Produce Food Safety and Interventions to Reduce Risk

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Abstract

The consumption of fresh and lightly processed produce has increased throughout the world due to changes in dietary patterns and the year-round availability of food via global food supply chains. These changes have been accompanied by a significant increase in cases of produce-borne disease caused by *Salmonella* spp., *Escherichia coli* O157:H7, other bacteria, protozoa and virus. The magnitude of the problem is likely many times higher due to under-reporting. Solutions are hampered by the fresh nature of the product, market trends towards minimally-processed food and limited availability of suitable processing interventions. To address this challenge, effective Good Agricultural Practices and novel intervention strategies are needed.

Introduction

Fresh produce presents a special challenge to food safety management because this class of food is eaten raw with little or no treatment to reduce or eliminate microbial hazards (Sivapalasingam et al., 2004). Consequently, HACCP systems have limited application in produce operations, since specific critical limits cannot be established and monitored to ensure that the hazard is reduced to acceptable levels. Instead, Good Agricultural Practices (GAP) and sanitation standard operating procedures (SSOPs) provide the primary levels of risk management.

To address this unique challenge, researchers and the produce industry are working together to determine established and novel intervention strategies that can effectively reduce pathogen load, while at the same time maintain a desired level of product quality. In real working terms, this goal is difficult to achieve. For example, most treatments involving heat, acidified solutions and sanitisers might reduce microbial numbers to a specified target level yet result in undesirable changes in product sensory properties. This is particularly true for leafy vegetables but less so for fruits with a pealed rind.

Produce contamination

Bacteria-plant interactions have received much attention in the field of plant pathology, and we can expect that solutions for human pathogens can reached through collaborations with this scientific discipline. Produce can be contaminated during field production, harvesting, post-

harvest handling and by infected food handlers (Beuchat, 2000). Risk posed by surface contamination typically involves two scenarios. In the first instance, pathogens on the product surface are directly ingested, such as with leafy vegetables. This is most relevant for minimally processed fruits and vegetables, and poses a greater risk when the pathogen survives desiccation conditions and resists washing and/or sanitization processes. In the second instance, surface contamination is transferred to the interior of the product during slicing, through surface breaks or porous sites, and in processing tanks when cold wash water forces organisms into plant tissues (Bartz and Showalter, 1981). Numerous studies have shown that the growth of plant and human pathogens in plant tissues is accelerated when surfaces are bruised or broken, and in areas where the surface has greater porosity. These regions provide pathogens will higher levels of nutrients and protect them from desiccation. Once bacteria gain access to the product interior, growth is enhanced by nutrients and high water activity (Lin and Wei, 1997;Samish et al., 1963).

Microbial hazards

Various pathogens have been isolated from produce and implicated in food borne disease (Beuchat, 2000). For example, *Salmonella* species have been linked to the consumption of sprouts, cabbage, lettuce, salad greens, tomatoes and a wide variety of other produce (Bean et al., 1996; Beuchat, 2000). *Escherichia coli* O157:H7 has caused disease following the consumption of celery, herbs, spinach and white radish sprouts (Bean et al., 1996; Beuchat, 2000; Produce Marketing Association, 2006).

Undoubtedly, we know much more about bacteria compared to viruses, due to insufficient isolation and identification techniques for the latter. There are more than 100 types of human pathogenic viruses that can be present in soils and water contaminated by human and/or animal faecal matter but only a small number can be readily detected by current methodologies (Bosh et al., 1998; Jones et al., 1991). Due to these problems, selected viral strains and bacteriophages have been used as indicators of viral contamination and as surrogates for other pathogenic viruses under a variety of testing conditions (Jones et al., 1991; Lukasik et al., 2000).

Challenges to the effective use of sanitisers

The surface of edible plants is by nature difficult to treat with sanitisers. Plant surfaces can interact directly with sanitisers (eg chloride-based) and competitively reduce antimicrobial effects on target microorganisms. In the case of sprout seed sanitation, this situation requires the use of 20,000 ppm hypochlorite to achieve a desirable effect on *Salmonella* species (Weissinger and Beuchat, 2000).

