Overview of Industry Practices

Minimizing the Risk of Foodborne Illness Associated with Cantaloupe Production and Handling in California

CALIFORNIA CANTALOUPE ADVISORY BOARD
Prepared by the University of California, Davis

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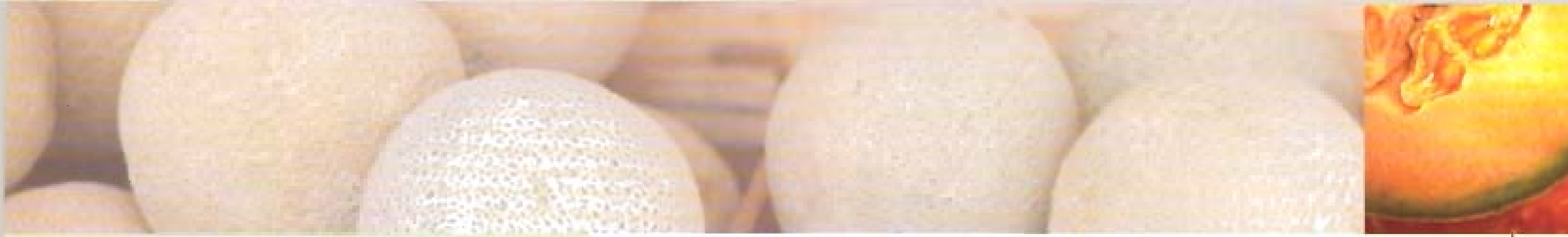


***Over the past six years,** the California melon industry has been supporting proactive research to address microbial food safety concerns. This research has taken a broad approach, applying modern microbiological methods and technology to address areas in production and handling, from the farm through 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 referred journals. It is our sincere hope that buyers, food specialists, procurers, 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 publicity surrounding the Food Safety Initiative of 1997 and the recurring sporadic outbreaks of foodborne illness attributed to fresh consumed produce. Sparked, in part, by broad media coverage of notable outbreaks on fresh and minimally processed fruits and vegetables not commonly associated with severe illness, 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 ever survey since 1998, conducted by the Produce Marketing Association (PMA 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 widely developed and adopted comprehensive food safety programs. These programs are based on various voluntary guidelines, typified by the 1998 *Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables* released by the Food and Drug Administration. This document provides a framework for the industry to establish 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 8103). 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 1997, 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 multi-year *Salmonella* survey was conducted involving over 2000 individual cantaloupes harvested directly from the fields, cooling operations, and shipping facilities in many producing regions of California. Melons packed directly into shipping cartons (field pack) and bulk melons entering clean-wash-pack operations (shed pack) were included in the survey. No detectable levels of live *Salmonella* were found in any samples, under the broadest range of locations and conditions ever conducted. Scientifically, this tells us that although one could never responsibly say that no cantaloupe could be contaminated, the practical likelihood of detecting *Salmonella* is extremely improbable under California conditions and practical, 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 (ANR 8085), cantaloupes produced in California, and by reasonable extension in other arid production regions that have access to adequate quality water, can be purchased with confidence and a very minimal concern for the potential for illness to be associated with their consumption.

Additional studies conducted in parallel with this survey strongly indicate that, although melon washing may 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 disinfectant wash handling operation. Distinct and substantial challenges to safe management of shed pack operations in these domestic and off-shore regions are being addressed by an international network of researchers. These and other key research findings are summarized in the following brochure.

Review of Cantaloupe Outbreaks

The focus of public heath 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 Saphra and *Salmonella* serotype Poona on cantaloupes several times, most recently in 1997 and 2000, 2001, and 2002. Although many consumers 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 melon 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 under laboratory models of current and potential handling practices. The sections 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 00-52102-9637 and 51110-01987). 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 454 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 excellent source of Vitamin C, β-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 net-veined fruits, while these are sometimes referred to as "muskmelons" in the Eastern United States. True cantaloupes are smooth-fruited melons, common in Europe but uncommon in the United States, and derived from those plants first developed in Cantaluppi, Italy. These have thick, scaly, 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 ribs. 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. 1998).

Cantaloupe Production in California

Originally a shed pack 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 or container. A flow diagram is provided on the back cover page. Within California, whether field or shed packed, the current system for cantaloupes does not include water immersion in a dump tank, hydrocooling (hydro-shower), or packing or over-spraying with ice (top-icing) for shipping. Field-packed fruit are containerized, stacked on a pallet in the field, and taken to facilities for air-cooling. California

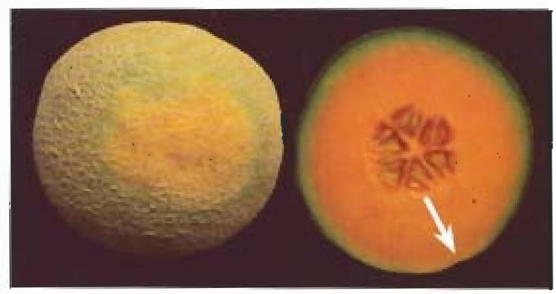
It is not the purpose of this document to detract from the significant advancements and on-going efforts of international producers to improve their individual situation relative to microbial food safety. Nonetheless, as foodborne illness and outbreaks associated with cantaloupes impacts the entire category, it is worthwhile to highlight the absence of particular practices from California production that are thought to be of particular risk concern and potential impediments to a comprehensive food safety plan.

(Note: For a detailed analysis of economic impacts of produce outbreaks see L. Calvin 2003 in Additional Reading.)

shed packing brings melons in to the packing facility in cartons, plastic bins, or in trailers where they are unloaded onto conveyers. Melons are then dry-brushed and/or wet-brush cleaned in a single-pass spray of disinfectant-treated water. A few operations utilize additional steps intended to further remove adhering soil and minimize surface mold development during distribution. Some of these differences in handling practices are important distinctions that are incorporated into the design of GAPs and preventive food safety management practices. The basic steps are outlined later in the document.

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 volumes in California and the U.S. The production, harvesting, and postharvest handling of California cantaloupes share some elements in common with melon 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.



The ground spot has been shown to be an area more susceptible to internal transfer by Salmonella *during postharvest handling. The arrow points to the thin subrind green transition tissue*

Current California production does not require or include practices such as hand-turning melons in order to prevent ground spot development in wet soils, which can introduce personnel hygiene issues. The **ground spot** is an area of the melon in direct contact with the soil that is characterized by a thin and underdeveloped outer rind. This area does not develop proper netting and is characterized by a thin sub-rind green tissue layer, more easily breached by soil inhabiting fungi. Proper planting-bed preparation and careful irrigation management, together with a predominant absence of rainfall during the harvest season, prevent or greatly minimize ground spot occurrence. Our laboratory research has shown the ground spot to be a site on the rind that is more susceptible to potential internalization by *Salmonella* during postharvest handling.

