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Review

Changes in U.S. produce grower food safety practices from 1999 to 2016

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ABSTRACT

As large, multistate foodborne illness outbreaks associated with produce have continued to occur growers, buyers, and government have responded with new organizations, standards, and regulations. Anticipating implementation of new U.S. Federal law, the U.S. Department of Agriculture carried out a national survey of U.S. produce grower food safety practices in 2015/16, the first national update since a similar survey in 1999. Since 1999, and before implementation of U.S. Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption, the share of growers who use practices that reduce the risk of microbial contamination increased. Fewer growers use flowing surface water for irrigation and more growers use well water. Concurrent with growth in the organic sector, more growers use manure and compost. While more growers' fields are adjacent to livestock, more growers use fencing around production areas. The most prominent example of change is the increase in frequency that growers and sanitize harvest tools. The decrease in growers who never wash harvest tools is drastic as is the decrease in those who never sanitize. These findings highlight the changes undertaken by industry to reduce risk associated with foodborne illness even before the implementation of a Federal regulation for on-farm food safety practices.

1. Introduction

Microbial contamination in produce is a public health concern. From 2000 to 2007 in the United States, each year an estimated 48 million people contracted a foodborne illness and 3000 died (Scallan, Griffin, Angulo, Tauxe, & Hoekstra, 2011). The annual burden of foodborne pathogens has been estimated to cost between $14 billion (Hoffmann, Batz, & Morris, Jr., 2012) and $36 billion (Minor et al., 2015). Produce is associated with 46 percent of foodborne illnesses with a known food vehicle (Painter et al., 2013). During 2018, the U.S. Food and Drug Administration (FDA) reported over 1000 illnesses and five deaths linked to multi-state outbreaks in melons, vegetable trays, lettuce-based salad mixes, and romaine lettuce (U.S. FDA, 2018a; 2018b; 2018c; 2018d; 2018e).

Because outbreaks in produce seriously impact public health and markets, the U.S. industry has worked to develop and adopt best food safety practices for growing produce. The push by industry to develop best practices has occurred alongside U.S. Federal government efforts to standardize food safety practices. FDA initiatives such as Good Agricultural Practices (GAPs) and more recently the Food Safety Modernization Act (FSMA) brought the discussion of food safety practices into the national spotlight.

Lacking from these recent discussions of U.S. food safety practices on the farm is a solid foundation of data. The first national survey of food safety practices on U.S. farms was not conducted until 1999, one year after the publication of GAPs. The 1999 data shed light on the types of food safety practices in use by various produce sectors at the time. Since then there have been many changes to food safety practices in the U.S. produce industry. One of the most recent changes is FSMA's Produce Rule (PR) which was partially finalized in 2015 and became mandatory for produce growers with more than $500,000 in produce sales in January 2018.[1] Between 1999 and 2015, no survey on produce food safety practices of comparable magnitude and scope had been replicated.

In 2015/16 the Economic Research Service (ERS) in the U.S. Department of Agriculture (USDA) undertook a similar survey of food safety practices on the farm (Astill, Minor, Calvin, & Thornsbury, 2018). This article bridges these two surveys to understand where significant advancements have been made and where little change has occurred over the intervening 16 years. The timing of the 2015/16 survey precedes implementation of the PR, and changes are attributable to industry-led factors prior to Federal legislation.

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[1] The Produce Rule is officially known as the "Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption" and is published in the Code of Federal Regulations (U.S. FDA, 2015b).

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We examine questions that are comparable between the two surveys related to the on-farm adoption of safety practices related to irrigation water, manure and compost, potential animal contamination, and the frequency of cleaning and sanitizing harvest tools.[2] Unsurprisingly, the adoption of many suggested safe practices have increased over time. Specifically, growers use water from safer water sources more frequently, growers use less raw manure, more growers on average monitor for and actively work to prevent animal contamination, and growers clean and sanitize harvest tools at a higher frequency. That said, survey results also suggest that more growers' fields are located adjacent to commercial livestock, which has been implicated in a recent, high-profile foodborne illness outbreak associated with romaine lettuce (U.S. FDA, 2018d, 2018e). Taken as a whole, results suggest that the U.S. produce industry has made significant strides in the adoption of best practices regarding food safety, even before U.S. Federal standards for the growing of safe produce in FSMA's PR became mandatory for growers.

