MICROBIAL HAZARD IDENTIFICATION IN FRESH FRUIT AND VEGETABLES

Edited by

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This book is dedicated to my parents Kenneth and Gloria James, and my daughter Tiffany – Thanks for your patience and encouragement.
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A healthy, balanced diet would not be complete without fresh fruit and vegetables. The United States Produce for Better Health Foundation recommends five to nine servings of fruits and vegetables daily for better health. Several government agencies have also introduced initiatives with the aim of increasing consumption of fresh fruits and vegetables. As the public has become more health conscious over the years, a number of widely publicized foodborne outbreaks associated with fresh produce have caused some concerns to the industry and consumers alike. Even though statistics show an increased trend in produce-related foodborne outbreaks, it is possible this trend is directly related to an improvement in monitoring programs. Not all countries are equipped to monitor outbreaks and conduct traceback investigations. Thus, a lack of information on outbreaks in many countries does not signify the absence of outbreaks.

Knowledge of microbial hazards in fresh fruit and vegetables, from the farm to the table, will help in providing wholesome, healthy food for consumers. Only if hazards are identified can adequate control measures be implemented to reduce risk of product contamination. Government agencies have proposed mitigation measures, guidelines, and codes of best practice for the industry to reduce contamination of fresh produce. In addition, trade associations have provided food-safety guidelines in farm production and fresh-cut processing operations. Scientific research, if carefully directed, would give growers, packers, and shippers the necessary tools to create preventive programs. Many guidelines are based on the potential for product contamination and not actual scientific data. The paucity of data opens the doors to many areas of future research for the fresh produce industry to understand the impact of product contamination.

All participants in the food chain, from the farm to the fork, should take responsibility for the safety of the food supply. Because vegetables and fruits may be eaten raw, growers, shippers, processors, and retailers have the added responsibility of safeguarding the product and supporting consumer confidence in the industry.

This book is a comprehensive reference for the fresh fruit and vegetable industry. It focuses on the major stages in growing and handling of produce. Possible hazards in production, harvesting, packing, distribution, retail, and consumer handling are identified. This book also covers a case study of a foodborne outbreak associated with fresh produce and the actual costs to the industry because of this outbreak.
The text will be particularly useful to advanced undergraduate and graduate students interested in postharvest biology and food-safety issues affecting horticultural crops. The text would also be useful in organizing short courses through University Extension programs catering to research and extension workers, consultants, quality management staff, and other people involved in managing food-safety programs for the fresh produce industry.

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CHAPTER 1

Overview of Microbial Hazards in Fresh Fruit and Vegetables Operations

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1.1 INTRODUCTION

Scientists recommend that everyone eat five to nine servings of fruit and vegetables every day in order to promote good health. The improved availability of fresh produce year round and increased choices of items on the supermarket shelves should certainly help consumers to meet this target of fresh produce consumption. Raw fruit and vegetables, however, have the potential of becoming contaminated with microorganisms, including human pathogens. Several widely publicized food-borne outbreaks in recent years have been associated with sprouted seeds, minimally processed produce, unpasteurized vegetable and fruit juices, as well as intact products. However, the proportion of fresh-produce-related outbreaks is low when compared to the number of foodborne outbreaks per year.

Fruits and vegetables normally carry nonpathogenic, epiphytic microflora. During production on the farm and all stages of product handling from harvest to point of sale, produce may be contaminated with pathogens (Beuchat, 1996; Beuchat and Ryu, 1997). Possible microbial hazards on the farm include the use of raw manure and contaminated soil amendments, dirty irrigation water, wild animals and birds, and dirty farming equipment. At harvest, employee health and hygiene is critical. In addition, farm tools, utensils, and packaging could possibly contaminate the product. Packhouses pose a risk when using water to wash product or convey product in water flumes. The water quality plays a key role in determining the final quality and safety of the product. Employee hygiene and food contact surfaces have the potential to affect product in the packhouse. In addition, transportation and distribution practices determine product quality and safety for future use. When product is displayed at retail and handled in food service operations, there is the potential for contamination. The end user or consumer also plays a critical role in maintaining product safety as produce items are taken from the store, preserved, and prepared in the home.

Major stakeholders in the fresh produce chain have introduced measures to prevent product contamination (FDA/CFSAN, 2001a). At the farm level, Good Agricultural Practices (GAPs) and documentation of these practices were introduced. Government guidelines for the industry help in promoting safe practices and large retailers encourage the use of these guidelines by demanding results of audits of practices (FDA, 1998a, b). Retailers feel assured that the product presented to consumers has been handled safely when farms and packhouses are audited to guidelines and standards.

