FOOD STANDARDS Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

Supporting Document 2

Review of foodborne illness associated with selected ready-to-eat fresh produce (December 2011)

Proposal P1015

Primary Production & Processing Requirements for Horticulture

---

Executive Summary

Background

Outbreaks of foodborne illness have been associated with the consumption of horticultural products both in Australia and internationally. Consequently, Food Standards Australia New Zealand (FSANZ) is assessing whether existing programs in the Australian horticulture industry are sufficient to manage food safety risks or whether regulation, in the form of a Primary Production and Processing (PPP) Standard, may be more appropriate.

Under the *Food Standards Australia New Zealand Act 1991,* FSANZ has three main objectives when developing or reviewing food standards:

(a) the protection of public health and safety; and

(b) the provision of adequate information relating to food to enable consumers to make informed choices; and

(c) the prevention of misleading or deceptive conduct.

Development and application of a PPP Standard for horticultural products depends on an analysis of the public health and safety risks, economic and social factors and current regulatory and industry practices. In regards to assessing the public health and safety risks, FSANZ uses a number of methodologies depending on the objective of the assessment and on the availability, quality and quantity of data.

The objective of this assessment is to determine whether the existing evidence identifying so-called 'high risk' horticultural commodities and risk factors involved in their production, is applicable to the Australian situation. In addressing this objective and within the context of the assessment, the following questions were considered:

- What are the main risk factors or activities contributing to contamination of horticultural products?
- Have risk factors other than those included in the assumptions been identified in horticultural related foodborne outbreaks?
- Are there different risk factors for different production systems (eg: field grown, hydroponics, organics, glasshouse)?
- What measures/controls may have minimised contamination of produce?

- What are the commodities most often implicated in horticultural related foodborne outbreaks?

There exists within the public domain a substantial body of evidence establishing the horticultural commodities most often implicated in foodborne illness and the production activities which contribute to their risk. Where particular plant products or foods have been identified, salads and fresh fruits are frequently implicated. A number of farming and processing activities (referred to as 'risk factors') are also commonly believed to increase food safety risks. These include the use of water (especially pre- and post-harvest), biological fertilisers, management of the environment and food handling practices.

This assessment primarily involves testing assumptions; that we know the commodities most often associated with horticultural related foodborne illness and the main contributing risk factors. These assumptions are tested through an analysis of selected, well documented, horticulture related outbreaks. Supporting the outbreak analysis, Australian epidemiological and surveillance data (where available) and existing international and domestic published and unpublished assessments are also utilised.

The key component of this assessment is a descriptive scoping review of horticultural produce-associated outbreaks. Based on a systematic review, the search strategy incorporated multiple layers linking pathogen, commodity and outcome variables to capture relevant studies from selected databases. From an initial 2204 articles and following two filtering steps, 41 articles describing 43 outbreaks were eventually selected as meeting the search criteria.

Conclusions

The outcomes of this assessment reaffirm the assumptions identifying the commodities and risk factors most likely to result in produce contamination and outbreaks of foodborne illness. However, these findings should not preclude the potential that other commodities and/or risk activities may be implicated in future horticultural-associated foodborne illness outbreaks. Where commodities could be identified, vegetables and fruits were contaminated in the field or during the initial processing, through the use of poor quality water or by direct faecal deposition on produce in the field. The size of outbreaks vary according to the pathogen involved, level of contamination, volume of produce contaminated, distribution networks, site and method of final preparation and the amount consumed. All these factors influence the likelihood that a particular food may cause illness when consumed. Therefore, care should be exercised in drawing specific conclusions about pathogen commodity pairings and what may constitute a risk to the consumer.

Only a very small number of outbreaks (that met the strict selection criteria) in the past 20 years have been associated with fresh produce in Australia. The microbiological data available from Australian surveys suggests there is a low level of contamination of fruits and vegetables available in the Australian supply chain, although infrequent contamination of fresh produce with pathogenic microorganisms can occur. The available evidence provides a high degree of confidence that Australians have access to safe fresh produce.

Table of Contents

Introduction

Outbreaks of foodborne illness have been associated with the consumption of horticultural products both in Australia and internationally. As a result, a substantial body of evidence has been generated which establishes the horticultural commodities most often implicated and the production activities which contribute to the risk of produce-associated foodborne illness.

Where particular plant products or foods have been identified, salads and fresh fruits are frequently implicated. A number of farming and processing activities (referred to as 'risk factors') are also commonly believed to increase food safety risks. These include the use of water (especially pre- and post-harvest), biological fertilisers, management of the environment and food handling practices. Internationally, these risk factors are acknowledged as contributing to the risk associated with the consumption of certain horticultural produce.

The Australian horticulture industry already has in place a number of quality assurance (QA) and food safety schemes which address many aspects of food safety. A question remains however, whether existing industry programs are sufficient to manage food safety risks or whether regulation may be more appropriate.

Food Standards Australia New Zealand (FSANZ) protects the health and safety of consumers through the development of food standards. Under the *Food Standards Australia New Zealand Act 1991,* FSANZ has three main objectives when developing or reviewing food standards:

(a) the protection of public health and safety; and

(b) the provision of adequate information relating to food to enable consumers to make informed choices; and

(c) the prevention of misleading or deceptive conduct.

Development and application of a Primary Production and Processing (PPP) Standard for horticultural products depends on an analysis of the public health and safety risks, economic and social factors and current regulatory and industry practices. In regards to assessing the public health and safety risks, FSANZ uses a number of methodologies depending on the objective of the assessment and on the availability, quality and quantity of data.

1 Objectives of the Assessment

The objective of this assessment is to determine whether the existing evidence identifying so-called 'high risk' horticultural commodities and risk factors involved in their production, is applicable to the Australian situation.

2 Scope

Included within the scope of this assessment are: those horticultural products considered to be fresh ready-to-eat (RTE) fruit and vegetables, including minimally processed fresh-cuts, and on-farm preparation and production activities through to retail, including transport and distribution. This includes processing activities, ie: washing and bagging, undertaken on farm.

Also included in the scope are those products not addressed as part of the PPP Standard for Seed Sprouts (P1004) including microgreens and snow pea shoots.

Specific horticultural commodities identified in the literature as being 'high risk' include fresh leafy vegetables, fresh leafy herbs, melons and minimally processed produce (e.g. bagged salad). The production factors; water (pre and post-harvest), fertilisers, faecal contamination and food handler hygiene, are cited as the primary risk factors for horticultural products.

3 Approach

Primarily this work involves testing two assumptions; that we know the commodities most often associated with horticultural related foodborne illness and the main contributing risk factors.

These assumptions are being tested through an analysis of selected, well documented, horticulture related outbreaks. The assessment also draws upon Australian epidemiological and surveillance data (where available) and existing international and domestic published and unpublished assessments.

3.1 Scoping review of horticultural-associated foodborne illness

A descriptive scoping review of available scientific literature regarding horticultural produce-associated foodborne illness outbreaks forms the foundation of this assessment (refer Section 6). The review incorporates elements of a systematic review, particularly documentation of the search strategy outcomes and review of all included papers, but does not include quantitative analysis.

The search strategy incorporates multiple layers linking pathogen, commodity and outcome variables to capture relevant articles from the PubMed and EBSCO databases. Relevant review articles are also examined to identify outbreaks not captured in the search.

Outbreak investigations reporting epidemiological data from well-designed studies and/or laboratory testing to link cases and horticultural commodity are also included. Those investigations where multiple foods are suspected as the source or the food commodity could not be determined or was part of a mixed dish (e.g. pasta salad), are excluded. Outbreaks associated with an infected/ill food handler immediately prior to consumption, for example an ill chef in a restaurant, are also excluded. The analysis also excludes review articles, experimental contamination studies and outbreaks associated with sprouts.

Details on included horticultural commodities, search terms and exclusion filters are contained at Appendix 3.

4 Questions

Within the context of this assessment the following questions have been developed to address the objectives:

- What are the main risk factors or activities contributing to contamination of horticultural products?
- Have risk factors other than those included in the assumptions been identified in horticultural related foodborne outbreaks?
- Are there different risk factors for different production systems (eg: field grown, hydroponics, organics, glasshouse)?
- What measures/controls may have minimised contamination of produce?
- What are the commodities most often implicated in horticultural related foodborne outbreaks?

5 Previous Assessments

5.1 Scientific literature

Within the scientific literature there are a number of examples of risk assessments undertaken for horticultural products. More commonly these follow the traditional risk assessment approach of considering a single commodity and pathogen pairing.

Duffy and Schaffner (2002) employed a quantitative risk assessment approach to characterise the risk of contamination of apples and apple cider with *E. coli* O157:H7. The model described and modelled the various sources of contamination to both dropped and tree-picked apples. Results of worst-case simulations indicated dropped apples presented higher risk than tree-picked apples (10^6 - 10^9 cfu/1000 apples *c.f.* 10^3 – 10^4 cfu/1000). Use of animal waste as fertilizer also contributed to increased risk. The model was, of necessity, conservative due to limited available data on contamination sources, frequency and concentration. Similarly, Danyluk and Schaffner (2011) describe risk estimates for *E. coli* O157:H7 in leafy greens determined from combining known behaviour of the organism under laboratory conditions with information gathered from the large 2006 *E. coli* O157:H7 spinach outbreak in the United States (US). Although a number of critical data gaps were identified, including estimates of initial prevalence and levels, time between contamination and harvest and the extent of cross-contamination of produce occurring during the washing process, the authors concluded that levels in the field of -1 log cfu/g and 1% prevalence could have resulted in an outbreak of approximately the same magnitude of the 2006 spinach outbreak.

Bassett and McClure (2008) developed a “fit-for-purpose” qualitative risk assessment to determine microbiological human pathogens associated with fresh fruits and recommend risk management measures. The authors modified the Codex Alimentarius (Codex) risk assessment framework to consider multiple hazards and multiple fresh, whole fruit, which was an attempt to simplify a complex issue hampered by a lack of available data. The authors grouped fruits based on intrinsic factors relevant to the survival and growth of pathogens (ie. pH >4) and used a number of factors to estimate the significance of the pathogen. Apparent from the study was the importance of prevention of contamination at the source and the application of effective good agricultural, good manufacturing and good hygiene practices. Washing to a recommended protocol was identified as an effective risk management measure, as was refrigerated storage for low acid fruit. The authors determined a number of risk management options for all fruits, with additional options for low acid fruits and aggregate fruits with respect to the risk from protozoa.

It is apparent that a lack of data and information exists for conducting risk assessments of horticulture products, particularly in relation to sources and extent of contamination. Complicating this is the vast range of horticultural commodities available and the different types of primary production and processing methods employed. Alternate approaches to assess the risk of horticulture products have therefore been considered by some regulatory agencies. Two such examples are briefly discussed below with further details provided at Appendix 1.

5.2 United Kingdom Food Standards Agency (UKFSA) report

Monaghan et al (2008) undertook a project for the UKFSA to review the scientific literature relating to foodborne outbreaks associated with RTE fresh produce; review assurance codes of practice commonly-encountered in the United Kingdom (UK) compared to the Codex standard and assess current UK fresh produce farming practices. Ready-to-eat was defined as crops that are sometimes or always consumed raw and as they are sold, without a cooking/processing stage that eliminates microbiological contamination. This included salad

vegetables, vegetables, fresh herbs, sprouted seeds and soft and top fruit.

Peer-reviewed scientific literature of outbreaks of foodborne illness associated with RTE fresh produce was reviewed with the authors noting that although a significant amount of foodborne illness outbreaks were *associated* with fresh produce; few cases *definitely* identified fresh produce as the cause. One reason proposed for this was the short shelf life of the product which often means no material is available for testing. Poor record keeping and traceback, as well as the variable susceptibility to infection within the human population, may also contribute.

The key recommendation of the report was that the agency investigates use of customised information and communication technologies to assist growers risk assess their production practices and water sources. Further recommendations included:

- Generation of guidance documents to show growers how to adequately risk assess their crops. Survey results indicated this was an area grower staff found particularly difficult.
- Consider classifying fresh produce into a standardised set of defined risk categories, as there was no harmony across the different QA systems reviewed. A number of crops allocated as medium or lower risk had been associated with foodborne illness.
- Noted information gaps relating to pathogen survival under commercial growing conditions has prevented development of stochastic models for fresh produce. Citing recently completed research, the report recommends consideration be given to developing stochastic models which describe the growing process for a number of key crops as a way of quantitating the roles of parameters that influence pathogen survival during production.
- Clearer instructions were necessary for describing requirements for microbiological testing of water, including description of organisms, what these organisms indicate and the scientific basis for associated criteria.
- Collection of compliance related microbiological test results to underpin the case control approach and control of outbreak situations.

The authors noted that suppliers to the retail sector are subject to QA schemes required by their customers; similar retail driven pressure is not seen for the wholesale sector. Improvements to traceability and food storage conditions were noted as areas which could be improved. Mandating the requirement for a QA program as a condition of supply was also proposed to further reduce the already low risk to UK consumers from fresh produce.

5.3 Food Science Australia

In 2006, FSANZ commissioned Food Science Australia (FSA) to review the microbiological status of plants and plant products available to Australian consumers (FSA 2006).

The objectives were to:

- Identify potential microbiological hazards associated with plants and plant products that may present a public health and safety risk to Australian consumers by reviewing the domestic and international literature.
- Identify the relative importance of microbiological hazards associated with plants and plant products available to consumers in Australia.

The review focussed on categories of fresh horticultural produce and fresh cut fruit and vegetables without an effective microbiological kill step before consumption; nuts, minimally processed oil seeds and grains, seed sprouts and vegetables in oil were also included. Fresh produce was defined as produce usually consumed raw without undergoing processes that inactivate pathogens or inhibit microbial growth (i.e. cooking). Fresh cut fruits and

vegetables included those that have been peeled, sliced, chopped, shredded, cored, trimmed or mashed with or without washing prior to being packaged.

For the identified product categories, the study reviewed available international and Australian data on the types and incidence of microbial pathogens on plants and plant products, potential sources of contamination and survival of pathogens, foodborne disease outbreaks and food recalls, as well as examining industry practices, including industry codes of practice, that impact on the reduction or elimination of pathogens. A descriptive relative risk rating exercise was then undertaken to determine a risk rating for each pathogen:product pair within identified high risk product categories.

From the reviewed evidence, the report concluded the highest risk products as being fresh cut vegetables and fruits consumed raw (i.e. packaged salad mix, prepared fruit salad and cut and plastic wrapped melons), unpasteurised fruit juices, seed sprouts and vegetables in oil. Specific pathogen:product pairs were identified as *Salmonella* spp. and seed sprouts, *Salmonella* spp. and tomatoes, *Salmonella* spp. and *Listeria monocytogenes* and fresh cut melons and *C. botulinum* and vegetables in oil.

Other key findings included:

- Contamination from handlers and improper handling causes the majority of produce associated (all traceable) foodborne disease.
- Procedures such as sanitising washes may have only limited success in removal and/or inactivation of pathogenic and other microorganisms. Preventing contamination of produce is likely to be more effective.
- Temperature control is an important bacterial and fungal control measure for fresh cut fruits and vegetables.

Evidence Base

6 Scoping Review of Outbreaks Associated with Fresh Produce

6.1 Background

The scoping review was restricted to assessing outbreaks of enteric pathogens associated with the consumption of fresh produce since these outbreaks afford the best option to assess commodities, pathogens and most importantly (where data was available), the critical points in production and processing that may fail and lead to produce contamination and subsequent human illness (see Section 3.1 and Appendix 3). In this context, fresh produce was defined as vegetables, herbs and fruits intended to be eaten raw, either unprocessed or minimally processed (e.g. pre-cut and packaged fruit, washed and bagged spinach or frozen berries). Mixed dishes were excluded if they contained non-produce items, such as chicken or seafood, and were only included in the final analysis if an unambiguous epidemiological or microbiological link could be made with a specific food item. This restriction was included since attribution is difficult for mixed food dishes. Commodities commonly consumed cooked (e.g. potato, pumpkin) were excluded, as were outbreaks associated with juices. Sprouted seeds were excluded as they are covered under a commodity specific PPP standard.

Outbreak investigations can be broadly separated into two evidence categories of food attribution; epidemiological and microbiological and many studies attempt both. Microbiological investigations can be further divided into simple food attribution studies and those that trace the pathogen to the source of food contamination (microbiological trace back) (Table 3). Published studies often report trace back and environmental investigations,

however, without supporting evidence from microbiological testing there tends to be a high degree of uncertainty in attributing supply chain failures and these assumptions may be subject to unquantifiable bias.

Table 3 *Types of outbreak investigations and their benefits and/or limitations*

Evidence	Investigation type	Benefits / limitations
Epidemiological food attribution	Case-control, retrospective cohort	Implicated food commodity can be identified in absence of food samples; can provide more rapid results; reliant on recall of foods consumed; multiple food commodities may be identified; potential for bias
Microbiological food attribution	Isolates from cases and implicated food matched by genetic analysis (e.g. pulsed-field gel electrophoresis (PFGE), multi-locus variable-number tandem repeat analysis (MLVA)	Contaminated food commodity microbiologically confirmed; short shelf life; food items may no longer be available; difficult to identify specific commodity in mixed dishes; may be a slow process depending on laboratory testing
Microbiological trace back	Isolates from cases, implicated food, environmental samples and source identified (e.g. animal faeces)	As above; identification of source of contamination; provides insight into specific risk management strategies required to mitigate contamination

The search strategy involved an initial scoping trawl of EBSCO and PubMed scientific search engines entering the search terms listed in Appendix 3. The initial search returned 2204 hits that were first filtered for appropriateness by title and, where necessary, abstract. The filtered scientific publications were entered into bibliographic software (Reference Manager) and duplicates were deleted. The 108 publications remaining after the first exclusion process were examined and measured against the inclusion criteria listed in Appendix 3. Forty-one publications describing 43 outbreaks were included in the final analysis described in this review (Table 4) and are summarised in Appendix 3.

Table 4 *Outbreaks attributed to fresh produce by evidence type*

Type of investigation	Total
Epidemiological food attribution	23
Microbiological trace back	8
Microbiological food attribution	12
Total	**43**

6.2 Key findings of the scoping review

The scoping review was constrained to those outbreaks that were thoroughly investigated and reported robust epidemiological and/or microbiological data. Outbreaks examined were associated with fresh horticultural commodities intended to be eaten uncooked and occurred as a consequence of a contamination event along the supply chain and with no steps that eliminated the pathogen before consumption. Apparent from the evidence was that source attribution is very difficult to achieve and significant challenges remain in pin-pointing both the origin and mechanism of produce contamination.

Of the 43 outbreaks captured in this review, 21 occurred in the US, 16 in western or northern Europe, five in Australia and one in Canada. From this data it is not possible to say that more outbreaks occur in the US compared to other reporting countries or more simply that the quality of the studies conducted in the US are more robust, more likely to be published and therefore met the selection criteria set for this review. Fifty-three per cent (23/43) of the outbreaks were associated with fresh produce that was imported, 39% (17/43) were associated with fresh produce that was grown in the country where the outbreak occurred and 7% (3/43) of outbreaks did not trace the source of the fresh produce.

For commodities identified in the scoping review, the following key findings are noted:

- Lettuce (multiple varieties) was the most common fresh produce vehicle attributed to outbreaks captured by the search string; responsible for eight outbreaks in six different countries.
- Rockmelon was the most common fruit attributed to outbreaks, causing seven outbreaks in two countries.
- Rockmelon (7), raspberries (4) and strawberries (2) were responsible for 13 of the 16 fruit associated outbreaks captured by this review.
- Tomatoes (semi-dried and fresh) were implicated in five foodborne outbreaks and possibly implicated in a sixth involving chilli peppers.
- *Salmonella* spp. were responsible for the most number of foodborne outbreaks, causing 13 outbreaks associated with a variety of food commodities from vegetables, leafy greens and fruit.
- The four *Yersinia pseudotuberculosis* outbreaks were restricted to Finland only.

A number of production activities were also identified, including:

- The use of poor quality water in post-harvest processing applications, such as washing, is an important source of produce contamination.
- The use of poor quality water pre-harvest (for produce that comes into contact with irrigation water or spray water, e.g. rockmelons, tomatoes) is an important source of produce contamination.
- The outbreak data provides evidence that wildlife incursions into growing areas prior to harvest are an important source of produce contamination.
- Wildlife were implicated in seven of the eight produce associated outbreaks that were traced back to source, three by direct contamination in storage, three by direct faecal contamination of produce in the field and one by contaminated water.
- Multiple breaches of good hygienic practice along the supply chain were noted in a number of outbreaks where a specific failure point was not identified.

6.3 Outbreaks occurring in Australia

Five foodborne outbreaks associated with fresh produce that met the inclusion criteria have been documented in the past 20 years in Australia. Two of these outbreaks were associated with imported produce; baby corn imported from Thailand was associated with a large outbreak of shigellosis (Lewis et al. 2009) (see Appendix 3, section 1.3.3) and imported semi-dried tomatoes were associated with a large multistate outbreak of Hepatitis A (Donnan et al. 2011) (see Appendix 3, section 1.2.3). The source of contamination for the tainted imported produce was not determined but poor sanitation was cited as a possible source of baby corn contamination (Lewis et al., 2009).

The three remaining outbreaks were associated with locally produced rockmelon (Munnoch et al. 2009), rockmelon and honeydew melon (OzFoodNet 2010a; Astridge 2011) and papaya (Gibbs et al. 2009) (see Appendix 3, sections 1.2.7 and 1.2.8, respectively). The 2006 outbreak of *Salmonella* Saintpaul was microbiologically linked to rockmelons grown and processed in the Northern Territory (NT); rockmelons from Queensland were found to

be contaminated with non-outbreak associated strains of *Salmonella* spp.. The outbreak strain could not be definitively linked to a farm, packing shed or processor, however, investigations of six processors in the NT and Queensland identified critical food safety issues in the production and processing of rockmelons that may have contributed to produce contamination; including the use of untreated or inadequately treated water on ready-to-eat melons, the incorrect use of disinfectants, temperature differential between fruit and wash water and processing of damaged fruit (Munnoch et al., 2009). Similarly, the use of untreated river water and incorrect use of chemical disinfectants was implicated as a possible source of fruit contamination leading to the papaya associated salmonellosis outbreak in Western Australia (WA) and Queensland from October 2006 to January 2007 (Gibbs et al., 2009). Unfortunately, no data or observations are available that provide details of the possible mechanisms of melon contamination that lead to the 2010 *L. monocytogenes* outbreak in New South Wales (NSW), Victoria and Queensland.