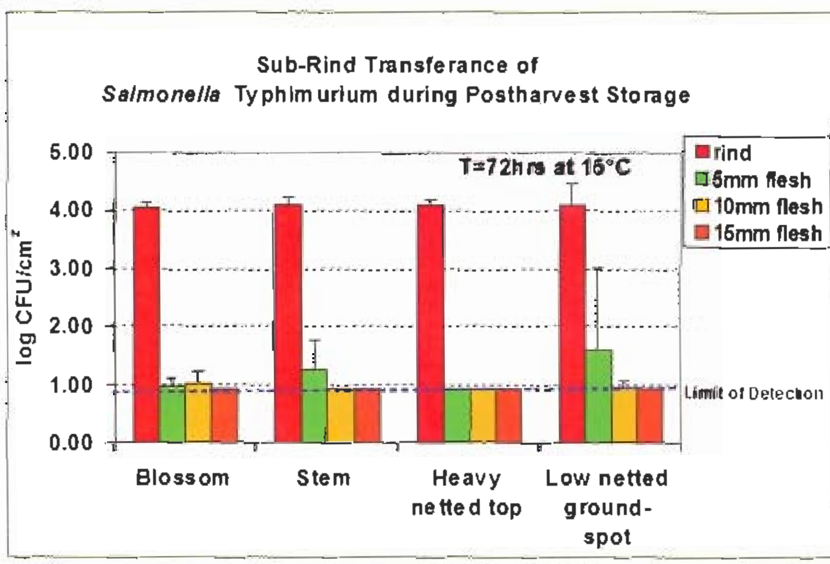


Figure 1 *In carefully controlled laboratory inoculations,* Salmonella *was detected as far as 10 mm (3/8 in) below the green rind transition zone. Sub-optimal postharvest handling conditions increased the likelihood of internalization of the edible flesh.*

California water sources are of adequate quality for its intended use in irrigation and foliar applications. GAP and food safety systems are in place which precludes the use of known or potentially contaminated surface water, such as from discharge of untreated or minimally treated sewage and waste disposal sites.

While it is not possible to unequivocally state that manure-based 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.

Late-season fungicide or whitewash foliar applications, necessary in some areas outside of California, that prevent sunscald of ripening melons are not necessary in the San Joaquin or Sacramento Valley regions. Packing washed and sub-optimally cooled melons in polymer bags, which may promote persistent condensation and stimulate microbial growth during distribution, are not necessary for distibution 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 dairy manure, chicken manure, or compost as soil amendments is reported by the industry to be an uncommon agricultural 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.

Plastic elevation disks are used in some areas outside of CA to minimize the development of ground spot due to wet soil conditions. The disks decrease the need for frequent hand turning of the melon to prevent this defect.

Field Preparation

For main 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 crews 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 (7.5–15 cm) below a covering of loose soil that helps retain moisture. After seed germination, this "soil-cap" is removed prior to seedling 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 seedling 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 systems 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

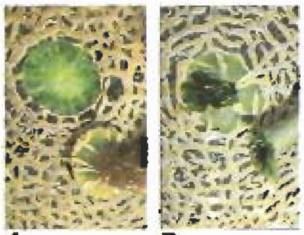
To set fruit and achieve the best size and yield, insects are required for the transfer of pollen. The primary pollinators are bees, particularly honey bees. Cantaloupe flowers generally open after sunrise, depending on sunlight, temperature, and humidity. The flower closes permanently in the afternoon 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 spraying is terminated 7-14 days prior to harvest, but there are exceptions for approved and registered materials to control late season leaf diseases. Best Management Practices advise that all spray tanks be filled with potable water from the public water agencies or other potable domestic sources. Regular spray tank and spray-line clean-out protocols are included in pesticide and chemical safety programs, more recently recognized as part of a microbial food safety plan as well as.

At harvest, the air temperatures are generally high (>90F), with very low humidity (< 40%) and high solar UV irradiance; conditions not favorable for bacterial survival.

Harvest Practices



A **B**

To market the highest quality cantaloupes, melons are hand-harvested when the fruit will cleanly and easily separate from the vine with only a light pulling and twisting motion. This stage of maturity is called "firm full-slip"(**A**), the standard quality stage in California. Less mature melons and 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 % °Brix. 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 beds to mobile packing stations. into the industry-standard 40-pound (18-kg) cartons. Fruits are sight-sized 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 bed-shoulder surface and lifted onto mobile trailer for palletization. Identification stamps and pallet tags are placed with each lot in the field. At harvest, the air temperatures are generally high (>90F), the very low humidity (< 40%) and high solar UV irradiance; conditions not favorable for bacterial survival.

Nonetheless, our research has shown that cantaloupes will harbor beneficial and benign bacteria on and within the netted rind, 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. If cells of *Salmonella*, *E. coli*

Example of Melon Survey Environmental Parameters at Harvest

Air temperature at 13:00 – 40.5C (105F)

Solar UV Irradiance – 188- 193 (mol m-2s-1)

Vine Surface temperature – 36-38C (97-101F)

Fruit Field temperature
- Exposed to Sun – 49C (120F)
- Exposed to Sun (sub-rind) – 42C (108F)
- Under Vine – 37C (99F)
- Under Vine (sub-rind) – 36C (97F)

Fruit Temperature at Pre-cooling
- Rind Surface – 27C (81F)
- Sub Rind - 25C (77F)

O157:H7 or *Shigella* are deposited on the exterior rind 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, cartons are typically maintained at the shipping/cooler 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, cartons are transported directly to the field harvest operation where they are formed and delivered to the packing crew. In some harvest operations, the cartons are placed at the ends of the rows prior to the beginning of harvest and used as needed.

Loading dock staging for cooling

Shipping Practices

After transport to the cooler, pallet loads of cantaloupes are placed in two channels within the cooling facility on either side of a large fan. A covering is drawn over the tops and rear of the channels and pallet openings are blocked to direct airflow through the vented cartons and around the packed fruit. This method of cooling is called pressure or **forced-air cooling**. Cooling to pre-shipping temperatures, 36 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.

Forced air cooling

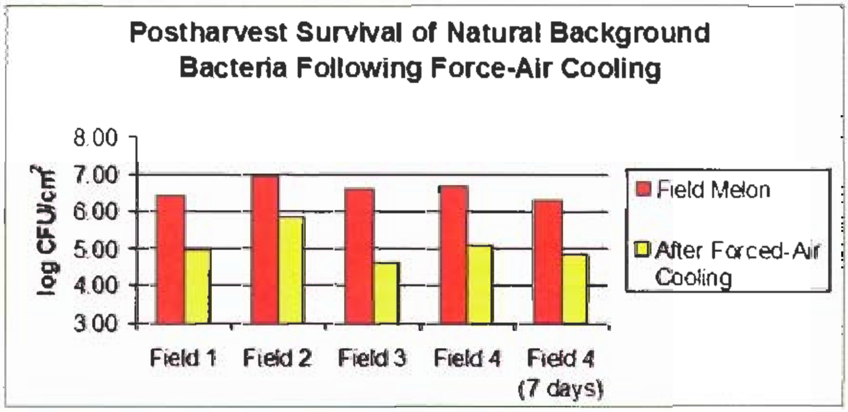


***Figure 2** Cantaloupes from four different fields were monitored for levels of non-pathogenic bacteria, related to* Salmonella *and* E. coli, *at harvest and after air-cooling. Bacterial counts were always significantly lower at the point of shipping. Populations were essentially unchanged (Field 4, 7 days) after typical postharvest storage. Our conclusion is that bacteria on the rind may be more resistant to stress than laboratory inoculated strains.*

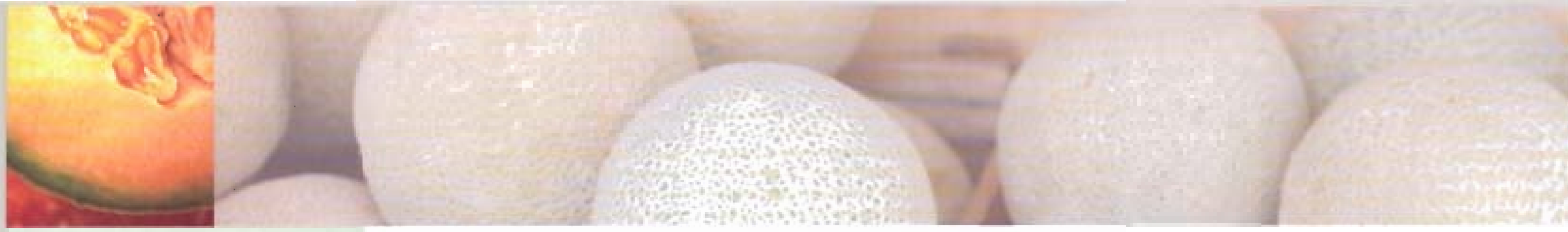
Storage racks

Pallets are loaded onto pre-cooled highway trailers for transport to a buyer's distribution facility or destination market. Once loaded, it is typical for dunnage 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 containers of cantaloupe that meet the inspection criteria are stamped with a "Westside One" 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 responsibility" identifying the company responsible for the fruit by location and origin.