Minimal processing of fruits and vegetables presents unique challenges, because cutting and slicing remove the natural protective barriers of the intact plant. Thus, implementing Hazard Analysis and Critical Control Points (HACCP) programs in high care facilities adds more assurance of food safety. More research is needed in the fresh produce chain to prove the effectiveness of mitigation measures. Many monitoring programs are based on assumptions that contamination can occur. Scientists have used surrogate organisms to imitate the survival of microbial pathogens in fresh produce and these studies could provide significant insight into controlling the spread of pathogens in the industry (FDA/CFSAN, 2001b).
Produce is moved globally to supply year-round demands and improvement in traceability methods would help in epidemiological investigations. Outbreak data have been limited to just a few industrialized nations because only these countries have active surveillance systems for monitoring. Thus, the generation of more epidemiological data on produce-related foodborne illness worldwide will help determine true levels of illness.

1.2 PATHOGENS AND OUTBREAKS ASSOCIATED WITH THE FRESH PRODUCE INDUSTRY

Biological hazards are of great concern to the fresh produce industry. They can be classified into spore-forming bacteria, non-spore-forming bacteria, viruses, and parasites. Certain bacteria form spores to withstand environmental stress conditions such as high heat on freezing. Spore-forming organisms can attach to vegetables grown near the soil. Examples of these organisms include Bacillus cereus, Clostridium perfringens, and Clostridium botulinum. Maintaining refrigeration temperatures at less than 5°C and promoting oxygen in packaging would reduce the risk of vegetative cell formation and the production of dangerous toxins that cause illness (Linton, 2003). Non-spore-forming bacteria such as enterotoxigenic and enterohemorrhagic Escherichia coli, Campylobacter jejuni, Listeria monocytogenes, Salmonella, Shigella spp., Staphylococcus aureus, and Vibrio spp. could contaminate fresh produce by cross contact with humans or animals carrying these organisms. The fecal–oral route is possibly the main mechanism of transfer. All of these bacteria have been associated with publicized fresh produce foodborne outbreaks of public health significance. The transfer of these organisms could be controlled by practising good personal hygiene, cleaning food contact surfaces, and always using potable water when water is required.

Foodborne viruses require a living host in which to grow and reproduce. Viruses tend to move from one food to another, from water supply to food, or from food handler to food. Hepatitis A, Norwalk virus, and rotavirus are viruses of public health significance. Hepatitis A has been isolated in vegetables washed with nonpotable water. A food worker can carry the organism virus for up to six weeks and contaminate food and other workers without any knowledge of signs and symptoms. The Norwalk virus and rotavirus have been associated with many foodborne infections. Raw fruits and vegetables washed with contaminated water were implicated in some outbreaks. These viruses are transmitted by person-to-person contact and by fecal contamination. Practising good personal hygiene and controlling staff carrying the virus are measures that could possibly eliminate foodborne illness.

Parasitic protozoa include Cyclospora cayetanensis, Giardia lamblia, and Cryptosporidium parvum. They are single-cell microorganisms that must live on or inside a host to survive. These parasites may be transmitted via contaminated water, by person-to-person contact, and by fecal contamination. Use of potable water for operations is critical.
In the last 15 years, knowledge of foodborne disease epidemiology evolved while the fresh fruit and vegetable industry was undergoing notable changes. Factors increasing the risk of foodborne illness associated with fresh produce include the following:

1. Modifications in agronomic practices, processing and packaging technologies;
2. Global marketing strategies allowing fresh produce supply to consumers with a wide variety of products, year round;
3. Changes in population demographics; and
4. Changes in food consumption patterns.

Increased awareness because of unique epidemiologic surveillance programs and increased media attention has contributed to better documentation of foodborne illness. Numerous pathogens have been isolated from a wide variety of fresh fruits and vegetables. It is important to note that the number of samples in each study varied substantially. Although not all of the pathogens have been associated with produce-related foodborne disease outbreaks, they are all capable of causing illness.

In the United States, a specific etiologic agent was identified for 187 produce-associated outbreaks during the years 1990–2002. Among these outbreaks, 102 (55%) were caused by bacteria, 68 (36%) were caused by viruses, and 17 (1%) were caused by parasites. Among the bacterial agents, *Salmonella* accounted for 60% of outbreaks, and pathogenic *E. coli* was responsible for 25% of bacterial outbreaks. Norovirus caused a majority of viral outbreaks, accounting for over 80% of cases. The apparent prevalence of norovirus has increased possibly as a result of improved surveillance and detection methods. *Cyclospora* caused the majority (65%) of parasitic produce-associated outbreaks. Over 40% of the outbreaks were caused by salad items (including lettuce and tomatoes), whereas fruit and fruit salads comprised 13% of the outbreaks. Melons, including cantaloupe, honeydew, and watermelon, represented 12% of produce-associated outbreaks, and sprouts comprised 10% of the outbreaks (CDC, 2004).

