Minimizing the Risk of Foodborne Illness Associated with Cantaloupe Production and Handling in California
Over the past six years, the California melon industry has been supporting proactive research to address microbial food safety concerns. This research has taken a broad approach, applying modern microbiological methods and technology to address areas in production and handling, from the farm through the shipping point. This research has also encompassed many issues related to distribution, fresh processing, foodservice, and consumer handling that are beyond the control of the supplier. The purpose of this informational brochure is to provide an overview of industry practices in relation to minimizing the risk of contamination, and to briefly summarize the current scientific basis for recommended melon production and handling practices in California. It also includes recommendations for implementing food safety programs for cantaloupe production and handling for melon producers and handlers in other regions, based on location independent risk evaluations and scientific publications available in refereed journals. It is our sincere hope that buyers, food specialists, processors, retailers, and food regulators, both unfamiliar and familiar with California melon production and melon production in general, will find this a useful and informative document.

Introduction

Consumer awareness of food safety issues related to microbial pathogens has remained high since the public's outraged reaction to the 1993 salmonella outbreak linked to cantaloupe. The public, in part, by broad media coverage of notable outbreaks on fresh and minimally processed fruits and vegetables, has not commonly associated with these illnesses. These events have elevated the interest in food safety among consumers and produce buyers alike. With repeated outbreaks linked to consumption of fresh produce, both of domestic and import origins, the apparent prevalence and severity of microbial foodborne illness has substantially replaced concern for pesticide residues as the foremost consumer confidence issue facing fruit and vegetable producers and shippers. In a survey conducted by the Produce Marketing Association's Fresh Trends Survey, nearly 60% of consumers say they are highly concerned about Salmonella and other foodborne pathogens in fresh produce.

In response to these concerns, those at the forefront of the produce industry within each commodity and industry association have worked to develop and adopted comprehensive food safety programs. These programs are based on various voluntary guidelines, such as the 1998 Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables adopted by the Food and Drug Administration. This document provides a framework for the industry to develop its own set of Good Agricultural Practices (GAPs) that are tailored by crop, region, and the specific channels of commerce. The core approach of any GAP or related program is to develop a detailed system plan for identifying hazards and potential risks of pathogen contamination, survival, and persistence (see ANR 8105). Once this comprehensive analysis is completed, the next challenge is to identify existing practices that minimize the risk, to innovate steps to prevent microbial pathogen contamination and to implement multiple, science-based barriers to survival, persistence, dissemination, and multiplication of pathogens.
California Cantaloupe Producers Take Proactive Steps

Beginning in 1995, the California Melon Research Board and the California Cantaloupe Advisory Board have taken a renewed and proactive approach to addressing general concerns prompted by the periodic occurrence of outbreaks due to Salmonella linked to contaminated melons, primarily cantaloupes sourced from outside of the United States. By a combination of research support and cooperative interactions with the University of California at Davis, a science-based approach to risk assessment and hazard identification was undertaken. A multiyear Salmonella survey was conducted involving over 2000 individual cantaloupes harvested directly from the fields, cooling operations, and shipping facilities for many producing regions of California. Melons packed directly into shipping containers (field packs) and bulk melons entering clear-mold-pack operations (shed packs) were included in the survey. No detectable levels of live Salmonella were found in any samples, under the broadest range of conditions and conditions ever conducted. Scientifically, this tells us that although one could never responsibly say that no cantaloupes could be contaminated, the practical likelihood of detecting Salmonella is extremely improbable under California conditions and practices, economical monitoring programs.

Could it happen? Sure. Is detection likely with even diligent inspection and sampling? No.

The clear implications of these results indicate that the chance of becoming ill from melons grown and packed in California is remote. Whether field packed or shed packed, with proper consumer education focused on safe melon handling and preparation in the home (AMI 8005), cantaloupes produced in California, and by reasonable extension in other and production regions that have access to adequate quality water, can be purchased with confidence and a very minimal concern for the potential for illnesses to be associated with their consumption.

Additional studies conducted in parallel with this survey strongly indicate that, although melon washing must ultimately be conducted safely within commercial packing operations, the best time to wash cantaloupes is immediately before food preparation and as close to consumption as possible. In contrast, cantaloupes produced in other regions are not suitable for field pack management and must enter a clean and disinfected wash handling operation. District and substantial challenges to safe management of shed pack operations in these domestic and offshore regions are being addressed by an international network of researchers. Their and other key research findings are summarized in the following brochures.

Review of Cantaloupe Outbreaks

The focus of public health officials and food regulators on cantaloupe consumption and its contribution to produce-related outbreaks and substantial cases of illness is understandable. Cantaloupe has been associated with outbreaks of Salmonella serotype Saffra and Salmonella serotype Poona on cantaloupes several times, most recently in 1997 and 2000, 2001, and 2002. Although many concerns in California were impacted, including two associated deaths, available information from traceback investigations in every case clearly places the origin of the consumed melons outside of the state. This is noted in Table 1 in this brochure. Regardless of the source of origin, the ability of bacterial pathogens of fecal origin, like Salmonella, E. coli O157:H7, or Shigella, to survive on the outer rind of melons and rapidly multiply on the edible flesh of cut melons has been clearly demonstrated. The potential for growth under poor or abusive postharvest and post-processing temperature management conditions leads to a presumption of elevated risk that impacts the whole industry. As a leading supplier of cantaloupes, the California industry deemed it necessary and desirable to develop a specific database for the frequency of occurrence of Salmonella at
the point of harvest in regional production fields and the predicted survival of these pathogens on the surface of fruit in laboratory models of current and potential handling practices. The sectors that follow include the results of on-going studies being conducted at the University of California at Davis and affiliated research grant collaborators at public universities within the United States Department of Agriculture Cooperative State Research Extension and Education System (USDA-CSREES 04-52102-9637 and 851-00-1987). Before reviewing these results, it is important to briefly establish a proper food safety perspective for cantaloupes produced in California by introducing an overview of the specific aspects of the industry.

Cantaloupe Consumption

In the United States, the consumption of fresh produce continues to increase as more people are incorporating the strong positive messages about the health benefits of consuming at least five servings per day of fruits and vegetables. The combined per capita consumption of vegetables and melons increased by 2% to 444 pounds in 1999 (USDA/ERS April 2000). Cantaloupe consumption featured prominently in this increased consumption with a 9% gain in per capita consumption. Cantaloupe is an important source of Vitamin C, beta-carotene for Vitamin A production in our bodies, as well as potassium, folic acid, iron, some dietary fiber, and calcium, all contributing to a healthful diet.

