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Knowledge and Implementation of Good Agricultural Practices among Kentucky Fresh Produce Farmers

SUMMARY

Kentucky fresh produce farmers' food safety practices, knowledge of food safety, and acceptance of food safety certifications such as Good Agriculture Practices (GAPs) have been largely unknown. The purpose of this research was to assess the knowledge and practices of Kentucky growers pertaining to GAPs. Data were analyzed from 160 questionnaires completed by fresh produce growers on-site at farmers' markets in 21 Kentucky counties. The results were mixed, with 90% of participants indicating familiarity with GAPs but only 47% opting to practice water quality GAPs and 55% choosing to observe soil amendment GAPs. Participants did report higher compliance with field sanitation (71%) and sanitary facilities (73%) GAPs, but indicated that cost (67%) and time (68%) were significant perceived barriers to completing GAPs audits. Participants failed to identify many sources of potential microbiological contamination, with soil being identified as a source of pathogenic contamination by only 41% of participants and irrigation water by 51% of participants. Even fewer participants believed that contamination could result from ice (26%) or refrigeration and cooling (28%). While many Kentucky farmers are aware of GAPs, this study highlights the need for further GAPs education to advance the understanding of food safety practices among farmers.

INTRODUCTION

The United States Food and Drug Administration (FDA) published the *Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables* in 1998 *(9)*. This publication identified concerns, risks, and safe practices associated with production and handling of fresh produce. To verify compliance with the FDA's produce recommendations, the United States Department of Agriculture (USDA) created Good Agriculture Practices (GAPs) as a food safety audit to evaluate farm management practices and guide small-farm process improvement *(27)*. Foodborne pathogenic contamination is estimated to cause approximately 48 million illnesses and 3,000 deaths per year in the United States *(5)*. Compliance with GAPs is one of the strategies that could be used to help decrease the foodborne pathogenic contamination in the United States, as produce has the potential to act as a vehicle for transmission of harmful pathogens in the farm-to-fork continuum *(20)*.

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Consumption of fresh produce in the United States has increased dramatically in recent years and is reflected in an upward trend of direct consumer purchase from small-scale farmers. According to the USDA, revenues from local food sales exceeded $7 billion in 2012, a marked increase from the $1 billion value of local food sale revenues in 2005 *(28)*. Fresh produce sales directly from producers to consumers have increased dramatically and account for a substantial proportion of local food sales. Recent data suggest that fresh produce growers prefer to establish customer bases in the local community by selling face-to-face *(17)*. Farmers' markets provide an increasingly popular vector for direct sale of fresh produce from growers to consumers. According to the USDA, the number of farmers' markets in the USDA National Farmers Market Directory has more than quadrupled since 1994. Nearly 8,500 farmers' markets operated in 2015, up from about 7,200 in 2011, 6,100 in 2010, 2,800 in 1998, and 1,800 in 1994 *(26)*. In Kentucky, more than 159 farmers' markets now deliver fresh local produce to consumers *(16)*.

Increased access to local fresh produce has occurred concurrently with an uptick in on-farm pathogenic contamination and subsequent foodborne illness outbreaks *(7)*. Produce, including fresh produce sold at farmers' markets, can result in transmission of pathogens resulting in approximately 46% of yearly foodborne illnesses, and leafy greens are the most common fresh produce type to be linked to such illnesses *(20)*. In 2006, an *Escherichia coli* O157:H7 outbreak associated with spinach in Kentucky sickened eight people, 4 of whom required hospitalization, with 2 developing hemolytic-uremic syndrome *(1)*. Between 1998 and 2015, Kentucky had 46 outbreaks, which resulted in 8,411 illnesses, 1,845 hospitalizations, and 31 deaths *(4)*.

