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Multistate foodborne disease outbreaks associated with raw tomatoes, United States, 1990–2010: a recurring public health problem

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SUMMARY

We examined multistate outbreaks attributed to raw tomatoes in the United States from 1990 to 2010. We summarized the demographic and epidemiological characteristics of 15 outbreaks resulting in 1959 illnesses, 384 hospitalizations, and three deaths. Most (80%) outbreaks were reported during 2000–2010; 73% occurred May–September. Outbreaks commonly affected adult (median age 34 years) women (median 58% of outbreak cases). All outbreaks were caused by *Salmonella* [serotypes Newport ($n = 6$ outbreaks), Braenderup ($n = 2$), Baildon, Enteritidis, Javiana, Montevideo, Thompson, Typhimurium ($n = 1$ each); multiple serotypes ($n = 1$)]. Red, round (69% of outbreaks), Roma (23%), and grape (8%) tomatoes were implicated. Most (93%) outbreaks were associated with tomatoes served predominantly in restaurants. However, traceback investigations suggested that contamination occurred on farms, at packinghouses, or at fresh-cut processing facilities. Government agencies, academia, trade associations, and the fresh tomato industry should consider further efforts to identify interventions to reduce contamination of tomatoes during production and processing.

Key words: Food safety, foodborne infections, outbreaks, produce, *Salmonella*, tomatoes.

INTRODUCTION

Produce-associated outbreaks are increasing in the United States [1–3]. Possible explanations include the increasingly centralized production of produce at agricultural facilities in close proximity to animal production zones, increased importation and transportation of produce over greater distances, increased fresh-cut processing (e.g. slicing) to provide convenient ready-to-eat raw produce, and increased consumer demand and consumption of fresh produce [2–4]. Because many produce items are consumed raw, a better understanding of the points of microbial contamination may lead to improved methods of prevention.

Consumption of raw tomatoes has been implicated in several large multistate outbreaks [5–11]. However, implicating raw tomatoes can be challenging in an

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outbreak setting. Tomatoes are commonly consumed, often in combination with other ingredients. Ill persons may have a difficult time recalling package labelling or tomato type especially if it has already been cut or sliced. Poor record keeping, labelling, and the practice of co-mingling tomatoes from multiple farms during sorting and packing makes traceback to the point of origin extremely difficult. Finally, by the time an outbreak investigation identifies tomatoes as the outbreak source, the implicated raw tomatoes may no longer be available for microbiological testing as a result of their short shelf-life. To better understand the characteristics of outbreaks associated with the consumption of raw tomatoes and to inform future outbreak investigations in which tomatoes are a suspected source, we reviewed data from outbreaks caused by raw tomatoes reported to the Centers for Disease Control and Prevention (CDC).

METHODS

A foodborne disease outbreak is defined as two or more similar illnesses resulting from the ingestion of a common food. State, local, territorial, and tribal health departments voluntarily submit foodborne disease outbreak reports to CDC's Foodborne Disease Outbreak Surveillance System (FDOSS). Data requested for each outbreak include the number of illnesses, hospitalizations and deaths, case demographics, implicated foods, locations of food preparation, and results of traceback investigations.

We reviewed reported foodborne disease outbreaks that occurred during 1973–2010 to identify multistate outbreaks only attributed to the consumption of raw tomatoes. Multistate tomato outbreaks were defined as outbreaks where the contaminated raw tomato was purchased and consumed in more than one US state or territory. Attribution of outbreaks to raw tomatoes was determined based upon the results of an epidemiological investigation and at least one of the following: microbiological evidence (e.g. aetiological agent identified in food), a traceback investigation identifying the likely source of tomato contamination (e.g. farm, packinghouse, fresh-cut processing facility), or findings from an environmental investigation at an implicated facility. Pre-sliced tomatoes were defined as those sliced or diced before further distribution or sale (e.g. at a fresh-cut processing facility) and held refrigerated or at room temperature before further food preparation (e.g. addition to a salad at a restaurant). Outbreak duration in days was estimated using the reported onset dates for the first and last cases in the outbreak. Missing data were corrected when possible by reviewing available additional data sources, including published manuscripts, government documents, and through communication with reporting agencies.

Data were downloaded on 2 August 2012; we performed all analyses using SAS version 9.3 (SAS Institute Inc., USA) and Microsoft Excel 2007 (Microsoft Corp., USA).