Characteristics of Cantaloupe

Cantaloupe is one of the numerous cultivated fruit vegetables in the highly diverse species Cucumis melo. The family Cucurbitaceae includes over 700 species such as cucumbers, squash, pumpkins, honeydew, watermelon, a wide array of gourds, and the loofah. Cucumis melo originated in parts of Africa, from where it was dispersed during ancient cultivation to Egypt, then to Europe, China, India, Asia, and finally throughout much of the world.

For most Americans, the term “cantaloupe” is generally reserved for those melon varieties with netted rinds, while these are sometimes referred to as “muskmelons” in the Eastern United States. True cantaloupes are smooth-skinned melons, common in Europe but uncommon in the United States, and derived from three plants first developed in Cantalupo, Italy. These have thick, waxy, rough, often deeply grooved, but not netted, rinds. The outer rind remains waxy throughout development. American cantaloupes are true muskmelons, mostly grown in the United States, Mexico, and Central America, and have finely netted rinds with shallow pits. The outer surface is covered with a layer of wax when immature. During the later stages of fruit development and rapid size expansion, the wax layer becomes interrupted with a network of fibrous and semi-porous tissue.

Cantaloupes are grown throughout the United States; California is the largest producer, shipping over 1 million tons of melons per year, which is generally 60 percent or more of the total U.S. market (USDA/ERS Aug. 1996).

Cantaloupe Production in California

Originally a specialty industry, the harvest practices and handling of cantaloupes evolved to a system that is predominated by field-pack, which is the direct placement of fruit into the final shipping unit, including a few diagram is provided on the back cover page. Within California, whether field or... Field-packed fruit are containerized, stacked on a pallet in the field, and taken to facilities for air-cooling. California
It is not the purpose of this document to detract from the significant advancements and on-going efforts of international producers to improve their individual situation relative to microbial food safety. Nonetheless, as foodborne illness and outbreaks associated with cantaloupes impacts the entire category, it is worthwhile to highlight the absence of particular practices from California production that are thought to be of particular risk concerns and potential impediments to a comprehensive food safety plan.

(Note for a detailed analysis of specific impacts of practices, see the Costel 2013 in Additional Reading.)

General Cantaloupe Production

For the purpose of this brochure, we will focus primarily on the typical production methods used in the San Joaquin Valley, the region of the main production volume in California and the U.S. The production, harvesting, and postharvest handling of California cantaloupes share some elements in common with other producers and handlers in other parts of the U.S. and internationally. However, there are some key differences that are likely to have important implications for food safety risk management.

Current California production does not employ the use or include practices such as hand-picking melons in order to prevent ground spot development in watermelon, which can introduce personal hygiene issues. The ground spot is an area of the melon in direct contact with the soil that is characterized by a thin and undeveloped outer layer. This area does not develop proper packing, and is characterized by a thin soft-end skin layer. The area is more easily breached by soil pathogens and is subject to improper irrigation. Poorly-planned irrigation management, together with a predominant absence of rainfall during the harvest season, prevent or greatly diminish ground spot occurrence. Our laboratory research has shown the ground spot to be a site on the soil that is more susceptible to potential internalization by Salmonella during postharvest handling or transport. A solution to the problem was the implementation of a sterile environment for the melon postharvest handling practices.

Sub-Rind Transference of Salmonella typhimurium During Postharvest Storage

<Figure 1>

California water sources are of adequate quality for use in irrigation and other applications. GAP and food safety systems are in place which includes the use of screened or minimally contaminated surface water, such as from discharge of untreated or minimally treated sewage and waste disposal sites. The general goal has been to avoid water that is more susceptible to potential internalization by Salmonella during postharvest handling.
Late-season fungicide or whitefly foliar applications, necessary in some areas outside of California, that prevent systemic of ripening melons are not necessary in the San Joaquin or Sacramento Valley regions. Packing washed and sub-optimally cooled melons in polyethylene bags, which may promote postharvest ripening, is not necessary for distribution to California destination markets. Definitively addressing these potential sources of contamination and risk in areas where these techniques are employed will be a benefit to all producers, buyers, and consumers, and will go a long way to maintaining and improving confidence in this valued and popular produce item.

**Manure**

The use of drier manure, chicken manure, or compost as soil amendments is reported by the industry to be an uncommon agronomic practice. While it is not possible to unequivocally state that these soil amendments are never used, voluntary Best Management Practices adopted by the majority of California growers do not include the use of manure at any time. Growers of organic cantaloupes are required to use only fully composted and certified manure-based soil amendments to qualify for organic certification.

**Field Preparation**

For many season production, loam and clay loam soils are preferred due to their greater water-holding capacity. This soil type reduces rapid fluctuations in water availability and permits a prolonged harvest period, typically without the need for additional irrigation between harvests. In some cases, when sub-surface drip irrigation is used, irrigation water may be applied between harvests, as the soil will not become too saturated for crops and equipment. Prior to seeding, fields are generally pre-irrigated, either by furrow or sprinkler. To ensure that soil moisture is uniformly deep into the profile. When dry enough for equipment to work the soil without compaction, fields are shaped into 80-inch (2-m) raised beds. Seeds are planted, in a single line, into the moist soil 3 to 6 inches (7.5 to 15 cm) below a covering of loose soil that helps retain moisture. After seed germination, this "soil-cap" is removed prior to seeding emergence.

**Irrigation**

The majority of California cantaloupe fields are furrow-irrigated. Depending on local conditions and soil type, two to five irrigations are applied after seeding establishment. Sprinklers are often used until shortly after seed emergence. Furrow irrigation, generally supplied by surface water from a public agricultural water agency, is applied until approximately 7 to 10 days before the beginning of harvest. Excessive irrigation late in the season can compromise fruit quality and increase the severity of root disease.

Currently, somewhat less than 10 percent of California cantaloupe acreage is drip-irrigated. Typically, buried lines are set in place with the expectation of specialized cropping systems and are intended for multiple year usage. With drip irrigation, the frequency of water application can vary from once a week early in the season to daily during the heat of summer production. No matter which irrigation method is used, growers manage water applications to keep the tops of the beds dry to minimize fruit contact with moist soil. Once fruit set has occurred, the presence of moist soil, especially near maturity, can result in unsightly ground spots (poor netted rind development), cosmetic blemishes from infecting soil fungi, and fruit rot. Sites of fungal invasion may also become areas where internalization of bacteria, including Salmonella, has been demonstrated in laboratory studies.
Pollination
To set fruit and achieve the best size and yield, insects are required for the transfer of pollen. The primary pollinators are bees, particularly honey bees. Cantaloupe flowers generally open after sunrise, depending on sunlight, temperature, and humidity. The flowers close permanently in the afternoon of the same day. Pollination is typically completed before noon.