7 Outbreak Data

Sources of foodborne illness are generally determined through epidemiological and/or microbiological associations in outbreak investigations. Critical in this process is the ability to identify an outbreak through the existing surveillance system to enable an investigation to then proceed. Difficulties exist in identifying and attributing illness to a particular food and include:

- Food recall biases when gathering food consumption histories (compounded by pathogens with long incubation periods, e.g. hepatitis A virus)
- Time delays in recognition or notification of an outbreak, including:
  - the time taken for infected persons to seek medical treatment
  - obtaining stool samples
  - laboratory confirmation of the presence of pathogenic organisms
  - notification to public health authorities, and
  - identification and subsequent investigation of the outbreak
- Inability to trace food products to their source
- Reluctance of individuals to participate in investigations
- Long exposure windows for specific pathogens (e.g. *L. monocytogenes*)
- Inability to obtain representative food samples for analysis
- A lack of precision in, or suitable methods for, sample analysis and pathogen identification
- Immune status of the exposed population
- Food attribution in dishes with multiple food items
- The potential for variation in categorising features of outbreaks depending on investigator interpretation and circumstances

It is important to recognise that outbreak data are likely to only represent a small proportion of actual cases of foodborne illness, as many illnesses go unrecognised and/or unreported to health authorities. Levels of underreporting of foodborne notifiable diseases in Australia have been estimated by Hall et al (2006). People do not always seek medical attention for mild forms of gastroenteritis, medical practitioners do not always collect specimens for analysis and not all foodborne illnesses require notification to health authorities.

7.1 OzFoodNet

The OzFoodNet outbreak register contains data on reported outbreaks of gastrointestinal disease in Australia since 2001, with foodborne and suspected foodborne outbreaks defined as two or more cases of illness associated with a common food.

Summary of aggregated data by a commodity type can be very difficult. The term “fresh produce” covers a large variety of different products and the identification of outbreaks that are due to fresh produce or a dish containing a fresh produce item, is limited by the quality of the data collected in the register. These data are often free-text, subjective summaries that do not uniformly report food vehicles by commodity type. Results may vary depending on search terms used to interrogate the data.

Data on reported outbreaks of gastrointestinal illness associated with fresh produce has been obtained from OzFoodNet covering the periods January 2001 to March 2010 and January 2010 to June 2011 (OzFoodNet unpublished data, 2010; OzFoodNet unpublished data 2011) and is summarised below.

Further details of the outbreak data are included at Appendix 2.

7.1.1 Summary

Between January 2001 and June 2011, OzFoodNet’s Outbreak Register recorded 93 produce-associated outbreaks reported in Australia (Appendix 2, Table 1) representing 7% (93/1,291) of all foodborne and suspected foodborne outbreaks reported during the period. Of these, 11% (10/93) were classified as confirmed, 29% (27/93) as suspected and 60% (56/93) as possible (Appendix 2, Table 2).

Of the 93 produce-associated outbreaks, at least 2,822 people became ill, 321 were hospitalized and seven people died. Only considering confirmed and suspected[1] outbreaks, they represented 44% (1247/2822) of all illnesses, 77% (234/321) of all hospitalisations and 57% (4/7) of reported deaths. Over half of all hospitalisations (51%: 165/321) were from a single confirmed outbreak (hepatitis A in semi-dried tomatoes).

7.1.2 Setting and aetiology

Produce-related outbreaks were most frequently associated with food consumed in restaurants (34%, 32/93), the community (18%, 17/93) and in private residences (12%, 11/93) (Appendix 2, Table 3). Outbreaks were most commonly of unknown aetiology (35%, 33/93), or caused by *Salmonella* Typhimurium (18%, 17/93), norovirus (18%, 17/93) or other *Salmonella* serovars (12%, 12/93) (Appendix 2, Table 4a).

7.1.3 Type of implicated produce

Vegetables were associated with 28% (26/93) of all outbreaks and fruits with 19% (18/93), while 48% (45/93) of implicated food contained mixed, unspecified or other produce ingredients (Appendix 2, Table 5a). With regard to only the confirmed and suspected outbreaks, fruits (14/37) were the more often implicated product followed by vegetables (11/37) (Appendix 2, Table 5b).

One of the largest produce-associated outbreaks captured in the fruit category was an outbreak in 2009 of hepatitis A associated with consumption of semi-dried tomatoes. In this outbreak, there were 392 suspected and confirmed cases, 165 hospitalisations and one person died. Other major contributors to the fruit category include an outbreak of *Salmonella* Saintpaul in 2006 associated with rockmelon resulting in at least 100 people becoming ill, including 9 hospitalisations and an outbreak of listeriosis in melon in which 9 people became ill with all 9 being hospitalised and two deaths. Melon (possibly a rockmelon, lettuce and mint dish) was also suspected in an outbreak of *Cyclospora* in 2010 which caused 314 illnesses (Appendix 2, Table 6).

[1] Definitions of ‘confirmed’ and ‘suspected’ outbreaks contained in Appendix 2

Within the vegetable category were two large outbreaks. One was a large outbreak of *Salmonella* Oranienburg associated with alfalfa sprouts where there were 133 suspected and confirmed cases and 32 hospitalisations, while the other was an outbreak of shigellosis in imported baby corn which resulted in at least 100 cases and 3 hospitalisations (Appendix 2, Table 6).

7.1.4 Conclusion

It is important to recognise that the data presented here are likely to be an under-representation of actual cases of foodborne illness attributable to produce items. These data confirm the association between foodborne illness and fresh produce. Further, produce-associated outbreaks in the community can be large due to the wide distribution of these products.

8 Microbiological Data

The *Australia New Zealand Food Standards Code* (the Code) does not prescribe microbiological limits for fresh RTE horticultural products. The FSANZ *Guidelines for the microbiological examination of ready-to-eat foods* (Food Standards Australia New Zealand 2001) outlines four quality categories of RTE foods based on microbiological limits for standard plate counts, indicator organisms and the number or presence of certain pathogens. Note, it is stated in these documents that guidelines are not applicable to "*nuts in the shell and whole, raw fruits and vegetables that are intended for hulling, peeling or washing by the consumer."*

The Department of Agriculture Fisheries and Forestry (DAFF) produced *Guidelines for On-Farm Food Safety for Fresh Produce 2nd Ed* (Department of Agriculture Fisheries and Forestry 2004) to assist in the assessment of the risk of food safety hazards occurring on-farm during the production of fresh produce crops. The document suggests three broad microbiological risk categories of produce based on growing characteristics and final use by consumers (i.e. eaten uncooked, peeled or cooked before eaten). Microbiological limits are stated for some indicator (*E. coli* ≤ 20 cfu/gram) and pathogenic microorganisms (*Listeria monocytogenes* ≤ 100 cfu/gram and *Salmonella* spp. negative in 25 grams).

In the absence of legislated microbiological limits for fresh horticultural products, the limits contained in these guideline documents are often used as the basis for microbiological surveys and quality assurance compliance testing. Although limitations exist in the use of microbiological testing for determining the safety of fresh produce, testing can be a useful verification tool for assessing gross contamination and effectiveness of practices to prevent, minimise or remove contamination (Department of Agriculture Fisheries and Forestry, 2004).

8.1 Survey Data

There have been few surveys conducted on fresh horticultural produce (excluding sprouts) in Australia. The majority of surveys analyse samples obtained at retail level and do not include testing for viruses due to limited laboratory capability in Australia. Through-chain sampling has been undertaken in two surveys; one coordinated by FSANZ in 2006, in which samples were random and could not be traced through the supply chain, and the other conducted by the Victorian Department of Primary Industries (Vic DPI) where samples could be tracked.

8.1.1 Through-chain surveys

During 2006, Vic DPI undertook a microbiological survey of high-risk vegetables and salad vegetables (category A in DAFF Guidelines) (Department of Primary Industries 2006). The survey included samples from four high risk vegetable types from 16 farms (with or without a food safety plan) around suburban Melbourne. Samples were tested at three points along the production chain (before harvest, after harvest and packing and delivery at retail) and analysed for indicator organisms (total aerobic bacteria, faecal (thermotolerant) coliforms, *E. coli*) and the pathogens *Salmonella* spp. and *Listeria monocytogenes*. In total, five microbiological tests were performed on 480 samples.

At harvest 15% of samples were positive for *E. coli*, however only 7/360 samples had a result greater than 20 cfu/g, and none of these were at the final sampling point. Of a total 13/360 positive samples for *Salmonella* spp., only one was positive at retail. For both *E. coli* and *Salmonella* spp. the results indicate a decline in contamination from the field to retail. Contamination rates for *L. monocytogenes*, however, appeared not to change throughout the production chain, although no sample exceeded the limit noted in the DAFF guidelines of 100 cfu/g.

It was noted that although the survey would need to be larger to provide statistically significant figures, it does provide a snapshot of the low level of microbial contamination of salad vegetables produced in Victoria.

In the period 2005-2007, FSANZ coordinated a national survey of the prevalence of microbiological contamination in fresh horticultural produce in Australia (Food Standards Australia New Zealand 2010). Samples were collected between October 2005 and July 2007 from three points in the supply chain: on-farm before harvest, farm gate and at retail and analysed for *E. coli*, verocytotoxin producing *E. coli* (VTEC) or *E. coli* O157:H7, *Listeria* spp., *Listeria monocytogenes*, *Salmonella* spp. and faecal coliforms. A total of 369 samples were analysed of which 134 were lettuce, 113 seed sprouts, 105 strawberry samples, 15 parsley and 2 basil samples.

Overall the results of the survey indicated a low level of prevalence of contamination on the sampled fresh horticultural produce. However, VTEC was detected on two samples (1 x seed sprout and 1 x parsley), four strawberry samples were positive for *L. monocytogenes* and *Salmonella* spp. was detected on one strawberry sample.

8.1.2 Retail surveys

A number of surveys have been conducted on retail samples of a range of fresh horticultural products within Australian states and territories. Results of surveys conducted as part of routine surveillance activities within jurisdictions are often not within the public domain. There are some published surveys available, a few of which are briefly described below.

In 2005, the Western Australia Department of Health surveyed a selection of raw fruit and vegetable samples for the presence of pathogenic organisms (Department of Health Western Australia 2005). There were 3,425 microbiological tests performed on 491 fruit and vegetable samples. Using the FSANZ guideline limits to assess results, 98.7% (n=3380) of results were considered to be of satisfactory microbiological quality. No *E. coli* O157:H7, *Campylobacter* or *Salmonella* spp. were detected on any sample. *Bacillus cereus* was detected on 0.7% of samples (n=26) including one spinach sample at levels deemed "potentially hazardous". *L. monocytogenes* was detected in two samples, both at levels <3 MPN, while *E. coli* was detected in the remaining 0.5% of samples.

Authorities in South Australia tested 55 samples of raw vegetable products from 21 retail outlets for *E. coli*, *E. coli* O157, *Salmonella* spp. and *Listeria monocytogenes* (South Australia Health 2009). There were no positive results for any of the broccoli, cauliflower, lettuce, carrot, green capsicum, Lebanese and continental cucumber sampled. A similar survey conducted in 2010 of 60 raw vegetable products, also returned no positive detections for pathogens (South Australia Health 2010).

A survey (n= 220) of cut ready to eat fruit was undertaken in Victoria (Food Standards Australia New Zealand 2011). Neither *Salmonella* spp. nor *L. monocytogenes* were detected. Most samples had *E. coli* levels below the limit of detection, 3 samples had levels between 10 – 100 cfu/g and one sample had a level of 120 cfu/g. Overall, the results indicated a low incidence of pathogens on cut fruit available for sale at the sampled establishments.

8.1.3 Summary

Comparison of results between surveys is difficult due to differences in study design, sampling plans and methodology. The data that is available suggests there is a low level of contamination of fruits and vegetables available in the Australian supply chain. Notwithstanding the low prevalence, these data also confirm that infrequent contamination of RTE fresh produce with pathogenic microorganisms can occur.

8.2 FreshTest Data

FreshTest Australia manages and collates maximum residue and microbiological test results conducted for verification of wholesaler's quality assurance and food safety programs in the fresh produce industry in Australia. Samples are drawn from central markets in Sydney, Melbourne, Brisbane, Adelaide and Perth. Independent facilitators select representative samples which are sent to National Association of Testing Authorities (NATA) accredited laboratories for analysis. Samples are collected across a wide selection on fresh produce including herbs, salad greens, berries and tree fruit.

Microbiological testing of fresh produce by FreshTest (2006-2010) includes both pathogens: *Listeria* spp. (positive results typed for confirmation as *L*. *monocytogenes*), *Salmonella* spp., coagulase positive Staphylococci and *Bacillus cereus*, and indicator microorganisms: Total plate count, *Escherichia coli*, faecal coliforms and Enterobacteriacea.

A total of 3507 unique fresh produce samples were identified in the FreshTest data after exclusion of water, environmental swabs, rice and noodle dishes, processed salads and meat products. Samples included both imported and domestically grown produce. The sampling of produce types was biased with greater emphasis on lettuce and salad leaves (n=277), strawberries (n=313), mushrooms (n=154), tomatoes (n=227) and cucumber (n=187). The sampling reflects verification of production systems and cannot be considered a random nor representative survey of all Australian produce. A summary of tests by microorganisms is presented in Table 5 below.

Table 5 *Summary of samples and number of positives tests by microorganism*

Microorganism	Number of samples tested	Number of positive samples
E. coli	3388	133
Salmonella spp.	2003	4
Listeria monocytogenes	2480	3
Coagulase positive staphylococci	1396	7
Faecal coliforms	1404	173

A small number of samples of fresh produce were found to have detections for pathogenic microorganisms (Table 1). *Salmonella* spp. was isolated from four (4/2003) samples including two lettuce samples (salad mix and shredded lettuce), and one each of pawpaw/papaya and coriander. There were nine *Listeria* spp. detections of which only three (3/2480) were confirmed to be *L*. *monocytogenes*. The concentration was reported for two samples at 10 cfu/g. Seven samples (7/1396) were positive for coagulase positive staphylococci, including one sample of chives that had a concentration of $1.2x10^6$ cfu/g.

The indicator microorganisms *E. coli* and faecal coliforms were detected in 3.9% (133/3388) and 12.3% (173/1404) of samples, respectively. Further analysis suggested that *E. coli* and/or faecal coliforms were more likely to be found in fresh herbs (65/356) (Table 6 and Figure 1) than other groups of fresh produce such as fruit (7/496), berries (10/383) and leafy greens (lettuce, rocket, spinach) (45/388).

Table 6 *Results for samples of fresh herbs tested for E. coli and Faecal coliforms*

Produce	Number of samples tested	Number of samples positive for *E. coli* or Faecal coliforms
Basil	49	4
Chervil	1	1
Coriander	60	11
Dill	26	3
Mixed Herbs	11	0
Lemon Thyme	8	3
Marjoram	8	4
Mint	24	9
Oregano	14	3
Parsley	99	18
Rosemary	28	1
Sage	8	1
Tarragon	9	4
Thyme	11	3

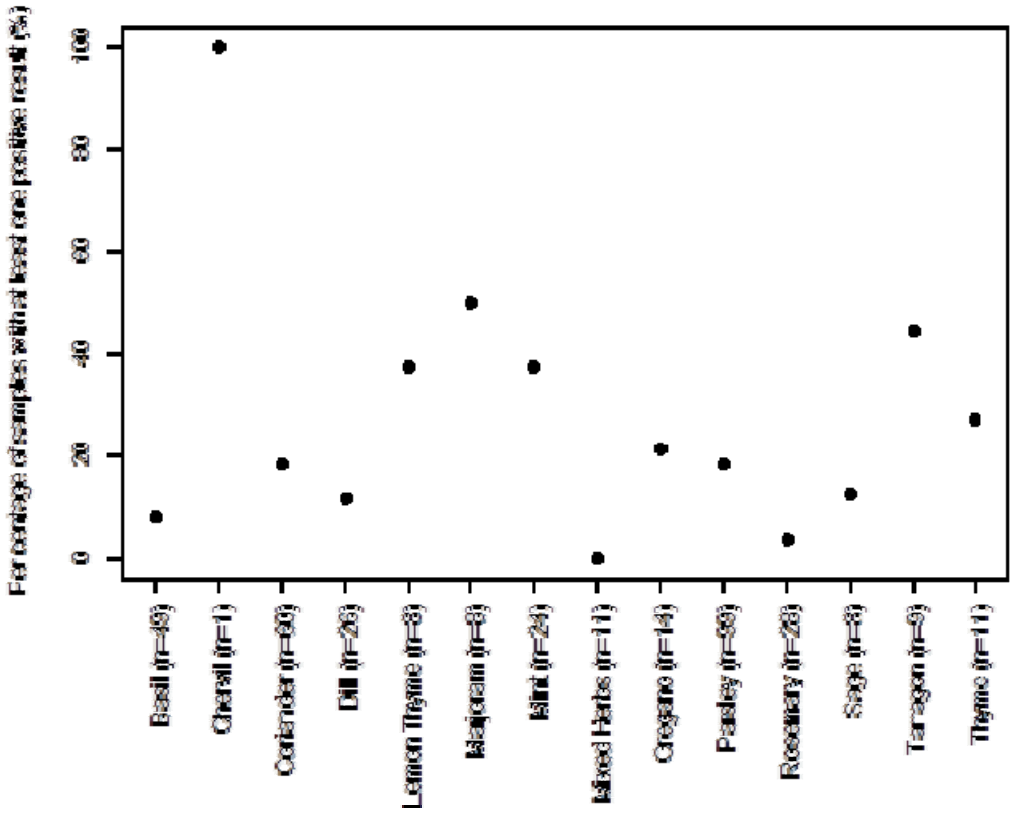


Figure 1 *Percentage of fresh herbs samples that were found to be positive to either E. coli or faecal coliforms*

Very few samples (n≤11) were tested for other microorganisms: *B*. *cereus*, total plate count and Enterobacteriacea. These results are not presented due to the low sample numbers.

In summary, the FreshTest data for fresh produce indicate that pathogenic bacteria are detected infrequently. Indicator organisms such as *E*. *coli* and/or faecal coliforms are detected more frequently than pathogenic bacteria, especially in fresh herbs.

9 Discussion

Foodborne pathogens are responsible for a number of illnesses worldwide and fresh produce commodities are an important source of infection. A number of risk assessments of horticultural products have been undertaken following the traditional single commodity and single pathogen pairing methodology. However, adoption of this approach for multiple pathogens and multiple commodities becomes unrealistic in terms of methodology, data and the resources required. There is a lack of data and information available for conducting risk assessments of horticulture products, which is complicated by the vast range of horticultural commodities available and the different types of primary production and processing methods employed.

What is widely accepted are that certain commodities are more often associated with outbreaks of foodborne illness, and that a number of production activities are recognised as

contributing to contamination. Specific horticultural commodities identified in the literature include fresh leafy vegetables, fresh leafy herbs, melons and minimally processed produce (ie: bagged salad). Production factors include water (pre and post-harvest), fertilisers, faecal contamination and food handler hygiene. We set about to determine whether these assumptions hold true to the Australian situation through an analysis of selected, well documented, horticulture related outbreaks. Supporting the outbreak analysis, Australian epidemiological and surveillance data (where available) and existing international and domestic published and unpublished assessments were also utilised.

An important limitation of the review of outbreaks was the tight restrictions placed on the inclusion of epidemiological attribution studies. These restrictions were applied to ensure that only the most robust epidemiologically associated outbreaks were included and studies identifying multiple ingredients or food items associated with illness were excluded. These restrictions may have resulted in an underrepresentation of commodities commonly consumed as part of a mixed dish, such as herbs and green onions, owing to the difficulty of analysing data for single ingredient associations. Similarly, small outbreaks of sporadic illness in multiple communities may have been underrepresented due to low observed attack rates or lack of microbiological data to link case patients to a specific pathogen. These limitations were not quantified, but the data captured was broadly reflective of Australian microbiological survey data, OzFoodNet outbreak data and FreshTest compliance testing data, as regards to the type of horticultural products that had evidence of contamination, and cause illness when consumed raw and/or minimally processed. Studies that demonstrated a microbiological link between case patients and implicated food were included with or without epidemiological evidence owing to the strength of association afforded by microbiological confirmation.

Source attribution using outbreak data utilises readily available data from outbreak surveillance and investigation to assess the fresh produce commodities associated with illness. The evidence presented here reaffirms the assumption that fresh leafy vegetables, fresh leafy herbs, melons and other minimally processed RTE produce can be a vehicle of foodborne illness. Important also is the determination of the point in the supply chain where contamination occurred and the specific activity that lead to produce contamination. Fresh produce can potentially become contaminated at any point along the supply chain, however it is recognised that the likelihood of contamination is greatest during three periods: in the field, during initial processing and during the final preparation in the kitchen (Lynch et al. 2009). Contamination occurring during the final preparation of a dish was excluded from the scoping review as the focus was on primary production and processing; however results do support the assertion that contamination in the field and in the processing stage are critical periods where contamination occurs.

