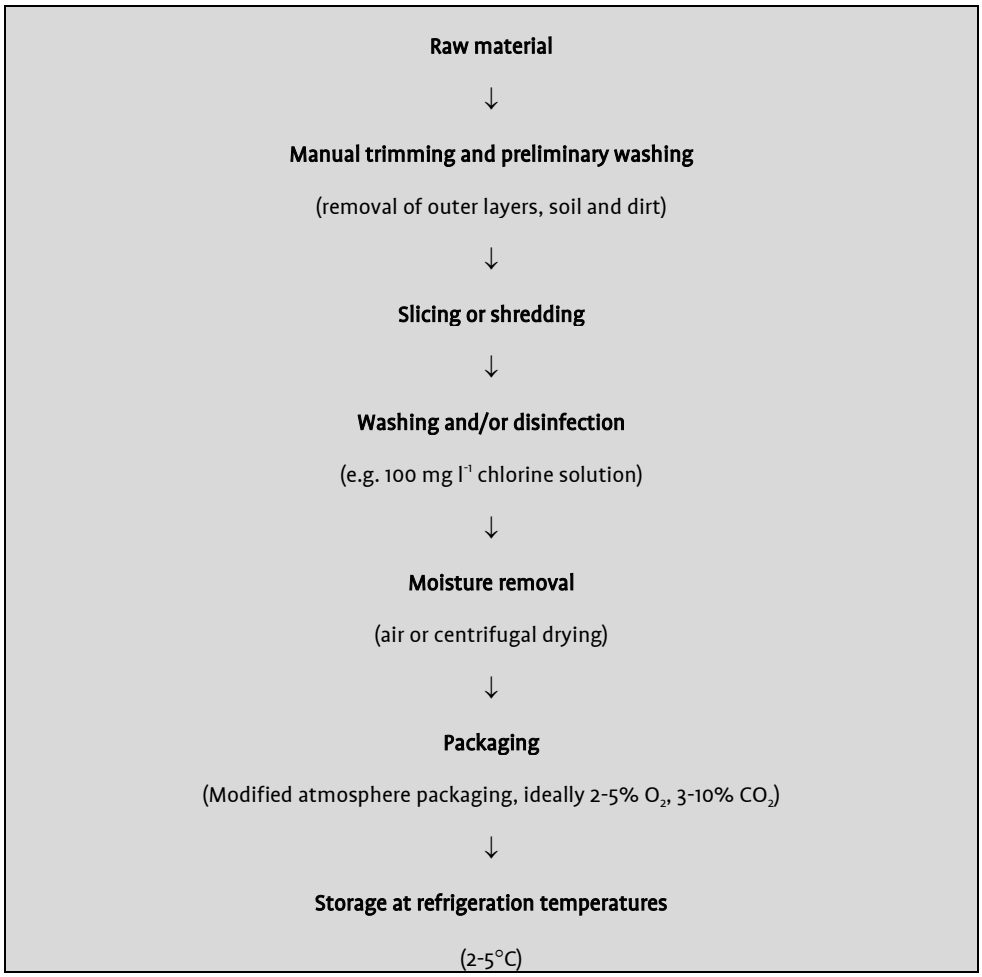
3.2.3.2 Preventing microbial contamination during harvesting

There are a number of steps that are taken to prevent the contamination of produce during the harvesting stage. These include measures to avoid contamination from field workers, harvesting equipment, water and transport vehicles (138). Field worker hygiene is important, as hands are used in much of the harvesting process. Also with a view to preventing cross-contamination during harvesting, thorough cleaning and decontamination of equipment, containers and transport vehicles must be undertaken.

3.2.3.3 Preventing microbial contamination during processing steps

There are a number of steps involved in the processing of RTE fruit and vegetables (Figure 3.2), however, the process varies depending on the nature of the produce and also the final product. This section describes the main steps that occur during the processing of fresh produce and also the main methods of reducing/eliminating contamination within each.

Figure 3.2 Typical flow diagram for the production of minimally processed vegetables (76)



It is important that hygienic practices are followed throughout the processing of fresh produce, and that raw materials and finished product are stored and handled in such a manner as to prevent contamination and damage, which may lead to internalisation of organisms. It is also critical that the temperature of processing is controlled to prevent product spoilage and also to prevent the growth of pathogens.

Trimming and peeling

Most leafy salad vegetables are trimmed to remove stalks, cores and outer leaves before they are further processed. These procedures tend to be manual, so consequently worker hygiene is important to prevent cross-contamination.

It has been recommended that, after trimming, the edible portions should be conveyed to a segregated, hygienic, temperature-controlled area within ten minutes for further processing (139).

Most root vegetables and fruits, such as oranges, apples, melons and pears require peeling. These produce types are usually washed in potable/disinfected water prior to peeling, and damaged parts are generally removed. In order to prevent structural damage, the peeling process should be as gentle as possible. Manual peeling causes less damage but this is not as economically viable so the use of a sharp knife blade is recommended. This will cause less damage and cross-contamination (140).

Additionally, peeling machinery needs to be thoroughly cleaned and disinfected regularly to avoid microbial build up, growth and subsequent contamination of the produce.

Cutting and slicing

There are many machines which can grate, chop, slice, shred or chip fresh produce. It is important to reduce the level of contamination on the surface of produce by washing or disinfecting to prevent cross-contamination of internal tissue.

Internalisation of pathogens in fresh produce

The internalisation of pathogens in fresh produce is a concern to the food industry because they are less likely to be removed during post-harvest washing than surface contaminants (141). *E. coli* O157:H7 that was inoculated into manure added to planting soil has been shown to contaminate and survive on lettuce plants grown in that soil. The pathogen was observed to be present within the plant tissues at a depth of up to 45µm (142). It has also been reported that *E. coli* O157:H7 was internalised in cress, lettuce, radish and spinach seedlings that had been contaminated as seeds. Mature plants did not remain internalised, however (143).

Some produce items that have a higher water content, e.g. unwaxed apples, celery and tomatoes, are susceptible to micro-organisms entering the skin via the stomata and through stem scars on the calyces of fruits. Bacteria can enter fruits through damage such as puncture wounds and splits.

Bacteria can also be internalised via waterborne contamination. This can occur when fruits are put into a wash tank and water is taken up into fruits, particularly when the fruits are warm and the wash water is cold.

Internalisation of potential pathogens is a problem as they will not be removed by surface washing. Due to the risk of internalisation of pathogens, dropped or bruised fruits should not be used, and practices which damage produce should be minimised. It is important to note that because of the potential for internalisation of pathogens, that the prevention of contamination at the pre-harvest stage may be arguably considered to be more critical than post-harvest decontamination.

Decontamination

All efforts should be taken to harvest fresh produce that is of the highest microbiological quality possible. As indicated above, however, there is some potential for RTE product to become contaminated with pathogens during the growing and harvesting stages. An effective decontamination stage is therefore essential prior to packaging, to help reduce the level of pathogenic and spoilage organisms in RTE produce.

There are a number of decontamination techniques available, as detailed in Table 3.5.

Table 3.5 Decontamination techniques

Acidified sodium chlorite	Hydrogen peroxide
Acids	Iodine
Alkali	Ionisation
Biocontrol	Irradiation
Bromine	Natural compounds
Chlorine	Ozone
Chlorine dioxide	Photodynamic inactivation
Combination treatments	Removal by brushing
High pressure	Trisodium phosphate
Hot water	Ultrasound

Adapted from (134, 144).

The most common compound used for the commercial disinfection of fresh produce is chlorine, with free chlorine concentrations of 50 - 100 ppm being used frequently. Initial removal of debris and organic matter is a prerequisite before the decontamination step as such material will reduce the efficacy of the disinfectant. It is the hypochlorous acid that is the active biocide, and its concentration in the solution is pH dependent. At pH 7, 78 per cent of hypochlorous acid remains in solution, and for

this reason citric acid is commonly used to maintain the pH at such levels. Maximum solubility of chlorine is achieved in water at about 4°C. However, the temperature of the chlorinated water should be at least 10°C higher than that of the fruits or vegetables, to achieve a positive differential, thereby minimising the uptake of wash water through stem tissues and open areas in the skin or leaves, whether due to mechanical damage or naturally present e.g. stomata (145).

Research funded by the FSA demonstrated that the removal of virus particles by washing in chlorinated water (100 ppm) was similar to that found with bacteria (reduction by one to two log cycles). The use of agitation marginally improved the sanitisation, but increasing the wash time above two minutes had little if any benefit. The researchers cautioned that if contamination levels are high, it is likely that after washing, sufficient virus particles would remain to cause infection (146).

Further to the decontamination step, the washing process should include a final tank stage using non-chlorinated rinse water which has been chilled to 1°C to 2°C. This will remove traces of chlorines, give the product a final wash, and also very importantly, reduce the product temperature to below 5°C, thus increasing its shelf-life (136).

Moisture removal

Once produce is washed, excess water needs to be removed as it could otherwise promote microbial growth. This can be achieved using a range of dewatering systems such as spin dryers, racks and sieves. It is important that the dewatering process is gentle so as to prevent damage which could lead to a deterioration in quality (78).

Packaging

Fresh produce is highly perishable and has a shelf-life of anything from one to ten days at chill temperature, but this can be highly dependent on product type (139). Therefore technologies to extend the shelf-life are of great economic importance to the fresh produce industry.

Ways in which shelf-life can be extended include the use of modified atmosphere packaging (MAP), or controlled atmosphere packaging (CAP). With MAP the gas composition is not controlled, whereas with CAP the gas atmosphere is kept constant.

MAP is defined as an atmosphere created by altering the normal composition of air to provide an atmosphere capable of extending shelf-life (147). In MAP, gases such as oxygen, carbon dioxide and nitrogen are used to alter the composition of the atmosphere around the product so that the storage life can be extended. The product is then sealed in a wrap like polyethylene, polypropylene, polyvinyl chlorine and edible film.

CAP results in a much more stable atmosphere than MAP, but requires gas-impermeable packaging, such as metal or glass. As a result it is more expensive and is not as widely used as MAP.

Tissue disruption caused by processing results in elevated respiration and transpiration, which can lead to rapid deterioration. In addition, cut tissues release nutrients that support the growth of micro flora present on raw produce. The O_2 level in packs is usually kept between one and five per cent, which will reduce the respiration rate and, therefore, oxidative breakdown of fruits and vegetables (148). Respiration uses O_2 and typically produces CO_2 therefore making packs anaerobic. O_2 levels below eight per cent also reduce the level of ethylene, which delays ripening and maturation. However, low levels of O_2 can increase anaerobic respiration and sensory degradation.

Given that MAP alone is not sufficient to prevent pathogen growth, chilling is extremely important and Hazard Analysis at Critical Control Point (HACCP), Good Manufacturing Practice (GMP) and Good Agricultural Practice (GAP) should be in place to prevent pathogen contamination.

High pressure processing

High pressure processing (HPP) utilises intense pressure, up to 600 Mega Pascals, applied for a few minutes at room temperature. This is sufficient to destroy many bacteria without affecting nutrients such as vitamins. Although the pressures used are immense, the processing conditions are designed so that foods retain their shape allowing foods to be preserved with minimal effects on taste, texture, appearance, or nutritional value. This technology has been applied successfully to a variety of fruit and vegetable products, including fruit juices, smoothies, guacamole and wet salads (149).

Infected food handlers

The role of infected food handlers in the transmission of pathogenic bacteria and viruses through RTE fruit and vegetables has been highlighted.

According to the Hygiene Package (specifically Regulation (EC) No. 852/2004), persons suffering from gastrointestinal symptoms are required to report their condition to their employer, be excluded from handling food, and required to seek medical advice, before being allowed to return to their duties. The requirement for suitable sanitary conditions, such as adequate hand washing facilities, at all stages within the food production chain, including primary production, is also stipulated. It is the legal responsibility of the food business owner to ensure that these rules are applied.

A number of guidelines have been issued on IOI in relation to food handler hygiene (150). Specific advice in relation to food handler hygiene for those involved in the fresh produce supply chain has been issued in ROI (136).

3.2.3.4 Preventing microbial contamination in the domestic setting

Washing or decontamination

Fresh fruit and vegetables are eaten in their raw, uncooked form and it is thus essential that these commodities are free from contamination, whether chemical or microbiological in nature. Current advice from the Advisory Committee on Pesticides, issued through the FSA, concluded that washing or peeling of fruit and vegetables is not required as a protection against pesticide residues. The FSA, however, advised that it was prudent to wash fruit and vegetables before consumption for reasons of general food hygiene (151). ***safe***food also advises consumers that fresh produce should be washed before eating.

A study investigating the efficacy of home washing methods in removing surface microbial populations from fresh produce, recommended that consumers should be instructed to rub or brush fresh produce under the cold running tap before consumption. Pre-soaking (immersing) in water before rinsing was found to significantly reduce bacterial numbers in apples, tomatoes and lettuce. Wiping apples or tomatoes with a dry or wet paper towel was shown to be less effective than soaking or rinsing (152).

Temperature control

The main growth limiting factor in minimally processed fruit and vegetables is temperature. At temperatures below 5°C, bacteria will multiply slowly, although this treatment may be less effective against *L. monocytogenes* (78). For this reason, the maintenance of the cold chain is essential for consumers to minimise the potential for the growth of the microflora present in minimally processed fruit and vegetables.

Storage and handling to prevent cross-contamination

The potential for cross-contamination from raw meat and poultry to RTE fruit and vegetables is well recognised. It is essential that all steps are taken during food storage and preparation to prevent such cross-contamination from taking place. This involves advising those involved in food preparation to correctly wash their hands before and after handing raw meat and poultry.

Raw and RTE foods should be kept completely separate by adequately decontaminating utensils and cutting boards between use (or using separate utensils and cutting boards). This was highlighted in a UK study (153) which found that in a domestic kitchen, 29 per cent of food preparation sessions resulted in positive *Campylobacter* isolates from prepared salads, cleaning materials and food-contact surfaces. Typing results showed that specific *Campylobacter* strains isolated from prepared chicken salads were the same as those isolated from raw chicken pieces, indicating microbial transfer during

food preparation. As previously mentioned in Section 3.2.2.3, a retrospective study of sporadic cases of campylobacteriosis found that the consumption of salad vegetables was a risk factor, which was most likely attributed to cross-contamination during food preparation (128).

On the other hand, however, a large retail survey of RTE organic vegetables failed to detect the pathogen (127), suggesting that contamination through the food supply chain is not a significant issue.

3.2.4 Sprouted seeds

Sprouted seeds (e.g. cress, mustard, alfalfa) represent a unique hazard, as the germination process results in the inhibitory barrier of the seed coat being breached. This can potentially allow any pathogens present to grow on nutrients from the sprouted plant. For this reason, and in response to a number of large food poisoning outbreaks associated with such products (Section 3.2.2), special precautions are required in the decontamination of seeds and their germination. The FSAI recommends:

- the treatment of seeds with chemical washes and heat treatment to reduce the number of pathogens present on seeds;
- the pre-soak cleaning of seeds to remove any foreign matter and organic matter;
- the surface decontamination of seeds in water using a high level of decontaminant (e.g. 100 to 200 ppm total chlorine);
- the use of chlorinated water for germination;
- the use of treated water for irrigation during the growth of the sprout;
- the washing of post-harvest sprouts with chlorinated water to remove the seed coat and reduce microbial load, and the storage of final product at a temperature of 3°C (136).

Following on from the 2011 German O104:H4 outbreak, EFSA published a scientific opinion on the public health risk of VTEC and other pathogenic bacteria that may contaminate seeds and sprouted seeds (154). The EFSA scientific opinion concludes that ready-to-eat sprouted seeds are a microbiological food safety concern, due to the potential for contamination with pathogenic organisms, subsequent growth of the organisms and consumption of the product, raw or minimally cooked. A number of risk factors along the whole production chain are identified, including risks to the effective identification and management of outbreaks. Potential risk mitigation options offered

focus on application of Hazard Analysis and Critical Control Point (HACCP) principles, Good Agricultural Practice (GAP), Good Manufacturing Practice (GMP), and Good Hygiene Practice (GHP) along relevant stages of the production chain. Potential seed decontamination treatments are also considered.

3.2.5 Spoilage

Food that has been damaged or injured so as to make it undesirable for human use, may be described as being spoiled. Such spoilage may be caused by insect damage, physical injury such as bruising and freezing, enzyme activity or that caused by microorganisms.

Despite the intrinsic mechanisms that plants have evolved to protect against harmful microorganisms, the destruction of plants by microbes is a common occurrence, particularly when growing and harvesting conditions are not optimal. About two thirds of such spoilage of fruits and vegetables is caused by moulds, involving members of the genera *Penicillium*, *Aspergillus*, *Sclerotinia*, *Botrytis* and *Rhizopus* (79).

3.2.6 Food safety regulation of the fruit and vegetable supply chain

3.2.6.1 Legislation

On January 1, 2006 new hygiene legislation, commonly referred to as 'The Hygiene Package' came into effect. It covers all aspects of the food chain from a food hygiene perspective (see Appendix B).

Commission Regulation (EC) No. 852/2004 sets out the requirements for the hygiene of foodstuffs. Article 4 of this regulation sets out the general and specific hygiene requirements. These include compliance with microbiological criteria for foodstuffs, compliance with temperature control requirements for foodstuffs, maintenance of the cold chain, and sampling and analysis. Article 5 sets out requirements in relation to HACCP.

Annex 1 of Commission Regulation (EC) No. 852/2004 sets out the hygiene requirements for foodstuffs, including the primary production of plant products. The latter include the following:

- The control of hazards in primary production and associated operations including measures to control contamination arising from the air, soil, water, feed, fertilisers, veterinary medicinal

products, plant protection products and biocides, and the storage, handling and disposal of waste.

- Food business operators producing or harvesting plant products are to take adequate measures, as appropriate:
    - to keep clean and, where necessary after cleaning, to disinfect, in an appropriate manner, facilities, equipment, containers, crates, vehicles and vessels;
    - to ensure, where necessary, hygienic production, transport and storage conditions for, and the cleanliness of, plant products;
    - to use potable water, or clean water, whenever necessary to prevent contamination;
    - to ensure that staff handling foodstuffs are in good health and undergo training on health risks (as mentioned in Section 3.2.3.3, p.53/
    - as far as possible to prevent animals and pests from causing contamination;
    - to store and handle wastes and hazardous substances so as to prevent contamination;
    - to take account of the results of any relevant analyses carried out on samples taken from plants or other samples that have importance to human health; and
    - to use plant protection products and biocides correctly, as required by the relevant legislation.

Annex 1 of Regulation (EC) 852/2004 also compels food business operators producing or harvesting plant products to keep records on (a) the use of plant protection products and biocides, (b) any occurrence of pests or diseases that may affect the safety of products of plant origin, and (c) the results of any relevant analyses carried out on samples taken from plants or other samples that have importance to human health.

Regulation (EC) 852/2004 requires all food businesses to be registered with the competent authority. It also stipulates that food business operators should apply the principles of the system of HACCP in order to identify critical control points that need to be kept under control in order to guarantee food safety. Food Business Operators must ensure that where and how the food is produced is hygienic, and that the premises are kept clean and properly equipped. Staff members must observe good personal hygiene practices, and be properly supervised and trained.

Commission Regulation (EC) No. 854/2004 sets out the official controls on products of animal origin intended for human consumption.

Commission Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs, specifies microbiological standards for the following pathogenic organisms:

- *L. monocytogenes* in RTE foods able to support the growth of *L. monocytogenes*, other than those intended for infants and for special medical purposes;
- *Salmonella* in RTE sprouted seeds, pre-cut fruit and vegetables and unpasteurised fruit and vegetable juices;
- *E. coli in* pre-cut fruit and vegetables and unpasteurised fruit and vegetable juices.

However, the legislation *states* that microbiological criteria, including sampling plans and methods of analysis, may be laid down if a need to protect public health arises.