The potential for contamination with pathogens on farms is highlighted by the recent finding in the southeastern United States that small-scale producers engage in a number of unsafe practices, including application of non-composted soil amendments and little or no sanitizing of food-handling surfaces *(12)*. Irrigation water safety is another area of concern, with a recent study of small-scale farmers in New York finding that the majority of growers surveyed had opted to use surface water, but less than one-fifth of them elected to test water for microbes in accordance with GAPs *(3)*. Data collected in Delaware and Maryland in 2016 found that three-quarters of small-scale farmers who participated in the study did not conduct testing for *E. coli* in their irrigation water *(18)*.

Under the provisions of the Food Safety Modernization Act of 2011, many small farms that sell fresh produce at farmers' markets are exempt from mandatory food safety certifications. Small farms that sell a yearly average of $25,000 or less of fresh produce in a three-year time frame are not required to maintain a food safety certification and may sell fresh produce directly to consumers with no food safety audit *(8)*. Because GAPs certification is voluntary, use of the audit is low among small-scale farmers, and many GAPs food safety principles have yet to gain traction *(10)*. A recent survey of fresh produce growers across the Midwestern United States found that although most participants were familiar with GAPs, they were not fully implementing them on their farms and furthermore did not believe that the majority of pathogenic contamination in fresh produce were the result of on-farm practices *(14)*. Similar surveys conducted in Vermont and Oregon found that GAPs certification had been achieved by only 22% and 25% of surveyed growers, respectively *(2, 22)*. However, a 2016 study of GAPs implementation by Mid-Atlantic fresh produce growers found that surveyed growers had begun to increase microbial water testing and harvest sanitation practices as well as to train farm workers in GAPs, indicating a possible success of educational outreach *(18)*.

The current food safety practices of fresh produce farmers, their knowledge of safety precaution awareness, and the likelihood of their implementing food safety practices such as GAPs are unknown in the Commonwealth of Kentucky. The goal of the present study was to assess current farm management practices utilized by Kentucky produce farmers, evaluate their knowledge of food safety, and investigate their attitudes toward GAPs. The study collected data on food safety practices through social surveys administered at fresh produce farms and completed by farmers' market vendors.

MATERIALS AND METHODS

Description

Surveys were administered to farmers' market vendors at farmers' markets in 21 counties across the Commonwealth of Kentucky. The survey tracked GAPs acceptance and implementation, food safety knowledge and current practices, perceived barriers to GAPs certification, and attitudes regarding food safety.

Questionnaire development

The survey consisted of 31 questions divided into four main sections: demographics, requirements and current practices, barriers and drivers for adoption, and future participation and interests in GAPs (Attachment A). The demographic portion of the survey included questions measuring the respondent's gender, highest educational degree earned, year of birth, size of their farm, their profile as a producer, and their home county. The second section of the survey included questions about the farmers' water source used for irrigation, types of products grown and method of sale, and previous or current participation in fresh produce audit requirements. The third portion allowed farmers to elaborate on their experience with GAPs or their perception of GAPs, and what perceived barriers prevented them from pursuing food safety certification. The last portion of the questionnaire investigated the future participation and interests of respondents in training and educational opportunities related to GAPs.

The questionnaire was approved by Western Kentucky University's Institutional Review Board (IRB). Before beginning formal data collection, the questionnaire was pre-tested at two farmers' markets to ascertain whether the farmers clearly understood the questions and response categories contained on the survey instrument. The questionnaire was also distributed to selected industry professionals, extension agents, and academic faculty for review and comment.

Participant recruitment

Data were collected at farmers' markets in 21 counties in the Commonwealth of Kentucky between April and August 2014. The counties were selected to represent different regions of the state that varied with regard to population size and density. Farmers' markets in Louisville and Lexington, the two largest metropolitan areas in Kentucky, were visited. Farmers' markets at the medium-sized Kentucky cities of Bowling Green, Elizabethtown, Paduacah, and Owensboro were visited as well. Finally, smaller towns in low-population counties were visited. The intent of this purposive sampling design was to ensure that data represented a broad spectrum of Kentucky farmers across the state.