In spring of 1996, CDC and Health Canada were alerted to over 1465 cases of foodborne illness caused by *Cyclospora* in the United States and Canada. The source of illness was incorrectly identified as California strawberries. At the peak of the California strawberry season, this mistake cost the industry $16 million in lost revenue (Calvin et al., 2002). It was later discovered that the illness was caused by Guatemalan raspberries and the United States stopped all imports of this commodity. Another incident occurred when 200 school children and teachers in Michigan contracted Hepatitis A in 1997. This outbreak was traced to frozen California strawberries. The fresh strawberry industry, through the California Strawberry Commission, was quick to alert the public of the subtle difference with the fresh strawberry market, thus limiting the financial impact and decline of fresh market sales as in the previous year (Calvin, 2003). Japan had the world’s largest reported vegetable outbreak in 1996 when over 11,000 people were affected and 6000 were culture confirmed. Three school children died from this outbreak,
which was caused by *E. coli* O157:H7 (Ministry of Health and Welfare of Japan, 1997). In the United States, *Salmonella* traced back to Mexican cantaloupes caused outbreaks in 2000, 2001, and 2002. The investigation was time-consuming and caused a decline in California cantaloupe sales following the Mexican growing season.

Growers and shippers were the focus of U.S. government investigations in the mid-1990s for outbreaks of food illness linked to fresh produce (Tauxe, 1997). Epidemiology of foodborne outbreaks will be discussed extensively in a following chapter. The lack of strong traceability details and poor reporting systems for outbreaks limits a thorough evaluation of the role of fruits and vegetables as a source of foodborne infections (European Commission, 2002).

### 1.3 POTENTIAL HAZARDS IN THE FOOD CHAIN/POINTS OF CONTAMINATION

#### 1.3.1 Hazards in Production

*Ranch History and Adjacent Land Use.* The ground where product is grown plays a vital role in safety of the product. If the area has a history of use for chemical waste or the processing of biosolids, this would present a potential source of contamination for crops. It is important to know the land history and the time required for the area to lay fodder, thus reducing the level of contaminants in the soil. Adjacent land use also affects the safety of the crop grown. If fruit and vegetables are grown next to an animal-rearing operation, there is a potential for product to become contaminated by animals. These animals may physically enter fields. Waste, high winds, and run-off from the animal operation may contaminate crops. The decision to grow next to a potentially hazardous location should be followed up with a risk assessment and the implementation of preventive measures to control risks identified. Sloping land from an adjacent field could be curbed by digging a ditch along the full length of the field to catch run-off water. Physical barriers and trenches may also prevent unwanted animal entry into fresh produce operations.

The importance of adjacent land was demonstrated in the first documented outbreak of *Escherichia coli* O157:H7 infection associated with a treated municipal water supply in Canada in May–June 2000. This was the largest multibacterial waterborne outbreak in Canada at that time (Public Health Agency Canada, 2000). The Walkerton residents who became ill numbered approximately 1286. Researchers confirmed that a well was subject to surface water contamination and elevated turbidity. Environmental testing of 13 livestock farms within a 4 km radius of the three wells identified human bacterial pathogens in animal manure on all but two farms. On nine farms, *Campylobacter* spp. were identified, on two farms both *E. coli* O157:H7 and *Campylobacter* spp. were found; this included a farm adjacent to the affected well. The evidence suggested that the pathogens that entered the well were likely to have originated from cattle manure on this farm (Public Health Agency Canada, 2000).
**Animals.** Fruit and vegetable growers and packers are discouraged from keeping animals because they represent a source of product contamination. Domestic animals such as chickens, dogs, and horses can contaminate crop with fecal droppings if they pass through growing areas. Nonfarm animals such as deer, other mammals, and birds can serve as reservoirs for pathogens (Dingman, 2000; Moncrief and Bloom, 2005). Wild animals present a unique hazard to fruit and vegetable growers and these animals are difficult to control. Droppings from birds, deer, and other wild animals present a risk. It is not economical in some instances to fence large production areas, but small farms may be fenced to keep out wild animals. Other physical barriers such as mounds, diversion berms, vegetative buffers, and ditches, provide protection from animals. Growers use scarecrows, reflective strips, and gunshots to ward off birds and pests from crop. Mechanical traps have been used to catch fieldmice in lettuce-growing operations in Yuma, Arizona. Growers implemented this emergency measure to alleviate a problem of mice in lettuce bound for the prepared salad industry. This measure was simple, yet effective in preserving product integrity.

**Manure and Soil Amendments.** An increased demand for organically grown produce promotes the use of alternative measures to protect plants from pests, mites, and fungi. In addition, organic fertilizers such as animal manure could introduce fecal pathogens to fresh produce if manure is not aged and treated before application. Treated manure or biosolids can be beneficial soil amendments. Growers have to manage these amendments very well to minimize contamination of fruits and vegetable with pathogenic fecal microorganisms. Published literature shows the presence and isolation of zoonotic pathogens in manure and on the surface of fresh produce (Dingman, 2000; Moncrief and Bloom, 2005). However, more research is needed to show a direct link from a manure application to finding pathogens in fresh produce. This research could help in assessing the level of risk. Active composting uses three Ts to treat manure: time, temperature, and turnings.

