DISCUSSION DOCUMENT ON PATHOGENS IN FRUITS AND VEGETABLES IN NEW ZEALAND

FINAL REPORT

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by

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SUMMARY

Consumption of fresh produce is a growing area of concern in terms of food safety. An increasing number of outbreaks of foodborne illness are being reported throughout the world attributed largely to the increasing use of produce from growing areas with poor water and fertiliser quality, and/or a lack of effective decontamination measures. In addition, an increasing consumption of raw, minimally processed produce which has been packaged and transported/stored over long distances/times has been observed both overseas and more recently in New Zealand. This discussion document was therefore undertaken to review available information to provide a preliminary guide as to possible risks in New Zealand associated with ready-to-eat (RTE) intact and fresh cut vegetables and fruits, fresh (unpasteurised) juices and sprouts to facilitate risk-based management decisions regarding the production, sale and consumption of safe produce in New Zealand.

While a vast array of pathogens can become associated with fruits and vegetables due to the nature of production, *Salmonella* spp. and *E. coli* O157:H7, and to a lesser extent protozoa and viruses, predominate in international literature. However, the lower prevalence of *E. coli* O157:H7 in New Zealand environments suggests that this pathogen is not of significant concern in domestic produce, and has not been found in limited domestic surveys of both conventional and organic produce to date. Regardless, the potential clearly exists for pathogen contamination to occur at a number of points during production, harvest, processing, distribution and sale. Viruses and other bacterial pathogens such as *Shigella* may occur in produce as a result of cross-contamination and poor food handling practices.

In terms of production practices that potentially contribute pathogens, contaminated irrigation water and improperly treated manures continue to dominate internationally, and both are recognised as hazards by the New Zealand Good Agricultural Practices (GAP) Programme. However, a standard does not currently exist regarding water quality. Organic certification programmes operate under a Compost Production Standard but the water requirements listed do not consider microbiological hazards.

Particular produce items have dominated the food safety literature. Green leafy vegetables, such as spinach and lettuce, have been especially prominent, mainly due to the ease with which they can become contaminated in the growing environment. Melons, tomatoes and raw berry fruits are also commodities susceptible to contamination with bacteria, protozoa and viruses, either via production or harvesting. Unpasteurised fruit juices, previously considered safe due to their acidic nature, have caused numerous outbreaks despite their inability to support the growth of bacterial pathogens. The production of sprouted seeds, on the other hand, can facilitate the rapid proliferation of pathogens originating from either the contaminated seed or irrigation water. Adherence to process controls is therefore particularly important for this product type.

Despite the obvious potential for produce-related food safety issues, only one confirmed outbreak – Hepatitis A in raw blueberries – has been documented in New Zealand. However, an additional outbreak of *Salmonella* Saintpaul was tentatively linked to the use of contaminated wash water, and a further VTEC outbreak investigation revealed the presence of *E. coli* O157 in stream water being used as a source of farm-level wash water. These outbreaks suggest failures in good agricultural practices, either as a consequence of

poor hygiene or the possible use of contaminated wash water. While both these aspects are addressed by the New Zealand GAP programme, they are acknowledged to be difficult to control and therefore areas of concern. In light of the information above, irrigation and processing water would therefore appear to be an area where additional risk management strategies may be particularly useful. Current underreporting, in combination with an anticipated increase in production and consumption of convenient RTE produce, may see additional incidents, perhaps outbreaks, in this country in the future. The contributions of organic production practices and the use of migrant workers to food safety risks from produce are unknown.

Based on the limited industry information gathered for this document, process controls (based on GAP and food safety programmes) have been put into place for production and processing of RTE produce by the larger produce companies. In New Zealand, the safety of domestic produce available on the retail market is likely to be enhanced by the fact that only a small number of companies do the majority of processing. Chlorine washing is the predominant decontamination method of choice, mainly for reasons of practicality and cost. However, the limited effectiveness and potential safety issues associated with the use of chlorine may see producers adopting alternatives such as ozone and iodine. This also serves to re-emphasise the need to focus food safety efforts at the farm level to minimise exposure to contamination prior to further processing and handling.

At the retail level, information is lacking on produce handling, processing operations (e.g. chopping and juicing) and temperature control in supermarkets, juice bars and other outlets, which may represent a potential concern, particularly where imported produce items of uncertain quality may be handled.

Given the breadth of this subject area, numerous data gaps need to be filled before a sensible assessment of the risk posed by pathogens in fruits and vegetables can be undertaken. A better description of the grower, processor and retail sectors in New Zealand needs to be assembled first in order to locate practices or specific products for further risk assessment.

1 INTRODUCTION

This document is intended to collate and review information on pathogens in fruits and vegetables in New Zealand. It has been written as part of a project conducted by ESR for the NZFSA, which also contracts the development of Risk Profiles. Risk Profiles consider a single food/hazard combination. The remit of this document is much broader, but for consistency the general structure of a Risk Profile has been adopted.

The sections are organised as much as possible as they would be for a conventional qualitative risk assessment, as defined by Codex (1999).

Hazard identification, including:

- A description of the organisms
- A description of the foods

Hazard characterisation, including:

- A description of the adverse health effects caused by the organisms.

Exposure assessment, including:

- Data on the consumption of the foods by New Zealanders.
- Data on the occurrence of the hazards in the New Zealand food supply.

Risk characterisation:

- Information on the number of cases of adverse health effects resulting from exposure to the organisms with particular reference to the food (based on surveillance data).

Risk management information:

- A description of the food industry sector, and relevant food safety controls.

Conclusions and recommendations for further action

1.1 Scope of the Current Study

Consumption of fresh produce is a growing area of concern in terms of food safety due to an increasing number of outbreaks of foodborne illness being reported throughout the world. Larger numbers of outbreaks occurring overseas have been attributed to the increasing use of produce from growing areas with poor water and fertiliser quality, and/or a lack of effective decontamination measures. In addition, an increasing consumption of raw, minimally processed produce which has been packaged and transported/stored over long distances/times has been observed both overseas and more recently in New Zealand.

It is difficult (and dangerous) to pick particular commodities as more likely infection vehicles than others given that contamination of produce can occur throughout the food chain, from growth, harvesting and processing, through to retail and consumer storage and handling. However, outbreaks associated with produce items such as lettuce, spinach, carrots (fresh cut and juiced), fruits (whole, fresh cut and juiced) and sprouted seeds have been more frequently documented than others.

This discussion document will therefore review available information to assess the risks in New Zealand associated with ready-to-eat (RTE) intact and fresh cut vegetables and fruits, fresh juices and sprouts. The purpose is to facilitate risk-based management decisions regarding the production, sale and consumption of safe produce in New Zealand. Organic and hydroponically grown vegetables and fresh herbs will also be considered, along with the role of nuts and other salad 'additives'. It will not address commodities such as grasses, dried herbs and spices, or those requiring cooking prior to consumption (e.g. potatoes and other similar root vegetables).

1.2 Objectives of the Current Study

Objectives agreed during discussions regarding the scope of this document in November 2006 are as follows:

- To collate and review previous NZFSA-commissioned work in this area including discussion of industry codes of practice and other information as deemed appropriate.
- To review the hazards associated with fresh vegetables and fruits in terms of their prevalence in New Zealand produce (suggestive overseas data will be consulted where domestic prevalence information is lacking)
- To comment on relative exposure of consumers to pathogens in vegetables and fruits via consumption information derived from the National Nutrition Survey (NNS) and Child Nutrition Survey (CNS), and on relative risk if able to be deduced.
- To assess and discuss qualitative relative risks associated with the consumption of fresh fruits and vegetables in conjunction with current risk management practices including industry codes of practice
- To identify data gaps.

Lists of relevant New Zealand-specific and internationally derived information gathered to date are shown below. These reports, and others, can be accessed via the NZFSA website at: http://www.nzfsa.govt.nz/science/research-projects/produce-safety/index.htm or http://www.nzfsa.govt.nz/science/risk-profiles/index.htm.

New Zealand-specific information (including previous NZFSA-commissioned work):

- Lake, R., Gilbert, S., Hudson, J.A. & Cressey, P. (2008). Risk Profile: *Toxoplasma gondii* in red meat and meat products ESR Client Report FW06106.
- Gilbert, S., Lake, R., Hudson, J.A. & Cressey, P. (2006). Risk Profile: Shiga-Toxin Producing Escherichia coli in Leafy Vegetables. ESR Client Report FW00456.
- Lake, R., Hudson, J.A., Cressey, P. & Gilbert, S. (2005). Risk Profile: *Listeria monocytogenes* in Ready-to-Eat Salads. ESR Client Report FW0446.
- Turner, N., Cressey, P., Whyte, R. & Lake, R. (2004). Review of non-commercial wild food in New Zealand. ESR Client Report FW0482.

- Wong, T. (2003). Levels of *Escherichia coli* O157:H7 in lettuces and *Salmonella* in apples. ESR Client Report FMA128.
- Hudson, J.A. & Turner, N. (2002). Risks Associated with Bacterial Pathogens in Exported Fruits and Vegetables. ESR Client Report FW0280.
- Graham, C.F. & Dawson, C. (2002). A Survey of Hydroponically Grown Vegetables in New Zealand. New Zealand Journal of Environmental Health, June 2002.
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- Faulkner, L. *et al.* (2001). Generic HACCP Models for Food Assurance programmes (operational research contract FMA 169). Interim Report. Prepared by AgriQuality New Zealand.
- Walker, S. & Faulkner, L. (2001a). Generic HACCP Models for Food Assurance programmes (operational research contract FMA 169). Implementation Guide. Prepared by AgriQuality New Zealand.
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- Graham, C.F. (2000). Validation of Testing Spent Irrigation Water for Pathogens During the Sprouting Process (Client Report FW00136).
- Graham, C.F. (1999). Food Safety and Hydroponically Cultivated Vegetables (Client Report FW9939).
- New Zealand GAP Approved Suppliers Programme (http://www.newzealandgap.co.nz/index.html).

<u>Internationally derived information</u>:

- CFSAN/FDA (2007). Guide to Minimize Microbial Food Safety Hazards of Fresh-Cut Fruits and Vegetables (Draft Final Guidance).
- Codex Committee on Food Hygiene (2003). Code of Hygienic Practice for Fresh Fruits and Vegetables (CAC/RCP 53 – 2003).
- European Commission (2002). Scientific Committee on Food. Risk Profile on the Microbiological Contamination of Fruits and Vegetables Eaten Raw (SCF/CS/FMH/SURF/Final).

2 HAZARD IDENTIFICATION: THE ORGANISMS

Comprehensive literature reviews (both from New Zealand and overseas) have identified a wide range of pathogens of concern in vegetables and fruits. However, these vary in terms of significance depending on where in the food chain contamination arises, and how the produce item is stored prior to consumption. Nonetheless, given the nature and complexity of contamination, few can be discounted from a New Zealand-based review with the possible exception of *Vibrio cholerae* which has been previously identified as a hazard in overseas reviews (ICMSF, 1998; European Commission, 2002) but is not considered a risk in New Zealand. Based on domestic and international information, and the association of particular pathogens with a variety of contamination sources, a list of relevant bacterial, protozoan and viral pathogens has been compiled (Table 1) for further consideration in this discussion document.

Table 1: Microbial pathogens of potential concern in fresh vegetables and fruits

Bacteria	Parasites	Viruses
Aeromonas spp.	*Cryptosporidium parvum*	Hepatitis A
Bacillus cereus	*Giardia lamblia*	Noroviruses
Campylobacter spp.	*Cyclospora cayetanensis*	Rotavirus
Clostridium botulinum	*Toxoplasma gondii*	
Clostridium perfringens		
Escherichia coli O157:H7		
Listeria monocytogenes		
Salmonella spp.		
Shigella spp.		
Staphylococcus aureus		
Yersinia spp.		

The initial microflora of vegetables and fruits is acquired from their interaction with soil, air, water, wildlife and insects, and can include pathogens (ICMSF, 1998; Beuchat, 2006). The types, levels and frequency of contamination are highly variable due to the nature of production but it is generally recognised that pathogenic bacteria, protozoa and viruses can all contribute to the microflora of a particular produce item at many points in the food chain. Given the sporadic nature of contamination, and the lack of sufficiently sensitive detection methodologies for certain pathogens, the value of prevalence testing and routine monitoring is generally regarded as limited (Zhao, 2005). However, it can be useful where follow-up targeted quantitative surveys are undertaken on produce where prevalence is considered significant from a risk perspective.

At the grower level, irrigation waters and fertilisers of animal origin have been identified as particularly important sources of pathogens, including protozoa and viruses (ICMSF, 1998; Steele & Odumeru, 2003; Islam *et* al., 2004; Gerba & Smith, Jr., 2005; Warriner, 2005; Beuchat, 2006; Chaidez *et al*., 2005). The introduction of pathogens into soils via these agricultural inputs can result in both environmental persistence and contamination of produce growing in such environments. The type of irrigation application (Steele & Odumeru, 2004) and the level of contamination also impacts on contamination levels. A number of groups have investigated these issues, mainly by the use of field studies, and such data have allowed the development of risk models to predict outcomes.

Islam *et al.* (2004) reported that *Salmonella* Typhimurium was recoverable from soils up to 231 days following the application of artificially contaminated animal manure compost (10^7 cfu/g) and irrigation water (10^5 cfu/mL). The pathogen was also detected on parsley and lettuce plants for up to 231 and 63 days respectively following contamination of the growing site. Research by Solomon *et al*. (2003) investigating the persistence of *E. coli* O157:H7 on lettuce plants following single and intermittent direct spraying with low pathogen populations confirmed that spray irrigation directly onto leaf surfaces produced persistent contamination, which was increased by repeated irrigation. Islam *et al.* (2005) also demonstrated recovery of *E. coli* O157:H7 from soils and vegetables (carrots and onions) grown in fields treated with contaminated irrigation water or manure compost. Survival in soil ranged from 154 to 196 days, and was detectable on carrots and onions for 168 and 784 days. A quantitative risk assessment model investigating irrigation of raw vegetables with reclaimed water concluded that the use of subsurface, furrow or drip irrigation could lower risks considerably (Hamilton *et al*., 2006), by preventing contamination of the edible portions of plants.

Other factors may also contribute to contamination. For example, Ng *et al*. (2005) demonstrated that several pesticides, made in solution with agricultural waters, supported the growth of naturally occurring bacteria including *Aeromonas* and various coliforms. For further information on production practices, please refer to Suslow *et al*. (2003).

Pathogen contamination post-harvest is generally related to poor practices in terms of hygiene, wash water quality and food handling at various levels including industry production and processing, retail display and sale, and in the home. Temperature abuse is an important factor where bacteria are concerned.

In terms of contamination of fresh produce, a wide variety of bacterial pathogens including *Salmonella* spp., *Campylobacter*, *E. coli* O157:H7, *Shigella* spp., *Listeria monocytogenes*, *Staphylococcus aureus, Aeromonas hydrophila* and the sporeformers *Bacillus cereus*, *Clostridium botulinum* and *C. perfringens* have been identified as hazards, predominately on vegetables (European Commission, 2002; Heard, 2002; Warriner, 2005). This is by no means an exhaustive list and other pathogens have been recognised as potential hazards. For example, non-O157 shiga-toxigenic (STEC) *E. coli* have been implicated in produce-related outbreaks, e.g. *E. coli* O111 in fruit juice (Vojdani *et al*., 2008). However, the detection methodology for non-O157 STECs is expensive and technically more difficult than for O157, and as a consequence prevalence data are lacking. The majority of reviews to date have therefore tended to consider *E. coli* O157 only.

In general, pathogenic bacteria do not tend to be associated with fruits to the same extent as vegetables, due to differences in production and the generally lower pH values of fruits due to their organic acid content. Survival of pathogens under these conditions is typically poor (Zhao, 2005), and as a consequence there has been only one report of bacterial foodborne illness associated with berry fruits. However, other fruits such as tomatoes and various melon varieties with higher pH values have been implicated in a number of outbreaks related to *Salmonella* and *E. coli* O157:H7 contamination (Harris *et al*., 2003). The possibility of internalisation of pathogenic bacteria into the edible tissues of certain fruits and vegetables (e.g. tomatoes, celery, unwaxed apples) via stomata and stem scars, or damaged tissues, may also increase risk (Warriner, 2005; Beuchat, 2006; *Safe*food, 2007). For this reason, it has been suggested that the temperature of wash water should ideally be at least 10°C higher than that of the produce to create a positive temperature gradient thereby minimising the uptake and internalisation of pathogens (Beuchat, 1998).