Foliar Applications
In response to local needs, weather, and variable seasonal production practices, growers may apply pesticide applications or foliar nutrients. Typically all foliar sprays are terminated 7-14 days prior to harvest; but there are exceptions for approved and registered materials to control late-season heat stresses. Pest Management Practices advise that all sprays should be washed with potable water from the public water agencies or other potable domestic sources. All foliar spray tank and spray-line clean-out protocols are included in pesticidal and chemical safety programs. More recently recognized as part of a microbial food safety plan as well.

Harvest Practices
To market the highest quality cantaloupes, melons are hand-harvested when the fruit will cleanly and easily separate from the vine with only a slight pulling and twisting motion. This stage of maturity is called "firm-fleshed" (A). The standard quality stage in California, less mature melons, or some newer extended shelf-life melons do not develop a full slip and must be torn or clipped at harvest. (B) Fields may be harvested 8 to 10 times over a two-week period, sometimes longer depending on markets and sustained quality. Fruit of good quality will have at least 10 percent soluble solids, but more commonly at least 12%. This is the same unit of measurement as for wine grapes, a good measure of the sugar content. California melons are mostly packed in the field, using various methods of lifting fruit from bines to mobile packing stations, into the industry-standard 40-pound (18-kg) cartons. Fruits are size-separated by skilled workers and packed 9, 12, 15, 18, or 23 per carton. Cartons are placed directly on pallets and secured with strapping. In a few systems, packed cartons are placed on the dry back-door surface and lifted onto mobile trails for palletization. Identification stamps and pallet tags are placed with each lot in the field. At harvest, the air temperatures are generally high (>80°F), the very low humility (<40%) and high solar UV irradiance: conditions not favorable for bacterial survival.

Nonetheless, our research has shown that cantaloupes will hurdle bacterial and benign bacteria on and within the netted skin, even under these stressful conditions (see Figure 2). Trailers of palletized melons are transported to the cooler, generally within three to four hours of harvest. (C) caps at Selenophylla, L. 190

Example of Nelson Survey Environmental Parameters at Harvest
Air temperature at 13:00 - 80.9°C (105°F)
Solar UV irradiance - 188-193 (mid =231)
Vine Surface temperature - 36-38°C (97-100°F)
Fruit Field temperature
Exposed to Sun - 59°C (138°F)
Exposed to Sun (submerged) - 42°C (108°F)
Under Vine - 37°C (99°F)
Under Vine (submerged) - 26°C (79°F)
Fruit Temperature at Pre-cooling and Surface - 27°C (81°F)
Sub-firm - 25°C (77°F)
SHIGELLA are deposited on the exterior rim of a cantaloupe at the time of harvest. Laboratory studies strongly suggest a decrease of at least 99% of the starting population may be expected under these conditions.

Prior to packing, cantaloupes are typically maintained at the shipping/cooling facility on pallets with a tight plastic covering to minimize contact with dirt or moisture and to exclude potential contact by rodents or birds. As needed, cantaloupes are transported directly to the field harvested operation where they are formed and delivered to the packing house. In some harvest operations, the cantaloupes are placed at the end of the rows prior to the beginning of harvest and used as needed.

**Shipping Practices**

May transport to the cooler, pallet loads of cantaloupes are placed in two channels within the cooler facility on either side of a large fan. A covering is blown over the tops and rear of the channels and pallet openings are blocked to direct airflow through the ventilated cantaloupes and around the packed fruit. This method of cooling is called pressure or forced-air cooling. Cooling to pre-shipment temperatures, 35 to 40°F, typically takes 3 to 4 hours. Pallets are moved to a short-term storage cooler and placed on the floor or on multi-level racks.

![Diagram of postharvest survival of natural background bacteria following forced-air cooling](image)

**Figure 2.** Cantaloupes from four different fields were received for levels of non-pathogenic bacteria (Salmonella and E. coli), at some and after storage. Bacterial counts were always significantly lower at the time of shipping. Populations were essentially unchanged (Field 4, 7 days) after traditional postharvest storage. Our conclusion is that bacteria on the fruit may not be as resistant to stress than laboratory inoculated strains.

Pallets are loaded onto pre-cooled highway trailers for transport to a buyer’s distribution facility, or the destination market. Once loaded, it is typical for damage or single-use air bags to be set in place to prevent shifting and damage during shipping.

**Lot Identification**

All cantaloupes packed in central California are subject to a marketing order requiring continuous inspection. The container of cantaloupes that meet the inspection criteria are stamped with a “Western U.S.” certification that includes “trace-back” and positive lot identification information. The stamp contains unique codes that identify the date, location, and packing crew that packed that particular box. The container also must clearly include a “Statement of Recipient” identifying the company responsible for the fruit by location and origin.

Loading dock staging for cooling

Forced-air cooling

Staging racks

Positive lot identification aids rapid trace back when necessary.
Mounting a Solid Offensive Strategy

As will be discussed later, the contamination of cantaloupes with human pathogens is, arguably, an infrequent or rare occurrence. However, producers and handlers of fresh melons have a unique set of challenges in preventing microbial contamination of their products. Like all food products, a melon is susceptible to the environment that it is grown or raised in, in addition to its processing environment. The nature of the water, soil, foliar applications and other aspects of production and handling contribute to or largely determine the overall safety of the food product, for both positive and potential negative traits. Unsanitary food products, fresh cantaloupe is consumed in its raw form, with little or no processing. There is no heating treatment or comparable terminal kill-step to destroy the microorganisms that may have contaminated the product on the way from the farm to the table. Even freezing of melon cubes will not eliminate contamination should it be on the fruit from whatever source in the production or handling pipeline.

It is because of this intimate relationship between the final quality of an agricultural product and all aspects of the product’s environment that a comprehensive plan must be adopted to minimize the risk of microbial contamination at every step of production, as outlined above. Developing a GAP plan is a comprehensive way to account for all aspects of production and to deal with the potential risks associated with each aspect.

To initiate a GAP plan for cantaloupes, each grower must put in place certain prerequisite programs in order to maximize the efficiency of the GAP plan. The first thing to consider is a sanitation program at each stage of production, as necessary. It is important that all companies involved in the operation carry out an appropriate sanitization program in order to prevent one component from contaminating another. Each the grower has verified that the programs are adequate, copies of each sanitization policy should be kept on file. The grower must then conduct a hazard analysis of the production pipeline that is within the grower’s control. This pipeline may extend all the way from planting to packing produce on the transportation vehicle. Hazard analysis includes identifying opportunities for microbial contamination or proliferation within the production sequence, and assessing the risk at each point. When assessing risk at a particular point, the grower and shipper should consider two questions:

- How likely is microbial contamination, survival or proliferation at each point of potential risk?
- How severe would the results be if these events did happen?

Using the answers to these questions, the grower and shipper should identify specific points in the production, harvest and postharvest sequence that require special attention. After the grower has determined whether special hazard areas exist in the operation, the GAP plan can be developed.