RESULTS

From 1973 to 2010, 15 multistate outbreaks associated with raw tomatoes were reported, resulting in 1952 laboratory-confirmed illnesses (median 86 illnesses per outbreak, range 8–429), 384 hospitalizations (median 16, range 2–129), and three deaths (Table 1). Outbreaks were first reported in 1990, but 80% occurred during 2000–2010. Most (73%) outbreaks occurred during May–September (Table 2). Outbreaks lasted a median of 44 days (range 21–151). Thirty-seven states were affected (median 9, range 2–24) (Fig. 1). States most commonly reporting outbreak-associated illnesses were predominantly located in the eastern United States and included Virginia ($n = 10$ outbreaks), Pennsylvania ($n = 9$), Georgia ($n = 8$), Illinois ($n = 8$), Massachusetts ($n = 8$), and Ohio ($n = 8$). In 80% of outbreaks, most cases were among women and overall, women represented 57% of total illnesses. Among outbreaks with available age information ($n = 11$), the median age was 34 years (range <1–97).

All outbreaks were caused by *Salmonella enterica*. Serotypes reported for 14 single-serotype outbreaks were Newport ($n = 6$ outbreaks), Braenderup ($n = 2$), Baildon, Enteritidis, Javiana, Montevideo, Thompson, and Typhimurium ($n = 1$ each) (Table 1). One outbreak was caused by multiple serotypes including Javiana, Typhimurium, Anatum, Thompson, Muenchen, and group D not further serotyped. Four of the six outbreaks caused by *S.* Newport occurring in 2002, 2005, 2006 and 2007 were associated with an indistinguishable pulsed-field gel electrophoresis (PFGE) *Xba*I pattern (JJPX01.0061). These four *S.* Newport outbreaks had a longer outbreak duration [median 119 days, interquartile range (IQR) 106–132 days] than the remaining 11 outbreaks (median 33, IQR 20–50).

Among outbreaks with a reported tomato type ($n = 13$), red, round (69%), Roma (23%), and grape

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Table 1. *Multistate outbreaks attributed to the consumption of raw tomatoes, United States, 1973–2010*

Year	*Salmonella* serotype	No. of states	No. ill	No. hospitalized	No. of deaths	Tomato type	Location of preparation	Location of contamination	Tomato origin
1990	Javiana	4	176	18	0	Red, round	Restaurant, home, daycare	Packinghouse	South Carolina
1993	Montevideo	4	100	16	0	Red, round	Restaurant, home	Packinghouse	South Carolina
1998	Baildon	8	86	16	3	Red, round	Restaurant, nursing home	Farm or packinghouse	Florida
2000	Thompson	10	43	15	0	Unspecified	Home, restaurant, nursing home	Farm or packinghouse	Florida or Georgia
2002	Newport	2	8	2	0	Grape	Home	Farm or packinghouse	Florida or Mexico
2002	Newport*	24	333	43	0	Red, round	Restaurant, hospital, university, daycare	Farm	Virginia
2004	Braenderup	16	125	25	0	Roma	Restaurant	Farm or packinghouse	Florida
2004	Multiple†	5	429	129	0	Roma	Restaurant	Farm, packinghouse, or fresh-cut processing facility	Florida, Georgia, or South Carolina
2005	Newport*	16	72	8	0	Red, round	Restaurant	Farm	Virginia
2005	Enteritidis	8	77	7	0	Unspecified	Restaurant	Farm or packinghouse	California
2005	Braenderup	8	82	29	0	Roma	Restaurant	Farm	Florida
2006	Newport*	19	115	37	0	Red, round	Restaurant	Farm or packinghouse‡	Virginia‡
2006	Typhimurium	21	190	24	0	Red, round	Restaurant	Farm or packinghouse	Ohio
2007	Newport*	18	65	11	0	Red, round	Restaurant	Farm or packinghouse	Virginia
2010	Newport	9	51	4	0	Red, round	Restaurant	Farm	Florida

* Indistinguishable pulsed-field gel electrophoresis (PFGE) pattern.

† Javiana (89% of cases), Typhimurium (6%), Anatum (1%), Thompson (<1%), Muenchen (<1%), and group D not further serotyped (1%).

‡ No traceback investigation conducted; suspected site of contamination and tomato origin based upon indistinguishable PFGE pattern and history of this pattern attributed to raw tomatoes produced in Virginia.