3.2.6.2 Enforcement

DAFM is responsible for enforcing the provisions of Commission Regulation (EC) No. 852/2004 in relation to primary producers of fruit and vegetables in ROI. Commission Regulation (EC) No. 852/2004 has been given effect, insofar as that Department has responsibility for its enforcement by the European Communities (Food and Feed Hygiene) Regulations 2005 (S.I. No. 910 of 2005), as amended by the European Communities (Food and Feed Hygiene) Regulation 2006 (S.I. No. 387 of 2006).

DARD Quality Assurance Branch carry out Plant Health Inspections on Horticultural produce to ensure that it is free from quarantine pests and diseases. These inspections can be carried out at any stage of the growing, packing or storage of the horticultural produce, but does not include processing, except in the case of potatoes where diseases such as Ring Rot or Brown Rot would be investigated to trace the supply route of any diseased material. DARD also carries out horticultural marketing inspections at grower, wholesale and retail level to ensure that horticultural produce complies with EU legislative standards (155).

Officers of DAFM and DARD already carry out inspections and other control procedures on fruit and vegetables under EU and national plant health and marketing standards legislation. This includes the enforcement of EU quality standards covering most fruit and vegetables marketed in IOI through inspections at wholesale and retail level. While the focus of these standards is to ensure visual uniformity, they also require that the produce must be free of any visible foreign matter and damage caused by pests and diseases. The product must be fit for human consumption. The control measures are subject to audit by the FSAI/FSA and FVO. More information on control procedures for foods from outside the EU is available from the Consumer Focused Review on food origin (156).

3.2.7 Codes of practice and guidelines

There are a number of codes of practice and guidelines that have been developed in both jurisdictions to ensure the safety of fruit and raw vegetables produced on IOI.

As indicated earlier in this document (Section 3.2.3), the FSA have produced draft guidelines for growers to minimise the microbial contamination of RTE crops (135).

In NI, the Department of Agriculture and Rural Development (DARD) has produced guidance notes on the Control of Pollution (silage, slurry and agricultural fuel oil) Regulations 2003 and Codes of GAP for the prevention of pollution of water (157), air and soil (158), respectively.

The FSAI has issued a code of best practice for food safety in the fresh produce supply chain, designed to minimise the risk of foodborne illness resulting from the consumption of fruit and vegetables (136). This code makes reference to the control of hazards associated with fruit and vegetable production including water, biosolids (manure, compost and faecal material), hygienic practice and the safe use of pesticides and biocides. The code also identifies the critical control points associated with ensuring prepared vegetable safety during processing, storage and retail sale. The particular microbial hazards associated with the productions of sprouted seeds are also included in the code, as are the steps that must be taken to ensure the safe production of both seeds and sprouts.

In the UK, the Fresh Produce Consortium has issued guidelines to producers for the control of microbial hazards (132), while the Chilled Food Association has issued microbiological guidance for produce supplied to chilled food manufacturers (138).

In the UK, the FSA and Horticultural Development Company (HDC) have published a guide for growers entitled 'Monitoring microbial food safety of fresh produce'. The document gives guidance to producers of fresh produce on the main foodborne disease-causing bacteria and viruses that can contaminate crops, how growers can monitor levels of possible contamination, and how good hygiene practice can reduce the risk of crop contamination (159).

A set of guidelines for the use of chlorine in fresh produce washing has also been developed by Campden and Chorleywood Food Research Association to assist companies producing, supplying and packing fresh produce (160).

3.2.8 Residues resulting from deliberate pre-harvest chemical treatments

3.2.8.1 Pesticides

A pesticide is any substance or mixture of substances used to prevent, destroy or repel a pest. Pesticides are, by definition, harmful to living organisms. They are mostly man-made substances and preparations, but also include certain natural compounds such as plant-produced phytotoxins and micro-organisms such as the microbial insecticide *Bacillus thuringiensis*.

Pesticides are categorised according to their target: those targeted at plants are categorised as herbicides, while those targeted at moulds and fungi are categorised as fungicides. Other categorisations include insecticides (insects), molluscicides (molluscs), rodenticides (rodents), avicides (birds) and soil-sterilants.

EU plant protection product legislation

Within the EU, pesticide authorisation and use is regulated by two main pieces of legislation; the Plant Protection Products Regulation (EC) No. 1107/2009 and the Biocides Directive (98/8/EC), as amended.

The Regulation was transposed into ROI law as Statutory Instrument No. 159 of 2012, and into UK (NI) law as the Plant Protection Products Regulations (PPPR) of 2011. In practice, the PPPR applies to new active substances coming onto the UK market and existing reviewed active substances that have obtained Annex I listing. The process for deciding whether a new active substance can be approved for use in plant protection products in the European Union (EU) involves all Member States, the European Food Safety Authority (EFSA) and the European Commission. Members of the public and other interested parties can also provide comments for consideration in the process, specifically through the public consultation process of EFSA. Only approved active substances can be authorised in plant protection products in the EU. An active substance can only be approved if it meets the requirements and conditions specified in Regulation (EC) No. 1107/2009 (161).

There are many active substances already approved for use in plant protection products in the EU. Under previous legislation (Directive 91/414/EEC), which introduced uniform regulatory standards in the EU, all previous existing active substances have already been reviewed against the harmonised EU principles established by that legislation. Active substances that were not supported by producers, or found, on the basis of a comprehensive scientific risk assessment, not to meet the necessary standards required by that legislation, were not approved for use in plant protection products. Existing products containing these active substances were withdrawn from the EU market. There is currently an on-going programme to renew the approval of all active substances which had been approved

under Directive 91/414/EEC, to ensure that they are considered against the latest standards and that they meet the criteria set out in the current Regulation. However, unlike the previous Directive, the Regulation accommodates the option of rejecting an active substance on the basis of its intrinsic properties – a concept known as 'hazard-based cut-off criteria'. Annex I to Directive 91/414 – the list of plant protection product active substances approved for use in the EU – is still valid.

As of May 2011, there were 353 plant protection product active substances listed in Annex I. This was a result of a review process which commenced in 1993 and was finalised in March 2009. Of 1,000 active substances on the market in at least one Member State before 1993, 26 per cent, corresponding to about 250 substances, passed the harmonised EU safety assessment. The majority of substances (67%) were eliminated because dossiers were either not submitted, incomplete or withdrawn by industry. About 70 substances failed the review and were removed from the market, because the evaluation carried out did not show safe use with respect to human health and the environment. A further set of active substances, which have already been risk-assessed by Member States, will also undergo EFSA's peer review by the end of 2012 (162).

Within ROI, the Pesticide Control Service (PCS) of the Department of Agriculture, Food and the Marine (DAFM) is the designated competent authority for the evaluation and national authorisation of plant protection (and biocidal) products. PCS is also responsible for national Regulations controlling pesticide residues in food. In the UK, the Pesticides Safety Directorate (PSD) is the responsible authority for plant protection product authorisations. The PSD is an executive agency of the Department for Environment, Food and Rural Affairs (Defra). The Department of Agriculture and Rural Development (DARD) is the responsible authority for the administration in NI of the UK-wide authorisation programme, and in this context it reports to Defra. The majority of products approved for use in Great Britain are subsequently approved for use in NI.

Toxicological testing requirements for plant protection products

Annexes II and III of the previous Directive 91/414/EEC specify the toxicological tests that are required for the active substance and sample product respectively, before the active substance can be considered for inclusion in Annex I, or that particular product can be marketed in the EU. The purpose of these tests is to evaluate the risks for operators and bystanders associated with the handling and use of the plant protection products containing the active substance, as well as the risk for consumers arising from residual traces remaining in food and water. These tests elucidate the behaviour of the active substance in the body, the toxic effects of single high doses and multiple repeat low doses of the active substance, skin and eye irritation and skin sensitisation potentials, genotoxicity, carcinogenicity, reproductive toxicity, and, where necessary, the neurotoxicity and immunotoxicity

potentials of the active substance. Medical data from manufacturing plant personnel, clinical cases, poisoning incidents and epidemiological studies are also taken into account. Of the parameters deduced from this data, two are important in terms of consumer protection, the acceptable daily intake (ADI) and the acute reference dose (ARfD).

The ARfD is the amount of plant protection product residue in food (or water) that can be ingested over a short period of time, usually during one meal or one day, without any ill effects. The ADI is a similar quantity but is established on the basis of daily ingestion over a lifetime. It is also critical to the establishment of maximum residue levels (MRL) for plant protection product residues in food.

Maximum residue levels

With regard to plant protection products, the MRL is the maximum permissible concentration of the active substance or its metabolites (known collectively as 'residues') in a food. The rules applicable before the first of September 2008 were complex. The new Regulation covers all agricultural products intended for food or animal feed. MRLs for 315 fresh food products are listed, but these MRLs also apply to the same products after processing, adjusted to take account of dilution or concentration during the process. The Regulation covers pesticides currently or formerly used in agriculture in or outside the EU (around 1,100). In addition, where a pesticide is not specifically mentioned, a general default MRL of 0.01 mg/kg applies.

In establishing an MRL, regulators take a number of factors into consideration. These include GAP recommendations, data on consumer residue intake, and the physico-chemical and biological properties of the chemical in question (including the ADI and ARfD). The most recent report in this area (based on 2008 figures) found that 96.5 per cent of samples tested in the EU that year were within the MRL limits. The majority of the remaining 3.5 per cent of samples that exceeded the MRLs limits were detected in foods imported into the EU. In total more than 70,000 samples of nearly 200 different types of food were analysed for pesticide residues (163). The Regulation clearly designates the role of the Member States, EFSA and the Commission in the setting of MRLs and contains:

(1) The EU MRLs (about 45,000) already in force before September 2008;

(2) The recently harmonised MRLs previously set by the Member States (about 100,000);

(3) A list of low risk substances for which MRLs are not necessary.

The MRL is primarily a check that GAP is being adhered to during the production of fruit and vegetables. (Note, GAP specifications do not necessarily include the caveat that the final product, as presented to the consumer, should be residue-free). It also serves to regulate trade in food commodities treated with pesticides. MRLs are not safety limits for human health, although the latter

are taken into consideration when establishing the MRL, which is invariably lower. Therefore, a violation is not necessarily a cause of concern to public health.

Monitoring for plant protection product residues in ROI

With regard to plant protection products, the annual monitoring programme for residues in food is undertaken by DAFM on behalf of the FSAI. The monitoring programme is based on the recommendations of the EU Commission, Irish consumer dietary patterns, information from previous monitoring programmes, pesticide sales data, and food preparation data (164-166). Both domestically-produced and imported products are sampled.

The primary goal of the monitoring programme is to ensure that the GAP specifications associated with each plant protection product have been adhered to. These should ensure that unacceptable residue levels are not experienced. Where breaches of established MRLs are detected, PCS has the authority to confiscate and destroy the affected produce. Prosecutions may follow. The residue levels are scrutinised for possible breaches of either ADI or ARfD, and if a risk to the consumer is identified, a rapid alert may be issued by the FSAI. The monitoring programme also targets plant protection products and other chemicals that are banned in the EU.

Results of monitoring for plant protection product residues in ROI

In 2010, a total of 764 fruit and vegetable samples were analysed for up to 331 pesticides and analytes, using multi-residue analytical methods. The total number of each variety of fruit and vegetables analysed ranged from one to 90 (for example, one variety of cranberry to 90 varieties of apples). Approximately 150 (19.6%) of all samples were grown in the ROI, 309 (40.4%) were imported from other EU countries, 258 (33.7%) from outside of the EU, and a further 47(6%) of unknown origin. A total of 290 (37.9%) of the fruit and vegetables sampled contained no detectable pesticide residue, 449 (58.7%) contained one or more detectable residues at or below the MRL, and 25 samples (3.3%) contained residues in excess of EU MRLs. The percentage of MRL breaches for fruit and vegetables varied from 3.6 per cent in 2007 to 2.2 per cent in 2008, 1.3 per cent in 2009 and 3.3 per cent in 2010. The increase in breaches in 2010 was primarily due to breaches related to table grapes from India, citrus fruits from Peru and citrus containing malathion (167).

In addition to the monitoring programme, five targeted samples of fruit and vegetables were taken as part of a sampling programme to follow up on MRL breaches recorded in 2009. Three of the four targeted commodities were imported, and were all found to contain detectable residues below the statutory MRLs. The remaining commodity was of domestic origin and was found not to contain pesticide residues above the limit of quantitation. No targeted sample was found to have exceeded the MRL and no further follow-up action was required (167, 168).

Monitoring for plant protection product residues in NI

The PSD is the national competent authority in the UK and NI for national authorisations and evaluations of pesticide products. Within the Directorate, the Pesticide Residues Committee (PRC) is an independent group of experts, whose main function is to manage the annual pesticide residues surveillance programme throughout the UK. In this role they advise Government Ministers, the Chief Executives of the PSD, and the FSA on all aspects of the monitoring programme.

In the 2010 monitoring programme 2,048 of 3,750 samples of fruit and vegetables collected from 24 sites in the UK (including NI) were analysed for 330 pesticide active substances. Residues were detected in 1,205 (58.8%) samples which, at 58.8 per cent is almost identical to the positive rate in the ROI for the same year. MRL breaches were registered in 102 samples (4.9%) of fruit and vegetables. Of these, concerns were expressed with regard to the level of chlormequat in Indian grapes. However, the chemicals regulation directorate (CRD) concluded that there were no health risks associated with the levels being found and had exceptionally allowed the grapes to be sold in accordance with a specific legal provision. CRD issued additional advice to importers and indicated that the future trade would be specifically targeted to check compliance with the MRL (168).

3.2.8.2 Nitrate

Nitrate occurs naturally in most plants and vegetables. The concentration of nitrate in plants is influenced by a number of factors including species, fertiliser use, the variety and the growing conditions, of which light is the most important. Poor light conditions can result in a lower rate of photosynthesis, creating an accumulation of nitrate in the plant tissues. This is particularly evident during winter production of some vegetables, especially spinach and lettuce.

Nitrate is a permitted food additive within the EU. Sodium and potassium nitrate (E251 and E252, respectively) can be added to certain meat, fish and cheese products and foie gras (145). Between 70 and 90 per cent of nitrate intake in the diet can be attributed to the consumption of vegetables.

Excessive nitrate intake can potentially have harmful effects, including anaemia in adults and possibly methemoglobinemia in infants (169). The toxicity of nitrate has been reviewed by both the European Commission's SCF and the Joint Food and Agricultural Organisation (FAO)/WHO Expert Committee on Food Additives (JECFA). Both recommend an ADI of 3.7 mg/kg bw/day. The EFSA review of 2008 agreed with this ADI (170). A subsequent review in 2010, which focussed on nitrate consumption in 1–18 year olds, particularly from consumption of lettuce and spinach, concluded that while chronic exposure was below or in the region of the ADI, infants and young children aged 1-3 years, who eat large amounts of spinach on a given day could be exposed to levels of nitrates that may be a health

concern. The Panel also recommended that children suffering from bacterial gastrointestinal infections should not be given spinach, because these infections result in a higher conversion of nitrate to nitrite, thereby increasing the risk of methaemaglobinaemia (171).

Commission Regulation (EC) No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs, sets maximum levels for nitrates in certain leafy vegetables. The new regulation includes the following changes in the maximum levels for nitrate:

- fresh spinach - increase from 3,000 to 3,500mg/kg. This increase relates to both summer and winter crops – previously there were different seasonal maximums fresh lettuce (non iceberg);
    - increase from 4,500 to 5,000 mg/kg for winter crops under cover
    - increase from 3,500 to 4,000 mg/kg for summer crops under cover
    - increase from 2,500 to 3,000 mg/kg for summer outdoor crops
- introduction of a maximum level for rocket of 6,000 mg/kg for summer harvested and 7,000 mg/kg for winter harvested – previously there were no specified maximum levels for this crop
- discontinuation of the local derogations including for the UK.

No changes have been made to the maximum nitrate levels for preserved, deep-frozen or frozen spinach, fresh lettuce (winter outdoor) or iceberg lettuce (172). However, the regulation allows for an optional derogation from the limits for nitrate in lettuce and spinach, providing the GAP requirements to ensure that the final nitrate level is as low as possible is adhered to. In December 2010, a revised action programme for Ireland was signed into law. S.I. 610 of 2010, also known as the European Communities (Good Agricultural Practice for the Protection of Waters) Regulations 2010, and governs the implementation of the Nitrates Directive in Ireland. Under the Nitrates Regulations (S.I. 610 of 2010), farmers must not apply more than 170 kgs of nitrogen from livestock manure per hectare per year. However, grassland farmers, with grazing stock, may apply annually for a derogation to apply up to a limit of 250kg per hectare in a calendar year, under certain conditions (58).

Measures under the Nitrates Regulations include:

- the timing and procedures for the land application of fertilisers,
- limits on the land application of fertilisers that are consistent with good agricultural practice,
- storage requirements for livestock manure, and general provisions on storage management.

Belgium, ROI, the Netherlands and the UK availed of derogation from the established levels for spinach, while ROI and the UK were entitled to derogation from the established levels for lettuce up until 2008. However this derogation is no longer in place. Lettuce and spinach are routinely monitored for nitrates in ROI.

3.2.9 Residues resulting from deliberate post-harvest chemical treatments

3.2.9.1 Chlorine

Chlorine is used in the treatment of drinking water and the maximum allowable drinking water concentration in the EU (as set out in Council Directive 98/83/EC) is 250 mg/l (normal municipal tap water contains approximately 0.5 mg/l total chlorine). Chlorine is also used as an antimicrobial wash or spray in the raw fruit and vegetable industry, where aqueous solutions typically in the order of 50 - 100 mg/litre are used. Chlorine is usually added as liquid chlorine or hypochlorous acid, but chlorine dioxide and acidified sodium chlorite are also used. Processes generally incorporate a final rinse with chilled water containing up to 4 mg/litre free chlorine (i.e. less than the chlorine concentration of tap water) (173).

The EU Biocides Directive 98/8/EC includes compounds used to improve the hygiene of food stuffs, and in this context covers treatment with chlorine. There are no maximum permissible levels expressed either for chlorine or its by-products, which can be generated on foodstuffs.

Chlorine is known to interact with organic matter present in water to generate a spectrum of by-products including trihalomethanes (chloroform, bromodichloromethane, chlorodibromomethane and bromoform), haloacetic acids, haloacetonitriles, haloketones, chloral hydrate and chloropicrin. The use of chlorine washes or sprays must comply with the legal definition of a processing aid, i.e., they should not perform a function in the final product and should leave no residues that present a health risk (Council Directive 89/107/EC on the approximation of the laws of the MS concerning food additives authorised for use in foodstuffs intended for human consumption). ROI and UK legislation sanctions the use of chlorine as an antimicrobial treatment for non-organic fruit and vegetables with this caveat (174).

No assessment of the potential risks of chlorine and chlorination by-products from fruit and vegetable processing has been performed. In 2005, the UK Committee on Toxicity (COT) concluded that it was possible for the aforementioned disinfection by-products to be generated in foods treated by chlorination or ozonation. Prior to any assessment of the risk to human health, more accurate and

comprehensive information on the nature and levels of the by-products formed is required. (An EFSA evaluation of the toxicological risks from disinfection of poultry carcasses with different compounds including chlorine dioxide and acidified sodium chlorite, found no evidence of chlorinated organic by-products and concluded their use presented no safety concern - (175)).

The toxicological profiles of chlorination by-products are incomplete. Concerns have been expressed regarding their carcinogenic and reproductive toxicity potentials. However, the data so far remains inconclusive and is certainly not robust enough on which to base any potential changes to current processing/disinfection practices (176). A US Environmental Protection Agency (EPA) study on the carcinogenic activity of, and potential interactions between, different trihalomethanes in drinking water was also inconclusive (177).

In 1998 (and reiterated in 2004), COT concluded that there was insufficient evidence of a link between exposure to chlorination by-products in tap water, and an increased risk of adverse reproductive outcomes (178). While advocating further research in the area, the COT concluded that current efforts by water companies to minimise consumers' exposure to chlorination by-products remained appropriate, once these measures did not compromise the efficiency of drinking water disinfection (179). Limits have been established for total trihalomethanes in drinking water in the EU under Council Directive 98/83/EC.

