Scientific Committee on Food

Risk Profile on the Microbiological Contamination of Fruits and Vegetables Eaten Raw

Report of the Scientific Committee on Food

(adopted on the 24th of April 2002)

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Executive Summary

The Committee is asked by the Commission to establish a risk profile on the microbiological contamination of fruits and vegetables eaten raw. A risk profile, as defined by Codex Committee on Food Hygiene, is a description of a food safety problem and its context developed for the purpose of identifying those elements of a hazard or risk that are relevant to risk management decisions.

Surveys of raw fruits and vegetables demonstrate that there is potential for a wide range of these products to become contaminated with microorganisms, including human pathogens. Outbreaks of gastrointestinal illness have been reported for intact products, cut/sliced/skinned/shredded or minimally processed products, sprouted seeds and unpasteurised fruit and vegetable juices. Of these categories, the products of most concern are sprouted seeds and unpasteurised juices. However, the proportion of reported outbreaks of food poisonings attributed to fruits and vegetables is low.

The range of microorganisms associated with outbreaks linked to fresh produce encompasses bacteria, viruses and parasites. Most of the reported outbreaks have been associated with bacterial contamination, particularly members of the *Enterobacteriaceae*. Of these, *Salmonella* and *Escherichia coli* O157 in sprouted seeds and fruit juices are of particular concern. The viruses involved in outbreaks have a human reservoir (e.g. Norwalk-like and Hepatitis A) and can be associated with intact products grown in contact with the soil and/or water. Outbreaks linked to protozoa (e.g. *Cryptosporidium, Cyclospora, Giardia*) have been associated more with fruits than with vegetables. Protozoa and viruses are most often associated with contaminated water or food handlers.

Fruits and vegetables normally carry a non-pathogenic epiphytic microflora. However, there are certain factors, which contribute to the microbiological contamination of these products with pathogens. Contamination can arise as a consequence of treating soil with organic fertilisers such as manure and sewage sludge and from irrigation water. Another aspect contributing to the microbial risk for the consumer is the increasing consumption of new products (e.g. sprouted seeds) or fruits and vegetables imported from outside the EU. Additionally, the application of technologies such as cutting, slicing, skinning and shredding will remove the natural protective barriers of the intact plant and open the possibility for providing a suitable medium for the growth of contaminating microorganisms.

Some preharvest measures will reduce the microbial contamination of fruits and vegetables. However, the relative contribution of these measures is not always equal in terms of efficacy or the level of safety achieved. Manure, bio-solids and irrigation water should be of a quality that does not introduce pathogens to the treated commodity. Special concern has to be taken to the risk with droppings from wild and domestic animals entering the production area and from fresh manure used as fertiliser. The potential of organic farming to contaminate fruits and vegetables with pathogens has to be investigated.

Harvesting at the appropriate time and storing the harvested products under controlled conditions will help retard growth of post-harvest spoilage and pathogenic microorganisms. Humid and warm storage conditions encourage the growth of microbial contaminants. The use of additional post-harvest procedures could reduce the contamination level of fruits and vegetables. Washing with water of potable quality can reduce the microbial load. Although a wide range of different agents is available for disinfecting/sanitising fresh produce their efficacy is variable and none are able to ensure elimination of pathogens.

The majority of the epidemiological information on fruits and vegetables as vehicles of foodborne disease comes from very few countries. This is likely to be a reflection of the surveillance systems in place, rather than there being particular problems with fruits and vegetables in these countries. Therefore, the information presented on outbreaks does not give a complete picture of the true situation.

It is often difficult to trace the origin of fresh produce associated with outbreaks of gastrointestinal disease. It is therefore necessary to improve traceability to assist epidemiological investigation and tackling the problem at source.

Information about vehicles of infection and aetiological agents largely comes from reported outbreaks of infection. Outbreaks may underestimate the burden of illness associated with fresh produce because the majority of cases of gastrointestinal illness are associated with so-called diffuse outbreaks (low attack rate) or sporadic infections rather than outbreaks.

Data on consumption patterns and trends are important in assessing exposure of consumers to potential microbiological hazards associated with fresh produce.

More epidemiological data on foodborne illness associated with contaminated fruits and vegetables are required to determine whether illness from these products is increasing in the EU. More information is also required on the survival of pathogens in fruit, vegetables and in irrigation water and manure. Attention should be paid to the development of decontamination procedures particularly for manure, sludge and irrigation water.

Conclusions and recommendations made related to the risks of microbiological contamination of fruits and vegetables are to be found at the end of this report.

1.   Introduction

1.1.   Terms of reference

The Committee is asked to advise the Commission on the potential risk for consumer health from the microbiological contamination of fruits and vegetables intended for raw consumption and ready-to-eat products thereof. It shall address in particular the relevance of this matter for consumer safety in the European Union.

During its deliberations the Committee is asked to first establish a risk profile, thereby focussing in particular on:

- the identification of the products of concern for the European consumer (e.g. pre-cut products, sprouted seeds) and the pathogens of most concern,

- the factors contributing to consumer exposure, and in particular contamination by agricultural and processing practices,

- the availability, efficacy and safety of pre- and post-harvest measures to reduce the microbiological contamination.

In addition, the Committee is asked to describe:

- the availability and accessibility of information (e.g. epidemiological data),

- the areas where additional information and/or further research would be required,

- any additional elements considered relevant.

Depending on the result of this risk profiling exercise, the Commission envisages the possible consultation of the Committee on a detailed risk assessment of this subject in the future.

1.2.   Acknowledgements

This risk profile document was prepared by a working group on Food Microbiology and Hygiene. The Working Group of the SCF consisted of Prof. Bevan Moseley, Prof. Dr. Reinhard Fries and Prof. Dr. Sven Lindgren. Contributions for the report were also received from Dr. Paul Cook, Prof. Peter Elias, Prof. Richard Gilbert, Prof. Walter Hammes, Dr. LeeAnne Jackson, Dr. Catherine Jacquin Navarro, Dr. Catherine Lagrue, Dr. Robert Mitchell, Dr. Cristophe Nguyen-The, Dr. Serve Notermans, Dr. Daniella Scandella, Prof. Nils Skovgaard, Dr. Frans van Leusden and Dr. Phil Voysey. The tables 2,4,5 and 6 in the annexes have been compiled from the reviews and data provided by these experts.

1.3. Background

The consumption of fresh fruits and vegetables is increasing as consumers strive to eat healthy diets and benefit from the year-round availability of these products that up until recently were considered to be seasonal. Global trade in fruits and vegetables and changing horticultural practices have enabled this year-round abundance to be possible, as well as adding new varieties of fresh produce to the market. During the last few decades pre-prepared minimally processed fruits and vegetables have become popular among the European consumers. These products include pre-washed pre-cut salads items, chopped crudités, sprouted seeds (e.g. mung-beans, alfalfa), grated vegetables, prepared fruit salads, or fruit combinations.

Most of these products are generally eaten without further processing. Some products are packed in modified atmospheres to provide extension of shelf life both in relation to the potential acceptable quality and safety of the product.

Fruits and vegetables carry a natural non-pathogenic epiphytic microflora. During growth, harvest, transportation and further processing and handling the produce can, however, be contaminated with pathogens from human or animal sources. Fresh produce has been implicated in a number of documented outbreaks of foodborne illness particularly in Europe, Japan, United States, and Canada. Outbreaks of illness caused by bacteria, viruses and parasites have been linked epidemiologically to the consumption of a wide range of vegetables and, to a lesser extent fruits. Surveillance of vegetables has indicated that these foods can be contaminated with various bacterial pathogens, including *Salmonella*, *Shigella*, *E. coli* O157:H7, *Listeria monocytogenes* and *Campylobacter*. However, the prevalence of foodborne pathogens on fruits and vegetables and their involvement in outbreaks are not well documented from a European perspective.

In most cases, fruits and vegetables or their products are washed after harvesting by producers, processors, packers and/or consumers and potable water is generally used for this purpose. The safe use of chemical decontaminants to reduce the microbial load and the implications of residues from this kind of treatment is not well documented.

Consumers are also increasingly concerned about the potential contamination of fruits and vegetables from the application of pesticides, chemical fertilisers and herbicides and there is a growing demand for organically grown products.

The Codex Committee on Food Hygiene is currently developing two Codes of hygienic practice for fruits and vegetables: one focusing on primary production, the other on pre-cut ready-to-eat fruits and vegetables. A code of "Hygienic Practices for Fresh Fruits and Vegetables" including an Annex on "Ready-to-Eat Fresh Pre-cut Fruits and Vegetables" and on "Sprout Production" have been elaborated by the Codex Alimentarius Committee on Food Hygiene. The proposed Code was moved to step 8 at the meeting in October 2001, Bangkok (FAO/WHO, 2001).

The United States has undertaken a wide range of studies of these products, particularly in relation to enterohaemorrhagic *E. coli* and has developed regulatory measures and guideline documents (FDA, 1998). WHO has also been active in this area through the development of document WHO/FSF/FOS/98.2 on surface decontamination of fruits and vegetables eaten raw (Beuchat, 1998).

