

PRODUCE

REDUCTION OF SALMONELLAE ON PRODUCE AND POULTRY BY ORGANIC ACID PLUS DETERGENT (M.P. Doyle)

A group of organic acids, including lactic acid, acetic acid, and levulinic acid, and sodium dodecyl sulfate (SDS), were evaluated individually or in combination for their ability to inactivate *Salmonella* and *E. coli* O157:H7. Results from pure culture assays in water with the treatment chemical reveal that 0.5% organic acid and 0.05-1% SDS, when used individually, reduced pathogen cell numbers by <2 log CFU/ml within 20 min at 21°C. Combining any of these organic acids at 0.5% with 0.05% SDS resulted in >7 log CFU/ml inactivation of *Salmonella* and *E. coli* O157:H7 within 10 sec at 21°C. A combination of levulinic acid and SDS was evaluated at different concentrations for pathogen reduction on lettuce at 21°C, on poultry (wings and skin) at 8°C, and in water containing chicken feces or feathers at 21°C. Results revealed that treatment of lettuce with a combination of 3% levulinic acid plus 1% SDS, for < 20 sec reduced both *Salmonella* and *E. coli* O157:H7 populations by > 6.7 log CFU/g on lettuce. *Salmonella* and aerobic bacteria populations on chicken wings were reduced by > 5 log CFU/g by treatment with 3% levulinic acid plus 2% SDS, for 1 min. Treating water heavily contaminated with chicken feces with 3% levulinic acid plus 2% SDS, reduced *Salmonella* populations by >7 log CFU/ml within 20 sec. The application of levulinic acid plus SDS as a wash solution may have practical application for killing foodborne enteric pathogens on fresh produce and uncooked poultry.

SURVIVAL AND GROWTH OF SALMONELLA IN SALSA AND RELATED INGREDIENTS (L. Ma, G. Zhang, P. Gerner-Smidt, R.V. Tauxe, and M.P. Doyle)

A large outbreak of *Salmonella* Saintpaul infection associated with raw jalapeno peppers, Serrano peppers, and possibly tomatoes was reported in the United States in 2008. During the outbreak, two clusters of illness were significantly associated with eating salsa. Experiments were done to determine the survival and growth characteristics of *Salmonella* in salsa and related major ingredients, i.e., tomatoes, jalapeno peppers, and cilantro. Intact and chopped vegetables and different formulations of salsas were inoculated with a five-strain mixture of *Salmonella* spp. and then stored at 4, 12, and 21°C for up to 7 days. *Salmonella* populations and total aerobic counts were monitored during storage. *Salmonella* did not grow but survived on intact tomatoes and jalapeno peppers, whereas significant growth at 12 and 21°C was observed on intact cilantro. In general, growth of *Salmonella* occurred in all chopped vegetables when stored at 12 and 21°C, with chopped jalapeno peppers being the most supportive of growth. Regardless of differences in salsa formulation, no growth of *Salmonella* (initial inoculation ca. 3 log CFU/g) was observed in salsa when stored at 4°C; however, rapid or gradual decreases in *Salmonella* population was only observed in formulations that contained both fresh garlic and lime juice. *Salmonella* grew at 12 and 21°C in salsas except those formulations that contained both fresh garlic and lime juice, in which salmonellae rapidly or gradually were inactivated depending on formulation. These results highlight the importance of preharvest pathogen contamination control of fresh produce and proper formulation and storage of salsa.

