Applied Economics
Education & Extension
an AAEA Journal

Astill, Gregory, D. Adeline Yeh, Donna Clements, et al. 2026. "Assessing Long-Term Grower Understanding of the Food Safety Modernization Act Produce Safety Rule." *Applied Economics Education and Extension* 8 (5). https://doi.org/10.71162/001c.172094.

Original Research Articles

Assessing Long-Term Grower Understanding of the Food Safety Modernization Act Produce Safety Rule

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Keywords: food safety, information networks, knowledge retention, Produce Safety Rule, regulatory compliance

JEL Classifications: Q1 Agriculture

https://doi.org/10.71162/001c.172094

Abstract

We assess the long-term impact of extension training in growers' understanding of the Food Safety Modernization Act Produce Safety Rule requirements using a knowledge question approach and explore how that impact varies depending on the factors growers face when making food safety decisions. A unique set of primary data collected months or years after Produce Safety Alliance Grower Training is used to assess respondents' knowledge of practices associated with the Food Safety Modernization Act Produce Safety Rule (PSR) 13 years after its passage and 8 years after the first compliance date. Continued engagement after participation in the PSA Grower Training with high-quality information networks like Cooperative Extension, with support and guidance from the Produce Safety Alliance, was associated with statistically significant higher levels of understanding across multiple dimensions of food safety knowledge. Continued development of resources from high-quality information networks is critical to improving knowledge gain and implementation of produce safety practices that effectuate lasting change in risk reduction practices. Assessing objective knowledge is crucial during regulatory changes and to evaluate knowledge retention, as self-reported data may introduce bias in compliance measurement. The relationship between actual knowledge and self-perceived understanding is often framed as objective versus subjective knowledge.

1. Introduction

The Food Safety Modernization Act (FSMA) was passed in 2011 to reduce the public health burden of foodborne illness outbreaks linked to fresh produce (FDA 2015b). The FSMA Produce Safety Rule (PSR) was finalized in November 2015 and builds upon the voluntary Good Agricultural Practices (GAPs) established in the 1998 *Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables* (FDA 1998) that initiated a movement among buyers to require food safety practices of their fresh produce suppliers. Before the passage of the FSMA PSR, buyers were the primary drivers of the adoption of produce safety practices. Buyer requirements remain the primary driver, but growers covered by the FSMA PSR also needed to comply with FSMA PSR requirements beginning in 2018, adding a layer of complexity for many growers. Compliance dates for pre-harvest agricultural water are still being phased in between April 2025 and April 2027.

Buyer requirements often mandate produce growers, packers, and industry members to adopt GAPs and engage with third-party audits to verify the implementation of practices to gain market access (Gravani 2009; Minor et al. 2019). The practices required for third-party GAPs audits are similar, but not the same, as FSMA PSR regulatory inspections conducted by FDA and certain states (Minor et al. 2019).

These regulatory inspections, depending on a grower's location, may occur every 1–5 years, whereas buyers require audits every year. Both the regulation and audits establish science-based standards, including practices around worker hygiene and training, biological soil amendments of animal origin, wildlife and domesticated animals, agricultural water, equipment, tools, sanitation, and recordkeeping, though again, the required practices may not be the same (FDA 2015b). There is no universal standard; growers may be subject to both FSMA PSR regulatory requirements and third-party audit standards, either, or none.

Recognizing that the FSMA PSR is the first federal regulation governing the production of fresh fruits and vegetables, the FDA established an educational training requirement that "at least one supervisor or responsible party from your farm must have successfully completed food safety training at least equivalent to that received under standardized curriculum recognized as adequate by FDA" ((FDA 2015b, 74421)). Extension training encourages growers to understand and adopt new practices by sharing knowledge and resources (Beecher et al. 2024; McGrath et al. 2025). This educational training requirement is intended to help the produce industry understand regulatory requirements and learn science-based practices to reduce risks and comply with key requirements in the FSMA PSR.

The FDA collaborated with the USDA and Cornell University to establish the Produce Safety Alliance (PSA) in 2010, knowing there would be a need for education and outreach on the FSMA PSR (FDA 2020). The FDA provided strategic and technical guidance while supporting PSA as the liaison with growers in the development of trusted, science-based trainings that played a critical role for the implementation of the PSR. The PSA developed the standardized PSA grower training (GT) course in partnership with the FDA, the USDA, and collaborators from academia and industry to meet this regulatory requirement. Partners engaged in an education and training materials conference to share resources, and 10 working committees were established to gather input on curriculum content and program delivery expectations (Produce Safety Alliance 2011). The PSA conducted eight focus groups with 89 growers nationwide to gain an understanding of grower preferences for produce safety training (Produce Safety Alliance 2012). Input shared by these growers was incorporated directly into the final PSA GT course delivery strategy and policies with final curriculum review by the FDA.