Table 2. *Multistate outbreaks attributed to the consumption of raw tomatoes by month of first and last illness onset, United States, 1973–2010*

Year	Serotype	No. of days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1990	Javiana	57												
1993	Montevideo	34												
1998–1999	Baildon	58												
2000	Thompson	22												
2002	Newport	21												
2002	Newport*	151												
2004	Braenderup	33												
2004	Multiple†	25												
2005	Enteritidis	30												
2005	Newport*	112												
2005	Braenderup	44												
2006	Newport*	126												
2006	Typhimurium	48												
2007	Newport*	89												
2010	Newport	22												

* Indistinguishable pulsed-field gel electrophoresis pattern.
† Javiana, Typhimurium, Thompson, Muenchen, Anatum, and group D not further serotyped.

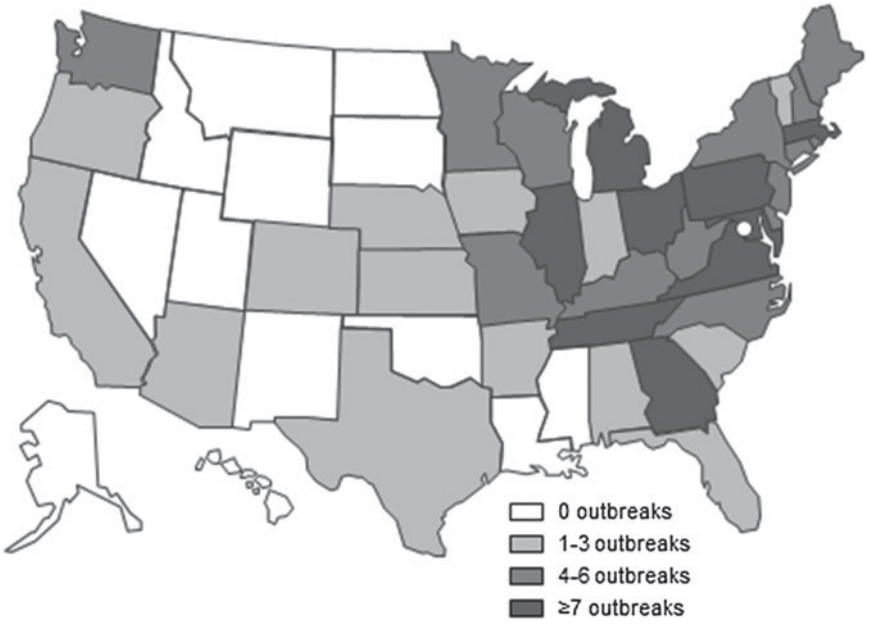

Fig. 1. Number of outbreaks caused by raw tomatoes, by state (multistate outbreaks assigned as one outbreak to each state involved), United States, 1973–2010.

(8%) tomatoes were implicated (Table 1). Pre-slicing or dicing of tomatoes was reported in six (46%) of these outbreaks; pre-slicing or dicing was reported at restaurants in three outbreaks and at a fresh-cut processing facility in three outbreaks.

A single type of location of food preparation was reported in 67% of outbreaks; among these, a restaurant or delicatessen was the most common location (90%), followed by a private residence (10%) (Table 1). Multiple types of locations of preparation were reported in 33% of outbreaks. Among all outbreaks, preparation in a restaurant or delicatessen was reported in 93% of outbreaks; other locations included private residences ($n = 4$ outbreaks), daycare

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centres ($n = 2$), nursing homes or hospitals ($n = 3$), and a university ($n = 1$).

Traceback investigations were performed in 14 (93%) outbreaks (Table 1). Four outbreaks were associated with tomatoes most likely contaminated on the farm, whereas in two outbreaks tomatoes were most likely contaminated in packinghouses. In the remaining eight outbreaks, traceback was inconclusive; in seven of these, tomatoes were thought to have been contaminated either on the farm or in a packinghouse, and in one outbreak tomatoes were thought to have been contaminated on the farm, in a packinghouse, or at a fresh-cut processing facility. Implicated farms and packinghouses were most commonly located in the southeast, in Florida ($n = 4$ outbreaks), Virginia ($n = 4$) and South Carolina ($n = 2$); tomatoes grown in Ohio and California were implicated in a single outbreak each. Facilities associated with contaminated tomatoes in multiple years were also identified. For example, a packinghouse in South Carolina was implicated in two outbreaks, one caused by *Salmonella* serotype Javiana in 1990, the other by serotype Montevideo in 1993. A tomato-growing region on the lower Delmarva Peninsula in Virginia was implicated in four outbreaks caused by *S.* Newport PFGE *Xba*I pattern JPX01.0061 in 2002, 2005, 2006, and 2007. In the 2002, 2005, and 2007 outbreaks, different farms and packinghouses in the region were implicated; limited traceback information was available to implicate a specific farm or packinghouse during the 2006 investigation.