3.2.9.2 Iodine/bromine

Iodine and bromine ions originate from the same chemical group as chlorine and, as such, display similar reactivity. Their use as disinfectants in the processing of fruit and vegetables is limited, due to health and safety and environmental concerns in the case of bromine, and the potential for iodine to dye organic matter (180). The potential by-products of disinfection treatment with bromine are largely the trihalomethanes (bromodichloromethane, chlorodibromomethane and bromoform).

In 1997, results from the UK Total Diet Study indicated that fruit and vegetables are unlikely to contribute significantly to the total daily intake of these ions, and concluded that these were no cause for health concerns (181).

3.2.9.3 Ozone

The use of ozonated wash and flume water for microbial control during fruit and vegetable handling and processing has been shown to be efficacious in the control of several bacterial species (175). The use of ozonated waters has been generally recognised as safe (GRAS) in the US since 1997 (182).

Ozonation can lead to non-halogenated by-products, such as aldehydes (e.g. formaldehyde); ketoacids and carboxylic acids; and brominated compounds, including bromate if bromide is present.

Ozone has a faster sterilisation and disinfection rate than chlorine. It is the disinfection method of choice for a number of municipal water treatment schemes, including those of Paris since 1903 and Los Angeles since 1984 (183).

3.2.9.4 Trisodium phosphate

In addition to its role as a disinfectant, trisodium phosphate is a permitted food additive in the EU (E339). Sodium phosphates are regarded as safe food additives both in the EU and the US. Nevertheless, the efficacy of trisodium phosphate as an antimicrobial agent for use on produce has been challenged (145).

Trisodium phosphate rapidly dissociates into its constituent sodium and phosphate ions. The main health concern is the possibility of an effect on the calcium-phosphorous-magnesium balance in the body. JECFA has established a maximum tolerable daily intake (MTDI: a similar parameter to the ADI) of 70mg/kg bw/day for trisodium phosphate.

No risk assessment has been conducted on the exposure to trisodium phosphate from fruit and vegetables. Its use as a disinfectant on poultry carcasses is not a cause for concern as the maximum exposure is in the order of four per cent of the MTDI (175). It is highly unlikely that exposure from treated fruit and vegetables would exceed this value.

3.2.9.5 Quaternary ammonium compounds

These compounds are cationic surfactants which can penetrate organic material. In Europe, these compounds are both authorised as a plant protection product in ornamental crops and as biocide for disinfection. Industry currently uses production line disinfectants containing these materials. After a review of available toxicological data and risk assessments, the European Commission Standing Committee of the Food Chain and Animal Health (SCoFCAH) advised in 2012, that certain types of these compounds, residues of benzalkonium chloride (BAC), and didecylmethylammonium chloride (DDAC), would be allowed at an enforcement level of 0.5ppm (184).

Quaternary ammonium compounds are most suited to surface disinfection for uncut fruit and vegetables which would subsequently be peeled before processing and consumption (175). However,

quaternary ammonium compounds are not widely used in fruit and vegetable processing, so it is likely that exposure from this source is not a significant risk factor.

3.2.9.6 Organic acids

Organic acids, such as lactic acid and acetic acid, can potentially be used as surface washes for antimicrobial control on fruit and vegetables (175). These are naturally occurring compounds in fruit and vegetables and do not present a human health risk at the levels present from this source of exposure.

3.2.9.7 Hydrogen peroxide

The antimicrobial activity of hydrogen peroxide depends on temperature, pH and other environmental factors (175). An assessment of exposure (and risk) to hydrogen peroxide from fruit and vegetable consumption is not available. EFSA has stated that the maximum exposure to hydrogen peroxide from treated poultry, based on normal dietary exposure, does not represent a safety concern (175). In addition, JECFA concluded in a review of food additives, that the reactivity of hydrogen peroxide with organic matter would result in its rapid breakdown into acetic acid, octanoic acid and water, and therefore does not pose a risk to health (185).

3.2.9.8 Waxes

Under EU Council Directives 95/2/EC and 2003/114/EC, a number of wax coatings have been sanctioned for use as glazing agents on certain fruits and vegetables. These include beeswax (E901), candelilla wax (E902), carnauba wax (E903), shellac (E904), microcrystalline wax (E905), montan acid esters (E912) and oxidized polyethylene wax (E914). The function of these additives is to help retain moisture in fruit and vegetables during shipping and marketing, inhibit mould growth, prevent other physical damage, and enhance the appearance of the product. These additives are also used on snacks, nuts, coffee beans, dietary food supplements, chewing gum, and certain confectionery and chocolate coatings. Morpholine is not allowed to be present as an additive to waxes or other food coatings. (184)

As with all food additives approved for use in the EU, these waxes undergo a rigorous scientific safety evaluation before being approved for use (145). In 2012, EFSA re-evaluated the safety of candelilla wax and carnauba wax and concluded that, within the currently authorised uses, neither substance gave rise to safety concerns (186) .

Although the waxes are considered safe to eat, they are nonetheless indigestible. They cannot be removed by washing so, apart from the obvious choice of buying unwaxed commodities, consumers must peel fruit and vegetables if they wish to avoid eating the wax coating.

3.2.9.9 Irradiation

Food irradiation is a processing technique that exposes food to electron beams, X-rays or gamma rays, and produces a similar effect to pasteurisation, cooking or other forms of heat treatment, but with less effect on appearance and texture (187).

There are no food irradiation facilities on IOI, therefore any irradiated foodstuffs or ingredients on the IOI market are imported, as there are no prohibitions or restrictions on the import of foods irradiated by other MS (188).

A combined WHO/FAO/International Atomic Energy Agency (IAEA) report concluded that irradiated food is both safe to consume and nutritionally adequate, provided that the sensory qualities of food are retained and harmful microorganisms are destroyed (189).

Two EC Directives relating to irradiated food have been implemented in MS. The Framework Directive 1999/2/EC of the European Parliament and Council covers general and technical aspects for carrying out the process, labelling of irradiated foods and conditions for authorising food irradiation (190).

The Implementing Directive 1999/3/EC provides a list of foods and food ingredients that are authorised across the EU for irradiation. Currently, only dried aromatic herbs, spices and vegetable seasonings are listed. That said, MS may continue to irradiate foods that have already received national authorisations prior to the implementation of the directive. MS may also retain existing restrictions or bans on irradiated foods not listed in the Directive.

Regulation of food irradiation in ROI is shared by three Government bodies: the FSAI, the Department of Health and Children, and the Radiological Protection Institute of Ireland. In NI, the FSA is responsible for the regulation of food irradiation.

3.2.10 Unintentional contamination

3.2.10.1 Mycotoxins

Mycotoxins are chemical compounds produced by moulds including those that colonise crops while in the field or post-harvest. As a result, they can enter the food chain and represent a significant health concern for both humans and farm animals. Mycotoxins have a wide range of toxic effects including carcinogenicity, genotoxicity and target organ toxicity.

Although any food susceptible to fungal contamination can, in theory, be a source of mycotoxins, the principal food commodities affected are cereals, nuts, dried fruit, coffee, cocoa, spices, oil seeds, dried peas, dried beans, and fruit, particularly apples and grapes.

Mycotoxin control is not as significant a problem in the production of fruit and vegetables as it is in cereal production. Those mycotoxins for which maximum levels have been established in certain food commodities, such as the aflatoxins and ochratoxin A, are not associated with fruit and vegetable production. However, certain trichothecene mycotoxins, zearalenone, citrinin and patulin have been detected on particular fruit or vegetable varieties.

Of these, the most significant is the occurrence of patulin in apples and apple-derived products, including cider and juice, as well as in fruit juices in general. Commission Recommendation 598 of 2003 provides guidance on the prevention and reduction of patulin contamination (191).

Maximum levels for the major mycotoxins in affected food crops have been set by Commission Regulation 1881/2006/EC, as amended by Commission Regulation (EC) No. 1126/2007.

3.3 Third country import controls

Imports of plants and plant products from Third Countries are covered primarily by the general food hygiene legislation or 'Hygiene Package' and other specific plant health legislation (Directive 2000/29/EC).

Unlike the requirements for Third Countries involved in the export of food of animal origin, those Third Countries involved in the export of food of non-animal origin do not have to appear on a list of exporters approved to export to the EU (normally held by the competent authority in cases of food of animal origin). In many cases, it is sufficient that exporting establishments in Third Countries are known to, and accepted as suppliers by, importers of food into the EU. For consignments containing plant or plant products which are covered by EU plant health legislation (listed in part B of Annex V to Directive 2000/29/EC), the exporter must obtain a phytosanitary certificate issued by the competent authority of the exporting country (192a). This normally involves registration. These measures exist to

prevent the introduction of serious diseases and pests of plants and plant products into and within the EU. The phytosanitary certificate certifies that the plants and/or plant products:

- Have been subject to the appropriate inspections;
- Are considered to be free from quarantine harmful organisms, and practically free from other harmful organisms; and
- Are considered to conform with the phytosanitary regulations of the importing country (193b).

Under Regulation (EC) No. 882/2004 (part of the Hygiene Package), the Commission can request Third Countries to provide accurate and up-to-date information on their sanitary and phytosanitary regulations, control procedures and risk assessment procedures with regard to products exported to the EU.

DAFM is responsible for the checks described in Section 3.3.2 on plants or plant products that are covered by Annex V to Council Directive 2000/29/EC. DAFM is also responsible for checking in accordance with Commission Regulation (EC) No. 1148/2001 that imported fresh fruit and vegetables conform to EU marketing standards. The function of the EU marketing standards regulations is to ensure that produce offered to the consumer is sound, clean, and of marketable quality, and that it is accurately labelled with information regarding the origin, quality class and packer and dispatcher information (194).

DARD carries out Plant Health Third Country import inspections on Horticultural produce to try to prevent the introduction of Quarantine pasts and diseases from being brought into Northern Ireland. Again, on the Horticultural Marketing front, imports of fruit and vegetables are inspected to ensure that they conform to EU standards (155).

3.3.1 European Commission, food and veterinary office

The function of the FVO is to ensure effective control systems through the evaluation of compliance with the requirements of EU food safety/quality, veterinary and plant health legislation, both within the EU and in Third Countries exporting to the EU. The FVO does this mainly by carrying out inspections in MS and in Third Countries exporting to the EU.

Each year the FVO develops an inspection programme, identifying priority areas and countries for inspection. In order to ensure that the programme remains up-to-date and relevant, it is reviewed mid-year. The FVO makes recommendations to the country's competent authority to deal with any

shortcomings revealed during the inspections. Following an inspection, the competent authority can be requested to present an action plan to the FVO on how it intends to address any shortcomings. Together with other Commission services, the FVO evaluates this action plan and monitors its implementation through a number of follow-up activities.

The Central Competent Authority in NI is the FSA, who is responsible for implementing the public health requirements, and also DEFRA who is responsible for implementing plant health requirements. Local Food Authorities (through EHOs) are responsible from farm gate through to the retail and catering stages of the food chain. In ROI, the Central Competent Authority is the FSAI. DAFM is responsible for the control of all fruit and vegetable products from production up to the point of retail, while the Health Service Executive (HSE), through Environmental Health Officers (EHOs), is responsible from farm gate through to the retail and catering stages of the food chain. DAFM and the HSE exercise their functions through service contracts with the FSAI.

In its role, the FVO, where appropriate, may highlight areas where the Commission may need to consider clarifying or amending legislation, or areas where new legislation might be required. In addition, the FVO produces other reports, such as summaries of the results of inspections or the annual EU-wide pesticide residues monitoring reports. The FVO also publishes an annual report on its activities, which reviews the progress of its inspection programme and presents the global results.

3.3.2 Border inspection posts

Imports of plants and plant products from Third Countries must come through designated Border Inspection Posts (BIPs), and be subjected to a series of checks before they are allowed access to the EU market. Third Country import controls can be undertaken in any one MS before the product is allowed to circulate freely in other MS, which effectively means that each MS is dependent on every other state to ensure that imports are controlled. It should be noted that the BIP is not always in the country of final destination of the product. The BIPs are situated in strategic locations in each MS, and are under the supervision of the relevant competent authority of the MS. The FVO routinely audits the controls carried out in these BIPs.

The list of BIPs operating within the EU is drawn up in Commission Decision 2001/881/EC, as amended. There are currently five BIPs on IOI, namely Dublin Airport, Dublin Port, Shannon Airport, Belfast International Airport and Belfast Port.

Council Directive 2000/29/EC contains provisions concerning the compulsory plant health checks to be carried out on certain plants and plant products coming from Third Countries. These checks consist

of documentary, identity, and physical plant health checks, with a view to ensuring compliance with the European Commission's general and specific import requirements. Documentary checks consist of verification of the certificates and documents that accompany a consignment, and in particular the phytosanitary certificate. Identity checks consist of verification that the consignment corresponds to the plants or plant products detailed in the certificate. Plant health checks consist of verification, on the basis of an inspection of a part of, or the entire consignment, that it is free from harmful organisms. Commission Regulation EC/1756/2004 provides for plant health checks at a reduced frequency where this can be justified.

Plants or plant products failing to comply with the control checks may be detained for further examination, returned to the exporting country, or destroyed. All rejections are notified to the EU Commission and if there is a public health risk, this is communicated to all MS via the Rapid Alert System for Food and Feed (RASFF). Once the shipment has met the required conditions, it is released for free circulation within the EU. Copies of the Health Certificate and the BIP clearance document must accompany the consignment to its destination.

The Competent Authority in the MS carries out initial monitoring of controls at BIPs. In the case of ROI, this is done by the DAFM on behalf of the FSAI, and in NI by DARD. The FVO is required to inspect BIPs; the frequency and scope of which is defined based on risk analysis, as outlined by Commission Decision 2005/13/EC. Where the operation or the facilities for checking product at a BIP is considered inadequate, approval of the BIP may be withdrawn.

3.4 Product traceability and recall

In recent years there have been a series of high profile food scares, which have focussed attention on how the supply chain operates, from production through processing, and finally distribution. Such 'scares' have the potential to seriously damage consumer confidence in the food chain, whether they present real or perceived food safety risks. They have also highlighted serious deficiencies in traceability systems and also in European Law. This resulted in the formulation and adoption of EU Commission Regulation (EC) No. 178/2002, which lays down the general EU principles and requirements of food law including traceability and recall requirements. This regulation was implemented as of 1 January 2005.

3.4.1 Product traceability

In today's global food market, effective traceability and product recall systems are paramount, even in the best-managed food business where an issue involving the safety of a foodstuff may occur.

Article 18 of regulation No. 178/2002 requires that traceability of 'food, feed, food producing animals, and any other substance intended to be, or expected to be, incorporated into a food or feed shall be established at all stages of production, processing and distribution.'

In the event of a foodborne hazard being identified in a particular batch of fruit or vegetables, or a case of foodborne illness associated with consumption of fresh produce having been reported, a full traceability system will permit identification of where the produce originated, the raw materials involved in its production, who handled the produce since it was produced, how it has been stored during transit, and the final destination of the produce. This information will enable a rapid and targeted recall of potentially hazardous product, thereby preventing any further food safety problems.

There is no S.I. in ROI for non-animal origin products, so no prosecution can be taken yet under 178 and no offence has been created for non-compliance.

3.4.2 Product recall

The objective of a product recall is to protect public health by informing consumers of the presence on the market of a potentially hazardous foodstuff and by facilitating the efficient, rapid identification and removal of the unsafe foodstuff from the distribution chain. There are two levels of product recall:

1) Recall – the removal of unsafe food from the distribution chain extending to food sold to the consumer, and
2) Withdrawal – the removal of an unsafe food from the distribution chain not extending to food sold to the consumer.

Regulation (EC) No. 178/2002, in addition to laying down the requirements for product traceability and recall, also established RASFF which is a notification system operated by the European Commission to exchange information on identified hazards between MS. In each MS there must be a single liaison contact point to deal with alerts arising within that State, or issued by RASFF. The FSA NI and the FSAI in ROI are the primary contact points on IOI.

Notifications of alerts are issued by the single liaison contact point within each MS to official agencies and food businesses relating to an identified hazard and are classified as either one of two categories, "For Action" or "For Information". Action is required when there is an identified direct or indirect risk to consumers. Information alerts do not require action, but relate information concerning a food or

feed product that is unlikely to pose a risk to health, e.g. inform relevant authorities of consignments blocked at border inspection posts.

The FSAI has issued a Guidance Note (195) relating to Product Recall and Traceability (applicable only to food) and also a Code of Practice on Food Incidents and Food Alerts (196). A similar guidance document has been issued by FSA NI, Guidance Note on EC Directive 178/2002 (197), and includes guidance on product recall and traceability.

In ROI, a "National Crisis Management Plan" was developed by the FSAI in conjunction with all of the official agencies so that a structured, co-ordinated and efficient response to any food safety crisis can be employed where the event arises. The FSA has set up an Incidents Taskforce to strengthen existing controls in the food chain so that the possibility of future food incidents occurring may be reduced. It also aims to improve the management of such incidents when they do occur (198).

3.4.2.1 RASFF notifications

Fruit and vegetables accounted for 670 notifications to the European Commission in 2011. Examples of notifications included dimethoate and omethoate in fruit and vegetables of various origins, formenthanate in peppers from Turkey and cucumbers from Spain. In addition, it was found that the rise in RASFF notifications for Salmonella spp. was most prominently for the product category fruits and vegetables. Out of the 100 notifications for Salmonella spp. in this product category, 86 were made for paan leaves, all but one by the United Kingdom. These leaves, traditionally chewed in Asia, originated in India, Bangladesh and Thailand.

There were no FSAI alerts (for action or information) relating to fresh fruit and vegetables in 2011. However, a number of alerts regarding fresh fruit and vegetables were recorded for the UK. There was no information specifically relating to fresh fruit and vegetable alerts in NI (199).

4 Nutrition

Key findings

For adults on IOI, vegetables contributed to less than three per cent of energy; 17 per cent of dietary fibre (Southgate method); 63 per cent of carotene; 32 per cent of total vitamin A; 13 per cent of vitamin E; 11 per cent of folate; and 24 per cent of vitamin C intakes. Peas, beans and lentils were the main contributors, to fibre while carrots were the main contributors to vitamin C.

Fruits contributed to less than three per cent of energy; 14 per cent of sugar; 25 per cent of vitamin C; and 11 per cent of copper intakes per day. Fruit and citrus juices were the main contributors to vitamin C intake from fruit.

The National Adult Nutrition Survey (NANS) 2011, conducted among 1,500 adults in ROI, found that the average intake of fruit and vegetable, excluding fruit juice and composite dishes, was 192g (2.4 portions) per day. This is considerably lower than the WHO recommendation of 400g per day. This recommendation was met by only 9 per cent of 18-64 year olds and 15 per cent of those aged over 65 years and over. The mean intakes of fruit and vegetables increased with age. The NANS found similar fruit and vegetable intakes to that of North-South Ireland Food Consumption Survey (NSIFCS) carried out in 1997 to 2000.

A comparison between SLÁN, 2007 (ROI) and the NI Health and Social Wellbeing Survey (HSWS) found a higher percentage of respondents in the ROI (83%) reporting that they ate a portion of fruit at least once a day compared to those in NI (58%) (200). Almost all respondents in the ROI (95%) ate at least one portion of salad or vegetables each day compared to 58 per cent in Northern Ireland.

The National Teens' Food Survey (2008) (conducted in 2006/6) among 224 males and 217 females from 32 secondary schools in ROI, found low intakes of fruit and vegetables among this age group. The average intake across this population per day of males and females was just over half the recommended intake (210g/day). Fruit consumption was much higher than vegetable consumption, with 77 per cent of fruit intake coming from fruit juices on average among consumers of fruit.

The NDNS 2011 (UK wide) found that boys aged 11-18 years, on average, consumed 3.1 portions of fruit and vegetables per day and 13 per cent met the 'five-a-day' recommendation. Girls in the same age group consumed 2.7 portions per day and 7 per cent met the recommendation.