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 potentially negative traits. Unlike animal-based food products, fresh cantaloupe is consumed in its raw form, with little process preparation. There is no final heat 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 intricate 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 program for cantaloupes, each grower must put in place certain pre-requisite 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 sanitation program in order to prevent one component from contaminating another. When the grower has verified that the programs are adequate, copies of each sanitation 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 loading 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.

All melon handlers, including consumers. must consistently maintain the highest level of personal hygiene.

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 history, equipment sanitation, container sanitation, temperature control, and water quality (See ANR 8103). Being aware of the quality of irrigation water and water for foliar sprays is 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 uses, the condition of impoundments or sumps, and run-off recapture and re-use practices. Good hygienic practice during harvest and transport includes routine cleaning and sanitizing of harvesting equipment and transport vehicles. Through proactive education, this message of safe food handling and hygienic practices is being extended to downstream processing, retail display, and home preparation (See ANR 8085). Exclusion of domestic animals and efforts to minimize rodent and bird harborage from all potential contact with, or transfer from, fields, 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 peeling, and as 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 egg, 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 (70-72F) or discarded. For highly susceptible populations (infants, toddlers, elderly, immuno-compromised), consumption of cantaloupe segments or wedges that are cross-stacked or displayed with the intact rind touching edible flesh is discouraged unless thorough brush-washing immediately prior to cutting and serving has been conducted.

Cantaloupes and Foodborne Illness

In comparison to smooth, uniformly waxy surfaced fruits (such as honeydew and watermelons), it is very difficult to remove or eliminate microbes from the outer rind of cantaloupe. The netted rind on cantaloupes can provide spaces for bacteria, yeast, and mold spores to settle and escape from contact with applied disinfectant chemicals, detergents, and other treatments intended to clean them from the melon surface (See photos, Page 12). Research has repeatedly shown it is, therefore, difficult to remove these microbes from the netted melon rind 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 each day, illness definitively 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. While most individuals can recover from foodborne illness without complications or the need for medical attention, some individuals such as the very young, the elderly and those who may be otherwise immuno-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 1990; 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 as 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 exporters could certify that Mexican grown and packed cantaloupes are produced under proper conditions that satisfy GAP and Good Manufacturing Practices (GMP) criteria. To date, only a few shippers have qualified for removal from the general Detention order.

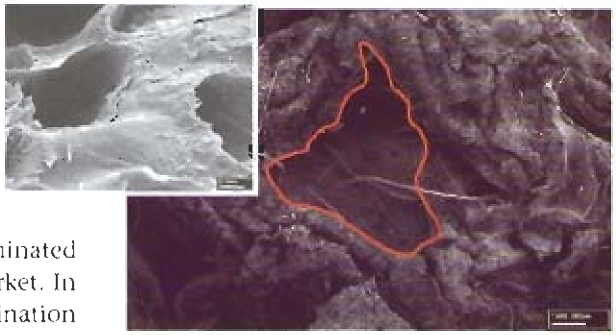
There is a zero-tolerance for food borne pathogens in the U.S.; such food items are considered adulterated and cannot be marketed. Produce surveys conducted by the U.S. Food and Drug Administration (FDA) on domestic fresh fruits and vegetables identified an incidence of 2.4% violative samples (positive detection) for *Salmonella* and 0.6% violative samples positive for *Shigella* in 115 samples of cantaloupes. In a parallel FDA survey of imported fresh produce, 5.3% and 2.0% of 151 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 the notation used by the Center for Disease Control (CDC) and the Food and Drug Administration (FDA).

Table 1

Year	Pathogen	Location	No. Cases	No. Deaths	Comments	Reference
1987	Norwalk virus	United Kingdom	206	0	Infected food handler	Iverson, 1987
1989-90	Salmonella Chester	30 states in U.S.	>245 (estimate 25,000 affected)	2	Melons were from Mexico and Central America. Cut cantaloupes were obtained from salad bars.	see CDC, 1991
1991	Salmonella Poona	23 U.S. States and Canada	>400 confirmed	NR	Fruit salads containing sliced cantaloupes from Texas and/or Mexico. Contamination from surface during slicing; possible multiplication on sliced fruit.	CDC, 1991
1993	E. coli O157:H7	Oregon	Unknown	NR	Cross-contamination	Del Rossario, 1994
1997	Salmonella Saphra	California	24	NR	Cut and uncut melon from retail and food service. Strong association traced back to packing plant in Mexico.	CA DHS and FDA
1998	Salmonella Oranienburg	Ontario, Canada	22	NR	Possible contamination with organism from surface when slicing. The cut fruit was probably left sitting at room temperature for several hours before consumption.	Health Canada
2000	Salmonella Poona	7 states in U.S.	47		Cut and uncut melon from retail and food service. Strong association traced back to packing plant in Mexico.	CA DHS and FDA
2000	Salmonella Poona	British Columbia and Alberta, Ontario	7	NR	As above but with possible sourcing from different shipper	Health Canada
2001	Salmonella Poona (2 types)	14 states in U.S.	50	2 (possible 3rd death)	Cut and uncut melon from retail and food service. Strong association traced back to packing plant in Mexico.	FDA and CDC
2002	Salmonella Poona	14 states and Canada	58		Cut and uncut melon from retail and food service. Strong association traced back to packing plant in Mexico.	

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 netted rind surface has many contours and a semi-porous structure. In the scale bar, 500 microns equals 0.019 inches. Between 80 to 100 cells of Salmonella *would fit in the outlined space on the rind.*

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 are long gone, or the source of cross-contamination at a foodservice outlet or consumer'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-circulated water used in hydrocooling or unsanitary cooling and shipping ice. Hydrocooling and top-icing 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 continuing practice of corralling cattle in areas immediately adjacent to cantaloupe fields. The seasonal prevalence of wildlife 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 premature or inaccurate reporting of outbreak investigations related to fresh produce can be particularly devastating economically. The timing of the outbreak press releases and technical reports are often disassociated with the seasonal availability or actual origin of the presumed contaminated product. False association of an entire category resulted in tens of millions of dollars in direct sales losses, as in the case of the California strawberry industry in an outbreak of *Cyclospora* from imported raspberries, and other unaccountable sources of lost revenue from residual concerns (See Calvin, ERS). Inaccurate reporting of the source of the product and the ultimate outcome of outbreak investigations related to cantaloupe consumption perpetuates the association of California melons with episodes of *Salmonella* contamination.

These outbreaks and the some of the uncertainty associated with resulting investigations have also severely impacted Mexican growers and shippers. In 2001 and 2002, two deaths in the U.S. and numerous foodborne 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 importers could certify that Mexican cantaloupes are produced under approved, audited, and certified GAP and Good manufacturing Practices (GMP) programs 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.

