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Assessment of region, farming system, irrigation source and sampling time as food safety risk factors for tomatoes

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A B S T R A C T

In the mid-Atlantic region of the United States, small- and medium-sized farmers use varied farm management methods and water sources to produce tomatoes. It is unclear whether these practices affect the food safety risk for tomatoes. This study was conducted to determine the prevalence, and assess risk factors for *Salmonella enterica*, Shiga toxin-producing *Escherichia coli* (STEC) and bacterial indicators in pre-harvest tomatoes and their production areas. A total of 24 organic and conventional, small- to medium-sized farms were sampled for six weeks in Maryland (MD), Delaware (DE) and New Jersey (NJ) between July and September 2012, and analyzed for indicator bacteria, *Salmonella* and STEC. A total of 422 samples – tomato fruit, irrigation water, compost, field soil and pond sediment samples – were collected, 259 of which were tomato samples. A low level of *Salmonella*-specific *invA* and Shiga toxin genes (stx_1 or stx_2) were detected, but no *Salmonella* or STEC isolates were recovered. Of the 422 samples analyzed, 9.5% were positive for generic *E. coli*, found in 5.4% (n = 259) of tomato fruits, 22.5% (n = 102) of irrigation water, 8.9% (n = 45) of soil, 3/9 of pond sediment and 0/7 of compost samples. For tomato fruit, farming system (organic versus conventional) was not a significant factor for levels of indicator bacteria. However, the total number of organic tomato samples positive for generic *E. coli* (1.6%; 2/129) was significantly lower than for conventional tomatoes (6.9% (9/130); (χ^2 (1) = 4.60, p = 0.032)). Region was a significant factor for levels of Total Coliforms (TC) (p = 0.046), although differences were marginal, with western MD having the highest TC counts (2.6 log CFU/g) and NJ having the lowest (2.0 log CFU/g). Tomatoes touching the ground or plastic mulch harbored significantly higher levels of TC compared to vine tomatoes, signaling a potential risk factor. Source of irrigation water was a significant factor for all indicator bacteria (p < 0.0001), and groundwater had lower bacterial levels than surface water. End of line surface water samples were not significantly different from source water samples, but end of line groundwater samples had significantly higher bacterial counts than source (p < 0.0001), suggesting that Good Agricultural Practices that focus on irrigation line maintenance might be beneficial. In general, local effects other than cropping practices, including topography, land use and adjacent industries, might be important factors contributing to microbiological inputs on small- and medium-sized farms in the mid-Atlantic region.

1. Introduction

The consumption of contaminated raw fruits and vegetables is increasingly recognized as a means of transmission of foodborne pathogens (Sivapalasingam et al., 2004), despite the recommendations to implement Good Agricultural Practices (GAPs) to reduce pre-harvest produce contamination, and increased education and awareness among farmers. Between 1998 and 2008, 46% of foodborne illness outbreaks were attributed to produce (Painter et al., 2013). *Salmonella*

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and vine-stalk vegetables persist as one of the most prominent pathogen-commodity pairs, causing a large number of outbreak-related illnesses from 2008 to 2010 (CDC, 2011, 2013). Fresh market tomatoes, in particular, have been associated with five multi-state foodborne illness outbreaks in the U.S. and suspected in another three within the last decade (CDC, 2005, 2007, 2009; Valadez et al., 2012).

In the U.S., tomatoes are grown in every state, and nationally on more than 161,000 ha of open fields. Of the area harvested for fresh market tomatoes, 73% is from farms greater than 40 ha in size (referred to hereafter as "large farms"; also classified as those with annual sales greater than $250,000) (Ali and Lucier, 2011; USDA, 2009b). However, in the mid-Atlantic region, comprised of the states of Delaware, Maryland, New Jersey, Pennsylvania, Virginia and West Virginia (USDA, 2009a), the majority (55%) of fresh market tomatoes are produced on farms less than 40 ha in size (referred to hereafter as "small- and medium-sized farms"; also classified as those with annual sales less than $40,000 or less than $250,000, respectively) (Ali and Lucier, 2011; USDA, 2009b). Tomato production in the mid-Atlantic is important from a food safety standpoint, as the majority of tomato-associated outbreaks between 1997 and 2007 have been traced back to tomatoes grown in Florida and on the eastern shore of Virginia (U.S. FDA, 2007). In a rare case where a direct link between a *Salmonella* outbreak and a tomato production area could be established, a *Salmonella* Newport strain isolated from a tomato farm irrigation pond on the eastern shore of Virginia was matched to an outbreak strain in 2005 and another that had occurred in 2002 (Greene et al., 2008).