The National Pre-School Nutrition Survey gathered detailed dietary data on children aged 1-4 years in ROI. The mean intake of fruit and vegetables (total population) at age one year was 194g/d compared to 258g/d at age 4 years. Fruit was consumed by practically all children (98%), rising from an average of 132g/day in 1 year olds to 198g/day in 4 year olds; however a large proportion of these intakes are made up of fruit juices (23g/day and 77g/day respectively).

Analysis of the National Children's Food Survey of 5-12 year olds in ROI has indicated a low intake of fruit and vegetables among this age group. The average intake of vegetables in this population is equivalent to a little more than half a portion per day (46g/day). Fruit intake is nearly equivalent to two portions per day (162g/day), but more than half of this fruit intake is made up of fruit juice (94g/day).

The way children consumed fruit was very different to the way they consumed vegetables. Vegetables were primarily eaten at lunch or during the evening meal. Fruit was mostly eaten as part of a packed lunch and as a snack throughout the day.

4.1 Introduction

The nutritional value of fruit and vegetables is reflected in the fact that these plant-based foods represent one of the five major food groups in dietary guidelines. International recommendations by the World Health Organisation (WHO) advocates a daily intake of at least 400g of fruit and vegetables for health, which equals five 80g portions per day (31).

Fruit and vegetables are described as 'generally low in energy density and, when consumed in variety, are sources of many vitamins and minerals'. In addition, they contain 'dietary fibre, and other bioactive compounds, such as phytochemicals' (WCRF & AICR, 2007). There are a number of plant-based foods which are strictly classified as fruit and vegetables, or are produced from fruit and vegetables, but are considered otherwise from a nutritional perspective. These include tubers such as potatoes that are classified as a starchy food, along with foods such as breads, rice and pasta due to their high starch content. Additionally foods such as jams and jellies derived from fruit and vegetables are classified as foods high in sugar due to fact that they lose much of their original nutritional value during processing. Herbs are generally also not classified as 'Fruit and Vegetables' as they are consumed in small amounts. Fruit juices made from fruit or fruit-concentrate are also classified as 'Fruit'.

4.2 Nutritional composition of fruit and vegetables

Different types of raw fruit and vegetables have differing nutrient compositions and are thus classified to reflect this (Appendix C). In general, fruit and vegetables are good sources of fibre (the bulk of which is non-starch polysaccharides (NSP)), carotenoids, vitamin C, folate, potassium and other vitamins, minerals and bioactive compounds. The low-energy density of fruit and vegetables is attributable to their generally high water content.

Raw fruit and vegetables are low in energy and fat. The exception to this rule is avocados, which contain more fat than most fruit and vegetables. However, avocados are rich in monounsaturated fats and vitamins and minerals including vitamin E, potassium and vitamin B_6. Avocados (flesh) contain 19g/fat per 100g compared to an apple which has 0.1g/fat per 100g (FSA, 2002).

The carbohydrate content of fruit and vegetables can be attributed to starch, sugar and fibre. Vegetables in general contain both starch and sugar, whereas fruit generally contain mostly sugar. The sugar present in fruit and vegetables is mainly in the form of fructose. This sugar is classified as 'intrinsic' sugar in contrast to 'added' or 'extrinsic' sugars, the latter of which should be limited in the diet (31).

Fruit and vegetables contain moderate to rich amounts of dietary fibre. NSP, the major component of dietary fibre, is the main measure used in the UK[2]. At an international level, NSP and other food components such as lignans and waxes are measured to determine total dietary fibre levels in food. Dietary fibre is characterised as insoluble and soluble depending on its physiological effects. Soluble fibre blocks glucose and lipid absorption, whereas insoluble fibre contributes to faecal weight and reduces intestinal transit time. The fibre found in fruit and vegetables in general contains higher concentrations of insoluble fibre.

Fruit and vegetables generally contain very small amounts of protein with beans and legume seeds being the exception. These have a protein of higher quality in comparison to other fruit and vegetables and offer a good source of protein for vegetarians.

Vitamin C is the micronutrient found in highest concentrations in fruit and vegetables. The vitamin C content of fruit and vegetables varies, with citrus fruits having some of the highest levels. However, different types of fruit and vegetables contain a range of vitamins, minerals and trace elements (see Appendix C).

Raw fruit and vegetables are a low energy-dense food source in the diet that offers a diverse range of micro-nutrients. Dietary guidelines recommend 'variety' in the consumption of fruit and vegetables, due to fact that different types of fruit and vegetables contain different nutrients.

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[2] EFSA: dietary fibre is defined as non-digestible carbohydrates plus lignin, including non-starch polysaccharides (NSP) – cellulose, hemicelluloses, pectins, hydrocolloids (i.e., gums, mucilages, ß-glucans), resistant oligosaccharides – fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS), other resistant oligosaccharides, resistant starch – consisting of physically enclosed starch, some types of raw starch granules, retrograded amylose, chemically and/or physically modified starches, and lignin associated with the dietary fibre polysaccharides. http://www.efsa.europa.eu/en/efsajournal/pub/1462.htm

There are two different methods used to measure fibre in foods – the Englyst method which is used in the UK and the AOAC (Association of Official Analytical Chemists) method which is used internationally. The Englyst method measures NSP only, while the AOAC method measures NSP and other components such as lignin and waxes.

In addition to nutrients, which have a defined metabolic role in humans, fruit and vegetables contain a wide variety of compounds known as phytochemicals. These compounds have the potential to exert a physiological effect, and there is a growing body of evidence to suggest that these compounds may play a protective role against chronic disease. Hundreds of these compounds have been identified in fruits and vegetables and include:

- Organosulphur compounds in onion, garlic, leeks, chives, cabbage, cauliflower, broccoli and brussels sprouts
- Terpenes in citrus fruits
- Flavanoids and other phenolic compounds in most fruits and vegetables
- Plant sterols in most vegetables
- Phytoestrogens in soyabean, seeds, fruits and berries.

4.3 Effects of processing and cooking on nutritional composition

Without intervention, the ripening and spoilage of fruit and vegetables occurs naturally, but will occur at a rate that will be dependent on air temperature and other environmental factors such as exposure to micro-organisms.

From a nutritional perspective, the spoilage process involves enzymatic activity which utilise many micronutrients, in particular antioxidant nutrients such as vitamins A, C and E and selenium. In addition, alterations in the macro-nutrient content can also occur. For example, as bananas ripen and the spoilage process begins, the predominant form of carbohydrate in the unripe fruit, starch, is slowly converted into sugar.

The skin of whole fruit and vegetables offers a degree of protection from the environment. Once the skin is broken, the fruit or vegetable is exposed to more oxygen, which initiates enzymatic activity and utilisation of micronutrients. For this reason, it is recommended that fruits and vegetables are peeled or chopped as close as possible to the time of consumption.

The following section outlines the effect of different storage, preparation and cooking techniques on the nutritional content of fruit and vegetables.

4.3.1 Preservation methods

Preservation methods used for fruit and vegetables aim to slow down or inactivate the spoilage process. The most common methods used are cold storage, canning and drying. Each method has an effect on the nutritional content of fruit and vegetables and is described below.

4.3.1.1 Cold storage - refrigeration and freezing

Refrigeration and freezing are practical methods for prolonging the shelf life of many fruit and vegetables. Refrigeration at temperatures of 3 to 5˚C reduces the level of enzyme activity in the fruit and vegetables, thus reducing the metabolism of nutrients. Studies have shown that fruit and vegetables stored at room temperature lose vitamins much more rapidly compared to refrigeration and freezing. For example, spinach stored at room temperature (20°C) lost 27 per cent of its folate over a ten-hour period compared to a 26 per cent loss over seven days when stored at 4°C (201). Nevertheless, not all fruit and vegetables are suited to refrigeration such as unripe bananas. These should not be stored in a refrigerator as this interrupts the ripening cycle and thus should be left at room temperature. Once ripened, bananas may be stored in a refrigerator for up to two weeks.

Deep-freezing at temperatures of around minus 18 to minus 20˚C extends the life of many fruit and vegetables for long periods, provided the food is well covered to prevent water loss due to sublimation. At these low temperatures enzymatic activity does not occur and if the fruit and vegetables are frozen within hours of harvest there is little effect on their overall nutritional composition.

It is common practice in industry to steam or blanch vegetables to inactivate enzymes prior to freezing and the addition of heat and excess water can result in the loss of some vitamins. Nevertheless, many frozen fruit and vegetables maintain higher vitamin contents compared to their fresh counterparts stored at room temperature or refrigeration. Some fruit may, however, have a softer texture on thawing.

4.3.1.2 Drying

Drying involves the removal of moisture from the cells and tissues of the food through the application of heat so that bacteria, yeasts and moulds cannot grow and cause spoilage. This treatment has a large impact on the nutritional composition of fruit and vegetables, primarily as a result of concentration of nutrients (such as energy and carbohydrate), as a result of water loss and the

application of heat which denatures heat sensitive nutrients. Drying can also cause a loss of vitamin C and folate, as these nutrients are readily oxidised when heated, therefore levels are greatly reduced in dried fruit and vegetables. For example, dried prunes contain 141kcal and a trace of vitamin C per 100g, whereas raw plums contain 36kcal and 4mg Vitamin C per 100g (202). A small amount of starch can also be rendered resistant due to the application of heat.

Fruit and vegetables may be pre-treated before drying. These treatments include immersion in a salt solution, ascorbic acid solution or steam blanching. This pre-treatment is usually carried out on light coloured fruit and vegetables, such as apples, peaches and pears as it prevents them darkening during drying and storage. It is therefore important to read the labels on dried fruit and vegetable packaging in order to determine if additional nutrients such as salt have been added.

4.3.1.3 Canning

The canning process involves placing foods in sealed containers and heating them to a temperature that destroys food spoilage bacteria. The sealed container further protects against oxidative changes.

Canning can result in the loss of micronutrients, particularly vitamin C and folate, with greater losses in some fruit and vegetables than others. For example, carrots can lose up to 5mg/100g vitamin C and some folate (41µg/100g) during canning. Similarly, canned peas have little vitamin C and less than half the folate content of fresh peas (202). Nevertheless, many nutrients are retained during canning and it is a very practical method of preservation. Canning will however, increase the level of sodium in vegetables if the vegetables are stored in brine (salt solution). For example, canning of carrots in brine is reported to increase the sodium content by 0.35g/100g (202).

Similarly for fruit, the medium that it is stored in will influence the nutritional content of the fruit to varying degrees. Canned fruit in syrup is significantly higher in energy and sugar compared to canned fruit in juice.

The fibre content of vegetables is also decreased when canned, for example canned tomatoes have 0.3g/100g less fibre than raw tomatoes (202).

4.3.1.4 Pickling

When compared to the raw form, pickled vegetables are lower in the macronutrients; energy, protein and carbohydrate. They are also lower in fibre content (pickled beetroot reduced by 0.2g/100g compared to raw beetroot).

Pickling significantly increases the sodium content of vegetables due to the use of salt in the process. For example, a 60g portion of pickled onions contains 0.27g more sodium than 60g of raw onions (202).

With regard to the other micronutrients, pickling results in a small reduction in the levels of iron, calcium and vitamin C, with folate content being most affected (100g of raw beetroot contains 150µg of folate, compared to pickled beetroot which contains 2µg/100g) (202).

4.3.1.5 Irradiation

The effect of irradiation on the nutritional quality of food is similar to, and in some cases less than that of other, preservation methods. Only minor changes are observed in the level of some vitamins (B_1, C, A and E), while carbohydrates, fats and proteins remain largely unaffected by low or medium doses. However, nutritional changes in food due to irradiation are dependent on factors such as the temperature, radiation dose, packaging environment and storage conditions. Irradiation of frozen food or of food in an oxygen-free environment has been shown to minimise nutrient loss (202). Refer back to Section 3.3.3.9 (p.80) for further information on food irradiation.

4.3.2 Preparation methods

4.3.2.1 Juicing

'Fruit juice' is the extracted juice of fruit, which has a shelf-life of "days". 'Fruit juice from concentrate' is juice, which has been concentrated and returned to its original state by the addition of water. It will have a longer shelf-life than 'fruit juice' (203).

A glass of fruit juice, whether or not it has been made from concentrate only provides one portion of the recommended five-a-day, irrelevant of how much is taken, as it does not have the same nutritional benefits as whole fruit. When compared to a raw eating apple, unsweetened concentrated apple juice can be significantly higher in energy and sugar. This is due to the fact that up to 15g of sugar (4 kcal/g sugar) per litre may be added to the concentrated juice to regulate acidic taste. This must be indicated in the ingredients, but the juice may still not have the label "sweetened" (203).

During processing, the outer layer of fruits such as apples, which is a good source of soluble fibre, is removed. There is also some loss of fibre during the extracting process which can further reduce the fibre content of the juice.

The biggest nutritional difference between fruit juice and concentrated fruit juice is the vitamin C content, due to its loss during processing. However, any vitamin C lost is generally replaced by the processor giving an increased level compared to the raw fruit. Fruit juice may also be fortified with calcium and iron.
Vegetable juices are less commonly consumed than fruit juices but are growing in popularity. The impact of juicing vegetables is similar to that of fruit (204).

4.3.2.2 Peeling and chopping

Peeling fruit and vegetables results in a small decrease in the fibre content, as the skins of fruit and vegetables are a source of fibre. An example of this is a medium-sized apple, approximately 100g, when peeled loses 0.2g of fibre (FSA 2002).
It is advisable to cook or consume fruit and vegetables as soon as possible after chopping or preparing them. If left at room temperature, chopped fruit and vegetables are more susceptible to oxidation which results in loss of nutritional value, as discussed earlier in this chapter.
Storing chopped fruit and vegetables in water for long periods of time can result in the leaching of nutrients into the water, in particular water soluble vitamins, such as vitamin C.

4.3.2.3 Mashing and smoothies

The Public Health Agency, formerly The Health Promotion Agency in Northern Ireland (NI), and the Department of Health and Children in ROI advise that most smoothies contain only one portion of fruit (205). Manufacturers of smoothies can claim up to 2 portions of fruit or vegetables depending on the ingredients. Mashing or making fruit and vegetables smoothies is similar to juicing; however, they have greater benefits as the nutritional composition of the mashed fruit and vegetables is closer to that of the raw fruit as the pulp is not removed. Smoothies and fruit juices made from fresh fruit, as opposed to fruit concentrate, have a more favourable vitamin profile. Those smoothies made with yoghurt or milk will also contribute to dairy intake. Fruit concentrates will have higher sugar content and some smoothies will contain added sugar. To make informed choices it is important that consumers of smoothie products are aware of the varied nutritional composition of smoothies (205).

Smoothies should be consumed with a meal for dental health reasons. They are high in naturally-occurring sugar which can damage teeth so drinking smoothies between meals should be minimised. Using a straw can reduce the exposure of the teeth to sugar and acidity that cause tooth decay.

4.3.2.4 Other preparation methods

The addition of salt, sugar and fat during preservation and cooking can dramatically alter the nutrient content of the food consumed.

Fruit and vegetables in the supermarket and catering establishments are prepared in many different ways. For example many salads are prepared with a dressing added. The typical energy and fat content of a portion (15g) of French dressing and a Caesar dressing are 82kcals and 8g of fat and 79kcals and 9g fat (202), respectively. By asking for, or preparing a dressing on the side, and reducing the actual amount of dressing added, considerable less energy and fat can be consumed.
Vegetables are also often prepared with a sauce. For example, a portion of boiled cauliflower contains 17kcals and 0.5g of fat compared to a portion of cauliflower in cheese sauce which contains 95kcals and 6g fat. In addition, some fruit and vegetables are manufactured with a coating of oil, breadcrumbs or batter. These products are much higher in energy, fat and sodium than less processed varieties. An example of this is garlic mushrooms, which contain 61 kcals and 6g fat per portion, compared to a portion of boiled mushrooms which contain 5 kcals and 0.1g fat.

4.3.2.5 Packaging

Consumer demand for fresh, naturally preserved food products has grown dramatically in recent years, and as a result, many fruit and vegetables are packaged in order to preserve them. As discussed in Section 3.2.3.3, the most common type of packaging used is MAP, with CAP being utilised to a lesser extent.

When compared with storage in air, MAP has been shown to have a positive effect on retaining the nutritional content of fruit and vegetables (206, 207). Other studies, however, have indicated a detrimental effect on the vitamin C content of fruit and vegetables (206, 207). In the latter studies, however, a controlled sample stored in air was not included to provide a valid comparison.

4.3.3 Cooking methods

There are a variety of cooking methods used today and all can affect the nutritional content of fruit and vegetables. Cooking is a necessary part of making many vegetables more edible, with the application of heat breaking down the starch. However, it should be noted that some starch is rendered resistant to absorption, resulting in a small increase in fibre.

4.3.3.1 Boiling, steaming and microwaving

Boiling is the traditional method of cooking vegetables. Although boiling has little impact on the macronutrient content of vegetables it can have a large impact on micronutrients.

The vitamin C, calcium and folate content of most vegetables are reduced significantly when boiled. This is primarily due to vitamins and minerals leaching into the cooking water. Vitamin and mineral loss can be reduced by boiling vegetables in as little water as possible or using alternative methods such as steaming or microwaving. To preserve some of the nutrients if boiling is the preferred method, the cooking water could be used to make sauces, soups or gravy.

The fibre content of the vegetables remains similar when boiled. Boiling in salted water retains the same level of nutrients as boiling in unsalted water, with the exception of sodium. Sodium levels of vegetables boiled in salted water can increase by up to 0.1g/100g.

Traditionally, baking soda is added to green vegetables to retain the colour. However, bicarbonate of soda not only increases the sodium content of the vegetables, but also destroys vitamin C.

Microwave cooking, if used correctly, does not change the nutrient content of foods to a larger extent than conventional heating. Studies suggest that there is a tendency towards greater retention of many micronutrients with microwaving, probably due to a shorter preparation time (208).

Schnepf and Driskell compared the losses of vitamin C in five different types of vegetables, which were cooked by steaming and boiling in a microwave oven, and with conventional steaming or boiling, with the highest loss of vitamin C occurring with conventional boiling (Table 4.1) (209).

Table 4.1 Effect of cooking methods on vitamin C retention

	Percentage of vitamin C retention			
Product	Microwave – steamed	Microwave - boiled[a]	Steamed	Boiled[b]
Broccoli	80	75	70	46
Cauliflower	85	81	67	45
Potatoes	92	86	84	63
Corn	65	61	45	41
Peas	76	64	60	53

Notes:

[a] Water : vegetables ratio (w/w) = 1 : 0.3, except for broccoli – 1 : 0.5 (no water was added to the potatoes)

[b] Water : Water: vegetables ratio (w/w) = 5 : 1, except for broccoli, 7.5 : 1

Source: Adapted from [16]

4.3.3.2 Stewing

Stewing is a traditional way of cooking fruit. When stewing without sugar, there is very little change to the nutritional composition of the fruit. One exception is the significant reduction in the fibre content. Stewing facilitates the process of hydrolysis, which breaks down the fibre causing a loss in the final product.

For small fruit such as blackberries, raspberries and red currants, there is a greater reduction in the vitamin C levels during stewing than for larger fruits such as pears, plums and rhubarb. For example, stewed raspberries lose 9mg of vitamin C per 100g compared to the loss of 1mg of vitamin C in 100g stewed rhubarb (202).

The addition of sugar will increase the final sugar content of the fruit consumed.

4.3.3.3 Other

Grilling, frying and baking are methods used frequently in the cooking of fruit and vegetables. The biggest impact these methods have on the nutritional value of the fruit or vegetable will depend on the addition of oil or other cooking fats. For example, fried onions contain over 10g more fat than baked or raw onions (per 100g; average portion is 60g) (202). Grilling instead of frying tomatoes can reduce the fat content by more than 7g (per 100g; average portion is 34g).

4.3.3.4 Overcooking

Overcooking fruit and vegetables will result in a change in the nutritional content of the food. There will be a greater loss in nutrients such as vitamin C which are unstable to heat, due to overcooking.