2. Background

Concern about U.S. microbial food safety for produce was heightened in the mid-1990s following several outbreaks involving both domestic and imported produce (Calvin, 2003, p. 23). Subsequent outbreaks increased calls for Federal regulation (Stenzel, 2009). Federal development of on-farm food safety standards began with voluntary frameworks. The FDA developed voluntary produce food safety guidelines, known as Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs), starting in 1998 (U.S. FDA, 1998).

To more fully understand where the industry was, with regard to food safety activities, USDA's National Agricultural Statistics Service (NASS) conducted a Fruit and Vegetable Agricultural Practices Survey, the following year. Results were published two years later (NASS, 2001). The survey, which provided a baseline of food safety practices, covered 30 commodities in 14 States with 6867 observations and represented the best source of information on food safety activities on the farm at that time. The survey gave a snapshot of where the industry was in 1999 with regard to food safety standards in produce. However, at the time food safety was only beginning to permeate the industry, and since then, many growers have voluntarily adopted additional practices.

During that period, various third-party organizations began offering audit services using their own developed standards (PrimusGFS, SQF, GlobalGAP, etc.). In response to the number of international, independent food safety audit standards, food companies developed the Global Food Safety Initiative (GFSI) in 2000 which benchmarked audit standards to determine equivalency (GFSI, 2019). Walmart adopted mandatory GFSI benchmarked audits for its produce suppliers in 2008 (Wal-Mart, 2008). By 2009, other grocers like Ahold, Delhaize, H-E-B, Kroger, Wegmans, and ShopRite began accepting GFSI benchmarked audits as well (Garren, 2009). Concurrent with the initial development of third-party audit standards, in 2002 the USDA's Agricultural Marketing Service (AMS) formally implemented the GAP and Good Handling Practices (GHP) audit verification program (Coleman, 2012).

Alongside the development of these voluntary federal and third-party standards, regional and commodity-specific grower associations developed standards specific to their markets. After large foodborne illness outbreaks in 2006 linked to spinach and lettuce, California leafy green growers coordinated to establish the Leafy Green Marketing Agreement in 2007 (Calvin, 2007). Because tomatoes had been implicated in foodborne illness outbreaks sporadically over the years (Olaimat & Holley, 2012), through the Florida Tomato Committee, in 2008 tomato growers backed a State law regulating the safe production and handling of all commercially-sold tomatoes (Florida Tomato Committee, 2019).

After two, large multi-state outbreaks involving cantaloupe (Fischer, Bourne, & Plunkett, 2015; Olaimat & Holley, 2012), growers in each implicated production region banded together to create voluntary regional commodity associations with mandatory food safety standards—the Rocky Ford Growers Association in Colorado in 2011 and the Eastern Cantaloupe Growers Association in 2012. The California Cantaloupe Advisory Board, originally established in 1988, implemented mandatory food safety standards for all cantaloupe growers and packers in the State in 2012 (California Cantaloupe Advisory Board, 2019).

While private industry advanced significantly over the previous decades, Federal law addressing food safety at the farm level was largely unchanged since the Federal Food, Drug, and Cosmetic Act of 1938 until 2011. In 2011, the passage of the FSMA shifted the policy focus from reaction to foodborne-illness outbreaks to risk-based preventive action. The standards in FSMA address many of the same potential contamination risks included in third-party and grower association food safety standards, but there are some differences. In 2015 under the FSMA umbrella, FDA released two rules directly impacting U.S. produce growers: the Preventive Controls Rule and the PR.[3]

The PR represents the first on-farm FDA regulation for U.S. produce and covers personnel qualifications and training; health and hygiene; agricultural water; biological soil amendments of animal origin (which includes manure and compost); domesticated and wild animals; growing, harvesting, packing, and holding activities; equipment, tools, buildings, and sanitation; recordkeeping; and special requirements for sprouts. In January 2018 most standards in the PR became mandatory for produce growers with more than $500,000 in produce sales. Compliance dates are staggered for other groups and other standards.