Produce outbreaks due to protozoa and viruses have been more typically associated with berry fruits, and their presence is more often the result of the use of contaminated irrigation water or fertiliser, contaminated soil or cross-contamination due to infected food handlers (European Commission, 2002; Koopmans & Duizer, 2004; Zhao, 2005). A number of protozoan and viral outbreaks associated with the consumption of raw berries have been recorded overseas (Harris *et al*., 2003). *Cyclospora* in particular has been implicated in several outbreaks elsewhere in the world, and while it may represent a threat to food safety in imported berries from particular countries, its importance in a New Zealand context is unknown. Detection of protozoa and viruses is technically more difficult than methods for bacterial pathogens, and may be of questionable value given the significant role of infected food handlers in contamination.

Although human viruses and protozoa do not multiply on foods due to their absolute need for an appropriate living host, contamination levels occurring at the farm level can nevertheless be high enough to allow persistence of the organisms on produce right through to the consumer end of the food chain. The efficacy of washing aggregate berry fruits has been debated, given both their structure and the ineffectiveness of chlorine against oocysts (Nichols & Smith, 2002) and to some extent viruses (Koopmans, 2002) but it is routinely recommended (Anon, 2005b; Bassett & McClure, 2008). In industry, processed berries are typically destemmed, washed, sometimes sliced (in the case of strawberries), and co-mingled prior to freezing, while raw berry fruits are often not washed to avoid mould growth. All of the additional handling during harvesting and processing and the preservative effects of freezing have been suggested as an explanation as to the more frequent implication of frozen berries in outbreaks (Zhao, 2005) despite the theoretical 'dilution' effects of washing and co-mingling.

Identifying the microbial culprits in produce-related outbreaks can be difficult and may also be complicated by factors such as the inclusion of non-vegetable ingredients, e.g. nuts, fresh herbs and cooked meats/seafood in mixed salads, which can contribute pathogens in their own right. It has also been suggested that the U.S. practice of coring and removing leaves from vegetables such as lettuce at the farm level, prior to transportation to processing facilities, may contribute to the spread of contamination. This practice exposes effectively sterile inner tissues (Aycicek *et al*., 2006) to environmental contamination. Co-mingling of products during processing and packing has also been criticised. This practice is both commonplace and problematic in terms of potentially contaminating large volumes of otherwise safe produce and makes traceback more difficult in the event of an outbreak (Harris *et al*., 2003). These issues obviously create delays in initiating recalls and, as occurred in a retail outbreak of *E. coli* O157:H7 associated with the fast-food chain Taco Bell in December 2006, can also result in false identification of the outbreak vehicle. In this particular situation, green onions were wrongly identified as the vehicle, placing blame on an innocent producer, while iceberg lettuce was later reported to be the more likely vehicle.

How significant a concern these bacterial, protozoan and viral pathogens actually are in terms of causing produce-related illness is ultimately determined by a number of factors including their relative abilities to: (i) persist in soil and water; (ii) colonise vegetables; (iii) grow (depending on the pathogen in question and the storage conditions); and (iv) survive post-harvest processing and storage. The presence of these pathogens is of particular importance on fresh ready-to-eat (RTE) produce items where adequate decontamination is most difficult to achieve and which may have been subjected to minimal processing steps such as peeling, chopping, shredding, etc. which serve to damage the outer layers and allow contaminants to invade tissues. Growth of bacterial pathogens on produce is in itself complex and depends on a number of factors including the intrinsic properties of the particular food item and the extrinsic growth and storage conditions. Cooked vegetables subjected to an inactivation treatment prior to consumption are generally not a concern, although there have been reported incidences of *B. cereus* food poisoning associated with the consumption of hot-held RTE potato products in New Zealand (Turner *et al*., 2006).

A brief summary of information pertaining to the pathogens of most concern in fresh produce in a New Zealand context follows. General information on these pathogens (excluding *Aeromonas*) can be located in the Microbial Pathogen Data Sheets located on the NZFSA website (http://www.nzfsa.govt.nz/science/data-sheets/index.htm).

2.1 Bacterial Pathogens

2.1.1 *Aeromonas* spp.

These opportunistic pathogens are frequently suggested as potential produce-related pathogens in the literature based on factors other than a proven involvement in outbreaks. These include (i) the ability to grow at refrigeration temperatures (Francis, 2003), (ii) a high frequency of isolation from organic and conventionally grown vegetables (McMahon & Wilson, 2001) and (iii) resistance to chlorination (Uyttendaele *et al*., 2004). According to Harris *et al.* (2003) "outbreaks associated with this pathogen have not been reported." However, a number of suspected outbreaks associated primarily with seafood were cited in a review by Kirov (2003). In New Zealand, an outbreak of *A. hydrophila* has been reported in EpiSurv (in 1998), but the information available is minimal with little evidence to confirm a foodborne origin (personal communication, Greg Simmons, Auckland Regional Public Health Service). Nonetheless, the limited information available suggests that certain species of aeromonads do have the potential to cause gastrointestinal disease, and as such should be regarded as "potential and/or emerging" pathogens (Kirov, 2003).

2.1.2 *Bacillus cereus*

Given the spore-forming nature of *B. cereus*, it is commonly isolated from soils and is therefore not an unexpected contaminant of produce. Although it has been recovered from sprouts and watercress (Warriner, 2005) and was implicated in a 1973 outbreak associated with sprouts grown from a home seed sprouting kit (Harris *et al*., 2003), it was not reported in any further produce-related outbreaks occurring in the U.S. from 1973 through 1997 (Sivapalasingam *et al*., 2004).

2.1.3 *Campylobacter* spp.

Although campylobacteriosis tops the notifiable disease tables in many countries, including New Zealand, it is most commonly associated with fresh produce via cross-contamination from other foods rather than as a naturally occurring contaminant. For example, an outbreak of campylobacteriosis at a training facility in Australia in 1995 was traced back to consumption of cucumber served in a salad bar (Kirk *et al.,* 1997). Cross-contamination via raw meat was the suspected cause. A Canadian survey of vegetables from farmers' markets and supermarkets did however find a 1.6 to 3.3% prevalence (Park & Sanders, 1992) while a microbiological survey of New Zealand-grown watercress in 2000 isolated *Campylobacter* from 11% of watercress samples and from water samples taken from all growing sites (Edmonds & Hawke, 2004). Although no formal cases of campylobacteriosis associated with watercress have been recorded in New Zealand, two suspected cases have been recorded (Turner *et al*., 2004). Four outbreaks associated with melon, strawberries and fruit salad have been recorded in the U.S. over a 25 year period (Sivapalasingam *et al*., 2004). Despite its inability to grow, *C. jejuni* has been shown to survive on watermelon and papaya for several hours (Castillo & Escartin, 1994).

2.1.4 *Clostridium botulinum*

The sporeformer *C. botulinum* is considered ubiquitous in soil and aquatic environments internationally and can therefore be associated with raw produce. However, its occurrence in soils around the world is quite variable (Notermans, 1993) and only becomes a problem when spores are able to outgrow and produce toxins in an anaerobic environment. Produce-related outbreaks have typically been associated with canned, bottled or acidified fruits and vegetables that have been either under-processed, poorly acidified or temperature abused (Notermans, 1993). Documented outbreaks of botulism (usually type A or B) have included fresh (chopped) garlic products stored in oil, canned mushrooms and beetroot (Notermans, 1993), and more recently fresh carrot juice (FDA, 2006a). New Zealand has a very low prevalence of *C. botulinum* in soil and marine sediments (Gill & Penney, 1982; Fletcher *et al*., 2008), and only one outbreak of botulism has been reported. This was associated with the consumption of a meal composed of puha (a native land plant also known as New Zealand sow thistle) and mussels (Flacks, 1985).

The use of modified atmosphere packaging (MAP) for fresh-cut vegetables has raised some concerns about product safety. While there is scientific evidence that *C. botulinum* can survive and grow under certain MAP conditions (albeit mainly at temperatures higher than refrigeration), in general the associated growth of spoilage microflora renders the appearance of the produce unacceptable (Farber *et al*., 2003). Nonetheless, given that toxin levels have been produced in the absence of spoilage in some situations, further research has been called for, particularly at more realistic storage temperatures above 7ºC (Farber *et al*., 2003).

2.1.5 *Clostridium perfringens*

C. perfringens is more typically associated with inadequate cooling or temperature abuse of meat and poultry products and is infrequently associated with fresh produce outbreaks. It was implicated in a 1993 Canadian outbreak associated with lettuce although the epidemiological evidence was cited as "weak" (Harris *et al*., 2003).

2.1.6 *Escherichia coli* O157:H7

Produce-related outbreaks of *E. coli* O157:H7 have been prominently reported in the U.S. recently due to several outbreaks associated with spinach (FDA, 2006b) and lettuce (Food Safety Network, 2006). Previous outbreaks, including a large sprouts-related outbreak in Japan and another in the U.S. associated with the consumption of contaminated unpasteurised apple cider, have been attributed to the use of improperly composted manure, contaminated irrigation and wash waters (possibly via farm runoff), and direct contact with livestock faeces (Sivapalasingam *et al*., 2004; Gerba & Smith, Jr., 2005). Cross-contamination of items such as cantaloupe has also occurred via raw meat juices (Harris *et al*., 2003). This organism is of particular concern due to the low dose required to give a significant probability of infection and the severity of complications in susceptible individuals.

2.1.7 *Listeria monocytogenes*

At lower storage temperatures psychrotrophic *L. monocytogenes* has been shown to grow on a variety of vegetables. It was first linked to a foodborne outbreak in 1981 when consumption of coleslaw, made from cabbage grown on a farm where two sheep had previously died of listeriosis, caused 41 cases and 17 deaths (Harris *et al*., 2003). Despite the ubiquitous nature of *L. monocytogenes* in the environment, evident from their frequent isolation from a variety of vegetables (Beuchat, 1998; Harris *et al*., 2003), no reported outbreaks of listeriosis were associated with produce in the U.S. from 1973 to 1997 (Sivapalasingam *et al*., 2004). While it is reasonable to assume that long incubation periods make it difficult to pinpoint the involvement of a particular food in an outbreak, equally it is also possible that contamination may be present at levels insufficient to cause infections.

2.1.8 *Salmonella* spp.

In the international literature, *Salmonella* species are prevalent in a wide variety of produce items and have caused a significant number of outbreaks associated with seeded sprouts, tomatoes, melons and (predominantly unpasteurised) fruit juices (Harris *et al*., 2003). During 2006, alfalfa sprouts, rock melon and pawpaw were all associated with outbreaks of salmonellosis in Australia (OzFoodNet, 2007) and tomatoes were identified as the vehicle for yet another produce-related outbreak in the U.S. associated with *Salmonella* Typhimurium (FDA, 2006c). Overall, these organisms cause a significant proportion of outbreaks associated with the consumption of fresh produce. For example, in a review of produce-related outbreaks in the U.S. from 1973 through 1997, *Salmonella* spp. were the most common bacterial agents of disease, with an outbreak frequency of 48% (Sivapalasingam *et al.,* 2004). In New Zealand, salmonellosis is the second most frequently notified enteric disease but only one outbreak (19 cases) in 2005 associated with the consumption of raw carrots has been tentatively linked to this pathogen (Neuwelt *et al*., 2006).

2.1.9 *Shigella* spp.

Pathogenic *Shigella* species are more typically transmitted from person-to-person but have been associated with several produce-related outbreaks related to the consumption of contaminated lettuce (Frost *et al*., 1995), salads, green onions (Sivapalasingam *et al.,* 2004) and less frequently melon (Harris *et al.*, 2003). In at least one of these outbreaks a contaminated worker was identified as the source of contamination (Harris *et al*., 2003).

2.1.10 *Staphylococcus aureus*

S. aureus intoxication is typically the result of poor food handling practices and temperature abuse rather than a production or processing issue. However, *S. aureus* is also generally regarded as a poor competitor and is unlikely to reach populations sufficient for enterotoxin production in fresh produce where significant growth of the spoilage microflora has also occurred (Harris *et al*., 2003). Only one fresh produce outbreak, associated with strawberries (Sivapalasingam *et al*., 2004) has been linked to this organism despite its at times high isolation rates from various vegetables, fruits and sprouts (Beuchat, 1998; Viswanathan & Kaur, 2001; Harris *et al.*, 2003). A further outbreak associated with canned mushrooms was suggested to have occurred due to growth and toxin production prior to processing (Harris *et al*., 2003).

2.1.11 *Yersinia* spp.

Yersinia enterocolitica has been isolated from sprouts and vegetables (Beuchat, 1998; Harris *et al*., 2003), and caused a 16 person outbreak associated with bean sprouts in the U.S. in 1982 (Sivapalasingam *et al*., 2004). Outbreaks of *Y. pseudotuberculosis* have also been reported in association with iceberg lettuce and more recently shredded carrots in Finland (Nuorti *et al.*, 2004; Jalava *et al.*, 2006). In both cases, the contamination source was identified as being at the farm level. The 2004 lettuce outbreak investigation was the first to link this presumptive pathogen to human illness via the consumption of contaminated food (Tauxe, 2004). Given the psychrotrophic nature of these organisms and their prevalence in raw produce, *Yersinia* spp. are increasingly being recognised as a concern. In New Zealand, yersiniosis represents the third most frequently reported bacterial enteric disease.

2.1.12 Other bacterial pathogens

Due to the ubiquitous nature of *Enterobacter sakazakii* in the environment, its known association with produce and its demonstrated ability to grow on fresh-cut and juiced produce (Kim & Beuchat, 2005), concerns have been raised regarding its possible role as a produce-related pathogen. Recent research to assess survival of this pathogen on strawberries, apples, cantaloupes, tomatoes and lettuce (Kim *et al.*, 2006) demonstrated persistence of *E. sakazakii* on produce, particularly items stored at refrigeration temperatures. However, significant reductions in pathogen levels by various sanitisers were also reported, suggesting that although *E. sakazakii* can be prevalent in such environments, it is susceptible to typical produce processing techniques.

2.2 Protozoan Pathogens

The protozoa, as mentioned previously, are unable to multiply in foods and their ability to cause disease in humans is related to the environmental persistence and transmission of protozoan (oo)cysts via either contaminated food and water, or animal-to-person or person-to-person transmission routes (Beuchat, 1998). Fruits and vegetables appear to be significant transmission vehicles as a consequence (Orlandi *et al*., 2002). The most commonly reported protozoa associated with produce are *Cryptosporidium parvum*, *Giardia lamblia* and *Cyclospora cayetanensis*, although *Toxoplasma gondii* has been implicated by several authors (Smith, 1992; Remington *et al*., 1995; Kapperud *et al*., 1996; Cliver, 2001; Dumètre & Dardé, 2003; Goldsmid *et al*., 2003) as a potential risk associated with vegetables, mainly due to the potential for soil contamination from the faeces of the definitive host, the cat family. A possible role of *T. gondii* in produce-related foodborne illness requires further investigation (Dawson, 2005).

Given the association of protozoan (oo)cysts with contaminated waters and faeces, and their resistance to chlorine (Orlandi *et al*., 2002), it is not unexpected that a number of produce-related outbreaks have occurred internationally. *C. parvum*, although less frequently implicated, has been associated with outbreaks related to consumption of green onions, apple cider (Sivapalasingam *et al*., 2004) and carrots (Ethelberg *et al*., 2005), while *G. lamblia* has been linked to outbreaks associated with tomatoes, onions, lettuce and fruit (Sivapalasingam *et al.,* 2004). *C. cayetanensis* has however featured prominently in at least 8 outbreaks associated with the consumption of imported raspberries, lettuce, basil and fruit salad (Harris *et al*., 2003; Sivapalasingam *et al*., 2004).