The course was developed to meet expectations that it be delivered in one-day, meets the one-time training regulatory requirement, be conducted in person and that written resources be provided (PSA 2012; Woods et al. 2020). Growers expressed the value of in-person training opportunities to ensure they could ask questions and receive direct technical assistance, while balancing the challenges of being away from the farm. While the PSA GT course was accomplished through in-person attendance with vetted instructors, delivery

policies have adapted to allow for remote and online delivery options as a result of technological improvements, the COVID-19 pandemic, and industry input; however, the basic requirements of providing a printed manual remain (Bugingo et al. 2023).

The PSA GT course is intended to impact behavior change among grower participants by building grower knowledge and encouraging the adoption of risk-reducing practices. The standardized evaluation for the PSA GT course is limited to self-assessments on perceived knowledge gain, confidence in implementing specific practices, instructor effectiveness, and sufficiency of the information and resources presented. By design, the PSA GT course evaluation does not include a pre/post-test, as that was not a regulatory requirement. Measuring the impact of educational programming on knowledge gain and behavioral change is challenging, often relying on biased self-perceptions, and can be time- and resource-intensive (Chen et al. 2021; McGilvery et al. 2025). One of the four regional centers created by the FDA and the USDA to support the critical training and education under FSMA rules, the Southern Regional Center for Food Safety Training, Outreach, and Technical Assistance ("Southern Regional Center") developed a knowledge assessment via pre- and post-test to be delivered immediately before and after trainings nationwide to help determine knowledge gain as a result of PSA GT course attendance (Perry et al. 2021; Narine et al. 2024; Schneider et al. 2024).

Although the PSA is most recognized for the standardized PSA GT course, the PSA maintains a knowledgeable staff and a host of additional resources. This network of programs and resources is intended to provide growers with access to accurate, timely information to help them understand and comply with regulatory requirements. These resources include tools to help implement produce safety practices and are publicly available on English- and Spanish-language PSA (2025) websites. Additionally, a standardized PSA train-the-trainer course and lead trainer process develop vetted PSA trainers to host PSA GT courses (Woods et al. 2020). A network of trainer-specific resources is maintained to support produce safety educators. These resources provide opportunities to continue engaging with produce safety information after completion of the PSA GT course and may therefore play an important role in long-term knowledge retention.

Although previous evaluations have demonstrated immediate knowledge gains following participation in the PSA GT course, less is known about whether that knowledge is retained over time or what factors influence long-term retention and application of produce safety concepts. Whereas Narine et al. (2024) evaluated knowledge acquired during the training itself using assessments administered immediately before and after course delivery, the present study investigates whether selected concepts taught during the training are retained months or years later. In addition to assessing retention of these concepts, we examine grower characteristics, information sources, and food

safety experiences associated with retained knowledge. By doing so, this study moves beyond measuring short-term learning outcomes to evaluate the sustained impact of the PSA GT course and identify factors that may support long-term knowledge retention.

2. Data and Methodology

An online survey was administered from March 2023 to June 2023 to produce growers who were selling to US markets. To ensure a diverse respondent pool, the survey was emailed to all individuals who had participated in PSA training (https://cals.cornell.edu/produce-safety-alliance) and distributed through various fresh produce associations' email newsletters (Produce Safety Alliance 2022). Three knowledge-based questions were included in addition to self-reported data on produce safety practices implemented on fresh produce farms, including certain packinghouses. All questions were pre-tested, refined, and administered via Qualtrics and participants were entered into a raffle for one of ten $75 prepaid Visa credit cards. Prior to administering, the survey design was reviewed and determined to be exempt by the University of Vermont Institutional Review Board (IRB), the host institute of the Northeast Center to Advance Food Safety and the organization that disseminated the survey and collected responses.

Of the 506 valid US-based responses, 70 percent reported having a produce safety role, while 64 percent had an ownership role, and 10 percent indicated another role. The vast majority, 86 percent, spent half or more of their time working on the farm or in the packinghouse, and 85 percent handled produce commodities commonly consumed raw and covered by the PSR. Not all survey respondents provided responses to every question: Later questions generally received fewer responses, resulting in varying sample sizes across items. Due to limited sample size of geographic regions, we conducted the analysis at a national level. More detailed descriptive statistics of the sample are summarized in the appendix and in Astill et al. (2025).

We selected questions from an existing pre- and post-test for the PSA GT course, designed to assess respondents' knowledge of the PSR and adapted for brevity (Perry et al. 2021; Schneider et al. 2024). Questions were selected for greatest change in knowledge gain between the pre- and post-tests. Scholars have examined the relationship between actual knowledge and individuals' self-perceived understanding—often framed as objective versus subjective knowledge—particularly within the context of consumer decision-making (Moorman et al. 2003; Carlson et al. 2009). Assessing objective knowledge is especially crucial during regulatory changes, as self-reported data may introduce bias in compliance measurement. Respondents might hesitate to acknowledge their lack of understanding of new regulations or noncompliance (Mack et al. 2024).