3. Comparison of the 1999 and 2015/16 food safety surveys

Because there has been so much change regarding food safety in the produce industry since 1999, the USDA's ERS, in conjunction with NASS, carried out a new, national Produce Grower Food Safety Practices Survey in 2015 and 2016. The sample consists of 4618 growers from 19 produce-heavy states who range in size from less than $25,000 in annual sales to more than $40 million in annual sales. The survey summary report contains comparisons of food safety practices by grower size and whether growers would be covered by the PR (Astill et al., 2018). The 2015/16 survey enables us to quantify progress that the produce industry has made over the intervening 16 years.

Since 1999 there have been many studies on produce food safety practices, but most have focused on relatively small growers or growers in a few States (Becot, Nickerson, Conner, & Kolodinsky, 2012; Calvin, 2017, pp. 1–64; Cohen, Hollingsworth, Olson, & Coli, 2005; Hardesty & Kusunose, 2009, pp. 1–16; Hultberg, Schermann, & Tong, 2012; Lichtenberg & Tselepidakis; Marine, Martin, Adalja, Mathew, & Everts, 2016; Page, 2016; Prenguber & Gilroy, 2013, pp. 1–40; Rangarajan, Pritts, Reiners, & Pedersen, 2002; Sullins, 2014; Tootelian, 2008). Adalja and Lichtenberg (2018) survey 394 growers in 2014, sampling with a national scope, but they focus on growers who belong to sustainable agriculture organizations (who tend to be smaller than average).

This article compares food safety practices used by produce growers in 1999 and 2015/16—national averages across all size categories—prior to the implementation of the PR. The characteristics of the

[2] Additional information that was collected in either survey but is not comparable is not discussed in this article.

[3] The Preventive Controls Rule is officially known as the "Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive Controls for Human Food" and published in the Code of Federal Regulations (U.S. FDA, 2015a). It is not further discussed here, as it predominantly impacts processors of produce, not growers.

1999 Fruit and Vegetable Agricultural Practices Survey sample summarized in the report are limited to the states where growers operated, the commodities grown, and averages of the food safety practices used. Thus, we are unable to statistically compare the 1999 sample to the 2015/16 sample. However, the criteria used to target growers in the 1999 and the 2015/16 are very similar which implies the samples would be similar.

Criteria used in the 1999 survey selected growers of the top fruit and vegetable commodities commonly consumed raw in fourteen states that maximized the share of national production of those commodities. The criteria used in the 2015/16 Produce Grower Food Safety Practices Survey did the same in the same fourteen states plus four more, except that there was no restriction that top fruit or vegetables be commonly consumed raw. For this analysis, growers are dropped from the 2015/16 who only grow produce for processing or who only grow commodities that are not commonly consumed raw in order to match the sample in the 1999 survey. The revised 2015/16 sample consists of 3152 growers. The 1999 sample consists of 6867 commodity level reports, with up to two commodity level reports per grower surveyed.

The 2015/16 survey does not contain the exact same questions as the 1999 survey, but there is overlap on food safety practices associated with irrigation water, manure and compost, animal contamination, and cleaning and sanitation. When questions are not exactly equivalent, we highlight in the text and tables that changes in the percent of growers using a practice should be interpreted carefully. The other limitation to the interpretation of these results lies in the possibility that the differences in practices between the two surveys may be due to differences in the characteristics of the farms in each sample. For example, perhaps more farms of all types are now using well water for irrigation, or perhaps farms of all types use the same amount of well water but the regional locations of farms in the sample have changed which in turn influences water source. Regardless, whether because of a shift in practices or a shift in the geographical regions of production, our results highlight some of the significant changes in the industry over a 16-year period, and more detailed studies should be conducted to fully understand all of these changes.

3.1. Irrigation water

Food safety outbreaks in fresh produce are predominantly associated with microbial contamination coming from animals or humans. In the U.S., animal feces are the biggest source of contamination, and both commercial livestock and wild animals are potential carriers of foodborne disease. Harvesting produce that has been contaminated directly with animal feces obviously has a high risk of causing foodborne illness. (We discuss manure and compost and animal contamination in the following two sections.) Fecal contamination of water that is used to irrigate; distribute fertilizer, pesticide, or fungicide; or wash produce crops has the potential to widely disperse pathogenic bacteria like *Campylobacter* spp., *E. coli* O157: H7, *Salmonella* spp., and *Listeria monocytogenes* (Pachepsky, Shelton, McClain, Patel, & Mandrell, 2011).