Composting can effectively reduce pathogens and parasites commonly found in manure as well as those that have mutated into different strains with new abilities, like surviving in acidic environments. Millner (2003) estimates that once certain time and temperature criteria are achieved, *E. coli* and *Salmonellae* in the compost are nearly eliminated (99.9999 percent kill rate). The pathogen-reduction criteria include a temperature of at least 131°F for three consecutive days in an aerated pile or 131°F for two weeks in the hot zones of a windrow pile with five turnings. This process can kill nearly all pathogenic microbes and still maintain populations of beneficial ones.

Applying raw manure to a vegetable-growing operation could cause product contamination. In addition, manure piles stored next to growing operations may also be a problem because of run off. Organic growers use a great deal of treated manure as fertilizer and soil amendment. Organic growers must be vigilant not to use fresh manure, because this would increase the potential for product contamination (Blaine and Powell, 2004; FDA, 1998b). Manure application should be carried
out well in advance of harvest so there is sufficient time for potential pathogens to break down naturally.

**Water.** Water may be used throughout the growing and harvesting of fresh fruit and vegetables. Irrigation water and water used for application of plant protection product, fertilizer, and frost protection should not introduce risk of pathogens to product. The source of agricultural water could determine the final safety of the food product. Municipal water or wells are generally safe. In the United States, municipal water is usually treated and tested routinely to monitor microbial contamination. Wells with sound casing and absence of leaks should provide water free of pathogens. Many growers also draw water from open water systems in areas where water is scarce. If effluent water from sewage plants is used in hydroponics plant production, the quality of this water is a concern for introduction of pathogens in edible food. The microflora of these systems changes daily and it is unknown what quality of water exists from one day to the next. Irrigation practices dictate product safety when using open systems like rivers and canals. Drip irrigation or furrow irrigation would bring water to the root of the plant without making contact with leaves or other edible portions. In the early growing stages, it is possible to use sprinklers to wet young plants. The time interval between planting and harvesting is sufficiently long to expect pathogens present to die off.

Greenhouse production is generally well protected from the environment, but is seen to favor the survival of human pathogens (Nguyen-the and Carlin, 2000). Special issues of control of pathogens in greenhouses concern the fact that all nutrients are delivered to plants in liquid form. If water used for mixing agricultural chemicals becomes contaminated in any way, the implications for the greenhouse are extensive. The pathogen would spread over a wide range of product on which it was applied. The conditions in the greenhouse – warm temperature (>21°C), moisture (>70 percent relative humidity), and light – would encourage the growth of pathogens (Moncrief and Bloom, 2005).

### 1.3.2 Contamination in the Field at Harvest

Harvesting is a critical period in the fresh produce chain, with potential for most product contamination. Employees in farming operations play a key role in maintaining the integrity of product grown. Their safe and hygienic practices – from land preparation, planting, weeding, and pruning, to harvesting – could influence whether product becomes contaminated. Personal hygiene, including hand washing all along the food chain, is critical in reducing or eliminating contamination with fecal pathogens. Ill employees harvesting by hand could contaminate product bound for the consumer if care is not taken in basic hygiene. Growers may use portable toilet facilities that follow workers in large fields to provide sanitary facilities. As part of Good Agricultural Practices (GAPs), companies train field employees in the basics of using toilet facilities instead of the field, where product may be contaminated. Employees are trained in proper hand-washing techniques. In the United States, the Occupational Health and Safety Act (29) CFR 1928.110,
subpart I, regulates the use of portable toilets. The Act specifies that the following practices should be adopted:

1. One toilet should be provided for every 20 workers.
2. The field sanitation unit should be placed within one quarter mile of the harvest crew.
3. Sanitary tissue, and soap and potable water for hand washing should be provided.
4. A means of hand drying, preferably disposable paper towels, should be provided.
5. Sanitary facilities in the field must be managed effectively so they do not become a source of contaminated product. A professional company should be used to empty and clean sanitary facilities.
6. Growers should have a containment plan in place in the unlikely event of a spillage.

Wounds are hosts to pathogenic bacteria and direct food contact should be avoided. Workers who receive minor cuts while harvesting should only continue to work if the cut is well protected using a plaster/bandage, and further covered with gloves. If gloves are used, they should not cause product contamination. Thus, gloves should be changed regularly or when damaged.

Equipment used for harvesting may also be a source of product contamination. Utensils should be cleaned and sanitized regularly to avoid cross-contamination. Some growers now use a sanitizing dip in the field during harvest so knives and other tools can be cleaned during the break and before start of harvest. Field containers should be washed routinely to avoid a build-up of debris. Some packhouses are equipped with crate washers that comprise a tunnel full of powerful water jets and in some cases an initial spray of foam cleaning detergent. Because produce crates are taken to the field daily, it is important not to create any instance of cross-contamination of produce by using dirty packaging.

Minimal processing of produce items like romaine hearts and head lettuce may be carried out in the field. Product is harvested, rinsed in the field on harvest rigs, and then packed in consumer packages and boxes. The harvest rigs should be cleaned and sanitized daily, because these products are advertised as “ready-to-eat”. Any wash water used on harvest rigs should be potable and suitable for its application. Utensils and vehicles used to transport packaged fruit and vegetables should be dedicated for this purpose, because cross-contamination could occur if other products are transported in the same vessels. A precautionary measure would be to wash and sanitize containers before use.