Cognizant of respondent burden, we settled on three questions for the online survey, adapted from the pre- and post-tests originally developed by the Southern Regional Center. These questions were selected because they had among the lowest rates of correct responses before training and showed some of the greatest increases in correct responses immediately after the PSA GT course (Narine et al. 2024). Consequently, they represented concepts for which the training appeared to have the greatest immediate impact, making them well suited for assessing long-term knowledge retention. The three questions are

1. Which packinghouse zone poses the greatest concern for cross-contamination of produce?
    a. Zone 1 *(correct answer)*
    b. Zone 2
    c. Zone 3
    d. Zone 4
2. Which of the following statements regarding cleaning and sanitizing is true?
    a. All surfaces can be cleaned and sanitized
    b. Cleaning and sanitizing are synonymous
    c. Sanitizing may be done in place of cleaning when unavoidable
    d. Surfaces that have not been cleaned cannot be sanitized *(correct answer)*
3. According to the FSMA Produce Safety Rule, which of the following statements regarding Farm Food Safety Plans is true?
    a. A written Farm Food Safety Plan is required
    b. The Farm Food Safety Plan is not required *(correct answer)*
    c. The Farm Food Safety Plan only needs to include covered produce
    d. The Farm Food Safety Plan should be provided to all consumers

Question 1 addresses knowledge common to third-party food safety audits and training outside of the PSR; and Question 2 addresses knowledge that applies to both PSR and third-party audits: Question 3 addresses knowledge unique to the PSR. Questions 1 and 2 were asked before and after PSA trainings to assess knowledge gain. We maintained consistency to be able to assess long-term knowledge retention.

In addition, the online survey asked which sources of information were used to learn about the PSR. The information sources used by growers in the sample were, in order of most to least common, PSA (39 percent), university, including extension (30 percent), state departments of agriculture (26 percent), FMSA legislation, rules, and guidance (25 percent), produce/agricultural news (20 percent), FDA (14 percent), grower/produce associations (14 percent), and neighbors/other growers (8 percent). Respondents who used PSA as a source of information were noted in the results as "used PSA for information."

In this study, we first examined the differences in correct response rates for the knowledge questions among various sub-sample categories. To determine whether these differences in proportions are statistically significant, we performed two-tailed Welch's tests for samples of different sizes, as indicated by the stars in the corresponding tables. We also performed two-tailed Welch's tests to identify statistically significant differences in response rates for other food safety coverage, practice, motivations, and challenges questions.

3. Results and Discussion

3.1. Knowledge Assessment Results Among Different Farm Groups

Table 1 summarizes the correct response rate for the three knowledge questions among different grouping variables. A third of the groups yielded a statistically significant difference at the 5 percent level (Table 1).

3.2. Q1: Packinghouse Zones

The first knowledge-based question was answered correctly by 79 percent of respondents who properly identified Zone 1 (food contact surfaces) to be the packinghouse zone that poses the greatest risk of cross-contamination for produce. Groups with a greater proportion of correct responses include growers with more than $603,202 in produce sales (87 percent vs. 75 percent), audited growers (85 percent vs. 73 percent) and covered growers (84 percent vs. 73 percent). These differences were statistically different at the 10 percent level or better, with the audited group significant at the 5 percent level. Neither PSA training nor using PSA resources for information were associated with a higher rate of correctly identifying Zone 1 to be the point of greatest risk of cross-contamination. This question is intended to assess whether training participants can identify which areas in the packinghouse should be prioritized to minimize the potential for cross-contamination, including regular monitoring, cleaning, and if possible, sanitizing practices (FDA 2015b).

Table 1. Proportion of farm respondents that answered knowledge questions correctly

	Q1: Packinghouse Zone		Q2: Cleaning and Sanitizing		Q3: Food Safety Plan	
	Correct	*N*	Correct	*N*	Correct	*N*
Full sample	79%	187	68%	253	13%	255
Third-party audit	85%**	82	72%	105	6%**	108
No audit	73%**	105	66%	148	18%**	147
Above $603,202[a]	87%*	53	70%	66	10%	68
$603,202 or less	75%*	129	68%	181	14%	181
Covered	84%*	95	67%	124	10%	128
Not covered	73%*	92	70%	129	16%	127
I know my PSR coverage status	80%	166	72%**	212	15%**	215
I don't know	75%	20	49%**	37	3%**	35
PSA training	78%	169	69%	218	14%	219
No PSA training	89%	18	63%	35	8%	36
PSA training and used PSA info	77%	149	73%*	184	16%***	180
Not both	84%	38	57%*	69	5%***	75
FSMA leg., rules, guid. used	80%	93	78%**	125	12%	122
FSMA resources not used	78%	94	59%**	128	14%	133
University resources used	81%	111	76%**	148	14%	147
University resources not used	75%	76	58%**	105	12%	108

Notes: Single, double, and triple asterisks (*, **, ***) indicate a statistically significant difference at the 10%, 5%, and 1% level, respectively, between farm characteristic row pairs in the same column.