The Committee is asked to advise the Commission on the potential risk for consumer health from the microbiological contamination of fruits and vegetables intended for raw consumption and ready-to-eat products thereof by establishing a risk profile. The format of a risk profile is still under consideration within the Codex system and included in the draft on "principles for risk management". A WHO Expert Consultation in March 2000 (Anon, 2000), concluded that it is critical that a risk profile is elaborated in co-operation between risk managers, risk assessors and other specialists. A risk profile is essential in guidance for further actions concerning management options to be taken. It is also used to identify the need or otherwise for a risk assessment and areas for further development of data.

This document does not cover frozen, canned, fermented and dried ready-to-eat fruits and vegetables. This document takes into account work published up mainly to the end of 2000. A number of relevant publications have appeared since then but these do not effect either the conclusions or the recommendations. This report seeks to elucidate both the products and the organisms of concern. No attempt has been made to prioritise them since this will come later if a risk assessment is requested.

1.4. The role of the EU in providing fruits and vegetables

The production of fruits and vegetables within the European Union is about 76 million tons/year (1998 figures). Two thirds are vegetables and one third is fruits. Spain and Italy are the main producing countries (more than 20 million tons each) followed by France and Greece (Table 1).

The European Union is also the world's main importer of fruits and vegetables. Intra-European Union trade represents 17 million tons/year of fruits and vegetables (and represents on average 2/3 imports in EU). This part varies from 40 to 90% according to the country. Belgium and The Netherlands re-export some of the imported products from third countries.

The main products imported into the EU are: bananas, citrus fruits, apples and pears, onions, pineapples, dessert grapes, tomatoes, kiwis and melons.

The consumption of fruits and vegetables in the EU in 1998 was nearly 64 million tons, of which 55% comprised vegetables and 45% fruits (Table 1). The average consumption was about 170 kg/person/year. The countries, which have the highest high production of fruits and vegetables also have the highest consumption. Greece, Italy and Spain consumed in excess of 240 kg/person in 1998 whereas Northern European countries such as Finland, Sweden and Denmark consumed less than 110 kg/person.

2. Production practices

Fruits and vegetables comprise a diverse range of plant parts (leaves, roots, tubers, fruits, and flowers). Production practices, growth conditions and the location of the edible part during growth (soil, soil surface, aerial part) will in combination with intrinsic, extrinsic, harvesting and processing factors affect their microbial status at the time of consumption.

The commodities are grown in open fields, in greenhouses and hydroponic systems. In hydroponic systems, the plants constantly absorb water and nutrients through a re-circulating process. To overcome unfavourable climatic conditions and/or to extend the production

periods fruits and vegetables are increasingly grown in greenhouses. Many products originally grown in the south of Europe are now also produced in northern countries. Production in greenhouses is usually well protected but the environment can in some instances be favourable for the survival of foodborne pathogens (Nguyen-the and Carlin, 2000).

Chemical compounds, manure, municipal sludge, and composted organic materials are used as nutrients for plants. The microbial composition of the different forms of organic fertiliser will vary depending on its origin and further treatment. The recent development of organically grown fruits and vegetables will presumably increase the use of organic fertilisers. In hydroponic plants effluent water from sewage plants can be used as a plant nutrient which raises a specific concern about hygienic treatment of this water.

The quality of the water used for irrigation and as a carrier for plant protection products, fertilisers and frost protection products has to be related to the potential risk it can cause at a later stage. Technologies for irrigation are important for the control of spreading microbiological hazards. The use of drop irrigation instead of flooding or spray irrigation should reduce waterborne contamination and aerosols. However, heavy rains and wind may provide other opportunities for the transfer of microorganisms from soil to plant surfaces.

Plant protection is principally done with chemical pesticides and fungicides and occasionally by using antibiotics. The potential for drug resistance as a consequence of the use of antibiotics needs to be recognised (SSC, 1999). The interest in biological alternatives for control is increasing as a result of the search for environmentally acceptable solutions.

Sprouted seeds exhibit a unique hazard potential, since the germination stage breaches the inhibitory barrier of the seed coat, allowing pathogens, which may be present to grow on nutrients from the sprouted plant. In addition, inappropriate hygiene during germination and subsequent storage and transport may result in contamination with pathogenic organisms and conditions may be created that will allow certain pathogens to multiply. For these reasons, sprouted seeds are considered to constitute a "special problem" in relation to fresh produce (NACMCF, 1999b; Thompson and Powell, 2000).

There is an increased demand on the market for organically grown fruits and vegetables. Production practices for this category of produce may involve the use of organic fertilisers and the use of alternative measures to chemical plant protection products for the control of pests, mites and fungi. Therefore, the potential risks for contamination of organically grown fruits and vegetables by faecal pathogens or by mycotoxin producing moulds have to be acknowledged.

The globalisation of the food market means that an increasing amount of non-traditional fruits and vegetables reaches the European market. The epidemiological consequences of this import are not known. The same can be said about the consumption of minimally processed products, including non-pasteurised fruit juices.

3.   Commodities and pathogens of concern

3.1.   Overview of outbreaks

Vegetables and fruits have been associated with outbreaks of foodborne disease in many countries. Organisms involved include bacteria, viruses and parasites (De Roever, 1998). These outbreaks vary in size from a few persons affected to many thousands (see Table 3). However, they represent only a small proportion of the total number of cases reported. For example, in the US between 1993 and 1997 fruits and vegetables were associated with only 1.4% to 3% of outbreaks. However, according to the Centers for Disease Control and Prevention, the number of produce-associated outbreaks per year in the US doubled between the periods 1973-1987 and 1988-1992 (Olsen *et al*., 2000).

The world's largest reported vegetable borne outbreak to date occurred in Japan in 1996 and of the over 11,000 people affected, about 6,000 were culture confirmed. The outbreak involved the death of three school children and was caused by *E. coli* O157:H7 (Ministry of Health and Welfare of Japan, 1997).

The frequency of produce-associated outbreaks in Europe appears to be similar to the US. Between 1992 and 1999, 60 outbreaks of foodborne infectious intestinal disease associated with the consumption of salad items, fruits and vegetables were reported from England and Wales (Table 7). 2170 people (ca. 12%) were affected (at risk = 19,650) and 27 were admitted to hospital. No deaths were reported. In 17 of the outbreaks more than 50 people were affected (range 4 to 193). Fruit and vegetable associated outbreaks represent 4.3% (60/1408) of the total number of outbreaks of foodborne disease reported during that period**.** In Sweden salad containing one or more cooked ingredients accounted for 4.3% of the 252 reported incidents of foodborne illness between 1992 and 1997 (Lindqvist *et al*., 2000). In an overview by ICMSF (1998) they report that animal wastes used as fertiliser in the Orient may contribute to as much as 20% of infections by *Shigella*, *Salmonella*, *Vibrio cholerae* and amoebas.

Higher figures have been reported in some countries (Schmidt, 1995). However, it is not always possible to separate categories such as salad dressings from the data on fruits and vegetables and therefore the data are not directly comparable.

The lack of robust traceability and weaknesses in reporting systems for outbreaks limits any comprehensive evaluation of the role of fruits and vegetables as a source of foodborne infections. Tables 2 to 7 summarise currently available information on outbreaks where raw fruits and vegetables, or their products, were identified or strongly suspected as being the source of infection. The data supplied is not intended to be fully comprehensive but is provided to illustrate the types of products and organisms of concern.

In considering these tables it should be noted that:

1.   It was assumed that the product was intact unless available information indicated otherwise.

2.   It was assumed that the product was not grown in direct contact with faecal material unless available information indicated otherwise.

In the tables products associated with outbreaks are categorised in terms of how their microbial ecology could potentially influence the presence, growth or survival of pathogens, i.e. whether or not the product is whole and intact, has been cut or exposed in some way or has been subject to minimal processing.

Most of the outbreaks listed in the tables were associated with intact products grown in contact with the soil/water. Fewer outbreaks have been associated with cut/sliced/skinned or shredded products. A significant number of outbreaks have been associated with sprouted seeds and fruit juices. All of the outbreaks linked to sprouted seeds and all but one of those associated with fruit juices have involved bacteria, particularly *Salmonella*.

A large number of the outbreaks listed are for a small number of countries, particularly the US and UK. However, there is no evidence that these countries have a particular problem with fresh produce. The number of outbreaks reported is more likely to reflect the comprehensiveness of the surveillance and reporting system operating in these countries than the incidence of disease associated with fresh produce.

3.2. Microbial flora

Microorganisms form part of the epiphytic flora of fruits and vegetables and many will be present at the time of consumption. The majority of bacteria found on the surface of plants are usually Gram-negative and belong either to the *Pseudomonas* group or to the *Enterobacteriaceae* (Lund, 1992). Many of these organisms are normally non-pathogenic for humans. The numbers of bacteria present will vary depending on seasonal and climatic variation and may range from 10^4 to 10^8 per gram. The inner tissues of fruits and vegetables are usually regarded as sterile (Lund, 1992). However, bacteria can be present in low numbers as a result of the uptake of water through certain irrigation or washing procedures. If these waters are contaminated with human pathogens these may also be introduced.