1.3.3 Post-Harvest Handling of Fresh Produce

Packhouses. After product is harvested, it should be protected to prevent any cross-contamination. Packing facilities should be cleaned and well maintained to
reduce the introduction of harmful microorganisms to product. Some growers move product from the field in large bins, which are taken to the packhouse for selection, grading, and repacking. No matter what method of packing is used, care must be taken with product. Cartons and other empty containers should not be stored uncovered in fields, because dust and animals could contaminate product. Rigs and utensils used for packing should be cleaned and monitored daily. Packhouses, whether open or enclosed, should be cleaned and protected to deter pest entry and possible product contamination. Harvest storage facilities, containers, or bins should be cleaned regularly, based on a set program.

Poor sanitation in the packhouse could lead to the formation of biofilms. Biofilms are layers of bacteria that attach to surfaces like stainless steel and plastic, and also attach to each other with the help of polymeric materials. The biofilms trap other bacteria, debris and nutrients. Poor sanitation programs cause biofilms to build up and become established. Nonpathogenic and pathogenic bacteria can form biofilms. Organisms in the film tend to be resistant to cleaners and sanitizers, as well as heat treatment. Thus, in the food industry a sound sanitation program is needed so that biofilms do not become entrenched on food contact surfaces.

Good sanitation practices enhance a company’s food-safety program. An important step is to provide training in sanitation to a wide base of employees, even those outside the sanitation department (Redemann, 2005). In daily sanitation programs, seven steps could be followed to ensure clean equipment:

1. Dry cleaning to remove gross debris from equipment and floors;
2. Prerinsing to remove debris from surfaces;
3. Using soap and scrubbing equipment on surfaces and floors;
4. Postrinsing to remove soap;
5. Removing standing water and reassembling equipment if necessary;
6. Inspecting cleaned area and recleaning with detergent if necessary;
7. Sanitizing equipment and floors in high-care facilities.

Many companies use chlorine-based cleaning chemicals. For effective cleaning, some chemicals could require a specific residence time on equipment. Sanitizers include halogen-based compounds and quaternary ammonium-based compounds. For a review on food plant cleaning and sanitizing, the reader is referred to Redemann (2005).

Pest management could prevent product contamination, recall, and other loss of productivity. A company should have a preventive program of pest control so that problems never develop. The packhouse manager should assess the risk in the plant to determine the level of prevention needed. Completely closed packhouses may have sophisticated pest control programs using a certified contract company. Windows and air vents should be screened and facilities kept free of debris. Any pest-control program implemented should be monitored and documented regularly to protect product.

**Water Flumes.** Where water is used to transport produce from one part of the packhouse to the next, the quality of that water will determine the quality and
safety of the product being packed. Primary water for rinsing to remove dirt may be of agricultural grade. However, potable water should be used for subsequent rinsing steps. Fresh-cut rinsing operations may use automated chlorination and acidification systems to control and monitor water quality. Flume channels used for sorting and grading product should be cleaned according to a planned sanitation program, thus preventing the build-up of debris from recycled water and avoiding product contamination. Where water is recycled, it should be treated to reduce the build up of microorganisms. Many companies use chlorine or other disinfecting chemicals to control the microbial load. Packers and processors use chlorine dioxide, chlorine (hypochlorous acid), UV light, ozone, hydrogen peroxide, peroxyacetic acid, and other sanitizers. The standard sanitizer used in packhouses in the United States is chlorine. This could be in the form of sodium hypochlorite granules, tablets, or liquid.

Water has been demonstrated to enter tomatoes through the stem end in a water dunk tank. This may be caused by the temperature differential of the produce item harvested in the field and the cooler water in the packhouse. At intake, any microorganisms in the water would also enter the produce item. Thus, it is imperative that any wash water in the plant be potable water. Any pathogens in water could become the source of a foodborne outbreak. A multi-State outbreak of *Salmonella enterica* Serotype Newport infection was linked to mango consumption in December 1999. Traceback of the implicated mangoes led to a single Brazilian farm, where hot water treatment was identified as a possible point of contamination. Hot water treatment was a new process introduced to prevent importation of an agricultural pest, the Mediterranean fruit fly. Contaminated water caused product contamination. This outbreak highlighted the potential global health impact of foodborne diseases and newly implemented food processes and the vulnerability of product placed in contaminated water (Sivapalasinsgam et al., 2003).

**Employees.** Packhouse employees should be trained in safe food-handling practices. Product safety of final consumer packs is directly influenced by the handling practices in the packhouse. Employees should receive training on the proper use of toilets, hand-washing procedures, use of protective clothing, and headgear to avoid product contamination. Many foodborne outbreaks have been linked to a sick employee who transferred pathogens via the fecal–oral route. Employees shedding pathogens in diarrhea may not wash their hands adequately before handling food. This is one possible route of contamination of fresh produce.