[a] The sales cutoff of $603,202 represents the FSMA Produce Safety Rule's $500,000 average annual produce sales threshold adjusted for inflation to 2023, the year the survey was conducted.

3.3. Q2: Cleaning and Sanitizing

In our sample, 68 percent of respondents correctly answered the second question. Unlike the question about risk of cross-contamination in different zones, there were no statistically significant differences between correct response rates among large and small growers, audited and non-audited growers, or covered and non-covered growers. However, information sources used are associated with differences in the rate of correct responses on this cleaning and sanitizing question. Among respondents who used FSMA legislation, proposed rules, and guidance as a source of information, 78 percent answered correctly compared to 59 percent of those who did not. Similarly, 76 percent of those who used university resources (e.g., training, extension, education, regional centers) answered correctly compared to 58 percent of those who did not. Respondents who did not know whether they were covered by the PSR had the lowest correct response rate of any group: 49 percent compared to 72 percent of those who knew their PSR coverage status. Among respondents who both went to a PSA training and used PSA resources for information, 73 percent answered correctly, compared to 57 percent of those who did not do both. This difference was statistically significant at the 10 percent level.

3.4. Q3: Farm Food Safety Plan

Respondents in the sample largely missed the third, knowledge-based question—only 13 percent answered correctly. Although the FSMA PSR does not require a Farm Food Safety Plan (FFSP), Extension educators assist growers

to develop FFSP to organize their procedures and records or comply with third-party audit requirements (Schmit et al. 2020). This was a difficult question for most respondents, and certain farm characteristics correlated with a higher correct response rate at the 5 percent statistical significance level.

Only 6 percent of growers that underwent a third-party audit correctly identified that the FFSP is not required under the PSR, whereas 18 percent of growers that were not audited answered correctly. The large share of audited growers that incorrectly answered the FFSP question faced no negative consequences for this incorrect belief: Believing that an FFSP is required under the PSR causes no harm. In fact, even though an FFSP is not required in the FSMA PSR, it is required for third-party audits. Although this misunderstanding does not create a food safety risk or regulatory compliance issue, it provides insight into growers' understanding of the difference between PSR requirements and third-party audit expectations. The standards in the FSMA PSR are required to be met for covered farms but are not required to be explicitly incorporated into a written FFSP. Thus, an audited farm that meets PSR standards and meets their auditors' standards is doing right under both frameworks. Among the non-audited farms, it is reasonable to conclude that a larger proportion of those farms looked into what minimum requirements apply to their particular operation and correctly concluded that they are not required to incur the additional cost of developing an FFSP distinct from the standards written in the PSR.

Second, those who do not know whether they are covered by the PSR are the least likely to correctly answer that an FFSP is not required under the PSR (3 percent, $n = 35$) compared to those who know their coverage status (15 percent, $n = 215$). PSR coverage status depends on several factors, including produce type, produce and food sales, distance of sales from the farm, and market (FDA 2015a). Navigating the exemptions and exclusions to determine coverage status can be challenging because sales thresholds change over time due to inflation adjustments, regulators may exercise enforcement discretion, in addition to the complexity of the standard exemptions and exclusions.

Third, even among growers who took the PSA GT course and rely on PSA for information, only 16 percent correctly answered the FFSP question (Table 2). This lack of understanding is not different in a statistically significant way between covered growers and non-covered growers or large growers and small growers. The misunderstanding of certain regulatory details, like whether an FFSP is required under the PSR, is actually more pronounced for growers most familiar with voluntary food safety standards enforced through third-party audits. This suggests that audit requirements may become conflated with regulatory requirements over time, illustrating how some produce safety concepts are retained differently than others.

Table 2. Proportion of PSA GT attendees versus 2023 long-term follow-up survey respondents that answered knowledge questions correctly

	Q1: Packinghouse Zone		Q2: Cleaning and Sanitizing		Q3: Food Safety Plan	
	Correct	*N*	Correct	*N*	Correct	*N*
Immediately before PSA training (i.e., pre-test)[a]	53%	5,239	54%	5,255	9%	5,263
Immediately after PSA training (i.e., post-test)[a]	90%	5,255	86%	5,256	59%	5,253
Long-term follow-up survey	79%	187	68%	253	13%	255
			Statistical Significance			
Pre-test vs. long-term	$p < 0.01$		$p < 0.01$		$p < 0.05$	
Post-test vs. long-term	$p < 0.01$		$p < 0.01$		$p < 0.01$	

Notes: [a] indicates results from Narine et al. (2024). Trainings occurred in 2019, 2020, 2021, or 2022. Questions in the pre- and post-assessments were numbered 19, 20, and 22, which we label questions 1, 2, and 3.