Farmers who attended the farmers' markets during the data collection visits were invited to complete the anonymous questionnaire. All respondents were required to sign informed consent documents prior to completing a questionnaire. The consent document informed respondents of the voluntary and anonymous nature of the study and clearly articulated that respondents were free to withdraw from the study at any time.

Data analysis

Data collected in the study were analyzed by use of the STATA 14 software. Descriptive statistics (means and standard deviations) were calculated for each variable. Chi-Square (Chi^2) tests of independence were employed to examine bivariate relationships between categorical variables, with statistical significance set at an alpha level of 0.05 ($\alpha < 0.05$) unless otherwise noted.

Bivariate analyses were used to test the relationship between demographic factors and current farming practices. Using these analyses, significant demographic differences between farmers currently utilizing GAPs and farmers not currently utilizing GAPs were identified. Similar analyses investigated correlations between demographic factors and respondents' desires to participate in education on food safety certification. The analysis demonstrated whether farmers who utilize GAPs and farmers who do not utilize GAPs differ significantly in their desire to receive further education on good farming practices and food safety certification.

RESULTS

Demographics of farmers

The questionnaire was distributed to 600 farmers selling produce at famers' markets in 21 counties across the Commonwealth of Kentucky, and 160 (27%) survey responses were completed and returned to the research investigator. These results are presented in *Table 1*. Demographics in the study were generally diverse, as distribution rates among gender, age, education, and farm size were very good. The participants were mostly males (54.4%), possessed a college degree (43%), and were middle aged, with 28.8% being 50–59. Participating growers reported a wide variety of land sizes used on their farm, with 65.6% of respondents growing fresh produce on less than 5 acres, and the largest number had been in farmimg 6–10 years (35.7%).

Respondents represented 21 counties in Kentucky. The three largest metropolitan areas in Kentucky contributed approximately half of all respondents. Fayette County, including Lexington, contributed the largest percentage of respondents (17.5%); Warren County, including Bowling Green, provided 16.9% of respondents; and just over 16% of respondents indicated Jefferson County, which includes Louisville, Kentucky's largest metropolitan area, as home. Slightly fewer than 10% of respondents were located in Hardin County, 8.8% of respondents in McCracken County, and 6.3% of respondents in Daviess County. All of the other counties contributed under 5% of the total respondents for this study.

Relationship between awareness of GAPs, size of land used for locally grown produce, education level, and current farming practices

The vast majority (90%) of fresh produce growers surveyed indicated familiarity with GAPs. Participants' awareness of GAPs was further investigated in correlation with current farming practices used on respondents' farms *(Table 2)*. A significant relationship ($\times^2 = 7.72$, $P < .01$) was observed between awareness of GAPs and use of transportation GAPs, with 64% of participants who were aware of GAPs indicating management of transportation. Fewer than half of respondents (47%) reported managing water quality, with just under 29% of the participants using tested well water on their farms. Municipal water was the most common choice of farm use water at 70.3%, while surface water was used by 15.9% of participants and rainwater was used by 53.6% of participants. Only 55% are managing manure and municipal biosolids applied on crops, with only 54% of the growers reporting use of composted manure. Sanitary facilities and field sanitation were the most likely GAPs to be reported as being utilized by participants who were aware of GAPs, at

TABLE 1. Demographics of fresh produce famers (N = 160)

	n	%
Gender		
Male	87	54.4
Female	73	45.6
Education		
High school or less	26	16.5
Some college	64	40.5
College degree	68	43.0
Age		
18–29 years	8	5.0
30–39 years	39	24.4
40–49 years	37	23.1
50–59 years	46	28.8
60–69 years	18	11.3
70 and over	12	7.5
Amount of land used to grow crops for farmers' market		
1 acre or less	20	12.7
2 acres	34	21.7
3 acres	24	15.3
4 acres	25	15.9
5–10 acres	39	24.8
More than 10 acres	15	9.6
Years growing produce for farmers' market		
Less than 5 years	51	32.5
6–10 years	56	35.7
11–20 years	33	21.0
More than 20 years	17	10.8

73% and 71%, respectively. Sixty-one percent of participants chose to engage in worker health and hygiene GAPs, and 60% reported engaging in packing facility sanitation GAPs.