While water appears to be an important means of transmitting *Cryptosporidium* and *Cyclospora* to humans, potentially via agricultural practices (Orlandi *et al*., 2002), the role of food handlers is also important, and in some cases asymptomatic shedding may occur (Harris *et al*., 2003). Although more typically associated with pork and other meat products, *T. gondii* oocysts have been shown experimentally to attach to raspberries, and to a lesser extent blueberries, and can survive storage at 4°C for up to 8 weeks, giving rise to acute infections in mice following consumption (Kniel *et al*., 2002). From limited data available, *Cyclospora* is generally more resistant to inactivation than either *Giardia* or *Cryptosporidium* (Erickson & Ortega, 2006).

2.3 Viral Pathogens

Viral pathogens such as Hepatitis A, noroviruses [previously referred to as Norwalk-like viruses (NLVs)] and rotaviruses are, in common with protozoa, unable to multiply without the aid of a living host but can be found on produce as a result of faecal contamination, either via an infected food handler or polluted water (Seymour & Appleton, 2001). The recurring issue of infected food handlers in viral transmission is complicated by the fact that noroviruses can commonly cause asymptomatic infections, which presumably contribute to increased viral dissemination (Koopmans & Duizer, 2004). In addition, international researchers have recently isolated human viruses from fresh animal manure (personal communication between Dr Gail Greening, ESR, and K. Matttison, Health Canada), suggesting that this may be an additional (although less significant) source of contamination either directly or indirectly.

While viral multiplication on produce will not occur, survival has been demonstrated (Harris *et al*., 2003) and a number of outbreaks linked with produce items such as lettuce, green onions, tomatoes, cut vegetables and fruits have been reported (Harris *et al*., 2003; Sivapalasingam *et al.,* 2004). Over a 25 year period in the U.S., Hepatitis A was responsible for 57% of viral outbreaks associated with produce, while noroviruses were responsible for the remaining 43% (Sivapalasingam *et al.,* 2004). To date, the only confirmed produce-related outbreak of foodborne illness in New Zealand was associated with the consumption of raw blueberries contaminated with Hepatitis A (Calder *et al*., 2003). Rotaviruses are rarely associated with foodborne or waterborne outbreaks in developed countries but these are significant transmission routes in other countries (Seymour & Appleton, 2001). While lifelong immunity is produced as a consequence of Hepatitis A infection, it has been suggested that a decline in exposure in developed countries has built up a susceptible population (Seymour & Appleton, 2001). As with some of the documented protozoan outbreaks, the importation of fruit and vegetable products from countries with a high incidence of Hepatitis A may thus expose susceptible populations to increased risk of infection. Likewise, recent low unemployment rates in New Zealand have dramatically reduced the supply of casual labourers. The employment of migrant workers from other countries to cover this shortfall could result in additional risks.

3 HAZARD IDENTIFICATION: THE FOOD

Based on overseas outbreak data and reviews of literature, a large number of outbreaks have been associated with the consumption of RTE intact and fresh cut vegetables and fruits, fresh juices and sprouted seeds (European Commission, 2002; Harris *et al*., 2003; Warriner, 2005; Zhao, 2005). Hydroponically grown vegetables and fresh herbs have also been identified as potentially problematic (Graham, 1999; Graham & Dawson, 2002; Harris *et al.,* 2003), and several groups have identified organic production as an area where further research is required to establish safety (European Commission, 2002; Harris *et al*., 2003). Nuts and other salad 'additives' such as cooked meats and seafood can also contribute pathogens and this can cloud the picture in terms of the true source of contamination.

3.1 Relevant characteristics of the food

The two most important intrinsic factors of foods in relation to microbial growth are pH and water activity (a_w), and it is generally accepted that foods with a pH greater than 4.6 and a_w of greater than 0.85 have the potential to support the growth of a variety of bacterial pathogens. Given the high water content of produce, and the pH values listed in Table 2 (from USFDA/CFSAN), it is clear that vegetables are most likely to support bacterial growth, while most fruits will not due to their lower pH values. The obvious exception is melons, and to some extent tomatoes.

Table 2: pH values for selected fruits and vegetables

Fruits	pH	Vegetables	pH
Lemons	2.2 – 2.4	Carrots	4.9 – 5.2
Oranges	3.1 – 4.1	Cucumber	5.1 – 5.7
Raspberries	3.2 – 3.7	Peppers	5.15
Blackberries	3.2 – 4.5	Cabbage	5.2 – 6.0
Apples	3.3 – 4.0	Onions	5.3 – 5.8
Blueberries	3.7	Spinach	5.5 – 6.8
Tomatoes	4.2 – 4.9	Parsley	5.7 – 6.0
Water melon	5.2 – 5.8	Lettuce	5.8 – 6.0
Cantaloupe melon	6.17 – 7.13	Peas	5.8 – 7.0
Honey dew melon	6.3 – 6.7	Potatoes	6.1

However, while a food may not be predicted to support the growth of bacteria on the basis of pH and a_w, this does not take into account the potential survival of pathogens such as the acid-tolerant *E. coli* O157 and *Salmonella* spp., as well as protozoa and viruses, all of which have been implicated in fruit-related outbreaks. In the U.S., foods of plant origin such as raw sprouts, cut melons and garlic-oil mixtures have been termed "potentially hazardous foods" and are acknowledged to require careful handling and storage (McSwane *et al*., 2000).

Many edible plant tissues also contain antimicrobial constituents. For example, garlic and onion contain allyl sulfoxides and protocatechoic acid respectively but these are only released from cut or injured tissue (Beuchat, 2006). Similarly, carrots have been reported to exhibit anti-bacterial properties against *L. monocytogenes* (Beuchat *et al*., 1994), *S. aureus* and *S.* Typhi (Viswanathan & Kaur, 2001) due to the production of falcarindiol and 6-methoxymellein (Beuchat, 2006). What remains questionable is the extent to which these antimicrobials contribute to pathogen reductions at the concentrations actually present. It has also been suggested that these antimicrobials may hamper the detection and enumeration of bacterial pathogens from such foods (Beuchat, 2006).

3.2 The Ready-to-eat (RTE) Vegetable and Fruit Market in New Zealand and Overseas

There is some discussion in overseas literature that increasing levels of produce-related disease are, in part, attributable to increasing consumption. Although specific figures are not available for the whole fresh-cut industry, New Zealand Fresh-Cuts Ltd. has reported sales growth of around 10% per year. What is unclear is whether increased sales actually translate into increased consumption. If, as is being suggested, there is increasing growth in this area within the New Zealand food industry, are we currently seeing (or likely to see in the future) increased incidence of foodborne illness associated with this commodity?

Ashley Berrysmith of New Zealand Fresh-Cuts Ltd. defines the term “fresh-cuts” as “added value minimally processed fruit and vegetables with the aim of offering a more convenient consumer product. Fresh-cut fruit and vegetables are normally washed, trimmed peeled and sliced. Fresh-cut processing does not include blanching, cooking or blending.” In addition he states, “The boundaries of fresh-cuts however are becoming blurred as many processors are including fresh-cuts in a more comprehensive meal solution. This would include meal kits packed in bags where the individual components are packed in separate sachets within the outer pack. Salad bowls are also becoming popular where the fresh-cut salad is contained in the bowl and the components are packed in a separate compartmentalized tray.”

Fresh-cuts as a percentage of fruit and vegetable retail sales in NZ and Australia is estimated to be between 5 and 7%. In the U.S. and U.K. this has been estimated at 18% and 22% respectively (based on information from United Fresh, U.S.; Geest, U.K.) so clearly there is plenty of scope for growth (personal communication, Ashley Berrysmith, New Zealand Fresh-Cuts Ltd.).

Two ACNielsen surveys on “Insights on Growth in Food and Beverages” from 2002 and 2004 both identified refrigerated salads and frozen fruits as areas of growth with 11% and 10% increases respectively in Europe and the U.S. (ACNielsen, 2002; 2004). Further sales increases for frozen fruits (9%), fresh RTE salads (8%) and fresh vegetables (7%) across a number of international markets were reported in the 2004 survey. In terms of the Asia-Pacific market, growth in fruits and vegetables increased by a more modest 3% (although frozen fruit reportedly increased by 38%). A media summary of the latest 2006 ACNielsen market report noted the continuing growth of ‘healthy items’ such as salads with “global sales of over US $1 billion” and growth “in double digits” (http://www.foodnavigator.com/news/printNewsBis.asp?id=74144).

3.3 Processing of RTE Produce

Although vegetables and fruits do not support the growth of bacteria to the same extent as foods of animal origin, damage to the integrity of the outer layers through minimal processing steps such as peeling, chopping, shredding and juicing (ICMSF, 1998) will allow bacteria to proliferate where pH values and storage temperatures are suitable. These processing steps usually occur at a processor prior to sanitation, packaging and delivery to retail outlets. However, a small amount of chopping (e.g. pineapples and melons) and juicing is known to occur in supermarkets, juice bars, etc. but information on handling practices prior to these activities is lacking. Anecdotal evidence suggests that certain practices such as washing and/or sanitising of the outside of melons prior to chopping and appropriate refrigerated display do not always occur at the retail level.

Sanitation of whole and cut vegetables and fruits is most commonly achieved by hypochlorite washing at levels of 50 to 200 ppm for 1 to 2 minutes (Beuchat, 1998), with significantly higher levels (up to ~3500 ppm) used to soak seeds prior to sprouting. In the case of bagged leafy green salads for example, processors typically apply up to three wash steps using agitation and rotating immersion drums to remove particulate and smaller leaves, followed by centrifugation or vacuum/infra red heat and fluidised bed cooling to remove excess water prior to packaging.

Unfortunately, in practice the use of hypochlorite in wash waters is often improperly controlled and a number of factors can impact on its effectiveness. These include free available chlorine levels, temperature and pH, as well as the type of produce, the associated microorganisms and potential inactivation by organic material (Beuchat, 1998; Parish *et al.*, 2003; Betts & Everis, 2005). Frequent monitoring and adjustment of pH to achieve a value ranging from 6.0 to 7.5 is therefore essential to ensure that enough free available chlorine is present in the water and to prevent equipment corrosion due to decreases in pH (Beuchat, 1998). Although maximum solubility of chlorine in water occurs at around 4ºC, overseas literature suggests that wash water should be at least 10ºC higher in temperature than the produce being washed to prevent uptake of wash water (Beuchat, 1998). The New Zealand GAP manual (Horticulture New Zealand Inc., 2006) recommends that wash water temperature should be "as close to that of the produce as possible (or slightly warmer)". A final wash in non-chlorinated potable water chilled to 1 – 2ºC has been recommended by the Food Safety Authority of Ireland to eliminate chlorine residues and reduce product temperature to below 5ºC (FSAI, 2001) but this also has the potential to re-contaminate produce.

As mentioned previously, hypochlorite is of limited effectiveness against protozoan oocysts and viruses, and some bacterial spore resistance also exists (Parish *et al*., 2003). Estimates of only 1 to 2 log reductions in total bacterial numbers at typical free chlorine levels have been reported (Parish *et al*., 2003; Betts & Everis, 2005). A study of inactivation of MS2 bacteriophage as a surrogate for norovirus on fresh produce using 100 ppm chlorine reported reductions of less than 1.5 $\log_{10}$ cfu (mean 0.89 $\log_{10}$ cfu across produce types), with viral survival exceeding shelf life (Dawson *et al*., 2005). Potable water alone gave a reduction of 0.3 $\log_{10}$ cfu, indicating that viral reduction was a consequence of both physical removal and chlorine inactivation. Despite the reductions achieved using chlorine in this research, it was concluded that a heavy initial viral loading would likely lead to infection due to sufficient survival in washed product.

Due to the limitations of hypochlorite treatment, its corrosive nature (Parish *et al.*, 2003) and concerns about the safety of workers and consumers due to the production of chlorine vapours and organochlorines respectively (Betts & Everis, 2005), a number of other chemical preservation procedures have been investigated. These include the use of chlorine dioxide, bromine, iodine, trisodium phosphate, acidified sodium chlorite, quaternary ammonium compounds, organic acids, hydrogen peroxide, hot water and ozone (Beuchat, 1998; Francis & O'Beirne, 2002; Parish *et al.*, 2003; Betts & Everis, 2005; Daş *et al.*, 2006; Ruiz Cruz *et al.*, 2006). However, these alternatives vary in their effects and may therefore have limited applications. For example, ozone is more effective than either chlorine or chlorine dioxide for inactivation of protozoa in water (Erickson & Ortega, 2006) and *Shigella sonnei* in water and shredded lettuce (Selma *et al.*, 2006), but it is highly unstable and reactive (Erickson & Ortega, 2006). Nonetheless, ozone technology is being adopted by other industries and has the potential to become the method of choice for the produce industry as well.

Hypochlorite is currently used in New Zealand for washing of produce such as lettuce and carrots, as well as for disinfection of sprout seeds. The Isan® system for automated delivery, measurement and monitoring of iodine for produce disinfection has been reported recently in New Zealand horticultural literature (Anon, 2006) and is generating some interest amongst both producers and processors. Tsunami®, a peroxyacetic acid-based EcoLab sanitiser, is reportedly used by some blueberry processors (personal communication, Greg Furniss, Blueberries New Zealand).

Despite the variety of chemical options available, differences in inactivation of groups of organisms (particularly the more resistant protozoa) are one of many stumbling blocks to widespread adoption of alternatives to chlorine. A number of biological and physical approaches to produce preservation also exist such as biocontrol, natural antimicrobials, ultrasound, high pressure, electroporation and irradiation (Heard, 2002; Schuenzel & Harrison, 2002; Betts & Everis, 2005; Brandi *et al.*, 2006; Erickson & Ortega, 2006; Muñoz *et al.*, 2006; Saroj *et al.*, 2006b). A combination of treatments, either at the same time or sequentially, may prove to be a more useful overall approach (Erickson & Ortega, 2006).

Irradiation has been promoted as a means of penetrating the entire product to eliminate pathogens (Thayer & Rajkowski, 1999) either internalised or in 'difficult to reach' areas, and as an alternative to thermal processing of juices. While its use has been reported for juices, fruits and sprouts (Saroj *et al.*, 2006a; Song *et al.*, 2006), it may not be suitable for all produce types such as leafy vegetables (Thayer & Rajkowski, 1999) and is not effective against *C. parvum* oocysts at the FAO/WHO recommended maximum dose of 10 kGy (Erickson & Ortega, 2006). Recently published work investigating the irradiation of three ready-to-use vegetables (blanched spinach, cucumber and seasoned burdock) reported that *S.* Typhimurium, *E. coli*, *S. aureus* and *L. ivanovii* were all reduced to "below the limit of detection" by a 3 kGy treatment (Lee *et al.*, 2006) although the use of enrichment procedures to confirm absolute elimination was not described.

Limited biocontrol studies using bacterial viruses, also known as (bacterio)phages, have also been reported more recently as an alternative means of controlling pathogens without the associated loss of epiphytic microorganisms normally associated with vegetables.

Leverentz *et al.* (2001) found that the use of a proprietary phage mixture (SCPLX-1) containing four lytic viruses reduced *Salmonella* Enteritidis populations on melon by 3.5 log_{10} units at storage temperatures of 5 and 10°C, while a reduction of 2.5 log_{10} units was observed at 20°C, reductions greater than those attributed to the use of chemical sanitisers. However, significant reductions in *Salmonella* numbers were not observed for apple slices, possibly due to inactivation of phages due to the lower pH of apples.

Subsequent work by Leverentz *et al.* (2003) on the biocontrol of *Listeria monocytogenes* on fresh-cut produce demonstrated reductions of up to 4.6 log_{10} units when melons were treated with phage, and increased up to 5.7 log_{10} cfu when nisin was combined with the phage treatment. A similar approach using two *Salmonella*-specific phages in broccoli and mustard seed has also been published (Pao *et al.*, 2004). However, a pathogen reduction of only 1.37 to 1.5 log_{10} cfu was achieved, suggesting that sprouts are a more complex and difficult food system to decontaminate.

The obvious limitation of this approach is the relative lytic capabilities of the phages employed, and this would have to be a key consideration of future applications. It is however anticipated that the FDA's recent approval of *Listeria monocytogenes*-specific phages for ready-to-eat meat and poultry applications (USFDA/CFSAN, 2006) will generate significant interest in this approach for other RTE commodities such as produce.