About two thirds of the spoilage of fruits and vegetables is caused by moulds (ICMSF, 1998). Members of the genera *Penicillium*, *Aspergillus*, *Sclerotinia*, *Botrytis* and *Rhizopus* are commonly involved in this process. The spoilage is usually associated with cellulolytic or pectinolytic activity, which causes softening, and weakening of plant structures. These structures are important barriers to prevent growth in the products by contaminating microbes.

The survival or growth of contaminating microorganisms is affected by intrinsic, extrinsic and processing factors. Factors of importance are nutrient composition, pH, presence of scales and fibres, redox potential, temperature and gaseous atmosphere. Mechanical shredding, cutting and slicing of the produce opens the plant surfaces to microbial attack.

3.3. Commodities

3.3.1 Intact products

Fruits and vegetables can become contaminated whilst growing in fields, or during harvest, handling, processing, distribution and use (Beuchat, 1995). At the point when an intact part of a plant is marketed, e.g. lettuce, carrot, cauliflower, eggplant, parsley or sprouted seeds, any microbial contamination present, is likely to reflect the environment through which the product has passed. The extent of microbial contamination of fruits and vegetables and the

impact of this contamination on consumer health are not well defined, as limited data are available.

Information compiled by Beuchat (1998) provides an overview of foodborne pathogens in different vegetable and fruit products. The frequency of microorganisms such as *Salmonella*, enterovirulent *Escherichia coli*, *Listeria monocytogenes*, *Campylobacter*, *Cyclospora*, etc., are subject to wide variation from study to study. The prevalence of *Campylobacter* is mostly at levels <3%, whereas the prevalence of *Salmonella* is higher. In a majority of reports the frequency of *Salmonella* was between 4 and 8%. *E. coli* O157:H7 and *Listeria monocytogenes* were in general found in a higher frequency compared to *Salmonella*. A conclusion of the report is that the presence of pathogenic microorganisms on raw fruits and vegetables varies considerably. Often no pathogens are detected. In other surveys high percentages of samples contaminated with pathogens is observed. Surveys of the presence of parasites or viruses are fewer because the lack of detection methods that can be applied to fruits and vegetables.

As would be expected from the ecology of these products, almost any pathogen, bacterial, viral or protozoan can be associated with them (Table 2a and 2b). It is not possible to comment on the frequency with which individual pathogens appear in the list, because of the lack of data. In addition, specific details of the surveillance system in place will heavily influence the frequency of reports, rendering valid comparison across individual countries, products or organisms difficult. However, the overall frequency with which enterovirulent *E. coli* and related organisms appear indicates cause for concern, particularly given the serious morbidity and mortality that can be associated with these bacteria. In effect, all subsequent categories of products are subsets of this category.

Particular attention has to be drawn to the potential risk associated with organically grown vegetables and fruits due to the use of organic fertilisers like manure and biosolids. Unless a hygienic control program is used for treatment of the intended fertiliser it is very likely that it will contaminate the fruits and vegetables with potential pathogenic organisms. Outbreaks may also be related to cross-contamination between animal effluents (such as runoff from manure piles) and the growing fields, even if manure had not been directly applied to the crop (NACMCF, 1999a).

The recent interest in the use of imported exotic herbs, spices and vegetables has introduced a new category of products to the EU market, which may become involved in health hazards. The potential of this source for foodborne illness has not been estimated. In a survey in Sweden more than 10% of the samples were contaminated with *Salmonella* (Anon, 2001).

3.3.2. Sprouted seeds

An investigation of the German market in 2000 (Hammes, unpublished results) revealed that sprouted seeds eaten raw were available forthe following seeds: adzuki beans, alfalfa, broccoli, buckwheat, chickpeas, cress, linseed, *Lathyrus sativa*, mung beans, mustard, green and yellow peas, onion, quinoa, radish, rye, sesame, sunflower, *Trigonella* and wheat. These products are eaten singly or in salad mixes and some are heated (e.g. sprouted soybeans) to inactivate anti-nutritional compounds.

Microbiological analyses have shown that alfalfa seeds routinely contain high levels of microorganisms, including coliforms and faecal coliforms (NACMCF, 1999b; Taormina *et*

al., 1999). The conditions under which seeds are sprouted (growing time, temperature, moisture and nutrients) are ideal for bacterial proliferation (Feng, 1997; Taormina *et al.*, 1999). An increase of 100 to 1000 fold (Prokopowich and Blank, 1991; Feng, 1997) can occur and the bacterial numbers may exceed 10^7 per gram of the sprouted seeds without affecting the appearance of the product (Taormina *et al.*, 1999).

Several pathogens have been implicated in sprouted seed-associated outbreaks (Table 3) or have been identified as a potential hazard due to their ability to proliferate during sprouting. These include *Salmonella,* enterohaemorrhagic *E. coli, Bacillus cereus, Listeria monocytogenes, Yersinia enterocolitica* and *Shigella* species. However, only *Salmonella* and *E. coli* O157:H7 have consistently been linked with sprout-associated outbreaks.

The National Advisory Committee on Microbiological Criteria for Foods in the US (NACMCF, 1999b) has reviewed the literature on sprout- associated outbreaks. A specific problem was identified in relation to pathogen contaminated seeds during the sprouting process. No effective decontamination process has been identified that will substantially reduce or eliminate contaminating pathogens. However, some improvement in hygiene could be achieved with appropriate chlorine treatments.

3.3.3. Ready-to-eat processed fruits and vegetables

Cutting, slicing, skinning and shredding removes or damages the protective surfaces of the plant or fruit. There are different consequences for food safety associated with this processing. During washing some microorganisms will be removed from the product, nutrients will become available, and pathogens can be spread from contaminated parts to uncontaminated parts. Examples of outbreaks of foodborne disease related to this type of product are presented in Table 4.

Cutters and slicers can be potent sources of contamination, since they usually provide inaccessible sites, which harbour bacteria. The presence of cut surfaces provides an increased surface area for contamination and growth and allows microbial infiltration of the tissues. Exposing vegetables to various types of cutting has been shown to result in a six to seven-fold increase in microbial numbers (Garg *et al.*, 1990; O'Beirne, 1999).

Fruit juices and minimally processed fruits and vegetables have also been involved in foodborne outbreaks. It would appear that the acidic properties of some juices does not always prevent the survival of organisms like *E. coli, Salmonella,* viruses and *Cryptosporidium* (Table 5). Minimally processed products with an extended shelf-life is a category of food that is increasing in popularity. Where a heat treatment is applied this is usually insufficient to inactivate all vegetative pathogens and safe storage is related to a time/temperature relationship. In Table 6 are two examples where this type of product has been associated with foodborne disease.

3.4. Other techniques: modified atmosphere packaging

Fresh fruits and vegetables continue to respire, consuming oxygen and producing carbon dioxide and water vapour. Modified Atmosphere Packaging (MAP) of fresh fruits and vegetables results in an extended shelf-life. A great deal of work has been carried out to assess the effect of MAP on the growth of pathogens associated with minimally processed fruits and vegetables, especially *Listeria monocytogenes*. The effect of MAP in inhibiting the growth of pathogens is influenced more by the type of vegetable than by the atmosphere used (Jacxsens *et al.*, 1999). In consequence, the gas composition needs to be established for each commodity, taking into account the risk of pathogen growth.

3.5. Pathogens

A wide range of enteric pathogens and their toxins can be transmitted via food, including the bacteria *Campylobacter* spp., *Salmonella* spp., *Shigella* spp., enterovirulent *E. coli*, *Clostridium botulinum*, *Listeria monocytogenes*, *Clostridium perfringen*s, some *Bacillus* spp., *Staphylococcus aureus,* the protozoa *Cryptospordium parvum*, *Cyclospora cyatenenesis* and *Giardia* spp. and viruses such as Norwalk-like viruses and Hepatitis A. Given the widespread use of human and animal faecal waste in agricultural practice it is not surprising that enteric pathogens can contaminate agricultural produce and cause outbreaks of illness following consumption. Spores of *Clostridium botulinum*, *Clostridium perfringen*s, *Bacillus cereus* can also be isolated from soil free from faecal contamination and *Listeria monocytogenes* can be found in decaying vegetables (De Rover, 1998). It is evident from Tables 1-6 that such organisms are associated with a wide range of products and outbreaks. A brief description of the main pathogenic microorganisms is provided in the following sections.

Fresh produce may contain plant pathogenic and spoilage microorganisms. These may be important in reducing the shelf-life and acceptability of fresh produce but are generally not important in terms of public health. Although the mycotoxin patulin can be produced by the growth of certain moulds on apples, mycotoxins are usually associated with low water activity foods (e.g. grain, nuts) intended for longer-term storage.

Some pathogenic organisms can have environmental sources although these are rarely defined. For example *Pseudomonas* may come from the environment, water or raw vegetables (Kominos *et al*, 1972).