Potential Sources of Contamination

Contamination by pathogens, such as Salmonella, can come from any number of sources. Points to consider when developing a comprehensive food safety plan include: personal hygiene and sanitary facilities, soil borne, equipment sanitation, container sanitation, temperature control, and water quality (see ANR 8013). Being aware of the quality of irrigation water and water for foliar sprays in important in minimizing the risk of contamination with microbial pathogens. The microbial status of water delivered by an irrigation district agency is not under the control of the grower. Nonetheless, it is important for a grower to be aware of the monitoring practices of the agency and any potential influences on water quality that may result from adjacent land use. The condition of sprinklers and sprays, and runoff recapture operations is also important. Good hygiene practice during harvest and transport includes regular cleaning and sanitizing of harvesting equipment and transport vehicles, and thorough pre- and post-handling. In addition, the entire production process from field to pack, equipment, processing and storage facilities are essential for a comprehensive food safety plan.
All melon handlers, including consumers, must consistently maintain the highest level of personal hygiene. It is important that consumers understand proper home preparation for melons, including that melons should be washed immediately before cutting and slicing, and are close to consumption as possible. Melons, like all fresh produce, must be strictly separated from all potential contact with food items such as raw chicken, raw meat, uncooked eggs, etc. Regardless of careful attention to preparation, unused edible portions of melons should be refrigerated following 2 hours of exposure to typical room temperature conditions (70-90°F) or discarded. For highly susceptible populations (infants, toddlers, elderly and immunocompromised), consumption of cantaloupe segments or sorbets that are cross-market dispayed with the intact rind touching edible flesh is discouraged unless thorough biohazard washing immediately prior to cutting and serving has been conducted.

Cantaloupes and Foodborne Illness

In comparison to smooth, uniformly waxy surfaced fruits such as bananas and watermelons, it is very difficult to remove or eliminate microbes from the outer rind of cantaloupe. The netted rind on cantaloupes can create spaces for bacteria, yeast, and mold spores to settle and escape from contact with topical disinfectant chemicals, detergents, and other treatments intended to clean them from the interior surface (see photo, Page 15). Research has repeatedly shown it is, therefore, difficult to remove those microbes from the netted rind and after they arrive. As will be discussed later, the contamination of cantaloupes with persistent or detectable levels of human pathogens is a very rare occurrence. Based on the overall consumption of cantaloupes, millions of servings daily, illness dramatically associated with contamination that occurs prior to food preparation handling is a very low probability event. However, it is equally clear that outbreaks linked to cantaloupes from various production areas have occurred and have impacted large numbers of individuals across many states and into Canada. With most individuals can recover from foodborne illness without complication or the need for medical attention, some individuals such as the elderly and those who may be otherwise immune-compromised may suffer complications, including those resulting in death.

Cases and Outbreaks

Cantaloupes have been implicated in investigations of foodborne illness outbreaks several times since 1998, as recently as 2002. In 2000, 2001 and again in 2002, over 100 recognized cases of salmonellosis were linked to consumption of cantaloupe, including at least two deaths. Most of the cases in both the U.S. and Canada were associated with the consumption of cantaloupes contaminated with Salmonella Poona, one of over 2000 types (called serotypes) of Salmonella known. The traceback investigations focused on melons produced and shipped from one region in southern Mexico. Salmonella Poona was identified in the cause of a similar large outbreak in 1991, from melons originating in a different part of Mexico, with over 400 cases in 23 states and Canada. This combination of events, including the finding of Salmonella serotypes and Shigella on imported cantaloupes in a random survey conducted by the FDA, led to the issuance of an importation exclusion (Detention without Inspection) on all Mexican cantaloupes by the FDA and the Canadian Food Inspection Agency until expenses could certify that Mexican grown and packed cantaloupes are produced under proper conditions that satisfy GAP and Good Manufacturing Practices (GMP) criteria. In date, only a few shippers have qualified for removal from the general Detention order.

There is a zero-tolerance for food borne pathogens in the U.S.; such food items are considered adulterated and cannot be marketed. Produce surveys conducted by the U.S. Food and Drug Administration (FDA) on domestic fresh fruits and vegetables identified an incidence: 2.4% violative samples (positive detection) for Salmonella and 0.6% violative samples positive for Shigella in 118 samples of cantaloupes, in a parallel FDA survey of imported fresh produce, 5.9% and 2.6% of 181 cantaloupe samples shipped from Mexico and Central America were positive for Salmonella and Shigella, respectively.
Table 1 below lists examples of outbreaks linked to melons. *Salmonella* serotypes are listed according to the notation used by the Center for Disease Control (CDC) and the Food and Drug Administration (FDA).

<table>
<thead>
<tr>
<th>Year</th>
<th>Pathogen</th>
<th>Location</th>
<th>No. Cases</th>
<th>No. Deaths</th>
<th>Comments</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td><em>N. taylori</em></td>
<td>United Kingdom</td>
<td>286</td>
<td>0</td>
<td>Infected food handler</td>
<td>Isola, 1987</td>
</tr>
<tr>
<td>1999-2000</td>
<td><em>S. montevideo</em> Cluster</td>
<td>36 states in U.S.</td>
<td>&gt;245 (at least 25,000 estimated)</td>
<td>2</td>
<td>Melons were from Mexico and Central America. Most cantaloupes were obtained from salad bars.</td>
<td>CDC, 1999</td>
</tr>
<tr>
<td>2001</td>
<td><em>S. enteritidis</em></td>
<td>27 states and Canada</td>
<td>&gt;400 confirmed</td>
<td>N/A</td>
<td>Fruits or cantaloupes were sent from the farms.</td>
<td>CDC, 1999</td>
</tr>
<tr>
<td>2001</td>
<td><em>S. enteritidis</em></td>
<td>Oregon, Canada</td>
<td>&gt;200</td>
<td>N/A</td>
<td>Cross contamination</td>
<td>Dell Rios, 1999</td>
</tr>
<tr>
<td>2003</td>
<td><em>S. enteritidis</em></td>
<td>California</td>
<td>34</td>
<td>N/A</td>
<td>Cut and serve</td>
<td>CA OHS and FDA</td>
</tr>
<tr>
<td>2003</td>
<td><em>S. enteritidis</em></td>
<td>Ontario, Canada</td>
<td>22</td>
<td>N/A</td>
<td>Cross contamination and improper cooling</td>
<td>Health Canada</td>
</tr>
<tr>
<td>2004</td>
<td><em>S. enteritidis</em></td>
<td>2 states in U.S.</td>
<td>47</td>
<td>N/A</td>
<td>Cut and serve</td>
<td>CA OHS and FDA</td>
</tr>
<tr>
<td>2004</td>
<td><em>S. enteritidis</em></td>
<td>Ecuador, Colombia and Alberta, Ontario</td>
<td>87</td>
<td>N/A</td>
<td>Cut and serve</td>
<td>Health Canada</td>
</tr>
<tr>
<td>2005</td>
<td><em>S. enteritidis</em></td>
<td>3 Florida states</td>
<td>50</td>
<td>2</td>
<td>Cross contamination</td>
<td>CDC and FDA</td>
</tr>
<tr>
<td>2002</td>
<td><em>S. enteritidis</em></td>
<td>14 states and Canada</td>
<td>28</td>
<td>N/A</td>
<td>Cut and serve</td>
<td>CDC and FDA</td>
</tr>
</tbody>
</table>

A three-year study involving over 1,900 cantaloupes (24-48 melons per field site), plus one melon for each group of 24 per field inoculated in the lab to give approximately 350 live *Salmonella* cells within a single, square inch target on the melon surface failed to detect any naturally-occurring contamination. Additional California melons obtained from wholesale distribution sources were also negative for *Salmonella*.