4 HAZARD CHARACTERISATION: ADVERSE HEALTH EFFECTS

The majority of the produce-related pathogens considered in this document are associated with the intestinal tracts and faecal material of animals and/or humans (Harris *et al*., 2003), and can cause acute gastrointestinal illness with occasional long term sequelae or mortality, generally reflective of the immune status of the infected individual. However, due to the severity of complications associated with *E. coli* O157:H7, *Salmonella* spp., *L. monocytogenes* and Hepatitis A infections, these particular agents have been identified in international literature as being of most concern in fresh produce (Zhao, 2005).

5 EXPOSURE ASSESSMENT

This section collates available information on the prevalence of pathogens in fruits and vegetables in New Zealand, followed by an analysis of data concerning consumption. A formal exposure assessment is not attempted.

5.1 A Survey of Hydroponically Grown Vegetables in New Zealand

In 1999 the New Zealand Ministry of Health commissioned a survey to examine the microbiological safety and quality of hydroponically grown vegetables (Graham, 1999; Graham & Dawson, 2002). A total of 291 samples comprising 117 sprout samples (46 samples from producers and 71 from retail sources), 114 leafy vegetables (producers) and 60 herb samples (producers) were tested for counts of *E. coli*, coagulase-positive staphylococci and *L. monocytogenes*, and the presence of *Campylobacter*, *E. coli* O157 and *Salmonella*. Sprouts were also tested for *B. cereus*. Results were then compared with Ministry of Health Microbiological Reference Criteria for Food (1995) for cultured seeds and grains (section 5.5) and salads – vegetables or fruit – excluding meat (section 5.25).

Salmonella, *Campylobacter*, *E. coli* O157 and *L. monocytogenes* were not found in any samples. All sprout samples were compliant for *B. cereus* (<1000/g), and all but one of the leafy vegetables complied with the coagulase-positive staphylococci criterion (<1000/g). However, *E. coli* was detected in 34 (11.7%) samples – 15 sprouts (12.8%), 16 leafy vegetables (14%) and 3 herbs (5%) – suggesting the potential for pathogens to be present in such products.

A HACCP-based questionnaire was administered to eight sprout producers and results were analysed to determine implementation of critical control points (CCPs). The most frequently non-implemented CCPs were: (i) seed sanitation, (ii) washing of product prior to harvest; and (iii) chilling and sanitation of harvest wash water. Six of the producers were only implementing between one and five of the 12 most common CCPs, with one producer not implementing any of these CCPs. This producer and one other with nine non-implemented CCPs were identified as producing *E. coli*-positive sprout samples.

Based on the results from this research, three recommendations were made to the Ministry of Health, including: (i) the need to promote seed disinfection as the primary means of preventing contamination of hydroponically grown vegetables; (ii) the adoption of HACCP-based food safety programmes by growers for their products; and (iii) testing of spent irrigation water from each batch of sprouts for the presence of *Salmonella* and *E. coli* O157 prior to market release (Graham, 1999). It is unclear what, if any, specific actions were taken in light of this research, but available information from industry indicates that these recommendations (with the possible exception of *E. coli* O157 testing) are being implemented by large growers and processors.

5.2 Risks Associated with Bacterial Pathogens in Exported Fruit and Vegetables

In 2002 MAF commissioned a more detailed study of the risks associated with bacterial pathogens in exported fruits and vegetables (Hudson and Turner, 2002). Parasites, viruses and *Yersinia enterocolitica* were not however considered in this report.

A number of potential biological hazards (Table 3) were identified, based on literature identifying the potential for growth and survival, disease severity, dose response and prevalence data from overseas. It was noted that prevalence information specific to New Zealand produce could not be located.

Table 3: Key microbial pathogens of concern in exported vegetables and fruits

Pathogen	Rationale for ranking of pathogens	Concern?
Aeromonas	Equivocal pathogen	No
B. cereus	Lack of association between pathogen and produce-related outbreaks	No
Campylobacter	Low dose; mainly cross-contamination; rarely detected	No
C. botulinum	Lack of association between pathogen and produce-related outbreaks	No
E. coli O157:H7	Low prevalence in New Zealand but low dose	Yes
L. monocytogenes	Low probability of infection	No
Salmonella	Dominant aetiological agent	Yes
Shigella	Low dose; related to poor hygiene	No
S. aureus	Lack of association between pathogen and produce-related outbreaks; related to poor hygiene	No

Overseas data indicated that the highest risk export foods were likely to be lettuces (mainly due to *E. coli* O157), and melons and tomatoes (due to *Salmonella*). However, New Zealand-grown melons were considered to be low risk and tomatoes, although associated with several outbreaks internationally, were considered to be lower risk due to the growth of export tomatoes in hothouses in New Zealand and the lack of documented evidence of issues regarding irrigation water.

Overall, three food-hazard combinations (lettuce & *E. coli*; apples & *Salmonella*; and tomatoes & *Salmonella*) were recommended for further investigation based on international data and export values.

5.3 Levels of *Escherichia coli* O157 in Lettuces and *Salmonella* in Apples

Based on the recommendations by Hudson & Turner (2002) as described above, a quantitative study was subsequently initiated to investigate the prevalence of *E. coli* O157:H7 on lettuce and *Salmonella* on apples (Wong, 2003). This study considered both conventionally and organically grown produce from a number of growers as summarised in Table 4.

Table 4: Summary of results for the examination of lettuces and apples for the presence of *E. coli* O157 and *Salmonella* respectively

Food/Hazard	Sample Number	Production	Varieties	Findings
Lettuce/*E. coli*	240 (48x5)	Conventional 22 growers	7	No *E. coli* O157:H7
Lettuce/*E. coli*	234 (46x5) + (1x4)	Organic 9 growers	13	*E. coli* O157:H16 isolated from 1 sample

Food/Hazard	Sample Number	Production	Varieties	Findings
Apples/ *Salmonella*	239	Conventional	8	No salmonellae isolated
Apples/ *Salmonella*	230	Organic	5	1 batch positive for *S.* Typhimurium DT12a

E. coli O157:H7 and salmonellae were not detected in 240 conventionally grown lettuces and 239 conventionally grown apples respectively. One organic lettuce sample (of 234 tested) did reveal *E. coli* O157:H16, but the isolate was later identified as non-verotoxigenic *E. coli* (non-VTEC) due to the absence of *stx*1, *stx*2 and *hly*A virulence genes. One batch of organic apples (from 230) was positive for *S.* Typhimurium DT12a (based on a pooled sample).

These survey results are in agreement with two similar organic lettuce surveys conducted in Northern Ireland and the U.S. by McMahon & Wilson (2001) and Mukherjee *et al*. (2004) respectively, although the sample numbers tested in both studies were much smaller than the New Zealand survey. Neither survey isolated *E. coli* O157:H7, although the U.S. survey demonstrated *E. coli* prevalence on organic lettuce at 24.4% (n=49) while prevalence on conventional lettuce was 16.7% (n=6). Prevalence was higher (30.8%) on uncertified organic farms using manure or compost less than 12 months old.

5.4 Review of non-commercial wild food in New Zealand

In 2004, ESR compiled a review assessing the potential for human exposure to foodborne hazards associated with the gathering and handling of wild foods (Turner *et al*., 2004). The sections of relevance here include the land plants, water plants, fungi and fruit. Campylobacteriosis featured most prominently in recorded food poisoning events, with two cases associated with the consumption of the land plant puha, seven cases possibly linked to the consumption of the water plant watercress, and one case linked to seaweed. Given that cross-contamination or other sources of infection could not be excluded, the true contribution of wild plants to foodborne illness is unclear. One case of salmonellosis was reportedly associated with collection of wild mushrooms, but this was attributed to environmental contamination rather than consumption. Bacterial pathogens were not assessed as important hazards in wild fruit (defined as berries, seeds and nuts).

5.5 Risk profile: *Listeria monocytogenes* in Ready-to-eat Salads

A risk profile commissioned by the NZFSA was conducted by Lake *et al*. (2005) to assess the risks associated with *Listeria monocytogenes* in ready-to-eat salads. These included lettuce and cabbage-based salads without dressings, and excluded coleslaws and salads with additional non-vegetable ingredients.

The risk profile indicated that invasive listeriosis rates in New Zealand are similar to other countries (at 0.5 – 0.6 per 100,000), and that no evidence currently exists to link RTE salads to *L. monocytogenes* infections. Due to the limited and dated domestic prevalence data available, overseas data were used suggesting a prevalence of up to 10% in RTE salads but at levels of less than 100 CFU/g. Under normal conditions of storage (4°C for 7 days), only a 1 to 2 log increase would be expected given the known behaviour of the pathogen at refrigeration temperatures. It was therefore concluded that RTE salads would be unlikely vehicles for infection in New Zealand, and that good agricultural practices and good manufacturing practices, in conjunction with microbiological testing already being done by the industry, are the best means of managing this risk.

It was noted that data on current prevalence, quantitative contamination levels, market size and structure, and consumption levels of RTE salads in New Zealand were lacking.

5.6 Risk Profile: Shiga-toxin Producing *Escherichia coli* in Leafy Vegetables

A more recent risk profile commissioned by the NZFSA was conducted by Gilbert *et al*. (2006) to assess the risks associated with STEC in leafy vegetables.

The risk profile noted that 91.5% of confirmed STEC infections in New Zealand in 2004 were due to *E. coli* O157:H7. Rates of infection in New Zealand are comparable to those of England and Scotland, lower than in Canada but higher than Australian data. Infections tend to be sporadic and no common source outbreaks had been detected. There are low shedding rates of *E. coli* O157 in cattle in New Zealand, although rates for other STECs are higher. Green leafy vegetables have not to date been linked to any domestic outbreaks and the importation of green leafy vegetables is a reportedly small component of the domestic market (although of the 259.2 tonnes of spinach imported from March 2002 to 2003, approximately a third was from the U.S. where more recent problems have come to light regarding *E. coli* O157 contamination (FDA, 2006b)).

Based on a 1998 FAO/WHO review, which suggested that microbial loadings are due to environmental factors rather than the type of vegetable, it was concluded that preventing contamination from animal faeces is a priority. This is particularly important given the limitations of chlorine washing and the internalisation of pathogens within plant tissues, rendering the organisms immune to the disinfection process.

Based on the information gleaned above, and the fact that *E. coli* O157:H7 has not been detected in surveys of domestic vegetables, it was concluded that green leafy vegetables are not an important risk for foodborne transmission of STECs in New Zealand. It was however noted that New Zealand data were limited in terms of prevalence and levels of STEC in green leafy vegetables, market size/structure and population levels of consumption

5.7 *Listeria monocytogenes* in Deli RTE Salads

This survey, undertaken by ESR on behalf of the NZFSA, is close to completion. Preliminary results to date indicate a 4.7% prevalence (14/297) of *L. monocytogenes* (predominantly serotype 1/2) in tested salads (personal communication, Dr TeckLok Wong, ESR). Of the 14 *L. monocytogenes*-positive salads, 12 were at levels of <10 cfu/g, while the other 2 (coleslaw) samples were found to have higher levels of 30 and 100 cfu/g. Based on the assumption that the coleslaw-type salads (4/14) were the only entirely vegetable-based salads, this reduces the prevalence of *L. monocytogenes* in RTE vegetable salads to 1.35%. The remainder had various ingredients including seafood, chicken, pasta or cooked potatoes/kumara.

These data are very similar to *L. monocytogenes* prevalence data of 4.8% and 3.8% respectively reported in a British survey of mixed raw vegetable salads containing cooked meat (76/1268) or cooked seafood (54/1418) (Little *et al*., 2005). Two salads containing chicken were found to have levels of ≥100 cfu/g *L. monocytogenes*, while all of the positive seafood salads were at levels <100 cfu/g. One salad in each category had between 10 and 99 cfu/g. As with the New Zealand RTE salads survey, a variety of other food ingredients (pasta, rice, mayonnaise, eggs, etc.) were included in these salads, therefore the actual source of *L. monocytogenes* contamination is impossible to speculate on.

5.8 Consumption Data

5.8.1 Fruits and vegetables

Table 5 summarises information from Food Balance Sheets (FBS) for fruits and vegetables consumed by New Zealanders. FBSs are maintained by the Food and Agriculture Organization of the United Nations (FAO; http://faostat.fao.org/) and represent the amounts of foods available for consumption, after considering production, importation and other uses. Information is presented in terms of the FAO food classification system. Data are from the most recent year for which FBS information is available (2004). Data are not presented for foods with a daily consumption level of less than 1 g/person.

Table 5: Food balance data on production, importation, exportation and consumption of fruits and vegetables in New Zealand

	Food Sources and Disposition (g/person/day)					
	Production	Import	Export	Feed and seed	Other net uses	Food consumption
Potatoes	350.89	18.45	74.96	45.71	41.39	207.27
Grapes (incl. Raisins, wine)	116.14	108.79	67.75	0	6.58	150.61
Apples	383.17	15.66	292.23	0	21.65	84.94
Tomatoes	61.76	33.88	12.33	0	7.61	75.69
Pumpkins, squash and gourds	109.48	1.21	55.45	0	5.54	49.69
Bananas	0	49.89	0.93	0	4.65	44.31
Peas, green	38.6	0.05	0	0	-0.3	38.93
Carrots and turnips	39.3	0	0.01	0	4.2	35.09
Cauliflowers and broccoli	38.25	0.06	0.1	0	3.83	34.38
Oranges	4.21	32.63	2.27	0	1.45	33.11
Pears and quinces	28.77	5.73	6.43	0	3.05	25.03
Onions (incl. shallots), green and ripe	169.83	0.46	128.3	0	18.58	23.41
Pineapples	0	22.86	0.89	0	0.2	21.76
Lettuce and chicory	21.76	0.08	0.15	0	2.19	19.5
Cabbages and other brassicas	21.05	0.04	0.27	0	2.11	18.72

	Food Sources and Disposition (g/person/day)					
	Production	Import	Export	Feed and seed	Other net uses	Food consumption
Fruit, nec (inc. persimm.)	18.58	4.6	3.15	0	1.38	18.66
Kiwi fruit	228.08	0.43	208.99	0	4.48	15.05
Sweet potatoes	11.23	0.39	0.05	1.15	0.01	10.39
Tangerines, mandarins and clementines	7.02	3.15	1.18	0	0.46	8.53
Apricots	3.23	5.94	0.92	0	0.27	7.98
Peaches and nectarines	5.26	3.21	0.52	0	0.65	7.31
Citrus fruit, nec	5.97	1.17	0.39	0	0.31	6.45
Mushrooms and truffles	5.97	0.98	0.31	0	0.59	6.05
Beans (incl. cow peas), dry	0	6.16	0.46	0	0.18	5.52
Plums and sloes	1.54	4.01	0.12	0	0.21	5.22
Avocados	9.97	0.23	4.5	0	0.51	5.18
Beans (incl. string beans), green	3.72	1	0.01	0	0.03	4.68
Strawberries	5.33	0.27	0.52	0	0.58	4.52
Cassava (fresh and dried)	0	11.38	0.14	0	6.79	4.45
Currants and gooseberries	4.29	0.02	0.15	0	0.23	3.94
Watermelons	1.83	1.67	0.01	0	0.37	3.12
Raspberries and other berries	2.73	0.02	0.04	0	0.01	2.69
Lemons and limes	2.6	1.12	0.88	0	0.18	2.67
Other melons (incl. cantaloupes)	0.74	2.15	0.27	0	0.3	2.3
Grapefruit and pomelo	1.12	1.24	0.11	0	0.1	2.15
Asparagus	2.81	0.06	0.65	0	0.14	2.08
Peas, dry	21.76	0.65	13.19	5.92	1.26	2.04
Garlic	1.05	0.77	0.34	0	-0.01	1.5
Leeks and other alliaceous vegetables	1.4	0	0.03	0	0.14	1.24
Spinach	1.35	0	0	0	0.13	1.22
Chillies and peppers, green	3.51	0.92	3.24	0	0.03	1.16
Cranberries, blueberries	1.4	0.08	0.33	0	0.04	1.12
Lentils	0.84	0.3	0.04	0	0.01	1.09

These data contain some anomalies, with the Food Balance Sheets suggesting that New Zealand imports significant amounts of cassava. Further investigation suggests that taro is included under this heading.

Table 6 contains a more detailed analysis of the most commonly imported fruits and vegetables for New Zealand, including information on the major countries providing those food items, for the year ending September 2005.