3.5.1. Bacteria

***Salmonella* spp.**
Salmonella spp. are an important cause of gastrointestinal illness in humans. *Salmonella enteritidis* and *Salmonella typhimurium* are the most frequently reported non-typhoidal serotypes in many countries and outbreaks have been associated with a diverse range of food vehicles. However, a wide range of serotypes have been associated with outbreaks involving fresh produce (Tables 2a, 2b, 3, 4 and 5). Salmonellosis is characterised by diarrhoea, fever, abdominal cramps and vomiting usually lasting 4-7 days (Anon., 2001). Although most *Salmonella* infections are self-limiting, in a small proportion of cases these may lead to bacteraemia. The case-fatality rate in industrialised countries is less than 1% (Anon., 2000a).

Campylobacter spp.

Campylobacter spp. and in particular, *Campylobacter jejuni,* are thought to be the most frequent bacterial cause of gastrointestinal disease in humans (Tauxe 1992; Allos and Taylor 1998; Anon., 2000a,b). Animals and birds are the main reservoir of human pathogenic *Campylobacter* (Doyle and Jones 1992; Stern 1992; Altekruse *et al.*, 1994) although water is also a potential source for contamination with these organisms (Koenraad *et al.*, 1997; Chynoweth *et al.*, 1998; Buswell *et al.*, 1999; Mason *et al.*, 1999). There is also potnetial forcross-contamination of fresh produce with *Campylobacter* from meat and poultry during food preparation(Beuchat, 1995). Although campylobacters are an important cause of sporadic human infections they are rarely reported as causing outbreaks of gastrointestinal disease (Anon., 2000a,b). *Campylobacter* infections usually present as abdominal pain profuse diarrhoea and malaise with a duration of 2-7 days. Bacteraemias are rare and the case-fatality rate in industrialised countries is about 0.05% (Anon., 2000a).

Enterovirulent *Escherichia coli*

Most *E. coli* are not pathogenic and are part of the normal human and animal gut flora. The enterovirulent *E. coli* include seven groups believed to be associated with diarrhoea. They are defined based on the presence of known or putative virulence factors including toxin production, adhesion and invasiveness (Sussman, 1997; Dupont and Mathewson, 1998; Nataro and Kaper, 1998) such as:

- Attaching and effacing *E. coli* (AEEC)
- Diffusely adherent *E. coli* (DAEC)
- Enteroaggregative *E. coli* (EAggEC)
- Enteroinvasive *E. coli* (EIEC)
- Enteropathogenic *E. coli* (EPEC)
- Enterotoxigenic *E. coli* (ETEC)
- Verocytotoxin-producing *E. coli* (VTEC)

EPEC have been associated with outbreaks of gastrointestinal illness in nurseries and hospital wards. ETEC is a common cause of infection in children in tropical countries and in travellers (Anon., 1994; Dalton *et al.*, 1999). EIEC are rare causes of diarrhoea and dysentery in travellers. EAggEC has been associated with diarrhoeal illness in infants and travellers and has been linked to outbreaks (Smith *et al.*, 1997; Spencer *et al.*, 1999; Anon., 2000b). The infectious intestinal disease (IID) study in England (Anon., 2000b) found that after correcting for foreign travel, consumption of salad at a restaurant was associated with an increased risk (four fold) of infection with EAggEC. Less is known about AEEC and DAEC. The case-fatality rate of EPEC, ETEC and EIEC infections in industrialised countries is less than 1% (Anon., 2000a).

Members of several different serogroups of *E. coli* produce verocytotoxins (VTEC) but the most commonly recognised is O157, first identified as a human pathogen in 1982 (Riley *et al.*, 1983). This has since emerged as a serious public health problem with major outbreaks in Europe, North America and Japan (Slutsker *et al.*, 1997; Mead and Griffin 1998; Michino *et al.*, 1998). Infection can involve severe diarrhoea that is bloody together with abdominal pain. Symptoms usually occur for 5-10 days (Anon., 2001). Complications such as haemolytic uraemic syndrome (HUS) may develop in a proportion of cases particularly young children. The case-fatality rate in industrialised countries is about 2% and is highest in infants and children (Anon., 2000a).

***Shigella* spp.**
Shigella sonnei is primarily spread by the person-to-person route although food and waterborne transmission can occur. Shigellosis can be endemic in institutional settings such as prisons, mental hospitals and nursing homes, where population densities are high and/or poor hygiene conditions may be present. *Shigella* infection usually presents as abdominal cramps, fever and diarrhoea, which may contain blood and mucus. The duration of illness is 4-7 days (Anon 2001). The case-fatality rate in industrialised countries is estimated to be 0.1% (Anon 2000a).

Vibrio cholerae
Vibrio cholerae serogroups O1 and O139 are the causes of epidemic cholera. This is predominantly a waterborne infection and high numbers of organisms are necessary to cause infection. Nevertheless, a significant number of fruit and vegetable borne outbreaks have been reported (Wachsmuth *et al.* 1994; Faruque *et al.* 1998; Anon 2000a). The characteristic profuse watery diarrhoea of cholera is due mainly to the effects of a heat labile enterotoxin elaborated by the organism in the intestine. Cholera is of rapid onset and can lead to severe dehydration and death within hours if left untreated. The illness usually lasts for 3-7 days (Anon., 2001).

Listeria monocytogenes
Listeria monocytogenes is an important foodborne pathogen capable of causing severe illness with a high mortality rate (Slutsker and Schuchat 1999; Anon., 2000a). Susceptible groups include pregnant women, the elderly and immunocompromised. A wide range of foodstuffs have been implicated in outbreaks of listeriosis (Slutsker and Schuchat 1999). An outbreak of *Listeria monocytogenes* occurred in 1981 in the Maritime provinces of Canada. A case-control survey of the implicated individuals indicated that coleslaw was the most likely cause of this outbreak (Table 4). Further investigation revealed that the cabbage used for preparing the coleslaw might have been contaminated with *L. monocytogenes* from sheep manure at the farm (Schlech *et al.*, 1983). Gastroenteritis has been reported as associated with listeriosis (Salamina *et al.*, 1996) although the disease usually presents with other symptoms such as fever, muscle aches, nausea. Pregnant women may suffer flu-like illness and infection can lead to stillbirth or premature delivery. The elderly and immunocompromised may develop bacteraemia or meningitis. The duration of illness is variable. The case-fatality rate for listeriosis in industrialised countries is up to 30% but may be higher in those who have not received adequate treatment (Anon., 2000a).

Other vegetative bacteria
The microbial ecology of raw fruits and vegetables, particularly cut products suggest that pathogens such as *Staphylococcus aureus*, *Aeromonas* and *Yersinia enterocolitica* have the potential to cause outbreaks (Anon., 2000a). For example, *Yersinia enterocolitica* is psychrotrophic and may persist for extended periods in refrigerated vegetables.
Outbreaks of pharyngitis caused by Group A Streptococci have been reported in Israel, Turkey and South America and are thought to be associated with various salads.

Spore-forming bacteria
Psychrotophic strains of *Bacillus* and *Clostridium* would be of concern in chilled products. The main source of contamination is the soil. Cases of botulism that have been linked to fresh produce are very rare (Hauschild, 1992). However, outbreaks involving cooked/processed vegetable products (e.g. garlic in oil, mushrooms) have been reported (De Roever, 1998).

3.5.2. Protozoa

These organisms are most often associated with contaminated water or food handlers. Outbreaks have tended to be associated more with fruit than with vegetables. The organisms that occur most frequently in outbreaks are *Cryptosporidium, Cyclospora* and *Giardia.*

Cryptosporidium
Although most outbreaks of cryptosporidiosis are waterborne, the infection can be acquired by consumption of food contaminated with *Cryptosporidium* spp. (Smith, 1993; MacKenzie *et al.*, 1994; Guerrant, 1997; Anon., 1996;). The oocysts of *Cryptosporidium* are resistant to environmental stresses, even to chlorine treatment used as a disinfection treatment in water supplies. *C. parvum* causes an acute self-limiting diarrhoeal illness in immunocompetent individuals and chronic, debilitating disease in the immunosuppressed (Anon., 1990; Casemore, 1991). Illness may last for days to several months (Anon., 2001).

Cyclospora
Outbreaks of cyclosporidiosis have been reported linked to the consumption of fruit (raspberries) and vegetables (e.g. baby leaves of lettuce, basil) (Herwaldt and Ackers, 1997; Herwaldt and Beach, 1999; Fleming *et al.*, 1998; Sterling and Ortega, 1999; Herwaldt, 2000). The oocysts of *Cyclospora cayetanensis* seem to have a similar susceptibility and resistance to environmental stresses and treatments as *Cryptosporidium.* Symptoms of *Cyclospora cayetanensis* infection include acute watery diarrhoea with abdominal cramps, vomiting and weight loss (Soave 1996). The illness may follow a relapsing course and persist for weeks or months (Sterling and Ortega, 1999; Anon., 2001).