SURFACE AND INTERNALIZED *ESCHERICHIA COLI* O157:H7 ON FIELD GROWN SPINACH TREATED WITH SPRAY CONTAMINATED IRRIGATION WATER

(C.C. Webb, M.C. Erickson, J.C. Diaz-Perez, S. Phatak, J.J. Silvoy,
L.E. McGhin, A.S. Payton, J. Liao, and M.P. Doyle)

Shiga toxin-producing *Escherichia coli* O157:H7 (STEC) strains have been identified as a cause of serious human gastrointestinal disease accompanied by severe complications, such as bloody diarrhea, hemorrhagic colitis, and the life-threatening hemolytic-uremic syndrome. Contamination of fresh produce by *E. coli* O157:H7 continues to be a problem facing the produce industry. For example, in the 2006 spinach outbreak, STEC contamination led to numerous reports of symptomatic enteritis and three deaths. In this and other outbreaks, several sources of contamination have been identified and include human cross-contamination events during pre- and post-harvest activities, improper composting of plant and animal waste, and direct or indirect fecal

contamination from livestock or feral animals. In particular, run-off from contaminated pastures or animal facilities may reach surface waters used for irrigation. In turn, pathogens within the irrigation water may be transferred to produce in the field. Although numerous field studies have demonstrated surface contamination of produce plants in the field, it is unclear whether internalization of the pathogens within the plant tissue occurs. To date, evidence to support this contamination route is based on growth chamber and hydroponic systems. Therefore, this study sought to differentiate the site of *E. coli* O157:H7 contamination when the pathogen was applied to field grown spinach through spray irrigation water.

Four Shiga toxin-negative strains of *E. coli* O157:H7, tagged with a Green fluorescent protein plasmid, were mixed in equal proportions and applied to spinach fields during the mid- (7-weeks post-transplantation) and late-growing season (10-weeks post-transplantation) to give concentrations in irrigation water of either 10^2 (low-dose), 10^4 (mid-dose), or 10^6 (high-dose) CFU/ml. Spray irrigation involved the use of a hand held sprayer held approximately 6 inches from the top of the plant. To five plots containing 64 plants each, 4 L of the appropriately diluted inoculum was applied to the leaf surfaces. To differentiate internalized and surface populations, leaves were treated with a HgCl₂/ethanol disinfectant wash prior to grinding the tissue samples for analysis of the former group. *E. coli* O157:H7 were quantified by direct plate counts or detected through enrichment culture.

Immediately following spray inoculation to the leaf surface, *E. coli* O157:H7 could not be detected through enrichment culture either internally or on the leaf surface of low-dose treated plants. In the case of mid-dose treated plants, *E. coli* O157:H7 was only detected on the surface (4 of 20 samples) whereas for high-dose treated plants, the pathogen was detected on both the surface (17 of 20) and internally (5 of 20). Seven days post-spraying, all spinach leaves tested negative for surface or internal contamination. Good agricultural practices with regard to irrigation water and the abstention of overhead spray irrigation one week prior to harvest will limit contamination of produce through irrigation water.

EVALUATION OF PATHOGEN INTERNALIZATION WITHIN FIELD GROWN SPINACH EXPOSED TO *ESCHERICHIA COLI* O157:H7 CONTAMINATED DRIP IRRIGATION WATER

(C.C. Webb, M.C. Erickson, J.C. Diaz-Perez, S. Phatak, J.J. Silvoy, L.E. McGhin, A.S. Payton, J. Liao, and M.P. Doyle)

Between 1990 and 2005, produce-associated outbreaks accounted for approximately 13% of all reported foodborne outbreaks with a known food item. Although traceback to the farm has occurred for a number of these produce outbreaks, definitive identification for the mode of contamination remains uncertain, however, both direct and indirect contamination routes are possible. Suspected pre-harvest sources include contaminated manure, manure compost, sewage sludge, irrigation water runoff, water from livestock operations, exposure to waste products from wild and domestic animals, as well as trophic interactions between plants and plant foragers like birds, mammals, and insects. With any of these sources, once introduced into the field, soil may act as a pathogen reservoir and transfer of pathogen to plants may occur through direct contact of aerial tissue with the ground or through rain or irrigated water splashes of soil onto the aerial tissue. Growth chamber and hydroponic system studies, however, have also demonstrated that pathogens in the soil are internalized into the roots of vegetable plants and in some cases translocated to aerial tissues. To investigate whether internalization occurs in field-grown spinach, this study applied *E. coli* O157:H7-contaminated drip irrigation water to soil and evaluated the fate of this pathogen.