3.5. Comparison to Pre-/Post-PSA Training Knowledge Assessments

To evaluate PSA GT course attendees' knowledge change, Narine et al. (2024) compiled pre- and post-tests from the four regional food safety centers, administered during the 2019–2022 period. We use the results reported by Narine et al. (2024) as a benchmark for immediate post-training knowledge gain and compare them with our long-term follow-up findings to evaluate knowledge retention (Table 2). Because attendees took the training in different years, we captured an average retention over 4 years of cohorts. Our results conformed to those published in Narine et al. and show different rates of knowledge retention for different questions. Respondents answered the first two questions (packinghouse zones and cleaning/sanitizing) correctly at high rates immediately after attending the PSA training (90 percent and 86 percent, respectively). After 1–4 years, the rate of correct responses observed in our survey drops to 79 percent and 68 percent, respectively, but remains significantly higher than the pre-PSA training rates of 53 percent and 54 percent, respectively. As discussed above, answering the third question regarding the FFSP incorrectly causes growers with third-party food safety audits no negative consequences. In 2023, the rate of correct response for the third question goes from 59 percent post-PSA training to 13 percent, closer to the pre-PSA training rate of 9 percent.

3.6. PSA Grower Training Course Attendance

Most respondents, 84 percent, attended a PSA GT course. More than half of the respondents, 54 percent, attended a Good Agricultural Practices (GAPs) training, and 56 percent had attended various other trainings.[1] Only 4 percent of respondents had never attended any type of food safety training.

Attendance at a PSA GT course, by itself, was not associated with a statistically significant difference in correctly answering any of the three knowledge questions. However, PSA GT attendance correlates with a higher

1 See Appendix Table A1 for the list of other trainings.

knowledge of participants' coverage status. Both knowing one's PSR coverage status and using PSA for both information and training are associated with a higher likelihood of answering knowledge questions correctly. These findings suggest that long-term retention of produce safety concepts may be influenced less by training attendance alone and more by continued engagement with produce safety information and understanding of regulatory requirements. We investigate further how these characteristics are related in the following sections.

One area where knowledge gaps persisted is related to PSR coverage status. The PSA GT includes limited information on FSMA PSR exclusions and exemptions, with additional material available as optional, but not required, content for trainers. Because this content was optional, the extent to which participants received instruction on PSR exclusions and exemptions likely varied among course offerings, potentially contributing to differences in growers' understanding of their coverage status.

Another area of confusion involved FFSPs. The concluding module of the PSA GT course includes recommendations and resources for writing an FFSP. The PSA GT states that an FFSP is not required, but it is possible that training attendees get confused because writing a plan is discussed in module 7 of the training. Additionally, the point about a plan not being required is typically covered at the end of a long training day. Uses of other sources of information were not associated with statistically significant differences in a correct response rate to the FFSP question.

3.7. Using PSA for Both Training and Information

Growers who attend a PSA GT or other trainings may have varying motivations, which may impact which pieces of information they pay attention to and retain. When we combine PSA GT attendance with an indicator of intention to seek out food safety information, we identify statistically significant differences that were not present when considering PSA training alone. Comparing respondents who use PSA for both training and information with other respondents, there are significant differences in the correct response rates for Q2 (72 percent vs. 49 percent) and Q3 (15 percent vs. 3 percent).

One-quarter of respondents in our sample did not know whether their operation was covered (25 percent, $n = 495$; Table 3). The share of farms that did not know whether they were covered by the PSR was more than double for those who did not take a PSA training (34 percent; $n = 71$) compared to those who did (15 percent; $n = 424$). Among those who used the PSA for both information and training ($n = 187$), 8 percent did not know whether they were covered by the PSR compared to 24 percent of those who did not use the PSA for both information and training ($n = 308$).

Table 3. PSA training, information, and PSR coverage status, including "I don't know"

	Covered	Qualified Exempt	Excluded	I Don't Know	Count of Responses	Share of Responses
No PSA training	0.324***	0.254	0.085	0.338***	71	0.143
PSA training	0.512***	0.250	0.085	0.153***	424	0.857
PSA not used for both	0.442***	0.214***	0.101	0.244***	308	0.622
PSA used for both info and training	0.556***	0.310***	0.059	0.075***	187	0.378
Count of responses	240	42	89	124	495	
Share of responses	0.485	0.085	0.180	0.251		

Notes: ***, **, * signify a statistically significant difference at the 1 percent, 5 percent, and 10 percent levels, respectively, between farm characteristic row pairs in the same column.