Table 6: Import quantities for some fruits and vegetables and major countries of origin, for the year ending September 2005

Food	Quantity imported (tonnes)	Major countries of origin (percent of total imports)
Fruit		
Bananas, fresh	75,677	Philippines (51), Ecuador (48)
Oranges, whole, fresh	13,475	U.S. (52), Australia (48)
Grapes, fresh	10,460	U.S. (42), Chile (32), Australia (26)
Pineapples, fresh	5,303	Philippines (>99)
Grapes, dried as sultanas	4,991	Turkey (89), Australia (9)
Melons, fresh	3,237	Australia (>99)
Grapes, dried as raisins	2,527	U.S. (41), Turkey (21), South Africa (16), Iran (14)
Watermelons, fresh	2,452	Australia (>99)
Mandarins, fresh or dried	2,155	Australia (83), U.S. (17)
Guavas, mangoes and mangosteens, fresh	2,040	Ecuador (33), Peru (33), U.S. (21)
Pears, European, fresh	1,907	Australia (53), U.S. (47)
Apricots, dried	1,856	Turkey (80), U.S. (6), South Africa (6)
Pears, other, fresh	1,528	Australia (48), China (47)
Vegetables		
Taro, fresh, chilled or dried	7,647	Fiji (94), Tonga (5)
Kidney beans, shelled, dried	6,684	Canada (94), China (5)
Tomatoes, fresh or chilled	4,004	Australia (>99)
Beans, fresh or chilled	1,467	Australia (90), China (4), Fiji (4)
Garlic, fresh or chilled	1,291	China (>99)
Capsicums	1,244	Australia (95), Fiji (4)

FBS's estimate the food **available** for consumption, which in some cases will differ significantly from the food consumed. The information in Table 7 is a consolidation of 24 hour dietary recall records from the 1997 National Nutrition Survey (Russell *et al*., 1999). Food Standards Australia New Zealand (FSANZ) (then ANZFA; ANZFA, 2001a) performed the analysis and a standardised set of recipes was used to convert composite foods to their raw commodity equivalents. The 'proportion of respondents consuming' is the percentage of the study population who reported eating the food in the previous 24 hour period and is indicative of the proportion of the New Zealand population who would consume the food in any given 24-hour period. The 'mean daily consumption' is a study population mean and includes both those who reported consuming the food and those who didn't. As for Table 5, the list of foods has been truncated at the 1 g/person/day level.

Table 7: Consumption of fruit and vegetables by adult (15+ years) New Zealanders, from 1997 National Nutrition Survey

Food	Proportion of respondents consuming (%)	Mean daily consumption, all respondents (g/day)	Estimate of proportion of servings consumed raw (%)*
Potato	67.8	117.9	0
Apple	36.3	58.2	90
Oranges, sweet, sour	23.9	53.8	100
Tomato	59.6	46.4	75
Grapes (including wine)			NA
- Wine	17.6	37.7	100
- Grapes (excluding	15.0	34.8	
wine)	3.3	2.8	
Banana	31.1	32.3	99
Carrot	47.6	19.5	22
Onion, bulb	63.8	15.5	17
Pumpkin	12.7	12.4	0
Pear	8.5	12.0	83
Garden pea, shelled	23.6	11.0	2
Cabbage, head	15.4	10.8	40
Sweet corn (corn on the cob)	25.4	8.0	0
Peach	7.1	7.9	25
Cauliflower	15.9	7.7	1
Lettuce, head	26.7	7.5	100
Broccoli	13.5	6.8	1
Sweet potato	5.9	6.6	0
Beans, except broad + soya	17.0	5.7	3
Lemon	15.7	5.4	3
Grapefruit	2.0	5.3	100
Pineapple	10.2	4.6	15
Kiwifruit	5.6	4.6	100
Nectarine	2.2	4.6	90
Beans (dry)	4.4	4.5	0
Mushrooms	14.5	4.4	10
Mandarin	3.0	4.3	99
Taro	1.0	4.3	0
Cucumber	18.2	4.1	100
Summer squash (courgette)	5.4	3.7	5
Soya bean (dry)	10.2	3.6	0

Food	Proportion of respondents consuming (%)	Mean daily consumption, all respondents (g/day)	Estimate of proportion of servings consumed raw (%)*
Dried grapes (sultanas, currants, raisins)	31.0	3.5	100
Currants, red, black, white	1.3	3.5	0
Apricot	8.2	3.5	35
Lime	4.0	3.0	100
Chard (silverbeet)	4.7	2.9	1
Peppers, sweet	11.1	2.3	50
Watermelon	0.5	2.3	100
Plums (including prunes)	4.0	2.3	65
Celery	14.9	2.1	60
Beetroot	6.5	2.0	3
Swede	5.2	2.0	0
Fungi, edible (not including cultivated)	89.1	1.9	0
Watercress	0.7	1.7	20
Avocado	2.2	1.5	100
Strawberry	2.6	1.5	100
Parsnip	2.7	1.4	0
Feijoa	1.1	1.3	86
Spinach	1.5	1.3	6
Brussels sprouts	1.4	1.1	0
Rhubarb	1.4	1.0	0

* For the purpose of this exercise, canned produce is considered to have been cooked. While fruit juices will often have undergone a pasteurisation process, they are classified as raw for this exercise

NA Not Applicable

A comparison was made of food consumption patterns for adults (15+ year, 1997 National Nutrition Survey) and children (5-15 years, 2002 Children’s Nutrition Survey). However comparisons are complicated by the fact that the two surveys not only study different population segments, but also look at them in different time frames. Consequently, some observed trends may represent true differences between adults and children, while others will represent changes in food consumption habits with time.

In general, children were less likely to consume fruits and vegetables. Exceptions to this general trend were for consumption of:

- Apples, consumed by 32% of children on the survey day, compared to 22% of adults.
- Mandarins, consumed by 8.4% of children, compared to 3.0% of adults.
- Oranges, consumed by 12.4% of children, compared to 9.1% of adults.
- Raisins, consumed by 2.4% of children, compared to 1.4% of adults.
- Potatoes, in the form of crisps (29% to 6%) or hot chips (24% to 15%), but not when eaten as potatoes (29% to 46%).

- Taro root (2.9% to 1.0%) and stalk (2.2% to 0.1%). These differences are as likely to be due to temporal trends and the over-sampling of Pacific Island groups in the CNS as to be due to actual differences.

The high proportion of respondents consuming potatoes in the NNS will include those consuming potato chips or crisps.

The 1997 NNS records indicate that salads (including green, lettuce, coleslaw, pasta, and other, excluding fruit salad) were consumed by 17.6% of respondents 15 years or older in the previous 24 hour period. Fresh fruit salads were consumed by 0.98% of respondents.

It is possible that the percentage of people consuming salads has increased since the NNS was conducted, given the increasing quantities of pre-prepared salads available in supermarkets and other outlets over the previous ten years.

5.8.2 Unpasteurised fruit juices

While pasteurised juices are capable of supporting the growth and/or survival of various microbial pathogens, unpasteurised juices are recognised as a more significant risk due to the absence of a thermal treatment designed to destroy pathogens. Pasteurised juices will therefore not be discussed in any significant detail in this document. In New Zealand, unpasteurised juices would likely originate from juice bars selling freshly squeezed juice products thus volumes are estimated to be minimal (probably < 1% of the total juice market volume). Simply Squeezed, Arano, McCoys and Charlies brands are all pasteurised, and any brands manufactured by Pinto are likely to be pasteurised (personal communication, Jacqui Dobbs, Danone). Kiwi Crush® kiwifruit concentrate is sold unpasteurised to avoid thermal destruction of heat-sensitive enzymes including Zyactinase® (naturally occurring digestive enzyme complex) during processing. However, it is stored in frozen form rather than refrigerated, with packaging instructions indicating the need to refrigerate and use within 5 days once thawed.

5.8.3 Sprouted seeds

Based on the NNS and CNS data, sprouts are consumed by 2.9% of adults and 0.4% of children in any given 24 hour period. The average daily consumption of sprouts by adults is 0.6 g/day and for children 0.1 g/day. The main sprout types consumed (in order from higher to lower consumption) are alfalfa>mung>other>snowpea.

These data only cover records where sprouts were explicitly identified so this may slightly underestimate overall consumption given that sprouts are often components of mixed foods such as salads, sandwiches, etc.

5.9 Overseas Risk Assessment Information

5.9.1 European Commission risk profile on the microbiological contamination of fruits and vegetables eaten raw

This document, published in 2002 by the Scientific Committee on Food, addresses the potential risks to consumers from microbiologically contaminated fruits and vegetables either eaten raw or as part of a ready-to-eat product.

An extensive range of bacterial, protozoan and viral pathogens were identified as concerns in produce in this document. These are similar to those pathogens previously listed in Table 1 for specific consideration in the New Zealand context, with the additional inclusion of Group A streptococci and *Vibrio cholerae*. *Toxoplasma gondii* was not considered, nor were the rotaviruses.

Commodities determined to be of most concern fell into three main groups: (i) the intact products; (ii) sprouted seeds; and (iii) RTE processed fruits and vegetables, including cut/sliced/skinned/shredded produce, fruit juices and minimally processed items such as chopped garlic and cabbage (coleslaw).

Some general commentary on outbreaks associated with raw produce was summarised including the following points:

- Most reported outbreaks tend to be bacterial in nature.
- Bacteria are mostly associated with intact products in contact with soil/water.
- A significant number of outbreaks associated with sprouted seeds and fruit juices have occurred. *Salmonella* & *E. coli* O157:H7 are particularly associated with these outbreaks.
- Protozoan outbreaks are more commonly associated with fruits than vegetables.
- Protozoa and viruses are more often linked with contaminated water or food handlers.

A number of issues and data gaps were raised such as:

- The actual proportion of reported outbreaks is low despite the potential for contamination to occur in a wide range of products (however outbreak numbers appear to be on the rise more recently);
- The frequency of pathogens on raw fruits and vegetables is highly variable from study to study;
- Potential contamination via organic farming should be examined;
- The impact of increasing availability and consumption of imported ‘exotic’ spices, herbs and vegetables (specific types undefined);
- Efficacy of disinfecting/sanitising agents is variable;
- Traceability of origin needs to be improved;
- Lack of epidemiological data;
- Lack of data on pathogen survival in products and in irrigation waters & manure;
- Effective decontamination methods required for manure, sludge and irrigation water.

6 RISK CHARACTERISATION

6.1 Adverse Health Effects in New Zealand

Determination of the burden of illness due to pathogens in produce would require information on the incidence of illnesses caused by the pathogens identified in Table 1, and attributable fractions to food generally and produce in particular. The following summarises the limited information available on these topics.

6.1.1 Incidence of disease

New Zealand reported rates of notifiable diseases caused by pathogens in Table 1 (Section 2) as produce-related hazards from 2001 to 2006 (ESR, 2001 – 2006) are shown in Table 8. The highest rate of bacterial infection was attributed to campylobacteriosis, followed by salmonellosis and yersiniosis.

The two notifiable protozoan diseases listed, cryptosporidiosis and giardiasis, had higher rates of infection than several of the bacterial diseases listed including *E. coli* (VTEC/STEC), listeriosis, shigellosis and yersiniosis. However, the proportion of foodborne cases is not known.

The only notifiable viral disease of significance to produce, Hepatitis A, had fairly consistent low rates of infection with the exception of a significant increase in 2002 related to an outbreak associated with the consumption of raw berries (see section 6.2 for further details of this outbreak).

Table 8: Rates of infection per 100,000 (and case numbers) for selected notifiable diseases in New Zealand 2001 – 2006

Disease	2001	2002	2003	2004	2005	2006
Botulism	0	0	0	0	0	0
Campylobacteriosis	271.5 (10,148)	334.2 (12,489)	395.6 (14,786)	326.8 (12,213)	370.3 (13,839)	383.5 (15,873)
E. coli infection (VTEC/STEC)	2.0 (76)	2.0 (73)	2.8 (105)	2.4 (89)	2.2 (92)	2.1 (87)
Listeriosis	0.5 (18)	0.5 (19)	0.6 (24)	0.7 (26)	0.5 (20)	0.5 (19)
Salmonellosis	64.7 (2417)	50.0 (1870)	37.5 (1401)	28.9 (1080)	37.0 (1383)	32.3 (1335)
Shigellosis	4.2 (157)	3.0 (112)	2.3 (87)	3.7 (140)	4.9 (183)	2.5 (102)
Yersiniosis	11.5 (429)	12.7 (476)	11.7 (439)	11.2 (420)	10.9 (407)	11.8 (487)
Cryptosporidiosis	32.3 (1207)	26.1 (974)	21.9 (818)	16.4 (612)	23.8 (889)	17.8 (736)
Giardiasis	42.9 (1603)	41.4 (1548)	42 (1569)	40.5 (1515)	32.9 (1230)	29.3 (1214)
Hepatitis (A)	1.6 (61)	2.9 (108)	1.9 (70)	1.3 (49)	1.4 (51)	2.9 (122)

For non-notifiable diseases the data are extremely limited. No data are available on infections with *Aeromonas* and *Cyclospora*. The incidence of intoxications by *B. cereus*, *C. perfringens* and *S. aureus* can only be estimated from reported outbreaks (ESR, 2008). Outbreaks of a number of other relevant pathogens are also reported. The numbers of reported outbreaks in 2007 (ESR, 2008) are listed in Table 9:

Table 9: Outbreaks and case numbers for selected non-notifiable diseases in New Zealand in 2007

Pathogen	Outbreaks	Cases	Foodborne outbreaks	Foodborne cases
Norovirus	206 (41.9%)	5902 (73.9%)	10 (13.5%)	35 (5.7%)
Rotavirus	5 (1.0)	69 (0.9%)	0	0
Cryptosporidium spp.	29 (5.9%)	102 (1.3%)	0	0
Giardia spp.	21 (4.3%)	111 (1.4%)	1 (1.4%)	6 (1.0%)
Salmonella spp.	8 (1.6%)	141 (1.8%)	7 (9.5%)	56 (9.2%)
Campylobacter spp.	20 (4.1%)	111 (1.4%)	12 (16.2%)	35 (5.7%)
VTEC/STEC	6 (1.2%)	13 (0.2%)	2 (2.7%)	4 (0.7%)
B. cereus	1 (0.2%)	51 (0.6%)	1 (0.2%)	51 (0.6%)
C. perfringens	13 (2.6%)	87 (1.1%)	12 (16.2%)	83 (13.6%)
S. aureus	2 (0.4%)	6 (0.1%)	1 (1.4%)	2 (0.3%)

These data are incomplete, as sporadic cases are not included and thus the foodborne proportion may not be indicative of the illness as a whole.

Fresh produce was associated with 12 (16.2%) of all foodborne outbreaks in 2007, including 111 (18.2%) of foodborne cases. This was the third most common food vehicle, after poultry and meat (ESR, 2008).

Information gathered from discharge records of publicly funded hospitals in New Zealand between 2000 and 2006 show 84 cases of (non-congenital) toxoplasmosis but it is impossible to comment further on the role of foods in transmission (Lake *et al*., 2008). The rate of infection by norovirus is also difficult to estimate. A recent estimate was 1,700 - 24,300 cases per 100,000, with a mean of 10,000 per 100,000 population (Cressey & Lake, 2007). A recent rotavirus study in Auckland amongst hospitalised children aged 0 to 4 years of age found a rate of 146 cases per 100,000 in this age group (Neuwelt & Simmons, 2006).

6.1.2 Attributable fraction

The proportion of these illnesses that can be assigned to foodborne transmission is very uncertain. Two estimates from overseas are summarised in Table 10 (Mead *et al*., 1999; Hall *et al*., 2005).

Table 10: Overseas estimates of the food attributable proportion of selected microbial diseases

Illness/hazard	USA % Foodborne	Australia % Foodborne
Bacterial		
Bacillus cereus	100	100
Campylobacter spp.	80	75
Clostridium perfringens	100	100
E. coli O157:H7	85	65
Listeria monocytogenes	99	NE
Salmonella non-typhoidal	95	87
Shigella spp.	20	10
Staphylococcus food poisoning	100	100
Yersinia enterocolitica	90	75
Parasitic		
Cryptosporidium parvum	10	10
Giardia lamblia	10	5
Viral		
Hepatitis A	5	NE

NE = not estimated

A New Zealand expert elicitation process provided the data shown in Table 11. The large variation in the estimated most likely value reflects the uncertainty for many illnesses.