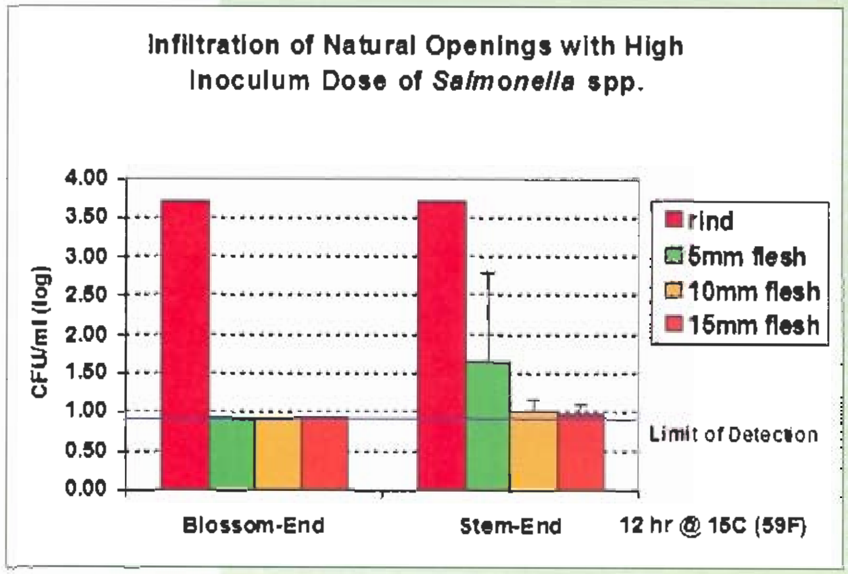


Figure 3 The potential for infiltration or transfer of Salmonella *from an artificially contaminated wash water was tested by placing known concentrations of bacteria (approx. 500,000 cells; log 5.7 CFU) at the blossom-end scar and the stem-end scar of 5 recently harvested melons. Following air-drying, melons were held at 41°F in a standard corrugated 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 1/5 to 3/5 in. (5-15 mm) below the green-flesh transition zone under the netted 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 *penetration was confirmed at 1/5 in below the green-flesh transition zone but was not detected below this zone. In summary, improper washing would increase the potential for sub-surface infiltration at natural openings and wound sites.*

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, pest 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

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.

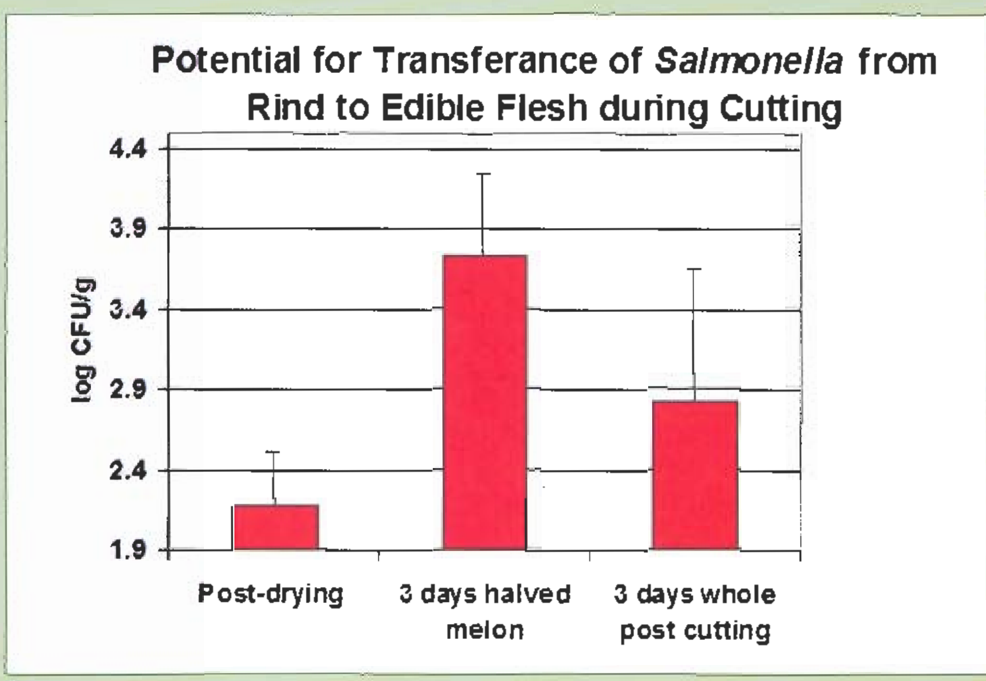


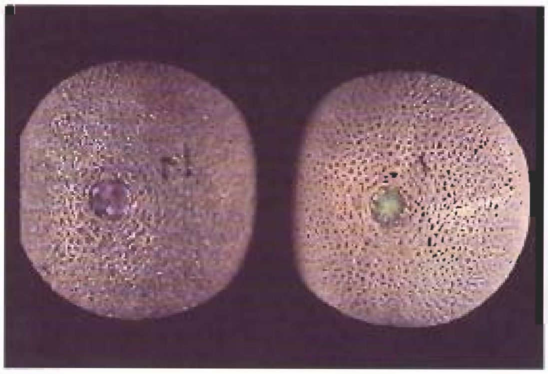
Figure 4 *Controlled inoculations were conducted to determine the potential to transfer* Salmonella *contamination from the outer rind to the edible flesh when halving a cantaloupe for foodservice, retail display or home use with or without storage at sub-optimal temperatures. Melons were inoculated with approx. log 6.0 CFU/cm² (essentially 1 million live cells) and, after air-drying, the recoverable population is usually around 15 to 25,000 cells of Salmonella. Upon cutting through the point of inoculation with a common kitchen knife, 200-300 cells were detected as having been transferred, per gram of edible flesh (removed as a one square-inch piece immediately under the cut). Inoculated, uncut melons were stored at 59°F (15°C) for 3 days at > 90% RH and then cut and assayed for* Salmonella *transfer, as before. After storage, the level of transfer was higher and more variable, ranging from approx. 800 to over 5,000 live cells per one square-inch piece. Additional replicated halved melons were covered with a foodservice clear film and stored at 59°F (15°C) for 3 days. The observed level, exceeding 10,000 cells in some replications, is a combination of transfer at cutting and multiplication of* Salmonella *at this permissive temperature. Stringent surface disinfection, length of storage, and temperature of storage must all be considered in overall safe food handling for cantaloupe.*

chlorine, chlorine dioxide, acidified sodium chlorite, ozone, or peroxyacetic acid. Handling methods that minimize scuffing, deep bruising, and especially open wounds will be beneficial to minimizing the chance for potential surface contamination to be internalized. Studies have demonstrated the presence of inoculated *Salmonella* up to 10mm (approx. 1/3 inch) below the green-transition flesh at the blossom-end scar and stem-scar wound, following direct placement of aqueous suspensions in these regions at the rind surface (See Figure 3). Inoculation of replicated stem-end scars from melons 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 sub-rind tissue.

Importance of Melon Temperature and Cooling Water

In addition, our studies, as well as studies conducted in other Universities and by FDA scientists have shown that Western Shipper cantaloupes with a high field heat load, 98°F (37°C), are somewhat more likely to have detectable internalized contamination at the blossom and stem-end scar and in any naturally induced or harvest wound site if submerged in water chilled to 41°F (5°C) or lower. This is a typical temperature range for hydrocooling 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 cantaloupes but not Western Shipper cantaloupes. These different outcomes illustrate the complexity of the analysis of risk evaluations with pathogens on fresh produce. Variations in specific variety, growing conditions, and postharvest handling history prior to any experimental use are important factors to consider. Our research used melons harvested directly from commercial production fields while those conducted by colleagues at UGA used melons purchased from wholesale or retail handlers, already several days old. Our laboratories, UC Davis and UGA, will be jointly addressing the basis for the different outcomes in future studies.