Furthermore, the complex three-dimensional surfaces of edible plants and seeds limit the penetration of sanitisers and provide protected sites for organisms. In these areas, bacteria, fungi and viruses are able to bind to or lodge in crevices containing organic debris. Additional protection is afforded within biofilms. To overcome these challenges, sonication has been used to dislodge surface debris and increase the penetration of surface chemicals but without the desired level of effect (Scouten and Beuchat, 2002).

Effectiveness of common interventions strategies

Food safety interventions must address not only microbial contamination, but also physical and chemical hazards. This begins on the farm with GAPs that consider external sources of contamination that might be introduced through land run-off, wind, and wild and domesticated

animals. In addition, the provision of accessible facilities and training that support worker hygiene is critical.

In processing operations, mechanical forces, such as friction via washes and rinses, have been shown to be relatively effective compared to chemical treatments. Detergents dislodge particles through the formation of micelles that solubilise particles. Chemical treatments also exert antimicrobial effects and are the most common method to reduce contamination. In many instances, ionizing radiation has been shown to provide the desired balance between food safety and product quality, however costs and anticipated consumer perceptions have limited the application of this promising technology (Rajkowski and Thayer, 2001).

Various studies have examined the efficacy of chlorine, heat and chemical treatments to inactivate human pathogens on produce. Free available chlorine is the amount of hypochlorous acid (HOCl) and hypochlorite ion (OCl-) in chlorinated water. Both are strong oxidizers that react with other dissolved chemicals as well as organic matter and microorganisms. Solutions using concentrations of 50 to 200 ppm free chlorine for one to two minutes are commonly used to treat produce (Beuchat, 2000). Lukasik et al. (2000) reported reductions in levels of *Escherichia coli* O157:H7 and *Salmonella* Montevideo at 200 to 300 ppm free chlorine, and that Polio 1 virus was reduced to similar levels at 50 and 100 ppm. At 300 ppm, *E. coli* O157:H7 and *S.* Montevideo were reduced an average of 95%. Bacteriophages (PRD1, phiX174, and MS2) were removed by an average of 99% and removal did not vary at 50 to 300 ppm free chlorine.

Additional studies of survival rates of *S.* Montevideo in tomatoes during storage have been reported (Zhuang et al., 1995). Relatively large increases in levels occurred within seven days and one day at storage temperatures of 20 and 30°C, respectively. Levels of the pathogen on surfaces and in tissues were reduced by dipping tomatoes in a solution containing 60 or 110 ppm chlorine for two minutes, respectively. Higher levels of treatment in 320 ppm chlorine did not cause complete inactivation.

A separate study examined the ability of *S.* Montevideo to grow and/or survive on tomato surfaces including unbroken skin, stem scars and bruised areas (Wei et al., 1995). The authors reported that *S.* Montevideo survival was influenced by inoculum dose and site, and by the medium that delivered the inoculum. The bacterial populations increased rapidly on puncture wounds and tomato slices but decreased on the unbroken surface and stem scars. Delivery of the inoculum in trypticase soy broth supported greater survival and/or growth, and protected against the effects of chlorine.

The efficacy of chlorine and hot water treatments in killing *Salmonella* Stanley on alfalfa seeds and its behaviour during soaking, germination, sprouting and refrigerated storage of sprouts has been reported (Jaquette et al., 1996). The authors showed that the treatment of alfalfa seed with chlorine concentrations up to 1,040 ppm did not eliminate the pathogen, although significant reductions were achieved. Treating seed with 2,000 to 4,000 ppm free chlorine greatly reduced levels of *S.* Stanley and other salmonellae but did not adversely affect germination. Treatments with hot water were not found to be commercially practical due to a decrease in germination of seed. Other related studies have shown that calcium hypochlorite or sodium hypochlorite at concentrations of 1,800 and 2,000 ppm active chlorine, respectively, and 6% hydrogen peroxide or 80% ethanol, effectively reduced *Salmonella* more than 100-fold (Beuchat, 1996).