4.3.3.5 Functional food products

The functional food market has grown internationally and has expanded into the area of fruit and vegetables. Such products tend to be smoothie-like products which have nutrients such as fibre and vitamins added to reflect the original product, although this will not be to the original levels found in the raw product. Whether these products have the same effect in the long-term as consuming fruit and vegetables, is as yet unknown.

4.4 Dietary composition patterns

4.4.1 Current consumption of fruit and vegetables on IOI

A breakdown of fruit and vegetable intakes among the adults surveyed is given in Appendix D.

4.4.1.1 Adults

The most recent detailed survey on fruit and vegetable intake on IOI was the National Adult Nutrition Survey (NANS) 2011, conducted among 1,500 adults in ROI. It found that fruit and vegetables were consumed by the majority of the population. The average intake, excluding fruit juice and composite dishes, was 192g (2.4 portions) per day. This is considerably lower than the WHO recommendation of

400g per day. This recommendation was met by only nine per cent of 18-64 year olds and 15 per cent of those aged over 65 years and over. The mean intakes of fruit and vegetables increased with age. The NANS found similar fruit and vegetable intakes to that of North-South Ireland Food Consumption Survey (NSIFCS) carried out in 1997 to 2000 (166) (210).

Examination of the data from the NSIFCS provides the most detailed information of fruit and vegetable intake among adults in IOI (166). Some of the key findings are outlined in Table 4.2.

Table 4.2 Findings on fruit and vegetable intake from the North-South Ireland Food Consumption Survey

Variable	Key Finding
Age	Age had a significant effect on the consumption of fruit and vegetables. The younger age group (18 to 45 years) had a significantly lower intake ($p<0.01$) of vegetables and fruit compared with the older group (51 to 64 years) (for vegetable intake this was a mean of 128g/d and 147g/d, respectively; and for fruit 114g/d and 156g/d, respectively). Younger males were less likely to eat green vegetables and cauliflower and more baked beans than older male age groups. Fruit intake increased with age among women.
Intake	The mean intake of fruit and vegetables among adults aged 18 to 64 years on the IOI was found to be 136g/d and 140g/d, respectively (210). This is approximately equivalent to 3.5 portions of fruit and vegetables per day.
Popular vegetables	Tomatoes[3] and carrots were the vegetables consumed in the highest quantities, with apples, bananas and orange juice being the most popular fruit consumed.
Vegetable in composite meals	Composite foods, i.e., foods that contain a mixture of ingredients, contributed a mean of 37g vegetables and 6g fruit per day among adults. This vegetable intake represents 26 per cent of total vegetable consumption. Carrots, tomatoes and other vegetables e.g. mushrooms, onions and peppers were the vegetables consumed in the highest quantities in composite meals. Composite meals contributed to five per cent of total fruit intake.
Gender	When adjusted for energy intake, fruit and vegetable consumption was higher ($p<0.01$) among women than men. Men consumed less salad vegetables, broccoli, peppers and tomatoes and more baked beans.
Meeting recommendations	Approximately 21 per cent of men and 19 per cent of women are meeting the current international and national recommendations of $\geq$400g/d. When considering the US Department of Agriculture's (USDA) separate recommendations for fruit and vegetables (at least two portions of fruit and three portions of vegetables), both men and women are more likely to achieve the fruit recommendations than vegetable recommendations. The percentage of individuals achieving the dietary recommendations for fruit and vegetables was found to increase with increasing social class and increasing level of education. Current smokers as a group were found to have the lowest number of compliers. The analysis carried out on the NSIFCS highlights the importance of composite foods to the intake of fruit and vegetables by the population on IOI.

[3] Tomatoes are ordinarily classified as a fruit. In the IUNA study, however, they were classified as a vegetable as this was what consumers perceived them as being.

Since composite dishes were found to be an important contributor to vegetable intake in the NSIFCS, the current estimates from NANS are likely to be an underestimation of total fruit and vegetable intake. A comparison between SLÁN, 2007 (ROI) and the NI Health and Social Wellbeing Survey (HSWS) found a higher percentage of respondents in the ROI (83%) reporting that they ate a portion of fruit at least once a day, compared to those in NI (58%) (200). Almost all respondents in the ROI (95%) ate at least one portion of salad or vegetables each day compared to 58% in Northern Ireland. The methodologies used in SLÁN and HSWS were based on food frequency questionnaires that over-report consumption of food when compared to the seven-day diary method used in NSIFCS (211). This in part explains the high compliance found compared to the NSIFCS and NANS. The daily recommended intake for fruit and vegetables has since increased in ROI from four to five portions per day. SLÁN also reported a social class and age effect on fruit and vegetable consumption. In both jurisdictions, a greater percentage of respondents in higher social classes ate one or more portions of salad or vegetables per day compared to those in lower social classes (ROI: $p<0.001$; NI: $p<0.001$) (Health Promotion Unit 2007).

In a more recent Health Survey NI, a third of respondents reported consuming five or more portions of fruit or vegetables a day, with females more likely to be meeting this guideline than males (36% and 27% respectively) (212).

4.4.1.2 Children and adolescents

The National Pre-School Nutrition Survey (213, 214) gathered detailed dietary data on children aged 1-4 years in ROI. The mean intake of fruit and vegetables (total population) at age one year was 194g/d compared to 258g/d at age 4 years. Fruit was consumed by practically all children (98%), rising from an average of 132g/day in 1 year olds to 198g/day in 4 year olds; however a large proportion of these intakes are made up of fruit juices (23g/day and 77g/day respectively). The percentage of children consuming juice increased from 33 per cent of 1 year olds to 65 per cent of 4 year olds. These figures include intakes from composite dishes (IUNA, 2012). Similarly, vegetables were consumed by 99 per cent of children as either discrete portions or in composite dishes or purees. The average daily intake of vegetables was 57g/day across all 1-4 year olds. Vegetables in composite meals contributed to approximately half of overall vegetable intake with a mean contribution of 53 per cent intake among 1 year olds compared to 38 per cent among the 4 year olds. The intakes of different types of fruit and vegetables for 1-4 year olds are given in Appendix E.

Analysis of the National Children's Food Survey of 5-12 year olds in ROI has indicated a low intake of fruit and vegetables among this age group (215, 216). The intake of different types of fruit and vegetables for the 5-17 year olds is given in Appendix F.

The average intake of vegetables in this population is equivalent to a little more than half a portion per day (46g/day). Fruit intake is nearly equivalent to two portions per day (162g/day), but more than half of this fruit intake is made up of fruit juice (94g/day). However, it should be noted that these figures do not include fruit and vegetable intake from composite foods and is likely to underestimate the true intake among the group. Secondary analysis of this data highlighted two key factors that are important to fruit and vegetable intake among this age group (217):

- The way children consumed fruit was very different to the way they consumed vegetables. Vegetables were primarily eaten at lunch or during the evening meal. Fruit was mostly eaten as part of a packed lunch and as a snack throughout the day.
- The number of times per week that a child consumed vegetables during the mid-day and evening meals was a more important predictor of their vegetable intake than the actual portion consumed; offering two vegetables (e.g. carrots plus peas) at dinnertime will boost vegetable intake more than offering a larger portion of a single variety. It is a combination of the amount consumed and the frequency of consumption that helps children achieve overall fruit and vegetable intake.

Among 9 year olds the Growing Up in Ireland (218) study found that 78 per cent of children had eaten at least one portion of fruit and 73 per cent had consumed at least one portion of cooked vegetables in the previous 24 hours using a frequency questionnaire.

The National Teens' Food Survey (2008)(219) (conducted in 2006/6) among 224 males and 217 females from 32 secondary schools in ROI found low intakes of fruit and vegetables among this age group. The average intake across this population per day of males and females was just over half the recommended intake (210g/day). Males aged 15-17 years were the group that consumed most vegetables (67g/day); girls aged 13-14 years had the lowest vegetable consumption (54g/day). The highest fruit consumption was boys aged 15-17 years (169g/day – just over 2 portions) the lowest was girls aged 13-14 years (133g/day). Fruit consumption was much higher than vegetable consumption, with 77 per cent of fruit intake coming from fruit juices on average among consumers of fruit. It should be noted that the data does not include fruit and vegetable intake from composite foods and is likely to underestimate the true intake among the group. The intake of different types of fruit and vegetables for the 5-17 year olds is given in Appendix F.

In the Health Behaviour of School Children (HBSC) (220) survey only 20 per cent of children aged 9-18 years reported eating vegetables more than once per day, with girls eating more than boys (22% and 19% respectively). Younger children and children from higher social classes were more likely to eat vegetable more than one time per day. Overall there was an increase in the proportion of children reporting to eat vegetables from the 2006 survey (18%).

In NI the Young Heart's Study of 1345 boys and girls aged 12 and 15 years also investigated fruit and vegetable intakes using a seven-day diary method (221). Average fruit intakes for 12 year old boys, 12 year old girls, 15 year old boys and 15 year old girls were 143, 178, 144 and 163 g/d, respectively. Average vegetable intakes were 61, 55, 70 and 59 g/d respectively.

The NDNS 2011 (222) (UK-wide) found that boys aged 11-18 years, on average, consumed 3.1 portions of fruit and vegetables per day and 13 per cent met the 'five-a-day' recommendation. Girls in the same age group consumed 2.7 portions per day and seven per cent met the recommendation.

4.5 Contribution of fruit and vegetables to nutrient intake

The NSIFCS quantified the contribution of fruit and vegetables (inclusive of composite foods) to nutrient intake of adults on IOI aged 18 to 64 years (223). These results are shown in Appendix G.

Vegetables contributed to less than three per cent of energy; 17 per cent dietary fibre (Southgate method); 63 per cent of carotene; 32 per cent of total vitamin A; 13 per cent vitamin E; 11 per cent of folate; and 24 per cent vitamin C intakes. Peas, beans and lentils were the main contributors to fibre intake, while carrots were the main contributors to vitamin C. The other major contributors to vitamin C intake were those vegetables that were classified as 'other vegetables' which included mushrooms, peppers and onions.

Results indicated that fruit contributed to less than three per cent of energy; 14 per cent sugar; 25 per cent vitamin C; and 11 per cent copper intakes per day. Fruit and citrus juices were the main contributors to vitamin C intake from fruit.

Appendix G also shows the contribution of fruit and vegetables to nutrient intakes from the NONS, NCFS and NTFS. In the pre-school years, fruit and vegetables contribute more to energy and carbohydrate intake, in particular sugar intake. However, this falls with age.

4.6 Patterns of consumption

International studies evaluating dietary patterns and their relationship to chronic disease have demonstrated that the achievement of fruit and vegetable recommendations is also clustered with other dietary recommendations such as a diet high fibre, rich in wholegrain, fish intakes, and moderate meat intakes (224).

In the US, epidemiologists have investigated dietary patterns and their association with chronic disease (225-227). The analysis of the Health Professionals Follow-up Study revealed two clear dietary patterns; the 'prudent diet' and 'western diet'.

Higher fruit and vegetable consumption is one of the characteristics of the 'prudent diet', along with higher intakes of fish, whole grains and poultry. The 'western diet' is associated with higher intakes of red meat, processed meat, refined grains, sweets and desserts. In analysis of the Framingham study, five dietary patterns emerged, with foods such as fish being a component of the 'Healthy Eating' pattern (226, 227). Similar to the previous findings, a high fruit and vegetable consumption was clustered with other positive dietary behaviours patterns.

It was found that a lower prevalence of the metabolic syndrome is associated with dietary patterns rich in fruits, vegetables, whole grains, dairy products, and unsaturated fats (228).

Lambert *et al.*, found that 7–16-year old boys in a school cafeteria setting in the UK, favoured beverages, desserts buns and cookies ten times more than fresh fruits and yoghurts (229).

Consumers with a positive attitude towards making a 'conscious effort to try and eat a healthy diet' consumed significantly greater amounts of wholemeal bread, breakfast cereals, cream, ice-cream and desserts, yoghurts, vegetables, fruit, and fish and fish dishes than respondents with negative attitudes (230).

5 Health benefits

Key findings

There is now a significant body of epidemiological evidence that links increased fruit and vegetable consumption to reduced risk of cardiovascular disease (CVD). Protective components such as fibre, folate, vitamins, potassium and other phenolic compounds may act through a variety of mechanisms such as lowering blood pressure, improving lipoprotein profile, reducing antioxidant stress and improving homeostasis regulation.

Recent research has found that a link between cancer risk and fruit and vegetable consumption is not as strong as previously thought, and many reports have come to the conclusion that the consumption of fruits in general was linked to a 'probable' decrease in the risk of cancer of the mouth and pharynx, larynx, oesophagus and stomach while allium vegetables 'probably' protect against colorectal cancer.

Diabetes is the result of the lack or insufficiency of the hormone insulin, which is responsible for regulating the circulating glucose in the blood and tissues. A consistent feature of the evidence that the WHO reviewed, in respect of diabetes, was that diets contain wholegrains in addition to fruit and vegetables were protective.

Osteoporosis affects approximately 300,000 people in ROI and 72,000 people in NI. Diet appears to have a moderate relationship to osteoporosis with calcium and vitamin D considered to be the most important elements. However, studies identifying an association between fruit and vegetable consumption and bone health are growing in number. Recent

studies have shown a positive association between fruit and vegetable consumption and improved bone mass and bone mineral content.

The prevalence of overweight and obesity has increased in recent years with two out of three adults on IOI carrying excess weight. The WHO recommends an increased consumption of fruit and vegetables, as well as legumes, whole grains and nuts to help reduce obesity at an individual level.

As the population ages, all cognitive disorders, including dementia, become more common. It is estimated that 41,700 people in ROI currently live with some type of dementia and most recent estimates for NI suggested that in 2007, 14,770 people lived with dementia. The investigation of dietary risk factors in the prevention of cognitive decline is a relatively young field of research and it is not yet certain whether increased fruit and vegetable consumption slows down the process of cognitive decline.

5.1 Introduction

Fruit and vegetables are important components of a healthy diet, and it is internationally recognised that a diet rich in fruit and vegetables can help prevent major chronic diseases including cardiovascular diseases and certain cancers (226, 231, 232).

Low consumption of fruit and vegetables (less than 400 grams per day) is thought to be one of the top ten risk factors for global mortality (233). It is estimated that 1.7 million, or up to three per cent of deaths worldwide are attributable to low fruit and vegetable consumption. Moreover, insufficient intake of fruit and vegetables is estimated to cause about 11 per cent of ischaemic heart disease deaths, about nine per cent of stroke deaths and around 14 per cent of gastrointestinal cancer deaths globally (233). In the European Union, 3.5 per cent of disease burden is considered to be due to low fruit and vegetable intake (234).

In 2001, the European Prospective Study of Cancer (EPIC) estimated that an increase in fruit and vegetable intake of just 50g/d has the potential of cutting the risk of premature death from any cause

by 20 per cent (235). The authors also estimated that consuming an extra two daily portions (160g) of fruit and vegetables could reduce the risk by as much as half.

As outlined in the previous chapter, fruit and vegetables are a rich source of many micro-nutrients, fibre and phytochemicals as well as being low in energy. It is these nutrients, either alone or in combination with each other, which contribute to the health protective effects of these foods.

Table5 1 outlines some of the key national and international disease prevention recommendations that support consumption of fruit and vegetables.

Table 5.1 National and international chronic disease guidelines

Author	Title	Guidance
World Health Organisation	Diet, Nutrition and The prevention of chronic diseases	Daily intake of fresh F&V, in an adequate quantity (400-500g per day), is recommended to reduce the risk of coronary heart disease, stroke and high blood pressure (31).
World Cancer Research Fund/ American Institute of Cancer research	Food, Nutrition, Physical Activity and the Prevention of Cancer	Eat at least five portions/servings (at least 400g or 14oz) of a variety of non-starchy vegetables and fruits every day (187).
European Society of Cardiology	2012 European Guidelines on CVD Prevention in Clinical Practice	30–45g of fibre per day, from wholegrain products, fruits, and vegetables. 200g of fruit per day (2–3 servings). 200g of vegetables per day (2–3 servings) (236).
European Commission	A Strategy for Europe on Nutrition, Overweight and Obesity-related health issues	Promotion of fruit and vegetable intake identified as a key action (237).
Department of Health, Social Services and Public Safety Northern Ireland	A Fitter Futures for All-Framework for Preventing and Addressing Overweight and Obesity in Northern Ireland 2012-2022	Eat five portions of fruit and vegetables per day (238).
Department of Health and Children, Republic of Ireland	National Cardiovascular Health Policy 2010-19	Increase by 20 per cent the proportion of adults consuming the recommended 5 or more daily servings of fruit and vegetables (from 65% to 78%) by 2014 (239).
Irish Heart Foundation	Guidelines for Heart Health	Increase in fruit and vegetable intake to be greater than 400 grams a day. Individuals should eat five portions of fruit and vegetables every day, choosing citrus fruit and their juices and green leafy vegetables regularly (240).

5.2 Cardiovascular disease

Cardiovascular disease (CVD), which includes heart disease and stroke, is one of the major contributors to lifestyle-related (non-communicable) diseases worldwide, and is the number one cause of death globally (241). In 2008, it accounted for 30 per cent of total global deaths, with 6.2 million deaths as result of stroke and 7.2 million due to coronary heart disease (CHD) (241). CVD is one of the main causes of death in NI, accounting for 28 per cent of all deaths in 2011(242). In ROI, it is the most common cause of death, with approximately 10,000 people dying each year from CVD (36 per cent of all deaths) – including CHD, stroke and other circulatory diseases (243).

CVD develops over a long period of time with the major risk factors including high blood pressure, overweight, dyslipidaemia (abnormal blood lipid levels), diabetes and low cardio-respiratory fitness. These risk factors are driven in part by unhealthy lifestyle behaviours, such as poor diet and inactivity. Such behaviours are important not only because they have been linked to CVD development, but also because they can be modified.

A number of features of a poor diet tend to occur simultaneously, and include a high intake of saturated fat, salt and refined carbohydrates, and a low intake of fruit and vegetables. A low intake of fruit and vegetables has been shown to be independently associated with an increased risk of CVD in a number of prospective and ecological studies (31, 244-248). Equally, it has also been shown that a high consumption of fruit and vegetables can have a protective role for some chronic diseases including CVD (249).

5.2.1 Role of fruit and vegetables in preventing CVD

There is now a significant amount of epidemiological evidence for the links between fruit and vegetable intake and CVD risks. Most of the evidence comes from prospective cohort studies, while randomised controlled trials (RCTs) are scarce.

A number of cohort studies have shown that the risk of CHD is decreased by high consumption of fruit and vegetables (245, 250, 251). For example, a large scale study conducted by Joshipura and colleagues showed that a high intake of fruit and vegetables was associated with a protective effect against developing CHD, especially in the case for those fruits and vegetables rich in vitamin C and leafy green

vegetables (247). Evidence also suggests that an increase in consumption of fruit and vegetables could reduce the burden of ischaemic stroke and ischaemic heart disease by as much as 19 per cent and 31 per cent respectively (252).

The effects of a diet rich in fruit and vegetables alone, and in combination with a low fat diet has also been investigated in the Dietary Approaches to Stop Hypertension (DASH) study (253, 254). The most effective diet was the combination of low fat dairy products and fruit and vegetables. However, an increase in fruit and vegetables alone was also shown to result in a small but significant reduction in blood pressure that could significantly impact on the public health risk of CVD at a population level (254).

In a six-month RCT, 690 healthy individuals were assigned either to a control group and advised to continue their dietary habits, or an intervention group where they were supported and encouraged to increase their intake of fruit and vegetables to five or more portions per day (255). A significant reduction in blood pressure, in particular systolic blood pressure was evident among the intervention group. This study also found that the mean increase in self-reported fruit and vegetables intake was 1.4 portions per day (255).