Inadequate water disinfection treatment and delayed post-wash surface drying has been shown to promote the development of molds in the stem scar region during distribution which has the potential to transfer Salmonella *to the edible flesh.*

Due to this phenomenon, which has also been demonstrated for tomatoes, apples, and citrus, the disinfection of this wash and cooling water takes on extreme importance in both food safety and decay control. The realities of bulk handling of melons at shipping is that water disinfection under variable commercial conditions is unlikely to be as efficient in risk-reduction as a highly controlled lab treatment, and even laboratory investigations with artificially applied *Salmonella* contamination is not 100% effective in pathogen elimination. In fact, 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), 5% hydrogen peroxide, or 1,000 ppm gaseous ozone for 60 min did not eliminate the background resident bacteria. Recently developed proprietary methods that may include combined or sequential heated high-pressure washes, surfactants and disinfection that are being employed in some commercial shed pack operations are reported to achieve a high level of melon sanitizing performance, however independent confirmation is not publicly available. While the normal microflora on a cantaloupe does not constitute "contamination" or a health hazard, their persistence after efforts to remove them with various treatments is indicative of how difficult it may be to remove and kill naturally contaminating pathogens.

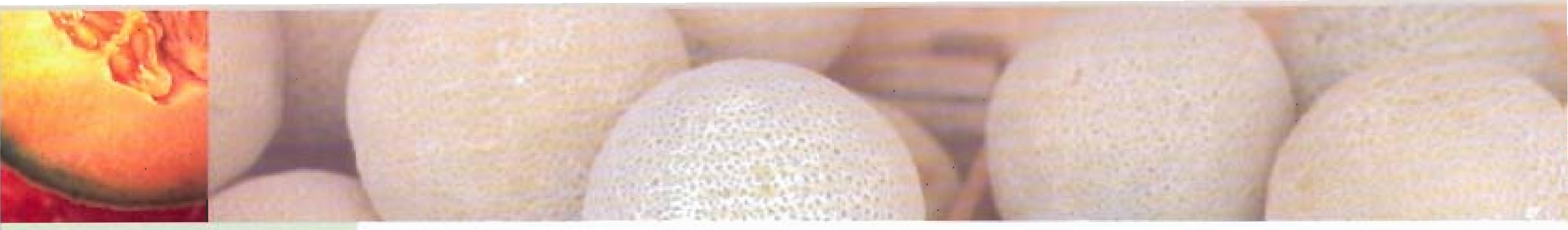
Surveys conducted in commercial shed pack operations in California and in other states in the U.S. recently confirmed these laboratory observations. Sub-optimal disinfectant treatment of wash and/or cooling water resulted in a greater average bacterial count on cantaloupes after packing as compared to melons entering the packing operation from the field. In addition, higher average bacterial counts in the stem-scar tissue and blossom-scar tissue were observed following passage along the wash and pack-line to final packing. In California tests, as before, no *Salmonella* were 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 cantaloupes 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 cantaloupe originating from California.

Does this mean melons from California shed pack operations are more likely to harbor *Salmonella* than field packed melons? Absolutely not. Does this mean that commercially washed cantaloupes are safer than field packed melons from California production regions? Again, clearly not.

No evidence yet exists, for melons grown and shipped from California, to suggest that field pack melons, properly handled by the ultimate food preparer, are inherently more risky for consumers than shed packed cantaloupes. Conversely, from a food safety perspective based on the available scientifically collected data, we have reservations and concerns about the elevation of risk associated

No evidence yet exists, for melons grown and shipped from California, to suggest that field pack melons, properly handled by the ultimate food preparer, are inherently more risky for consumers than shed packed cantaloupes. Conversely, from a food safety perspective based on the available scientifically collected data, we have reservations and concerns about the elevation of risk associated with the operational difficulty of minimizing cross-contamination within shed pack management on a day in and out basis



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.*

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

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. At this time, to the best of our knowledge, no independent confirmation of such a system is publicly accessible.

From these studies conducted over several years, it is reasonable to predict that careful handling during field packing, adequate cleaning and sanitation 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 cooling or wash water during pre-shipping handling should be carefully evaluated, under strict scientifically designed protocols, for the potential to increase risk and to result in cross-contamination or the introduction of contamination from the packing operation environment or equipment. Although limited data is available, dry brushing prior to shipping or removing adhering dirt before display may be preferable to washing, even with chlorinated water. Although less problematic than handling in water, caution is also advisable with dry brushing cantaloupes, as laboratory research during these studies have demonstrated that *Salmonella* can remain in a viable condition in the dry "duff" removed from the netted rind.

Survival Potential on Rind

Laboratory data from controlled inoculation studies shows that various strains of *Salmonella*, *E. coli* O157:H7, 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 netted rind lose more than 99% viability if rapid drying (30-45 min) occurs. The survival rate can become undetectable, using standard detection methods, when the melon surface is exposed to direct natural sunlight and low humidity. More sensitive methods, called enrichment, revel 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 shaded from sunlight. While this data does not help us design a reliable control method, the consistent message from all survival studies conducted thus far strongly suggest that typical production and harvest conditions would tend 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.

Table 2

Total Melons Inoculated	**222**
No Direct Recovery	**203**
Direct Recovery	**19**

Salmonella *serotypes were found, infrequently, to become internalized during postharvest storage. Carefully controlled inoculations of intact upper rind surfaces resulted in an 8.5% frequency of detectable transfer. Internal transfer was often associated with the development of surface molds.*

Beyond the simple presence of low levels of external contamination, several other events would likely be necessary for contamination of the edible flesh to occur and result in illness following consumption. The key events are internalization of contamination, transference of contamination during food preparation, and the presence of an infectious dose to a susceptible individual. Prevention of internalization during harvest and postharvest 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 thresholds 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 the 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 is expected, the higher the number of bacteria on the melon rind, the more likely it is that this cross-contamination will occur (See Figure 5). In commercial fresh cut processing operations, it is therefore imperative that the melon rind be properly cleaned with disinfectant-treated water, to the maximum extent possible, before cutting, and that diligent temperature control is maintained after cutting and during distribution and retail display or foodservice inventory management.

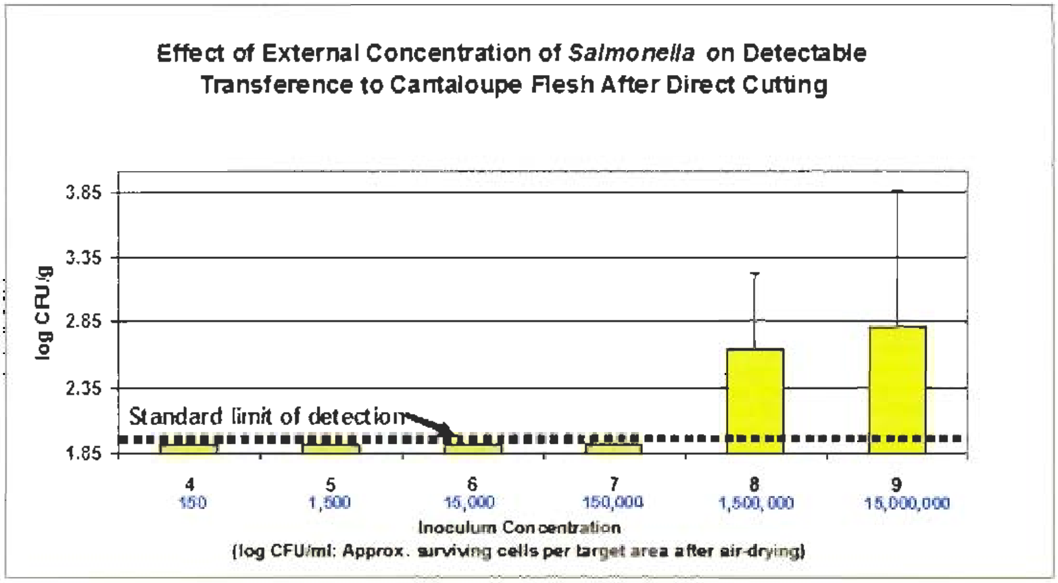


Figure 5 *By standardized methods of direct detection, high populations of external Salmonella contamination were necessary to result in edible flesh contamination during cutting. However, in follow-up studies with these melons, and repeated similar tests (data not shown), using more sensitive methods of Salmonella concentration and enrichment, it was observed that positive detection was possible between 10^5 (**5** on figure) and 10^7 (**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 melon survey support the acceptability of reserving 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 (See ANR 8095 and 8103). 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 (wetting 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.