The determination of the source of contamination in an investigation of an outbreak associated with fresh produce is very difficult. The highly perishable nature of most fruits and vegetables means that during the period of time for illness to occur and be recognized by public health officials, the contaminated item will most likely already be out of the market. In most recognized cases, the problem of contamination is of a highly localized origin, potentially restricted to a single field, a confined region, or a single packing facility. Most often, due to the complexity of produce marketing channels, the traceback investigation takes months, long after the crop residues have been turned into the soil. The stored inventory in a cooler or distribution center is long gone, or the source of cross-contamination at a foodservice outlet or restaurant's home have been disposed. The source(s) of *Salmonella* in any of the most notable cantaloupe outbreaks have not been definitively determined. However, site investigations conducted in response to these outbreaks have generally identified issues with poor sanitation practices related to general production and harvest conditions (including irrigation...
water), hydrocooler water and facility or shipping ice. It is suspected that in most cases contamination came from inadequately disinfected and re-disinfected water used in hydrocooling or sanitary cooling and shipping ice. Hydrocooling and top-sizing for shipping have not been used in California for some time. Additional areas of concern have been the clear evidence of farm animals in production fields and the continued practice of recontaminating cattle in areas immediately adjacent to cantaloupe fields.

The seasonal prevalence of salmonellae in some Mexican production and packing locations, notably iguanas known to harbor Salmonella Poona, is suspected to serve as a reservoir for these human pathogens.

Regrettably these outbreak occurrences combined with the impact of processor orinnacle reporting of outbreak investigations related to freshproduce can be particularly devastating economically. The testing of the outbreaks, post-mortem and technical reports are often disconnected with the seasonal availability or actual origin of the processed contaminated product. The association of an entire category resulted to tens of millions of dollars in disputed losses, as in the case of the California strawberry industry in an outbreak of salmonellae from imported raspberries, and other unaccountable sources of high revenue from residual concerns (See Colona, USA). Accurate reporting of the source of the product and the ultimate outcome of outbreak investigations related to cantaloupe consumption propagates the association of California melons with episodes of Salmonella contamination.

Those outbreaks and the scope of the uncertainty associated with resulting investigations have also severely impacted Mexican growers and shippers. In 2001 and 2002, rejections in the U.S. and numerous locustal illnesses in both the U.S. and Canada were associated with the consumption of Mexican cantaloupes contaminated with Salmonella Poona. This led to the issuance of import alert on all Mexican cantaloupes by the FDA and the Canadian Food Inspection Agency until inspectors could certify that Mexican cantaloupes are produced under approved, audited, and certified GAP and Good Manufacturing Practices (GMP) program and conditions. To date, two shippers have qualified with the FDA to export cantaloupes produced in Mexico to the U.S. Collaborative research among UC Davis and Mexican scientists is being conducted to assist in the process of establishing a scientific basis for GAP implementation.

Research Results

The Rind as a Natural Barrier

Numerous repetitions of controlled contamination studies have shown that an intact rind, at harvest, is an effective barrier to penetration of bacteria to the edible flesh of cantaloupe (See Table 2). Natural openings, post damage, or harvest-wound openings may provide passive channels for internalization of external contamination, particularly if the melons are immersed in water that is inadequately treated with a registered disinfectant treatment, such as

Figure 1: The potential for external or transfer of Salmonella from an artificially contaminated water was tested by placing known concentrations of bacteria (approx. 100,000 cells/log 5.7 CFU) as the blossom end scar and the stem-end scar of 5 recently harvested melons. Following applying, melons were held at 41°F in a standard sterilized shipping carton for 72h. After an additional 12h at 59°F, they were processed using standard lab protocols. At the stem-end scar, Salmonella were detectable on the rind surface, and at 1/3 to 1/2 in. (2.5 to 5 cm) below the green-rind transition zone under the central rind. In repeated tests, detection was highly variable on any melon, ranging from none detected to almost 1000 cells. Salmonella were detected only at the rind surface from the blossom end, using standard methods. In related tests, using more sensitive methods of detection, Salmonella populations was confirmed at 1/3 in below the green-rind transition point that was not detected below this zone. In summary, improper washing would increase the potential for surface contamination of natural openings and wound sites.
The realities of bulk handling of melons at shipping are that water disinfection will never be as efficient in risk-reduction as a highly controlled lab treatment, and even these are not 100% effective in pathogen elimination. In fact, in studies conducted in our lab and in independent labs throughout the U.S., even treatment with concentrations as high as 2,000 parts per million hypochlorite did not eliminate the background resident bacteria. We applaud the management of those shed pack operations who may have identified and addressed their potential hazards and barriers to operational consistency of water disinfection and practical approaches to substantial elimination of the potential for cross-contamination.

![Figure 4 Controlled inoculations were conducted to determine the potential to transfer Salmonella contamination from the watered or the edible flesh when handling a contaminant for bovine rectal, meat display or hand use with or without storage at sub-optimal temperatures. Melons were inoculated with approx. log 6.0 CFU/cm² (99.9% of total bacteria in the inoculum) and then cut and washed for 90 second intervals. Each log unit inoculated for the fresh melon was watered at 5°F (15°C) for 3 days, and then cut and washed for 90 second intervals. Post-drying inoculated melons show a characteristic thin film and scored at 3.5°F (1.9°C) for 3 days. The observed level, Nevertheless, 10,000 cells to some replicates, is a combination of water at cutting and multiplication of Salmonella at this permissive temperature on stainless surface disinfection, length of storage, and temperature of storage must all be considered in overall safe food handling for cantaloupes.