Meta-analyses conducted by Dauchet *et al.,* reported a decrease in CHD risk of four per cent for each additional portion of fruit and vegetables per day. A five per cent reduction in risk of stroke for each additional portion of fruits and vegetables has also been reported (256, 257). He *et al.,* updated these estimates by adding two extra cohorts, and reported that consumption of more than five portions of fruit and vegetables a day was associated with a 26 per cent reduced risk of stroke, while an 11 per cent reduction in risk was found in those who consumed three to five portions per day (258). Similarly, when assessing CHD risk, they found that compared with those who consume less than three portions of fruit and vegetables a day, individuals with more than five portions a day have an approximately 17 per cent reduction in CHD risk, whereas those individuals consuming three-five portions a day have smaller and borderline significant reduction in CHD risk (seven per cent reduction) (259).

5.2.2 Specific components of fruit and vegetables which may help prevent CVD

Fruit and vegetables may reduce chronic diseases by means of their protective components such as fibre, folate, vitamins, potassium and other phenolic compounds. These nutrients act through a

variety of mechanisms such as lowering blood pressure, improving lipoprotein profile, reducing antioxidant stress and improving homeostasis regulation (260-262).

Dietary fibre

Fruit and vegetables are important sources of fibre and it is well established that consumption of dietary fibre reduces the risk of CVD (236). Although the exact mechanism is not yet clarified, it is known that a high fibre intake lowers total and LDL cholesterol levels (263, 264).

Potassium

The protective effect of fruits and vegetables seems to be somewhat stronger for the prevention of stroke compared with the prevention of CHD. One of the reasons for this can be the effect of fruit and vegetables on blood pressure, based on the fact that they are a major source of potassium. In the case of stroke risk, sodium has a negative association while potassium has a positive effect on this CVD event. The fruit and vegetable contribution to the intake of these minerals is thought to be a major mechanism through which they can contribute to a lower risk of stroke (265).

Folate

Fresh vegetables and some fruit are good sources of folate. The relationship of folate to CVD has been mostly explored through its effect on homocysteine, which may itself be an independent risk factor for CHD and probably also for stroke. Folate has been shown to reduce elevated levels of the cardiovascular risk factor homocysteine through diet and supplements (266). Wald *et al.,* conducted a meta-analysis which concluded that a higher intake of folate (0.8mg folic acid) would reduce the risk of ischaemic heart disease by 16 per cent and stroke by 24 per cent (267). While this intake would be unachievable through diet alone, the contribution of folate along with other cardio-protective nutrients in a fruit and vegetable rich diet will have a greater impact on health than folic acid supplements alone.

Flavonoids

Flavonoids, which belong to the group of phytochemicals, are also found in fruit and vegetables. The WHO has indicated that the evidence to date supports a negative association between flavonoids and CVD (31). This finding is supported by a recent prospective cohort study where results suggest that high intakes of flavonoids may be associated with decreased risk of ischaemic stroke and possibly with reduced CVD mortality (268).

Supplements

A number of studies have evaluated the effect of supplemental forms of antioxidants, vitamin C and carotenoids, and also vitamin E on CVD. There was no effect on cardiovascular events with these supplements alone, indicating that it may be these vitamins in combination with the other components of fruit and vegetables that confer the beneficial effects (269, 270).

Overweight and obesity

Overweight and obesity are also key risk factors for CVD. Fruit and vegetables are low energy (calories) dense and low-fat foods, and thus can play a crucial role in regulating calorie intake. Inclusion of five or more portions of fruit and vegetables a day can reduce the energy density of a diet without reducing bulk. This is particularly pertinent given the rapid rise in overweight and obesity worldwide (271).

5.3 Cancer

Cancer is a leading cause of death worldwide, accounting for 7.6 million deaths or around 13 per cent of all deaths in 2008 (272). One in three people in the ROI will develop cancer during their lifetime with an average of 30,000 new cases of cancer diagnosed each year. This number is expected to rise to over 40,000 per year by 2020 (273). In NI, cancer was one of the main causes of death in 2011, causing 4,059 deaths or 29 per cent of all deaths – the largest number of cancer deaths on record. The proportion of

all deaths due to cancer has increased in NI from 18 per cent in 1981 to 29 per cent of all deaths in 2011 (242).

Tobacco use, alcohol use, unhealthy diet and physical inactivity are the main cancer risk factors worldwide. More than 30 per cent of cancer deaths could be prevented by modifying or avoiding these key risk factors, and while tobacco use is the single greatest avoidable risk factor for cancer mortality worldwide, dietary modification is considered to be another important approach to cancer control. (274).

5.3.1 Role of fruit and vegetables in preventing cancer

Recent research into the association of fruit and vegetable consumption and cancer risk has shown that the link is not as strong as previously thought. During the 1990s, it was believed there was convincing evidence that high consumption of fruit and vegetables decreased the risk of certain cancers; 'for most cancer sites, persons with low fruit and vegetable intake experience about twice the risk of cancer compared to those with a high intake, even after control for potentially confounding factors' (275). However, recent research has not been able to conclusively establish an inverse association between fruit and vegetable consumption and overall cancer risk (276).

In November 2007, the World Cancer Research Fund Global Network published its expert report on the links between lifestyle and cancer risk. They found that consumption of fruits in general was 'probably' associated with a decreased risk of cancer of the mouth, pharynx, larynx, oesophagus, lung and stomach. Consumption of non-starchy vegetables was also found to 'probably' be associated with a decreased risk of cancer of the mouth and pharynx, larynx, oesophagus, and stomach. Allium vegetables such as garlic, onion, leeks and scallions, etc., probably protect against stomach cancer, while garlic was found to 'probably' protect against colorectal cancer (277). Refer to Table 2 for more information.

Table 5.2 Fruit and vegetables and cancer risk

Exposure	Cancer site	Decreased risk
Non-starchy vegetables[1]	Mouth Pharynx Larynx Oesophagus Stomach	Probable
Allium vegetables[1]	Stomach	Probable
Garlic[1]	Colorectum	Probable
Fruits[1]	Mouth Pharynx Larynx Oesophagus Lung Stomach	Probable
Foods containing folate[2]	Pancreas	Probable
Foods containing carotenoids[2]	Mouth Pharynx Larynx Lung	Probable
Foods containing beta-carotene[2]	Oesophagus	Probable
Foods containing lycopene[2 3]	Prostate	Probable
Foods containing vitamin C[2 4]	Oesophagus	Probable
Foods containing selenium[2 5]	Prostate	Probable
Non-starchy vegetables[1]	Nasopharynx Lung Colorectum Ovary Endometrium	Limited - Suggestive
Carrots[1]	Cervix	Limited - Suggestive
Fruits[1]	Nasopharynx Pancreas Liver Colorectum	Limited - Suggestive
Pulses (legumes)[7]	Stomach Prostate	Limited - Suggestive
Foods containing folate[2]	Oesophagus Colorectum	Limited - Suggestive
Foods containing pyridoxine[2 8]	Oesophagus	Limited - Suggestive
Foods containing vitamin E[2 6]	Oesophagus Prostate	Limited - Suggestive

Foods containing selenium[2 5]	Lung Stomach Colorectum	Limited - Suggestive
Foods containing quercetin[2]	Lung	Limited - Suggestive

1 Judgements on vegetables and fruits do not include those preserved by salting and/or pickling.

2 Includes both foods naturally containing the constituent and foods which have the constituent added (see Chapter 4.2).

3 Mostly contained in tomatoes and tomato products. Also fruits such as grapefruit, watermelon, guava, and apricot.

4 Also found in some roots and tubers — notably potatoes. See Chapter 4.1.

5 Also found in cereals (grains) and in some animal foods. See chapters 4.1 and 4.3.

6 Also found in plant seed oils. See Chapter 4.5.

7 Including soya and soya products.

8 Vitamin B6. Also found in cereals. See Chapter 4.2.

This is in line with the 2003 review by the WHO. The review concluded that there is 'probable evidence' for oral cavity, oesophagus, stomach and colorectal cancers for a decreased risk with fruit and vegetable intake. The data that has emerged since the 2003 WHO report has not provided any clearer answers (278). A series of analyses that pooled data from prospective studies for specific cancer sites confirmed the weak and non-statistically significant associations (279, 280).

A number of explanations for the data inconsistencies have been put forward; these include methodological issues, changes in population exposures over time and the fact that cancer is a diverse range of diseases (278). Early studies may also have been prone to certain biases due to, for example, using case-controlled study designs, misreporting 'usual diets' and a greater proportion of 'health conscious' respondents being represented.

While recent research indicates that efforts to increase consumption of fruits and vegetables will not have a major effect on cancer incidence, efforts are still worthwhile because they will reduce risks of CVD and a small benefit for cancer remains possible.

5.3.2 Specific components of fruit and vegetables which may help prevent cancer

This weak association between fruits and vegetables and the risk of cancer does not discount the possibility that one or a small group of fruits or vegetables, or indeed a specific substance in some of these foods, has an important protective effect (281).

The mechanisms through which fruit and vegetables may contribute to reduction of cancer risk are attributed to their micronutrient, fibre and phytochemical content. Fruits and vegetables contain many nutrients and compounds, and because of the nature of this composition, it is difficult to identify which chemical(s) help prevent cancer, and to pinpoint their mode of action (31, 277).

Many studies have investigated individual components of fruit and vegetables as risk factors for certain cancers. There is considerable evidence that various carotenoid types probably protect against lung, prostate, esophageal, mouth, pharynx, and larynx cancers. Research suggests that lycopene, selenium, folate and tomato products may reduce the risk of prostate cancer, while folate may also have a role in protecting against colorectal and esophageal cancer (277).

The link between cancer and fruit and vegetables still requires further investigation.

5.4 Type II diabetes

It is estimated that 347 million people worldwide have diabetes (282). In 2010, it is estimated that over 135,000 (8.9 per cent) of adults aged 45+ years in ROI have diabetes. More than 12,000 (0.7 per cent) of adults aged 18-44 years in ROI have clinically diagnosed diabetes in 2010 (283). By 2020, the number of adults aged 45+ years with diabetes is expected to rise to more than 175,000 (9.1 per cent) representing a 30 per cent increase in ten years (283). In NI, in 2010, the number of adults aged 18+ years living with clinically diagnosed diabetes is estimated to be almost 55,000 (4.0 per cent). By 2020, this number is expected to rise to almost 66,000 (4.4 per cent), an increase of an additional 20 per cent (283).

Diabetes is the result of the lack or insufficiency of the hormone insulin which is responsible for regulating the circulating glucose in the blood and tissues. Type I diabetes is characterised by partial or total failure of the beta-cells in the pancreas to produce insulin and normally develops suddenly in children and young adults. The more common form of diabetes, type II, is characterised by insulin resistance resulting from production of insufficient or ineffective forms of insulin. The latter form is

associated with obesity and poor lifestyle behaviours, and develops slowly appearing more commonly in middle to later life. In more recent times type II diabetes has become more common and evident in younger people and children (282, 284). Healthy diet, regular physical activity, maintaining a normal body weight and avoiding tobacco use can prevent or delay the onset of type II diabetes.

Type II diabetes can result in devastating health consequences. In addition to the micro-vascular complications such as retinopathy and nephropathy, the disease increases the risk of cardiovascular disease. Abnormal lipid levels and high blood pressure, two of the major risk factors for CVD, are associated with type II diabetes.

5.4.1 Role of fruit and vegetables in preventing diabetes

The nutritional management of both type I and type II diabetes involves a diet where the consumption of five or more portions of fruit and vegetables is fundamental (285). The WHO recommends that to prevent or delay the onset of type II diabetes, a healthy diet of between three and five servings of fruit and vegetables a day should be followed (282). A diet containing 45 to 60 per cent carbohydrate, mainly derived from complex, fibre rich foods with a low glycaemic index (i.e. foods that contain carbohydrates which are released more slowly into the blood stream, which means that blood sugar levels stay steady) such as starchy cereal foods, fruits and vegetables, is recommended. This control of carbohydrate intake allows control of blood glucose levels. In addition to the management of blood glucose levels, abnormal lipid levels occur in diabetes. Soluble fibre has a small beneficial effect on blood lipid levels.

The WHO reviewed the evidence for a role of the diet in the development of type II diabetes (31). It concluded that there is probable evidence that dietary fibre plays a protective role in the prevention of type II diabetes. The 'probable' rather than 'convincing' conclusion was drawn due to the lack of clarity of the different roles of soluble and insoluble fibre.

A consistent feature of the evidence that the WHO reviewed in respect of diabetes was that diets contained wholegrains in addition to fruit and vegetables. Consequently one of the key recommendations for diabetes prevention that the WHO makes is the achievement of dietary fibre (minimum of 20g/d) through consumption of wholegrains, fruits and vegetables. Fruit and vegetables are a major source of fibre in the diet on IOI (210).

A review conducted in 2007 found that consumption of three of more portions of fruit and vegetables a day was not associated with a substantial reduction in the risk of type II diabetes (286). However this review was restricted by language and searched only a small number of electronic databases. Results

from a more recent meta-analysis concluded that increasing the amount of green leafy vegetables in an individual's diet could help reduce the risk of type II diabetes. Results suggest that an increase of 1.15 servings a day was associated with a 14 per cent decrease in incidence (287).

5.5 Osteoporosis

Osteoporosis is a disease affecting millions of people worldwide (31). In ROI, it is estimated that 300,000 people have osteoporosis, with one in five men and one in two women over 50 years developing a fracture due to osteoporosis in their lifetime (288). In NI, it is estimated that 72,000 people suffer from osteoporosis with the combined cost of hospital and social care for patients with a hip fracture estimated to be £65 million (289).

Osteoporosis is a disease of the skeleton where there is low bone mass and deterioration of the structure of the bone resulting in increased susceptibility to fracture. The condition often goes undiagnosed until later in life when a fracture occurs and results in reduced mobility and loss of independence. Osteoporosis is more common in women than men due to the accelerated bone loss that occurs around the menopause. It is estimated that globally one in three women and one in five men aged greater than 50 years will have osteoporosis in their lifetime (290-292).

Bone is a very metabolically active organ and up until the time of attainment of peak bone mass in the third decade of life, the process of bone formation exceeds that of bone resorption (removal of calcium from bones). After this point the balance between these two processes switches in favour of bone resorption and results in bone loss. Strategies for osteoporosis prevention focus not only on decelerating bone loss in middle to later life, but also on the attainment of as high a peak bone mass as possible. The majority of peak bone mass occurs in adolescence.

5.5.1 Fruit and vegetable and lower risk of osteoporosis

Diet appears to have a moderate relationship to osteoporosis, with calcium and vitamin D considered to be the most important elements, at least in older populations. Many other nutrients and dietary factors may also be important for long-term bone health and the prevention of osteoporosis. The association between fruit and vegetable consumption and markers of bone health was first identified

in older populations (293-295). More recent studies have shown a positive association between fruit and vegetable intake and the attainment of peak bone mass in children and young people (221, 296-298).

In a study evaluating the association between fruit and vegetable intake and bone mineral status, a positive association in adolescent boys and girls and older women aged 60-83 years was found. The size of the effect in the older women was impressive; doubling the fruit intake would have resulted in a five per cent increase in spine bone mineral content (299). Similar results were found in a recent systematic review which looked at fruit and vegetable intake and bone health in women aged 45 years and over; the study found that fruit and vegetable intake is beneficial to bone health, however, it does not outweigh the negative effects of hormonal changes in later years (300). A three-month DASH intervention study also found that a diet high in fruit and vegetables significantly reduces bone turnover (301).

The WHO has concluded that there is 'possible evidence' that fruit and vegetable intake is a protective factor in osteoporosis, and advise that increasing their consumption may prove helpful in terms of reducing fracture risk (31).

As the evidence for a beneficial effect of fruit and vegetable on bone health is growing, there is increased research interest in the mechanisms driving the association. Fruit and vegetables are major food contributors of magnesium and potassium, which may help in maintaining an acid-base balance, as well as vitamin C, carotenoids, and other food constituents that may contribute to antioxidant protection. One popular theory is that fruit and vegetables provide alkaline salts of potassium that balance the acidity of a westernised diet rich in protein (293). It is known that bone has the potential to release potassium to balance circulating acidity and this theory proposes that fruit and vegetable derived potassium protects bone from losing its own store of the mineral.

Other protective mechanisms include the beneficial effects of key nutrients found in fruit and vegetables, including folate and vitamin K and non-nutrient compounds such as phytoestrogens and flavanoids. In an observational study, flavonoid intakes and bone mineral density were analysed; it was found that there was positive associations between the two, however, they are not strong and should be considered only as indicators (302). It is likely that the combined effect of all these factors plays a role in contributing to the beneficial effects of fruit and vegetables on bone health.

5.6 Overweight and obesity

Internationally, the prevalence of overweight/obesity has increased steadily in recent years. Worldwide, the WHO estimates that more than 22 million children under the age of five years are obese, and that by 2015, about 2.3 billion adults will be overweight and 700 million people will be classified as obese (303). This rise in prevalence is associated with increasing rates of the co-morbidities such as cardiovascular disease, cancer and diabetes. Two out of three adults on IOI are carrying excess weight (304, 305).

There is convincing evidence that a high dietary intake of fibre (most specifically NSP) is a factor in protecting against weight gain and obesity, as well as being an effective weight loss strategy (31).

The WHO recommends an increased consumption of fruit and vegetables, as well as legumes, whole grains and nuts to help reduce obesity at an individual level (303). Fruit and vegetables are rich in water and fibre, and low in energy density, therefore their consumption has been proposed as an obesity prevention strategy (31, 306, 307). They also may reduce the risk of obesity, due to the displacement of energy-dense foods or the satiating effect of fibre, resulting in fewer calories consumed (308, 309). Previous reviews have come to conflicting conclusions (310-312). A recent systematic review on fruit and vegetable consumption on adiposity concluded that an inverse relationship between fruit and vegetable intake and adiposity among overweight adults appears weak, while this relationship among children is unclear (313).

The WHO and national and regional recommendations for the prevention of overweight and obesity include the promotion of fruit and vegetables among adults and children.

5.7 Cognitive decline

As our populations age, all cognitive disorders, including dementia, become more common. There are many types of dementia, the most common being Alzheimer's disease and vascular dementia. As of yet, there is no known treatment that can stop or cure its progression because the pathophysiology is complex and still largely unclear. In ROI, there are currently over 41,700 people living with dementia and this is expected to rise to 147,000 by 2041. It is estimated that approximately 4,000 cases of dementia are identified in ROI each year (314). In the UK, there are approximately 800,000 people

living with dementia and the most recent data estimates that in 2007 there were 14,770 people living with dementia in NI 2007 (315).

Although diet is one of the few preventative risk factors that affects all persons and, for the most part, is under the individual's control, the investigation of dietary risk factors in the prevention of cognitive decline is a relatively young field of research. In recent years, different food groups, especially fish and dietary fat, have been shown to be associated with cognition (316). It is not yet certain whether increased fruit and vegetable intake slows down the process of cognitive decline, and this is due to a limited number of studies and these study findings being inconsistent.

The Mediterranean Diet (MeDi) has received a lot of attention in recent years because of evidence relating it to lower risk for cardiovascular disease (317), several forms of cancer (318), and overall mortality (319). It is also believed to include many of the components reported as potentially beneficial for cognitive decline and that higher adherence to the MeDi is associated with reduced risk for Alzheimer's Disease (320). This association may be mediated by the composite effect of some of its beneficial components, such as higher intake of fish (321, 322), fruits, and vegetables rich in antioxidants such as vitamin C (323-326), vitamin E (323-328) and flavonoids (329) and higher intake of unsaturated fatty acids (321, 330).

For fruit and vegetable intake specifically, consumption of fruit and vegetables as a whole have been found to be positively associated with cognitive performance (331) and memory function (332). Results from a recent systematic review suggest that increased intake of vegetables is associated with a lower risk of dementia and slower rates of cognitive decline in older age. The association between increased fruit intake and dementia however is still not conclusive (333).