See: http://vm.cfsan.fda.gov/~lrd/tpproduc.html
www.pma.com
http://www.aboutproduce.com/faq/clean.html

Soaps and household bleach are not approved for produce washing purposes. They may be absorbed by porous produce or transferred during peeling or cutting, leaving off-flavors. Too much ingested residue of strong detergents may cause gastro-intestinal distress.

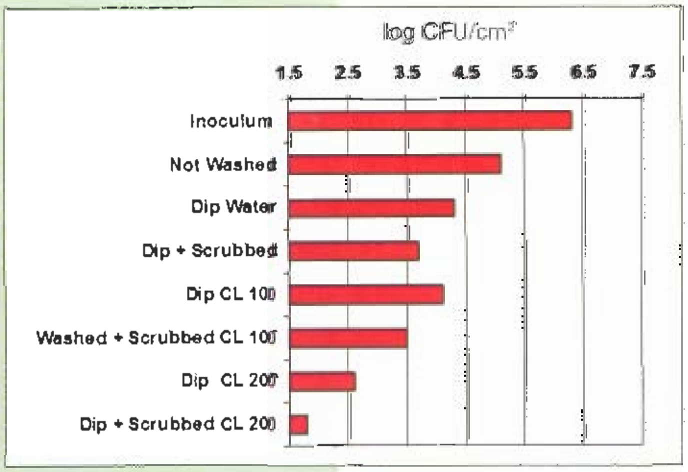
Scrubbing the melon surface during a non-chlorinated water wash helps to reduce the number of total bacteria on the melon rind only slightly more than washing with water without scrubbing (See Figures 6 and 7). Scrubbing melons in chlorinated wash water has been shown to further reduce the number of *Salmonella* left on the rind by more than 100 fold compared to scrubbing with just water alone. Chlorine, chlorine dioxide, peroxyacetic acid, ozone, peroxide, and organic acids are all effective in reducing the number of microorganisms on a melon rind to some degree, but none can be relied upon to completely eliminate microbial contamination. Using chlorinated (or other permitted disinfectant) wash water and scrubbing the fruit during washing is the most effective option, and the use of chlorine is essential in preventing the buildup of contamination in wash water and on brushes, as well as preventing transference to the next melon or other produce item. While using chlorinated water (typically 200 parts per million of free available chlorine at pH 6.5 to 7.5) significantly reduces the number of bacteria on the rind, no practical treatments have been shown to be successful in completely eliminating pathogenic bacteria on a cantaloupe rind. This highlights the importance of a comprehensive food safety programs implemented throughout the handling chain, beginning with preventing and minimizing the chances for 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 unintended for foods and food contact surfaces. Recommended consumer washing and handling practices for cantaloupes are available in ANR 8095.

Submerging cantaloupes in non-running, non-chlorinated water with no scrubbing can actually make a 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 melons 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 rind, with or without chlorine, does not significantly affect the texture of the melon flesh.

Figure 6 The maximum reduction of potential surface contamination is achieved by a wash with scrubbing at 100 to 200 parts per million (ppm) of hypochlorite (or other similarly effective disinfectant at the appropriate dose). The numbers at the top correspond to the level of lab-inoculated Salmonella *recovered from the rind following each treatment. A value of 6.0 is equivalent to one million live cells of* Salmonella *and each lower value (5,4,3,2) reflects a 10-fold reduction in recovered cells. For example, an unwashed surface had approximately 100,000 live cells as compared to a 200 ppm washed and scrubbed surface from which approximately 75 live cells were recovered. This level of reduction was achieved under laboratory conditions with strict replenishment of chlorine levels for each replicated melon.*



Other Barriers to Survival

Exposure to natural ultraviolet light from the suns rays 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 vine-cover, it was useful to compare the expected behavior of common benign bacteria well-adapted to life on most plant surfaces, such as *Pseudomonas fluorescens*, to *Salmonella* following exposure to sunlight (See Figure 9).

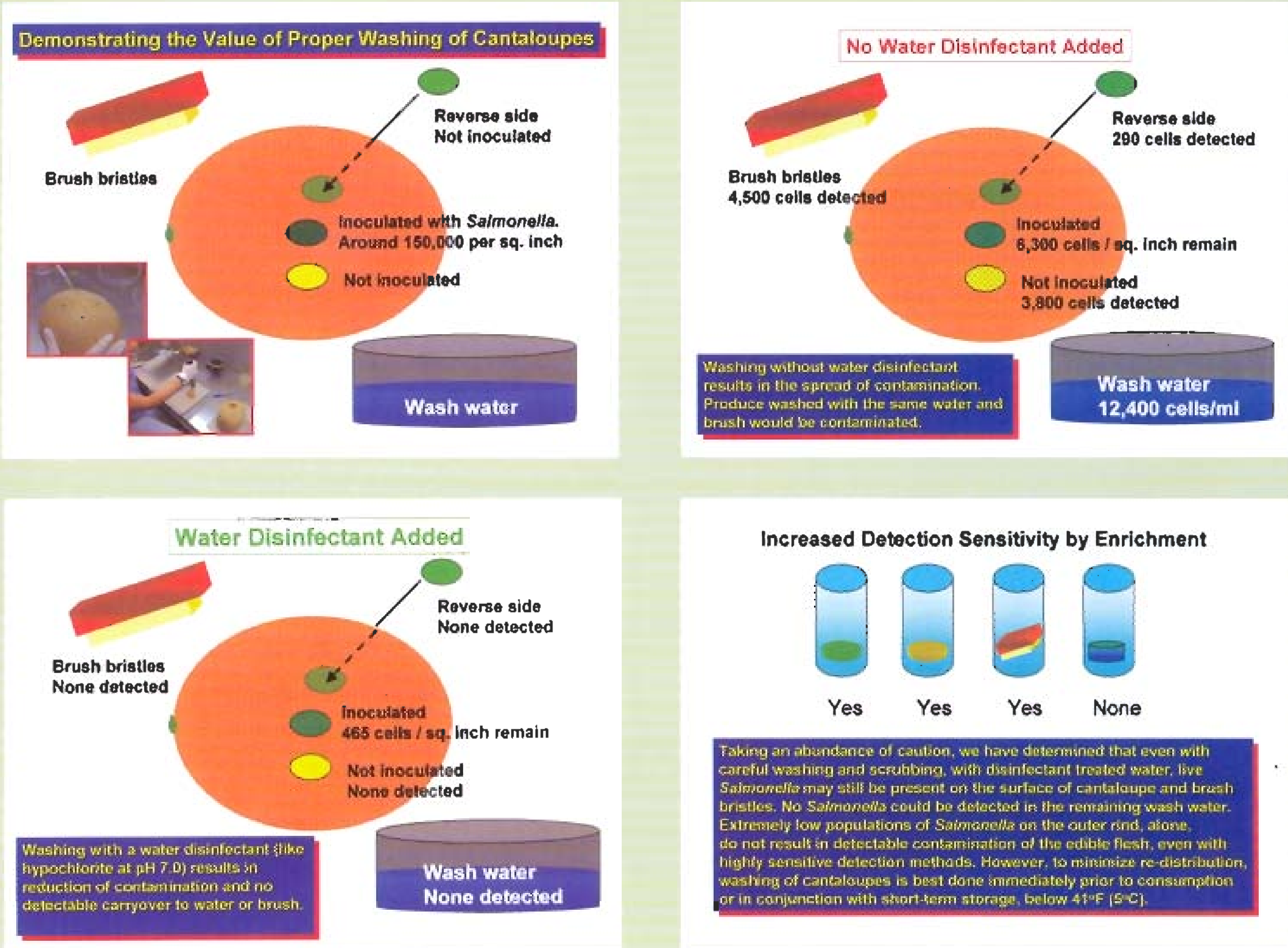


Figure 7- These illustrations, summarizing several laboratory experiments, demonstrate the potential for inadequate or incomplete water disinfection to increase the potential for pathogen contamination by moving live bacterial cells to non-contaminated areas on a melon and by cross-contamination from mechanical aides (brushes) and re-used or re-circulated wash water. The pathogen reductions in single melon handling, represented by these data, would be most likely achieved in a foodservice or consumer handling situation. The efficiency of reproducing this level of surface disinfection under bulk washing and cooling operations at shipping would require careful experimental verification.