Two highly publicized outbreaks in U.S. romaine lettuce in 2018 were caused by *E. coli* O157:H7 strains that were found in sources of irrigation water. Beginning in March 2018, FDA and the Centers for Disease Control and Prevention (CDC) investigated the largest U.S. *E. coli* O157:H7 outbreak since 2006 in which 210 individuals became ill and five died from eating contaminated romaine lettuce from Yuma, Arizona. The FDA reported in their environmental assessment that genetic matches to the outbreak strain were found in three samples from a 3.5 mile stretch of irrigation canal next to fields of some farms identified as potential sources (U.S. FDA, 2018d). Also, adjacent to the 3.5 mile stretch of canal was a concentrated animal feeding operation. The FDA notes that they found no evidence to support alternative explanations to the contamination originating from the animal operation. In November 2018, another U.S. *E. coli* O157:H7 outbreak occurred when 52 individuals were made ill after eating contaminated romaine lettuce from California. The FDA with CDC reported finding a genetic match to the outbreak strain in the sediment of a water reservoir on a California farm (U.S. FDA, 2019).

Table 1
Food safety practices survey questions related to irrigation water.

Survey question	1999	2015/16	T-test	
Did you…?	Percent		P value	Sig.[a]
Use flood, furrow, drip, or sub irrigation[b]	44.4	69.1	< 0.01	***
Use sprinkler or overhead irrigation[b]	36.2	53.2	< 0.01	***
Use standing surface water for irrigation	11.5	11.8	0.62	
Use flowing surface water for irrigation	23.2	19.1	< 0.01	***
Use well water for irrigation	43.7	49.9	< 0.01	***
Use municipal water for irrigation	3.8	8.4	< 0.01	***
Use other water for irrigation	2.1	1.7	0.13	

Sources: 1999 Fruit and Vegetable Agricultural Practices Survey (NASS, 2001); 2015/16 Produce Grower Food Safety Practices Survey (Astill et al., 2018).

[a] "Sig." is a *t*-test of means for the 1999 and 2015/16 survey data. The null hypothesis is no difference between the means of the two groups. *, **, and *** indicate rejection of the null hypotheses (i.e., the means are statistically different) at the 10-, 5-, and 1-percent confidence levels, respectively.

[b] The sum use flood, furrow, drip, or sub irrigation and use sprinkler or overhead irrigation is less than 100 in 1999 because growers could only chose one irrigation category, whereas the sum of the first two irrigation categories exceeds 100 in 2015/16 because growers could chose multiple categories.

In general, USDA survey results indicate that U.S. growers increasingly use irrigation water to support produce crop growth. Fewer than half did so in 1999, whereas more than half did so in 2015/16. In 1999 44.2 percent of growers reported using a flood or furrow, drip or trickle, or sub irrigation system compared to 69.1 percent of growers in 2015/16 (Table 1). Growers similarly use sprinkler or overhead irrigation more often—36.1 percent in 1999 and 53.2 percent in 2015/16. Two-tailed T-tests of the difference between the means of both irrigation types are statistically significant at the 1 percent level (As noted in Table 1, in 1999 surveyed growers could report at most one type of irrigation, so percentages may be lower than they would be if growers had been able to report all types of irrigation, as they were able to in the 2015/16 survey.). Resembling findings from the 2015/16 USDA survey data, in a stand-alone survey of small and medium Vermont produce farms in 2011, 63 percent use trench, furrow, or drip irrigation and 54 percent use overhead irrigation (Becot et al., 2012).

Generally the risk of microbial contamination is higher for surface water sources than ground (well) water sources, and municipal water sources carry the least risk (Suslow et al., 2003). From 1999 to 2015/16 growers replaced potentially riskier sources of irrigation water with less risky sources. Produce growers use less flowing surface water for irrigation (4.1 percentage point decrease) and more well water (6.2 percentage point increase) and municipal water (4.6 percentage point increase). These three changes are all statistically significant at the 1 percent level, but no statistically significant difference is seen in the use of standing surface water and other water. Similar to the changes found here, in 1998 among New York produce growers (Rangarajan et al., 2002), most used surface water for irrigation (55 percent), and fewer used well water (28 percent) or municipal water (12 percent).