The quality of water used for pre-harvest activities and post-harvest processing emerged as the dominant cause of product contamination. Four documented outbreaks were associated with fresh produce that was either confirmed or suspected to have been contaminated by pre-harvest water use; lettuce, chilli peppers and tomato (Soderstrom et al. 2008; Greene et al. 2008; Behravesh et al. 2011; Mody et al. 2011). Five outbreaks were associated with fresh produce that was likely contaminated during post-harvest use of poor quality water, rockmelon, papaya, mango, mamey and lettuce (Hilborn et al. 1999; Katz et al. 2002; Sivapalasingam et al. 2003; Munnoch et al., 2009; Gibbs et al., 2009). An outbreak in the US associated with spinach may have also been associated with faecally contaminated irrigation water but may have been caused by direct faecal deposition (Jay et al. 2007). Direct faecal deposition in the field was associated with at least two and possibly three outbreaks; peas (Gardner et al. 2011), strawberries (Anonymous 2011a; Anonymous 2011b) and spinach (Jay et al., 2007).

The exact mechanism of produce contamination is rarely, if ever, definitively established

even if a thorough environmental and trace back investigation was conducted. The majority of outbreak reports examined in the scoping review did not provide details of environmental investigations or did not report results that provided sufficient detail to define a source of produce contamination. Several investigations found multiple hygiene issues along the supply chain but could not define the specific failure point.

From the evidence presented in this assessment, specific mitigation activities addressing inputs and activities in the growing and initial processing stages would minimise the potential for produce contamination. To address water quality, faecal deposition and storage problems, the following mitigation activities would reduce the potential for produce contamination:

(i) Pre-harvest water managed to minimise risk of contaminating produce, specifically to avoid contamination from human activities, livestock production activities, domestic animals and wildlife
(ii) Equipment used to apply water onto produce is maintained to a suitable standard to prevent contamination of good quality pre-harvest water
(iii) Post-harvest water managed to minimise risk of contaminating produce and is of potable quality
(iv) Exclusion of domestic animals and wildlife from growing, packing and storage areas
(v) Produce grown away from bird roosting and migration areas
(vi) Pests controlled in growing, packing and storage areas
(vii) Disposal of poor quality produce
(viii) Personnel involved in production, harvest and post-harvest activities be sufficiently knowledgeable to take actions, where necessary, to minimise or prevent produce contamination

The review also provides evidence that mitigation activities that ensure adherence to good hygienic practice, incorporating good agricultural practice (GAP) and good manufacturing practice (GMP) would similarly minimise the potential for produce contamination. While this review did not specifically identify particular failures of hygienic practice that lead to produce contamination, a number of outbreak investigations identified poor hygienic practice as a likely source of produce contamination (Hutin et al. 1999; Lewis et al., 2009; Anonymous 2011c).

To address this issue, the following mitigation activities would reduce the potential for produce contamination:

(i) Toilet and washing facilities maintained in good working order and sufficient to meet the demands of the labour force employed to harvest, pack and transport produce
(ii) Facilities constructed and maintained in such a way as to minimise or prevent contamination of produce
(iii) Equipment used during production and processing fresh produce maintained in good working order and regularly cleaned to prevent contamination of produce
(iv) Personnel involved in production, harvest and post-harvest activities be sufficiently knowledgeable to take actions, where necessary, to minimise or prevent produce contamination

The potential application of the mitigation activities listed above and how they might have been applied to the outbreaks captured in this scoping review are summarised in Appendix 3, Table A3.2.

10 Response to Questions

What are the main risk factors or activities contributing to contamination of horticultural products?

From the available data, the use of poor quality water for pre- and post-harvest activities emerged as the most common cause of product contamination. Direct faecal deposition on produce growing in a field also emerged as a source of contamination. Multiple breaches of good hygienic practice along the supply chain were also noted in a number of outbreaks where a specific failure point was not identified.

Have risk factors other than those included in the assumptions been identified in horticultural related foodborne outbreaks?

From the available evidence, no additional risk factors were identified. It should be noted however, that the exact mechanism of produce contamination is rarely, if ever, definitively established. The majority of outbreak reports examined in the scoping review either did not include environmental investigations or sufficient detail to identify a source of contamination. A number of failures in hygienic practices throughout the supply chain were identified as possibly contributing to contamination, but sufficient detail to identify specific failure points were often lacking.

Are there different risk factors for different production systems (eg: field grown, hydroponics, organics, glasshouse)?

The results of the scoping review did not contain specific detailed information to determine whether different risk factors are associated with different production systems. Production activities identified during the analysis included use of poor quality water (pre- and post-harvest), faecal contamination and poor hygienic practices. It would not be unreasonable to assume that should these factors apply to a commodity which is intended to be eaten uncooked, and where there is no step to eliminate pathogens before being eaten, regardless of whether the commodity was grown in a field, hydroponically or in a glasshouse, then contamination may occur which could lead to outbreaks of foodborne illness.

What measures/controls may have minimised contamination of produce?

- Pre-harvest water managed to minimise risk of contaminating produce:
    - Water used for pre-harvest activities (e.g. irrigation, application of pesticides and herbicides) are managed to avoid contamination from human activities, livestock production activities, domestic animals and wildlife
    - Equipment used to apply water onto produce is maintained to a suitable standard to maintain the quality of the water
- Post-harvest water managed to minimise risk of contaminating produce:
    - Water used for post-harvest activities (e.g. washing) is of potable quality
- Exclusion of domestic animals and wildlife from growing, packing and storage areas
- Produce grown away from bird roosting and migration areas
- Pests controlled in growing, packing and storage areas

What are the commodities most often implicated in horticultural related foodborne outbreaks?

Fresh horticultural commodities involved in outbreaks are intended to be eaten uncooked without any steps to eliminate pathogens before consumption. Two general commodities categories were identified from the outbreak data; soft fruit and vegetables. Vegetables

included leafy greens (lettuce, spinach), herbs (coriander, basil and Thai basil), green onions, baby corn, sugar peas, carrots and chilli peppers. Fruits included melons (rockmelon/cantaloupe, honeydew), papaya, mango, tomatoes (including semi-dried), mamey and berries (raspberries, strawberries).

- Lettuce was the commodity most often associated with an outbreak. Eight outbreaks have been epidemiologically or microbiologically associated with lettuce consumption.
- Tomatoes, either semi-dried or fresh, were epidemiologically or microbiologically associated with five foodborne outbreaks and fresh tomatoes were possibly associated with a sixth outbreak that was associated with Jalapeno and Serrano peppers.
- Rockmelon was the fruit most often associated with an outbreak. Seven outbreaks have been epidemiologically or microbiologically associated with rockmelon consumption, either purchased pre-cut or whole.
- Raspberry consumption was epidemiologically or microbiologically associated illness in four outbreaks.

11 Conclusion

The outcomes of this assessment reaffirm the assumptions identifying the commodities and risk factors most likely to result in produce contamination and outbreaks of foodborne illness. However, these findings should not preclude the potential that other commodities and/or risk activities may be implicated in future horticultural-associated foodborne illness outbreaks. Where commodities could be identified, vegetables and fruits were contaminated in the field or during the initial processing of produce through the use of poor quality water or by direct faecal deposition on produce in the field. The size of outbreaks vary according to pathogen involved, level of contamination, volume of produce contaminated, distribution networks, site and method of final preparation and the volume consumed. All these factors influence the likelihood that a particular food may cause illness when consumed. Therefore, care should be exercised in drawing specific conclusions about pathogen commodity pairings and what may constitute a risk to the consumer.

Furthermore, only a very small number of outbreaks (that met the strict selection criteria) in the past 20 years have been associated with fresh produce in Australia. The microbiological data available from Australian surveys suggests there is a low level of contamination of fruits and vegetables available in the Australian supply chain, although infrequent contamination of fresh produce with pathogenic microorganisms can occur. The available evidence provides a high degree of confidence that Australians have access to safe fresh produce.

Appendices

1. Previous Risk Assessments and Reviews
2. Outbreak Data
3. Scoping Review

References

Ackers ML, Mahon BE, Leahy E, Goode B, Damrow T, Hayes PS, Bibb WF, Rice DH, Barrett TJ, Hutwagner L, Griffin PM, Slutsker L (1998) An outbreak of *Escherichia coli* O157:H7 infections associated with leaf lettuce consumption. The Journal Of Infectious Diseases 177(6):1588–1593

Anonymous (2011a) *E. coli* 0157 - USA (03): (Oregon) Strawberry: Archive No. 20110809.2413. Promedmail (Online): International Society for Infectious Diseases, Boston. http://promedmail.com. Accessed 10 August 2011a

Anonymous (2011b) *E. coli* 0157 - USA (06): (Oregon) Strawberry, deer dropping source: Archive No. 20110819.2520. Promedmail (Online): International Society for Infectious Diseases, Boston.
www.promedmail.com. Accessed 17 August 2011b

Anonymous (2011c) Listeriosis, Fatal - USA (14): Cantaloupe, more cases and deaths. Archive No. 20111105.3290. Promedmail (Online): International Society for Infectious Diseases, Boston.
www.promedmail.com. Accessed 16 November 2011c

Anonymous (2011e) Listerosis, Fatal - USA (05): Cantaloupe, more cases and deaths. Archive No. 20110922.2871. Promedmail (Online): International Society for Infectious Diseases, Boston.
www.promedmail.com. Accessed 23 September 2011e

Anonymous (2011d) Listerosis, Fatal - USA (04): Cantaloupe, Alert. Archive No. 20110921.2866. Promedmail (Online): International Society for Infectious Diseases, Boston.
www.promedmail.com. Accessed 22 September 2011d

Astridge, K. (2011) Multijurisdictional outbreak of listeriosis associated with rockmelons - 2010. Master of Applied Epidemiology, Australian National University.
Accessed 4 October 2011

Bassett J, McClure P (2008) A risk assessment approach for fresh fruits. J Appl Microbiol 104(4):925–943

Behravesh CB, Mody RK, Jungk J, Gaul L, Redd JT, Chen S, Cosgrove S, Hedican E, Sweat D, Chavez-Hauser L, Snow SL, Hanson H, Nguyen TA, Sodha SV, Boore AL, Russo E, Mikoleit M, Theobald L, Gerner-Smidt P, Hoekstra RM, Angulo FJ, Swerdlow DL, Tauxe RV, Griffin PM, Williams IT (2011) 2008 outbreak of *Salmonella* Saintpaul infections associated with raw produce. New England Journal Of Medicine 364(10):918–927

Caceres VM, Ball RT, Somerfeldt SA, Mackey RL, Nichols SE, MacKenzie WR, Herwaldt BL (1998) A foodborne outbreak of cyclosporiasis caused by imported raspberries. Journal Of Family Practice 47(3):231–234

Campbell JV, Mohle-Boetani J, Reporter R, Abbott S, Farrar J, Brandl M, Mandrell R, Werner SB (2001) An outbreak of *Salmonella* serotype Thompson associated with fresh cilantro. The Journal Of Infectious Diseases 183(6):984–987

CDC (1996a) Update: outbreaks of *Cyclospora cayetanensis* infection--United States and Canada, 1996. Morbidity and Mortality Weekly Report 45(28):611–612

CDC (1996b) Outbreaks of *Cyclospora cayetanensis* infection--United States, 1996. Morbidity and Mortality Weekly Report 45(25):549–551

CDC (2002) Multistate outbreaks of *Salmonella* serotype Poona infections associated with eating cantaloupe from Mexico--United States and Canada, 2000-2002. Morbidity and Mortality Weekly Report 51(46):1044–1047

CDC (2003) Hepatitis A outbreak associated with green onions at a restaurant--Monaca, Pennsylvania, 2003. Morbidity and Mortality Weekly Report 52(47):1155–1157

CDC (2006) Ongoing multistate outbreak of Escherichia coli serotype O157:H7 infections associated with consumption of fresh spinach--United States, September 2006. Morbidity and Mortality Weekly Report 55(38):1045–1046

CDC (2008) Outbreak of *Salmonella* serotype Saintpaul infections associated with multiple raw produce items--United States, 2008. Morbidity and Mortality Weekly Report 57(34):929–934

CDC (2011) Multistate outbreak of listeriosis associated with Jensen Farms cantaloupe - United States, August - September 2011. Morbidity and Mortality Weekly Report 60(Early release)

Danyluk MD, Schaffner DW (2011) Quantitative assessment of the microbial risk of leafy greens from farm to consumption: preliminary framework, data, and risk estimates. Journal of Food Protection 74(5):700–708

Dentinger CM, Bower WA, Nainan OV, Cotter SM, Myers G, Dubusky LM, Fowler S, Salehi ED, Bell BP (2001) An outbreak of hepatitis A associated with green onions. The Journal Of Infectious Diseases 183(8):1273–1276

Department of Agriculture Fisheries and Forestry (2004) Guidelines for on-farm food safety fo fresh produce. http://www.daff.gov.au/__data/assets/pdf_file/0003/183171/guidelines_onfarm_food_safety_fresh_produce_2004.pdf

Department of Health Western Australia (2005) Microbiological quality of fruit and vegetables in Western Australian retail outlets.

Department of Primary Industries V (2006) Survey of microbiological risks of fresh and fresh cut vegetable products.

Donnan EJ, Fielding JE, Gregory JE, Lalor K, Rowe S, Goldsmith P, Antoniou M, Fullerton KE, Knope K, Copland JG, Bowden DS, Tracey SL, Hogg GG, Tan A, Adamopoulos J, Gaston J, Vally H (2011) A multistate outbreak of hepatitis A associated with semi-dried tomatoes in Australia, 2009. Clinical Infectious Diseases In press

Duffy S, Schaffner DW (2002) Monte Carlo simulation of the risk of contamination of apples with Escherichia coli O157:H7. International Journal of Food Microbiology 78(3):245

Elviss NC, Little CL, Hucklesby L, Sagoo S, Surman-Lee S, de Pinna E, Threlfall EJ (2009) Microbiological study of fresh herbs from retail premises uncovers an international outbreak of salmonellosis. International Journal of Food Microbiology 134(1/2):83–88

Ethelberg S, Lisby M, Bottiger B, Schultz AC, Villif A, Jensen T, Olsen KE, Scheutz F, Kjelso C, Muller L (2010) Outbreaks of gastroenteritis linked to lettuce, Denmark, January 2010.

Euro Surveillance 15(6)

Food Standards Australia New Zealand (2001) Guidelines for the microbiological examination of ready-to-eat foods. http://www.foodstandards.gov.au/_srcfiles/Guidelines%20for%20Micro%20exam.pdf

Food Standards Australia New Zealand (2010) Microbiological survey of fresh horticultural produce in Australia, 2005-2007. http://www.foodstandards.gov.au/scienceandeducation/monitoringandsurveillance/foodsurveillance/microbiologicalsurve4782.cfm;file://F:\Risk Assessment - Microbiology\SECTION\Reference Manager\Electronic Documents\Plants\Report on the Microbiological survey of fresh horticultural produce in Australia.pdf

Food Standards Australia New Zealand. Microbiological surveillance of cut ready to eat fruit. Food Surveillance Newsletter Autumn. 2011.

Frost JA, McEvoy MB, Bentley CA, Andersson Y (1995) An outbreak of *Shigella sonnei* infection associated with consumption of iceberg lettuce. Emerging Infectious Diseases 1(1):26–29

FSA (2006) Identification of microbiological hazards associated with plants and plant products.

Gallot C, Grout L, Roque-Afonso AM, Couturier E, Carrillo-Santisteve P, Pouey J, Letort MJ, Hoppe S, Capdepon P, Saint-Martin S, De VH, Vaillant V (2011) Hepatitis A associated with semidried tomatoes, France, 2010. Emerging Infectious Diseases 17(3):566–567

Gardner TJ, Fitzgerald C, Xavier C, Klein R, Pruckler J, Stroika S, McLaughlin JB (2011) Outbreak of campylobacteriosis associated with consumption of raw peas. Clinical Infectious Diseases 53(1):26–32

Gibbs R, Pingault N, Mazzucchelli T, O'Reilly L, MacKenzie B, Green J, Mogyorosy R, Stafford R, Bell R, Hiley L, Fullerton K, Van BP (2009) An outbreak of *Salmonella enterica* serotype Litchfield infection in Australia linked to consumption of contaminated papaya. Journal of Food Protection 72(5):1094–1098

Grant J, Wendelboe AM, Wendel A, Jepson B, Torres P, Smelser C, Rolfs RT (2008) Spinach-associated *Escherichia coli* O157:H7 outbreak, Utah and New Mexico, 2006. Emerging Infectious Diseases 14(10):1633–1636

Greene SK, Daly ER, Talbot EA, Demma LJ, Holzbauer S, Patel NJ, Hill TA, Walderhaug MO, Hoekstra RM, Lynch MF, Painter JA (2008) Recurrent multistate outbreak of *Salmonella* Newport associated with tomatoes from contaminated fields, 2005. Epidemiology and Infection 136(2):157–165

Hall G, Raupach J, ohannes K (2006) An estimate of under-reporting of foodborne notifiable diseases: *Salmonella Campylobacter* Shiga toxin producing *E. coli* (STEC). NCEPH Working Paper Number 52. National Centre for Epidemiology and Population Health, The Australian National University,

Heier BT, Nygard K, Kapperud G, Lindstedt BA, Johannessen GS, Blekkan H (2009) *Shigella sonnei* infections in Norway associated with sugar peas, May-June 2009. Euro Surveillance 14(24)

Hilborn ED, Mermin JH, Mshar PA, Hadler JL, Voetsch A, Wojtkunski C, Swartz M, Mshar R,

Lambert-Fair MA, Farrar JA, Glynn MK, Slutsker L (1999) A multistate outbreak of *Escherichia coli* O157:H7 infections associated with consumption of mesclun lettuce. Archives of Internal Medicine 159(15):1758–1764

Ho AY, Lopez AS, Eberhart MG, Levenson R, Finkel BS, da Silva AJ, Roberts JM, Orlandi PA, Johnson CC, Herwaldt BL (2002) Outbreak of cyclosporiasis associated with imported raspberries, Philadelphia, Pennsylvania, 2000. Emerging Infectious Diseases 8(8):783–788

Hoang LM, Fyfe M, Ong C, Harb J, Champagne S, Dixon B, Isaac-Renton J (2005) Outbreak of cyclosporiasis in British Columbia associated with imported Thai basil. Epidemiology and Infection 133(1):23–27

Hutin YJ, Pool V, Cramer EH, Nainan OV, Weth J, Williams IT, Goldstein ST, Gensheimer KF, Bell BP, Shapiro CN, Alter MJ, Margolis HS (1999) A multistate, foodborne outbreak of hepatitis A. National Hepatitis A Investigation Team. New England Journal Of Medicine 340(8):595–602

Irvine WN, Gillespie IA, Smyth FB, Rooney PJ, McClenaghan A, Devine MJ, Tohani VK (2009) Investigation of an outbreak of *Salmonella enterica* serovar Newport infection. Epidemiology and Infection 137(10):1449–1456

Jalava K, Hakkinen M, Valkonen M, Nakari UM, Palo T, Hallanvuo S, Ollgren J, Siitonen A, Nuorti JP (2006) An outbreak of gastrointestinal illness and erythema nodosum from grated carrots contaminated with *Yersinia pseudotuberculosis*. The Journal Of Infectious Diseases 194(9):1209–1216

Jay MT, Cooley M, Carychao D, Wiscomb GW, Sweitzer RA, Crawford-Miksza L, Farrar JA, Lau DK, O'Connell J, Millington A, Asmundson RV, Atwill ER, Mandrell RE (2007) Escherichia coli O157:H7 in feral swine near spinach fields and cattle, central California coast. Emerging Infectious Diseases 13(12):1908–1911

Kangas S, Takkinen J, Hakkinen M, Nakari UM, Johansson T, Henttonen H, Virtaluoto L, Siitonen A, Ollgren J, Kuusi M (2008) *Yersinia pseudotuberculosis* O:1 traced to raw carrots, Finland. Emerging Infectious Diseases 14(12):1959–1961

Kapperud G, Rorvik LM, Hasseltvedt V, Hoiby EA, Iversen BG, Staveland K, Johnsen G, Leitao J, Herikstad H, Andersson Y, . (1995) Outbreak of *Shigella sonnei* infection traced to imported iceberg lettuce. Journal of Clinical Microbiology 33(3):609–614

Katz DJ, Cruz MA, Trepka MJ, Suarez JA, Fiorella PD, Hammond RM (2002) An outbreak of typhoid Fever in Florida associated with an imported frozen fruit. The Journal Of Infectious Diseases 186(2):234–239

Lewis HC, Ethelberg S, Olsen KE, Nielsen EM, Lisby M, Madsen SB, Boel J, Stafford R, Kirk M, Smith HV, Tikumrum S, Wisetrojana A, Bangtrakulnonth A, Vithayarungruangsri J, Siriarayaporn P, Ungchusak K, Bishop J, Molbak K (2009) Outbreaks of Shigella sonnei infections in Denmark and Australia linked to consumption of imported raw baby corn. Epidemiology and Infection 137(3):326–334

Lofdahl M, Ivarsson S, Andersson S, Langmark J, Plym-Forshell L (2009) An outbreak of *Shigella dysenteriae* in Sweden, May-June 2009, with sugar snaps as the suspected source. Euro Surveillance 14(28)

Lynch MF, Tauxe RV, Hedberg CW (2009) The growing burden of foodborne outbreaks due to contaminated fresh produce: risks and opportunities. Epidemiol Infect 137(3):307–315

Maunula L, Roivainen M, Keranen M, Makela S, Soderberg K, Summa M, von Bonsdorff CH, Lappalainen M, Korhonen T, Kuusi M, Niskanen T (2009) Detection of human norovirus from frozen raspberries in a cluster of gastroenteritis outbreaks. Euro Surveillance 14(49)

Mody RK, Greene SA, Gaul L, Sever A, Pichette S, Zambrana I, Dang T, Gass A, Wood R, Herman K, Cantwell LB, Falkenhorst G, Wannemuehler K, Hoekstra RM, McCullum I, Cone A, Franklin L, Austin J, Delea K, Behravesh CB, Sodha SV, Yee JC, Emanuel B, Al-Khaldi SF, Jefferson V, Williams IT, Griffin PM, Swerdlow DL (2011) National outbreak of *Salmonella* serotype saintpaul infections: importance of Texas restaurant investigations in implicating jalapeno peppers. PLoS One 6(2):e16579