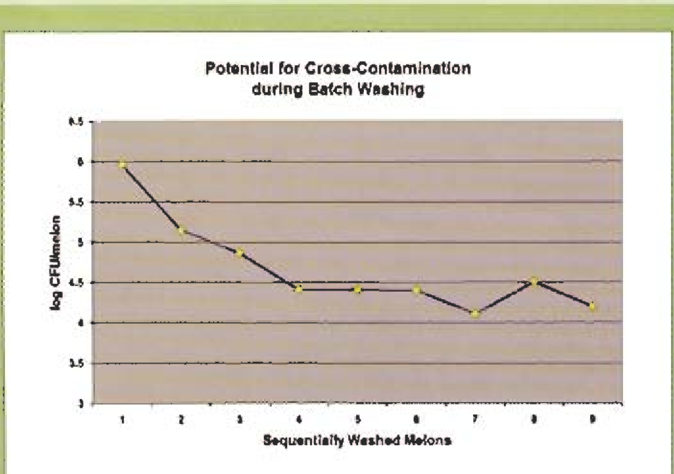


Figure 8 Salmonella *was shown to readily transfer from a single, artificially contaminated melon (no.1) to others in the same, sequential batch wash system.*

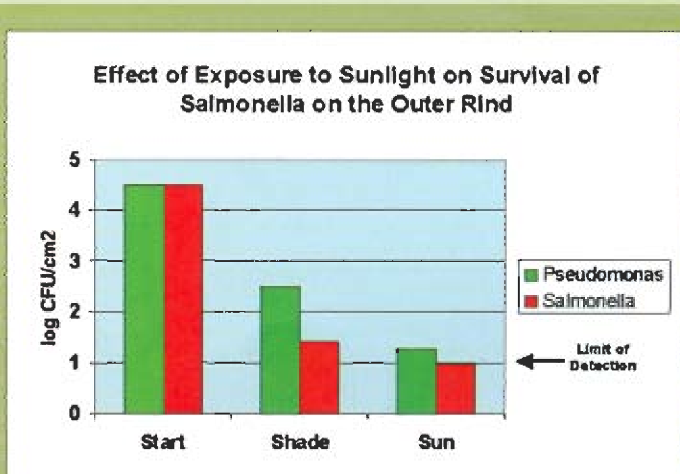
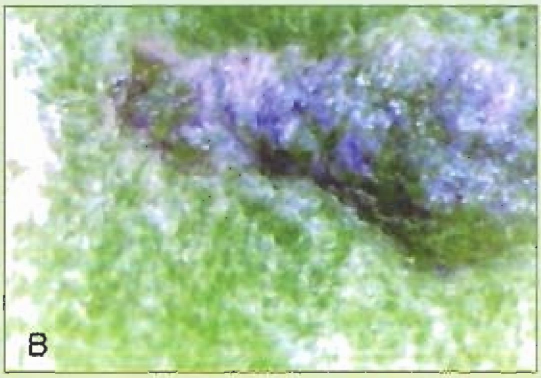


Figure 9 In controlled tests, the normal plant surface resident bacteria, Pseudomonas fluorescens, *survives better than* Salmonella, *whether shaded or fully exposed to bright sunlight. In full sunlight, the inoculated* Salmonella *became undetectable and unrecoverable after two hours.*



Compromises to Barrier Integrity

Immersion of whole, warm cantaloupe melons in a solution of dilute tracer dye have shown that an intact rind, at standard commercial maturity, appears to prevent penetration of water into the sub-rind tissue. The purple dye is readily absorbed by the porous netted rind (A), but no evidence of dye in the green transition zone was observed. However, at the blossom-end scar and at wound sites (B), careful excision of tissue did reveal evidence of dye penetration into sub-rind tissue. Although dye particles and bacterial cells may not move into fruit tissue in precisely the same amount, our conclusion is that if surface contamination were present, water may carry bacteria into natural openings or harvest and handling wounds.

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 water-borne contaminants results in a high rate of bacterial cell death. However, after the initial large decline, although bacteria like *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 10).

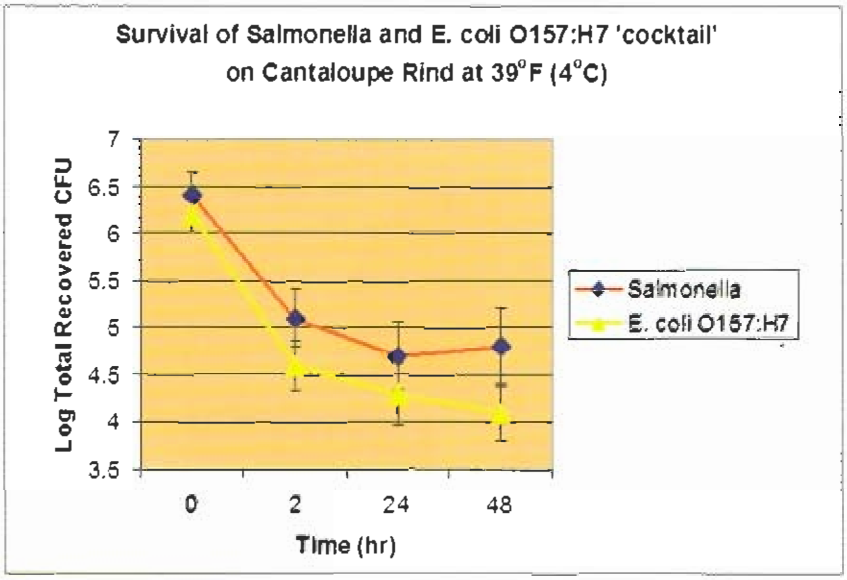
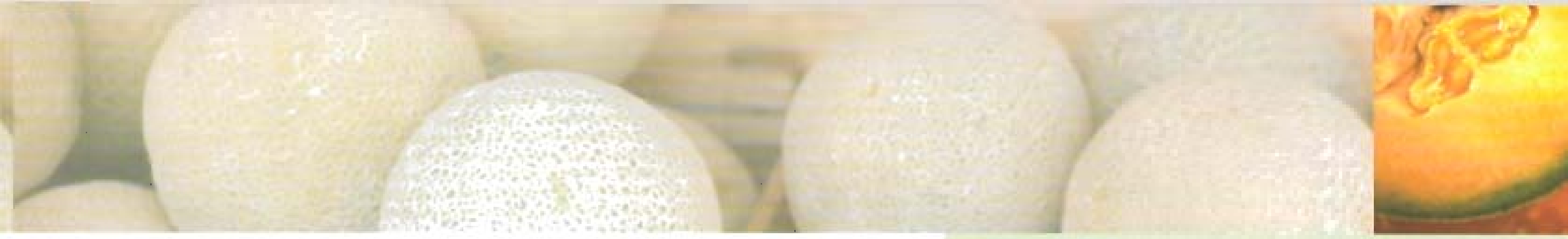