Changing irrigation type or source (such as installing drip irrigation or drilling a groundwater well) is a significant decision for produce growers due to high fixed costs (Taylor & Zilberman, 2017). Installing drip irrigation, sub irrigation, or digging wells all require a substantial investment of time and money. Growers who intermittently rely on irrigation during dry spells must also make the decision to invest in irrigation systems under additional uncertainty from future weather. In highly competitive produce markets, growers must balance the cost of installing new irrigation infrastructure with the reduction in risk of microbial contamination. During the past decade and a half, USDA survey results indicate that growers have made clear shifts towards less risky types of irrigation systems and sources of irrigation water.

3.2. Manure and compost

Increases in the use of manure-derived fertilizer may be associated with increases in organic or sustainable production systems which rely on organic fertilizer instead of synthetic fertilizer. To prevent microbial contamination, the USDA National Organic Program (NOP) requires that compost be made following specific time and temperature requirements to destroy pathogens and requires that raw manure be incorporated into the soil a minimum of 120 days or 90 days prior to harvest, the longer interval corresponding to crops where the edible portion contacts the soil (Coleman, 2012).[4] Many organic and sustainable producers voiced concerns over proposed manure application requirements in the draft PR, and in the final PR the FDA encouraged growers to follow NOP standards without defining specific requirements.

Consistent with the rise in organic production, the percent of growers in the USDA surveys who report using manure-derived fertilizer increased 2.6 percentage points to 11.7 percent in 2015/16 (Table 2). This difference is statistically significant at the 1 percent level. The percent of growers using potentially more risky forms of organic fertilizer like raw or aged manure decreased 1.5 percentage points to 4.9 percent in 2015/16—a statistically significant change at the 5 percent level. In contrast, in 2015/16, 8.9 percent of growers used potentially less-risky composted manure up from 2.7 percent in 1999—a statistically significant difference at the 1 percent level (As noted in Table 2, in 1999 surveyed growers could report at most one type of manure or compost, so percentages may be lower than they would be if growers had been able to report all types of manure like the 2015/16 survey.). In light of NOP manure standards, the use of either raw or composted manure does not necessarily imply increased risk if growers follow scientifically supported standards to prevent microbial contamination.

Unsurprisingly, in other research the rate of manure and compost use among organic growers is much higher when compared with conventional growers. For a 2014 sample of growers of predominantly direct marketers—the average grower in the sample sold more than half of their produce directly to consumers and one-third were a member of a “sustainable grower organization”—a much larger percent report using manure and compost: 43 percent used soil amendments of animal origin, 31 percent used untreated soil amendments, and 12 percent used treated soil amendments (Adalja & Lichtenberg, 2018).

Two surveys of New England farms show a similar trend towards increased compost use, and both find the percentage of growers who use compost to be much greater than that in USDA's national surveys. Rangarajan et al. (2002) find that on New York produce farms in 1998, 27 percent of growers applied manure and 19 percent applied compost. About one decade later Becot et al. (2012) find that in 2011, 43 percent of Vermont produce farms produce compost on-farm, which is much greater than the percent of produce growers who compost manure on-farm in the USDA's national sample. In the 2015/16 USDA national sample, 3.4 percent of growers composted manure on-farm—up 1.2 percentage points from 1999—and 7.0 percent of growers purchased compost from others—up 4.4 percentage points. As organic production continues, the safe management of manure and compost will continue to be an important consideration in produce food safety and the PR.

[4] Aged manure has been stored for a period of time and may have undergone some decomposition, but in some cases it can still contain high levels of microbial contamination.

Table 2
Food safety practices survey questions related to biological soil amendments.

Survey question	1999	2015/16	T-test	
Did you…?	Percent		P value	Sig.[a]
Use manure-derived fertilizer	9.1	11.7	< 0.01	***
Apply raw or aged manure[b]	6.4	4.9	< 0.01	***
Apply composted manure[b]	2.7	8.9	< 0.01	***
Compost manure on your farm	2.2	3.4	< 0.01	***
Purchase composted manure from others	2.6	7.0	< 0.01	***

Sources: 1999 Fruit and Vegetable Agricultural Practices Survey (NASS, 2001); 2015/16 Produce Grower Food Safety Practices Survey (Astill et al., 2018).