Mohle-Boetani JC, Reporter R, Werner SB, Abbott S, Farrar J, Waterman SH, Vugia DJ (1999) An outbreak of *Salmonella* serogroup Saphra due to cantaloupes from Mexico. The Journal Of Infectious Diseases 180(4):1361–1364

Monaghan JM, Thomas DJI, Goodburn K, Hutchison ML (2008) A review of the published literature describing foodborne illness outbreaks associated with ready to eat fresh produce and an overview of current UK fresh produce farming practices. B17007. United Kingdom Food Standards Agency,

Muller L, Jensen T, Petersen RF, Molbak K, Ethelberg S (2009) Imported fresh sugar peas as suspected source of an outbreak of *Shigella sonnei* in Denmark, April-May 2009. Euro Surveillance 14(24)

Munnoch SA, Ward K, Sheridan S, Fitzsimmons GJ, Shadbolt CT, Piispanen JP, Wang Q, Ward TJ, Worgan TL, Oxenford C, Musto JA, McAnulty J, Durrheim DN (2009) A multi-state outbreak of *Salmonella* Saintpaul in Australia associated with cantaloupe consumption. Epidemiology and Infection 137(3):367–374

Nuorti JP, Niskanen T, Hallanvuo S, Hallanvuo S, ikkola J, ela E, atakka M, redriksson-Ahomaa M, yytikainen O, iitonen A, orkeala H, uutu P (2004) A widespread outbreak of *Yersinia pseudotuberculosis* O:3 infection from iceberg lettuce. The Journal Of Infectious Diseases 189(5):766–774

OzFoodNet (2008) Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: Annual report of the OzFoodNet Network, 2007. Communicable Diseases Intelligence 32(4):400–424

OzFoodNet (2010a) OzFoodNet Quarterly report, 1 April to 30 June 2010. Communicable Disease Intelligence 34(3):345–354

OzFoodNet (2010b) Monitoring the incidence and causes of diseases potentially transmitted by food in Australia: Annual report of the OzFoodNet Network, 2009. Communicable Diseases Intelligence 34(4):396–426

OzFoodNet (2010c) OzFoodNet Quarterly report, 1 January to 31 March 2010. Communicable Disease Intelligence 34(2):127–136

Petrignani M, Verhoef L, van HR, Swaan C, van SJ, Boxman I, Ober HJ, Vennema H, Koopmans M (2010a) A possible foodborne outbreak of hepatitis A in the Netherlands, January-February 2010. Euro Surveillance 15(11)

Petrignani M, Harms M, Verhoef L, van HR, Swaan C, van SJ, Boxman I, Peran IS, Ober H, Vennema H, Koopmans M, van PW (2010b) Update: a food-borne outbreak of hepatitis A in the Netherlands related to semi-dried tomatoes in oil, January-February 2010. Euro

Surveillance 15(20)

Pezzoli L, Elson R, Little C, Fisher I, Yip H, Peters T, Hampton M, de Pinna E, Coia J, Mather H, Brown D, Moller Nielsen E, Ethelberg S, Heck M, de Jager C, Threlfall J (2007) International outbreak of *Salmonella Senftenberg* in 2007. Eurosurveillance 12(24)

Pezzoli L, Elson R, Little CL, Yip H, Fisher I, Yishai R, Anis E, Valinsky L, Biggerstaff M, Patel N, Mather H, Brown DJ, Coia JE, van PW, Nielsen EM, Ethelberg S, de PE, Hampton MD, Peters T, Threlfall J (2008) Packed with Salmonella--investigation of an international outbreak of *Salmonella* Senftenberg infection linked to contamination of prepacked basil in 2007. Foodborne Pathogens and Disease 5(5):661–668

Reller ME, Nelson JM, Molbak K, Ackman DM, Schoonmaker-Bopp DJ, Root TP, Mintz ED (2006) A large, multiple-restaurant outbreak of infection with *Shigella flexneri* serotype 2a traced to tomatoes. Clinical Infectious Diseases 42(2):163–169

Rimhanen-Finne R, Niskanen T, Hallanvuo S, Makary P, Haukka K, Pajunen S, Siitonen A, Ristolainen R, Poyry H, Ollgren J, Kuusi M (2009) *Yersinia pseudotuberculosis* causing a large outbreak associated with carrots in Finland, 2006. Epidemiology and Infection 137(3):342–347

Sarvikivi E, Roivainen M, Maunula L, Niskanen T, Korhonen T, Lappalainen M, Kuusi M (2011) Multiple norovirus outbreaks linked to imported frozen raspberries. Epidemiology and Infection doi:10.1017/S0950268811000379

Sivapalasingam S, Barrett E, Kimura A, Van Duyne S, De Witt W, Ying M, Frisch A, Phan Q, Gould E, Shillam P, Reddy V, Cooper T, Hoekstra M, Higgins C, Sanders JP, Tauxe RV, Slutsker L (2003) A multistate outbreak of Salmonella enterica Serotype Newport infection linked to mango consumption: impact of water-dip disinfestation technology. Clinical Infectious Diseases 37(12):1585–1590

Soderstrom A, Osterberg P, Lindqvist A, Jonsson B, Lindberg A, Blide US, Welinder-Olsson C, Lofdahl S, Kaijser B, de JB, Kuhlmann-Berenzon S, Boqvist S, Eriksson E, Szanto E, Andersson S, Allestam G, Hedenstrom I, Ledet ML, Andersson Y (2008) A large *Escherichia coli* O157 outbreak in Sweden associated with locally produced lettuce. Foodborne Pathogens and Disease 5(3):339–349

South Australia Health (2009) Food Act Report 2009, Appendix III Microbiological quality of raw vegetables.

South Australia Health (2010) Food Act Report 2010, Appendix IV Mircobiological quality of raw vegetables.
http://www.dh.sa.gov.au/pehs/publications/FoodActReport-PEHS-2010.pdf

Wendel AM, Johnson DH, Sharapov U, Grant J, Archer JR, Monson T, Koschmann C, Davis JP (2009) Multistate outbreak of *Escherichia coli* O157:H7 infection associated with consumption of packaged spinach, August-September 2006: the Wisconsin investigation. Clinical Infectious Diseases 48(8):1079–1086

Wheeler C, Vogt TM, Armstrong GL, Vaughan G, Weltman A, Nainan OV, Dato V, Xia G, Waller K, Amon J, Lee TM, Highbaugh-Battle A, Hembree C, Evenson S, Ruta MA, Williams IT, Fiore AE, Bell BP (2005) An outbreak of hepatitis A associated with green onions. New England Journal Of Medicine 353(9):890–897

Appendix 1

Previous Reviews and Risk Assessments

1. UKFSA

Monaghan et al (2008), *"Review of the published literature describing foodborne illness outbreaks associated with ready to eat fresh produce and an overview of current UK fresh produce farming practices"*, Food Standards Agency Project B17007, 2008.

At the request of the United Kingdom Food Standards Agency (UKFSA), Monaghan and colleagues undertook a review of the scientific literature relating to foodborne outbreaks associated with ready-to-eat (RTE) fresh produce; reviewed assurance codes of practice commonly-encountered in the UK and compared these to the Codex Alimentarius standard and assessed current UK fresh produce farming practices.

Ready-to-eat was defined as crops that are sometimes or always consumed raw and as they are sold, without a cooking/processing stage that eliminates microbiological contamination. Included within the scope were salad vegetables, vegetables, fresh herbs, sprouted seeds and soft and top fruit.

Literature Review

Published peer-reviewed literature relating to foodborne illness associated with ready to eat fresh produce was sourced and reviewed. Although readily available, the authors purposely excluded listings of small multiple sourced outbreaks often reported by reputable government agencies and scientists as being too subjective and poorly documented to include.

Results of the literature search revealed a range of bacterial, viral and protozoan pathogens had been associated with outbreaks of produce related foodborne illness outbreaks, including *Salmonella* spp., *E. coli* O157:H7, *Shigella* spp., *Yersinia pseudotuberculosis,* norovirus, hepatitis A, calicivirus, *Cyclospora* and *Cryptosporidium*. Commodities cited were fruits and nuts (raw almonds, apples used for unpasteurised juice, various berries (strawberries, raspberries), melons, mangos, oranges for unpasteurised juice), vegetables (cabbage, carrot, snow peas), herbs (basil, coriander, parsley) and salad vegetables (lettuce, cucumber, green onions, rocket, spinach, tomatoes).

Although the review summarises reports that identify with some confidence contaminated RTE produce as causing foodborne outbreaks, the authors also highlight the contamination event itself is often never satisfactorily explained. There are however, a number of factors often described as possible vectors. These include:

- animal (domestic and wild) access to crops, processing facilities or stored produce
- inadequate personal hygiene of people (or working whilst ill) involved in harvesting, processing or serving RTE fresh produce
- use of contaminated irrigation water or use of inadequately prepared manure fertilisers on land used to cultivate RTE
- use of contaminated water for washing or cooling produce
- inadequate kitchen preparation of RTE (including lack of washing), and
- inadequate cleaning and sanitation of processing equipment

The authors note outbreak investigations are often conducted using case control studies or questionnaires, and subsequently discuss the inherent limitations of these approaches which

may contribute to the inability to definitively identify a source. Other reasons proposed were poor record keeping and traceback and the short-life of fresh produce which often means no material is available for microbiological testing.

Grower survey

The authors conducted a review of assurance codes of practice for fresh produce commonly encountered in the UK and surveyed growers to determine compliance with these codes and identify areas which were either difficult to comply with or implement. Questionnaires were developed covering key areas where hazards were likely to occur, and subsequently able to be managed, including:

- Site history
- Water used for primary production (source, treatment applied, microbiological testing, method of application and timing of application prior to harvest)
- Manure inputs (type, composting)
- Worker hygiene
- Wildlife/farm animal access
- Harvest equipment hygiene
- Handling, storage and transport
- Post-harvest treatment and training

The survey covered a range of crops, business sizes and supply routes such as to large, medium or small retailers, wholesalers, direct sales or farmer's markets. Proportionally, more businesses were surveyed who produced relatively higher risk crops such as salad leaves and herbs, while organic production was also covered for all crops.

From the survey, the authors noted retailers were driving QA scheme compliance as a condition of supply and, because growers often supplied multiple routes, the highest applicable standard was subsequently applied to all. The report also notes compliance to a QA scheme was often not a requirement for supply to wholesalers, food service or caterers. This was an important finding by the authors as it was noted 65% of outbreaks in the UK linked to prepared salads occurred in commercial food service premises which are more likely to be supplied by wholesalers. It was also a finding that small producers lacked an understanding of bacteria, protozoa and viruses and why it was important to follow good practice to ensure safety of fresh produce.

Conclusion

Although a significant amount of foodborne illness outbreaks are *associated* with fresh produce; few cases *definitely* identify fresh produce as the cause. One reason proposed by the authors was the short shelflife of the product, often meaning no material is available for testing. Poor record keeping and traceback, as well as the tendency for susceptibility to infection within the human population to be a distribution, may also contribute.

The key recommendation of the report was that the Agency investigates the use of custom information and communication technologies to help growers risk assess their production practices and water sources.

Based on information from the literature review and grower survey, the authors also proposed a number of other recommendations, including:

- Generation of guidance documents that shows growers how to adequately risk assess their crops as this was an area that grower staff found particularly difficult
- Consider classifying fresh produce into a standardised set of defined risk categories. No harmony across different QA systems reviewed, with a number of examples

where crops allocated as medium or lower risk associated with foodborne illness.
- Note that information gaps relating to pathogen survival under commercial growing condition have prevented development of stochastic models for fresh produce. Noting completion of recent research, the report recommends consideration be given to developing stochastic models which describe the growing process for a number of key crops as a way of quantitating the roles of parameters that influence pathogen survival during production.
- Clearer instructions were necessary describing requirements for microbiological testing of water be developed, including description of organisms, what these organisms indicate and the scientific basis for associated criteria.
- Collection of compliance related microbiological test results to underpin the case control approach and control of outbreak situations.

Suppliers to the retail sector are subject to QA schemes required by their customers. Similar retail driven pressure was not seen for the wholesale sector. Improvements to traceability and food storage conditions were noted as areas which could be improved.

Mandating the requirement for a quality assurance program as a condition of supply was also proposed to further reduce the already low risk to UK consumers from fresh produce.

2. Food Science Australia

Food Science Australia (2006), "Identification of microbiological hazards associated with plants and plant product", Food Science Australia Project Number 110564

In 2006, FSANZ commissioned Food Science Australia to review the microbiological status of plants and plant products available to Australian consumers. The review updated and enhanced a previous report (undertaken for New South Wales Food Authority.

The objectives of the review were to:
- Identify potential microbiological hazards associated with plants and plant products that may present a public health and safety risk to Australian consumers by reviewing the domestic and international literature
- Identify the relative importance of microbiological hazards associated with plants and plant products available to consumers in Australia.

The review focussed on categories of fresh horticultural produce and fresh cut fruit and vegetables where there is no effective microbiological kill step in production before consumption and which may carry microbiological hazards. Nuts, oil seeds and grains that are either minimally or further processed, seed sprouts and vegetables in oil were also included. Fresh horticultural produce were defined as produce usually consumed raw without undergoing processes that inactivate pathogens or inhibit microbial growth (ie: cooking). Fresh cut fruits and vegetables included those that have been peeled, sliced, chopped, shredded, cored, trimmed or mashed with or without washing prior to being packaged.

For the identified product categories, the study reviewed available international and Australian data on the types and incidence of microbial pathogens on plants and plant products, potential sources of contamination and survival of pathogens, foodborne disease outbreaks and food recalls, as well as examining industry practices, including industry codes of practice, that impact on the reduction or elimination of pathogens. A descriptive relative risk rating exercise was then undertaken to determine a risk rating for each pathogen:product pairs within identified high risk product categories.

A number of production activities/inputs are noted in the literature as contributing to the risk

of fresh produce. Soil, water, fertilisers (organic and inorganic), access of animals or birds to production or packaging facilities and handling during harvest, packing or transport have all been implicated as contributing factors to horticultural related foodborne illness. The report reviews these factors with respect to vegetable, fruit, nut and seed production.

Pathogenic organisms have been associated with a wide variety of whole, intact and minimally processed fruits and vegetables. In acknowledging this, the report also acknowledges a lack of data on the types, levels and prevalence of pathogenic organisms on fresh produce in Australia. Data that was available indicated a low prevalence of pathogenic organisms on fresh ready-to-eat produce available in Australia.

The report also discusses survival of pathogens on produce, the effectiveness of sanitising washes and particular farming practices such as composting. It's noted that although uncommon on the surface on intact produce, the potential for growth and/or survival of pathogenic organisms increases once the protective outer surfaces of produce have been breached, ie through physical damage or by the action of other microorganisms. The report also discusses the limited effectiveness of sanitising washes to control growth of pathogen on the surfaces of produce.

Use of compost during the production of organic produce is reviewed, with the report noting limited evidence is available to support the assertion that organic produce is less microbiologically safe than conventionally produced produce. Similarly, the perception that mushrooms are a high risk product was also investigated. As noted in the report, the common white mushroom is produced on pasteurised substrate: meaning these mushrooms present no greater risk than other vegetables which do not undergo a kill step prior to consumption. Speciality mushrooms which are grown on substrates unable to be pasteurised, ie: logs, may present a higher risk and should be assessed separately in any risk assessment.

The review determined appropriate control measures as including good agricultural practices to prevent contamination in the field, post-harvest decontamination practices, such as us of sanitising agents, minimising cross contamination and temperature control of fresh cut fruit and vegetables. No conclusions or recommendations where made regarding any differences between different production systems, ie: hydroponic, field grown etc.

From the reviewed evidence, the report concluded the highest risk products as:

- fresh cut vegetables and fruits consumed raw – examples include packaged salad mix, prepared fruit salad and cut and plastic wrapped melons.
- unpasteurised fruit juices
- seed sprouts
- vegetables in oil

Within these categories, the report also recommended further investigation of the specific pathogen/commodity pairs: *Salmonella* and seed sprouts, *Salmonella* and tomatoes, *Salmonella* and *Listeria monocytogenes* and fresh cut melons (rockmelon and honeydew) and *C. botulinum* and vegetables in oil.

Other key findings included:

- Contamination from handlers and improper handling causes the majority of produce associated (and in fact all traceable) foodborne disease.
- Procedures such as sanitising washes may have only limited success in removal and/or inactivation of pathogenic and other microorganisms. Preventing contamination of produce (e.g. by using good agricultural practices and education of food handlers along the production chain) is likely to be more effective in ultimately

reducing produce associated foodborne illness. The correct use of a sanitising agent, such as chlorine, in wash water does, however, help to minimise cross contamination.

- Temperature control is an important bacterial and fungal control measure for fresh cut fruits and vegetables. Control of viral and parasite infection can only be controlled by the measures noted above.

Appendix 2

Outbreak Data

The below data summarising reported illness due to outbreaks of gastrointestinal disease associated with fresh produce has been obtained from unpublished OzFoodNet reports covering the periods January 2001 to March 2010 and January 2010 to June 2011 (OzFoodNet unpublished data, 2010; OzFoodNet unpublished data 2011).

It can be very difficult to summarize aggregated outbreak data by commodity. The term "fresh produce" covers a large variety of different products and the identification of outbreaks that are due to fresh produce or a dish containing a fresh produce item, is limited by the quality of the data collected in the register. These data are often free-text, subjective summaries that do not uniformly report food vehicles by commodity type. Results may vary depending on search terms used to interrogate the data.

The terms used to interrogate the OzFoodNet Outbreak Register are below.

1. Outbreak Register search details

Data analysis
The analysis was carried out in the following manner:

- Reports of outbreaks were extracted from the OzFoodNet Outbreak Register. These were compared those reported in Quarterly and Annual Reports. A full list of the search terms used to extract the data from the outbreak register is at Appendix 2A.
- Data were cleaned and recoded to provide consistent categories for data fields, including aetiological agents and food vehicles.
- To be included as a produce-associated outbreak, multi-ingredient foods or mixed dishes must have a specifically listed produce item as implicated or suspected, or as being a principal ingredient of an implicated dish, or are commonly known to contain a produce ingredient. If an ingredient other than the produce ingredient was implicated in multi-ingredient dishes, (such as raw eggs used in a Caesar salad dressing) the outbreak was discarded. Where a range of possible high risk foods (other than produce) are listed, an outbreak was not included unless a produce ingredient is specifically implicated or suspected by investigators.
- All unmodified plant products were considered primary produce for this analysis, except wheat flour, rice and other cereals.
- Data were categorized as confirmed, suspected or possible based on the level of evidence available that the outbreak was due to contaminated produce items:

  Confirmed outbreaks were single ingredient produce items or food where produce items were a principle ingredient and;
    - epidemiological, microbiological and traceback evidence showed that the item was contaminated in a primary produce environment (not all of these outbreaks have setting=primary produce)

  Suspected outbreaks were single ingredient produce items or a dishes containing a produce item and;
    - there was epidemiological and/or microbiological evidence to implicate the dish.
    - the produce item was a principle ingredient, or specifically listed as implicated, and
    - investigators did not discount the possibility of the product being contaminated in primary produce environments

Possible outbreaks involved single ingredient produce items or dishes that contained or are commonly known to contain a produce item as an ingredient and;
    - there was descriptive, epidemiological and/or microbiological evidence to implicate the dish *but*
    - that a range of modes of contamination of the food were considered likely, such as ill food handler or cross-contamination *and*
    - there was no particular evidence that the primary produce ingredient was the source of contamination
- Data were analysed in Excel 2003 to summarise the number of people ill, year, aetiology and implicated food vehicle and to provide a linelist of data at Appendix 2B.

Data dictionary

Calculated or added fields in the data are:

Month of outbreak – calculated from onset of the first case

Food vehicle mod – modified from another field Food vehicle, but incorporating information from the field Remarks where relevant

Food code translated – translated from the four digit food codes used by the US Centers for Disease Control and Prevention

Produce ingredient category – based on the field food vehicle mod

Confirmation status – based on criteria specified in the data analysis section

Comments – Explanatory information taken from a field Remarks that may aid interpretation

Fields direct from the outbreak register are:

Seqnum A unique ID supplied by the state

Year Year of onset of the first case

State Where the outbreak occurred, or sometimes, where cases were resident

Transmission mode Description of the mode by which the outbreak was spread

Setting where food was prepared

Seteat where food was eaten

Ill Number of people meeting suspected and confirmed case definitions

Hospitalised Number of cases hospitalized during the outbreak.

Died Number of cases who died during the period of the outbreak. The relative contribution of the infection to the deaths is not generally known.