- Chlorine dioxide, added sodium chlorite, ozone or peroxyacetic acid. Handling methods that minimize scaling, dust building, and especially open wounds will be beneficial in minimizing the chance for potential surface contamination to be introduced. Studies have demonstrated the presence of inoculated Salmonella up to 10 mm (approx. 1/3 inch) before the germ-tissue. Fresh at the blossom-end scar and water used, following direct placement of annular suspensions in these regions at the shelf surface (see Figure 1). Inoculation of replicates started from colonies that had been stored under commercial conditions for several days, where drying of the wound would have occurred, resulted in similar levels of Salmonella detection in subcool tissue.

**Importance of Melon Temperature and Cooling Water**

In addition, our studies, as well as studies conducted at other Universities and USDA scientists have shown that Western Shipping Center documents with a high field heat load, 95°F (35°C), are somewhat more likely to have elevated bacterial contaminations at the blossom-end scar and in any manually induced or bacterial wound would show if introduced to water chilled to 4°F (−19°C) or less. This is a typical temperature range for unchilled water used in some cantaloupe packing operations. Recent research conducted at the University of Georgia (UGA) found, under their test conditions, that this
temperature differential phenomenon was an
important factor in Eastern-type cantharides but
not Western-type cantharides. These findings
contradict the hypothesis that these phenomena
are the result of heat, which is only rare in
California. Variations in specific variety, growing
conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
growing conditions, and postharvest handling history
prior to any experimental use are important
tools in the analysis of risk with pathogens on
fresh produce. Variations in specific variety,
uptake water disinfection treatment and delayed
pack-site sub-surface drilling has been shown to promote
the development of mold in the door seam region
during distribution which has the potential to transfer
Salmonella to the edible flesh.

Due to the phenomenon, which has also been demonstrated for tomatoes, apples, and other similar
disinfection of this wash and cooling water takes on extreme importance in both food safety and
distribution. The realities of bulk handling of melons at shipping is that water disinfection and
variable commercial conditions is unlikely to be as effective in reducing/resisting in a highly controlled lab
treatment, and even laboratory investigations with minimally applied Salmonella contamination is not
100% effective in pathogen elimination. To date, in studies conducted in our lab and in independent labs
throughout the U.S., treatment with concentrations as high as 2,000 parts per million (ppm) of sodium hypochlorite (bleach), the lytic agent for most, or 10,000 ppm aqueous ozone for 30 min did
not eliminate the background resident bacteria. Recently developed proprietary methods that may
include combined or sequential heated high-pressure waters, surfactants and disinfectant that are being
employed in some commercial shed pack operations are reported to achieve a high level of melon
sterilizing capabilities, however independent confirmation is not publicly available. While the normal
microflora on a cantharide does constitute "contamination" or a health hazard, their persistence after
ery to control these varies throughout treatments is indicative of zero difficulty. It may be to remove
and kill naturally contaminating pathogens.

Suveys conducted in commercial shed pack operations in California and in other states of the U.S.
recently confirmed these laboratory observations. Sub-optimal disinfectant treatment of both Atlanta
cooling water resulted in a greater degree bacterial count on cantharides after packing as compared to
melons undergoing the packing operation from the field. In addition, higher average bacterial counts in
the stomata-tissue and bloom-site tissue were observed following passage along the wash and pack-
line to final packing. In California, tests as before, showed Salmonella was detected. In other states, similar
surveys reported by university researchers, Salmonella was detectable at low levels using essentially
identical or even somewhat less sensitive detection methods.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.

Pathogen surveys from cantharides collected at shipping point and point of purchase studies and
conducted by the FDA and USDA also report no cases of positive detection from any cantharide
originating from California.
Salmonella serotypes appear to tolerate rapid desiccation better than the other common bacterial pathogens evaluated. The level of survival and persistence is dependent on the initial concentration at the time of contamination, the environmental conditions immediately following deposition, and to some extent whether contamination is associated with a protective organic carrier.

| Table 2: Total Melons Inoculated 222 | No Direct Recovery 203 | Direct Recovery 19 |

Salmonella serotypes were found, interestingly, to become internalized during postharvest storage. Cerebrospinal fluid contamination of intact upper end surface resulted in an 8.3% frequency of detectable toxin. Internal transfer was often associated with the development of surface molds.

with the operational difficulty of minimizing cross-contamination within shed pack management on a day-to-day basis. For those regions outside of California whose shed packing is not an option, some practices employed in melon handling, such as rotation of melons from field to trailer, give the prevention of increased rather than decreased potential risk. Specific data is needed to confirm or give cause to dispute this concern.

We applaud the management of those shed pack operations who may have identified and addressed their potential barriers and barriers to operational feasibility of water disinfection and practical approaches to substantial elimination of the potential for cross-contamination. At this time, to the best of our knowledge, no independent confirmation of such a system has been publicly accessible.

From these studies conducted over several years, it is reasonable to predict that careful handling during field packing, adequate cleaning and sanitization of melon-packing contact surfaces, as well as maintaining a dry melon surface during cooling and shipping will help to minimize survival and internalization of potential contaminants. Any application of inorganic washwater during post-harvest handling should be carefully evaluated, under strict scientifically designed protocols, for the potential to become a risk and to result in cross-contamination or the introduction of contamination from the packing operation environment or equipment. Although limited data is available on drying prior to shipping or removing adhering dirt before display may be preferable to washing, even with chlorine water. Although less problematic than handling in water, compost is also advisable with dry brushing canals before an interdisciplinary research during these studies have demonstrated that Salmonella can remain in a viable condition in the dry "dust" removed from the wash rind.

Survival Potential on Rind

Laboratory data from controlled inoculation studies show that various strains of Salmonella, E. coli 055:77-H, and Shigella can survive on the surface of cantaloupe under stressful environmental conditions. In approximate decreasing order of environmental stress tolerance, Salmonella serotypes appear to tolerate rapid desiccation better than the other common bacterial pathogens evaluated. The level of survival and persistence is dependent on the initial concentration at the time of contamination, the environmental conditions immediately following deposition, and to some extent whether contamination is associated with a protective organic carrier. Concentrations in excess of one million cells per square inch of red eye, temperatures of rapid drying (20-45 min) occurs. The survival rate can be calculated using standard detection methods, when the melon surface is exposed to direct natural sunlight and low humidity. More sensitive methods, called enrichment, reveal that there are invariably low levels of survivors even under extreme conditions. In tests conducted at the same time, survival has been shown to be low but detectable with standard methods, when melons, inoculated in the same way, are subjected to sunlight.

While this data does not help design a reliable control method, the consistent message from all survival studies conducted thus far suggests that typical production and harvest conditions would lead to reduce transient sources of contamination on the surface due to environmental stresses for the bacteria. Our data consistently shows that conditions that lead to rapid drying on the melon surface will also lead to faster bacteria death.