From the information available from environmental investigations ($n = 12$) at farms, packinghouses, distributors, and fresh-cut processing facilities identified during traceback investigations, multiple potential points of contamination, proliferation, and amplification were identified. Reported on-farm deficiencies included the use of surface water for irrigation and applying chemicals to tomato plants (seven outbreaks), presence of wild (e.g. reptiles, amphibians, birds, rodents, feral swine, or other mammals) or domesticated (e.g. cattle) animals or their faeces in tomato fields or in adjacent wild animal habitats or pastures (four outbreaks), and location of tomato fields in low-lying, flood-prone areas (two outbreaks). Environmental microbiological sampling on farms yielded the outbreak strain in three outbreaks. Reported packinghouse deficiencies included problems with tomato wash systems (e.g. inadequate chlorination, improper temperature regulation, inadequate record keeping of chlorine or temperature measurements, or visible field debris in wash water) (seven outbreaks) and wild animals or their faeces inside the packinghouse (three outbreaks). In fresh tomato processing facilities, pooling of tomatoes from multiple sources (two outbreaks) and improper temperature regulation of tomato wash systems (two outbreaks) were reported. Environmental samples collected from packinghouses and fresh-cut processing facilities during investigations did not yield outbreak strains. However, outbreak strains were isolated from implicated raw tomato products collected from points-of-service (two outbreaks) and on a produce slicer in a restaurant (one outbreak).

DISCUSSION

Since 1990, multistate outbreaks attributed to the consumption of raw tomatoes have been increasingly recognized, investigated, and reported. These outbreaks are geographically widespread and seasonal, mostly occurring during warm summer months. A variety of tomato types, including red round, Roma, and grape tomatoes, have been implicated. Although the majority of outbreaks were associated with tomatoes consumed in restaurants, the distribution of cases in multiple states suggests that the initial source of contamination likely occurred early in tomato production, on farms, in packinghouses, or at a fresh-cut processing facility and not at locations of food preparation or service.

Tomatoes can become contaminated at many points along the farm-to-table continuum. On farms, the surfaces of tomatoes can become contaminated through contact with wild or domesticated animal faeces, soil contaminated by crop debris and irrigation water, splash from rain water, and water used to mix chemicals (e.g. pesticides) applied directly to plants [12–16]. Studies have also shown that *Salmonella* can enter tomato plants through roots, flowers, leaves, stem scars, small cracks in the fruit's skin, or wounds on the plant to contaminate the internal flesh of tomato fruits [16–19]. In packinghouses and fresh-cut processing facilities, use of tomato wash systems can result in cross-contamination and internalization of pathogens found on the tomato surface; tomatoes placed in water maintained at temperatures significantly lower than the temperature of the tomato will draw water, along with pathogens, into the tomato's internal flesh, where these pathogens are protected from subsequent washing [20]. In addition, *Salmonella* has been shown to persist at detectable levels on packing line surfaces, including wood,

stainless steel, and conveyer belts, under common environmental conditions maintained in tomato packinghouses [21]. Finally, some tomatoes are placed in modified or controlled atmospheric storage to extend shelf-life before distribution; *Salmonella* survival and growth during extended storage is dependent upon temperature and relative humidity [22].

Tomato handling practices during food preparation, including storage, washing and slicing, can also result in cross-contamination and amplification of pathogens. Slicing a tomato can transfer *Salmonella* to the interior tomato surface and *Salmonella* can persist there when pre-sliced tomatoes are stored at room or refrigerated temperatures [23, 24]. For the outbreaks included in this review, limited information was reported regarding the handling of pre-sliced tomatoes in implicated establishments. However, during an observational survey of restaurants in 2006, 52% of pre-sliced tomato batches were stored at temperatures above the recommended 5 °C, and 74% of these batches were held at room temperature longer than the recommended 4 h [25–26]. In retail food establishments, cut tomatoes are considered a potentially hazardous food and are subject to time and temperature controls to prevent the survival and proliferation of pathogens during storage [27].