Lukasik et al. (2000) examined the effects of washing conditions and a variety of disinfectants on the reduction of selected bacterial and viral pathogens and bacteriophages inoculated on fresh strawberries and tomatoes. Experimental treatments included the effects of water temperature, surface friction, washes containing household chemicals, sanitiser washes, disinfectants and novel experimental chemical washes. Warm (43°C) tap water was nearly twice as effective as 22°C tap water. Hand-rubbing further enhanced the removal of pathogens at all temperatures, underlining the benefits of simple friction on pathogen reduction. Disinfectant washes were also effective in reducing both viruses and bacteria.

Stabilized chlorine dioxide, acidified sodium chlorite and peroxyacetic acid have been marketed as disinfectants. In studies by Lukasik et al. (2000), the chlorine dioxide generating compound Carnebon® and Oxine® at 100 or 200 ppm, were as effective as free chlorine at 100 ppm or 200 ppm. However, Carnebon® and Oxine® produced more reproducible results than free chlorine. The pH of these wash solutions was more buffered and less affected by the quality of source water. The use of Alcide® containing 100 or 200 ppm acidified sodium chlorite produced greater inactivation than stabilized chlorine dioxide or free chlorine at similar concentrations. Tsunami® containing 100 ppm peroxyacetic acid resulted in a similar level of inactivation as Alcide® at 200 ppm. However, Tsunami® affected the colour of strawberries.

Lukasik et al (2000) also reported that cetylpyridinium chloride (0.1% CPC), commonly used in mouthwashes, was somewhat effective on bacterial pathogens but not viruses. Trisodium phosphate (1% TSP) had the opposite effect. Hydrogen peroxide at 0.5% resulted in significant reductions of bacteria and viruses, but also reduced the quality of strawberries. These authors emphasised that the emergence of more tolerant pathogenic strains, increased contamination of produce and heightened concerns about the safety of chlorine and its sensitivity to organic load and pH argues for alternative disinfectants.

Beuchat and Scouten (2002) also evaluated various chemical treatments (hot water, $Ca(OH)_2$, Tween and Tsumani®) on the survival of *Salmonella* and *E. coli* O157:H7 on alfalfa seeds. They found that 1% $Ca(OH)_2$ was most effective at reducing *Salmonella* and *E. coli* O157:H7, while still maintaining seed viability.

Novel interventions strategies

Competitive exclusion has been shown to effectively limit the growth of pathogens in various systems. Fett and coworkers have pioneered the application of this technique in controlling *Salmonella* spp. in sprouts. Fett reported that *Pseudomonas fluorescens* strain 2-79 inhibited the growth of *Salmonella enterica* by 5 $\log_{10}$ for up to 6 days of sprouting (Fett, 2006). Matos and Garland (2005) showed that mixed microbial communities produced greater inhibition than single-species systems at later days of germination. The use of competitive exclusion may be an effective component in a multiple-hurdle approach. In addition, this technique might be more appealing to consumers that accept probiotic foods.

Another microbial-based approach to controlling food borne pathogens is the use of bacteriophage. In recent years, there has been a marked increase in the use of phage to control pathogens in animal production and processing operations (Barrow, 2001). Purified phage

lysates have been used for the species-specific control of bacteria during the pre- and post-harvest phases of food production and storage (Greer 2005).

Conclusions

Fresh produce presents a significance challenge in terms of food safety risk management. Consumers increasingly desire diverse types of produce at all times of the year that are fresh, without additives and minimally processed. As expected, this presents a difficult challenge to food producers and risk managers, and shifts the focus to GAPs, supplier certification and the development of novel intervention strategies. This report shows that various commercially-feasible antimicrobial treatments can effectively reduce pathogens to some degree but none eliminate risk. To achieve that level of protection, treatments would cause unacceptable changes in product quality and/or not meet the growing consumer demand for minimally processed foods. Instead, in the near term, the safety of produce will likely be addressed through effective and verifiable GAP at the farm level and through Good Manufacturing Practices employed by processors, wholesalers and retail outlets. In the long term, research will define novel technologies and hurdle applications that result in food safety management systems comparable to other sectors of the food industry.

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