Beyond the simple presence of low levels of external contamination, several other events would likely be necessary for contamination of edible flesh to occur and result in illness following consumption. The key events are internalization of contamination, translocation of contamination during food preparation, and the presence of an infectious dose to a susceptible individual. Prevention of internalization during harvest and post-harvest handling are steps that growers and shippers identified as potential areas where science-based data was needed before appropriate actions could be designed. Although outside of the grower's ability to control, the conditions and uncertainties for the transfer of contamination during preparation were determined to be areas for research determination. These
threshold values for potential contamination of the interior edible flesh were viewed as a prerequisite baseline number prior to conducting any field survey of cantaloupes for pathogen presence. Each of these investigations will be discussed in separate sections below.

Potential for Transference during Cutting

Laboratory studies have shown that passing a cutting blade through an artificially inoculated cantaloupe rind that has been air-dried will not surprisingly result in the transfer of Salmonella to the melon flesh. As expected, the higher the number of bacteria on the melon rind, the more likely it is that the cross-contamination will occur (see Figure 5). In commercial flesh-cutting processing operations, it is therefore imperative that the melon rind be properly cleansed with disinfectant-treated water, to the maximum extent possible, before cutting, and that subsequent temperature control is maintained after cutting and during distribution and retail display of fresh fruit to minimize contamination.

![Graph showing the effect of external concentration of Salmonella on detectable transference to cantaloupe flesh after direct cutting](image)

**Figure 5:** By standardized methods of direct detection, high populations of external Salmonella contamination were necessary to result in edible flesh contamination during cutting. However, in commercial studies with these methods, and repeated similar tests (data not shown), using more sensitive methods of Salmonella concentration and enrichment, it was observed that positive detection was possible between 10^3 (5 on figure) and 10^5 (7 on figure) cells. From these and cumulative related experiments, a minimum sensitivity of detection, 350 cells per melon, was selected for surveys of cantaloupe production fields in California.

Effectiveness of Washing and Chlorination

At this time, the results from our recent survey support the acceptability of removing the responsibility for washing California cantaloupes to the ultimate food preparer, and as close to consumption as possible. There are several options to reduce the number of bacteria on the surface of a cantaloupe, with varying degrees of success: the ANSR 81093 and 81938. One method that is often mistakenly suggested, even by some public health officials, is the use of soaps and common detergents. While food grade surfactants (detergent agents) may be safely used by qualified processors, current FDA recommendations are strongly against the use of soap for melons or other fresh produce by home consumers, even if peeled after washing.
Snaps and household bleach are not approved for produce washing purposes. They may be absorbed by produce or transferred during peeling or cutting, leaving off-labels. Too much ingested residue of strong detergents may cause gastrointestinal distress.

Scrubbing the melon surface during a non-chlorinated water wash helps to reduce the number of total bacteria on the melon and only slightly more than washing with water without scrubbing (see figures 6 and 7). Scrubbing melanin in chlorinated wash water has been shown to further reduce the number of Salmonella (on the skin by more than 100-fold) compared to scrubbing with just water alone. Chlorine, chlorine dioxide, peroxyacetic acid, ozone, peroxycarbonate, and organic acids are all effective in reducing the number of microorganisms on a melon skin to some degree, but none can be relied upon to completely eliminate microbial contamination. Using chlorinated water, or other permitted disinfectants, wash water and scrubbing the fruit during washing is the best option, and the use of chlorine is essential in preventing the buildup of contamination in wash water and on brushes, as well as preventing transfer to the next melon or other produce item. While using chlorinated water (typically 250 parts per million of free available chlorine at pH 6.0 to 7.5) significantly reduces the number of bacteria on the fruit, no practical treatments have been shown to be successful in completely eliminating pathogenic bacteria on a contamination risk. This highlights the importance of a comprehensive food safety program implemented throughout the handling chain, beginning with preventing and minimizing the chances of contamination in the first place.

We do not recommend the addition of standard household bleach to wash water for cantaloupes, or any fruit or vegetable. In foodservice establishments or by home consumers, household bleach contains additives intended for foods and food contact surfaces. Recommended consumer washing and handling practices for cantaloupes are available in ANS 4908.

Submerging cantaloupes in non-chlorinated, non-chlorinated water with or without scrubbing can actually make the contamination problem worse than leaving the melon surface dry and untreated prior to shipping. Data shows that this succeeds in spreading the contamination around to adjacent sites on the cantaloupe (fig. 7) and to subsequent cantaloupes washed in the same batch water (fig. 8).

One concern that processors may have about surface disinfection is its effect on melon flesh texture. Laboratory studies show that washing the surface of a melon skin, with or without chlorine, does not significantly affect the texture of the melon flesh.

Other Barriers to Survival
Exposure to natural ultraviolet light from the sun may be contributing to the goal of minimizing pathogen survival. If contamination were to occur due to uncontrollable factors in a natural, open environment. Although we cannot rely on UV exposure to occur on every melon and at all melon surfaces, especially under a heavy overgrowth, it was useful to compare the observed behavior of common fennel bacteria with adapted to 30% on most plant varieties, such as Penicillium digitatum, to Salmonella (following exposure to sunlight) See figure 9.)
Figure 7: These illustrations, summarizing several laboratory experiments, demonstrate the potential for inadequate or incorporeal water disinfection to increase the potential for pathogen contamination by moving live bacterial cells to non-contaminated areas on a melon and by cross-contamination from mechanical aids (brushes) and reused or re-circulated wash water. The pathogens reductions in single melon handling, represented by these facts, would most likely he achieved in a foodservice or consumer handling situation. The efficiency of reproducing these levels of surface disinfection under bulk washing and cooling operations at shipping would require careful experimental verification.

Figure 8: Salmonella was shown to readily transfer from a single, artificially contaminated melon (col. 1) to others in the same sequential batch wash system.

Figure 9: In controlled tests, the normal plant surface resident bacteria, *Pseudomonas fluorescens*, survived better than *Salmonella*, whether shaded or fully exposed to bright sunlight. In full sunlight, the inoculated *Salmonella* became undetectable and unrecoverable after two hours.
Surface Drying during Cooling

From field packing to shipping, under typical conditions, the surface of a cantaloupe would be expected to remain dry or lose some moisture. Laboratory studies with many produce items have consistently shown that rapid drying of waterborne contaminants results in a high rate of bacterial cell death. However, after the initial lag phase, although bacteria for Salmonella and E. coli O157:H7 cannot grow at standard shipping temperatures, populations may remain on the surface for an extended time under refrigerated storage and forced-air cooling (Fig. 2 and 3).

![Graph showing survival of Salmonella and E. coli O157:H7 on cantaloupe rind at 39°F (4°C) over time.