Giardia intestinalis
Giardiasis is mainly acquired by transmission of cysts of *G. intestinalis* via soiled hands, contaminated drinking water, and food contaminated with faeces (Petersen *et al*., 1988; Mintz *et al*., 1993). Cysts survive well in the environment and are resistant to chlorination in water supplies. Giardiasis may cause chronic diarrhoea, malabsorption and weight loss with symptoms persisting for several months (Hill, 1993; Anon., 2001).

3.5.3. Viruses

Foodborne viruses causing human diseases originate from human faeces. Many enteric viral infections are mild and of relatively short duration (Appleton, 1991; ACMSF, 1998). Most cases are probably not identified because specimens are not commonly examined for viruses and the detection methods used routinely identify only some of the viruses known to cause infectious intestinal disease (IID). Transmission is mainly by person-to-person contact by inhalation of airborne droplets and fecal contamination. Many outbreaks of viral gastroenteritis associated with fresh fruit and vegetables have been described (Appleton, 1991; Hedberg and Osterholm, 1993; ACMSF, 1995; ACMSF, 1998; Anon., 1999).

Based on epidemiological criteria described by Kaplan *et al* (1982), it is estimated that 32-42% of foodborne enteric infections in the US are caused by viruses, especially the enteric viruses. Hepatitis A and Norwalk-like viruses (NLV) (formally known as Small Round Structured Viruses [SRSVs]) are the most commonly documented viral contaminants in food (ACMSF, 1998; Anon., 1999).

Norwalk-like viruses
Outbreaks of NLV are common in children and adults of all ages in hospitals, nursing homes, hotels and institutions where the virus is usually transmitted person to person. The virus can be spread in aerosols and the infectious dose is considered to be very low (10-100 virus particles). Foodborne outbreaks have been associated with infected food handlers and with shellfish or vegetables contaminated by human sewage (Hedberg and Osterholm, 1993; ACMSF, 1998; MMWR, 2001). De Roever (1998) concluded that the number of cases caused by NLV are most likely underreported. NLV infection is usually associated with nausea, vomiting and diarrhoea lasting 20-60 hours (Anon., 2001).

Further information about food-borne Norwalk-like viruses has been produced by the Scientific Committee on Veterinary Measures relating to Public Health in their report "Opinion on Norwalk-like viruses" (SCVMPH, 2002).

Hepatitis A
Hepatitis A has been associated with shellfish harvested from contaminated waters, raw produce, cooked foods and uncooked foods that are not re-heated after contact with an infected food handler (ACMSF, 1998; Anon., 1999). In countries with faecal-oral transmission of the hepatitis A virus most of the exposed children acquire active immunity by 5 years of age. Improved sanitation has reduced the incidence of hepatitis A infections in many regions. Symptoms of hepatitis A infection include diarrhoea, jaundice and flu-like illness. The duration of illness is variable lasting from 2 weeks to 3 months (Anon., 2001).

4. Pre-harvest, harvest and post-harvest measures

Conditions and measures taken during pre-harvest, harvest and post-harvest affect the microbial contamination of fruits and vegetables. Most of the contaminating flora is non-pathogenic and has a natural occurrence on the produce. However, pathogens from the human and animal reservoir as well as other pathogens from environment can be found at the time of consumption. The survival of enteric pathogens in soil, manure, municipal wastes and irrigation water depends on different factors like relative humidity, microbial adhesion, rainfall, sunlight, etc. (De Roever, 1998).

4.1. Pre-harvest

Soil
Soil is a rich reservoir for a variety of microorganisms and the non-pathogenic flora is important for the mineralisation of plants and animals after their death in the environment. Tissue degrading properties of this flora contaminating fruits and vegetables may cause damage during transport and storage of products thereby exposing them to further microbial attack.

Additionally, soil is a reservoir of foodborne pathogens, such as *Bacillus cereus, Clostridium botulinum,* and *Clostridium perfringens* (Lund, 1986). *Listeria monocytogenes* has been isolated from non-cultivated soil (Welshimer and Donker-Voet, 1971). Pathogenic organisms from the human/ animal reservoir can be found in the soil due to irrigation and fertilisation with manure and sludge or due to droppings of animals in the farming area.

Water

Water is mainly used for irrigation of plants and its quality will vary depending on whether it is surface water or potable water. Water may be a source of contaminating microorganisms Surface water from streams and lakes may be contaminated with pathogenic protozoa, bacteria and viruses. The occurrence of *L. monocytogenes*, *Salmonella* and viruses has been reported (Castillo Martín *et al.*, 1994; Nguyen-the and Carlin, 1994 and 2000;).

The transfer of foodborne pathogenic microorganisms from irrigation water to fruits and vegetables will depending on the irrigation technique and on the nature of the produce (NACMCF, 1999a). Spray irrigation would be expected to increase the risk of contamination in comparison to drip irrigation or flooding. Leafy vegetables provide large surfaces for contact with water and for the attachment of microorganisms.

In hydroponic sytems water is used for the transport of nutrients to the plant. Water from sewage plants can be used for this purpose. Without further hygienic treatment it may represent a risk for contaminating the crop. There is a similar concern with the use of recycled water.

Recycling of water for agricultural purposes have been implemented in several countries such as Australia, Germany, Israel, Spain, The Netherlands and US (Castillo Martín *et al.,* 1994). The safety of treated sewage water depends on the efficiency and reliability of treatments to inactivate pathogens.

Organic fertilisers

Sewage, manure, slurry, sludge and compost of human and animal origin are commonly used as organic fertiliser for fruit and vegetable production particularly in organic production systems. The faecal origin of these fertilisers, however, indicates a potential risk of contamination by viruses, bacteria and parasites pathogenic to humans.

Members of the *Enterobacteriaceae* like *Salmonella*, *Shigella*, *Yersinia*, *E. coli* as well as *Campylobacter* can be found in the intestinal tract of a wide range of domestic, wild and companion animals. In Belgium and Finland *L. monocytogenes* was found in 6.7 to 20% of the samples analysed (Husu, 1990; Van Renterghem *et al.,* 1991), and in sewage sludge (Strauch, 1991).

De Luca *et al.* (1998) found *Listeria* in sewage sludge and concluded that fertilizing land with this material, for vegetable farming, could potentially present health risks. In Italy and The Netherlands, *L. monocytogenes* has been detected in sewage treatment plant effluents (Bernagozzi *et al.*, 1994; Dijkstra, 1989). In the UK, in 1992 1,029,555 tonnes (dry solids) of sewage sludge were generated, and over 460,000 tonnes of it were applied to agricultural land (Maule, 2000). By contrast the volume of farm animal waste applied to land is much greater than for sewage sludge. In the UK some 21 million tonnes (dry solids) of farm animal waste are spread annually on the land (ACMSF 1999).

In general, increasing the delay between the application of organic fertilisers and harvest could reduce the occurrence of foodborne pathogens on fruits and vegetables. More evidence is needed to establish the minimum delay necessary for pathogens to be completely eliminated.

In some foodborne outbreaks linked to the consumption of raw fruits and vegetables, epidemiological investigations identified manure as the source of contamination: *L.*

monocytogenes on cabbage in Canada, and *Salmonella* and *E. coli* O157:H7 on apples used to make apple juice in the US (Tauxe *et al.*, 1997; Nguyen-the and Carlin, 2000). Occurrence of *E. coli* O157:H7 on fresh produce may also be a result of field contamination because of water runoff from nearby cow pastures, exposure to droppings from wild animals (Hilborn *et al,* 1999; Rice *et al,* 1995).

The microbiological process during composting or aeration is not well understood. An important factor is the increase in temperature to 50-60°C and the treatment time. If this process is managed carefully it will kill those foodborne pathogens that do not form spores (Strauch, 1991). However, the adequacy of existing methods and regulations for composting need to be reviewed (Tauxe *et al.*, 1997).

Usually, vegetative foodborne pathogenic bacteria and viruses decline within a few days after their introduction into the soil (Geldreich and Bordner, 1971; Tierney *et al.*, 1977; Watkins and Sleath, 1981; Van Renterghem *et al.*, 1991; Dowe *et al.*, 1997) or on the plant surfaces (Nichols *et al.*, 1971; Kott and Fishelson, 1974; Ward and Irving, 1987) although they may survive (in low numbers) for several weeks or months (Bryan, 1977; Chandler and Craven, 1981; Watkins and Sleath, 1981; Al-Ghazali and Al-Azawi, 1990; Dowe *et al.*, 1997). Survival in the soil is influenced by several factors, e.g. soil type, soil humidity and its variation, temperature and soil microflora (Bryan, 1977; Tierney *et al.*, 1977; Dowe *et al.*, 1997). *E. coli* O157:H7 survived in bovine and ovine manure from several weeks up to 12 months depending on environmental conditions (Kudva *et al.*, 1998; Fukushima *et al.*, 1999).

Plant protection products
Chemical biocides are in general used for protection of plants against pests and plant diseases. Even though substances authorised for this purpose have undergone extensive safety evaluations, there is consumer concern about their need and safety. These substances are not authorised for use in organic production of fruits and vegetables. This has stimulated the development of alternatives control methods based on microorganisms or their metabolites. The use of microorganisms for biocontrol is a scientific field where limited knowledge exists on the potential risk for the consumers at the time at consumption.