Four Shiga toxin-negative strains, tagged with a Green fluorescent protein plasmid, were mixed in equal proportions and applied to spinach fields during the early-, mid-, and late-growing season to give concentrations in irrigation water of either 10^2 (low-dose), 10^4 (mid-dose), or 10^6 (high-dose) CFU/ml. Up to 3-weeks after application of 50 ml of one of the doses to the soil at the base of each plant, soil, leaf, and root samples were collected and *E. coli* O157:H7 quantified by direct plate counts or detected through enrichment culture. To differentiate internalized and surface populations, leaves and roots were treated with an HgCl₂/ethanol disinfectant wash prior to grinding the tissue samples for analysis of the former group.

E. coli O157:H7 persisted in the soil 21, 22, and 7 days following application of contaminated irrigation water to soil in the early-, mid-, and late-growing seasons. Despite persistence in the soil, no internalized *E. coli* O157:H7 was detected in any of the spinach leaves. Internalized *E. coli* O157:H7 was also not detected in root samples collected up to 3-weeks following the early- or late-season exposure. Internalized pathogen was detected in root samples collected 7-days after the mid-season soil exposure. At this sampling time, enrichment of root samples yielded 3 of 10, 1 of 10, and 1 of 10 for the low-, mid-, and high-dose treatments, respectively. One

week later when the plants were evaluated on Day 14, the pathogen was no longer detected nor was it detected on Day 22 which was considered the harvest point. These results indicate that internalization events are rare but when they occur, the pathogen does not persist.

MICROBIOLOGICAL EXAMINATION OF VEGETABLE SEED SPROUTS IN KOREA

(H. Kim, Y. Lee, L. R. Beuchat, and J.-H. Ryu)

Consumption of sprouted vegetable seeds in Korea has been increasing due in part to their nutritional benefits. Since sprouts are often eaten without being heated or cooked, they have occasionally been implicated in foodborne diseases such as in *Escherichia coli* O157:H7 infections and salmonellosis. Sprouts caused at least 37 outbreaks of foodborne disease in several countries between 1995 and 2005. Growth of *Salmonella* and *E. coli* O157:H7 that may be present on seeds or introduced from the environment during sprouting and subsequent handling may occur. *Enterobacter sakazakii* (*Cronobacter*) is known to grow on several types of fresh-cut fruits and vegetables but its incidence and behavior on seed sprouts have not been described. Studies on the general microbiological quality of soybean sprouts commonly consumed in Korea have been investigated. However, there is limited information on the microbiological quality of other types of seed sprouts. The objective of this study was to determine the general microbial quality and the prevalence of *Salmonella*, *E. coli* O157:H7, and *E. sakazakii* in different types of sprouts and seeds commercially available for the consumers in Korea. We profiled the microbiological quality of sprouts and seeds sold at retail shops in Seoul, Korea. Ninety samples of radish sprouts and mixed sprouts purchased at department stores, supermarkets, and traditional markets, and 96 samples of radish, alfalfa, and turnip seeds purchased from on-line stores were analyzed to determine the number of total aerobic bacteria (TAB) and molds or yeasts (MY) and the incidence of *Salmonella*, *E. coli* O157:H7, and *E. sakazakii*. Significantly higher numbers of TAB (7.52 log CFU/g) and MY (7.36 log CFU/g) were present on mixed sprouts compared to radish sprouts (6.97 and 6.50 CFU/g, respectively). Populations of TAB and MY on the sprouts were not significantly affected by location of purchase. Radish seeds contained TAB and MY populations of 4.08 log CFU/g and 2.42 log CFU/g, respectively, whereas populations of TAB were only 2.54 - 2.84 log CFU/g and MY were 0.82 - 1.69 log CFU/g on alfalfa and turnip seeds, respectively. *Salmonella* and *E. coli* O157:H7 were not detected on any of the sprout and seed samples tested. *E. sakazakii* was not found on seeds but 13.3% of the mixed sprout samples contained this potentially pathogenic bacterium.