**Figure 10:** Experiments were conducted to simulate the survival of surface contamination during cooling. In the above graph, the greatest level of reduction occurs in the first hour of drying. Bacterial populations tend to decline in refrigerated storage but microbial contamination may persist. At this time, because no naturally contaminated treatments have been identified in California production trials, our research is not identified. Whether these simulation results accurately reflect the expected rate of die-off and survival. We are confident that these results provide support for the functionality of rapid drying as one of several potential barriers to persistence of Salmonella on the surface of cantaloupe melons.

CA Survey Results

A survey of California cantaloupes was undertaken to determine the frequency of Salmonella contamination in the field at the optimum time of harvest. The sequential detection-step methods used combined an initial non-selective enrichment (no aqueate stressed cells), a direct selective enrichment to minimize background competitors that could interfere with detection of low levels of Salmonella cells, and a final screen of samples using a highly specific generic-activity test for salmonella, similar to DNA fingerprinting. A three-year study involving over 1,900 cantaloupes (24 - 48 melons per field) plus one melon for each group of 24 per field inoculated in the lab to give approximately 100 live Salmonella cells within a single square inch nagen in the melon surface failed to detect any naturally-occurring contamination (Table 3). Additional California
melons obtained from wholesale distribution sources were also negative for Salmonella. The laboratory inoculated Salmonella melons, the 'positive control group', were determined to result in a 100% positive detection, even at the very low initial numbers. The starting point of 500 cells was shown in earlier project research to be the lowest number likely to result in detectable transfer during cutting. This level of sensitivity exceeds that used in standard melon survey detection procedures. Surveys of a subset of over 200 of the same melons, using similar methods specific for the Salmonella, did not detect this additional human bacterial pathogen found on cantaloupe from other regions. Identical application of this detection procedure, in our laboratory, to environmental samples not associated with cantaloupe production identified very low levels of five cells of a Salmonella strain that is not associated with human illness, but is known to be carried by reptiles and some birds. For this reason, were are confident that our methods are sufficiently sensitive and were appropriate and accurate for use in this survey.

**Table 3**

<table>
<thead>
<tr>
<th>Survey Year</th>
<th>Total Melons Tested</th>
<th>Number of Farm Locations</th>
<th>% Natural Salmonella Positive</th>
<th>% Inoculated Control Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>165</td>
<td>5</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2000</td>
<td>312</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2001</td>
<td>390</td>
<td>20</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2002-03</td>
<td>995</td>
<td>25</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2003-2004</td>
<td>150</td>
<td>2</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

**Summary and Recommendations**

Historical evidence and current research, specific to California production, handling, and shipping practices for both field pack and seed pack operations, strongly support industry assertions that consumers of California cantaloupe are at minimal risk of becoming ill and that the likelihood of outbreaks traced back to these production sources is quite remote. Contamination of cantaloupe by bird or animal droppings, non-hygienic human handling, exposure to contaminated water, or by direct contact with a surface previously contaminated with Salmonella is, of course, possible. However, the reasonable conclusion to draw from all current, scientifically acquired information is that such contamination and resultant illness should be considered of a low probability of occurrence.

In the absence of detectable prevalence of contamination by Salmonella and Shigella combined with the current and future improvements in preventive GAP and GMP programs being implemented by producers, processors, and retail and foodservice handlers, it is reasonable to conclude that both field pack and seed pack methods of handling may be considered a low risk for foodborne illness. In both systems, independent third-party audits certify that harvest crews and packers are regularly trained in personal hygiene and all field sanitation facilities are maintained in a manner compliant with California Occupational Safety and Health Administration (CAL-OSHA) requirements.

Regarding field packing of cantaloupes in California, it is important to
recognize that an aspect of this method minimizes the potential for food cross-contamination of melons in a given lot. Melons taken directly from the growing bed are placed on a pallet or conveyer which carries them to the packers, as described above. Best Management Practices (BMPs) that harvest operations should implement and document a daily cleaning procedure and removal of any fruit residue to minimize survival and the risk of cross-contamination on the packing platform (See Figure 10). Melons are generally placed in corrugated boxes or, for some boxes, in reusable plastic containers (RPCs). Once in these shipping units, melons are essentially segregated from contact with melons in other packing units. As removal of fruit debris is accomplished strictly with pressure washing with air blowers for cooling, rather than chilled water or ice, cross-contamination is minimized. As no sites or sources of naturally contaminated cantaloupes have ever been detected in our studies or reported by another research group or agency, it has not been possible to specifically address pathological questions regarding the potential for cross-contamination of melons by aerosolized bacteria during forced-air cooling. It is entirely reasonable to permit similar melons with Salmonella for such a study. Further, no validated and food-safe surrogate strains have been approved for such a study, however this is an active area of ongoing research in our laboratory.

If contaminated, the mature cantaloupe fruit is a complex and excellent surface for survival, and has been shown to have the potential for limited growth if allowed to remain wet. The internal flesh is clearly an excellent "growing ground" for pathogenic bacteria, if not refrigerated. There are many places for microorganisms to grow on a refined melon surface, and the topographical nature of the fruit lends to make deep crevices and ridges of bacteria very difficult. Chlorine washing (or other disinfectants) and aluminum oxide or ceramic gauze have been found to reduce the contamination levels on single melons in the lab, but to true "kill step" has been found to eliminate the contamination and thereby the total risk following food preparation. Our research has shown that the introduction of cantaloupes into dump tanks and flumes or batch washing methods are likely to create an increased potential for cross-contamination, a potential transfer of bacteria to natural openings and wounds, a potential for infiltration to survival during storage, and may increase superficial fungal growth and decay which further elevate the chance for contamination of internal flesh.

Hypothetically, handling methods such as water drops, hydrocooling, sub-optimal disinfectant washes, and even dry brushes that have contacted contaminated melons can re-distribute the entire cantaloupe lot with pathogens from a very small number of melons. Without a true "kill step", the practical existing and water-based cooling methods currently available may be more likely to spread any pathogens present rather than remove it.

For California cantaloupes, based on our research, the likely low (often undetectable) number of cells, if it were to occur, means that testing for pathogens on melons lots and products is not practical and, therefore, not economical or advisable under any reasonable scenario. Keeping the melons whole, firm textured, free from injury or digs, and dry from shipping until just prior to processing, in a qualified food facility or close to consumption following home preparation, is the best food safety practice to protect consumers and to safeguard their confidence in delicious and nutritious food.

Bottom Line

All the available research from many labs confirms the comparatively high risk potential for human illness if cantaloupes become contaminated with pathogens such as Salmonella. Based on the available research data and the food safety programs of conscientious California growers, shippers and handlers, we believe the risk exposure for consumers is low.

The clear message from university research is that once a cantaloupe has been contaminated, removing or killing the pathogen is not an easy task. In order to protect and maintain California's strong reputation for high-quality melons that are also safe to consume, a comprehensive and standardized food safety program is a necessary goal for the cantaloupe industry to continue to evolve and improve.