Table 11: Proportion of disease due to foodborne transmission – summary of expert opinion, May 2005

Disease	Most Likely (%)		
	Min	Mean	Max
Bacillus intoxication	90	97.4	100
Campyobacteriosis	30	57.5	80
Listeriosis	50	84.9	100
Norovirus infection	10	39.6	60
Salmonellosis	20	60.7	80
STEC infection	5	39.6	95
Toxoplasmosis	3	31.5	80
Yersiniosis	40	56.2	90

6.1.3 Discussion

The above information allows only qualitative indications of the burden of illness from produce. Despite the high incidence of viral and parasitic infections by pathogens associated with produce, the indications from New Zealand reported outbreaks and expert estimations from New Zealand and overseas, are that foodborne transmission is less important than other transmission routes (e.g. person to person and waterborne). The exception is norovirus, where the high estimated rate would make this an important illness even if fresh produce related illnesses (possibly from infected foodhandlers) were even a small proportion of the burden.

The data suggest that for bacterial pathogens foodborne transmission is more important. Certainly New Zealand has rates of illness that are similar or higher than comparable countries for most bacterial illnesses, and foodborne transmission is considered generally to be the most important route. However, the importance of fresh produce within the foodborne proportion cannot be estimated from the data above.

6.2 Outbreaks of Foodborne Illness Potentially Associated with Fresh Vegetables and Fruits in New Zealand

The outbreak module of EpiSurv (from 1997 to 2008) was investigated for foodborne outbreaks that included mention of fresh (raw) fruits, vegetables or salads as either a suspected or confirmed vehicle. Only one confirmed outbreak associated with the consumption of raw berries was found. A large number of additional outbreaks were identified but the food vehicles suspected were predominantly of a "mixed" nature, foods usually containing poultry, red meat or seafood, accompanied by salad(s). In many cases it was unclear as to the nature/composition of the salad in question. The vast majority of outbreaks are therefore likely to be associated with non-produce items, or a consequence of cross-contamination rather than a direct contribution from a contaminated produce item. This clearly makes further analysis of these data very difficult.

The 2002 raw blueberries outbreak was responsible for 43 cases of Hepatitis A infection associated with consumption of fruit originating from a single orchard. A site investigation identified a number of likely causes including inadequate hand washing facilities (no running water, soap or hand towels), bare hands picking (i.e. no gloves) and the presence of a child on the farm who later developed symptoms consistent with a Hepatitis A infection (Calder *et al*., 2003). In the aftermath of this outbreak, hand sanitisers (alcogel) were introduced into berry orchards and industry levies were rebated to companies setting up and using HACCP-based programmes (personal communication, Greg Furniss, Blueberries NZ).

Three additional outbreaks associated with *Giardia*, *Salmonella* and VTEC also have possible (but unconfirmed) links to contamination events occurring at the grower/farm level consistent with breakdowns in good agricultural practices (GAP). The outbreak of giardiasis in the Tauranga area was associated with the consumption of home grown salad vegetables fertilised with animal (possibly sheep) manure, but given the nature of this outbreak, only three cases were identified within the same family. An investigation of this outbreak revealed a lack of awareness regarding the application of manure to avoid contact with the edible portions of vegetables (personal communication, Anika Davies, Toi Te Ora Public Health). The *Salmonella* Saintpaul outbreak in Auckland and Waikato was linked to the consumption of uncooked carrots grown in Ohakune, which had been washed in stream water by the producer. The stream water was later shown to have high coliform counts, although *Salmonella* Saintpaul was not isolated from tested waters at this stage (Neuwelt *et al*., 2006). This was a larger outbreak with 19 notified cases.

A recent investigation of an outbreak of VTEC affecting 14 individuals on the North Island identified a combination of foods potentially implicated in disease including deli sandwiches (with lettuce), washed carrots, sliced ham and chicken eaten outside the home (personal communication, Maurice Wilson, ESR). The fact that three cases were vegetarians initially suggested that produce may have been involved but due to an inability to isolate *E. coli* O157 from various food samples including carrots and lettuce it was concluded that cross-contamination or another unidentified source was responsible. Interestingly, it was discovered during the investigation that stream water (post-use) from a carrot farm contained high levels of generic *E. coli*. In addition, stream water tested pre-use was found to be positive for *E. coli* O157, although the PFGE pattern was different to that of the outbreak strain. The water was not chlorinated prior to use, and was reportedly sourced from an open stream in a dairy farming area. Although carrots were eventually eliminated from final multivariate modelling of food exposures, the presence of *E. coli* O157 in a non-chlorinated water source being used to wash raw produce shares similarities with the *S.* Saintpaul outbreak previously described.

It is difficult to comment further on the New Zealand outbreak data available as there are a number of issues that make it difficult to definitively attribute sources of infection. It has also been recognised that a lack of consumer awareness regarding fresh vegetables and fruits as transmission vehicles may also contribute to incorrect attribution. This assertion has been described in a recent report of consumer concerns regarding food safety associated with fruits and vegetables surveyed in Northern Ireland and the Republic of Ireland (*Safe*food, 2007). In this report, these consumers perceived fruits and vegetables as "one of the healthiest and also the safest food categories". Only after more intense questioning were concerns raised regarding farming/production practices (mainly in relation to the perceived use of chemicals and genetic modification leading to long term illnesses such as cancer). However, most claimed that there was little risk associated with washed fruits and vegetables, and food safety practices in the home were not perceived to be an issue. When prompted regarding specific microbiological risks (e.g. *Salmonella*, *E. coli*, Hepatitis A), consumers were unaware of their association with produce, linking them instead to meat and poultry items (*Safe*food, 2007). It is therefore possible that a similar lack of awareness exists in New Zealand, resulting in attribution of illness to food products perceived to be more risky, e.g. poultry.

6.3 Food Recalls Associated with Fresh Vegetables and Fruits in New Zealand and Australia

No recalls listed on the Consumer website (www.consumer.org.nz) for the period January 2003 – present have been produce-related. A delicatessen salad recall was initiated in March 2004, but all salads (two of which were potato-based) contained ham identified as the source of *L. monocytogenes*. Further information could not be obtained from the NZSFA website.

Australian recall information archived on the Food Standards Australia New Zealand website (www.foodstandards.gov.au) lists one recent recall (February 2006) of several varieties of sprouts (mainly alfalfa, onion & salad sprouts as well as bean shoots and mung beans) due to *Salmonella* contamination. An earlier recall, involving *Salmonella* Havana contamination of alfalfa sprouts, was initiated in October 2003 (personal communication, Maureen Wempe, FSANZ).

6.4 Overseas outbreaks – data and contributing factors

Outbreaks of foodborne illness associated with the consumption of salads, fruits and vegetables in Australia (Dalton *et al.*, 2004), England and Wales (Hughes *et al.*, 2007), and the U.S. (Bean *et al*., 1996; Olsen *et al.,* 2000; Lynch *et al.,* 2006) are summarised in Table 12. It should be noted that reporting parameters are slightly different depending on the country and the time of reporting, which obviously complicates any comparisons of data between countries. For example, U.S. reporting has changed from grouping fruits and vegetables as a single vehicle of transmission (from 1988 – 1997) to splitting these into two groups: (i) vegetables and (ii) fruits and nuts (1998 – 2002).

Table 12: Summary of notified outbreaks associated with the consumption of vegetables, fruits or salads in Australia, England & Wales, and U.S.

	Reporting period	Vegetables	Fruits	Salads	Total	% of total foodborne outbreaks
Australia	1995 – 2000	1	3	12	16	7.5
England & Wales	1992 – 2003	96			96	8
U.S.	1998 – 2002	192	87[a]	NR[c]	279	4.2
U.S.	1988 – 1997	130[b]		173	303	5.9

[a] May also include data on nut-related outbreaks
[b] Excludes reported data on mushrooms (likely to be canned rather than fresh)
[c] Not reported due to changes in food vehicle reporting

In addition, the reporting of salad-related outbreaks has been handled quite differently in the U.S. where outbreaks associated with potato salads and poultry, fish and egg salads have been reported separately from the total salads data. This means that the other countries may be over representing the contribution of potato, pasta and meat-containing salads in this category, and as a consequence falsely increasing the percentage of total outbreaks attributed to fresh produce overall.

England and Wales, and Australia have the highest reported rates of 8 and 7.5% of total outbreaks associated with produce, while the U.S. rates range from 5.9% to 4.2%. However, due to differences in reporting parameters, caution should be exercised regarding international comparisons.

Summaries of overseas outbreaks have been consulted in the construction of the next sections. These are not necessarily representative of all outbreak data available and in the case of Harris *et al.* (2003) do not report beyond 2000. However, they serve to highlight the key produce vehicles, pathogens and factors contributing to produce-related foodborne illness.

6.4.1 Vegetable-related outbreaks

Microbial food safety issues in vegetables overseas have centred on the consumption of contaminated lettuce or salad. Table 13 summarises examples of overseas outbreaks associated with the consumption of various vegetables and herbs (from Harris *et al*., 2003; Sivapalasingam *et al*., 2004; Ethelberg *et al*., 2005; FDA, 2006b; FDA, 2006c).

Table 13: Examples of overseas produce-related outbreaks of illness associated with the consumption of raw vegetables and herbs

	Cabbage	Carrots	Garlic	Green onions	Lettuce / Salad	Herbs
C. jejuni					2 / 0	
C. botulinum	1	1	2			
C. perfringens					1 / 0	
C. parvum		1		1		
C. cayetanensis					2 / 0	1
E. coli O157	1	1			5 / 2	
Giardia					1 / 1	
Hepatitis A		1		1	2 / 5	
L. monocytogenes	1					
Noroviruses					3 / 6	
Salmonella spp.					3 / 7	
Shigella spp.				1	2 / 6	1
Vibrio cholerae	1				1 / 0	
Y. pseudotuberculosis		1			1 / 0	
Unknown		1			8 / 49	

Lettuce and salad have predominated in terms of both the number of outbreaks and the diversity of pathogens implicated in these outbreaks. This is not surprising given the potential for contamination of vegetables during growth, particularly leafy vegetables with large edible surface areas, and opportunities for cross-contamination prior to consumption, particularly for more heavily handled items such as herbs (Aycicek *et al*., 2006). A pre-harvest evaluation of *E. coli* on organic lettuce produced on farms in Minnesota, U.S. using animal manure estimated prevalence at 22.4%, higher than any other produce type tested (Mukherjee *et al*., 2004). Data from a longitudinal survey investigating organic, semiorganic and conventionally farmed produce also found that product type was important, and was more likely to influence contamination than the type of production (Mukherjee *et al*., 2006). Lettuces, leafy greens and cabbages were found to have significantly higher levels of *E. coli* than other products.

Based on a review of fresh produce outbreaks in the US from 1973 to 1997 (Sivapalasingam *et al.*, 2004), 33 outbreaks reported during this period were associated with the consumption of lettuce. Of these, bacterial, viral and protozoan pathogens were identified in 25 outbreaks. In an outbreaks summary table compiled and published on-line in 2006 by Doug Powell at the Food Safety Network (www.foodsafetynetwork.ca), 28 outbreaks of *E. coli* food poisoning have been reported in North America since 1993 (some of which will have already been included in Table 13). Nineteen of the outbreaks were caused by *E. coli* O157:H7 with two outbreaks associated with spinach, seven with salad and ten with lettuce.

A number of contributing factors regarding 19 outbreaks associated with raw lettuce or salads have been reported (Harris *et al*., 2003) and are summarised in Table 14. In a few instances more than one contributing factor was reported, therefore the number of outbreaks does not add up to 19 in total.

Table 14: Factors contributing to 19 overseas outbreaks of foodborne illness associated with consumption of raw lettuce and/or salads (1970 –1998)

Contributing factors to outbreaks	Number of outbreaks	Pathogens involved
Cross-contamination (chopping boards, food handlers, other foods e.g. meat)	8	*C. jejuni* (x2), Calicivirus, *E. coli* O157:H7 (x2), Hepatitis A, *S. sonnei*, *Giardia*
Improper washing	2	Calicivirus, *Giardia*
Poor food storage	1	*C. jejuni*
Already spoiled	1	*E. coli* O157:H7
Contaminated water/compost (farm level)	2	*E. coli* O157:H7, *V. cholerae*
Cattle in grower fields	1	*E. coli* O157:H7
Unknown/not stated	7	*C. perfringens*, *C. cayetanensis*, *E. coli* O157:H7 (x2), Hepatitis A, *S. sonnei* (x2),

Cross-contamination, mainly via food handlers or other foods either directly (e.g. meat) or indirectly (e.g. via contaminated chopping boards), was the predominant contributing factor reported by Harris *et al*. (2003) and was implicated in eight out of 19 outbreaks. However, for seven outbreaks, the source of contamination and any other contributing factors were either unknown or not stated. Contributing factors associated with farm-level contamination (via water, compost or cattle) were only identified in three outbreaks and all were bacterial in nature. It is highly likely that the occurrence of contamination at the farm level is underrepresented, mainly due to the difficulties associated with identifying problems at this level and possible traceability issues.

These, and additional issues such as large production, increasing consumption, diverse and complex processing and distribution, and extensive international trade have resulted in the highest prioritisation of leafy green vegetables (lettuce, spinach, cabbage, chicory, leafy fresh herbs and watercress) as the produce commodity of greatest concern at a recent expert meeting convened by the FAO and WHO (FAO/WHO, 2008). Green onions were ranked as a level 2 priority, while carrots, cucumber, onions, garlic and celery were all considered level 3 priorities.

A generic survey of RTE organic vegetables in the United Kingdom in 2001 found that the majority of samples tested (3185/3200; 99.5%) were of satisfactory or acceptable quality based on the absence of *L. monocytogenes*, *Salmonella*, *Campylobacter* and *E. coli* O157, and the absence or low prevalence of *E. coli* and *Listeria* spp. (Sagoo, Little & Mitchell, 2001). The unsatisfactory results were related to levels of *E. coli* and *Listeria* spp. in excess of 10^2 cfu per gram. Conventionally grown produce were not considered. An Australian survey of domestic and imported vegetables tested 292 samples of 19 different types but did not isolate *Campylobacter*, *E. coli* O157 or *Salmonella* (Anon, 2005b). Based on FSANZ guidelines for the microbiological examination of ready-to-eat foods, ten unsatisfactory results due to *E. coli* (≥100 CFU/g) or *B. cereus* (10^3 – 10^4 CFU/g) were recorded for locally grown garlic, onions, spinach, sweet potatoes and turnips and imported snow peas and sweet corn. Only one potentially hazardous result was obtained for locally grown spinach (≥10^4 CFU/g *B. cereus*). *L. monocytogenes* was detected at a marginal level of <10^2 CFU/g in one sample of mushrooms (of unknown origin).

6.4.2 Fruit-related outbreaks

Fruit-related outbreaks have typically involved the consumption of unpasteurised fruit juices, cut fruits and raw or frozen berries. Reported outbreaks of foodborne illness overseas associated with the consumption of unpasteurised fruit juices date as far back as 1898, but became more frequently reported in the 1990s. Most of these outbreaks have occurred in the U.S., where it is estimated that about 2% of all juices sold are unpasteurised (Zhao, 2005).

6.4.2.1 Unpasteurised fruit juices

The most commonly reported illnesses associated with unpasteurised juices involve the pathogens *E. coli* O157:H7, *Salmonella,* and the protozoan *Cryptosporidium parvum* (Table 15). The majority of the outbreaks listed in this table have been linked to either (i) the use of fruit dropped in orchards where cattle or other animals had previously grazed, (ii) contaminated water or (iii) poor sanitation practices (ANZFA, 2001b; Harris *et al*., 2003).