TRANSFER OF *ESCHERICHIA COLI* O157:H7 TO ICEBERG LETTUCE VIA SIMULATED FIELD CORING

(P. J. Taormina, L. R. Beuchat, M. C. Erickson, L. Ma, G. Zhang, and M. P. Doyle)

Between 1995 and 2006, nine outbreaks of *E. coli* O157 infections were attributed to consumption of lettuce or spinach grown in or near the Salinas Valley in California. Investigation of this region led to the conclusion that *E. coli* O157 contamination of growing fields and produce is a dynamic and interrelated process involving transport and distribution of the pathogen via the watershed or possibly other non-water mechanisms. Epidemiologic evidence and traceback investigations indicated that STEC within the Salinas Valley growing region may be transferred in some way to leafy greens during cultivation and/or harvesting. Questions remain as to the mechanism(s) whereby cells of STEC become associated with lettuce in ways that they survive processing and distribution and reach the consumer. A major portion of commercially grown iceberg lettuce is cut and cored in the field. It is thought that soil might be transferred to edible tissues during this practice. Referred to in the industry as “field-coring” or “cut and core,” the process involves field workers using hand-held devices consisting of a stainless steel blade, shaft, and cylindrical coring ring to sever lettuce heads from roots and remove the core. Initial stem cuts are made near the soil surface using a wedge-shaped metal blade. The coring ring is then inserted around the stem of the lettuce head to remove the core. Depending on worker accuracy with each event, as well as soil conditions, blades of field-coring devices may contact the contaminated soil and transfer it to lettuce tissues, resulting in cross contamination. Transfer of foodborne pathogens from stainless steel to lettuce can occur to various extents, depending on the amount of water on the leaf surface. The potential for cut tissues of lettuce to become contaminated with the pathogen as a result of physical damage incurred during harvesting merits further study. Specifically, the potential and degree to which *E. coli* O157:H7 can become transferred to cored lettuce during field-coring needs to be determined. We undertook a study to determine the extent of contamination of iceberg lettuce via soil inoculated with *E. coli* O157:H7 by simulating mechanical damage of lettuce tissue resulting from cut-and-core practices used in commercial harvesting operations. The efficacy of

chlorinated water treatment for removal or inactivation of *E. coli* O157:H7 on coring blades and cored lettuce was determined. The goal of the study was to provide information identifying various factors associated with contamination and elimination of *E. coli* O157:H7 on field-cored iceberg lettuce. Chlorinated water treatment was evaluated for its efficacy in removing or inactivating *E. coli* O157:H7 on the blade portion of the field-coring device (FCD) and on cored lettuce. FCD inoculated by immersing blades in soil containing *E. coli* O157:H7 at 3.74 or 6.57 log CFU/g contained 3.13 and 4.97 log CFU/blade, respectively. Treatment of inoculated FCD blades by immersing in chlorinated water (200 µg/ml, total chlorine) for 10 s resulted in a reduction of 1.56 log CFU/blade, which was 1.42 log CFU/blade greater than achieved using water, but insufficient to eliminate the pathogen on blades. FCD inoculated by contacting soil containing *E. coli* O157:H7 at 2.72 and 1.67 log CFU/g, then repeatedly used to cut and core ten lettuce heads, transferred the pathogen to ten and five consecutively processed heads, respectively. Lettuce cores remained positive for the pathogen after spraying with 100 µg/ml free chlorine for 120 s at 2.81 kg/cm² (40 psi), regardless of the inoculum level. The number of *E. coli* O157:H7 recovered from inoculated lettuce cores treated for 10 s with chlorine was significantly ($P \leq 0.05$) different than the number recovered from tissues treated with water. Dipping contaminated FCD in chlorinated water may not be effective in killing the pathogen and controlling cross-contamination from head to head. Spraying contaminated lettuce with chlorinated or untreated water reduces but does not eliminate *E. coli* O157:H7.