A wide range of microorganisms are used in biological control including members of Bacillaceae, Micrococcaceae, *Streptomyces, Trichoderma,* fungi, viruses, Lactobacillaceae, and the *Pseudomonas* group (Kirschbaum, 1985). Strains of *Bacillus thuringiensis* (Bt) or its bioactive crystalline protein has been used for the control of insects (Vaeck *et al.*, 1987). Bt is also permitted in organic production of fruits and vegetables and the gene for the active protein has been inserted into GM-plants for insect control. The genomic structure of Bt is similar to *Bacillus cereus* and. discrimination between these organisms is largely onto the basis of possession of the Bt toxic crystalline protein. Bt strains used for pest control have been found to express *B.cereus* enterotoxin (Damgaard, 1995).

Viruses have also a long tradition for control of pests and mites. A well-known example is the use of Baculo viruses against arthropods (Hunter-Fujita *et al.*, 1998).
Antibiotic substances like kasugamycin, octhilinone, oxytetracycline, validamycin, polyoxin, and streptomycin are used for plant protection in some countries. The emerging risk related to this practice was discussed in an opinion of the SSC on antibiotic resistance (SSC, 1999).

4.2.   Harvest

Fruits and vegetables can become contaminated with pathogenic microorganisms during harvesting through faecal material, human handling, harvesting equipment, transport containers, wild and domestic animals, air, transport vehicles, ice or water (Beuchat, 1995).

In an investigation of several foodborne illnesses associated with fresh produce (NACMCF, 1999a), agricultural workers were in many cases the likely source of the pathogen. Lack of suitable sanitary hand-washing facilities in the production area can potentially create a hygienic problem. This appears to be particularly important in the transmission of enteric viruses, such as hepatitis A virus NACMCF concluded that persons who harvest and/or process fresh produce should be viewed as food handlers rather than agricultural workers (NACMCF, 1999a). Beuchat (1995) referred to outbreaks of *Shigella flexneri* and hepatitis A which could be traced back to infected people working on the fields or in the packaging facility.

Clean, well-designed and maintained equipment is less likely to cause damage to fresh produce and to introduce spoilage and pathogenic microorganisms (Brackett, 1992). Dirty storage facilities and the presence of rodents, birds and insects may increase the risk of contamination with foodborne pathogens (FDA, 1998). Finally, harvesting at the appropriate time and keeping the harvested product under controlled environmental conditions will help retard growth of post-harvest spoilage (Brackett, 1992) and pathogenic microorganisms.

4.3.   Post-harvest

Post harvest treatment of fruits and vegetables includes handling, storage, transportation and cleaning. During these practices conditions may arise which lead to cross contamination of the produce from other agricultural materials or from the workers. Environmental conditions and transportation time will also influence the hygienic quality of the produce prior to processing or consumption.
Poor handling can damage fresh produce, rendering the product susceptible to the growth/survival of spoilage and pathogenic microorganisms. This damage can also occur during packaging and transport. The presence of cut and damaged surfaces provides an opportunity for contamination and growth of microorganisms and ingress into plant tissues (Francis and O'Beirne, 1999).

5.   Washing and Decontamination

5.1.   Washing

The first washing of vegetables at harvest removes much of the adhering soil and dirt. However, it should be recognised that washing may also be a source of microbial contamination. An example is the contamination of tomatoes with *Salmonella javania* and of parsley with *Shigella sonnei,* which caused large outbreaks in the US (NACMCF, 1999; CDC, 1999). Mangoes exported to the US from Brazil were found to be infecting consumers with *Salmonella* (Sivapalasingam *et al* 2000). However, there was no evidence that consumers in Europe were being infected. The infection was traced to contaminated hot water used to kill fruit-flies in the mangoes. For the mangoes exported to Europe ethylene-bromide was used for the same purpose (Personal communication by Tauxe, 2001).

Recycling may be necessary to conserve water resources. However, purification of this water, which frequently contains high organic loading is difficult. More data are needed on the hygienic consequences of reusing water in fruit and vegetable production and. Washing can reduce the microbiological load of raw fruits and vegetables.

However, even where washing is applied, effective washing and decontamination of ready-to-eat fruits and vegetables (including fresh leafy herbs) is difficult. Not all commodities lend themselves to being washed. Some e.g., strawberries and mushrooms depreciate in quality if they are washed prior to marketing. Studies show that the effect of washing in reducing the number of bacteria present is small with reductions of 0.1 to 1 $\log_{10}$ units (Beuchat *et al.*, 1998).

5.2. Decontamination

Various disinfectants can be used to reduce the microbial load on fruits and vegetables. However, the safety assessments of these substances and the legal requirements concerning such treatments also have to be taken into account. The purpose of using these agents is to control plant pathogens (plant protection) or food pathogens or spoilage organisms (preserving additive). The effect of disinfectants on contaminants depends on many factors including the concentration used, treatment time, temperature, pH and sensitivity of the target organism(s).

Chlorine is the major compound used for disinfection of fresh produce. During sprouting of seeds chlorine can be used in the water to prevent growth of contaminating microorganisms. The most effective form is hypochlorous acid (HOCl) (Simons and Sanguansri, 1997) and chlorine concentration of 100 ppm are frequently used. However, the use of chlorine does not ensure elimination or even an efficient reduction in pathogen levels. Other substances many be used including organic acids, chlorine dioxide, hydrogen peroxide and ozone (Beuchat, 1998). Organic acids alone, or in combination with chlorine, have been shown in experimental designs to effectively reduce the number of pathogens for example, *Yersinia enterocolitica* and *Listeria monocytogenes* in parsley (Karapinar and Gonul, 1992; Zhang and Farber, 1996).

Ozone has been cited as a safe alternative for disinfecting fresh produce. Little information is available on the effect of ozonated wash water in fruits and vegetables. Chlorine dioxide has been considered as a disinfectant for fruits and vegetables although it has the disadvantage of being unstable (Simons and Sanguansri, 1997). Several studies suggest that hydrogen peroxide has potential as a sanitising agent for fruits and vegetables (reviewed in Beuchat, 1998). It is classified in the US as Generally Recognised As Safe (GRAS) for use in food products (Sapers and Simmons, 1998).

Although a wide range of different agents is available for disinfecting/sanitising fresh produce their efficacy is variable and none are able to ensure elimination of pathogens. Consequently it is not possible to rely solely on disinfection to control contamination by pathogens. Beuchat (1998) concluded that prevention of contamination at all points of the food chain is preferred over the application of disinfectants.

5.3. Irradiation

Doses of irradiation, that would be required to inactivate human pathogens, are known to have an adverse effect on fruits and vegetables, and relatively little commercial activity is carried out to control foodborne pathogens in these foods. Irradiation up to a maximum dose of 1 kGy has been approved in the US for the disinfestation of grains, fruits and vegetables for the inhibition of sprouting and for delaying ripening, in order to extend the shelf-life.

6. Consumers at risk

6.1. Vulnerable groups for infection with pathogens and opportunistic pathogenic organisms

Apart from pre-weaning infants, no group of the population is excluded from eating raw vegetables, sprouted seeds and fruits etc. The young, the old, the pregnant and the immuno-compromised consumers potentially have a higher risk of bacterial, viral or protozoan infection than other groups. This factor is important in risk assessment and risk management relating to the consumption of fruits and vegetables. A particular concern relates to infection of young children with *E.coli* O157:H7 and the potential for these infections to progress to Haemolytic Uraemic Syndrome (HUS) (Parry and Palmer, 2000).

Diarrhoea is a significant cause of morbidity and mortality in the elderly. Lew *et al.* (1991) noted that 51% of deaths caused by diarrhoea over a 9-year period occurred in individuals over the age of 74. Older patients may be at increased risk of *Salmonella* infection because of achlorhydria, decreased intestinal motility associated with medications, gastrointestinal diseases prevalent in the elderly, and more frequent use of antibiotics (Dressman *et al.* 1990; Lew *et al.* 1991; Russell *et al.* 1993). Infectious hepatitis is a common complication in patients with acute leukaemia and has been related to several agents, including hepatitis virus types A (Dienstag 1988). The classic pathogens identified in patients with defects in cell-mediated immunity are *Listeria monocytogenes*, *Salmonella* and non-tuberculous Mycobacteria (Meunier 1995; Burckhardt et al. 1999; Gruter *et al.* 2000).

Transplant recipients, and also patients with AIDS, can acquire infections caused by a wide range of bacteria, viruses, protozoa and fungi (Jurado *et al.* 1993; Ho and Dummer 1995). *Listeria* infections may arise from contaminated food sources (Schlech *et al.*, 1983) or the environment. However, a source is rarely identified in the sporadic cases of meningitis seen in those undergoing transplants.

7. Management of Risk

7.1. Management Responsibilities

Good Hygienic Practice (GHP) as defined in the Codex document on "General Principles of Food Hygiene" in combination with HACCP is the basis for safe food production (Codex Alimentarius, 1997). The application of HACCP for safety of fruits and vegetables is considered to be problematical, particularly the identification of robust Critical Control Points (CCP) for the destruction of pathogens and the record keeping for measures taken at the CCP.