Among respondents who were aware of GAPs, a statistically significant relationship (χ^2 (1) = 19.1, $P < 0.001$) existed between the amount of land used on participants' farms for growing produce and the practice of managing worker health and hygiene *(Table 3)*. Respondents who utilized 4 acres of land for growing produce were most likely to manage worker health and hygiene (84%). There was also a significant correlation (χ^2 (1) = 15.8, $P < 0.01$) between the amount of land used for growing produce and the practice of managing facilities sanitation. Management of facilities sanitation peaked at 3 acres of land used, with 88% of respondents indicating use of this practice. When asked about management of manure and municipal biosolids, significantly more farmers utilizing 3 acres for growing produce, rather than other amounts of land, responded in the affirmative (χ^2 (1) = 12.7, $P < 0.05$).

Table 4 shows the relationship between level of education of participants and their GAPs usage. A significant relationship (χ^2 (1) =8.15, $P < 0.05$) was observed between level of education and management of packing facility sanitation. About 70% of participants who held a college degree practiced packing facility GAPs, while 54% of those who had

TABLE 2. Relationship between awareness of GAPs and current farming practices

GAP Practice[a]	Managing current practice	Not managing current practice	Chi²
	n (%)	n (%)	
Water quality	64 (47)	71 (53)	0.00
Manure & municipal biosolids	74 (55)	61 (45)	2.50
Worker health and hygiene	82 (61)	53 (39)	2.40
Sanitary facilities	98 (73)	37 (27)	2.42
Field sanitation	96 (71)	39 (29)	0.13
Packing facility sanitation	81 (60)	54 (40)	2.22
Transportation	86 (64)	49 (36)	7.72**
I choose not to implement GAPs	2 (1)	133 (99)	1.85

[a]Respondents were allowed to indicate more than one response (n = 135).
* = $P < .05$
** = $P < .01$
*** = $P < .001$

TABLE 3. Relationship between size of land used for locally grown produce and management of GAPs

GAP Practice[a]	Land used for growing produce							
	1 acre or less	2 acres	3 acres	4 acres	5–10 acres	> 10 acres	Total	Chi²
							(n = 150)	
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
Managing water quality	9 (53)	13 (41)	15 (63)	13 (52)	15 (41)	6 (40)	71 (47)	4.23
Managing manure & municipal biosolids	9 (53)	11 (34)	18 (75)	16 (64)	20 (54)	5 (33)	79 (53)	12.7*
Managing worker health & hygiene	7 (41)	13 (41)	19 (79)	21 (84)	18 (49)	10 (67)	88 (59)	19.1***
Managing facilities sanitation	8 (47)	25 (78)	21 (88)	21 (84)	20 (54)	11 (73)	106 (71)	15.8**
Managing field sanitation	12 (71)	19 (59)	20 (83)	19 (76)	25 (68)	11 (73)	106 (71)	4.4
Managing packing facility sanitation	7 (41)	15 (47)	17 (71)	20 (80)	20 (54)	8 (53)	87 (58)	10.6
Managing transportation	7 (41)	15 (47)	17 (71)	19 (76)	24 (65)	15 (100)	150 (100)	9.3
I choose not to implement GAPs	(0) 0	0 (0)	0 (0)	1 (4)	2 (5)	0 (0)	3 (2)	4.5

[a]Respondents were allowed to indicate more than one response (n = 150).
* = $P < .05$
** = $P < .01$
*** = $P < .001$