Confusion about PSR coverage may exist for a couple of reasons (Astill et al. 2025). First, determining a farm's coverage involves navigating the definitions and details of various exemptions and exclusions within the PSR (e.g., rarely consumed raw produce, qualified exemption status). This also includes navigating inflation-adjusted values for total produce sales and total food sales, which are updated by the FDA each year usually around April. The PSA training only includes one required slide discussing PSR exemptions and exclusions. Once the PSA training was launched and it became apparent that growers and PSA trainers wanted more information, a set of supplemental slides reviewing the exemptions and exclusions was developed and posted on the PSA (2025) website. Trainers are encouraged to use these supplemental slides or provide them to growers when they want more information on their coverage status.

These results indicate that participating in a PSA GT alone may not be sufficient to provide US produce growers with all the information they need to determine whether they are covered by the PSR. Even though using additional information from the PSA is associated with a lower proportion of uncertainty, there is still a significant amount of confusion among the most intensive PSA-use group. (Hereafter, we refer to these two categories of growers as PSA-use groups: respondents who use the PSA for both information and training and respondents who do not use the PSA for both.)

3.8. Sources of Information by PSA-Use Groups

In a produce safety dialogue process facilitated by the Reagan-Udall Foundation (2025), growers expressed the importance of cooperative extension, through universities, in providing technical assistance and food safety knowledge. PSA was specifically listed as an important extension group. One of the top priority areas highlighted in this dialogue was the development of a sustainable funding framework for produce safety outreach. Our results corroborate their findings. The use of the PSA as an information source is correlated with the use of all other sources of information (Table 4). More than half of growers that use the PSA for both info and training also use universities (including cooperative extension), state regulatory agencies, and FDA FSMA documentation as information sources. In contrast, 8–12 percent of growers

Table 4. Sources of information used to understand the FSMA Produce Safety Rule

	PSA Not Used for Both	PSA Used for Both Info and Training	Count of Responses	Share of Responses
Produce Safety Alliance (PSA)	0.025***	1.000***	196	0.387
University	0.119***	0.606***	152	0.300
State Dept. of Agriculture	0.075***	0.569***	131	0.259
FSMA leg., rules, and guidance	0.079***	0.548***	128	0.253
Produce/ag news	0.079***	0.410***	102	0.202
FDA (listening sess., website)	0.044***	0.309***	72	0.142
Grower/produce assoc.	0.038***	0.303***	69	0.136
Neighbors/other growers	0.013***	0.191***	40	0.079
Count of responses	318	188	506	
Share of responses	0.628	0.372		

Notes: Single, double, and triple asterisks (*, **, ***) indicate a statistically significant difference at the 10%, 5%, and 1% levels, respectively, between farm characteristic column pairs in the same row.

who do not use PSA for both information and training use universities, state regulatory agencies, or FDA documentation. Rates of use among both PSA-use groups decrease through the remaining information sources, with the "PSA used for both information and training" group always statistically significantly higher than the "PSA not used for both" group.

3.9. Food Safety Practices, Motivations, and Challenges by PSA-Use Groups

Table 5 summarizes the differences in food safety practices, motivations, and challenges among PSA-use groups. While PSR coverage makes growers legally responsible to follow the food safety practices codified in the FSMA PSR, there is widespread understanding in the produce industry that food safety practices are necessary to prevent consumers from getting sick from eating contaminated fresh produce. Over 92 percent of farms that did not use PSA for both information and training have implemented food safety practices, and 98 percent of farms that use PSA for both information and training have.

Growers that used the PSA for both information and training were statistically more likely to make changes related to food safety based on animals adjacent to the produce operation (80 percent) compared to those who did not use the PSA for both (59 percent). The most common motivator to implement food safety practices reported by respondents was meeting PSR standards (58 percent), personal commitment (48 percent), and maintaining market access (47 percent).

There was no statistical difference between the PSA-use groups in reporting meeting PSR standards or a personal commitment to be a top reason to implement food safety practices. However, a larger proportion (64 percent) of growers that do not use the PSA for both information and training report maintaining market access to be a top reason to implement food safety practices compared to 54 percent of growers that use the PSA for both.

Table 5. Differences by use of PSA resources in the proportion of farm respondents that answered "yes" to the following produce food safety practices, motivations, and challenges.

	PSA Not Used for Both	PSA Used for Both Info and Training	Count of Responses	Share of Responses
Have you implemented produce food safety (FS) practices?	0.923***	0.984***	471	0.946
Have you made any changes based on adjacent animals?	0.593***	0.797***	119	0.672
Have you stopped growing covered produce?	0.108	0.089	40	0.099
Top reasons to implement FS practices: meet PSR standards	0.739	0.740	295	0.583
Top reasons to implement FS practices: personal commitment	0.590	0.633	243	0.480
Top reasons to implement FS practices: maintain market access	0.635**	0.537**	236	0.466
Top challenges: recordkeeping	0.523**	0.627**	227	0.455
Top challenges: wildlife and domesticated animals	0.419	0.401	164	0.326
Top challenges: worker health and hygiene training	0.387	0.316	142	0.296
Count of responses	318	188	506	
Share of responses	0.628	0.372		

Notes: Single, double, and triple asterisks (*, **, ***) indicate a statistically significant difference at the 10%, 5%, and 1% levels, respectively, between farm characteristic column pairs in the same row.