FATE OF *ESCHERICHIA COLI* O157:H7 ON FRESH AND FRESH-CUT ICEBERG LETTUCE AND SPINACH IN THE PRESENCE OF NORMAL BACKGROUND MICROFLORA

(M. Harrison, W. Hurst, and W. Kerr)

Produce such as lettuce and spinach can become contaminated with foodborne pathogens at numerous points from the field to the retail market. UGA food scientists used the systems approach to determine the fate of *E. coli* O157:H7 in the presence of normal background microorganisms on iceberg lettuce and baby spinach under conditions that mimic actual practices between production and retail sale. While *E. coli* O157:H7 levels decreased on products handled and stored under recommended conditions, survivors persisted. Factors in the system significantly affecting *E. coli* O157:H7 populations from the time iceberg lettuce or baby spinach was harvested to the time products were put into retail bags were field temperature, time before cooling, and wash treatment. Time after cooling until lettuce was bagged was significant. However, for spinach this step was highly insignificant. *E. coli* O157:H7 contamination level on lettuce was not significantly different after vacuum cooling compared to before cooling. On greens packaged and stored at 4°C, *E. coli* O157:H7 contamination was detected, although populations decreased in many cases by at least 1.5 logs.

MICROBIAL ANTAGONISTS OF *ESCHERICHIA COLI* O157:H7 ON FRESH AND FRESH-CUT LETTUCE AND SPINACH

(M.A. Johnston, M.A. Harrison, and R.A. Morrow)

Fresh-cut lettuce and spinach can become contaminated with pathogens at numerous points from the field to the retail market. Natural microflora present on fresh produce may help reduce the pathogen load. Previous studies typically determined the presence of these competitive microorganisms at a particular stage in the handling of the product rather than following a product through typical processing and handling steps to see if the presence of these competitive microbes varies due to processing and handling. The objective of this study was to identify microbial isolates naturally found on fresh and packaged fresh-cut iceberg lettuce and baby spinach that were inhibitory to *E. coli* O157:H7 and to identify their possible modes of inhibition. Background microflora found on lettuce and spinach (aerobic mesophilic and psychrotrophic bacteria, coliforms, yeasts and molds, and lactic acid bacteria) were collected under conditions that mimicked actual practices from harvest to retail sale. These isolates were then randomly chosen for screening for inhibitory action against *E. coli* O157:H7. Isolates exhibiting inhibitory activity were characterized based on their morphological and biochemical properties and possible inhibitory activity (supernatant inhibition, acid production, and protease sensitivity). Evidence of naturally-occurring microorganisms on fresh lettuce (295 isolates) and spinach (200 isolates) with possible antagonistic activity toward *E. coli* O157:H7 was documented. Common inhibitory isolates were identified as *Pseudomonas*, *Pantoea*, *Klebsiella*, and *Enterobacter*. Inhibitory activity by several isolates was due either to acid production or bacteriocins. Isolates with inhibitory activity were isolated from every step in the processing and handling of the fresh-cut iceberg lettuce and baby spinach. The inhibitory isolates that pose no potential

health threat of their own may prove beneficial. However, there would be several hurdles to overcome if antagonistic microorganisms were to be used in a biocontrol strategy with fresh or fresh-cut produce. A more realistic phenomenon would be to consider the possibilities that the natural microflora that is present provides some measure of food safety protection by inhibiting foodborne pathogens like *E. coli* O157:H7.