Similarly, Morris *et al.,* investigated the association between rate of cognitive change and dietary consumption of fruits and vegetables (334). Findings showed that high vegetable (especially green leafy vegetables), but not fruit, consumption may be associated with slower rate of cognitive decline with older age over a six-year period. Comparable results were previously observed in the Nurses' Health Study (335). In both studies, higher intakes of fruits and vegetables and consumption of fish at least once a week were associated respectively with reduced risk of cognitive decline or dementia.

Further research is needed to verify findings before recommendations can be made.

5.7.1 Obesity and cognitive decline

Cognitive decline and obesity are public health problems that are rapidly increasing and cause a significant burden of disease. Results of a recent meta-analysis, which aimed to investigate the relationship between body mass index and dementia, found that underweight, overweight and obesity in midlife is associated with increased dementia risk later in life. Authors concluded that normal BMI in midlife confers the lowest risk of dementia, while obese BMI in midlife confers the greatest risk (336). The results of this review are similar to those of other systematic reviews conducted over the last decade (337, 338). Furthermore, a recent prospective cohort study which examined the association of BMI and metabolic status in midlife with cognitive function and decline found that cognitive decline over a 10-year period was similar in all participants, although participants who were both obese and had metabolic abnormalities showed the greatest decline (339). Further research to understand optimal weight, biological mechanisms as well as later-life BMI and cognitive decline is required.

While obesity's influence on cognitive decline remains relatively poorly understood, the maintenance of a normal weight, of which adequate consumption of fruit and vegetables play a key role, throughout one's lifespan is a worthwhile intervention for the prevention of cognitive decline.

6 Legislation, labelling and other issues

Key findings

In 2008, the Commission Regulation (EC) No. 1221/2008 repealed 26 of the 36 specific marketing standards. This meant that the 36 standards which were defined by 34 regulations were replaced by a single regulation for 10 specific standards in addition to one general marketing standard. Fruit and vegetables not covered by a specific standard must meet the general standard – or the applicable UNECE standard.

The nutrition labelling of foodstuffs is governed by Council Directive 90/496/EEC, as amended. This piece of legislation states that nutrition labelling is compulsory when a health claim is made. In this instance, and in other instances where nutrition labelling is provided voluntarily, the information given must consist of one of two formats - group one (the 'Big Four') or group two (the 'Big Eight').

In ROI and NI, the EU Food Information for Consumers Regulation (No. 1169/2011) has been published in the Official Journal of the European Union. This means that the transition process has begun to replace the current food labelling regulations. The transitional arrangements mean that most of the requirements do not apply until 2014, with nutrition labelling becoming mandatory in 2016, allowing food business time to become accustomed to the new labelling requirements.

FSAI has a clearly defined food safety training policy (340). It established the Food Safety Training Council (FSTC), which comprises representatives from education and training, the

food industry, and inspectors from the official agencies with responsibility for food safety, such as health boards and local authorities. The FSAI, with input from the FSTC, has set training standards for the foodservice, retail, and manufacturing sectors. These standards are outlined in a series of food safety training guides covering three levels of skills: induction, additional, and for management. In NI, the FSA recommends three levels of training for food handlers: foundation, intermediate, and advanced. FSA does not provide a database of training providers in NI but recommends three professional bodies for food safety training: the Chartered Institute of Environmental Health (CIEH), the Royal Institute of Public Health (RIPH), and the Royal Society for the Promotion of Health (RSPH).

Organic food constitutes a relatively small but growing part of the food supply chain on IOI. In Ireland, approximately 85 per cent of organic foods are sold via supermarkets with the remaining 15 per cent through more direct channels such as famers markets, farm shops and box deliveries. Fruit and vegetables comprise the largest organic food type.

A new EU logo was introduced in July 2010 on all pre-packaged organic food products produced in EU member states. A two-year transition period allowed industry to adapt product packaging before the logo became compulsory on July 1st 2012. The 'Euro-leaf' remains optional for non-packaged and imported organic products.

6.1 Introduction

The following chapter covers other aspects of the food safety continuum, including labelling, quality assurance schemes, and training, which have not been discussed in earlier sections.

6.2 Labelling

Labelling allows consumers to make informed decisions about the food they eat and also builds confidence in products. The general labelling of fresh produce (and indeed all food products) is

governed by Council Directive 2000/13/EC on the Labelling, Presentation and Advertising of Foodstuffs, and by Council Regulation (EC) No. 2200/1996 which lays down marketing standards for quality and labelling of fresh fruit and vegetables.

6.2.1 General food labelling requirements

Council Directive 2000/13/EC sets out general provisions on the labelling of pre-packaged foodstuffs to be delivered to the ultimate consumer. Sale of loose (over the counter), non-prepackaged food (when it is packaged on the premises from which it is to be sold), is governed by Article 14 of Directive 2000/13/EC. This legislation permits individual MS to decide what labelling information needs to be shown, and how it should be displayed, subject to the condition that the consumer still receives sufficient information. The only requirement for foods sold loose specified on IOI is that the name of the product must be given.

Directive 2000/13/EC is implemented in ROI by the European Communities (Labelling, Presentation and Advertising of Foodstuffs) Regulations 2002 (S.I. No. 483 of 2002) and in NI by the Food Labelling Regulations (NI) 1996 (SR NI 1996 No. 383), as amended. Enforcement of this legislation lies with the FSAI in ROI and District Councils in NI.

Directive 2003/89/EEC, amending Directive 2000/13/EC, concerns the labelling of allergens in foodstuffs. This legislation requires food manufacturers to indicate the presence of potential allergens (from a list of 14 as laid down in the Directive) if they are used as ingredients in pre-packed foods, including alcoholic drinks, regardless of their quantity. Celery is currently one of the fourteen specific allergens listed for inclusion on product labelling.

In 2006, the European Commission introduced new legislation to harmonise the way nutrition and health claims are made across the EU. The Regulation (Regulation (EC) No. 1924/2006) of the European Parliament and of the Council of 29th December 2006 on nutrition and health claims made on foods), is in force since January 1st 2007. EC Regulation No. 1924/2006 is implemented in NI by the Nutrition and Health Claims Regulations (Northern Ireland) 2007.

6.2.2 Specific fruit and vegetable labelling requirements

In 2008, the Commission Regulation (EC) No. 1221/2008 repealed 26 of the 36 specific marketing standards. This meant that the 36 standards which were defined by 34 regulations were replaced by a single regulation for 10 specific standards, in addition to one general marketing standard. The general marketing standard introduces a definition of "sound, fair and of marketable quality" for certain fruits and vegetables and requires them to bear the full name of their country of origin (Table 6.1) (European Commission, 2012). Fruit and vegetables not covered by a specific standard must meet the general standard – or the applicable UNECE standard (341).

Table 6.1 Fresh fruit and vegetables covered by the general marketing standard

Class	Fruit	Veg
Products covered by specific standards	Apples, citrus fruit, kiwifruit, peaches and nectarines, pears, strawberries and table grapes.	Lettuces, curled-leaved and broad-leaved endives, sweet peppers and tomatoes.
Products no longer covered by specific standards	Apricots, cherries, melons, plums and watermelons.	Artichokes, asparagus, aubergines, avocados, beans, brussels sprouts, carrots, cauliflower, courgettes, cucumbers, cultivated mushrooms, garlic, headed cabbages, leeks, chicory peas, ribbed celery, spinach and onions.
Products exempt from specific standards	National authorities can exempt products (e.g. misshapen, under-sized) from specific marketing standards if they are labelled "*products intended for processing*" or "*for animal feed*" or any other equivalent wording.	

Every EU country is required to set up a database of traders that market fresh fruit and vegetables covered by the marketing standards. The national authorities must also ensure that checks are carried out selectively, based on risk analysis and with appropriate frequency, to ensure compliance with the standards and other statutory requirements for marketing fruit and vegetables (57).

When imported from non-EU countries, customs may only accept import declarations for products subject to specific marketing standards if:

- The goods are accompanied by a conformity certificate, or
- The Department of Agriculture, Food and the Marine has informed Customs that the lots concerned have been issued with a conformity certificate, or
- The Department of Agriculture, Food and the Marine has informed Customs that the lots concerned do not need to be checked in the light of the Department's risk assessment. In this situation the lot must be accompanied by an invoice or document indicating the name and the country of origin of the product(s) and, where appropriate, the class, the variety or commercial type (if required by the relevant specific marketing standard), or the fact that it is intended for processing.

Countries whose checks on conformity have been approved are listed in Annex IV (Appendix) of Commission Regulation (EC) 1580/2007 (as amended). The General Marketing standard covers all fruit and vegetables listed in Part IX to Annex I of Commission Regulation (EC) No 1234/2007.

The marketing standards stipulate that produce of all quality classes (Class I, Class II, and Extra Class – the latter applies to selected products only) must be sound, clean and of marketable quality. The person selling or offering the produce for sale must ensure that the produce is placed in the correct quality class. It is their responsibility to re-grade or downgrade to a lower quality class any product, which may have deteriorated while in stock. If only a few items of produce from a batch have deteriorated, then the retailer may opt to remove the deteriorated items rather than downgrade the entire batch to a lower quality class (see Appendix G for further information).

The standards also state that each container or display of produce is clearly marked with the correct information regarding quality class, origin and, in certain cases, variety (Table 6.2).

Table 6.2 Information required on the label

Packer and/or dispatcher identification
Nature of produce (if not visible)
Origin of produce
Commercial specifications - quality class, size (if applicable, weight or number of units
Official control marking (optional)
Name of seller within the EU
Date of minimum durability
Packed in a modified atmosphere (if applicable)

This information is usually marked on the packages in which the fresh produce is supplied. Specific requirements are laid down for product which is sold (i) loose, (ii) in original packing, and (iii) in pre-packs.

6.2.2.1 Product sold loose

Products may be presented unpackaged (loose) provided that the retailer displays (at point of sale) a card showing, prominently and legibly, the information particulars specified in the quality standards relating to variety, origin of the product and class. Individual loose products are not required to display a label.

6.2.2.2 Products sold in original packing

All packages must be labelled with all of the information required. In the case of packer/dispatcher identification, it is permissible to use either the name or address of the packer and/or dispatcher, or an officially issued or accepted code representing the packer, and/or dispatcher indicated in close connection with 'packer and/or dispatcher'.

6.2.2.3 Produce sold in pre-packs

All pre-packs must display all of the required information and also the net weight or number (if not clearly visible). The packer and/or dispatcher must be identified on the pre-pack using either the name and address of the packer and/or the dispatcher, or the name and address of a seller established within the Community indicated in close connection with the mention 'packed for'. An officially issued code representing the packers name and address must also be included.

The marketing standards do not apply to processed or prepared fresh produce. This legislation is given effect in ROI by the European Community (Fruit and Vegetables) Regulations 1997 (S.I. 122 of 1997) and in NI by the Food Labelling (Amendment) Regulations (NI) 1998 (as further amended).

Additional legislation pertaining to the marketing of fresh fruit and vegetables is outlined in Table 6.3.

Table 6.3 Other legislation pertaining to the marketing of fresh fruit and vegetables

Legislation	Concerning
Commission Regulation 1148/2001	On checks on conformity to the marketing standards applicable to fresh fruit and vegetables.
Commission Regulation 1135/2001	Amending the provisions concerning sizing, presentation and labelling laid down in the marketing standards for certain fresh vegetables and amending Regulation (EC) No. 659/97.
Commission Regulation 48/2003	Laying down the rules applicable to mixes of different types of fresh fruit and vegetables in the same sales package.
Commission Regulation 907/2004	Amending the marketing standards applicable for fresh fruit and vegetables with regard to presentation and labelling. This regulation sets out marketing standards for fresh and processed fruit and vegetables. Provisions for a management committee that apply to the fruit and vegetable sector as well as a range of other agricultural products came into effect on the 1st January 2008. Traders offering fresh fruit or vegetables for sale are responsible for ensuring the product meets minimum quality requirements and is correctly as well as clearly labelled with the required information.
Commission Regulation 1234/2007	An amendment of Regulation Commission 1580/2007 which lays down implementation rules for the fruit and vegetable sector, including marketing standards, from July 1st 2009.
Regulation Commission 1221/2008	Regulation (EC) No 1221/2008 has introduced the new implementing rules regarding marketing standards and associated checks, following the reform of the common market organisation for the fruit and vegetables sector.
Commission Regulation 543/2011	Specific marketing standards are set down for certain fruits and vegetables which outline the minimum quality requirements, classification criteria and in certain instances, set presentation provisions. This regulation reduced the number of specific marketing standards from 36 to 10 while it also contains a general marketing standard which applies to other fruit and vegetables.

Adapted from (342, 343)

6.2.3 Nutrition labelling

The nutrition labelling of foodstuffs is governed by Council Directive 90/496/EEC, as amended. This piece of legislation states that nutrition labelling is compulsory when a health claim is made. In this instance, and in other instances where nutrition labelling is provided voluntarily, the information given must consist of one of two formats - group one (the 'Big Four') or group two (the 'Big Eight'). Group one consists of energy value, protein, carbohydrate and fat, while group two consists of the latter four, plus sugars, saturates, fibre, and sodium. Nutrition labelling may also include starch, polyols, mono-unsaturates, polyunsaturates, cholesterol and any minerals or vitamins that are listed in the legislation.

Nutrition information must be given 'per 100g or 100ml'. It may also be given 'per serving size', provided that the serving size is also stated. This piece of legislation applies to prepackaged foodstuffs to be delivered to the ultimate consumer, and also foodstuffs intended for supply to 'mass caterers', i.e. restaurants, hospitals, canteens, etc. It does not, however, apply to non-prepackaged foodstuffs packed at the point of sale at the request of the purchaser, or prepackaged with a view to immediate sale.

Nutrition labelling on a food is only compulsory if a nutrition claim, such as 'high in vitamin C', is made on the label. When nutrition information is placed on a label it must adhere to the rules set out in the food labelling legislation.

A list of approved health claims and conditions for their use, rejected health claims, and permitted nutrition claims have been published by the European Commission, and are listed in the Community Register (see Important Information for Food Business Operators below). Health claims not appearing on the authorised list can no longer be used after 14th December 2012 (344).

In ROI and NI, the EU Food Information for Consumers Regulation (No. 1169/2011) has been published in the Official Journal of the European Union. This means that the transition process has begun to replace the current food labelling regulations. The transitional arrangements mean that most of the requirements do not apply until 2014, with nutrition labelling becoming mandatory in 2016, allowing food business time to become accustomed to the new labelling requirements. The responsibility for the Food Information for Consumers Regulations (FIR) varies across the UK. In Scotland and Northern Ireland, the FSA has retained responsibility for all aspects of general food labelling and nutrition labelling policy, including liaison with district councils, while the FSAI retained responsibility in ROI.

6.3 Quality assurance schemes

6.3.1 Bord Bia quality assurance scheme

Two quality assurance schemes for horticultural produce have been developed in ROI by Bord Bia, in conjunction with the FSAI, DAF and industry representatives. A quality assurance scheme, for a food product, is a programme whereby the foods are produced to a set of standards and the producer/processor is inspected to ensure that production is in accordance with those standards (345). The standards were developed in response to consumer concerns and also to assist producers in complying with the relevant legislation. They are based on a number of criteria, including relevant national and EU legislative requirements, and also recognised international quality management systems.

Membership of the schemes is voluntary. Certification to the standard, however, is only granted to processors who meet the relevant requirements and demonstrate on-going compliance in subsequent audits. Audits are conducted independently by the National Standards Authority of Ireland (NSAI). Certification to the standard entitles the producer to use the Bord Bia quality symbol for horticultural produce.

Requirements of the standard are overseen by a Technical Advisory Committee, while a Horticultural Certification Committee makes decisions as to whether to grant or renew, extend, refuse or withdraw certification.

6.3.1.1 Prepared vegetables standard

This standard details the requirements for food business operators involved in the preparation and packaging of raw, pre-cut vegetables (ready-to-use) for human consumption, and is open to all prepared fruit and vegetable food business operators. The primary objectives of this standard are:

- To set out the requirements for best practice in prepared fruit and vegetable production
- To provide a uniform mechanism for recording and monitoring quality assurance criteria with a view to achieving continuous improvement in production standards

- To underpin the successful marketing of quality assured prepared fruit and vegetables (345).

Bord Bia can remove samples of produce for the purposes of testing by an independent laboratory, to determine compliance with the requirements of the standard. This testing may include microbial and chemical analysis and any other tests as recommended by Bord Bia's technical advisors.

The standard comprises of five main areas:

1. Quality System Core Elements (including quality policy; records; training; HACCP and GMP plans; product identification, traceability and labelling; and product recall)
2. General Hygiene and GMP (including microbiological cross contamination; and pest control)
3. Environmental Hygiene
4. Personal Hygiene
5. Plant and Facilities (including water requirements).

6.3.1.2 Bord Bia specification for horticultural producers

The Bord Bia Specification for Horticultural Producers (345) covers a number of key areas such as cropping practices, quality and hygiene standards in relation to personnel and premises, packhouse, cool chain facilities, crop protection products usage and storage, record keeping, maintaining appropriate documentation, traceability, and implementing environmentally friendly practices.

6.3.2 Assured produce scheme

The Assured Produce Scheme is a wholly owned subsidiary of Assured Food Standard for the production of assured fruit, salads and vegetables. It is an industry-wide initiative designed to maintain consumers' confidence in the safety and integrity of the produce they eat, and has been awarded UKAS accreditation. The scheme is owned by the Assured Produce Company Ltd, a non-profit making company which is comprised of two main bodies: the Assured Produce Scheme Board and the Assured Produce Scheme Council. The Board and Council are made up from representatives of the UK supermarkets, growers, processors and the National Farmers' Union (346).

The scheme involves registering the crops grown, followed by the completion of the Self-Assessment Questionnaire (SAQ), and a visit to the farm by a certifier to verify that the requirements are being met. The scheme licences a number of independent certification bodies to carry out audits. Every member of the scheme is verified once every year (346).

The general standard and individual crop protocols are developed and revised annually by authors with specialised knowledge of the crop. This ensures that the consumer benefits from the investment and work undertaken by growers in meeting the standards (346).

6.4 Training

Food handlers must receive training in food hygiene in accordance with the Hygiene Package, specifically Regulation 852/2004 on the hygiene of foodstuffs (please refer to Section 3.2.3.3). This is the case for all staff, part-time, full-time or casual, or whether they are employed in the public or private sector. From the 1st of January 2006, staff responsible for the development and maintenance of the food business's Hazard Analysis Critical Control Point (HACCP) system must have received adequate training in the application of the HACCP principles. There is, however, no legal requirement for other individuals to undergo certified training programmes (347)

Due to the growing number of foreign nationals in the horticultural workforce on IOI, there is a need for training in a number of languages. Training is a major focal point in quality assurance schemes, and also in quality standards such as British Retail Consortium, EFSIS and ISO 22000. Better Training for Safer Food is a European Commission training initiative covering food and feed law, animal health and welfare and plant health rules. It trains European Union member state and candidate country national authority staff involved in official controls in these areas. The programme aims to keep participants up-to-date with European law and should help to ensure more harmonised and efficient controls. The workshops centre around the following topics:

- Food Contact Material – basic and advanced
- HACCP implementation and assessment
- Food hygiene and controls - Meat and meat products
- Milk and dairy products
- Fishery products and live bivalve molluscs

- Baby food
- Regulation 669/2009
- Feed law
- Food additives and the control of their use and marketing
- EC 'Better Training for Safer Food initiative': Training courses on Risk Assessment (348).

In NI, the FSA recommends three levels of training for food handlers: foundation, intermediate, and advanced. FSA does not provide a database of training providers in NI but recommends three professional bodies for food safety training: the Chartered Institute of Environmental Health (CIEH), the Royal Institute of Public Health (RIPH), and the Royal Society for the Promotion of Health (RSPH). In addition, CAFRE (College of Agriculture, Food and Rural Enterprise) provide full-time and part-time courses in horticulture on their Greenmount campus, where students develop practical, technical and management skills.