Aetiology Name of bacteria/parasite toxin

2. Summary of data

Table 1 *Outbreaks of gastrointestinal illness associated with produce (2001 to June 2011) by state/territory and year of onset of the first case*

State	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	To Jun 2011	Total
Multi-state	1	0	0	0	1	2	1	0	1	1	0	7
ACT	0	0	1	0	0	0	0	0	0	1	0	2
NSW	1	3	3	0	4	3	5	3	7	2	4	35
NT	0	0	0	0	0	0	0	1	0	0	1	2
QLD	2	0	1	0	1	0	4	3	2	1	0	14
SA	1	1	0	0	0	1	0	0	1	0	0	4
TAS	0	0	1	0	0	0	0	0	1	0	0	2
VIC	3	0	3	1	1	1	3	2	0	3	2	19
WA	2	0	0	0	0	2	1	0	1	1	1	8
Total	**10**	**4**	**9**	**1**	**7**	**9**	**14**	**9**	**13**	**9**	**8**	**93**

Table 2 *Confirmation status, number of produce-associated outbreaks, illnesses, hospitalisations and deaths (2001 to June 2011)*

Outbreaks	Number of outbreaks	Number Ill	Number Hospitalised	Number Died
Confirmed	10	830	234	3
Suspected	27	745	15	1
Possible	56	1247	72	3
Total	**93**	**2822**	**321**	**7**

Table 3 *Setting where foods were eaten in all produce-associated outbreaks of gastrointestinal illness (2001 to June 2011)*

Setting where food eaten	Number of outbreaks	Number Ill	Number Hospitalised	Number Died
Restaurant	32	504	26	0
Community	17	1033	253	4
Private residence	11	112	9	0
Commercial caterer	5	113	4	0
Other	5	193	0	0
Aged care	4	48	4	3
Camp	3	56	7	0
Health spa/resort	3	53	1	0
Child care	2	42	0	0
Cruise/airline	2	338	0	0
Hospital	2	41	1	0
Institution	2	101	0	0
Fair/festival/mobile service	1	5	0	0
National franchised fast	1	36	6	0

Setting where food eaten	Number of outbreaks	Number Ill	Number Hospitalised	Number Died
food				
Picnic	1	30	0	0
School	1	17	1	0
Unknown	1	100	9	0
Total	**93**	**2822**	**321**	**7**

Table 4a *Aetiology, number of people affected, number hospitalised and number of deaths in all produce-associated outbreaks (2001 to June 2011)*

Aetiology	Number of outbreaks	Number Ill	Number Hospitalised	Number Died
Unknown	33	368	6	0
Norovirus	17	510	4	0
Salmonella Typhimurium	17	568	55	1
Other *Salmonella* serovars	12	409	70	2
Clostridium perfringens	5	46	0	1
Hepatitis A	3	424	169	1
Campylobacter	1	27	0	0
Cyclospora species	1	314	0	0
Escherichia coli O157	1	31	5	0
L. monocytogenes	1	9	9	2
Shigella sonnei biotype g*	1	100	3	0
Staphylococcus aureus	1	16	0	0
Total	**93**	**2822**	**321**	**7**

Table 4b *Aetiology, number of people affected, number hospitalised and number of deaths in confirmed and suspected produce-associated outbreaks (2001 to June 2011)*

Aetiology	Number of outbreaks	Number Ill	Number Hospitalised	Number Died
Unknown	13	177	4	0
Other *Salmonella* serovars	7	348	59	0
Salmonella Typhimurium	5	86	4	0
Norovirus	4	81	0	0
Clostridium perfringens	2	10	0	1
Campylobacter	1	27	0	0
Cyclospora species	1	314	0	0
Escherichia coli O157	1	31	5	0
Hepatitis A	1	392	165	1
L. monocytogenes	1	9	9	2
Shigella sonnei biotype g*	1	100	3	0
Total	**37**	**1575**	**249**	**4**

Table 5a *Categorized produce ingredients listed in foods implicated in all produce-associated outbreaks (2001 to June 2011)*

Produce Ingredient Category	Number of Outbreaks
Mixed/unspecified/other produce	45
Vegetables	26
Fruits	18
Herbs and spices	3
Fruits and Vegetables	1
Total	**93**

Table 5b *Categorized produce ingredients listed in foods implicated in confirmed and suspected produce-associated outbreaks (2001 to June 2011)*

Produce Ingredient Category	Number of Outbreaks
Fruits	14
Vegetables	11
Mixed/unspecified/other produce	9
Herbs and spices	2
Fruits and Vegetables	1
Total	**37**

Table 6 *Confirmed outbreaks, number of people affected, number hospitalised and number of deaths in produce-associated outbreaks (2001 to June 2011)*

Outbreaks	Number of outbreaks	Number Ill	Number Hospitalised	Number Died
Confirmed	**10**	**10**	**10**	**10**
Fruits	***6***	***559***	***191***	***3***
Fruit platter	1	15	0	0
Norovirus				
Melons and/or melons contained within fruit salads	1	9	9	2
L. monocytogenes				
pawpaw	2	43	8	0
Salmonella Litchfield	*1*	*26*	*5*	*0*
Salmonella Saintpaul	*1*	*17*	*3*	*0*
Rockmelon	1	100	9	0
Salmonella Saintpaul				
semi-dried tomatoes	1	392	165	1
Hepatitis A				
Mixed/unspecified/other produce	***1***	***2***	***2***	***0***
Vegetables	***3***	***269***	***41***	***0***
Alfalfa sprouts	1	133	32	0
Salmonella Oranienburg	1	133	32	0

Outbreaks	Number of outbreaks	Number Ill	Number Hospitalised	Number Died
baby corn	1	100	3	0
Shigella sonnei biotype g*	1	100	3	0
chicken salad pita bread wrap (using iceberg lettuce)	1	36	6	0
Salmonella Bovismorbificans 32	1	36	6	0
Possible	**56**	**1247**	**72**	**3**
Suspected	**27**	**745**	**15**	**1**
Total	**93**	**2822**	**321**	**7**

Appendix 2A Search terms

Search terms used to identify produce-associated outbreaks in the OzFoodNet Outbreak Register:

- [Field: Year] = >"2000"
- [Field: Transmission=Foodborne/Suspected Foodborne]
- [Field: Food vehicle] Like "*salad*" Or Like "*sand*" Or Like "*lett*" Or Like "*cantal*" Or Like "*onion*" Or Like "*cucu*" Or Like "*spin*" Or Like "*produce*" Or Like "*toma*" Or Like "*veget*" Or Like "*sprou*" Or Like "*rock*" Or Like "*paw*" Or Like "*fruit*" Or Like "*pean*" Or Like "*cucum*" Or Like "*waterme*" Or Like "*almond*" Or Like "*cuc*" Or Like "*apple*" Or Like "*pear*" Or Like "*orange*" Or Like "*lupin*" Or Like "*melo*" (year 2010 – 2011)
- [Field: Remarks] Like "*salad*" Or Like "*sand*" Or Like "*lett*" Or Like "*cantal*" Or Like "*onion*" Or Like "*cucu*" Or Like "*spin*" Or Like "*produce*" Or Like "*toma*" Or Like "*veget*" Or Like "*sprou*" Or Like "*rock*" Or Like "*paw*" Or Like "*fruit*" Or Like "*pean*" Or Like "*cucum*" Or Like "*waterme*" Or Like "*almond*" Or Like "*cuc*" Or Like "*apple*" Or Like "*pear*" Or Like "*orange*" Or Like "*lupin*" Or Like "*melo*"(year 2010 – 2011)
- [Field: Food code] Like "45*" or like "70*" or like "75*" or like "71*"
- [Field: etiology] Like "185" *(This was used to capture an outbreak that was known to have been produce associated from annual and quarterly reports, but not coming up in the search).*

Appendix 2B Line list of outbreaks obtained from Outbreak Register search

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
2001	Multi-state	Community	30	3	0	*Salmonella* Stanley	Peanuts	Mixed/unspecified/other produce	Suspected
2001	NSW	Restaurant	2	0	0	Unknown	Steak and vegetables	Vegetables	Possible
2001	QLD	Restaurant	56	0	0	Norovirus	Potato, Pasta, Steak	Vegetables	Possible
2001	QLD	National franchised fast food	36	6	0	*Salmonella* Bovismorbificans 32	chicken salad pita bread wrap (using iceberg lettuce)	Vegetables	Confirmed
2001	SA	Fair / festival / mobile service	5	0	0	*Salmonella* Typhimurium 185	cucumber	Vegetables	Suspected
2001	VIC	Restaurant	27	0	0	*Campylobacter*	tomato and cucumber salad	Mixed/unspecified/other produce	Suspected
2001	VIC	Restaurant	9	0	0	*Clostridium perfringens*	Potato and bacon soup	Vegetables	Possible
2001	VIC	Restaurant	50	1	0	*Salmonella* Typhimurium 99	Eye fillet meal with onions, potato, salsa Verde and red wine jus	Mixed/unspecified/other produce	Possible
2001	WA	Cruise / airline	24	0	0	Norovirus	Caesar salad	Vegetables	Possible
2001	WA	Restaurant	56	0	0	Norovirus	Chicken spinach salad	Mixed/unspecified/other produce	Possible
2002	NSW	Restaurant	21	0	0	*Salmonella* Typhimurium 126	Thai salad	Mixed/unspecified/other produce	Possible

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
2002	NSW	Restaurant	4	0	0	Unknown	Meal of pumpkin soup, roast pork, vegetables, fruit salad and ice-cream	Mixed/unspecified/other produce	Possible
2002	NSW	Restaurant	15	1	0	Unknown	Roast beef, rice noodle salad	Mixed/unspecified/other produce	Possible
2002	SA	Restaurant	78	15	0	*Salmonella* Typhimurium 8	Caesar salad	Vegetables	Possible
2003	ACT	Child care	9	0	0	Unknown	Vegetable pasta	Vegetables	Possible
2003	NSW	Other	67	0	0	Norovirus	apple strudel	Fruits	Possible
2003	NSW	Private residence	11	1	0	Salmonella Typhimurium 135a	Rice salad	Mixed/unspecified/other produce	Possible
2003	NSW	Private residence	13	2	0	Unknown	suspected Iraqi basil	Herbs and spices	Suspected
2003	QLD	Commercial caterer	16	0	0	*Staphylococcus aureus*	Pasta salad	Mixed/unspecified/other produce	Possible
2003	TAS	Camp	22	2	0	Hepatitis A	Coleslaw	Vegetables	Possible
2003	VIC	Community	6	1	0	*Salmonella* Litchfield	suspected cucumber	Vegetables	Suspected
2003	VIC	Community	213	22	1	*Salmonella* Typhimurium 135	Pork Rolls containing cucumber, chilli, spring onions, coriander, carrot and other	Mixed/unspecified/other produce	Possible

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
							ingredients		
2003	VIC	Other	28	0	0	Unknown	Vegetable and chilli dish	Vegetables	Suspected
2004	VIC	Commercial caterer	28	3	0	*Salmonella* Typhimurium 12a	Suspected gourmet rolls including red onion	Vegetables	Suspected
2005	Multi-state	Community	133	32	0	*Salmonella* Oranienburg	Alfalfa sprouts	Vegetables	Confirmed
2005	NSW	Community	23	0	0	*Clostridium* perfringens	possibly yellow rice (turmeric and fried onions)	Mixed/unspecified/other produce	Possible
2005	NSW	Child care	33	0	0	*Salmonella* Typhimurium	suspected to be ready to eat food such as hand cut fruit and sandwiches prepared in CCC	Mixed/unspecified/other produce	Suspected
2005	NSW	Restaurant	7	0	0	Unknown	Possibly vegetable naan or rice	Vegetables	Possible
2005	NSW	Restaurant	2	0	0	Unknown	suspected freshly squeezed blood orange juice crush	Fruits	Suspected
2005	QLD	Aged care	6	4	2	*Salmonella* Potsdam	Possibly fruit and vegetables	Mixed/unspecified/other produce	Possible

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
2005	VIC	Private residence	6	0	0	Unknown	Possibly hummus dip	Mixed/unspecified/other produce	Possible
2006	Multi-state	Community	26	5	0	*Salmonella* Litchfield	pawpaw	Fruits	Confirmed
2006	Multi-state	Unknown	100	9	0	*Salmonella* Saintpaul	Rockmelon	Fruits	Confirmed
2006	NSW	Restaurant	8	1	0	Norovirus	Unknown - common foods were salad and cooked potato chips	Mixed/unspecified/other produce	Possible
2006	NSW	Private residence	2	0	0	*Salmonella* Typhimurium 170	Suspect dip - salad dip and babbaganush dip	Mixed/unspecified/other produce	Possible
2006	NSW	Private residence	3	0	0	Unknown	potato salad suspected	Mixed/unspecified/other produce	Suspected
2006	SA	Restaurant	6	0	0	*Salmonella* Typhimurium 9	Sweet potato and feta cheese salad	Vegetables	Possible
2006	VIC	Restaurant	11	1	0	*Salmonella* Saintpaul	Possibly bean shoots	Vegetables	Possible
2006	WA	Other	29	Unknown	0	Norovirus	green salad	Vegetables	Suspected
2006	WA	Other	19	Unknown	0	Unknown	Possibly beef and salad roll	Mixed/unspecified/other produce	Possible
2007	Multi-state	Community	100	3	0	*Shigella sonnei* biotype g*	baby corn	Vegetables	Confirmed
2007	NSW	Restaurant	5	0	0	Unknown	Chard (spinach, tamarind and yoghurt dish)	Vegetables	Suspected

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
							suspected		
2007	NSW	Community	6	0	0	Unknown	Fresh fruit juices suspected	Fruits	Suspected
2007	NSW	Restaurant	2	0	0	Unknown	Possibly doner kebab with salad	Mixed/unspecified/other produce	Possible
2007	NSW	Restaurant	14	0	0	Unknown	Raw capsicum, onions, fresh herbs, chicken and/or beef	Mixed/unspecified/other produce	Possible
2007	NSW	Hospital	7	0	0	Unknown	suspected watermelon	Fruits	Suspected
2007	QLD	Institution	45	0	0	Norovirus	Ham; Salad; Bread	Mixed/unspecified/other produce	Possible
2007	QLD	Restaurant	24	0	0	Norovirus	Mixed salad	Mixed/unspecified/other produce	Possible
2007	QLD	Private residence	5	0	0	Norovirus	Suspected salad	Mixed/unspecified/other produce	Possible
2007	QLD	Health spa / resort	15	1	0	*Salmonella* Virchow 8	Possible vegetables or salad	Mixed/unspecified/other produce	Possible
2007	VIC	Commercial caterer	18	1	0	Norovirus	Fruit Salad	Fruits	Possible
2007	VIC	Hospital	34	1	0	Norovirus	Possibly fruit platters and sandwiches	Fruits	Possible
2007	VIC	Commercial caterer	37	0	0	Unknown	Passionfruit coulis on dessert	Fruits	Suspected

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
2007	WA	Private residence	2	2	0	Unknown	bitter lupin flour	Mixed/unspecified/other produce	Confirmed
2008	NSW	Restaurant	5	1	0	Unknown	barramundi, lamb, salad	Mixed/unspecified/other produce	Possible
2008	NSW	Restaurant	17	0	0	Unknown	Fattouch salad from Whispers Restaurant	Mixed/unspecified/other produce	Suspected
2008	NSW	Community	4	0	0	Unknown	pasta with tomato sauce (suspected)	Fruits	Suspected
2008	NT	Community	15	3	0	*Salmonella* Weltevreden	Possibly produce item in sandwiches and wraps	Mixed/unspecified/other produce	Possible
2008	QLD	Restaurant	2	0	0	*Clostridium perfringens*	Refried Mexican Beans	Mixed/unspecified/other produce	Suspected
2008	QLD	institution	56	0	0	Norovirus	Deli meat & salad dish	Mixed/unspecified/other produce	Possible
2008	QLD	Restaurant	6	0	0	Unknown	Possibly rocket lettuce or onions	Vegetables	Possible
2008	VIC	Restaurant	10	2	0	Hepatitis A	Salads and sandwiches	mixed/unspecified/other produce	Possible
2008	VIC	Restaurant	9	0	0	Unknown	Ready to eat foods - salads and garnishes	Mixed/unspecified/other produce	Possible
2009	Multi-state	Community	392	165	1	Hepatitis A	semi-dried tomatoes	Fruits	Confirmed
2009	NSW	Picnic	30	0	0	Norovirus	Unknown, possibly Caesar, pasta,	Vegetables	Possible

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
							seafood & chicken, or coleslaw salad		
2009	NSW	Restaurant	14	2	0	*Salmonella* Chester	Fresh chillies used to prepare chilli sauce	Vegetables	Possible
2009	NSW	Health spa / resort	15	0	0	Unknown	Possibly fruit platter	Fruits	Possible
2009	NSW	Restaurant	13	0	0	Unknown	Salad meal or a meal containing salad	Mixed/unspecified/other produce	Possible
2009	NSW	Restaurant	4	0	0	Unknown	unknown - suspected Hickory Steak with Chips and Salad	Mixed/unspecified/other produce	Possible
2009	NSW	Aged care	25	0	0	Unknown	Unknown: possibly vegetable gravy	Vegetables	Possible
2009	NSW	Restaurant	4	0	0	Unknown	Unknown possibly salad items	Mixed/unspecified/other produce	Possible
2009	QLD	Restaurant	4	0	0	*Clostridium perfringens*	Possibly roast beef with vegetables and gravy	Vegetables	Possible
2009	QLD	Health spa / resort	23	0	0	Norovirus	Chicken Caesar salad; Roast Chicken	Vegetables	Suspected

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
2009	SA	Camp	31	5	0	*Escherichia coli* O157	potato salad	Herbs and spices	Suspected
2009	TAS	Commercial caterer	14	0	0	Norovirus	green salad	Vegetables	Suspected
2009	WA	Community	17	3	0	*Salmonella* Saintpaul	pawpaw	Fruits	Confirmed
2010	NSW	Other	50	0	0	Unknown	Fruit kebabs	Fruits	Suspected
2010	NSW	Community	3	0	0	Unknown	Orange and Mango Fruit Drink	Fruits	Suspected
2010	Multi-state	Community	9	9	2	*L. monocytogenes*	Melons and/or melons contained within fruit salads	Fruits	Confirmed
2010	QLD	Private residence	6	1	0	Norovirus	Unknown; possibly salads	Mixed/unspecified/other produce	Possible
2010	VIC	Private residence	19	0	0	Unknown	Unknown; possibly prawn salad, fruit salad, lentil salad, carrot salad	Mixed/unspecified/other produce	Possible

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
2010	VIC	Aged care	9	0	0	Unknown	Tuna and salad sandwiches	Mixed/unspecified/other produce	Possible
2010	VIC	Private residence	15	1	0	*Salmonella* Typhimurium 141	Pasta salad	Mixed/unspecified/other produce	Possible
2010	WA	Cruise / airline	314	0	0	*Cyclospora* species	Possibly cantaloupe, lettuce and mint	Mixed/unspecified/other produce	Suspected
2010	ACT	Community	47	5	0	*Salmonella* Typhimurium 170	Chicken pesto salad, Greek salad	Mixed/unspecified/other produce	Possible
2011	NT	Camp	3	0	0	*Salmonella* Typhimurium 9	Fruits and Vegetables	Fruits and Vegetables	Suspected
2011	NSW	School	17	1	0	*Salmonella* Typhimurium 170	Apple turnover, banana pancakes	Fruits	Suspected
2011	WA	Private residence	30	2	0	*Salmonella* Typhimurium 193	Unknown; meal with assorted salads	Mixed/unspecified/other produce	Possible
2011	VIC	Restaurant	15	0	0	Norovirus	Fruit platter	Fruits	Confirmed
2011	VIC	Aged care	8	0	1	*Clostridium perfringens*	Unknown; possibly vegetable soup	Mixed/unspecified/other produce	Suspected
2011	NSW	Community	5	2	0	*Salmonella* Typhimurium 9	Possibly doner kebab	Mixed/unspecified/other produce	Possible

Year	State	Setting	Ill	Hospitalised	Died	Aetiology	Food vehicle modified	Produce ingredient category	Confirmation status
2011	NSW	Community	4	0	0	Unknown	Possibly doner kebab with tomato and lettuce	Mixed/unspecified/other produce	Possible
2011	NSW	Restaurant	4	2	0	*Salmonella* Typhimurium 135	Prawn dumpling with coriander	Herbs and spices	Possible

Appendix 3

Scoping Review

1 Outbreak summaries

1.1 Microbiological trace back investigations

Eight of the 43 outbreaks that met the inclusion criteria of this review included a microbiological trace back component to the investigation and provided sufficient detail to assess a probable supply chain failure point. Three of these outbreaks were caused by *E. coli* and were associated with lettuce (Sweden), spinach (US) and strawberries (US). Three outbreaks were caused by *Yersinia pseudotuberculosis*, all associated with carrots (Finland). Single outbreaks were caused by *Salmonella* Newport associated with tomatoes (US) and *Campylobacter jejuni* associated with peas (US). The production and processing failure points that lead to these eight foodborne outbreaks could be broadly assigned to the following three categories:

(i) faecally contaminated water used during the growing stage,
(ii) direct faecal contamination of fresh produce in the field by wildlife, and
(iii) poor post-harvest storage and handling practices (Appendix 3, Table A3.2).

1.1.1 Faecally contaminated water

The use of faecally contaminated water during the growing phase has the potential to contaminate multiple paddocks and batches of produce, and depending on the distribution network in a particular country, there exists the potential for widespread outbreaks affecting multiple jurisdictions. This was evidenced in the US during a national outbreak in which tomatoes were implicated as the food vehicle (Greene et al., 2008). In total, 17 states reported cases of *Salmonella* Newport in 2005 with the same outbreak strain causing illness in multiple states in 2002, 2003 and 2004 (Greene et al., 2008). The outbreak strain was traced to a pond used for irrigation in the state of Virginia. Farmers reported that irrigation water did not come into contact with fruit; however, one farmer reported using the pond water to apply pesticide to fruit (Greene et al., 2008). The outbreaks occurred in autumn and summer and large numbers of geese and turtles were reported on the ponds in the summer of 2006, although no samples were collected from these wildlife species (Greene et al., 2008). The authors concluded that the precise source of contamination could not be determined but persistent outbreaks over a number of years indicated a persistent environmental source of contamination and water use, possibly irrigation or chemical application, could have provided the mechanism for fruit contamination (Greene et al., 2008).

Contaminated irrigation water was also implicated in an outbreak of verotoxin-producing *E. coli* O157 (VTEC; Stx 2) in Sweden in 2005 that was associated with lettuce consumption (Soderstrom et al., 2008). The outbreak strain was isolated from cattle upstream of the implicated lettuce farm and irrigation water samples were positive for the *Stx* 2 gene by polymerase chain reaction (PCR) (Soderstrom et al., 2008). No outbreak strains were cultured from irrigation water samples but the stream from which irrigation water was extracted was highly polluted and not potable. Furthermore, the level of pollution exceeded limits considered acceptable for swimming (Soderstrom et al., 2008). High rainfall during the summer months preceding the outbreak was assumed to have caused the exceptionally high faecal contamination levels in the stream (Soderstrom et al., 2008).