Top challenges to implementing food safety practices reported by growers include recordkeeping (46 percent), wildlife and domesticated animals (33 percent), and worker health and hygiene training (30 percent). Recordkeeping is the only challenge for which statistical differences exist in the PSA-use group. In this case, 63 percent of growers who use the PSA for both information and training report recordkeeping to be a top challenge compared to 52 percent of those who do not.

The direction of causality is not easily identified in these cases. The PSA GT course and the use of the PSA materials were not imposed on respondents in the sample as experimental conditions. Thus, certain growers may have intrinsic characteristics that cause them to seek out more informational resources including the PSA materials, to self-select into certain marketing channels, or to focus on certain food safety practices. The data do, however, support a clear association between the use of the PSA for both training and information and understanding of one's coverage status, two of three knowledge-based questions, the likelihood of implementing food safety practices, implementing changes based on adjacent animals, and reporting recordkeeping to be a top challenge. In this case, it is also conceivable that those who less often report recordkeeping to be a challenge are also less likely to be keeping records. In other words, those who best understand the PSR requirements, food safety principles, and food safety information may be the ones best able to understand the challenge of implementing recordkeeping to a standard sufficient to prevent contamination and fulfill the expectations of the FDA and their downstream supply chain partners. Food safety is largely an obscure problem whose consequences may or may not ever be traced back to one's operation. In the rare cases when contamination is traced back to an

individual operation with a high degree of certainty, it is not unusual to find that the farm had passed a third-party audit and had "no concerns about food safety prior to the outbreak" (US House of Representatives 2012).

4. Conclusion

Whereas Narine et al. (2024) demonstrated immediate knowledge gains following participation in the PSA GT course, the present study examined whether selected concepts taught during training were retained months or years later and identified factors associated with that retention. Results from this recent survey of US produce growers demonstrate the importance of high-quality information networks like the PSA based on their association with statistically significantly higher levels of understanding across the concepts evaluated in this study. A single training can increase knowledge in the short term. Our findings, however, suggest that training attendance alone may not be sufficient to support long-term retention of produce safety concepts. This is especially true as scientific understanding evolves including how different components of the natural production environment contribute to contamination risks across different geographies during different periods of the local growing season.

Our findings show that knowledge gained through training may decline over time without continued engagement and reinforcement of food safety concepts. In fact, those growers that do have repeated access to information on food safety practices still experience knowledge loss, although to a lesser degree, suggesting that ongoing educational efforts remain important. The findings presented here are important, not because they show how growers performed on a post-training evaluation test but because they demonstrate that these lessons need to be repeated to be adopted. For food safety to work, it needs to be incorporated into the farm culture as day-to-day practices, not something that is done only before an inspection or audit or after a food safety problem has been identified. Rather food safety needs to be incorporated into the regular routine of growing, harvesting, and selling every day.

The results of this survey emphasize the importance of high-quality information networks to disseminate both scientific information from the lab and practical knowledge on implementation from the commercial operation when it comes to effectuating real, lasting change in produce safety best practices. We identified statistically significant differences among those who used information from the PSA, the FDA's online FSMA resources, and university agricultural extension, education, and food safety centers of excellence. The PSA carefully researches and curates information based on grower input and the most recent science from universities and regulatory guidance from state and federal agencies. The PSA also directly engages the produce industry through technical assistance, webinars, and educational materials hosted on their websites and mentors PSA trainers to facilitate

training alignment and collaboration. These results highlight the role the PSA plays as a hub in the network of key US produce safety information sources used by growers.

Together, these findings demonstrate that long-term retention of produce safety concepts is influenced by more than attendance at a single training and point to the importance of sustained, diverse, and tailored educational models that reinforce recommended practices. Extension education networks are critical pedagogical infrastructure that support not only the initial delivery of standardized curricula such as the PSA GT and refresher trainings but also other topic-specific workshops or educational events as well as farm-specific direct education and technical assistance which influence grower attention to needs and adoption of practice to reduce risk. Our work suggests it is important to implement extension-based produce safety educational strategies that support reinforcement of learning and updates of knowledge leveraging trusting relationships over months and years in ways that are accessible and relevant to the target audience.

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Acknowledgments

This work is supported by the Food Safety Outreach Program grant no. 2024-70020-42957 from the USDA National Institute of Food and Agriculture and without our sponsor this work would not have been possible. Some authors were supported by U.S Food and Drug Administration U2FFD007392 and U01FD008283. This research was supported in part by the US Department of Agriculture, Economic Research Service. The findings and conclusions in this publication are those of the authors and should do not necessarily represent the official views of, nor an endorsement by, the USDA, FDA, or the US government.