### 1.3.4 Storage and Distribution

Refrigeration temperatures in storage and distribution are crucial to maintaining product quality. These temperatures also reduce the proliferation of human pathogens if they are present on produce items. Refrigeration units are thought to spread mold throughout warehouses, and routine servicing of air filters and
refrigeration systems is required. As cold air systems blow mold spores into the air, there is also the risk that pathogens may be spread along with the spores from one pallet to the other. More research is needed in the area of air quality in storage and distribution in order to implement effective control measures. This topic will be discussed extensively in Chapter 7.

Pest control programs are necessary at any storage facility. A basic rodent control program would reduce the presence of pests that harbor harmful microorganisms forming a potential hazard to food. A contract company or trained individual should monitor traps or bait stations regularly and document any pest activity observed.

Vehicles and containers used to transport fresh produce could also be sources of potential contamination. Vehicles used to transport fresh produce should be clean and free of odors, dirt, and debris before loading. The ideal situation would be to use dedicated containers and vehicles for each application; that is, produce, meat, or refuse should be transported by separate means. The produce containers and vehicles should also be cleaned routinely as part of Good Hygienic Practices (GHPs) to prevent contamination between loads. Good hygienic and cleaning practices ensure product safety when loading or during inspections. The temperature of transport would also determine the potential for growth of pathogens. Thus, refrigeration temperatures are used to transport many produce items. The cold temperature helps to preserve product quality as well as safety.

1.3.5 Fresh-Cut Fruit and Vegetables: Potential Hazards

The fresh-cut fruit and vegetable industry in the United States grew from supplying quick-serve restaurant chains to providing consumer-size convenience products. From the 1980s to the 2000s, bagged salads and other convenience items experienced tremendous growth in demand. Sales of bagged salads topped $3 billion in 2004, while whole peeled carrots reached about $1 billion (Gorny, 2005).

Fresh-cut processors have worked with growers, retailers, and food service operations to ensure raw material and finished product are handled safely. When fresh produce is washed, cut, and sliced, the natural defense mechanisms on the plant material are removed. The high level of handling increases the potential for product to be contaminated by microorganisms in the environment. Because there is no kill step in fresh-cut processing, using HACCP is imperative in maintaining food safety standards with preventive programs (Nguyen-the and Carlin, 1994, 2000). Growers implement Good Agricultural Practices (GAPs) reducing risks during growing and harvesting (FDA, 1998a). Retailers and food service operations implement the principles of HACCP to manage food safety in their operations. In the United States, the International Fresh Cut Produce Association (IFPA) published Food Safety Guidelines for fresh-cut food processors. Guidance documents produced include a model HACCP plan, best practice guidelines for activities,
a model food allergen plan, and a Sanitary Equipment Buying Guide and Development Checklist. The IFPA has also developed a GAP program in conjunction with the Western Growers’ Association. The industry is thus equipped with proactive guidance to produce safe food.

1.3.6 Retail and Food Service Operations

The primary cause of foodborne illness in the United States is thought to be the mishandling of food during preparation in food service operations or in the home (Gorny, 2005). Statistics collected by the Center for Disease Control and Prevention (CDC) provide a strong link between foodborne illness outbreaks and the end users in restaurants and retail (CDC, 2004). Consumers could be a source of fresh produce contamination in retail outlets. Consumers touch fruit and vegetables as they make a decision on whether to purchase product. If a person’s hands are contaminated because of improper hygiene, this product could be affected. The consumer may also place bare fruits and vegetables into shopping carts, which are generally unwashed. Cross-contamination by microorganisms present in the shopping cart onto fresh produce items could present a food safety hazard, especially if the cart was used to transport meat, fish, or poultry. The final step of bagging produce items could present a food safety hazard if fruits and vegetables are placed in the same bag as raw meat or fish.

When the consumer places grocery bags in the car, vehicle temperature and time to cooling determine the potential for present pathogens to multiply. Linton (2003) describes a “temperature danger zone” of 5–60°C for food in general. A rule of thumb in the industry is that it takes four hours in the temperature danger zone for pathogens to multiply enough to cause illness. For this reason, hot food should be stored at temperatures over 60°C and cold foods at less than 5°C for optimum safety (Linton, 2003).

Retail operations and restaurants should take a proactive role in carrying out a risk assessment of their operations to understand the different types of hazards. When these potential problems are identified using the principles of HACCP, they may be controlled. Salads and juices are sometimes prepared in the fresh produce section of a retail operation. Workers should be trained in good food-handling practices to ensure food quality and safety are maintained:

1. Ready-to-eat foods should be kept at safe temperatures.
2. Food contact surfaces in food-preparation areas should be cleaned and sanitized regularly.
3. Display counters and shelves should be cleaned regularly to prevent cross-contamination.
4. Water used to wash produce should be potable, because poor-quality water is a major source of contamination.
5. Color-coded chopping boards should be used to distinguish boards for cutting produce from those used for cutting meat.
6. Employees bagging product at the cashier’s desk should be trained to avoid cross-contamination by placing raw meat in separate bags from fresh produce.