Table 15: Reported foodborne disease outbreaks associated with unpasteurised fruit juices

Pathogen	Year	Fruit Source	Outbreak Location(s)	Juice Type	Cases	Deaths
C. parvum	1996	U.S.	U.S.	Apple	20(c)[a] + 11(s)[b]	0
Cryptosporidium	1993	U.S.	U.S.	Apple	160 primary 53 secondary	0
E. coli O157:H7	1999	U.S.	U.S.	Apple	7	0
E. coli O157:H7	1998	Canada	Canada	Apple	14	0
E. coli O157:H7	1996	U.S.	U.S.	Apple	14	0
E. coli O157:H7	1996	U.S.	U.S.	Apple	6	0
E. coli O157:H7	1996	U.S.	U.S. & Canada	Apple	70	1
Enterotoxigenic *E. coli*	1992	India	India	Orange	6	0
E. coli O157:H7	1991	U.S.	U.S.	Apple	23	0
E. coli O157:H7	1980	Canada	Canada	Apple	14	1
S. Agona	1992	U.S.	U.S.	Orange	25	0
S. Enteritidis	2000	U.S.	U.S.	Citrus	14	0
S. Gaminera, *S.* Hartford & *S.* Rubislaw	1995	U.S.	U.S.	Orange	62	0
S. Meunchen	1999	Mexico	U.S. & Canada	Orange	207(c) + 91(s)	1
S. Typhi	1922	France	France	Apple	23	0

Pathogen	Year	Fruit Source	Outbreak Location(s)	Juice Type	Cases	Deaths
S. Typhi	1898	France	France	Apple	NR[c]	NR
S. Typhimurium	1999	Australia	Australia	Orange	502	0
S. Typhimurium	1974	U.S.	U.S.	Apple	296	0
Shigella flexneri	1995		South Africa	Orange	NR	NR

[a] (c): confirmed
[b] (s): suspected
[c] NR: not reported

Two orange juice outbreaks, associated with Norwalk-like virus (NLV) and *S*. Typhimurium contamination respectively, have occurred in Australia. The 1991 NLV outbreak, which affected over 3000 people, resulted from juice reconstituted with contaminated water, while contamination of oranges in a packing shed (via the fungicide used in fruit dipping) was responsible for the 1999 outbreak of salmonellosis (ANZFA, 2001b). A further three outbreaks of Hepatitis A and typhoid fever, associated with the consumption of reconstituted orange juice, have also been documented overseas (Harris *et al*., 2003). Food handlers were implicated in all of these. The source of a large outbreak in 1965, causing 563 cases, was suspected to be contaminated water but the causative agent was not identified.

While juice-associated outbreaks have not been reported in New Zealand, it is acknowledged that "fresh" unpasteurised juices are readily available to consumers, mainly via retail juice bars. Unlike large juice manufacturers however, these juicing operations operate under the terms of the New Zealand Food Hygiene Regulations (1974) and are inspected for compliance by Environmental Health Officers from local authorities. In this situation, the safety of the juice products produced is directly related to the use of good quality fruit, good food handling practices and effective cleaning of equipment. Long-term storage of such juices would not be anticipated given the nature of sale.

A risk assessment of fruit and vegetable juices has been conducted by ANZFA (2001b). This report concluded that "any fruit or vegetable juice may contain a physical, chemical or microbiological hazard. However, juice is more likely to contain a microbiological hazard and untreated juices are more likely to be the source of such a hazard than treated juices. While there is a low probability of untreated juice being contaminated with dangerous pathogens, if it is, the consequences can be severe for at risk groups and in extreme cases death could occur."

Several microbiological surveys of unpasteurised juices have also been conducted. A survey commissioned by the Food Safety Authority of Ireland (FSAI, 2002) reported that 100% of unpasteurised juice samples were free of detectable *Salmonella*, *E. coli* O157 and *L. monocytogenes* (n=67). A similar survey by the United Kingdom Food Standards Agency (Little & Mitchell, 2002) established that 100% of samples (n=291) were acceptable (290) or satisfactory (1) based on RTE microbiological guidelines for Enterobacteriaceae, *E. coli* (including O157), *Listeria* spp. (including *L. monocytogenes*) and *Salmonella* spp.

Increasing consumption of "freshly squeezed" unpasteurised juices from juice bars and other retail outlets was a driver for a similar microbiological survey in Victoria, Australia

(Anon, 2005a). A range of juice samples (apple, orange, carrot, celery, cantaloupe, watermelon, wheatgrass and mixed) were collected from various retail outlets (e.g. juice bars, cafes, takeaways and health food shops), and analysed for *E. coli*, *L. monocytogenes*, *Salmonella* spp. and coagulase-positive staphylococci (n=291). The pH of juices was also measured. Results were then compared to guidelines for ready-to-eat foods. The survey found that seven juice samples contained *E. coli*, with one sample each of cantaloupe (pH 4.06) and wheatgrass (pH 5.58) juice at unsatisfactory levels of 110 cfu/mL. Nine juice samples contained *Listeria*, one of which (celery juice; pH 5.75) was assessed as potentially hazardous with an *L. monocytogenes* level of >25,000 cfu/mL. None of the samples contained salmonellae, and all were deemed satisfactory for coagulase-positive staphylococci with undetectable levels less than 100 cfu/mL.

The pH data collected showed values ranging from 3.0 to 6.66, with fairly large variations within juice types. For example, apple juices ranged in pH from 3.0 to 4.68, while carrot juice samples varied from 3.56 to 6.66. Wheatgrass had the highest mean pH value of 5.76 and all samples analysed were greater than pH 5.11. Mixed juices also varied dramatically in pH, from 3.22 to 6.45, related to the volumes and types of juices used. Two of the three juices described above as unsatisfactory or potentially hazardous had pH values of 5.58 and 5.75.

6.4.2.2 Whole and cut fruits

Reported outbreaks of foodborne disease associated with whole or cut fruits have been predominantly associated with berries, tomatoes and melons (Harris *et al*., 2003; Sivapalasingam *et al*., 2004; FDA, 2006c), all of which have recently been given a level 2 priority ranking behind leafy greens (FAO/WHO, 2008). Examples of overseas outbreaks are summarised in Table 16.

Table 16: Examples of overseas produce-related outbreaks of illness associated with the consumption of whole or cut fruits

	Raw berries	Frozen berries	Melons	Tomatoes
C. cayatenensis	5			
E. coli O157			1	
Hepatitis A		4		1
Norovirus		2	1	
Salmonella			10	4
Shigella			1	
S. aureus	1			

Outbreaks attributed to raw or frozen berries have predominantly been associated with viral or protozoan contamination (as previously mentioned in Section 2) while *Salmonella* contamination has more commonly caused outbreaks associated with melons and tomatoes. Two salmonellosis outbreaks in Australia in 2006 were reported to be the result of consumption of rock melon and pawpaw respectively (OzFoodNet, 2007). As previously discussed, melons in particular have pH values higher than other fruits and are therefore more likely to support the survival and growth of bacterial pathogens on cut surfaces.

Microbiological surveys of fresh-cut fruit have been conducted overseas. A United Kingdom survey (Little & Mitchell, 2002) established that 7.8% of samples (78/997) were positive for *L. monocytogenes*. Of these, one melon sample was deemed of unacceptable microbiological quality due to *L. monocytogenes* at a level of 260 cfu/g. Three samples (0.3%) were also unsatisfactory based on high *E. coli* levels but *Salmonella* spp.and *E. coli* O157 were not detected. A similar survey commissioned by the Food Safety Authority of Ireland (FSAI, 2002) reported combined results for both pre-cut fruits and vegetables so comparisons with the U.K. survey are more difficult. *L. monocytogenes* was detected in 4.1% (21/513) of samples *Salmonella* spp. were present in 0.19% (1/529) samples and *E. coli* O157:H7 was undetected in 148 samples.. As with the U.K. survey, one (unidentified) sample was contaminated with *L. monocytogenes* at a level greater than 100 cfu/g. Based on their own comparison with the U.K. survey results, the Irish authors concluded that there was no significant difference in *Salmonella* data, but a significant difference ($p<0.05$) was noted for *L. monocytogenes.* However, it should also be noted that two of the 21 *L. monocytogenes*-positive samples from the Irish study were not tested quantitatively.

An Australian survey of domestic and imported fruits tested 199 samples of 20 different types but did not isolate *Campylobacter*, *E. coli* O157 or *Salmonella* (Anon, 2005b). Based on FSANZ guidelines for the microbiological examination of ready-to-eat foods, three unsatisfactory results due to *B. cereus* (10^3 – 10^4 CFU/g) were recorded for imported kiwifruit and locally grown peaches. *L. monocytogenes* was detected at a marginal level of $<10^2$ CFU/g in one sample of locally grown pineapple.

A recent risk assessment of pathogens associated with fresh fruits (Bassett and McClure, 2008) has made a number of generic recommendations for fruit related to fruit quality, prevention of recontamination following washing and the use of good hygienic practices during growth and harvesting. In particular it was recommended that fruit be dried after washing if its use was not immediate, and stored at ≤ 4°C for no more than four days if fruit has a pH > 4.0. Additional freezing, irradiation or heating was recommended for aggregate fruits (such as raspberries and blackberries) due to the difficulties associated with removal of protozoa.

6.4.3 Sprout-related outbreaks

Sprouts can be contaminated with pathogens via seed contamination, contaminated irrigation water or as a consequence of the sprouting process conditions where a moist environment and warm temperatures are particularly conducive to growth of a variety of pathogens (Saroj *et al*., 2006a). As a result, a number of outbreaks have been reported internationally and sprouts have been ranked as a level 2 priority behind leafy green vegetables in terms of fresh produce safety (FAO/WHO, 2008). Harris *et al.* (2003) reported examples of 24 outbreaks of *B. cereus*, *E. coli* O157, *Salmonella* and *Y. enterocolitica* associated with the consumption of sprouts. Of these outbreaks, *Salmonella* contamination accounted for 18 outbreaks (75%), with *E. coli* O157 implicated in four (17%).

A survey of sprouts grown and sold in India also identified *Salmonella* as the most prevalent contaminant in a variety of sprout types, ranging in prevalence from 4 – 40% (Saroj *et al*., 2006a). Overall, sprouts were of poor quality with total aerobic counts ranging from 7.6 to 8.9 $\log_{10}$ cfu/g, and coagulase-positive staphylococci from 3.3 to 6.6

log_{10} cfu/g. However, *L. monocytogenes* and *E. coli* O157:H7 were not detected. In the U.K. survey of unpasteurised juices, cut fruits and sprouted seeds discussed previously (Little & Mitchell, 2002), sprouts had the lowest percentage of satisfactory results (776/808; 96.1%) and the highest number of unsatisfactory results (16/808; 1.9%) of the three categories tested. One sample (0.1%) was deemed unacceptable due to the presence of *L. monocytogenes* at a level of 100 cfu/g. The equivalent Irish survey reported that all sprout samples were satisfactory for *Salmonella* spp., *E. coli* O157:H7 and *L. monocytogenes* but only 27 samples were tested (FSAI, 2002).

While outbreaks were not reported in relation to this work, a survey investigating the occurrence of parasites in fruits and vegetables in Norway identified mung bean sprouts as significantly more likely to be contaminated with *Giardia* cysts or *Cryptosporidium* oocysts than other produce items tested (Robertson & Gjerde, 2001). Contamination was linked to the irrigation water used for sprouting. A subsequent risk assessment predicted that about 20 cases of infection could occur per 100,000 population following consumption of sprouts contaminated with protozoa at levels similar to those found in the 2001 survey report (Robertson *et al*., 2005).

7 RISK MANAGEMENT INFORMATION

7.1 Relevant Food Controls – New Zealand Codes of Practice and other pertinent information

7.1.1 New Zealand GAP

At the farm level, safe produce can be achieved by adhering to good agricultural practices (GAP). In New Zealand this programme, formerly known as the New Zealand Fresh Produce Approved Supplier Programme, is now known as New Zealand GAP. This quality assurance programme is administered by Horticulture New Zealand and covers grower-level production, packaging and distribution of fruits and vegetables (as well as flowers). It is audited once a year by AsureQuality New Zealand. It does not however address activities by processors in terms of fresh-cut produce, sprouted seeds, etc.

New Zealand GAP addresses the following areas:

1. Management responsibility
2. Product/service identification and traceability
3. Production management
4. Fertiliser
5. Pest and disease control/chemicals
6. Harvest
7. Quality control
8. Handling, storage, packaging and delivery
9. Product & staff safety
10. Vehicles, equipment and machinery
11. Training
12. Purchase of goods & services
13. Complaints/corrective action

A number of these areas, particularly compliance areas 3, 8 and 9, address key criteria to manage microbiological safety issues associated with growers and pack houses, handling practices, water and fertiliser quality and suggested testing procedures.

In terms of fertiliser quality, a decision diagram to determine risks to food safety associated with the use of organic or animal fertilisers is included in the New Zealand GAP manual (Horticulture New Zealand Inc., 2006). In the event that there is some risk, for example where faecally derived fertiliser will likely come into contact with the crop or the crop is not peeled before being consumed, best management practices to minimise the risk are suggested. These include:

- Minimising contact with edible part of crop through application method or growing practice;
- Incorporating fertiliser into soil;
- Maximising the period between application and harvest;
- Adopting treatments designed to reduce or eliminate pathogens (e.g. heat treatment or composting);
- Obtaining relevant documentation from supplier or purchasing from an Approved Supplier;

- Avoiding cross-contamination of fresh produce from fertiliser treatment or storage areas.

A New Zealand standard (NZS4454:2005) for the safe and effective processing of organic materials into composts, soil conditioners and mulches is available for purchase from Standards New Zealand.

According to the New Zealand GAP manual, there are "currently no regulations or standards that specify critical limits for microbial levels on produce sold for fresh consumption or for water used in the production of fresh produce." However, water is considered "a significant food safety hazard under this programme".

Food safety-related decision diagrams for both irrigation water used by growers and post harvest waters used by pack houses respectively are included in the manual to establish the acceptability of water being used, and to identify any changes. Where quality is questionable, i.e. where water is from a non-potable source, it is advised to test water for total *E. coli* numbers (as per the Ministry of Health Drinking Water Standard for New Zealand (DWSNZ2005)), using the following interpretations and corrective actions:

Total *E. coli* (cfu/g)	Interpretation of result	Corrective actions
<20	Risk not significant	None required
20 - <100	Risk acceptable	Work to reduce the risk e.g. using an alternative source
≥100	Risk not acceptable	Manage the risk by e.g. using an alternative source know to be acceptable for human consumption or recognised treatment system

Where water is non-potable, applied within 48 hours of harvest, and the product is not subjected to washing and/or peeling and/or cooking prior to consumption, then testing of product for *E. coli* is advised. The temperature of wash water is recommended to be "as close to that of the produce as possible (or slightly warmer)".

A code of best practice for the transportation of fresh vegetables by road is also distributed with the New Zealand GAP manual. This covers aspects relating to responsibilities, documentation, minimum standards for vehicles, recommended minimum standards for short (0-2 hr), medium (2-4 hr) and long haul (>4 hr) journeys, and a reference section containing information on temperature requirements for various categories of vegetables and fruits as well as gases, odours and moisture. It should be noted that the recommended transport temperatures for category 1 (e.g. carrots, lettuce, spinach) and category 2 (e.g. capsicums, melons, tomatoes) items are 1 - 7ºC and 7 - 10ºC respectively

7.1.2 Organic Certification

7.1.2.1 BioGro

BioGro was established in 1983 and certifies over 700 operations including producers, processors, and the retail and export sectors. They estimate that they trademark over $100 million worth of products every year (http://www.bio-gro.co.nz/main.php?page=145).

BioGro-certified operations function under the BioGro New Zealand Organic Standards Version 1.30 (April 2001) available on-line (http://www.bio-gro.co.nz/main.php?page=170).

For the production of fresh and processed vegetables, arable and seed crops, herbs and annual fruit crops the Crop Production Standard (Module 4.2) is used. This standard stipulates that composts can either be purchased from an approved supplier, or made on the farm. If made on the farm, compost must be heated, aerated, mixed and matured in compliance with the Compost Production Standard. Raw animal manures cannot be applied directly to soil (and must be hot-composted before use), while sewage and sewage by-products are not permitted for use. While the requirements for irrigation water discuss water source purity, Annex Two: Residue Levels in Certified Products, Water, Soil and Composts is heavily skewed towards pesticide and heavy metal residues and makes no mention of microbiological contamination.