1.1.2 Direct faecal contamination

Direct faecal contamination of produce in the field has been implicated in at least three of the foodborne outbreaks that met the selection criteria for this review. In 2006, a large multistate outbreak of *E. coli* O157:H7 was associated with the consumption of raw spinach resulting in at least 199 cases. Spinach was epidemiologically and microbiologically confirmed as the food vehicle causing the outbreak (CDC 2006; Jay et al., 2007; Grant et al. 2008; Wendel et al. 2009). The outbreak was traced to a single production date at one processing plant and fields located on four farms on the central California coast (cited by (Jay et al., 2007). Product testing in multiple states revealed that only spinach samples that were bagged at the implicated processing plant on 15 August 2006 were positive for the outbreak strain (Grant et al., 2008; Wendel et al., 2009).

Trace back investigations conducted several months after the outbreak found that *E. coli* O157 isolates from three of the implicated farms did not match the outbreak strain using PFGE typing; however, the outbreak strain was recovered from cattle, feral pigs, soil and surface water from a single implicated farm (Jay et al., 2007). Irrigation and well water samples were negative for the outbreak strain. Feral pig incursion into the spinach field growing area was documented and pig faeces were detected in the field. Cattle were also separated from the field by a fence (Jay et al., 2007). Contamination of spinach in the field could have occurred indirectly by faecal contamination of irrigation, well and surface water or directly by faecal deposition on the field (Jay et al., 2007). Baby spinach harvesters operate like a lawnmower and could have picked up faeces that had been directly deposited in the field (Jay et al., 2007).

The exact mechanism of produce contamination is rarely, if ever, definitively established and some level of speculation is often required. This was apparent during the spinach O157 outbreak described above, whereby a very thorough investigation yielded plausible but speculative outcomes; however the direct deposition hypothesis and picking up of faeces by the harvester appeared to be the most plausible and was consistent with a single batch contamination.

Recently in 2011, a multistate outbreak of *E. coli* O157:H7 in the USA was microbiologically and epidemiologically linked to deer defecating in strawberry fields while grazing amongst the crop (Anonymous, 2011a; Anonymous, 2011b). Subsequent sale of contaminated strawberries at roadside stalls and farmers markets resulted in at least 17 confirmed cases, 7 hospitalisations and one death (Anonymous, 2011a; Anonymous, 2011b). This outbreak was reported on the International Society for Infectious Diseases' electronic reporting system for infectious disease outbreaks (www.promedmail.com) and at the time of preparing this report, no results had been published in the international literature.

Wild birds (Sandhill cranes) defecating on pea fields in the state of Alaska (US) were linked to an outbreak of *C. jejuni* in that state resulting in at least 132 cases, of which five were hospitalised. Outbreak strains were isolated from case patients, from cranes and pea samples taken from the implicated farm (Gardner et al., 2011).

The above outbreaks involving cattle/wild pigs and deer serve to highlight the need for vigilance in maintaining barrier fencing capable of keeping out domestic and wild grazing or foraging animals. The latter outbreak serves to highlight the difficulty of controlling the production of fresh produce in an environment where migratory birds may introduce a pathogen onto crops during the growing phase.

1.1.3 Post-harvest storage and handling

Three outbreaks of *Y. pseudotuberculosis* associated with the consumption of carrots have

been documented in Finland since 2003 (Jalava et al. 2006; Kangas et al. 2008; Rimhanen-Finne et al. 2009). A large outbreak in 2003 was epidemiologically traced to a carrot production farm that had stored carrots in open bins in an unenclosed barn accessible to rodents. No manure fertiliser was used during growing, no domestic animals were on the farm and none were observed near the unfenced fields. Carrots were washed and peeled on farm and delivered to a kitchen without further washing steps. Soil samples containing carrot residue were positive for the *Y. pseudotuberculosis* outbreak subtype and these samples originated from the area where washing and peeling was carried out (Jalava et al., 2006). The exact mechanism of contamination could not be determined but conditions favoured faecal contamination of carrots stored in open bins by rodents or other small wildlife and subsequent contamination of washing and peeling equipment. The carrots were grated at the implicated kitchen and stored chilled for 5 days prior to serving, which may have also facilitated bacterial growth (Jalava et al., 2006).

A second outbreak in 2004 was epidemiologically linked to carrots and a farm producer. Subsequent microbiological trace back investigations positively identified the outbreak subtype on the carrot peeling line and in spoiled carrots and carrot residue collected from the implicated processing plant (Kangas et al., 2008). The outbreak was further traced to a farm where the outbreak subtype was isolated from the intestines of a small mammal (shrew). The exact mechanism for the contamination was not determined but it was speculated that small infected shrew may have been picked up by harvesting equipment thereby contaminating the carrots and the long-term cold storage over winter facilitated bacterial growth (Kangas et al., 2008).

A third outbreak in 2006 was microbiologically linked to a carrot distributor's storage facility and environmental sampling did not show evidence of contamination originating on the implicated farm (Rimhanen-Finne et al., 2009). The outbreak was associated with poor quality carrots that had been stored on farm for six months and for a further four months at the distributor's facility. A large proportion of the carrot batch associated with the outbreak had to be destroyed due to the poor quality of the produce. The rest of the batch was peeled and grated and then distributed to two municipality kitchens, with further distribution to 23 schools and five day-care centres without additional washing steps (Rimhanen-Finne et al., 2009).

The direct source and mechanism of contamination could not be categorically determined in each of these three outbreaks but the common critical factor in each was the long term storage of tainted produce allowing *Y. pseudotuberculosis* to multiply over the winter storage period. *Yersinia pseudotuberculosis* is able to grow at low temperatures and long term storage in Finland at temperatures of 1 - 2°C provides favourable conditions for multiplication (Rimhanen-Finne et al., 2009). Rimhanen-Finne et al. (2009) noted that instructions to improve hygiene practices in storage and handling of raw carrots in Finland were issued to prevent outbreaks; farmers, vegetable processing plants and institutional kitchens were informed of the risk of *Y. pseudotuberculosis* arising from stored, domestic carrots. To our knowledge, no outbreaks of *Y. pseudotuberculosis* associated with carrots have been reported from Finland since 2006.

1.2 Microbiological food attribution investigations

1.2.1 Lettuce

In January and February 2010, 11 distinct outbreaks occurred in the eastern half of Denmark resulting in at least 260 cases of gastroenteritis. Case investigations revealed the outbreaks were caused by norovirus (multiple genotypes) and enterotoxigenic *E. coli* (ETEC) O6:K15:H16. Epidemiological evidence implicated consumption of lettuce imported from France. The reporting of epidemiological data was, however, insufficient to meet the

inclusion criteria of this review. The epidemiological investigations lead the investigators to conduct microbiological examination of lettuce supplied by two implicated food catering companies. Norovirus genotype II was recovered from lettuce associated with one outbreak and no ETEC was recovered from any lettuce samples tested. Lettuce consumption could only be loosely associated with ETEC infections based on limited epidemiological data.

1.2.2 Jalapeño chilli peppers (and Serrano peppers and fresh tomato)

In 2008 a large multi-state outbreak of *Salmonella* Saintpaul involving 43 states and the District of Columbia in the US affected more than 1400 people with the highest incidence observed in Texas and New Mexico. Additional cases were also detected in Canada (CDC 2008). An initial multi-state case control study using cases matched with healthy community controls implicated fresh tomatoes as the vehicle of transmission. Further studies using cases matched to healthy eating companions from outbreaks linked to restaurants, implicated fresh salsa and guacamole, and specifically jalapeño and serrano peppers. Jalapeño peppers were not associated with all outbreaks, nor were serrano peppers or tomatoes, indicating multiple fresh produce commodities were involved. Microbiological investigations identified the outbreak strain on jalapeño peppers taken from a distributor in Texas and from a jalapeño pepper collected from the household of an infected person in Colorado. The implicated peppers were imported from Mexico and the outbreak strain was isolated from serrano peppers and irrigation water on one of two farms investigated that grew serrano and jalapeño peppers. The epidemiologic and microbiologic data indicated jalapeño peppers were the main transmission vehicle for infection, but that serrano peppers also had a role. It was also likely that tomatoes were a vehicle for transmission in the early stages of the outbreak making the outbreak unique in that multiple fresh produce commodities grown in the same area of Mexico with a common source of contaminated irrigation water caused a widespread outbreak across large tracks of North America. Neither the source of contamination, nor the on-farm or post-harvest practices that lead to the contamination were determined (CDC, 2008; Mody et al., 2011; Behravesh et al., 2011).

1.2.3 Semi-dried tomatoes

A large outbreak of hepatitis A (HAV) occurred across several Australian states during 2009.

Five hundred and sixty two cases of hepatitis A were notified in Australia in 2009, representing a two-fold increase on the number notified in 2008 and on the annual average for the years 2004-2008. Sequence analysis of HAV RNA positive samples showed 144 of 153 (94%) cases tested had an identical IB genotype, providing supporting evidence of a widespread, common source of infection. The outbreak was first detected in March 2009 in Victoria with concurrent increases in cases reported in South Australia (SA), Queensland, Western Australia (WA) and New South Wales (NSW). OzFoodNet subsequently coordinated a multi-jurisdictional investigation to identify a source (Donnan et al., 2011).

Two case-control studies were conducted. The first was a multi-jurisdictional case-control study conducted in April - May 2009 and the second, a case-control study conducted only in Victoria in October - November due to a recrudescence of cases. Cases were defined as a person with serologically confirmed hepatitis A by detection of anti-hepatitis A IgM (in the absence of recent vaccination), or detection of HAV by nucleic acid testing. For the multijurisdictional study, cases notified to health departments in Victoria, NSW, Queensland and WA between 8 April and 29 May, aged 18-60 years, were eligible for the study and were excluded if they: had been interviewed for hypothesis generation; travelled overseas to a country where hepatitis A is moderately to highly endemic; had close contact with a confirmed case during their incubation period; were unable to estimate a date of onset of illness; or were not contactable by telephone or registered letter. For the Victorian study, cases notified to the Victorian Department of Health between 14 September and 5

November were eligible (Donnan et al., 2011). Victorian controls were randomly selected from the 2008 Victorian Population Health Survey database and for other states, controls were selected from the National Gastroenteritis Survey Control Bank and frequency matched to cases by state in a 3:1 ratio.

The epidemiological studies provided strong evidence associating the hepatitis A outbreak to the consumption of semi-dried tomatoes. In the multi-jurisdictional study, only semi-dried tomatoes were associated with hepatitis A in the multivariate model (adjusted odds ratio: 17.8, 95% CI: 3.6-88.0). Whereas in the Victorian study, semi-dried tomatoes, feta and antipasto were significantly associated with hepatitis A in the multivariate model (Donnan et al., 2011). The differentiation of primary and secondary cases was not reported and the total number of cases attributed to consumption of semi-dried tomatoes was not estimated.

Hepatitis A virus RNA was detected in 31% (21/67) of semi-dried tomato samples collected in June 2009 and the investigators found a 100% sequence homology in the VP3 region of the genome with HAV detected from cases' sera (Donnan et al., 2011). HAV RNA was detected in both imported and local product; contaminated manufacturing environments as well as contaminated raw ingredients were considered plausible explanations for the prolonged outbreak throughout 2009.

Outbreaks of hepatitis A associated with semi-dried tomatoes were subsequently reported in the Netherlands (Petrignani,M et al. 2010a; Petrignani,M et al. 2010b) and France (Gallot et al. 2011) in 2010. Frozen semi-dried tomatoes imported from Turkey were implicated in the French outbreak (Gallot et al., 2011). All outbreaks were caused by a very similar (98-100% homology) IB strain of HAV (Petrignani,M et al., 2010a) indicating a possible common source of contaminated fresh produce.

1.2.4 Sugar peas

At least 20 cases of shigellosis were registered in Norway in May and June 2009 with an identical outbreak strain of *Shigella sonnei*. All cases reported eating sugar peas imported from Kenya. Investigators detected *S. sonnei* by PCR from an unopened bag of sugar peas collected from the household of a case (Heier et al. 2009). An outbreak of *S. sonnei* was also detected in Denmark from April-May 2009 involving imported sugar peas. Laboratory testing of isolates from cases showed similarity to the Norwegian outbreak isolates but this was not confirmed. *S. sonnei* was not isolated from food items in the Danish outbreak and sugar peas were also imported from Kenya, but batches of sugar peas also came from Ethiopia and from Guatemala (Muller et al. 2009).

Sugar snaps were also implicated in an outbreak of shigellosis in Sweden from May to June 2009 (Lofdahl et al. 2009). The Swedish outbreak was caused by *S. dysenteriae* and was believed to have been associated with peas imported from Kenya. The Danish and Swedish studies did not meet the inclusion criteria for this review owing to a lack of microbiological data and rapidly disseminated epidemiological studies lacking detail. They have, however, been included here due to the similarities with the Norwegian outbreak regarding timing, country of origin and the implicated food vehicle.

1.2.5 Basil

In the first half of 2007 the Health Protection Agency Laboratory of Enteric Pathogens reported on 55 primary cases of *Salmonella* Senftenberg in England and Wales, which was a significant increase compared to less than 10 in the same time period in 2005 and 2006 (Pezzoli et al. 2008). Forty of these isolates were received since 9 April 2007 (week 15). In the UK investigation, 32 cases matched the case definition of being a resident of England or Wales and had a *Salmonella* Senftenberg isolate identical to the outbreak strain (designated

SSFTXB.0014) by plasmid profiling and pulsed-field gel electrophoresis (PFGE) and received after 8 April 2007. Twenty of the 32 cases were interviewed and no epidemiological link to basil was found. Thirty percent of the 20 cases interviewed reported consumption of fresh herbs in the three days prior to onset of illness but only a few could specifically recall eating fresh basil and 40% reported consumption of pre-packaged leaf salad (Pezzoli et al. 2007; Pezzoli et al., 2008).

Three cases of *Salmonella* Senftenberg matching the outbreak strain were also reported from the Shetland Islands, Scotland, in April 2007 (Pezzoli et al., 2008). In May 2007, a national survey of fresh herbs collected from UK retail premises was initiated and samples were tested for *Salmonella* spp. and other enteric pathogens (Pezzoli et al., 2008; Elviss et al. 2009). The outbreak strain of *Salmonella* Senftenberg was detected in eight samples of intact pre-packaged fresh basil sold in the UK and grown in Israel (Pezzoli et al., 2008; Elviss et al., 2009). Environmental investigations were conducted in June 2007 in Israel and did not detect *Salmonella* Senftenberg in 50 samples of basil, herbs and environmental samples collected from farms exporting to the UK. In addition, all hand and stool samples collected from farm workers were negative for *Salmonella* Senftenberg (Pezzoli et al., 2008). Commercial production of herbs in Israel is generally done in greenhouses using treated municipal water and no farm animals were reported to be kept near production areas. Investigations of UK packing facilities did not detect *Salmonella* contamination (Pezzoli et al., 2008).

In the outbreak period (January to June 2007), Denmark, the Netherlands, Israel and the United States reported isolation of *Salmonella* Senftenberg. In Denmark 11 cases were reported and three matched the UK outbreak strain, 2 of these three cases reported possible exposure in the UK and US. In the Netherlands, 5 cases were reported and two matched the UK outbreak strain. Eleven human isolates of *Salmonella* Senftenberg matching the UK outbreak strain were identified during the outbreak period. In Israel, seven cases of *Salmonella* Senftenberg were reported during the outbreak period but none matched the UK outbreak strain (Pezzoli et al., 2008).

1.2.6 Raspberries

Multiple norovirus outbreaks occurred in Finland throughout 2009 (Maunula et al. 2009; Sarvikivi et al. 2011). Between March and August of that year, 13 outbreaks resulted in approximately 900 cases (Sarvikivi et al., 2011) and a cluster of outbreaks in southern Finland between September and October 2009 resulted in a further 200 cases (Maunula et al., 2009). Norovirus was isolated from cases and genetically typed for 11/13 outbreaks reported up to August; 10 were caused by genogroup GII and one by genogroup GI.4. Although investigations of outbreaks varied greatly, analytical studies were conducted for 7/13 outbreaks which implicated raspberries in all these outbreaks (Sarvikivi et al., 2011); however none of the epidemiological studies complied with the criteria set out for this scoping review.

The largest outbreak occurred in Seinajoki and affected greater than 500 people. Epidemiological data implicated a raspberry-cranberry desert and a green salad but norovirus was not detected in any food samples associated with the outbreak (Sarvikivi et al., 2011). A batch of imported frozen raspberries, designated batch *b*, was found to be contaminated with norovirus genogroup GII and this batch was genetically matched to an outbreak affecting 32 people and implicated by trace back to two other outbreaks affecting a further 42 people (Sarvikivi et al., 2011). In the second cluster of outbreaks in the last half of 2009, norovirus was detected by RT-PCR from raspberries sampled from three different outbreak settings, two restaurants and one day-care centre. All virus isolates from raspberries belonged to genogroup GI and one raspberry isolate was genotyped as GI.4. These three outbreaks resulted in illness in 76 people and norovirus was isolated from

patients from two of these outbreaks (Maunula et al., 2009). Raspberries testing positive for norovirus were grown in Poland and packaged into 2.5kg bags in Finland. During the investigation, only two samples from the 20,000kg batch of wholesaler's stock were tested for norovirus, however norovirus was not found.

Raspberries were also implicated in an outbreak of *Cyclospora cayetanensis* at a wedding reception on 10 June 2000 in Pennsylvania, USA (Ho et al. 2002). A retrospective cohort investigation of 79/84 wedding attendees identified 54 case patients who met the case definition. On univariate analysis, several food items were associated with illness and after multivariate analysis, only the wedding cake, that had a raspberry and cream filling, was significantly associated with illness. PCR analyses confirmed the presence of *Cyclospora* DNA in the raspberry filling but not from the top icing of the cake or in the cake itself. Raspberry was the only fresh produce component of the cake. Five case patients had laboratory confirmed cyclosporiasis (Ho et al., 2002). Trace back investigations could not determine where the raspberries originated due to poor traceability. Raspberries from Guatemala, Mexico or the US could have been used to make the wedding cake filling.

1.2.7 Rockmelon

At least two outbreaks of listeriosis have been microbiologically and epidemiologically linked with the consumption of rockmelons, both occurring in the past two years.

Most recently, a large multistate outbreak of listeriosis in the US was associated with rockmelons (cantaloupe) produced on Jensen Farms in the state of Colorado (CDC 2011; Anonymous, 2011c) resulting in greater than 130 cases and 29 deaths (Anonymous, 2011c). A case was defined as illness with one of the outbreak strains isolated on or after 1 August 2011. Outbreak strains were initially defined as (i) clinical isolates of *L. monocytogenes* with specimen collection dates in August, (ii) with a two-enzyme PFGE pattern combination that occurred in two or more persons and (iii) that matched any of the three pattern combinations found among Colorado residents in August. Subsequently a fourth PFGE pattern was detected in a multistate cluster and an isolate of *L. monocytogenes* from the implicated farm had this pattern. Isolates with this pattern were then considered to be among the outbreak strains. All four outbreak strains of *L. monocytogenes* were isolated from whole and cut cantaloupe samples from patients' homes or from samples of Jensen Farms cantaloupe collected from grocery stores and the farm (CDC, 2011). Investigations and testing conducted by the US Food and Drug Authority detected widespread *Listeria* contamination at the Jensen Farm packing plant in Granada, Colorado, indicative of poor sanitary practices at the facility (Anonymous, 2011c).

A relatively small multistate outbreak of listeriosis occurred in Victoria, NSW and Queensland, Australia, from February to September 2010 resulting in nine cases that were epidemiologically associated with consumption of rockmelon and microbiologically linked to ingredients of implicated fresh-cut fruit salad, including rockmelon and honeydew melon (Astridge, 2011). All nine cases were considered to be immunocompromised and the median age of cases was 78 years. An outbreak case was defined as *L. monocytogenes* isolate designated PFGE: 121:119:1 or *L. monocytogenes* isolate designated PFGE 122:4N:1. Opportunistic food samples were collected from a production facility of a fresh-cut fruit salad manufacturer initially linked to a Victorian cluster by an epidemiological investigation. The outbreak strain *L. monocytogenes* (PFGE subtype 121:119:1) was isolated from waste fruit juice, fruit rinse water and the washings from rockmelons. The outbreak strain *L. monocytogenes* (PFGE 122:4N:1) was also isolated from a honeydew melon. The melons from which the outbreak strains were isolated in Victoria were subsequently traced to Griffith, NSW (Astridge, 2011), however the source of melon contamination was not determined.

In the period 1 September to 30 November 2006, there were 232 reported cases of

Salmonella Saintpaul in Australia compared to a five year average of 45.4 cases for the same period in the years 2001-2005. Of these reports, 115 cases were confirmed to harbour the same strain of *Salmonella* Saintpaul based on multiple locus variable-number tandem repeat analysis (MLVA). The 115 cases with this defined outbreak strain were identified in six Australian jurisdictions with the epicentre in the south-eastern jurisdictions of NSW, Victoria and the Australian Capital Territory (ACT).

An unmatched case-control study was conducted with 36 cases who were defined as an infection with the outbreak strain of *Salmonella* Saintpaul isolated from a faecal specimen by MLVA on or after 6 October 2006 in residents of NSW, Victoria and the ACT. The epidemiological study using an unmatched selection of controls did not match the criteria of this scoping review, but consumption of rockmelon was found to be significantly associated with illness. Thirty-three of the 36 cases participating in the case-control study were able to recall the point of sale of rockmelon purchased prior to the onset of illness. A total of 141 samples of whole melon, three half melons and one rockmelon piece were tested during trace back investigations and the outbreak strain was detected on the skin of a whole and half melon sampled from the same retail premises (Munnoch et al., 2009).

Mixing of fresh rockmelon stock from different processors, poor documentation by retail premises and poor traceability of fresh produce were noted to complicate and hamper trace back investigations during this outbreak. However, the two melon samples that tested positive for the outbreak strain were grown and packaged in the Northern Territory (NT). The outbreak strain could not be definitively linked to a farm, packing shed or processor, however investigations of six processors in the NT and Queensland identified critical food safety issues in the production and processing of rockmelons that may have contributed to produce contamination; including the use of untreated or inadequately treated water on RTE melons, the incorrect use of disinfectants, temperature differential between fruit and wash water and processing of damaged fruit (Munnoch et al., 2009).