7. Regular hand washing should be enforced to prevent product contamination.

All employees in a retail operation should thus have a basic knowledge of food safety and their responsibility of protecting the public.

Outreach and education of the consumer would be the most effective means of explaining the dangers of mishandling food to the ultimate customers. Retailers may also assume the role of educating the public so the food-safety message reaches into people’s homes. Brochures, videos, and posters at display counters have been used effectively for consumer education in retail operations. Modern technology and a bit of creativity on the part of retailers could go even further to enlighten the public and promote safe handling of food.

Restaurant chains represent one important point in the handling of fresh fruits and vegetables before consumption. Food-service operations have been linked to several foodborne outbreaks involving fresh produce (CDC, 1999; CNN, 1996, 2003). Adequate training of food-service employees and implementation of a HACCP program to control food-safety in kitchens and food-display counters are the best ways to control food handling.

The “Serve Safe” program developed by the International Food Safety Council of the National Restaurant Association Educational Foundation has become the industry standard in food safety training. Serve Safe is accepted in almost all U.S. jurisdictions that require employees’ certification. The Serve Safe program provides accurate, up-to-date information for all levels of employees on all aspects of handling food, from receiving and storing to preparing and serving. The International Food Safety Council promotes food-safety education to the restaurant and food service industry, and also conveys the industry’s food-safety commitment to the public. The Serve Safe program has introduced a number of control measures for food-service operations similar to those mentioned above for retailers handling minimally processed product. In the United States, food service operations may also be subject to food-safety inspections, depending on the laws in each State. Only a very strict food-safety program in food-service operations would reduce the risk of pathogen contamination and illness to the ultimate consumer. The topic of U.S. retailer programs reducing food-safety risks in stores and educating the public will be presented in Chapter 8.

1.3.7 Consumer Handling of Fruits and Vegetables

Fruit and vegetables, besides being perishable items, could be the source of mishandling by consumers, eventually leading to foodborne illness. Consumers sometimes mishandle produce by cross-contamination with meat items being placed in the same bag or cart. Temperature abuse in a hot car would promote the growth of microorganisms, if present. In the home, food-safety practices such as hand
washing before handling fresh produce, or after handling meat, may not be observed. Most consumers store produce in the refrigerator; however, some items are stored at room temperature (Li-Cohen and Bruhn, 2002). Room-temperature storage is good for tomatoes, bananas, and unripe climacteric fruits. However, refrigeration extends the freshness and slows bacterial growth if a produce item contains harmful microorganisms. The home refrigerator may also harbor harmful organisms if it is not cleaned routinely. Meat drippings on shelves could cross-contaminate fresh produce placed on the same shelves. Consumers do not generally have a cleaning schedule for refrigerators, but this is a critical point in home hygiene in the kitchen. Refrigerator surfaces should be cleaned and sanitized to remove potential pathogens every two weeks, or more often, depending on contamination.

Another reservoir for pathogenic microorganisms is the kitchen sink. Consumers may place fresh produce items in the sink without washing or sanitizing the area. This causes cross-contamination from items previously placed in the sink. Sinks should be cleaned and sanitized before being used to wash fresh fruits and vegetables. In addition, mixing of utensils would invite cross-contamination, leading to foodborne illness. Consumers may not always wash fruits and vegetables, but even the simplest washing with running water is sufficient to cause one $\log_{10}$ CFU/g reduction in microbes. Fresh-cut fruit and vegetables should always be stored in refrigeration, first to extend shelf life, and then to reduce the potential growth of pathogens, which are usually mesophilic organisms. Chopping boards carry microorganisms in the form of biofilms if they are not cleaned and sanitized thoroughly. Consumers should implement good cleaning programs when using chopping boards for fresh produce, and preferably use different utensils than those used for meat.

Consumer attitudes to handling of fresh produce and statistical data collected in surveys of consumer behavior will be presented in Chapter 9.

1.4 MITIGATION MEASURES

1.4.1 Improvements in Produce Handling and Research Efforts

Scientists at the Agricultural Research Service, USDA, proposed research programs in 1999 to investigate new technologies for decontaminating fresh produce containing human pathogens. The presence and survival of human pathogens in unpasteurized juices, sprouts, melons, lettuce, and berries is known. These commodities have been implicated in a number of foodborne illness outbreaks. Typical methods of washing and sanitizing produce are not effective in removing pathogens, and increasing the knowledge of sources of microbial contamination requires more research. Thus, scientists have tried to identify sources of human pathogen contamination and develop interventions to prevent contamination and remove or inactivate pathogens on fresh and minimally processed produce (Beuchat, 1998; Jaquett et al.,
These studies provide a foundation for the development of treatments to assure the microbiological safety of fresh produce.