7.1.2.2 Organic Farm New Zealand (OFNZ)

Another organic certification system, OFNZ, has operated in New Zealand since November 2002 and currently has about 200 producer members (http://www.organicfarm.org.nz/aboutus.html). It is "designed for the small grower to be low-cost, educative and supportive". The system operates using a "pod" system of 3 – 5 growers who peer review each other. An independent auditor then checks peer review documents, and once a year one of the growers in the pod will be independently audited. The pod system is considered advantageous, as it is perceived to create a tendency amongst growers to be overzealous in adhering to standards, as well as build in a "more than one pair of eyes" peer review approach and develop both a sense of ownership and support networks. Existing BioGro production standards are used in the OFNZ programme (http://www.organicfarm.org.nz/ofnzcerfitication.html).

7.1.3 Validation of testing spent irrigation water for pathogens during the sprouting process

A literature review regarding an FDA recommendation to test spent irrigation water for pathogens was conducted in 2000 (Graham, 2000). This review concluded that this testing regime was an effective means of measuring the safety of sprouts before they reach the marketplace, and was a better option than testing of growing sprouts. However, little peer-reviewed information on validation of this approach was available at this time. It was therefore recommended that further decisions regarding either implementation of or conducting a New Zealand-based validation of the FDA recommendation be postponed until further information was published.

7.1.4 Generic HACCP models for Food Assurance Programmes

A project entitled Generic HACCP models for Food Assurance Programmes was commissioned by MAF Policy and undertaken by AgriQuality New Zealand. Three reports were produced during this work – an interim report (Faulkner *et al.*, 2001), an implantation guide (Walker & Faulkner, 2001a) and a final report (Walker & Faulkner, 2001b). This project focussed on specific export crops, with objectives to:

- Review previous documentation on MAF Plants Biosecurity Code of Practice (FMA 101);
- Identify data gaps regarding knowledge about hazards, application of HACCP methodology, CCPs validation and food safety relevance;
- Identify critical food safety issues, hazards and desired outcomes from international literature;
- Reference international HACCP requirements for market access and food safety.

The interim report (Faulkner *et al*., 2001) identified three groups of potential biological hazards: (i) bacteria (*E. coli* O157, *Salmonella, Campylobacter, Shigella, Clostridium botulinum, Clostridium perfringens, L. monocytogenes* and *Y. enterocolitica*), (ii) parasites (*Giardia, Cyclospora cayetanensis* and *Cryptosporidium parvum*), and (iii) viruses (Noroviruses, Hepatitis A and Rotaviruses)

A range of export crops was considered including root crops (potatoes, carrots, onions), fruit crops (apples, kiwifruit, summer fruit, sub-tropicals), seeds/sprouts, leafy green (lettuce, brassicas), glasshouse (tomatoes, capsicums), berry fruits and organic crops.

Generic HACCP models for the production, packaging, storage and distribution of these export crops were then developed for each group. It was recommended by the authors that the application of HACCP principles in conjunction with good agricultural practices was more appropriate than the application of "HACCP in its truest sense". Product descriptions and process flows were then tabulated and used for hazard identification purposes.

Due to the potential for produce to become contaminated at a number of points, a number of bacterial, viral and protozoan pathogens were listed as potential hazards throughout processing, with identified potential hazard sources including fertiliser application, contaminated water, soil and infected food handlers. A number of control measures were identified for the various processing steps involved. These included for example the use of certified manures, biosolids and other fertilisers (or sources from a reputable supplier) to control the hazards associated with inadequately decomposed compost. For steps involving water, it was suggested that control be addressed using good agricultural practices by the individual operator, and a recommendation was made suggesting that "a water management programme be developed and implemented in each operation/facility using a HACCP approach." The critical control points identified were (i) incorrect fertiliser and (ii) incorrect agrichemical applications.

Two key microbiological issues warranting further research were identified. These were the presence of *Y. enterocolitica* in New Zealand waters and the level of health risk associated with *C. cayetanensis.*

7.2 Additional Codes of Practice and Industry Guidance Documents

A number of codes of practice and industry guidance documents addressing pertinent produce-related issues are easily accessible via international websites. For example, the Canadian Food Inspection Agency has published codes of practice for minimally processed ready-to-eat vegetables, the hygienic production of sprouted seeds and production and distribution of unpasteurised apple and other fruit juice/cider. An industry guidance document on sample collection and testing for sprouts and spent irrigation water is also available via their website (http://www.inspection.gc.ca).

7.2.1 Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (1998) and Guide to Minimize Microbial Food Safety Hazards of Fresh-cut Fruits and Vegetables (2007).

Two 'Guidance for Industry' documents pertaining to the fruit and vegetable industry in the U.S. are currently available on the Food and Drug Administration (FDA) website. The 1998 guide addresses microbial food safety hazards pertaining to fresh fruits and vegetables (http://www.foodsafety.gov/~dms/prodguid.html) while the 2007 guide is a draft final guidance document addressing the fresh-cuts industry (http://www.cfsan.fda.gov/~dms/prodgui3.html).

The former document covers information pertinent to growers (water, manure and municipal biosolids, worker health and hygiene, sanitary facilities, field sanitation, packing facility sanitation, transportation and traceback), while the latter document offers guidance with non-binding recommendations more specifically targeting produce processors (personnel, building and equipment, sanitation operations, production and process controls, documentation and records, traceback and recall).

As with the New Zealand GAP information available, these guidance documents promote the management of food safety risks appropriate to particular produce commodities using good agricultural practices and HACCP principles rather than by compliance with specific standards.

7.2.2 Code of Hygienic Practice for Fresh Fruits and Vegetables (CAC/RCP 53 – 2003) including annexes on RTE fresh pre-cut fruits and vegetables and sprout production

The objectives of this Codex Alimentarius Commission document address "Good Agricultural Practices (GAPS) and Good Manufacturing Practices (GMPs) that will help control microbial, chemical and physical hazards associated with all stages of the production of fresh fruits and vegetables from primary production to packing. Particular attention is given to minimizing microbial hazards. The code provides a general framework of recommendations to allow uniform adoption by this sector rather than providing detailed recommendations for specific agricultural practices, operations or commodities." (www.codexalimentarius.net/download/standards/10200/cxp_053e.pdf).

As with similar codes of practice, water and manure quality are addressed in some detail. Again, growers are responsible for water quality and it is indicated that they should "identify sources of water, assess its microbial quality, and its suitability for intended use, and identify corrective actions to prevent or minimize contamination. Where necessary, growers should have the water they use tested for microbial contaminants". Special attention to water quality should be considered for irrigation and harvesting, and water for fertilizers, pest control and other agricultural chemicals. Other areas considered include growing and harvesting facilities; personnel health, hygiene and sanitary facilities; equipment associated with growing and harvesting; prevention of cross-contamination;

storage and transport from field to packing facility; cleaning, maintenance and sanitation; control of operation (including post-harvest water, cooling and cold storage); and recalls.

8 DISCUSSION

It is obvious from this review of the domestic and international produce food safety literature and outbreak data that particular pathogens, including *Salmonella* spp., *E. coli* O157:H7, protozoa and viruses, have caused the bulk of foodborne illnesses related to the consumption of fresh fruits and vegetables. It is also evident from the literature regarding contributing factors that these are the organisms most likely to be associated with breakdowns in GAP, particularly in relation to the use of contaminated water and manure-based fertilisers. Poor food handling practices are also a significant factor in the produce-related transmission of viruses and, to a lesser extent, protozoa.

Despite the fact that *Salmonella* and *E. coli* O157:H7 have been implicated in 69% of all bacterial produce-related outbreaks in the U.S. from 1973 through 1997 (Sivapalasingam *et al*., 2004), limited New Zealand surveys carried out to date have failed to isolate *E. coli* O157 from commercial and organically-grown lettuce, while only one out of 230 batches of organic apples tested positive for salmonellae. Surveys conducted in the U.S. and elsewhere have reported prevalence values ranging from 0 to 100% for various bacterial groups, which is unsurprising given the variability occurring between studies in relation to testing criteria such as choice of target pathogen(s), methodology and sample size. However, such variability also suggests that this is an area that needs to be addressed in order to ensure appropriate, comparable and robust testing protocols for both survey work and routine testing. Actions taken by growers/processors in light of positive test results should also be explored to ensure the rigour of testing protocols. In the context of the New Zealand farming environment, the current prevalence of *E. coli* O157 seems to be significantly lower than in the U.S. and elsewhere. However, given its recent isolation from farm-associated stream water during a VTEC outbreak investigation, it is conceivable that it may, from time to time, gain access to produce via the use of unchlorinated wash water.

In contrast, a high prevalence of other pathogens such as *Aeromonas* and *S. aureus* in international produce surveys has not translated into a concomitant number of outbreaks. *S. aureus* in particular is unlikely to be a risk although enterotoxin production has occasionally been associated with temperature-abused produce. *Listeria monocytogenes*, a pathogen of some concern in ready-to-eat foods such as deli RTE salads containing mixed ingredients, does not however appear to be so in RTE produce. Given the sporadic nature of *L. monocytogenes* infections and its usual occurrence at low levels in foods, the shorter shelf life of RTE fresh produce may in part limit its ability to multiply to levels where disease is likely to occur.

The prevalence of protozoa and viruses in domestic and internationally grown produce is unknown and testing produce for them may be of questionable value given the significant role of infected food handlers in contamination at various levels in the food chain. Overall, efforts may be better directed towards determining the microbiological quality and safety of established and common sources of contamination, particularly water and manure, for domestically grown produce, and the efficacy of decontamination methods.

New Zealand recalls and outbreaks data for produce are limited. From analysis of available data for disease notifications from 1997 to 2008, only one confirmed outbreak associated with consumption of raw blueberries has been recorded. However, investigations of two additional outbreaks of salmonellosis and VTEC infection identified the presence of generic *E. coli* and *E. coli* O157 in water sourced from streams running through farm land which is potentially used without chlorination. The only other reported outbreak, although related to poor agricultural practices, occurred at a domestic level and was limited to the immediate family.

It is impossible to comment on these data in relation to overseas data and the effectiveness of quality programmes such as New Zealand GAP, but it does appear that there may be some potential weaknesses associated with water quality management in particular. It is also possible that small and/or uncertified producers selling produce directly to consumers in road-side stalls and farmers' markets might pose a greater risk to consumers (although the actual quantities being distributed in this manner are insignificant in comparison to the volume of produce sold through supermarkets). However, limited surveys of produce from farmers' markets in Canada (Park & Sanders, 1992) and the U.S. (Thunberg *et al*., 2002) have reported a generally low incidence of pathogens.

Underreporting of outbreaks may, to some extent, be hiding produce-related issues given that consumption is typically associated with mixed foods (therefore identification of infection vehicles is more difficult) and consumer perception is more likely to be skewed towards the nutritional health benefits associated with a diet rich in fruits and vegetables rather than the food safety risks. Moreover, the anticipated increase in consumption of convenient RTE produce, including organic and imported fruits and vegetables, may have an impact on domestic food safety issues.

Limited information on recalls of fresh produce in New Zealand suggests that none have been initiated (with the exception of deli salads known to contain other ingredients such as meat). There have been two large recalls of sprouts in Australia in 2003 and 2006 associated with *Salmonella* contamination.

More specific comments pertaining to individual groups of produce items follows.

<u>Fresh whole/cut vegetables</u>
Whole and fresh cut vegetables have been implicated in a number of significant international disease outbreaks. Lettuce and spinach have been more frequently implicated than other vegetables, with various routes of contamination identified, the most significant of which appear to be faecal contamination either directly to plants or via contaminated irrigation water. The quality of produce wash water used for whole and cut vegetables is another obvious and important food safety consideration which is typically managed by chlorination. However, at the grower level, the practice of using unchlorinated wash water has been identified as a potential problem. The removal of the outer skin of vegetables will reduce surface contamination of vegetables such as carrots, but it should be remembered that cross-contamination may occur, re-introducing pathogens onto the cut vegetable surface where released plant nutrients may enhance growth.

<u>Fruit</u>
Berries and fresh-cut fruits, particularly melons, have been implicated in several overseas outbreaks, including two outbreaks in Australia last year. In New Zealand, an outbreak of Hepatitis A in 2001 was conclusively linked to the consumption of blueberries. Melons are more frequently implicated due to their lower acidity and the potential for

contamination on the outer skin to be spread to the inner tissues during cutting. In the case of bacterial contamination temperature abuse may allow proliferation to higher levels, which, depending on the pathogen in question, could increase the likelihood of infection. The importation of contaminated melons (and other fruits) into New Zealand could therefore pose a problem, as has been documented for berry fruits overseas. It is unknown whether melons are washed and/or sanitised by New Zealand supermarkets and juice bars prior to chopping and juicing. The absence of this step compounded by inadequate temperature control could therefore be a cause for concern.

The sale of unpasteurised fruit juices in New Zealand is estimated to be a small segment of the juice market overall, while the bulk of juices are heat processed and sold refrigerated or shelf-stable. Two large outbreaks associated with unpasteurised and reconstituted orange juice respectively have occurred in Australia. Given the increasing popularity of juice bars, it is possible that contamination via poor quality fruit and/or food handlers may occur. Currently no standards exist regarding the production and labelling of unpasteurised juices in New Zealand.

<u>Sprouts</u>

Although sprouted seeds are particularly susceptible to pathogen contamination via a variety of sources, and sprouting conditions favour bacterial growth, no outbreaks attributed to the consumption of sprouts have been recorded in New Zealand. An early investigation of the microbiological quality of domestically grown hydroponic sprouts (Graham, 1999; Graham & Dawson, 2002) identified the presence of generic *E. coli* in 12.8% of sprout samples tested. However, no pathogens were detected. A grower survey subsequently identified failures by growers to implement CCPs. The absence of outbreaks and recalls in New Zealand may be attributed to limited consumption and/or sector domination by one company which reportedly produces 75% of sprouts on the domestic retail market (personal communication, Stephen Dench, New Zealand Fresh-Cuts Ltd.).

<u>Organic</u>

There is no evidence from the limited surveys conducted in New Zealand that organically grown produce is of inferior microbiological quality with regard to pathogens, although evidence overseas has shown that non-certified organic produce is more likely to harbour generic *E. coli* than either certified organic or conventional produce. Organic certification does exist in New Zealand but the literature available is exclusively concerned with control of chemical residues in agricultural waters and fails to mention microbial risks.

<u>Hydroponic production</u>

Information on the microbiological quality of hydroponically grown produce available in New Zealand is limited and relatively old, but the prevalence of generic *E. coli* in leafy vegetables and herbs at levels of 14% and 5% respectively determined in a New Zealand survey (Graham, 1999; Graham & Dawson, 2002) does suggest that there can be problems with this type of production (although pathogens were not detected). Also see comments on sprouts above. As mentioned previously, water appears to be a common factor and, given the absence of standards, this may be an area worthy of further consideration.

9 CONCLUSIONS

The surveillance information gathered for this report suggests that exposures to pathogens in fruits and vegetables in New Zealand are not responsible for as high a proportion of reported outbreaks as overseas. However, the information about the aetiology of outbreaks in New Zealand is generally poor.

Information on the prevalence of pathogens in fruits and vegetables in New Zealand is patchy. Examination of hydroponically grown vegetables, lettuce and apples did not find a high prevalence of pathogens, while the prevalence of *Listeria monocytogenes* in deli RTE salads is low. The variability of survey results from overseas studies also raises questions regarding methodology, the choice of pathogens being screened, and the sample size and frequency of testing, all of which may have additional implications for routine monitoring programmes.

The operation of growers and/or processors under certification and food safety programmes provides some reassurance that many in the sector are aware of, and take steps to control, pathogens. However, issues regarding water quality suggest that this is a food safety management area that requires further investigation. Additional information describing actions taken in light of positive pathogen results would also be useful in determining how well these programmes are managing food safety risks.

From anecdotal observations, it is likely that New Zealanders are changing the ways in which they consume fruits and vegetables:

- an increasing number and variety of minimally processed RTE products that include fruits and vegetables as ingredients;
- the increasing popularity of organic produce (e.g. dedicated sections of supermarkets);
- the popularity of farmers markets with direct interaction of small producers and consumers (farmers markets are likely to be affected by the legislative changes as a result of the Domestic Food Review).

There are numerous data gaps to be filled before a robust assessment of the risk posed by pathogens in fruits and vegetables can be undertaken. The limited information gathered to date suggests that a better description of the grower, processor and retail sectors in New Zealand needs to be assembled in order to locate practices or specific products for further risk assessment.

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