Figure 10 Experiments were conducted to simulate the survival of surface contamination during cooling. In the insert figure, the greatest level of reduction occurs in the first hour of drying. Bacterial populations continue to decline in refrigerated storage but residual contamination may be present. At this time, because no naturally contaminated melons have been identified in California production fields, our research has not identified whether these simulation tests 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 pre-enrichment (to resuscitate stressed cells), a dual selective enrichment (to minimize background competitors that could interfere with detection of low levels of *Salmonella* cells), and a final screen of samples using as highly specific genetic-affinity test for *Salmonella*, similar to DNA fingerprinting. 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 (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 350 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 *Shigella*, 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 live 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

Survey Year	Total Melons Tested	Number of Farm Locations	% Natural Salmonella Positive	% Inoculated Control Recovery
1999	166	5	0	100
2000	312	10	0	100
2001	500	20	0	100
2002-03	995	25	0	100
2003-2004	150	2	0	100

Summary and Recommendations

Historical evidence and current research, specific to California production, handling, and shipping practices for both field pack and shed pack operations strongly support industry assertions that consumers of California cantaloupes 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 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 shed 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 sanitary 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

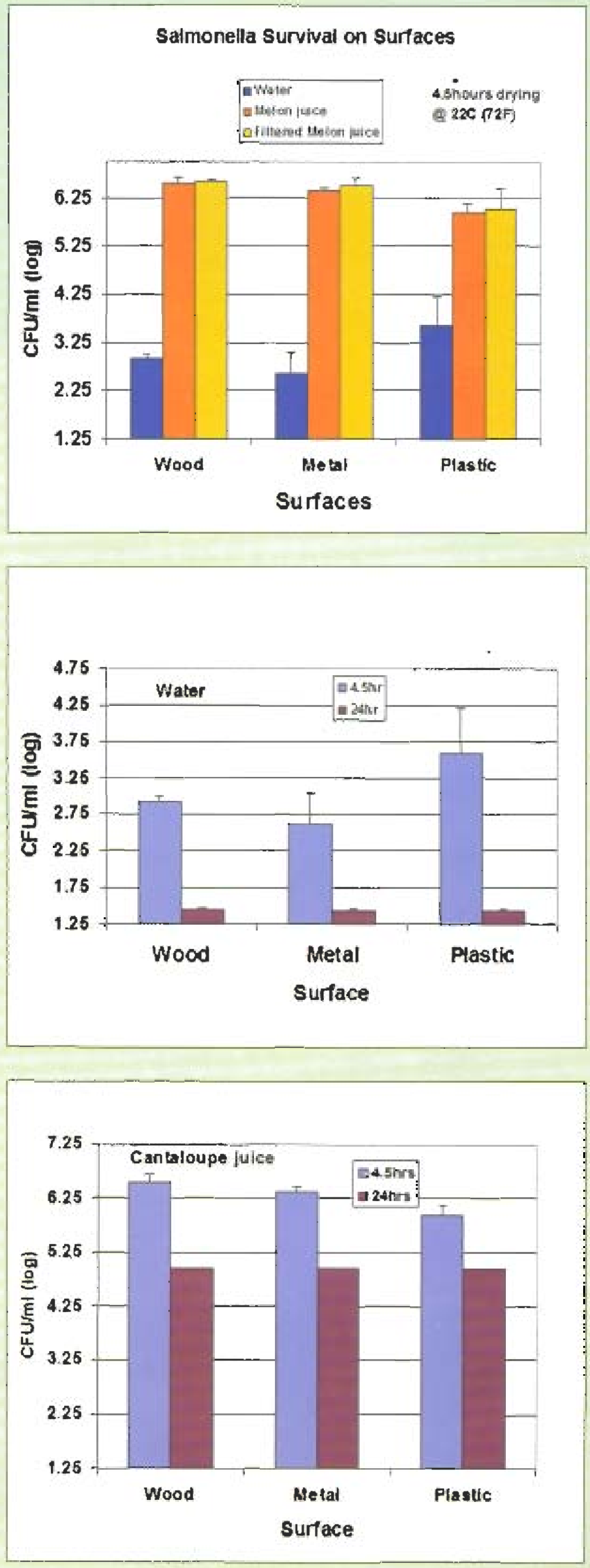


Figure 11

recognize that an aspect of this method minimizes the potential for broad cross-contamination of melons in a given lot. Melons taken directly from the growing bed are placed on a platform or conveyer which carries them to the packers, as described above. Best Management Practices identify that harvest operations should implement and document a daily clean-up procedure and removal of any fruit residues to minimize survival and the risk of cross-contamination on the packing platform (See Figure 11). Melons are generally placed in corrugated boxes or, for some buyers, in returnable plastic containers (RPCs). Once in these shipping units, melons are essentially segregated from contact with melons in other packing units. As removal of field heat is accomplished strictly with pressure cooling with air (forced-air 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 hypothetical questions regarding the potential for cross-contamination of melons by aerosolized bacteria during forced-air cooling. It is neither responsible nor permissible to inoculate 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 on-going research in our laboratory.

If contaminated, the mature cantaloupe rind 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 microbes to settle on a netted melon surface, and the topographical nature of the rind tends to make deep cleaning and removal of bacteria very difficult. Chlorine washing (or other disinfectants) and chlorine dioxide or ozone gassing have been found to reduce the contamination levels on single melons in the lab, but no 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 sub-rind tissue 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 dumps, 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 cleaning and water-based cooling methods currently available may be more likely to spread any pathogen present rather than remove it.

For California cantaloupes, based on our research, the likely low (thus far undetectable) numbers of cells, if it were to occur, means that testing for pathogens on melon lots and products is not practical and, therefore, not economical or advisable under any reasonable scenario. Keeping the melon whole, firm textured, free from injury or decay, 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 this 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 implement.

Additional Reading and Resources

A comprehensive directory of melon food safety related references is maintained at http://ucfoodsafety.ucdavis.edu under Melon Food Safety Research.

Multiple Outbreaks of Salmonella *Serotype Poona Infections Associated with Eating Cantaloupe from Mexico* United States and Canada, 2000–2002 MMWR Nov. 2002. 51:1044-1047

Calvin, L. 2003. Produce, Food Safety, and International Trade. Chapter 5 in International Trade and Food Safety AER-828. *Economic Research Service* USDA pp. 78-96

FDA Talk Paper: Impact Alert on Cantaloupes from Mexico. October 28, 2002 http://www.fda.gov TO2-40

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- USDA CSREES Award # 00-52102-9637. 2002–2005. *Improving the safety of fruits and vegetables: A tri-state consortium*

University of California statement on pesticides and pesticide recommendations. The information contained in this publication should not be viewed as an authoritative source for current registration status or legal use recommendations of any product. For more information, contact the California Department of Pesticide Registration Information Center at (916) 324-0399. This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. Prior to final publication, a review process for this manuscript will be managed by the ANR Associate Editor for Vegetable Crops.

For Further Information

You'll find more information on cantaloupe food safety and postharvest handling in the following ANR Communication Services publications:

Cantaloupe: Safe Methods to Store, Preserve, and Enjoy. ANR 8085

Key Points of Control and Management of Microbial Food Supply: Information for Producers, Handlers, and Processors of Melons. ANR 8103

Water Disinfection: A Practical Approach To Calculating Dose Values For Preharvest and Postharvest Applications. ANR 7256

Ozone Applications for Postharvest Disinfection of Edible Horticultural Crops. ANR 8133

Postharvest Chlorination Basics, Publication ANR 8003, 1997 available at http://ucgaps.ucdavis.edu

Postharvest Technology of Horticultural Crops, Second Edition, Publication 3311, 2002

To order or obtain these publications and other products, visit the ANR Communication Services online catalog at http://anrcatalog.ucdavis.edu. You can also place orders by mail, phone, or FAX, or request a printed catalog of our products from:

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HARVEST AND POSTHARVEST OPERATIONS OF CANTALOUPES