[a] “Sig.” is a *t*-test of means for the 1999 and 2015/16 survey data. The null hypothesis is no difference between the means of the two groups. *, **, and *** indicate rejection of the null hypotheses (i.e., the means are statistically different) at the 10-, 5-, and 1-percent confidence levels, respectively.

[b] The sum of apply raw or aged manure and apply composted manure equals the value for use manure-derived fertilizer in 1999 because growers could only chose one manure category, whereas the sum of the two manure categories exceeds the value for use manure-derived fertilizer in 2015/16 because growers could chose multiple categories.

3.3. Animal contamination

In their case study of leafy green growers in California, Calvin, Jensen, Klonsky, & Cook (2017) report that about 20 percent of food safety costs can be attributed to unharvested produce near animal tracks or feces and to the time spent by harvest foremen inspecting for animal tracks or feces prior to harvest. Direct contamination of produce by animals occurred in the 2011 *E. coli* O157:H7 outbreak in Oregon strawberries caused by deer feces and in the 2005 *Salmonella* outbreak in Florida tomatoes where feces from cattle and wild animals were found adjacent to fields (CDC, 2015).

Growers have increasingly taken measures to prevent contamination of produce from sources of animal contamination like those identified by CDC. From 1999 to 2015/16 in the USDA survey data, all changes to practices used to prevent animal contamination are statistically significant at the 1 percent level. The use of fencing around production areas or surface water sources for irrigation to keep out domestic and wild animals has increased to 42.7 percent of growers in 2015/16 compared to only 10.6 percent of growers in 1999 who reported using pest exclusion as a field environment pest control method (Table 3). Other research corroborates this trend. Becot et al. (2012) find that in 2011 among 79 small and medium Vermont produce farms that 46 percent used fencing around crop production areas. Similarly (Hultberg et al., 2012), find that 68 percent of Minnesota vegetable farmers take measures to reduce the risk of wild or domestic animals entering growing areas. The percent of growers in USDA surveys who trap or eliminate animals increased to 33.4 in 2015/16 from 26.6 percent of growers in 1999 who reported traps or chemicals for rodents as a field environment pest control method.

Animal agriculture also poses risks to microbial contamination of produce. Typically, the risks of contamination from adjacent land used for animal agriculture are considered to be animals entering produce fields directly or water that has contacted animal manure running off into produce fields. However, recent research finds that *E. coli* can be transmitted via air from nearby manure concentrations to fields nearly 600 feet away, especially in dry, dusty conditions (Berry et al., 2015).

Indicative of a potential increase in risk of contamination is the 9.9 percentage point increase in the share of growers in USDA surveys who report growing produce in a field next to commercial livestock: 12.5 percent in 2015/16 versus 2.6 percent in 1999 reported growing in a field located next to a confined animal production facility. The questions in the 1999 and 2015/16 USDA surveys are not exactly equivalent given that commercial livestock includes both confined animal production and livestock on open range land. In spite of potential

Table 3
Food safety practices survey questions related to animal contamination.

Survey question	1999	2015/16	T-test	
Did you…?	Percent		P value	Sig.[a]
Fence production areas or surface water sources	10.6	42.7	< 0.01	***
Trap or eliminate animals	26.6	33.4	< 0.01	***
Grow produce in a field next to commercial livestock	2.6	12.5	< 0.01	***

Sources: 1999 Fruit and Vegetable Agricultural Practices Survey (NASS, 2001); 2015/16 Produce Grower Food Safety Practices Survey (Astill et al., 2018).
[a] "Sig." is a *t*-test of means for the 1999 and 2015/16 survey data. The null hypothesis is no difference between the means of the two groups. *, **, and *** indicate rejection of the null hypotheses (i.e., the means are statistically different) at the 10-, 5-, and 1-percent confidence levels, respectively.

measurement error between surveys, proximity to livestock remains a potential source of contamination.