Determining environmental sources of pathogens and understanding the mechanism of produce contamination, however, remain difficult. Microbiological surveys to assess the prevalence of pathogens on produce farms and within major produce growing regions within the U.S. have recovered *Salmonella* from irrigation water, soil and pond sediment in the mid-Atlantic (Micallef et al., 2012), from surface water and soil in New York (Strawn et al., 2013) and from water (including irrigation water), soil and sediment in California (Gorski et al., 2011). Surface water sources used for irrigation consistently appear to be the major reservoir for *Salmonella*, with incidence rates as high as 11% in New York (Strawn et al., 2013) and 7.7% in the mid-Atlantic (Micallef et al., 2012), with the highest prevalence during the growing and harvesting seasons. Shiga-toxin producing *E. coli* (STEC) was also isolated from surface water sources used for irrigation (Strawn et al., 2013) and in watersheds near major vegetable production areas (Cooley et al., 2007a). However, none of the studies that sampled produce detected these human pathogens on tomatoes.

Small- and medium-sized tomato farms could face distinct food safety risks compared to large producers. They differ in their fertilization and cropping methods, harvesting and post-harvest handling practices, and access to capital and labor resources. They also target different markets — selling mostly through local farmer's markets, community supported agriculture programs (CSAs) and pick-your-own operations, rather than wholesale. One common practice that depends more on source availability rather than being driven by farming philosophy, scale or economic feasibility, is irrigation. More than half (48 of 84) of surveyed fresh produce growers in New York reported using surface water to irrigate their crops, including 35 small- and medium-sized farms and 13 large farms (Bihn et al., 2013). Surface water may also be the only water source available to growers of any size in the mid-Atlantic region of the U.S.; in Maryland, for example, approximately 10% of community water systems rely on surface water (Maryland Department of the Environment, 2006). Since surface water has been identified as a predominant *Salmonella* reservoir in U.S. eastern states (Haley et al., 2009; Micallef et al., 2012; Strawn et al., 2013), the produce safety risks associated with this practice in tomato farming would appear equal, regardless of the scale of production. Yet, the ability to monitor and remediate problems could be scale-dependent, with disadvantages skewed to small- and medium-sized farms (Parker et al., 2012). Recently, rainfall and soil drainage were identified as predominant factors affecting the likelihood of a farm to harbor *Salmonella* (Strawn et al., 2013), raising the question of whether geographical, meteorological or edaphic factors might be more important influences than agricultural practices and production scale for produce safety risks.

To address these questions and better understand food safety risks associated with small- to medium-scale tomato production in the mid-Atlantic, this study was conducted to assess the prevalence of two major produce-associated pathogens, *Salmonella enterica* and STEC on farms in Maryland, Delaware and New Jersey. The survey included farms adopting both conventional and organic practices and using a variety of irrigation water sources. To evaluate the microbiological quality of tomato, water and other environmental samples, bacterial indicators were also enumerated. Ultimately, this study aimed at associating any differences in the occurrence of pathogenic or indicator bacteria with location, farming system, irrigation water source and other factors.

2. Materials and methods

2.1. Farmer recruitment

Farms were recruited by personal invitation, by email, phone or by personal visit. The participation of farmers was based on their cultivation scale (small- or medium-sized operations), their willingness to provide samples and information about their farm practices, and their geographical location, i.e., situated in Maryland, Delaware and New Jersey. Farmers did not receive any compensation for participating in this study. Information about on-farm practices was obtained through one or more conversations (via email, phone or in-person) with individual farmers before or after sample collection. Conventional, certified organic and non-certified organic farms were included in this study. Non-certified organic farms used only organic methods but had not completed the certification process. Although more than 100 individual farms were contacted, a total of 24 farms agreed to participate: 14 from Maryland (7 located on the Eastern Shore), 8 from New Jersey, and 2 from Delaware. Maryland was sampled as two distinct regions – Central Maryland and Eastern Shore – due to differences in regional agriculture, environmental and climatic conditions. The 24 farms consisted of 12 conventional and 12 certified and non-certified organic operations, distributed evenly in all locations (4 conventional and 3 organic farms in MD, 3 conventional and 4 organic farms in ES, 4 conventional and 4 organic farms in NJ, and 1 conventional and 1 organic farm in DE).

2.2. Sample collection

During July to September 2012, participating farms were visited every two weeks during the tomato harvest season. The following sample types were collected: tomato fruit; irrigation well, pond or creek water; pond or creek sediment (based on if a pond or creek was used for irrigation); field soil; and compost (based on availability). Latex gloves were worn for sample collection, changed between each farm, and disinfected with 70% ethanol between samples. Each tomato fruit sample (approximately 400 g) consisted of four or more tomatoes either from random plants throughout the field (random tomato sample; RTS) or from a targeted area in the field (targeted tomato sample; TTS). Any tomato attached to the vine and not touching the ground or plastic mulch could be included in a RTS. A maximum of 4 tomato fruit samples (2 RTS and 2 TTS) were aseptically collected into sterile Whirl-pak bags (Nasco, Fort Atkinson, WI) from each farm at each sampling trip. Preference was given to round red and beefsteak tomato varieties. Based on what the participating farmer would harvest for market, tomatoes were collected at stages of maturity ranging from physiological maturity (mature-green stage) through full-ripe. Irrigation well and pond water samples (approximately 1 L) were collected from the source (well water tap, pond or creek) and from the end of the irrigation system (drip line or sprinkler). Prior to sampling, well water taps, the open end of the drip irrigation tubing and sprinkler heads were disinfected with