Sapers et al. 2000 showed that washing with hypochlorite or commercial surfactant formulations, as a means of decontaminating apples inoculated with *E. coli*, had limited success with only 1 to 2-logs (90–99 percent) reduction. However, experimental washing with hydrogen peroxide resulted in a 3-log (99.9 percent) reduction. Annous et al. (2001) demonstrated the inability of brush washing to decontaminate apples in field tests. It was thought that bacteria in inaccessible sites, growth of bacteria in skin punctures, and possible infiltration of bacteria into calyx and core tissues prevented their destruction.

In work with apples, mature and immature fruit from various locations were examined for evidence of internal or external bacterial contamination. A decay-causing fungus, *Glomerella cingulata*, permitted growth of *E. coli* O157:H7 in inoculated apples, probably because of a decrease in acidity that resulted from fungal growth. This clearly demonstrates the potential risk of using decayed apples for production of unpasteurized cider (Riordan et al., 2000). Sapers et al. (2001) researched the microbiology of fresh and fresh-cut cantaloupe, providing knowledge about attachment and survival of bacteria, including surrogates of human pathogens on external melon surfaces. They studied the efficacy of washing treatments in decontaminating cantaloupe melons, and effective treatments for extending the shelf-life of fresh-cut cantaloupe. Cantaloupe melons were artificially contaminated with nonpathogenic *E. coli* and *Salmonella stanley*, a human pathogen, and survival of these bacteria on melon rind during washing and their transfer to the melon flesh during fresh-cut processing was measured. Researchers found that chlorine and hydrogen peroxide solutions became progressively less effective in reducing contaminant populations as the time between contamination and washing increased. Surviving bacteria were transferred to the melon flesh and growth occurred (Sapers et al., 2001).

Chlorine dioxide is one sanitizer approved by the U.S. Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA). Chlorine dioxide is said to be as powerful as peroxyacetic acid and more economical. It has less of a negative impact on the environment than quaternary ammonium salts, chlorine, or bromine (Stier, 2005). Ozone and peroxyacetic acid have been introduced to decrease the microbial content of fresh-cut produce. Chlorine bleach and bromine create carcinogenic trihalomethanes that enter the environment through drains. Chlorine dioxide is also thought to destroy biofilms and prevent their formation. Chlorine continues to be the most widely used sanitizer in the produce industry in the United States; however, certain countries in the European Union have banned its use. Heat pasteurization is one innovation receiving a great deal of attention in disinfecting fresh-cut apples and melons (Gorny, 2005). The outside of the fruit is pasteurized before cutting, thus reducing the entry of surface microorganisms to the flesh.

In fresh-cut processing operations, ATP bioluminescence is used to monitor food contact surface contamination. It is a rapid means of informing sanitation crews if
bacteria and organic material remain on food contact surfaces. This method of testing is, however, very expensive and finds application mainly in large processing operations.

**US Food Safety Programs: GAP, GMP, and HACCP.** Use of GAP, GMP, and HACCP is voluntary in the fresh produce sector. However, retailers have demanded that their suppliers implement structured food-safety programs under various schemes and these practices are now subject to auditing by a third party.

Good Agricultural Practices (GAPs) describe preventive measures implemented in farming operations to reduce product contamination. The U.S. government in 1998 introduced a “Guide to Minimize the Microbial Contamination of Fresh Fruit and Vegetables”. This Guide was used in the United States, as the basis for developing GAPs (FDA, 1998a). The major risk factors identified as needing control included water, manure, worker health and hygiene, sanitary facilities, pest control, and traceback. GAPs provide guidance for food-safety practices in the field. Implementing GAPs provides some assurance to the retailer that product is safe from the farmer’s gate. A small number of foodborne illnesses have been associated with contamination at the farm through an ill harvester, or use of unsanitary water.

Current GMPs (FDA, 2003) were made law in U.S. food-processing and handling facilities and this code has been reviewed. The code provides guidance on the safe handling of product in buildings used for food production. In the fresh produce sector, packhouses should follow guidance set out in cGMPs in order to put out wholesome food product.

The principles of HACCP, a system developed by the NASA space program in the 1950s, are now used as the basis for risk assessment and initiating food-safety measures throughout the industry (FDA, 2001). Although most fresh produce farming and packing operations do not have critical control points, the HACCP program forces operations to go through each area in a packhouse, conducting a risk assessment. The assessment may also indicate where GMPs are failing and help in improving GMPs. The use of GAPs, GMPs, and HACCP in the fresh fruit and vegetable industry provide the basic framework for safe products for the consumer.

### 1.4.2 Improvements in Distribution and Retail

To aid the integration of the supply chain from the source to the end consumer, automated systems are being developed. These data-based systems would provide complete and constant visibility of product, package, purchasing, and distribution of food. Automated warehouse management systems using robotics could increase accuracy of the picking and assembling of pallets for dispatch. With laws restricting the weight of product lifted at food plants, automated systems could also aid manufacturers in compliance with labor laws. As customer demands for fresh