3.4. Cleaning and sanitation

In the investigation of the 2011 *Listeria monocytogenes* outbreak in Colorado cantaloupe that sickened 147, hospitalized 143, and killed 33, FDA inspectors found genetic matches to the outbreak strain on packing equipment that they determined to be difficult to clean and sanitize (U.S. FDA, 2011). Microbial contamination from fields or other sources can become established on the surfaces of tools and equipment, which can then lead to the contamination of produce that touches contaminated surfaces (Newman et al., 2017). Regularly cleaning and sanitizing the surfaces of tools and equipment that contact large quantities of produce has become a key element of produce food safety standards.

The increase in frequency of cleaning and sanitizing is the most clear-cut example of U.S. produce growers' adoption of food safety practices. From 1999 to 2015/16, there has been a combined 28.1 (26.3) percentage point increase in the share of growers who wash (sanitize) their harvest tools daily and weekly and a 28.0 (41.8) percentage point decrease in the share of growers who never wash (sanitize) their harvest tools (Fig. 1). In 2015/16 the percentage of growers who never washed (sanitized) their harvest tools decreased to 2.1 (11.6) percent. Changes for all but one frequency reported in Table 4 are statistically significant at the 1 percent level and point to an industry cleaning and sanitizing more frequently across the board.

Table 4
Food safety practices survey questions related to the cleaning and sanitation of harvest tools.

Survey question	1999	2015/16	T-test	
Did you…?	Percent		P value	Sig.[a]
Wash harvest tools daily	46.5	54.5	< 0.01	***
Wash harvest tools weekly	1.3	21.4	< 0.01	***
Wash harvest tools monthly	0.0	5.0	< 0.01	***
Wash harvest tools seasonally	0.9	10.1	< 0.01	***
Wash harvest tools at other frequency	21.2	6.6	< 0.01	***
Never wash harvest tools	30.1	2.1	< 0.01	***
Sanitize harvest tools daily	29.4	40.0	< 0.01	***
Sanitize harvest tools weekly	1.2	16.9	< 0.01	***
Sanitize harvest tools monthly	0.1	9.1	< 0.01	***
Sanitize harvest tools seasonally	5.2	12.1	< 0.01	***
Sanitize harvest tools at other frequency	10.6	9.7	0.27	
Never sanitize harvest tools	53.4	11.6	< 0.01	***

Sources: 1999 Fruit and Vegetable Agricultural Practices Survey (NASS, 2001); 2015/16 Produce Grower Food Safety Practices Survey (Astill et al., 2018).
[a] "Sig." is a *t*-test of means for the 1999 and 2015/16 survey data. The null hypothesis is no difference between the means of the two groups. *, **, and *** indicate rejection of the null hypotheses (i.e., the means are statistically different) at the 10-, 5-, and 1-percent confidence levels, respectively.

Other research with smaller, more focused samples finds rates of never cleaning (sanitizing) harvest tools to be higher than the 2015/16 sample average, but are less different than 2015/16 results broken down by size (20 percent of growers not covered by the PR never sanitize; Astill et al., 2018). Among 47 Mid-Atlantic leafy green and tomato growers in 2012, 22.2 percent reported they never washed harvest containers and 28.3 percent never sanitized their facility (Lichtenberg & Tselepidakis Page, 2016). Among a 2014 sample heavily weighted towards direct marketers and sustainable growers, 30 percent of growers never sanitized their harvest containers (Adalja & Lichtenberg, 2018).

As noted here for cleaning and sanitizing and in previous sections, the share of growers that use various food safety practices may differ between samples having different distributions of firm characteristics like size, marketing channel, and organic production. In the case of differences by size, Astill et al. (2018) find that large growers use practices to reduce the risk of microbial contamination at higher rates than smaller growers. This difference by size is consistent with what produce growers themselves describe when interviewed (Astill, Minor, Calvin, & Thornsbury, 2019). Larger growers sell more often into strictly managed, high-value supply chains where retail buyers require