TABLE 4. Relationship between level of education and management of GAPs

GAP Practice	High school or less	Some college	College degree	Total	Chi^2
	n (%)	n (%)	n (%)	n (%)	
Managing water quality	13 (54)	28 (46)	29 (46)	70 (47)	0.54
Managing manure & municipal biosolids	11 (46)	32 (52)	36 (57)	79 (53)	0.93
Managing worker health & hygiene	12 (50)	33 (54)	41 (65)	86 (58)	2.31
Managing facilities sanitation	15 (63)	39 (64)	51 (81)	105 (71)	5.35
Managing field sanitation	19 (79)	40 (66)	45 (71)	104 (70)	1.59
Managing packing facility sanitation	9 (38)	33 (54)	44 (70)	86 (58)	8.15*
Managing transportation	13 (54)	37 (61)	39 (62)	89 (60)	0.45
I choose not to implement GAPs	0 (0)	3 (5)	0 (0)	3 (2)	4.37

* = $P < .05$
** = $P < .01$
*** = $P < .001$

TABLE 5. Sources of microbiological contamination on farm identified by fresh produce farmers

Source of contamination[a]	n	%
Soil	56	41
Irrigation water	69	51
Animal manure	87	65
Inadequately composted manure	59	44
Wild and/or domestic animals walking through your farm	100	75
Workers clothing and hands	78	58
Harvesting equipment	56	42
Transport containers	70	52
Produce wash and rinse water	48	36
Ice	35	26
Refrigeration or cooling	38	28
Transport vehicles	60	45
Cross-contamination in storage, display or preparation	69	51

[a]Respondents were allowed to indicate more than one response.

some college practiced packing facility GAPs. Those with an education level of high school or less reported the lowest usage of packing facility GAPs (38%).

Farmers' knowledge of on-farm sources of contamination

Respondents were given a list of microbiological contamination sources and asked to select all that they believed were a risk on a farm. Each contamination source on the list is a risk identified in the USDA GAPs audit checklist, and consequently, the correct answer would have been to select all of the items on the list. However, survey results indicated that many sources of contamination were not believed by respondents to be potential sources of microbiological contamination *(Table 5)*. Wild and domestic animal intrusion on farm-use land was most commonly identified as a source of microbiological contamination, with three-quarters (75%) of respondents identifying this risk. Animal manure was the second most commonly identified risk, among 65% of respondents. Only 58% of respondents identified workers' clothing and hands as possible sources of microbiological contamination. Slightly more than half (52%) of respondents identified transport containers, irrigation water (51%), and cross-contamination in storage, display, or preparation (51%) as possible vectors for microbiological contamination. Less than half of respondents believed transport vehicles (45%), inadequately composted manure (44%), harvesting equipment (42%), or soil (41%) to be possible sources of microbiological contamination. Only 36% of respondents indicated that produce wash and rinse water can be potential cause of microbiological contamination. Furthermore, a relatively small number of respondents indicated that microbiological contamination could come from refrigeration or cooling (28%) and ice (26%).

No relationship was found between the respondents' knowledge of sources of microbiological contamination and level of education *(Table 6)*. Although sources of contamination were generally identified by a larger percentage of respondents with a college degree than of those with only a high school diploma or less, no significant differences were observed, and a minority of respondents answered in the affirmative on more than half of all data categories. These findings closely support the data presented in *Table 6* and continue to suggest that Kentucky farmers are inadequately informed on the risks of pathogenic transmission present on their farm operation.

Obstacles in GAPs implementation

Growers were asked about the obstacles that prevented them from implementing GAPs *(Fig. 1)*. Lack of time (68%) to undergo auditing and the cost of certification (67%) were the two most salient perceived barriers. Forty percent of the respondents believed that investing in GAPs certification would not provide a worthwhile return, while 35% of respondents believed that a lack of access to training and educational opportunities on GAPs would be an obstacle to certification. Slightly more than a quarter of respondents (27%) believed that being unsure of how to prioritize GAPs would be a barrier to certification, while 26% of respondents identified a lack of technical solutions as a barrier to a GAPs audit. Lack of knowledge of GAPs was the least-selected perceived barrier to GAPs certification among respondents (17%).