INACTIVATION OF *SALMONELLA* TYPHIMURIUM AND *ESCHERICHIA COLI* O157:H7 IN ALFALFA SEEDS BY LEVULINIC ACID AND SODIUM DODECYL SULFATE WASHING TREATMENT

(T. Zhao, P. Zhao, and M.P. Doyle)

Since 1995, raw sprouts have been increasingly implicated as the vehicles of outbreaks of *E. coli* O157:H7 and *Salmonella* nationally and internationally. Most involved alfalfa sprouts, but cress, mung bean, and clover sprouts were also implicated. Thirteen *Salmonella* serotypes were isolated from the clinical cases. Various intervention approaches, including heating and chemical treatments (NaOCl, Ca(OCl)₂, acidified NaClO₂, acidified ClO₂, Na₃PO₄, Vegi-Clean, Tsunami, Vortexx, and H₂O₂) have been evaluated for their efficacy for reduction of *E. coli* O157:H7 contamination in alfalfa seeds. Results revealed that none of the above chemical treatments was able to eliminate or satisfactorily reduce *E. coli* O157:H7 on alfalfa seeds and sprouts. The focus of this research project was to determine the optimum concentration and exposure time of our newly developed chemical solution (levulinic acids plus sodium dodecyl sulfate, SDS) for treatment of alfalfa seeds for reduction of *E. coli* O157:H7 and *Salmonella* and to determine whether this treatment would affect seed germination characteristics. A 5-strain mixture of *E. coli* O157:H7 or *S. Typhimurium* at 10⁸ CFU/g was inoculated onto the alfalfa seeds. The seeds were dried at 21°C in a laminar flow hood for up to 72 h. *E. coli* O157:H7 counts at 4, 24, 48, and 72 h were 8.1, 4.8, 4.0 and 4.0 log CFU/g, respectively; and of *S. Typhimurium* at 4, 24, 48, and 72 h were 6.6, 4.4, 4.3, and 4.1 log CFU/g, respectively. The 0.5% levulinic acid and 0.05% SDS treatment for 5 min at 21°C reduced *E. coli* O157:H7 and *S. Typhimurium* populations by 5.6, >3.3, >2.4, >2.3; and 6.4, >2.7, 4.3, and 2.4 log CFU/g on seeds contaminated and dried for 4, 24, 48, and 72 h, respectively. However, some samples treated were positive by selective enrichment only. Seeds contaminated with 10⁴ *E. coli* O157:H7 cells/g and dried for 2 h at 21°C in a laminar flow hood were tested with 0.5% levulinic acid plus 0.05% SDS at 40°C for up to 5 min. *E. coli* O157:H7 in samples (25 g) tested at 1, 2, 3, and 5 min of exposure were negative by a direct plating method, but were positive by selective enrichment (<0.7 log CFU/g). All the levulinic acid + SDS used for treatment at 1, 2, 3, and 5 min were negative for *E. coli* O157:H7 by selective enrichment culture.

REDUCTION OF *ESCHERICHIA COLI* O157:H7 ON PRODUCE USING ELECTROLYZED WATER UNDER SIMULATED FOOD SERVICE OPERATION CONDITIONS

(P. Pangloli, Y.-C. Hung, L. R. Beuchat, C. H. King, and Z.-H. Zhao)

Bacterial pathogens most often involved in produce-related outbreaks of infections are *Salmonella* and *Escherichia coli* O157:H7, accounting for 50 and 20%, respectively, between 1998 and 2002. In 2005 – 2006, four multistate outbreaks of salmonellosis associated with eating tomatoes in restaurants sickened at least 450 people in 21 states. In 2006, outbreaks of *E. coli* O157:H7 infections linked to bagged spinach affected at least 183 people in 26 states and outbreaks associated with consumption of lettuce in fast-food restaurants sickened 81 individuals in three states. In 2008, an outbreak of salmonellosis implicating consumption of jalapeno peppers contaminated with *Salmonella* Saintpaul involved more than 1,400 infected people in 43 states, the District of Columbia, and Canada. Contamination of produce with pathogens can occur during production, harvesting, processing, storage, and handling or during preparation in food service kitchens or at home. Vegetables and fruits such as lettuce, cabbage, tomatoes, lemons, and oranges used to make salads and fresh-squeezed juices or in sandwiches in restaurant kitchens often require washing with water before serving. However, this washing step may be ineffective in completely removing all pathogenic microorganisms from produce. Electrolyzed water (EW) is produced through electrolysis of a mild salt (NaCl) solution in a chamber with cathode and anode electrodes. Acidic EW (AcEW), generated from the anode side, is lethal to most foodborne bacterial pathogens due to its low pH, high oxidation-reduction potential (ORP), and the presence of hypochlorous acid. Alkaline EW (AkeW), generated from the cathode side, has a strong cleaning effect. Most studies examining the efficacy of EW as a produce sanitizer have been conducted under conditions not necessarily mimicking food service practices. The objective of our study was to evaluate the efficacy of EW in killing or removing *E. coli* O157:H7 attached to the surface of produce under simulated food service operation conditions. The efficacy of EW in