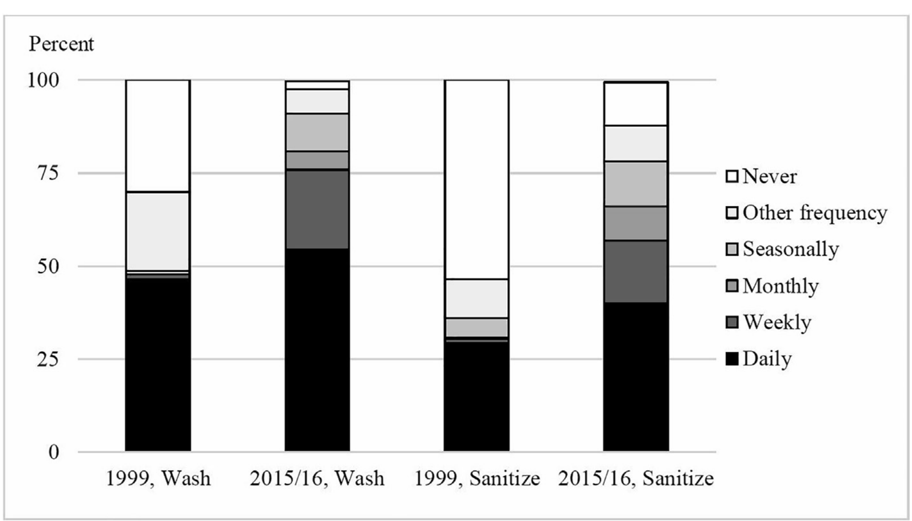

Fig. 1. Frequency of washing and sanitation of harvest tools in 1999 and 2015/16.
Sources: 1999 Fruit and Vegetable Agricultural Practices Survey (NASS, 2001); 2015/16 Produce Grower Food Safety Practices Survey (Astill et al., 2018).

food safety practices to be implemented by growers (Minor, Hawkes, McLaughlin, Park, & Calvin, 2019).

4. Conclusions

Foodborne illness is a complex issue caused by microbes that are literally constantly evolving. As large, multistate foodborne illness outbreaks associated with produce continued to occur over the years, growers, buyers, and government responded with new organizations, standards, and regulations. In 1999—one year after the FDA published GAPs for produce food safety and one year before GFSI began benchmarking third-party food safety audit standards for produce—the USDA carried out its first survey of food safety practices used by U.S. produce growers. Much has changed in the produce industry since.

Produce growers established various industry association standards to decrease the risk of microbial contamination, as did many commercial buyers and the Federal government. The PR in FSMA is the first set of on-farm, Federal food safety requirements for produce. Anticipating changes induced by the PR, prior to PR implementation, ERS and NASS in USDA carried out a new national food safety practices survey among U.S. produce growers in 2015/16. The comparison made possible from linking these two unique datasets shows the many changes that have occurred in food safety practices used by U.S. produce growers.

The national data gathered by USDA indicate that a larger share of produce growers use practices to reduce the risk of microbial contamination in 2015/16 than did in 1999. The food safety practices used by growers at higher rates cover contamination from irrigation water, manure and compost, animal contamination, and harvest tools. Growers increasingly use irrigation water to support produce crop growth. Fewer growers use irrigation water from potentially riskier sources like flowing surface water, and more growers use irrigation water from less risky sources like well water. The share of growers who never wash or sanitize harvest tools has decreased by large margins. Those decreases have been replaced in large part by the increases in the share of growers who wash or sanitize harvest tools daily or weekly.

Two instances where potential for increased risk stand out: the percent of growers use manure-derived fertilizers and the percent of growers who operate a produce field next to commercial livestock. Growers continue to use manure-derived, especially growers who use organic or sustainable practices. If these growers use manure and compost according to standards that have been scientifically validated to reduce the risk of microbial contamination, like the NOP standards, this increase in use need not imply an increase in risk. The percent of growers who have produce fields next to commercial livestock increased, but the percent of growers who fence production areas to prevent animal contamination has also increased, suggesting that while animal contamination may be more of a concern to growers, it is a concern that they actively take steps to control.

This report highlights some areas of substantial growth in the adoption of food safety practices by the produce industry from 1999 to 2016. While this study compares two snapshots in time, it lays the groundwork further research into the key drivers of the adoption of food safety practices. The data available for this article also demonstrates a real need to implement more frequent measures of food safety practices within this rapidly evolving industry. A repeated cross-section may allow rigorous statistical analyses into the reasons for the adoption of food safety practices, which may in turn inform where outreach and education might be most useful or where policy can most effectively support the production of safe food."

Disclaimer

The findings and conclusions in this article are those of the authors' and should not be construed to represent any official U.S. Department of Agriculture or U.S. Government determination or policy.

Declaration of interest

None.

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