Within the area of fruit and vegetable safety the development and application of measures applicable in Good Agricultural Practices (GAP) is a required tool.

Some retailers appear to demonstrate clear responsibility for the safety of fruits and vegetables. This is reflected in specifications to be met by producers in respect of factors affecting the safety of these commodities. Retailers may conduct inspections including tests to verify these programs. These programs are likely to expand given the focus on consumer safety by stakeholders in the market.

In a guidance for the US industry (FDA, 1998) the FDA and USDA define practices to be taken in respect of microbial food safety hazards and good agricultural and management practices common to growing, packaging and transport of fruits and vegetables. The guide focuses on water quality for different purposes, manure and municipal biosolids, workers health and hygiene, field sanitation, packaging facility sanitation, transportation and trace back.

7.1.1. EU Member States

Microbiological safety of fresh fruits and vegetables eaten raw are affected by conditions regarding the use of organic fertilisers (manure, bio-solids, etc.), water quality, plant protection products, washing, irradiation and decontaminants can be applied for improvement of hygiene. Risk management legislation within EU or its Member States for these subjects fall within different areas like environment protection, plant protection products, food additives and food hygiene.

7.1.2. Codex Alimentarius Committee on Food Hygiene

A code of "Hygienic Practices for Fresh Fruits and Vegetables" including an Annex on "Ready-to-Eat Fresh Pre-cut Fruits and Vegetables" and on "Sprout Production" have been elaborated by the Codex Alimentarius Committee on Food Hygiene. The proposed Code was moved to step 8 at the meeting in October 2001, Bangkok (FAO/WHO, 2001).

The Codes were initiated in response to the growing concerns about fresh fruits and vegetables as a source of foodborne pathogens. They addresses Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP) that will help to control microbial, chemical and physical hazards at all stages of the production of fresh fruits and vegetables from primary production to packing. The following areas of importance for microbial safety are acknowledged: environmental hygiene, hygienic production (water, manure, soil, agricultural chemicals, biological control, indoor facilities, personal hygiene), handling, storage, transport, cleaning, maintenance and sanitation.
The draft code follows the format of the Codex code for General Principles of Food Hygiene. It merely addresses hazards to be managed by the producer according GAP and GMP. It does not in general define measures to be taken and criteria to be obtained. The draft code does not recognise HACCP (Hazard Analysis and Critical Control Points) for safe production.

8. Conclusions

Published surveys of raw fruits and vegetables demonstrate that there is potential for a wide range of these products to become contaminated with microorganisms, including human pathogens. Almost any ready-to-eat fruit or vegetable that has been contaminated with pathogens either from the environment, from human or animal faeces or through storage, processing and handling could potentially cause diseases. However, epidemiological traceability is difficult for fruits and vegetables as carriers of foodborne pathogens.

Outbreaks have been reported involving a range of bacterial, viral and protozoan pathogens. The frequency of foodborne outbreaks of gastrointestinal illness associated with fruits and vegetables appears to be low compared to products of animal origin. However, it appears that food-borne illnesses associated with fruit and vegetables are increasing. The reason for this is not clear but factors include improved reporting, increased consumption, new commodities and changes in production practices. The large outbreak of *E. coli* O157 in Japan in 1996 linked to sprouted radish illustrates the potential for serious public health problems arising from the contamination of fresh fruit and vegetables.

Most of our information is based on data from only a few countries. It is important to recognise that the frequency and types of outbreaks identified will reflect the surveillance and reporting systems operating in different countries. Only in countries with an active surveillance system are outbreaks likely to be reported.

Fruits and vegetables can be contaminated with pathogens from animal and human reservoirs and the environment as a result of production practices. A major source of contamination is organic fertiliser (e.g. manure, municipal sludge) and faecal contaminated water. The specific risk with manure and sewage sludge for organic production has to be acknowledged.

Harvesting at the appropriate time and keeping the harvested products under well-controlled conditions will help in restricting growth of pathogenic and post-harvest spoilage microorganisms.

The increase in global trade as well as the increase in the organic farming will expose consumers to products with limited information concerning their microbiological safety.

Limited data exist on the safety of microorganisms used for bio-control of pests during production of fruit and vegetables.
The use of additional post-harvest procedures can reduce the contamination level on vegetables and fruits. In most cases water will be used but there are products where its use would not be appropriate. Chemical decontaminants are not widely used, with the exception of chlorine, and their impact on microbial food safety is not well established. Chemicals used for these purposes have to undergo a safety assessment.

Fruits and vegetables can be contaminated during harvest and the further processing by food handlers. This problem is particularly associated with the occurrence of human intestinal viruses.

Available data are insufficient to indicate clear trends in consumption of specific categories or types of fruits and vegetables. However, there is a marked increase in the production of cut and packed ready-to-eat fresh vegetables.

There are a number of ready-to-eat commodities of special concern. They comprise sprouted seeds and fruit juices, which have not undergone a treatment to kill or to remove microorganisms.

GAP and GHP are the basis for safe production of fresh produce. A problem is the identification and monitoring of effective critical control points in production of fruits and vegetables. The application of HACCP as an integral part of these practices needs to be evaluated.

The most efficient way to improve safety of fruits and vegetables is to rely on a proactive system reducing risk factors during production and handling. Apart from washing other methods of decontamination seem to have a limited influence on safety.

9. Recommendations

Public health professionals investigating incidents of food-borne illness, persons involved in the production chain and consumers should be made aware that contaminated fruits and vegetables eaten raw can be potential vehicles of pathogenic agents.

Robust traceability would greatly improve the epidemiological investigation, identification of causal or contributory factors and the control of suspected incidents of foodborne illness.

There is a need for improved surveillance systems on food-borne pathogens, on food products and on outbreaks so that comparable data are available from a wider range of countries.

There is a need to collect data on the microbiological safety of (i) fruits and vegetables newly introduced into the EU market, (ii) products produced using new technologies for preparation and preservation, and (iii) traditional European products which are now also being sourced from third countries.

Production measures for fruits and vegetables based on GHP, GAP and HACCP need to be introduced. Special concern has to be taken to the risk with droppings from wild and domestic animals entering the production area and from fresh manure used as fertiliser. Irrigation water can also be a source of faecal contamination of fresh produce. The potential of organic farming to contaminate fruits and vegetable with pathogens has to be investigated.

Water used in the production, irrigation and washing of fruits and vegetables should be of a quality that does not introduce microorganisms at a level that might cause harm to the consumer.
Organic fertilisers and sewage sludge should be treated in such a way that they do not contaminate fresh produce with microorganisms at levels that might cause harm to the consumer.

Further studies are required on the microbiological status and survival of various pathogens in the agricultural environment, in/on raw fruits and vegetables and the most efficient decontamination procedures. Safety of chemicals used for decontamination processes has to be assessed.

National regulations that cover or impact on the production of fruits and vegetables need to be compiled in order to develop a harmonised European approach.

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ANNEX I. TABLES

Table 1. Production, Exchanges, and Estimation of Consumption of Fruits and Vegetables within the EU in 1998

1998 (in thousand tons)	GERMANY	AUSTRIA	BELGIUM & LUXEMBURG	DENMARK	SPAIN	FINLAND	FRANCE	GREECE[3]	IRELAND	ITALY	NETHERLANDS	PORTUGAL	UNITED KINGDOM	SWEDEN	EUROPEAN UNION
FRUITS (except raisins)															
Production	1218	196	627	51	8892	13	3314	2428	17	10223	711	681	328	15	28712
Transformation[1]					1480		572	625		2020					4697
Imports	4358	337	2253	212	557	222	2318	149	151	1194	1606	372	2765	515	17007
Exports	302	72	1860	6	4021	3	1498	669	17	2257	1216	63	74	24	12082
Interventions	7	0	10	0	130	0	109	53	0	75	25	1	1	0	411
Consumption	5267	461	1010	256	3818	232	3453	1230	150	7065	1076	989	3017	506	28529
Population (in million inhab.)	82.3	8.1	10.6	5.3	39.4	5.2	58.6	10.6	3.7	57.4	15.7	9.9	58.9	8.9	375
Consumption (kg/pers/year)	64	57	95	48	97	45	59	116	41	123	69	100	51	57	76
VEGETABLES (except potatoes)															
Production	2683	425	1359	215	11610	209	6093	4081	260	12060	3248	2196	2884	227	47550
Transformation tomato					1182		328	1248		4352		988			8098
Transformation other veg.[2]	595		492		622		935			102	304		470		3520
Imports	2894	225	833	121	134	81	1379	29	109	367	765	144	1387	245	8713
Exports	164	84	640	16	4008	4	855	250	33	894	2279	18	75	5	9325
Interventions	4	0	3.1	0	53	0	25	0	0	12	0	1	0	0	97
Consumption	4814	566	1057	320	5879	287	5329	2613	335	7067	1430	1334	3726	466	35223
Population (in million inhab.)	82.3	8.1	10.6	5.3	39.4	5.2	58.6	10.6	3.7	57.4	15.7	9.9	58.9	8.9	375
Consumption (kg/pers/year)	58	70	100	60	149	55	91	246	91	123	91	135	63	52	94
Consumption of fruits and vegetables (kg/pers/year)	122	127	195	109	246	100	150	363	131	246	160	235	114	109	170

[1] Transformation is processed food (e.g. canning).
[2] Estimation over several years.
[3] Including 320 000 T of bananas of Guadaloupe and Martinique.