killing the pathogen during washing and/or chilling iceberg lettuce, and washing cabbage, tomatoes, and lemons was determined. We evaluated the efficacy of EW in killing *Escherichia coli* O157:H7 using washing and/or chilling treatments simulating those followed in some in food service kitchens. Greatest reduction on lettuce were achieved by sequentially washing with 14 A acidic EW (AcEW) for 15 or 30 s followed by chilling in 16 A AcEW for 15 min. This procedure reduced the pathogen by 2.8 and 3.0 log CFU/leaf, respectively, whereas washing and chilling with tap water reduced the pathogen by 1.9 and 2.4 log CFU/leaf. Washing cabbage leaves for 15 or 30 s with tap water or 14 A AcEW reduced the pathogen by 2.0 and 3.0 log CFU/leaf and 2.5 to 3.0 log CFU/leaf, respectively. The pathogen was reduced by 4.7 log CFU/lemon by washing with 14 A AcEW and 4.1 and 4.5 log CFU/lemon by washing with tap water for 15 or 30 s. A reduction of 5.3 log CFU/lemon was achieved by washing with 14 A alkaline EW for 15 s prior to washing with 14 A AcEW for 15 s. Washing tomatoes with tap water or 14 A AcEW for 15 s reduced the pathogen by 6.4 and 7.9 log CFU/tomato, respectively. Application of EW using procedures mimicking food service operations may minimize cross-contamination and reduce the risk of *E. coli* O157:H7 being present on produce at the time of consumption.

**INACTIVATION OF *SALMONELLA* SPP. AND *E. COLI* O157:H7 ON TOMATOES BY
ALLYL ISOTHIOCYANATE, CARVACROL AND CINNAMALDEHYDE IN VAPOR-STATE
(M.M. Obaidat and J.F. Frank)**

The activity of various volatile antimicrobials in vapor state was determined. *Salmonella* spp. and *E. coli* O157:H7 on sliced and whole tomatoes were treated in a 120 ml sealed container with various concentrations of allyl isothiocyanate (AIT), cinnamaldehyde and carvacrol in vapor-state, with incubation at 4 and 10°C for up to 10 days and at 25°C for up to 10 h. AIT exhibited the greatest inactivation against the pathogens on sliced and whole tomatoes followed by cinnamaldehyde. The lowest level of AIT (1µl/120 ml volume) inactivated *Salmonellae* on sliced tomatoes by 1.0 and 3.5 log CFU at 4 and 10°C, respectively, in 10 days and by 2.8 log CFU at 25°C in 10 h. This level of AIT inactivated *Salmonellae* on whole tomatoes by 1.5 and 2.2 log CFU at 4 and 10°C, respectively, in 10 days and by 2.8 log CFU at 25°C in 10 h. AIT also inactivated *E. coli* O157:H7 on sliced tomatoes by 4.0 and 3.0 log at 4 and 10°C, respectively, in 10 days with no inactivation at 25°C in 10 h. AIT reduced *E. coli* O157:H7 on whole tomatoes surface by 3.0 and 1.0 log CFU at 4 and 10°C, respectively, in 10 days and by 2.0 log CFU at 25°C in 10 h. Greater inactivation occurred for all treatments at 10 than at 4°C. Pathogens on sliced tomato were not inactivated at 25°C. Antimicrobials in vapor form may be useful for controlling pathogens on fresh tomatoes marketed in packages containing head space.