AI Disclosure

AI was not used in writing this paper.

Human Subjects Disclosure

Prior to administering, the survey design was reviewed and determined to be exempt (STUDY00002485) by the University of Vermont Institutional Review Board (IRB), the host institute of the Northeast Center to Advance Food Safety and the organization that disseminated the survey and collected responses.

Published: November 16, 2026 CST.

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Appendix: Respondent Characteristics

Table A1 reports sample characteristics. Although 1,314 individuals started the survey, we included only the 506 respondents who reported having knowledge about the produce safety practices used on their associated farm or packinghouse and who are located in US states (California [10 percent], Washington [5 percent], New York [5 percent], Michigan [5 percent], other states [64 percent]) and Puerto Rico (11 percent). Seventy percent of respondents reported having a produce safety role, while 64 percent had an ownership role, and 10 percent indicated another role. The sample was approximately half female (52 percent) and half male (44 percent), with less than 1 percent reporting as nonbinary and 3 percent preferring not to say. In terms of education, 3 percent did not graduate from high school, 32 percent graduated from high school but did not obtain a bachelor's degree, 43 percent had a bachelor's degree, and 21 percent had an additional degree beyond a bachelor's degree. Regarding age, 21 percent of the sample were 39 or younger, 18 percent were between 40 and 49, 19 percent were between 50 and 59, 22 percent were 60 or older, and 20 percent did not respond.

Half of the farms had 10 or fewer acres of produce in 2022, and 36 percent sold less than $30,160[1] worth of fruit and vegetables in 2022. On the other end of the size spectrum, 33 percent of farms had more than 100 acres of produce, and 26 percent sold more than $603,303 worth of produce. Most farms, 56 percent, used conventional practices, 21 percent were certified organic, and 36 percent used organic practices but were not certified. Additionally, 18 percent of farms used controlled environment agriculture, hydroponic, or aquaponic techniques.

1 These sales values ($30,160 and $603,303) are adjusted for inflation at the time of survey development. Initial cut-offs were based on 2011 values established when FSMA was signed into law. These values represent the cut-off for a not covered farm ($25,000) and a qualified exempt farm ($500,000). FDA maintains a FSMA Inflation Adjusted Cut Offs website, updated each spring.

Table A1. Respondent characteristics

Question	Responses	Percentage	*N*
What is your role on the farm? Check all that apply.			
	Produce safety	70%	353
	Ownership	64%	322
	Other, besides produce safety or ownership	10%	52
What percentage of your time do you work on the farm and/or in the packinghouse?			
	100%	47%	238
	51% - 99%	28%	139
	50%	12%	59
	Less than 50%	13%	67
	No response	0.6%	3
Do you grow produce commonly consumed raw & covered by FSMA PSR?			
	Yes	85%	428
	Unsure	6%	30
	No	9%	48
	No response	0.4%	2
What is your farm's coverage status under the FSMA Produce Safety Rule?			
	Covered	47%	240
	Qualified Exempt	25%	124
	Excluded	8%	42
	I don't know	18%	89
	No response	2%	11
What is your gender?			
	Female	52%	265
	Male	44%	224
	Non-binary	0.6%	3
	Prefer not to say	2%	10
	No response	0.8%	4
What is the highest level of school you have completed?			
	Less than high school	3%	13
	High school or less than bachelor's degree	32%	164
	Bachelor's degree	43%	219
	More than bachelor's degree	21%	106
	No response	0.8%	4
What is your age?			
	39 or less	50%	256
	40 to 49	22%	110
	50 to 59	6%	32
	60 or older	2%	8
	No response	20%	100
How many acres did you have planted in produce (owned and rented) for the 2022 calendar year?			
	2 or less	25%	125
	More than 2, up to 10	24%	123
	More than 10, up to 100	22%	112
	More than 100	22%	113
	No response	7%	33
Your farm is (multiple choices)?			
	Conventional	56%	285
	Organic	17%	85
	Using organic practices but not certified	36%	181
	Controlled environment agriculture, hydroponic, or aquaponic	18%	93
	Plain Sect (including Amish)	2%	9
Which sales category best fits your farms' 2022 fruit and vegetable revenues (gross)?			
	Under $30,160	36%	182
	Between $30,160 - $301,60	27%	137

Question	Responses	Percentage	*N*
	Between $301,601 - $603,202	7%	37
	Above $603,202	26%	130
	No response	4%	20
What produce safety training(s) have you attended?			
	Produce Safety Alliance	84%	426
	Good Agricultural Practices	54%	272
	Good Manufacturing Practices	22%	109
	Hazard Analysis and Critical Control Points	21%	107
	On-farm Readiness Review	15%	75
	Other	13%	68
	Good Handling Practices	13%	66
	ServSafe	13%	65
	Preventive Controls for Human Food	12%	59