Multistate outbreaks associated with raw tomatoes were often attributed to recurrent sources of tomato contamination. *S.* Newport infections with PFGE *Xba*I pattern JJPX01.0061 have been detected in multiple years since 2002 and traced to tomatoes grown in Virginia [6]. These recurrent outbreaks suggest that the tomato-growing environment could be an ongoing source of tomato contamination between harvest seasons. While *Salmonella* was the only pathogen associated with multistate outbreaks attributed to raw tomatoes, pathogens other than *Salmonella* have been implicated in single-state outbreaks. For example, *Shigella flexneri* serotype 2a was implicated in a large outbreak involving multiple restaurants in New York in 2001 [28]; the outbreak was ultimately attributed to overripe raw tomatoes from a single distribution facility. Multiple breakdowns in the tomato supply chain between the distributor and the point of service, including the distribution of bruised and broken tomatoes that were consumed raw, unrefrigerated transport, and storage of sliced tomatoes next to a warm grill, likely contributed to this outbreak.

Our analysis was restricted to outbreaks where exposure occurred in multiple states, resulting in an incomplete understanding of outbreaks associated with raw tomato consumption. Large outbreaks caused by raw tomato consumption in a single state have also been reported [28, 29]. Furthermore, not all tomato-associated outbreaks are reported. Only a small proportion of foodborne illnesses reported each year are identified and associated with outbreaks. And, because tomatoes are commonly consumed, often with other ingredients, ill persons may not recall consuming raw tomatoes and it may be difficult to identify raw tomatoes as the cause [6]. Among the known multistate tomato outbreaks, the short shelf-life, issues with poor labelling, and the practice of co-mingling tomatoes from different sources during repackaging and distribution often made traceback and subsequent source investigations difficult. The seasonal nature of tomato growing combined with the time required to recognize an outbreak, identify the causative food vehicle and complete the source traceback, often delayed environmental investigations at farms and packinghouses to the following tomato harvest, which limits observations of tomato handling practices that may have contributed to the outbreak and makes interpretations of negative environmental testing difficult. Additionally, restaurants are probably over-represented as a location of food preparation; restaurant clusters can enhance the identification of raw tomatoes as the causative vehicle because a single shipment of tomatoes is generally consumed over a narrow time-frame. Restaurants are also likely to maintain records that can identify specific lots of tomatoes for traceback. Therefore, we may be underestimating the occurrence of outbreaks attributed to raw tomatoes at locations of preparation other than commercial food establishments.

Collaboration among all industry partners is important to identify the most common sources of tomato contamination and effective interventions to prevent contamination at each level in the tomato supply chain. Prevention campaigns, including safe tomato handling and storage practices in restaurants and private residences, will continue to play an important role in efforts to reduce the occurrence of tomato outbreaks [27, 30]. Because tomatoes are usually consumed raw and washing does not remove all pathogens from the surface or from within the tomato, consumers have limited ability to protect themselves from pathogenic organisms that have contaminated tomatoes intended to be eaten raw [13]. Therefore, strategies to prevent tomato contamination at farms, packinghouses, distributors, and processing facilities deserve attention [31]. There

are available guidelines that review recommended practices to prevent microbial contamination of fresh fruits and vegetables, including tomatoes, at different levels of the supply chain [32–37]. These guidelines are voluntary in all states except Florida, where they are mandated by the state and local law. In January 2013, the FDA published a proposed rule, the 'Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption', under the Food Safety and Modernization Act (FSMA) that proposes enforceable science and risk-based standards for the safe production of produce that incorporate many of the standards proposed by various food safety programmes [38]. Improving practices to prevent contamination of raw tomatoes will require continued collaboration between the human and animal public health experts, the food industry, and food consumer groups.

Research is ongoing to better understand the role current tomato handling practices have on tomato contamination and the proliferation of pathogens on tomatoes to be consumed raw. Public health interventions should continue to focus on reducing contamination early in tomato production on farms, in packinghouses, and during repackaging and fresh-cut processing and preventing the proliferation of pathogens during processing, storage, and food preparation in restaurants. Universal adoption of available tomato safety guidelines would increase the safety of raw tomatoes.

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DECLARATION OF INTEREST

None.

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