6.4.1 Republic of Ireland

FSAI has a clearly defined food safety training policy (340). It established the Food Safety Training Council (FSTC), which comprises representatives from education and training, the food industry, and inspectors from the official agencies with responsibility for food safety, such as health boards and local authorities. The FSTC advises the FSAI on the contribution to food safety through training, on agreeing levels of skills required for best practice in food safety, and agreeing guidelines for assessing the impact of food safety training in the work environment. The FSAI, with input from the FSTC, has set training standards for the foodservice, retail, and manufacturing sectors. These standards are outlined in a series of food safety training guides covering three levels of skills: induction, additional, and for management.

The FSAI has published a Guidance Note on the Inspection of Food Safety Training and Competence (No. 12), the purpose of which is to establish a consistent approach to the inspection of the training and competence of operational staff dealing with food, and provide advice to food businesses in relation to training.

Bord Bia and Teagasc are involved in training initiatives with people working in the horticultural sector on ROI. Bord Bia provides assistance to the industry in terms of recruiting staff internationally to

alleviate labour shortages which threaten the industry. Teagasc provides a number of third-level and further education courses in horticulture. These courses take place in a number of locations including horticultural colleges (Warrenstown College, National Botanic Gardens, and Kildalton College) and Institutes of Technology. The courses are accredited by HETAC/FETAC. Teagasc also provides adult and continuing education courses in environment and food safety issues which include pesticide application and food assurance. FÁS (the national training and employment authority on ROI) also provides a number of training courses in horticulture. A number of these courses are conducted in conjunction with Teagasc.

6.5 Organic produce

'Organic' is a term used to describe a particular method of production at farm level, and is as such a 'process claim' rather than a 'product claim'. Organic food constitutes a relatively small but growing part of the food supply chain on IOI. In Ireland, approximately 85 per cent of organic foods are sold via supermarkets with the remaining 15 per cent through more direct channels such as farmers markets, farm shops and box deliveries. Fruit and vegetables comprise the largest organic food type (approximately 37 per cent per cent in ROI, a decrease of 7 per cent from 2004 figures (73)).

6.5.1 Production requirements

Organic produce must be produced in accordance with the standard practices set out by the European Council Regulation 834/2007 of the 28th of June 2007. This EU regulation came into effect for the production, control and labelling of organic products on the 1st of June 2009. The new regulations place greater emphasis on environmental protection, biodiversity and high standards of animal protection. The regulation outlines that organic production must respect natural systems and cycles. It also indicates that sustainable production should be achieved insofar as possible with the help of biological and mechanical production processes, through land-related production and without the use of genetically modified organisms (GMO)(349). In addition to this, two commission regulations were also adopted. The first commission regulation, EC No. 889/2008, indicates that in addition to EU legislation on organic farming and organic production, organically operating farmers and processors

must also adhere to generally applicable rules on agricultural production and processing of agricultural products. This means that all generally applicable rules on the regulation of the production, processing, marketing, labelling and control of agricultural products also apply to organic foods. The second commission regulation, EC No. 1235/2008, details rules concerning the import of organic products from third countries (350). Claims for organic farming include consideration and application of production methods that do not damage the environment, concern for animal welfare, sustainability, and the production of high quality goods.

Organic farming avoids the use of synthetic fertilisers, chemicals and/or additives. Produce which has been produced by genetic modification, or contains any such produce, cannot be considered organic. This is also the case for produce that has been treated with ionising radiation

The organic sector on IOI is regulated by DAFM (ROI) and DARD (NI). Farmers, growers, processors and importers have to undergo a stringent annual inspection process before receiving a licence from one of the certification bodies to sell their produce as organic. All food produced to these standards is permitted to be labelled with the word "ORGANIC".

6.5.2 Labelling requirements

EC Regulation 834/2007 also governs the marketing of organic produce and includes requirements on labelling of products at the point of sale. Foods may only be marked as "organic" if at least 95 per cent of their agricultural ingredients are organic. Organic ingredients in non-organic food may be listed as organic in the list of ingredients, as long as this food has been produced in accordance with the organic legislation (341). In addition to this, a new EU logo was introduced in July 2010 on all pre-packaged organic food products produced in EU member states. A two-year transition period allowed industry to adapt product packaging before the logo became compulsory on July 1st 2012. The 'Euro-leaf' remains optional for non-packaged and imported organic products. Where used, the organic logo must be accompanied by an indication of the place where the agricultural raw materials were farmed – stating that raw material originated from 'EU Agriculture', 'non-EU Agriculture' OR 'EU/non-EU Agriculture'. If all raw materials have been farmed in only one country, then the name of the specific country, in or outside the EU, can be indicated instead. Other private, regional or national logos can also appear alongside the EU label (57).

All Organic produce certified in Ireland must also carry the words Certified Organic on the label along with the code of the certifying body:

- IE-ORG-01 (IMO)
- IRL-OIB2-EU / IE-ORG-02 (IOFGA)
- IRL-OIB3-EU / IE-ORG-03 (Organic Trust)
- IRL-OIB4-EU (Global Trust)
- IRL-OIB5-EU (BDAA).

The name and logo of the certification body may also appear on the packaging. Produce sold in Ireland as organic, but originating in another EU Member State must carry labelling or an identifying mark to indicate that it has been produced in accordance with EU organic standards. Food can be imported directly from a non-EU (third) country and sold as organic within the EU, if that country is on the list of approved third countries that have satisfied the Commission as to their organic certification and inspection standards for those food categories (343). Organic products imported from Third Countries must be produced in conformity to EU standards.

6.5.3 Food safety and nutrition aspects of organic produce

The question of whether organic food is significantly different to conventional food with respect to nutritional content or quality is still a matter of public and scientific debate, with published literature supporting both sides of the argument (351). However, while the nutritional composition and quality of foods can be influenced by the farming system used, other factors can also have an effect. These factors include variations in plant or animal varieties, climatic conditions, prevailing soil types and farming practices such as irrigation, crop rotation and fertilising regimes (352).

Organic foods are subject to the same stringent food safety regulations as all food consumed, distributed, marketed or produced on IOI and, as such, are considered as safe as any other food on the market.

6.5.4 Monitoring of organic fruit and vegetables

Organic fruit and vegetables are grown without artificial pesticides (certain naturally-derived substances are permitted for pest control – see Council Regulation (EEC) No. 2092/91). As part of the ROI 2004 monitoring programme, 42 samples of organically-produced fruit and vegetables were analysed (353). Of these, 38 showed no detectable levels of pesticides, while three samples from Spain and one from France registered pesticide contamination at or near the limit of analytical detection. These did not represent a risk to the consumer, although one exceeded the established MRL. It is unknown whether the levels were due to deliberate use of pesticides during growing or contamination during subsequent handling.

Organic produce was also sampled as part of the UK 2004 pesticide residue monitoring programme. The actual number of samples tested that were organic is not stated in the 2004 report. However, it does state that the number reflects consumer purchasing habits. Residues were found in a sample of Chilean apples and Spanish strawberries. There were no MRL breaches.

6.5.5 Authenticity

While the farming systems can differ substantially, it is difficult to distinguish between the end products of organic farming and their conventionally produced counterparts. There is no recognised scientific test to differentiate between organic and conventional produce. However, the presence of certain pesticide residues, growth promoters or genetically modified material in a food product could indicate that the food was not produced to organic standards which would prohibit it from being labelled organic.

6.6 Genetic modification

Genetically Modified Organisms (GMOs) are defined in the legislation as organisms, with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination (Article 2 of Directive 2001/18/EEC).

Genetic modification of plants can offer the opportunity to produce more vigorous crops with higher yields. It can also be used to confer herbicide tolerance, virus resistance, delayed ripening and other traits on plants for food use.

EU legislation on GMOs has been in place since the early 1990s and has two main objectives. Firstly, to protect human health and the environment, and secondly, to ensure the free movement of safe, genetically modified products in the EU. A GM organism, and any associated food or feed product, can only be put on the EU market after being approved on the basis of a detailed safety assessment. The authorisation procedure is based on a scientific assessment of risks to human and animal health and the environment. Only foods that have undergone the authorisation process as detailed in EU Regulation (EC No. 1829/2003) may be sold in the EU. Ingredients from maize, soya bean and oilseed rape are the most common types of GM foods currently on the EU market (354). A list of GMOs that have received authorisations and can be marketed in the EU can be found on the Europa Commission website (57)

The FSA in NI and the FSAI in ROI are responsible for enforcing GM food regulations on IOI, and in doing so monitor the market to ensure only EU-authorised GM foods made available and that they are labeled appropriately.

EU legislation provides for the labeling of foodstuffs when authorised GM material is used in foods at any level. A food may contain an authorised GM ingredient at 0.9 percent or less without labeling, if it can be shown that its presence is adventitious (accidental) or technically unavoidable. GM foods that have been through the authorisation process and currently on the EU market are considered as safe as their conventional counterparts (354).

Perceived concerns about GM include food safety, potential damage to the environment, disruption of ecosystems, and ethical and moral objections. The first three concerns are addressed by a rigorous pre-market assessment and post-market monitoring. The labelling requirements for GM foods are designed to provide a choice for consumers who wish to avoid them for whatever reason.

Table 6.4 EU legislation relating to GM food

Legislation	Concerning
Directive 2001/18/EC	On the deliberate release into the environment of GMOs
Regulation (EC) No. 1829/2003	The authorisation and labelling of GM food and feed
Regulation (EC) No. 641/2004	Rules for the implementation of Regulation (EC) No. 1829/2003 in regard to the application process
Regulation (EC) No. 1946/2003	Trans-boundary movements of GMOs between MS, EU and Third Countries
Regulation (EC) No. 1830/2003	Concerning the traceability and labelling of GMOs and the traceability of food and feed products produced from GMOs
Council Directive 90/219/EEC	On the contained use of GMOs

Appendices

Appendix A Climate types for fruit and vegetables

Fresh Fruit	
Temperate	*Tropical and subtropical (incl. exotics)*
• Apples/pears • Grapes • Deciduous fruit (peaches, nectarines, apricots, cherries, etc.) • Berries (strawberries, raspberries, blueberries, etc.) • Melons/watermelons	• *Bananas* • *Citrus fruit* • *Pineapples* • *Avocados* • *Mangoes* • *Lychees* • *Papayas* • *Others: passionfruits, dates, figs, etc.*
Fresh vegetables	
Temperate	*Tropical and subtropical*
• *Tomatoes* • *Onions/shallots/garlic* • *Beans and peas* • *Asparagus* • *Courgettes* • *Eggplants* • *Capsicum* • *Sweet maize*	• *Cassava* • *Arrowroot* • *Yams* • *Sweet potatoes* • *Dasheen* • *Breadfruit*

(355)

Appendix B The hygiene package

The new Hygiene Package comprises the following legislation:

- Regulation 852/2004 on the hygiene of foodstuffs
- Regulation 853/2004 laying down specific hygiene rules for food of animal origin
- Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption
- Directive 2002/99 laying down the animal health rules governing the production, processing, distribution and introduction of products of animal origin for human consumption
- Directive 2004/41 repealing certain directives concerning food hygiene and health conditions for the production and placing on the market of certain products of animal origin intended for human consumption and amending Council Directives 89/662 and 92/118 and amending Decision 95/408
- Regulation 2073/2005 on microbiological criteria for foodstuffs.

Appendix C Nutritional composition of different classes of fruit and vegetables - adapted from (356)

VEGETABLES – generally a good source of NSP/fibre, vitamin C, folate, potassium and pytochemicals.		
Type	**Examples**	**Nutritional value**
Roots	Carrots, beetroot, parsnips, swede and turnip.	Typically high in water and low in protein components. The carbohydrate is found as a mixture of sugar and starch and there are lower amounts of fibre than found in other vegetables. Low concentrations of micro-nutrients such as folate, vitamin C, calcium are found. Carrots and beetroot are rich sources of carotenoids (or their precursors).
Leafy vegetables	Cabbages, brussels sprouts, kale, cauliflower, broccoli, lettuce, chicory, endive, celery, many herbs, spinach.	Typically high in water and low in dry matter content. They do contain small amounts of protein, sugar and fibre. They are consumed in large portions and contribute to intake of carotenoids, folates, vitamin C, potassium, magnesium and many trace elements. Also a source of haem iron and calcium.
Onions	Onions, leeks, chives.	Similar nutritional composition to leafy vegetables.
Legumes - Beans and pulses	Peas, beans and lentils.	A good source of protein (of good biological value) particularly the seed legumes including haricot, lentil, mung and soya beans. They are a rich source of starch and fibre, vitamins and inorganic matter. They are also a source of haem iron. Peas and beans such as runner, broad and French beans are a good source of vitamin C. Lentils are source of zinc.
Vegetables consumed as their fruits	Cucumbers, marrows, courgettes, pumpkins and squashes, sweet peppers.	High water content, low nutritional content, great for adding in texture and taste. Good source of vitamin C.
FRUITS generally a good source of vitamin C, potassium, fibre/NSP and phytochemicals. Fruit is generally higher in sugar than vegetables.		
Examples	**Nutritional value**	
Tomatoes	Rich source of carotenoids and significant source of vitamin C.	

Apples and pears	Source of sugar and vitamin C.
Stone fruits e.g. plums, peaches, apricots, cherries	Source of vitamin C and skin of peaches and apricots a good source of carotenoids.
Berries	Good source of vitamin C.
Currants	Good source of vitamin C.
Citrus fruits	Rich source of vitamin C. Oranges a good source of folate and carotenoids and potassium. Melons are a significant source of carotenoids and vitamin C.
Grapes	Low in fibre and vitamin c. Rich in bioactive compounds.
Banana	Good source of starch and excellent source of potassium
Dates	Rich source of sugars and contain low amounts of vitamins

Appendix D Mean daily intake of vegetables (excluding potatoes) in Irish men and women aged 18 - 64 years and 65+ from the National Adults Nutrition Survey – Total Population- adapted from (357)

	Men Mean (SD) g/day		Women Mean (SD) g/day		All Mean (SD) g/day	
	18 – 64 years	65+ years	18 – 64 years	65+ years	18 – 64 years	65+ years
Vegetable and pulse dishes	17 (34)	8 (21)	24 (48)	19 (35)	20 (42)	14 (30)
Peas, beans and lentils	22 (32)	13 (23)	14 (25)	14 (20)	18 (29)	14 (21)
Green vegetables	12 (23)	18 (26)	14 (23)	20 (24)	13 (23)	19 (25)
Carrots	13 (19)	17 (19)	13 (19)	17 (19)	13 (19)	17 (19)
Salad vegetables	17 (25)	18 (33)	24 (30)	24 (31)	21 (28)	21 (32)
Other vegetables, e.g., onions	25 (32)	28 (35)	27 (32)	27 (31)	26 (32)	27 (33)
Tinned or jarred vegetables	3 (12)	3 (19)	3 (9)	2 (7)	3 (11)	2 (14)
Total vegetables	*109*	*105*	*119*	*123*	*114*	*114*
Fruit juices	57 (103)	43 (69)	43 (75)	49 (76)	50 (90)	46 (72)
Bananas	27 (44)	31 (46)	25 (37)	30 (34)	26 (41)	30 (40)
Other fruits, e.g., apples, pears	45 (71)	54 (87)	54 (73)	80 (95)	49 (73)	68 (92)
Citrus fruit	10 (32)	20 (58)	18 (48)	24 (50)	14 (41)	22 (54)
Tinned fruit	1 (11)	5 (15)	2 (11)	6 (21)	2 (11)	5 (19)
Total fruit	*140*	*153*	*142*	*189*	*141*	*171*

Appendix E Intake of fruit and vegetables among 1 to 4 year olds in ROI from the National Pre-School Nutrition Survey- Total Population – adapted from (213)

	1 years (n=126)	2 years (n=124)	3 years (n=126)	4 years (n=124)
	Mean (SD) g/day	Mean (SD) g/day	Mean (SD) g/day	Mean (SD) g/day
Fruit and fruit juices	132 (100)	163 (103)	191 (125)	198 (125)
Of which is:				
Apples, pears, pineapples, berries, etc.	43 (39)	56 (55)	59 (57)	59 (50)
Bananas	29 (28)	30 (29)	30 (34)	30 (30)
Fruit purees and smoothies (100% fruit)	25 (45)	23 (45)	21 (43)	19 (43)
Citrus fruits	8 (17)	12 (22)	12 (27)	11 (24)
Dried fruit	4 (7)	4 (6)	3 (6)	2 (5)
Tinned fruit	1 (3)	1 (4)	0 (2)	1 (3)
Fruit juices (100% fruit)	23 (50)	38 (61)	65 (82)	77 (99)
Total vegetables	62 (40)	53 (36)	53 (34)	60 (37)
Discrete vegetables	30 (33)	28 (28)	31 (28)	38 (30)
Of which is:				
Peas, bean and lentils	7 (11)	8 (12)	8 (12)	10 (16)
Baked beans	6(12)	6 (12)	6 (12)	9 (17)
Carrots	6 (11)	5 (9)	8 (12)	8 (12)
Other vegetables	8 (14)	7 (13)	6 (10)	8 (12)
Green vegetables (including green beans)	5 (9)	4 (8)	5 (11)	6 (10)
Salad vegetables	2 (5)	3 (8)	2 (6)	3 (8)
Tinned and jarred vegetables	1 (5)	1 (3)	1 (3)	2 (6)
Vegetables in composite dishes[4]	33 (27)	25 (26)	22 (22)	23 (21)

[4] Including vegetables in composite foods and dishes, excluding tomato ketchup and dried vegetables in soups and sauces.

Appendix F Intake of fruit and vegetables among 5 to 17 year olds in ROI from the National Children's Food Survey and National Teens' Food Survey – Total Population – adapted from (358) (216216, 219)

	Boys Mean (SD) g/day		Girls Mean (SD) g/day	
	5-12 years	13-17 years	5-12 years	13-17 years
Vegetable and pulse dishes	5 (25)	5 (15)	5 (13)	9 (21)
Peas, beans and lentils	14 (19)	19 (25)	11 (18)	12 (19)
Green vegetables	6 (10)	8 (14)	6 (10)	7 (11)
Carrots	11 (14)	11 (16)	8 (11)	8 (12)
Salad vegetables	2 (7)	7 (14)	5 (12)	8 (14)
Other vegetables, e.g., onions	9 (15)	14 (25)	9 (18)	12 (18)
Tinned or jarred vegetables	1 (6)	1 (4)	1 (3)	1 (3)
Total vegetables	*48*	*65*	*45*	*57*
Fruit juices	84 (108)	87 (124)	103 (122)	85 (108)
Bananas	18 (29)	21 (47)	15 (23)	14 (28)
Other fruits, e.g., apples, pears	40 (47)	37 (98)	42 (44)	36 (49)
Citrus fruit	10 (22)	10 (33)	11 (21)	7 (17)
Tinned fruit	1 (8)	1 (7)	2 (6)	1 (7)
Total fruit	*153*	*156*	*173*	*143*

Appendix G Contribution (%) of fruit and vegetables to the intake of nutrients among different age groups

	NSIFCS	NANS	NPNS	NCFS	NTFS
Age (y)	18-64	18+	1-4	5-12	13-17
Year conducted	1997/8	2008/10	2010/1	2003/4	2005/6
Nutrient					
Energy	5.4	8.0	10.7	5.8	5.3
Fat	2.4	18-64y: 4^ >65y: 3^	2.5	1.3 ^	1.9 ^
Carbohydrate	8.7	10	18.0	9.1	7.9
Total sugars	19.1		31.5		
Starch	2.2				
Dietary fibre	22.4	18-64y: 27 >65y: 33	33.9	21	18
Potassium	8.9	18-64y: 15.5 >65y: 18.7	25.4	14.8	13.1
Total vitamin A	32.1	18-64y: 35.6	27.7	28.7	27.4^
Vitamin E	12.7	18-64y: 16.0	17.5	11.5	11.2
Copper	15.1	18-64y: 10.2	20.2	13.7	10.7
Folate	15.6	18-64y: 15.0	17.7	14.2	13.5
Vitamin C	48.7	18-64y: 49.0	50.2	45.9	43.6

^ Includes vegetables and vegetable dishes only

Source: IUNA 2012 – unpublished data

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