These figures must be used with many precautions. Indeed consumption per person is the resultant of compilation of numerous data sources, which may be very different. ATTENTION! Losses are not taken into account in these calculations.

SOURCE OF DATA: Eurostat, elaborated by Ctifl.

Table 2a Foodborne Disease Outbreaks Related to Intact Products Grown in Contact with Soil and/or Water

Product	Origin	Country	Organism	Ref.[1]
Salad	Not reported	UK	*Salmonella enteritidis* PT4	a
Potato salad	Not reported	UK	*Salmonella enteritidis* PT4	a
Coriander	Not reported	UK	*Salmonella typhimurium*	a
Melon	Not reported	US	*Salmonella javiana*	b
Cantaloupe	"Imported"	US	*Salmonella chester*	b
Tomato	Not reported	US	*Salmonella javiana*	b
Meney	Guatemala	US	*Salmonella typhi*	c
Mango	Not reported	US	*Salmonella* spp	c
Lettuce, tomato	Not reported	UK	*E. coli* O157	a
Salad (mixed)	Not reported	UK	*E. coli* O157	a
Lettuce	Not reported	US	*E. coli* O157:H7	b
Salads	Not reported	US	*E. coli* O157	d
Lettuce	Not reported	UK	*Campylobacter*	a
Salad vegetables	Not reported	UK	*Shigella flexneri*	a
Salad	Not reported	UK	*Shigella sonnei*	a
Iceberg lettuce	Spain	Germany, Sweden, UK	*Shigella sonnei*	e
Baby corn	Thailand	Denmark	*Shigella* spp.	d
Parsley	Mexico	US	*Shigella* spp.	c
Lettuce	Not reported	US	Hepatitis A virus	b
Frozen raspberries	UK	UK	Hepatitis A virus	b
Frozen strawberries	Not reported	US	Hepatitis A virus	b
Tomato	Not reported	US	Hepatitis A virus	b
Carrot	Not reported	UK	SRSV	a
Salad (mixed)	Not reported	UK	SRSV	a
Salad (green)	Not reported	UK	SRSV	a
Salad (raw)	Not reported	UK	SRSV	a
Salad (raw)	Not reported	UK	SRSV	a
Tomato & cucumber	Not reported	UK	SRSV	a
Watercress	Not reported	UK	SRSV	a
Celery	Non potable water?	US	Norwalk virus	b
Green onions	Not reported	US	*Cryptosporidium* sp	
Raspberries	Guatemala?	Canada, US	*Cyclospora cayetanensis*	b
Mesclun lettuce	Not reported	US	*Cyclospora cayetanensis*	c
Lettuce, onion, tomato	Not reported	US	*Giardia lambia*	d
Basil	Not reported	US	*Cyclospora cayetanensis*	c

[1] References to the Tables:
a personal communication, data presented at the FMH WG meetings, see point 1.2
b Tauxe *et al.* (1997).
c US FDA (2000).
d Anon (2000c).
e Gilbert (2000).
f Taormina et al. (2000).

Table 2b. Foodborne Disease Outbreaks Related to Intact Products Grown in Contact with Soil and/or Water and Directly Exposed to Faecal Material

Product	Origin	Country	Organism	Ref.[1]
Alfalfa sprouts	US	US	*S. montevideo* *S. meleagridis*	f

[1] Ref.: see Table 2a.

Table 3.   Reported Outbreaks of Illness Associated with Seed Sprouts, 1973-1999

Year	Pathogen	Confirmed Cases[a]	Location	Type of Sprout	Likely Contamination	Reference
1973	*Bacillus cereus*	4	1 US state	Soy, cress, mustard	Seed	Portnoy *et al.*, 1976
1988	*S. saint-paul*	143	UK	Mung	Seed	O'Mahony, 1989
1989	*S. gold-coast*	31	UK	Cress	Seed and/or sprouter	Joce *et al.*, 1990
1994	*S. bovis-morbificans*	595	Sweden, Finland	Alfalfa	Seed	Puohiniemi *et al.*, 1997; Ponka *et al.*, 1995
1995	*S. stanley*	242	17 US states, Finland	Alfalfa	Seed	Mahon *et al.*, 1997
1995-1996	*S. newport*	133[b]	>7 US states, Canada, Denmark	Alfalfa	Seed	Van Beneden *et al.*, 1999
1996	*S. montevideo* and *S. meleagridis*	~500	2 US states	Alfalfa	Seed and/or sprouter	Mouzin *et al.*, 1997
1996	*E. coli* O157:H7	~6,000	Japan	Radish	Seed	Min. Health Welfare Japan, 1997
1997	*E. coli* O157:H7	126	Japan	Radish	Seed	Gutierrez, 1997
1997	*S. meleagridis*	78	Canada	Alfalfa	Seed	Buck *et al.*, 1998
1997	*S. infantis* and *S. anatum*	109	2 US states	Alfalfa, mung, other	Seed	Glynn *et al.*, 1998
1997	*E. coli* O157:H7	85	4 US states	Alfalfa	Seed	CDC, 1997
1997-1998	*S. senftenberg*	52	2 US states	Clover, alfalfa	Seed and/or sprouter	*
1998	*E. coli* O157: NM	8	2 US states	Clover, alfalfa	Seed and/or sprouter	*
1998	*S. havana, S. cubana*, and *S. tennessee*	34	5 US states	Alfalfa	Seed and/or sprouter	*

Adapted from Taormina, 1999

[a] The number of culture-confirmed cases represents only a small proportion of the total illness in these outbreaks, as many ill persons either do not seek care or do not have a stool culture performed if they do seek care.

[b] Includes only culture-confirmed cases in 0regon and British Columbia.

* Mohle-Boetani J., pers. comm. to Taormina

Table 4.   Foodborne Disease Outbreaks Related to Cut/Sliced/Skinned/Shredded Products

Product	Origin	Country	Organism	Ref.[1]
Shredded coconut	Malaysia	UK	*Salmonella java* PT Dundee	e
Cantaloupe fruit salad	Mexico and South America	US, Canada	*Salmonella poona*	e
Watermelon	Not reported	US	*Salmonella*	b
Shredded lettuce	Not reported	US	*Shigella* spp.	b
Coleslaw	Not reported	US	*E. coli* O157	d
Cabbage?	Canada	Canada	*Listeria*	e
Sliced raw vegetables	Not reported	US	*Giardia lambia*	d
Fruit Salad	Not reported	US	*Giardia lambia*	d

[1] Ref.: see Table 2a.

Table 5.   Foodborne Disease Outbreaks Related to Fruit Juices

Product	Origin	Country	Organism	Ref.[1]
Melon & papaya	Not reported	UK	SRSV	a
Apple cider	US	US	*E. coli* O157:H7	b
Apple cider	US	US	*S. typhimurium*	b
Apple cider	US	US	*Cryptosporidium* spp.	b
Frozen coconut milk	"Imported"	US	*Vibrio cholerae* O1	?
Orange juice	Not reported	US	*S. hartford*	b
Orange juice	Not reported	US	*S. anatum*	c
Orange juice	Not reported	US	*S. typhi*	c
Orange juice	Not reported	US, Canada	*S. muenchen*	c
Orange juice	Not reported	US	*S. anatum*	c
Orange juice	Not reported	US	*Bacillus cereus*	c

[1] Ref.: see Table 2a.

Table 6.   Foodborne Disease Outbreaks Related to Minimally Process Products with Extended Life

Product	Origin	Country	Organism	Ref.[1]
Extended life – ambient				
Chopped Garlic	Not reported	US	*Clostridium botulinum*	b
Extended life – chilled				
Cabbage? (Coleslaw)	Canada	Canada	*Listeria monocytogenes*	b, d

[1] Ref.: see Table 2a.

Table 7.   General Outbreaks of IID Associated with the Consumption of Salad Items, Vegetables or Fruit* Reported to CDSC, England & Wales, 1992-1999

Year	General Outbreaks	Foodborne Outbreaks	Salad/fruit/veg Outbreaks	Percent
1992	373	224	9	4.0
1993	456	227	5	2.2
1994	488	191	15	7.9
1995	834	178	5	2.8
1996	732	161	12	7.5
1997	591	220	3	1.4
1998	609	120	5	4.2
1999	505	87	6	6.9
Total	4588	1408	60	4.3

Source: GSURV database, Epidemiology Division, PHLS CDSC – 07/06/00

* More that one vehicle may have been reported for any single outbreak. The figures above represent the number of outbreaks in which at least one of the vehicles reported was a salad/vegetable/fruit product.