1.2.8 Papaya

A small multistate outbreak of 26 cases of *Salmonella* Litchfield occurred in the Australian states of WA and Queensland between October 2006 and January 2007. Cases were defined as a person with a laboratory confirmed case of *Salmonella* Litchfield with a PFGE pattern indistinguishable from the outbreak strain and reporting to the state health departments between 26 October 2006 and 16 January 2007. An unmatched case-control study of 12 cases and 24 controls was stopped after preliminary data analysis of the 36 study participants strongly implicated consumption of papaya as the vehicle of transmission. Environmental studies determined that 9/38 papaya samples collected on 1 December 2006 were contaminated with *Salmonella* Litchfield, five samples were whole papaya and four half papayas (cut by store staff). The contaminated papayas were traced to three farms in northern WA with the papaya isolates indistinguishable from clinical isolates from patients in WA and Queensland by PFGE (Gibbs et al., 2009). On farm investigations did not detect *Salmonella* Litchfield from environmental samples or papaya samples but *Salmonella* spp. were detected in water samples collected from two farms. The investigators concluded that the use of untreated river water and incorrect use of chemical disinfectants was a possible source of fruit contamination (Gibbs et al., 2009).

1.3 Epidemiological food attribution investigations

1.3.1 Lettuce

Since 1994, six additional foodborne outbreaks of gastrointestinal illness have been associated with the consumption of lettuce with sufficient epidemiological detail to be included in this scoping review.

In 1994, iceberg lettuce was associated with outbreaks of shigellosis in several European countries. In England and Wales, an outbreak of *S. sonnei* infection was detected in June following a report of increased infections in Sweden. Infections were predominantly associated with two phage types of *S. sonnei*. A study of 27 cases and 44 controls who were nominated by cases and matched by age and sex, found a significant association between consumption of iceberg lettuce and shigellosis (Frost et al. 1995). The authors concluded that the strong epidemiological evidence in combination with an increase in reporting of *S. sonnei* cases in other European countries, implicated iceberg lettuce as the vehicle of infection. The epidemiological study was further supported by laboratory studies which showed a change in predominant phage types during the period of the outbreak. The predominance of the same phage types in lettuce-associated *S. sonnei* infections in a number of countries added further weight to this conclusion (Frost et al., 1995).

Between May and June 1994, 110 culture-confirmed cases of *S. sonnei* infection were detected in Sweden. A study of 47 cases and 155 controls matched by age, sex and geographical location, found a strong association between infection and consumption of iceberg lettuce. Lettuce imported from Spain was implicated in the outbreak but no food samples were positive for *S. sonnei* contamination (Kapperud et al. 1995). Outbreaks in other European countries, including Scotland and Norway, were also associated with contaminated lettuce (Kapperud et al., 1995; Frost et al., 1995) but the studies did not match the inclusion criteria for this review.

In July 1995, 40 residents in the state of Montana, US, were identified with laboratory confirmed *E. coli* O157:H7 infection and a further 52 residents had bloody diarrhoea without laboratory confirmation. Twenty eight cases with the PFGE outbreak pattern were matched by age and telephone exchange to two controls to ascertain the food vehicle causing infection. Consumption of purchased leaf lettuce in the five days prior to illness was strongly associated with infection, however, trace back investigations were inconclusive and no food or environmental samples were positive for *E. coli* O157:H7 (Ackers et al. 1998).

The following year in June 1996, another outbreak of *E. coli* O157:H7 occurred in the US and was associated with locally produced lettuce. Twenty-one patients from Connecticut, 28 patients from Illinois and a further five interstate patients exposed in Connecticut were infected with the outbreak associated subtype based on PFGE sub-typing analysis (Hilborn et al., 1999). Matched case control studies were undertaken in each state and cases were matched with two age, sex and geographical location controls. In Connecticut, 25 cases and 35 controls were interviewed and consumption of Mesclun lettuce and unspecified mixed greens were significantly associated with illness. In Illinois, 23 cases and 46 controls were interviewed and red leaf lettuce was found to be associated with lettuce. The investigators conducted a follow up study of 19 cases and 26 controls interviewed in the initial Illinois study to ask more specific questions about lettuce type. The second study identified consumption of Mesclun and Green leaf lettuce significantly associated with infection (Hilborn et al., 1999).

Trace back investigations implicated a single grower/producer company that supplied lettuce to implicated retail outlets in both Connecticut and Illinois. This small producer was inspected in July 1996 and several potential problems were encountered; lettuce was grown in fields adjacent to a small cattle operation and free range chickens had access to both cattle and lettuce fields. The grower did not report use of cattle manure as fertiliser but used composted chicken manure but wells on the farm provided water for the cattle and lettuce growing and processing operations. Sanitation facilitates for farm workers were found to be inadequate and the filtration system used to clean well water prior to use in the lettuce wash tanks was not working in the month before the outbreak commenced. Environmental and lettuce samples collected on farm did not yield any *E. coli* O157:H7 isolates but generic

E. coli was detected in water sampled from wash tanks, the pipes used in the water reticulation system and from lettuce samples collected on the premises indicative of wide spread contamination. The investigators concluded that the wash water was the most likely source of the outbreak but this could not be confirmed (Hilborn et al., 1999) owing to a lack of microbiological evidence.

In October 1998, the number of cases of *Y. pseudotuberculosis* serotype O:3 markedly increased from routine reporting in Finland. Nationwide, 47 case patients were identified with the outbreak strain based on PFGE subtyping and one patient died. An outbreak investigation was initiated and 38 cases and 76 healthy community controls matched by age, sex and post code, were enrolled in a case control study. Only iceberg lettuce consumption in the 2 weeks prior to the onset of illness was associated with infection (Nuorti et al., 2004). Trace back investigations implicated a single shipping company who was supplied by four farms in southwest Finland, poor traceability and incomplete documentation prohibited the investigation identifying a single lettuce grower (Nuorti et al., 2004). No iceberg lettuce was tested and environmental sampling could not be carried out due to snow and frost cover. Farm inspections in May 1999 determined that iceberg lettuce crops were grown in open unfenced fields and untreated water was used for spray irrigation of the fields. Two farms sourced water through a ditch from a nearby lake and two farms sourced water from man-made ponds. The region where the farms are located have a large population of roe deer and large quantities of roe deer faeces were found all over the lettuce fields and around all the irrigation water sources. *Y. pseudotuberculosis* was recovered from one soil and one irrigation sample collected in November 1999 and two lettuce samples collected in 2000, but they did not match the outbreak strain from 1998 (Nuorti et al., 2004).

A large outbreak of *Salmonella* Newport infection occurred in Northern Ireland during September and October 2004. PFGE subtyping of isolates from 129 case-patients confirmed the outbreak strain was indistinguishable from that identified in concurrent UK outbreaks in regions of England, Scotland and in the Isle of Man. In total, 130 cases were identified over a four week period. Twenty-three cases and 39 meal-matched controls who had eaten a meal outside their home after 20 August 2004 were interviewed to determine the food vehicle responsible for the outbreak. A statistically significant association with a history of having eaten lettuce in a meal outside the home and being a case was found. Over 300 food samples were tested and none yielded any *Salmonella* spp.. Supply chain complexity and limited traceability in salad vegetable distribution hindered detailed investigations of the source of the outbreak.

1.3.2 Tomato

At the end of May 2001, a large outbreak of gastrointestinal illness involving five restaurants under the same ownership in New York State was notified to the Centers for Disease Control and Prevention (CDC). Culture-confirmed *Shigella flexneri* serotype 2a infection was reported in four persons who had eaten at one of the restaurants before onset of illness. Subsequently, a nurse reported diarrhoea in 19 of 70 persons who ate a hospital lunch catered by the same restaurant implicated in the first four cases. Reports of illness in persons who had eaten at the other four local restaurants followed. Three hundred and six of 886 ill restaurant patrons and 167 control subjects were included in a case-control study. Controls were also patrons of the restaurants and were matched to cases by date of meal and the restaurant. Matched univariate analysis showed that several food items were associated with illness, however only tomatoes remained significant in multivariate models. Illness peaked at each restaurant within 24 hours after the arrival of hand-sorted bruised and overripe ‘special grade’ tomatoes that were supplied to the restaurants by a new distributor (Reller et al. 2006). The investigators concluded that the contamination occurred at the terminal distribution site but the evidence presented was speculative.

1.3.3 Baby corn

In August 2007, an international outbreak of *S. sonnei* resulted in 215 laboratory confirmed cases in Denmark (Lewis et al., 2009) and 55 cases in Australia (OzFoodNet 2008).

A retrospective cohort study was undertaken in Denmark and a case-patient was defined as any person with multi-drug resistant (resistant to tetracycline, ampicillin, sulphonamides, cephalothin, and streptomycin) *S. sonnei* infection acquired in Denmark or Australia in August 2007, excluding those who had travelled to an endemic area in the three days before onset of symptoms or those that could be explained by an alternative exposure. A web-based cohort study was conducted in one of the larger workplaces affected by the outbreak in Denmark and 95 of 170 people working in the workplace the week of the outbreak responded to the questionnaire and had eaten at the canteen. Of these 95 respondents, 27 met the case definition. There was an increased risk of illness for people who had eaten at the canteen on the 6, 7 and 8 August and baby corn was the only food item found to be significantly associated with illness on 7 August and three food items were associated with illness on 6 August; baby corn, peas and cauliflower. After multivariate analysis only baby corn was independently associated with illness on 6 August (Lewis et al., 2009).

Shigella species were not detected in any of the 121 samples collected from different batches in Denmark and no baby corn from the implicated batch in Australia was available for testing (Lewis et al., 2009). However, batches in both Denmark and Australia were found to harbour multiple enteric pathogens including *E. coli*, *Salmonella* spp. and *S. flexneri* (Lewis et al., 2009). Trace back investigations revealed that one common packing shed in Thailand supplied baby corn to wholesalers implicated in the outbreak batches in both Denmark and Australia. Investigations by Thai authorities found multiple problems in the implicated packing shed, including low concentrations of chlorine added to wash water and unhygienic work practices, but there was no microbiological confirmation of baby corn as the vehicle of human infections and the source of contamination was not determined (Lewis et al., 2009).

1.3.4 Coriander

An outbreak of *Salmonella* Thompson was detected in southern California, US, in April 1999 through an increase in laboratory detections. Concurrently, a restaurant-associated outbreak of *Salmonella* Thompson was reported in Los Angeles, California. In total, 35 “sporadic” cases and 41 restaurant-associated cases were detected with onset of illness between 6 and 31 March 1999; all “sporadic’ cases were independent of the restaurant-associated cases. A matched case-control study was undertaken, whereby cases were defined as *Salmonella* Thompson infection in a resident of southern California, with onset in March 1999. At least two controls per case patient were selected by randomly generating telephone numbers on the basis of case patient’s area code and prefix and exclusion until an age match was identified. Eating coriander (cilantro) at a restaurant was significantly associated with infection, as was eating fresh salsa. The investigators analysed the results based on ingredients in the salsa and the same ingredients eaten alone or in other dishes (raw tomato, raw onion and raw coriander); only fresh salsa and coriander were associated with infection after stratifying the survey population by age group. The investigators attempted trace back and were able to identify common distributors of coriander to Californian restaurants implicated in the outbreak, but poor record keeping hampered the identification of a single supplier or farm growing coriander (Campbell et al. 2001).

1.3.5 Basil

Thirty cases of cyclosporiasis (*Cyclospora cayetanensis*) were reported in British Columbia, Canada, between 1 January and 15 June 2001, sixteen of these cases reported no travel

history. A case-control study was conducted whereby a case was defined as a laboratory-confirmed case between 1 April and 15 June 2001 with no history of travel. Each case, or their physician, was asked to nominate an unrelated, age, ethnicity and gender matched control that had not shared a meal with the case, had no travel history and had not had symptoms of gastroenteritis. Twelve cases and 16 controls were interviewed about food and event exposures in the two weeks before onset of symptoms, specifically asking about raw produce and herbs popular with Vietnamese cuisine. On univariate analysis, both Thai basil and raw bean sprouts were associated with cyclosporiasis, but after conditional multiple logistic regression only Thai basil was significantly associated with being a case. The investigators traced the bean sprouts to multiple local sources and the Thai basil was imported from two distributors in the USA. Further trace back confirmed the Thai basil was grown in a single state but no data or documentation was available to trace further to the farm level or to determine if a single batch or multiple batches were contaminated. The investigation also attempted detection of oocysts on basil samples but was unsuccessful (Hoang et al. 2005).

1.3.6 Green onions

In November 2003, a large outbreak of hepatitis A was identified among patrons of a single restaurant in Pennsylvania, US. In total, 601 cases were identified and of these, three died and 124 were hospitalised. A case was defined as an acute illness consistent with hepatitis A with onset occurring between October 1 and December 1, 2003, having had consumed food at the implicated restaurant during the two to six weeks before the onset of illness and had a positive test for IgM antibody to HAV indicative of acute infection. A case-control study was undertaken to determine the food vehicle causing infection and cases and controls were asked about dishes eaten, with ingthe restaurant providing ingredient level details. Controls included meal companions of case-patients or persons who were identified through credit-card receipts as having dined at the implicated restaurant between 3 and 6 October 2003. Controls were excluded if they reported having had symptoms of acute hepatitis A, had a history of hepatitis A, or had received hepatitis A vaccine. In total 240 cases and 134 controls were recruited into the study, on univariate analysis five menu items and seven food ingredients were associated with illness. After multiple logistic regression analysis only mild salsa and green onions were associated with illness. Additional analysis showed that consumption of green onions in menu items other than mild salsa was independently associated with illness and there was a dose response detected.

Thirteen of the 69 restaurant employees were positive for IgM antibody to HAV and were symptomatic. Dates of onset were similar to patrons and all had worked and eaten at the implicated restaurant between 3 and 6 October; none reported a history of travel to a HAV endemic country. Molecular epidemiological studies demonstrated that the HAV isolates analysed from case-patients were similar (>96% homology) to isolates from residents or people recently returning from Mexico or isolates from cases from Hispanic communities of the US. A FDA trace back investigation found that two farms in northern Mexico were the source of green onions shipped to the implicated restaurant in late September and early October 2003 (Wheeler et al. 2005). The investigators concluded that the green onions responsible for this large outbreak were apparently contaminated before or during packing into shipping boxes on the implicated farms (Wheeler et al., 2005) but the evidence presented was somewhat circumstantial and this assertion could not be certain.

Green onions were also implicated as the food vehicle responsible for a smaller outbreak of hepatitis A in 1998 in the state of Ohio in the US. In total, 43 cases of hepatitis A were reported between 13 November and 4 December 1998 and all reported eating at a single restaurant. A case control study was undertaken to determine the food vehicle. A primary case was defined as a person with onset of illness between 13 November and 4 December 1998, in association with the presence of IgM antibody to HAV (anti-HAV) or an

epidemiologic link to a laboratory-confirmed case patient between 15 October and 31 November 1998. One to three controls per case were matched by date of eating at the implicated restaurant, either by being nominated by a case or selected from other healthy patrons who had eaten within one day of the case patient. Controls were excluded if they reported a history of hepatitis A, were vaccinated against HAV, had received immunoglobulin in the 3 months before the outbreak or had symptoms of hepatitis A in the preceding 4-6 weeks. Forty cases and 64 controls were included in the study and no menu items were significantly associated with illness.

As with the study described above, a sub-analysis on individual ingredients found green onions, diced tomato, cheese and honey mustard sauce were significantly associated with illness. When the data were stratified by containing green onion, only items that contained green onions were associated with illness. Samples taken from all staff employed at the time of the outbreak (91) and 21 previous staff were negative for IgM antibody to HAV. Molecular epidemiological studies found the restaurant outbreak isolates similar to two cases suspected to have been acquired in Mexico and were genetically distinct from sporadic case isolates from Ohio or other US isolates with no link to Mexico (Dentinger et al. 2001). The investigators concluded the contamination occurred before delivery to the restaurant based on the evidence described and that only a single ingredient was associated with illness. If the contamination occurred in the restaurant, they then assumed more than one food item was associated with illness (Dentinger et al., 2001).

1.3.7 Raspberries

The CDC reported that approximately 850 cases of laboratory confirmed *Cyclospora cayetanensis* infection had been reported during May and June 1996 (CDC 1996a). A retrospective cohort study of an outbreak in persons who had attended a luncheon in South Carolina was undertaken to determine the food vehicle responsible. All 64 luncheon attendees and the chef were interviewed regarding food and beverage exposures and a case was defined as greater than, or equal to, three loose stools per day or greater than, or equal to, two loose stools if using anti-motility drugs after attending the luncheon. *Cyclospora* oocysts were detected in 11 of 13 faecal samples submitted for laboratory testing. In total, 38 case patients were identified and fresh raspberries, strawberries and potato salad were all associated with illness on univariate analysis. After controlling for exposure to raspberries, strawberries were no longer significantly associated with infection, whereas the risk of illness associated with potato salad diminished but remained significant.

The population attributable risk for exposures to raspberries, strawberries and potato salad were 73%, 50% and 20%, respectively, and the investigators concluded raspberries were the source of infection. After interviewing the chef regarding food preparation, the raspberries, strawberries and potato salad were all prepared on the same counter within a two hour period; the potato salad was reportedly prepared first and the raspberries and strawberries were washed in the same strainer as the potatoes. Cross handling of finished dishes for tasting was also reported (CDC 1996b; Caceres et al. 1998). Strawberries from the same source as served at the outbreak luncheon were served to another luncheon in an adjacent room and no cases were reported from the second luncheon (CDC, 1996b). The implicated raspberries were traced to Guatemala (Caceres et al., 1998). Investigations in other states also implicated raspberries as a vehicle of infection (CDC, 1996a; CDC, 1996b).

1.3.8 Strawberries

In February and March 1997, a multistate outbreak of hepatitis A affected 213 children from 23 schools in Michigan and 29 cases from 13 schools in Maine, US. Genetic analysis of HAV isolates recovered from patients in Michigan were all identical and 8/10 isolates recovered from patients in Maine were identical to the Michigan outbreak strain, indicating a single

source of infection. Cases and controls were recruited for enrolment in multiple case control studies, whereby cases were defined as acute illness with clinical symptoms compatible with the disease in association with IgM antibody to HAV. Controls were recruited from healthy class mates or staff from affected schools.

In Michigan, two independent investigations were conducted in Saginaw and Calhoun Counties and in Maine, two studies were reported. In the Michigan studies, thawed frozen strawberries were served as a component of strawberry shortcake and this menu item was the only item significantly associated with illness. In Maine, thawed frozen strawberries were served as a component of the strawberry shortcake and also served in a cup. Menu items containing strawberries were the only items significantly associated with illness in Maine. Trace back investigations determined that the strawberries implicated in this multistate outbreak were grown in Mexico, processed and frozen in California and distributed through the Department of Agriculture for school lunch programs. Investigations at the processing plant found that strawberries were carried on a conveyor belt, washed in a chlorine solution of 12 parts per million, mechanically sliced, combined with a sucrose solution, packed, and frozen. Hand contact was limited to the rejection of unacceptable berries as they passed on the conveyor belt. Investigations of three of four growing fields in Mexico found river water filtered through sand was used for drip irrigation, however poor quality sanitation facilities were provided and pickers did not wear gloves and picked off stems with their finger nails (Hutin et al., 1999).

1.3.9 Rockmelon

Three multistate outbreaks of *Salmonella* Poona occurred in the US in the spring of consecutive years during 2000-2002. Forty seven confirmed cases from six states with indistinguishable PFGE patterns occurred during April and June 2000. A matched case control study was undertaken an identified the food vehicle, 20 cases, defined as laboratory confirmed *S.* Poona with the outbreak PFGE pattern in April to June, were matched by age category to healthy community controls and only consumption of rockmelon was significantly associated with infection after multivariable modelling. Fifty confirmed cases of *Salmonella* Poona (H_2S-negative) from five states occurred during April to May 2001. A matched case control study including 11 case patients with laboratory confirmed H_2S-negative Salmonella Poona infection and 19 age matched community controls found that illness was only associated with consumption of rockmelon. Fifty-eight confirmed cases of *Salmonella* Poona infection from 10 states in the US and four states in Canada with indistinguishable PFGE patterns occurred during March to May 2002. The PFGE pattern in the 2002 outbreak was indistinguishable from the outbreak strain identified in 2000. A matched case control study of 27 case patients with laboratory confirmed infection were matched by age to 54 healthy community controls and illness was only significantly associated with consumption of rockmelon. In all outbreaks either whole or pre-cut melon was associated with illness. In each outbreak, trace back investigations identified rockmelon imported from farms in Mexico as the source of infection. The FDA conducted on-farm investigations and for the farms associated with the 2000 and 2001 outbreaks multiple problems were encountered through the entire supply chain and concluded that measures were not in place to minimise microbial contamination in the growing, harvesting and processing of rockmelon (CDC 2002).

Rockmelons were also implicated epidemiologically in an outbreak of *Salmonella* Saphra in the spring of 1997. Twenty-five residents of California, US, were confirmed to be infected with *S*. Saphra during February and May 1997 and 24 patient isolates had an identical PFGE pattern that was distinct from case isolates reported in California in previous years. Eighteen case patients were age matched to healthy community controls and only consumption of rockmelon (purchased whole or pre-cut) was significantly associated with illness. Trace back investigations identified a single distributor who supplied rockmelon to restaurants and grocery stores where the implicated rockmelon was purchased; the sole source of

rockmelons for this distributor was a packer in Mexico.

1.3.10 Mango

In December 1999, a cluster of cases of *Salmonella* Newport from 13 states in the US were detected. The PFGE patterns of the cluster isolates were indistinguishable and a case-control investigation was conducted to determine the food vehicle responsible for the outbreak. Case patients, defined as diarrhoea with onset in November or December 1999 for which a stool culture yielded *S*. Newport with the outbreak PFGE pattern, self-nominated healthy controls who were age and ethnicity matched but did not share a meal. In total, 28 case patients and 42 controls were interviewed regarding food exposures in the five days prior to onset of symptoms and in a matched analysis only consumption of mangoes was significantly associated with illness.

The investigators undertook trace back investigations based on information provided by four cases from three states. From this information, no common store, distributor, importer or shipment could be identified, however, the investigators determined that a single farm in Brazil supplied mangoes to all four venues (Sivapalasingam et al., 2003), even though the details of how this trace was arrived at were not presented. Environmental investigations on the implicated Brazilian farm revealed several problems in the packing and processing of mangoes. The first mango wash water tank was not monitored for chlorine level even though it was supposedly chlorinated at a concentration of 100mg/L and was only changed when it became grossly turbid. Mangoes destined for the US market underwent hot water treatment to kill fruit fly and then dunked into a cool water tank before drying and packing. Furthermore, all processing tanks were unenclosed and faecal material from birds and other wildlife were noted near the tanks. Simulation studies conducted after this investigation demonstrated that *Salmonella* spp. was internalised by the hot and cool treatment (Sivapalasingam et al., 2003).

1.3.11 Mamey

An outbreak of typhoid fever (*Salmonella* Typhi) in Florida, US, involving at least 16 persons during the winter of 1998-1999 was investigated. A case was defined as a febrile illness with a stool, blood or urine sample culture positive for *S*. Typhi. Fifteen confirmed cases were identified and preliminary studies using a standard typhoid fever questionnaire did not identify a common source of infection. In unstructured interviews three case subjects mentioned consumption of frozen mamey drinks and a structured case-control study was designed to investigate fruit and beverage exposures. Controls were matched to confirmed and probable cases by age and ethnicity and the final analysis included one probable and nine confirmed cases and 39 matched controls. Illness was significantly associated with consumption of frozen mamey purchased from a vendor rather than mamey consumed at home. Trace back investigations determined that the implicated frozen mamey was imported from either Guatemala or Honduras. No *S*. Typhi was detected in tested food samples but faecal coliforms and *E. coli* were detected in a high proportion of samples tested. Inspection of two processing plants in Guatemala found that at one plant, untreated water from a shallow hand-dug well was used to wash the fruit; at the second plant chlorinated well water from a deep community well was used to wash fruit. Both processing plants had poor quality record keeping the plant using the shallow well eventually closed rather than upgrading (Katz et al., 2002).

Table A3.1 *Summary of outbreaks associated with fresh and minimally processed produce stratified by commodity, pathogen and outcomes*

Commodity	Pathogen	Year	Location/s	Implicated commodity country of origin	Outbreak size, cases	Epi comments[2]	Supply chain failure[3]	References
Lettuce	*E. coli*	2005	Sweden	Domestic	135	E, L	Outbreak strain traced to cattle up-stream of implicated lettuce farm. Irrigation stream heavily contaminated with enteric bacteria. Stx 2 detected by PCR in irrigation inlet and on farm.	(Soderstrom et al., 2008)
	E. coli	1996	USA	Domestic	61	E	Trace back investigations identified a single farm enterprise. On farm processing were unsanitary and non-O157:H7 *E. coli* were isolated from wash tanks.	(Hilborn et al., 1999)
	E. coli	1995	USA	Domestic	>70	E	n.d.	(Ackers et al., 1998)
	Salmonella	2004	UK	n.d.[1]	105	E	n.d.	(Irvine et al. 2009)
	Shigella	1994	Norway	Imported	110	E	n.d.	(Kapperud et al., 1995)

Commodity	Pathogen	Year	Location/s	Implicated commodity country of origin	Outbreak size, cases	Epi comments[2]	Supply chain failure[3]	References
	Shigella	1994	UK	n.d.	432	E	n.d.	(Frost et al., 1995)
	Yersinia	1998	Finland	Domestic	47	E	n.d.	(Nuorti et al., 2004)
	Norovirus	2010	Denmark	Imported	185	(E), L	n.d.	(Ethelberg et al. 2010)
Semi-dried tomato	Hepatitis A	2009	Australia	Imported	>500	E, L	n.d.	(OzFoodNet 2010b; OzFoodNet 2010c; Donnan et al., 2011)
	Hepatitis A	2010	Netherlands	Imported	13	E	n.d.	(Petrignani,M et al., 2010a; Petrignani,M et al., 2010b)
	Hepatitis A	2010	France	Imported	59	E	n.d.	(Gallot et al., 2011)
Fresh tomato	*Salmonella*	2005	USA	Domestic	72	E, L	Outbreak strain traced to irrigation pond water in 2005; one farm in the implicated region used pond water for pesticide application in 2006.	(Greene et al., 2008)
	Shigella	2001	USA	Domestic	886	E	n.d., but overripe and bruised 'special grade' tomatoes supplied to restaurants immediately prior to outbreak.	(Reller et al., 2006)
Chilli peppers,	*Salmonella*	2008	USA	Imported	1500	E, L	Outbreak strain detected	(CDC, 2008; Mody et al.,

Commodity	Pathogen	Year	Location/s	Implicated commodity country of origin	Outbreak size, cases	Epi comments[2]	Supply chain failure[3]	References
(Tomato?)							in irrigation on implicated farm in Mexico but source of contamination not determined	2011; Behravesh et al., 2011)
Baby corn	*Shigella*	2007	Denmark	Imported	215	E	Implicated corn in Denmark and Australia imported from Thailand and traced to same packing shed. Poor hygienic practice during de-silking process implicated as source of contamination.	(Lewis et al., 2009)
	Shigella		Australia	Imported	55	E	As above	(OzFoodNet, 2008; Lewis et al., 2009)
Peas	*Campylobacter*	2008	USA	Domestic	132	E, L	Outbreak epidemiologically linked to peas, trace back and microbiological analysis identified outbreak strains on peas and in	(Gardner et al., 2011)

Commodity	Pathogen	Year	Location/s	Implicated commodity country of origin	Outbreak size, cases	Epi comments[2]	Supply chain failure[3]	References
							Sandhill cranes that grazed and defecated on pea fields.	
	Shigella	2009	Norway	Imported	20	E, L	n.d.	(Heier et al., 2009)
Spinach	*E. coli*	2006	USA	Domestic	199	E, L	Outbreak strain identified on spinach and from stream, cattle manure and wild pigs in production area. Exact cause of product contamination not determined.	(CDC, 2006; Jay et al., 2007; Grant et al., 2008; Wendel et al., 2009)
Carrots	*Yersinia*	2006	Finland	Domestic	>400	E, L	Carrots stored for 6 months on implicated farm and 4 months in distributors storage facility and were of poor quality. Outbreak strain was identified from carrot residue and surfaces at distributor's facility.	(Rimhanen-Finne et al., 2009)

Commodity	Pathogen	Year	Location/s	Implicated commodity country of origin	Outbreak size, cases	Epi comments[2]	Supply chain failure[3]	References
	Yersinia	2004	Finland	Domestic	53	E, L	Outbreak strain identified on carrot peeling line, from spoiled carrots, from fluid from spoiled carrots and from a common shrew on implicated farm. Shrew possibly picked up by harvesting equipment.	(Kangas et al., 2008)
	Yersinia	2003	Finland	Domestic	111	E, L	Outbreak strain identified on farm processor plant from soil and carrot residue samples; carrots were stored in open bins accessible to storage rodents. Carrots from implicated farm were washed and peeled by a distributor subsequently delivered and grated	(Jalava et al., 2006)

Commodity	Pathogen	Year	Location/s	Implicated commodity country of origin	Outbreak size, cases	Epi comments[2]	Supply chain failure[3]	References
							without further washing steps.	
Coriander	*Salmonella*	1999	USA	Domestic	76	E	n.d	(Campbell et al., 2001)
Basil	*Cyclospora*	2001	Canada	Imported	33	E	n.d.	(Hoang et al., 2005)
	Salmonella	2007	UK	Imported	55	E, L	n.d.	(Pezzoli et al., 2007; Pezzoli et al., 2008; Elviss et al., 2009)
Green onions	Hepatitis A	2003	USA	Imported	601	E	n.d.	(CDC 2003; Wheeler et al., 2005)
	Hepatitis A	1998	USA	n.d.	43	E	n.d.	(Dentinger et al., 2001)
Raspberries	*Cyclospora*	2000	USA	Imported	54	E, L	n.d.	(Ho et al., 2002)
	Cyclospora	1996	USA	Imported	38	E	n.d.	(CDC, 1996a; CDC, 1996b; Caceres et al., 1998)
	Norovirus	2009	Finland	Imported	76	E, L	n.d.	(Maunula et al., 2009)
	Norovirus	2009	Finland	Imported	>260	E, L	n.d.	(Sarvikivi et al., 2011)
Strawberries	*E. coli*	2011	USA	Domestic	17	E, L	Outbreak strain linked to deer faeces on implicated strawberry farm.	(Anonymous, 2011a; Anonymous, 2011b)
	Hepatitis A	1997	USA	Imported	242	E	n.d., inadequate on farm sanitation facilities	(Hutin et al., 1999)

Commodity	Pathogen	Year	Location/s	Implicated commodity country of origin	Outbreak size, cases	Epi comments[2]	Supply chain failure[3]	References
							suspected.	
Rockmelon	*Listeria*	2011	USA	Domestic	100	E, L	n.d.	(CDC, 2011; Anonymous 2011d; Anonymous 2011e)
	Listeria	2010	Australia	Domestic	9	E, L	n.d.	(OzFoodNet, 2010a; Astridge, 2011)
	Salmonella	2006	Australia	Domestic	115	E, L	Inconclusive; use of non-potable water in processing ready-to-eat melons likely failure point.	(Munnoch et al., 2009)
	Salmonella	2000	USA	Imported	47	E	Multiple problems found along the entire supply chain on Mexican farms and pack houses.	(CDC, 2002)
	Salmonella	2001	USA	Imported	50	E	As above	(CDC, 2002)
	Salmonella	2002	USA	Imported	58	E	As above	(CDC, 2002)
	Salmonella	1997	USA	Imported	25	E	n.d.	(Mohle-Boetani et al. 1999)
Mango	*Salmonella*	2006	USA	Imported	494	E	n.d.; possibly linked to internalisation of *Salmonella* during hot water treatment to	(Sivapalasingam et al., 2003)

Commodity	Pathogen	Year	Location/s	Implicated commodity country of origin	Outbreak size, cases	Epi comments[2]	Supply chain failure[3]	References
							control fruit fly.	
Papaya	*Salmonella*	2006	Australia	Domestic	26	E, L	Inconclusive; use of non-potable river water to wash fruit was the likely failure point.	(Gibbs et al., 2009)
Mamey	*Salmonella*	1999	USA	Imported	16	E	Inconclusive; possibly linked to untreated water sourced from a shallow well	(Katz et al., 2002)

[1] n.d., not determined; [2] E, epidemiological study; L, laboratory confirmed link between outbreak strain and implicated commodity or farm;

Table A3.2 *Production and processing failure points implicated in commodity contamination and mitigation activities to prevent contamination*

Production and processing failure	Commodity	Pathogen	Control measure to mitigate contamination
Water contaminated with animal faeces used for irrigation and/or chemical application	Lettuce	*E. coli* O157	• Water used for pre-harvest activities managed to avoid contamination from human activities, livestock production activities, domestic animals and wildlife • Equipment used to apply water onto produce is maintained to a suitable standard to prevent contamination of pre-harvest water • Personnel involved in production, harvest and post-harvest activities be sufficiently knowledgeable to take actions, where necessary, to minimise or prevent produce contamination
Water contaminated with wildlife faeces used for irrigation and/or chemical application	Tomato	*Salmonella* Newport	
Contaminated water used for irrigation and/or chemical application	Chilli peppers and tomato	*Salmonella* Saintpaul	
Contaminated water used for washing produce. Unsanitary processing facility	Lettuce	*E. coli* O157:H7	• Water used for post-harvest activities is of potable quality • Facilities constructed and maintained in such a way as to minimise or prevent produce contamination • Equipment used during production and processing fresh produce be maintained in good working order and regularly cleaned to prevent contamination of produce • Personnel involved in production, harvest and post-harvest activities be sufficiently knowledgeable to take actions, where necessary, to minimise or prevent produce contamination
Contaminated water used for washing produce and incorrect use of disinfectants	Rockmelon	*Salmonella* Saintpaul	
Contaminated water used for washing produce and incorrect use of disinfectants	Papaya	*Salmonella* Litchfield	
Contaminated water used for washing produce	Mango	*Salmonella* Newport	
Contaminated water used for washing produce	Mamey	*Salmonella* Typhi	
Direct faecal deposition in the field (cranes)	Peas	*Campylobacter jejuni*	• Exclusion of domestic animals and wildlife from growing, packing and storage areas • Produce grown away from bird roosting and migration areas • Pests controlled in growing, packing and storage areas
Direct faecal deposition in the field (feral pigs)	Spinach	*E. coli* O157:H7	

Production and processing failure	Commodity	Pathogen	Control measure to mitigate contamination
Direct faecal deposition in the field (deer) Post-harvest storage and handling. Processing poor quality produce	Strawberries Carrots	*E. coli* O157 *Yersinia pseudotuberculosis*	• Personnel involved in production, harvest and post-harvest activities be sufficiently knowledgeable to take actions, where necessary, to minimise or prevent produce contamination • Exclusion of domestic animals and wildlife from growing, packing and storage areas • Pests controlled in growing, packing and storage areas • Disposal of poor quality produce • Facilities constructed and maintained in such a way as to minimise or prevent produce contamination • Equipment used during production and processing fresh produce be maintained in good working order and regularly cleaned to prevent contamination of produce • Personnel involved in production, harvest and post-harvest activities be sufficiently knowledgeable to take actions, where necessary, to minimise or prevent produce contamination
Poor quality fruit	Tomato	*Shigella flexneri*	• Dispose of damaged fruit that may enable internalisation and growth of pathogen • Personnel involved in production, harvest and post-harvest activities be sufficiently knowledgeable to take actions, where necessary, to minimise or prevent produce contamination
Poor hygienic practice and unsanitary processing facility Poor hygienic practice and unsanitary harvest and processing practices Widespread contamination of processing facility	Baby corn Raspberries Rockmelon	*Shigella sonnei* Hepatitis A virus *Listeria monocytogenes*	• Water used for post-harvest activities is of potable quality • Facilities constructed and maintained in such a way as to minimise or prevent produce contamination • Equipment used during production and processing fresh produce be maintained in good working order and regularly cleaned to prevent contamination of produce • Toilet and washing facilities maintained in good working order and sufficient to meet the demands of the labour force employed to harvest, pack and

Production and processing failure	Commodity	Pathogen	Control measure to mitigate contamination
			transport produce • Personnel involved in production, harvest and post-harvest activities are sufficiently knowledgeable to take actions, where necessary, to minimise or prevent produce contamination.

2 Search strategy

2.1 Search string

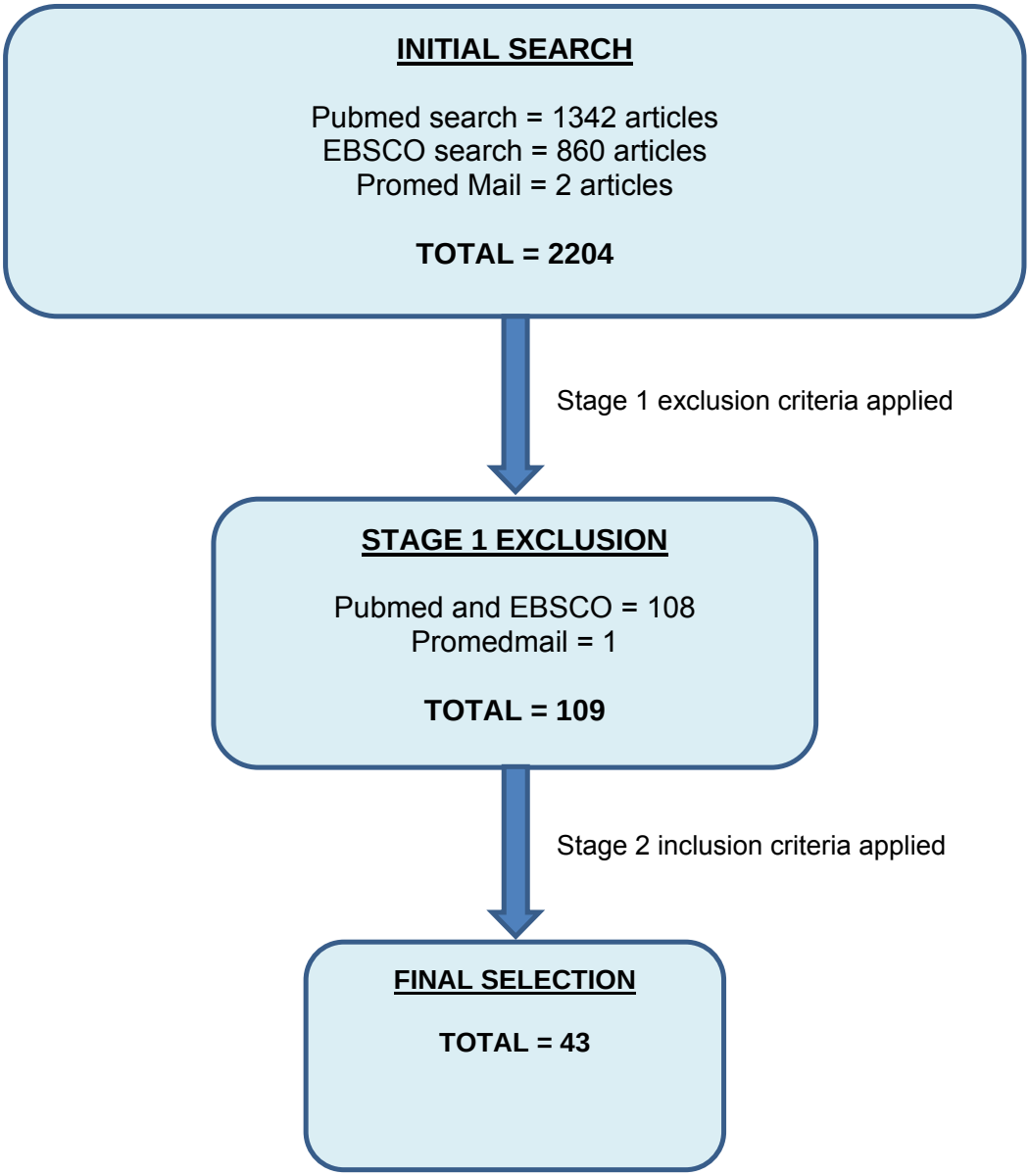
Pathogen list	AND	Commodity list		AND	Outcome list
Escherichia coli		Leafy	Cucumber		Food-borne
“E coli”		Vegetable	“Fresh produce”		Foodborne
“E. coli”		Lettuce	Herb		Outbreak*
Salmonella		Spinach	Herbs		“Risk factor*”
Salmonellosis		Scallion	Basil		“Case control”
Listeria		Shallot	Mint		Case
Listeriosis		Spring onion	Oregano		Investigation*
monocytogenes		Rocket	Cilantro		
Campylobacter		Arugula	Coriander		
Campylobacteriosis		Cabbage	Parsley		
Clostridium		Watercress	Marjoram		
Clostridia		Tomato*	Cress		
Clostridial		Capsicum	Dill		
Bacillus cereus		Jalapeno	Kale		
Staphylococcus		Pepper*	Mushroom		
Staphylococcal		Chilli*	Microgreen*		
aureus		Fruit	Shoot*		
Shigella		Berry	Pea		
Shigellosis		Berries	Peas		
Yersinia		Raspberry			
enterocolitica		Raspberries			
Vibrio		Strawberry			
Cyclospora		Strawberries			
Cyclosporiasis		Blueberry			
Giardia		Blueberries			
Giardiasis		Melon*			
Cryptosporidium		Honeydew			
Cryptosporidiosis		Rockmelon			
Cryptosporidiasis		Cantaloupe			
“Hepatitis A virus”		Sugar melon			
“Hepatitis A”		Watermelon			
HAV		Muskmelon			
Hepatitis		Mango*			
Norovirus		Papaya*			
norwalk		Paw paw*			

Search terms were combined in the following format:
(pathogen1 OR pathogen2 OR …) AND (commodity1 OR commodity2 OR …) AND (outcome1 OR outcome2 OR…)

2.2 Search engines

i. Pubmed (http://www.pubmed.org)
   Simple search with date limits (01/01/1990 – 31/12/2011)
ii. EBSCO (Food Science Source; FSTA – Food Science and Technology Abstracts; Medline; Medline with Full text)
   Boolean phrase simple search
   Limiter: 1990-2011; Peer reviewed
   Source type: Periodicals
iii. Promedmail (www.promedmail.com)
   Postings of outbreaks with data satisfying the inclusion criteria

3 Inclusion and exclusion criteria



Stage 1 exclusion criteria

- Exclusion of duplicates
- Exclusion of prevalence studies
- Exclusion of experimental contamination studies
- Exclusion of outbreaks associated with multiple commodity, e.g. chicken pasta salad
- Exclusion of reviews
- Exclusion of outbreaks if an infected handler contaminated finished dish during preparation
- Exclusion of non-English language studies

Stage 2 inclusion criteria

- Inclusion of epidemiological studies if:
    - Case definition provided
    - Odds Ratio/Risk Ratio > 1, *P*-value < 0.05 and Attack Rate > 50%
    - Modelling methods were described
    - Number of cases and controls reported
    - For case control studies, controls were matched to cases
- Inclusion of microbiological studies if case pathogen was laboratory matched to isolates from fresh produce
- Inclusion of microbiological trace back studies if environmental or animal isolates matched case pathogen plus a microbiological or epidemiological link to a fresh produce commodity