DISCUSSION

Although 90% of fresh produce growers surveyed indicated familiarity with GAPs, current farming practices used on farms may increase the potential for on-farm pathogenic contamination and subsequent risk of foodborne illnesses. Water is necessary for the production of fresh produce; however, poor quality water can be a direct cause of contamination of agricultural crops. Water quality is vital to effective food safety practices on a farm, as irrigation and post-harvest water both provide common vectors for pathogens to contaminate fresh produce *(3)* and spread contamination from one location to another. *Salmonella* and *E. coli* O157:H7, the pathogens most often associated with fresh produce contamination, can survive at 5°C for over 9 months *(25)*. In the current study, reported adherence to water quality management was found to be low, with only 47% of respondents choosing to mitigate microbiological contamination in farm use water with GAPs. Only 29% of the participants used tested well water on their farms. These results are similar to results of previous surveys in other regions that have reported low rates of routine testing of irrigation water. Marine, Martin, Adalja, Mathew, & Everts *(18)* reported that 48.5% of growers in 2010 and 23.4% of growers in 2013 used surface water at least some of the time. The same survey also found that only 25% of all growers tested their irrigation water at least once a year for generic *E. coli* as an indicator of fecal contamination *(18)*. Bihn et al. (2013) reported that more than half (57%) of New York fruit and vegetable growers used surface water to irrigate their crops, but less than 19% of those who applied surface water overhead reported testing the water for any indicators of fecal contamination *(3)*. Additionally, a 2005 study found that only 18% of small-scale farmers tested groundwater *(6)*. Surface water is recognized to be the source most likely to be contaminated. Potential sources of surface water contamination include raw human and animal wastes, sewage water discharges, manure storage or waste disposal. Wildlife is an additional source of contamination that is very difficult to control. Surface water was found to be the main *Salmonella* reservoir in Mid-Atlantic tomato farms *(19)*. In 2005, a *Salmonella* Newport strain isolated from pond water used to irrigate tomato fields on the eastern shore of Virginia was traced back to a multistate outbreak strain *(11)*. Under the FSMA produce safety rule, the FDA set food

TABLE 6. Relationship between sources of microbiological contamination on farm identified by fresh produce farmers and education level

Source of contamination[a]	High school or less	Some college	College degree	Total	Chi^2
	n (%)	n (%)	n (%)	n (%)	
Soil	10 (50)	19 (36)	27 (44)	56 (42)	1.48
Irrigation water	9 (45)	28 (53)	32 (52)	69 (51)	0.40
Animal manure	13 (65)	36 (68)	38 (62)	87 (65)	0.39
Inadequately composted manure	7 (35)	26 (49)	26 (43)	59 (44)	1.21
Wild and/or domestic animals walking through your farm	12 (60)	37 (70)	51 (84)	100 (75)	5.51
Workers' clothing and hands	8 (40)	32 (60)	38 (62)	78 (58)	3.25
Harvesting equipment	6 (30)	24 (45)	26 (43)	56 (42)	1.43
Transport containers	6 (30)	31 (58)	33 (54)	7 (52)	4.88
Produce wash and rinse water	3 (15)	19 (36)	26 (43)	48 (36)	5.00
Ice	3 (15)	14 (26)	18 (30)	35 (36)	1.65
Refrigeration or cooling	4 (20)	15 (28)	19 (31)	38 (38)	0.92
Transport vehicles	5 (25)	27 (51)	28 (46)	60 (45)	4.01
Cross-contamination in storage, display or preparation	6 (30)	28 (53)	35 (57)	69 (51)	4.58

[a]No significant differences were found at $P < .05$

safety standards for farms in an effort to minimize the risks of microbiological contamination that may occur during the growing, harvesting, packing, and holding of fresh produce. Because water of unacceptable quality is a direct source of microbial contamination for fresh produce, the FDA produce safety final rule requires routine testing of untreated water.

Participants in the current study indicated mixed usage of composted manure and municipal biosolids applied to crops, with only 54% of the growers reporting the use of composted manure. Harrison et al. found that more than 56% of the farmers surveyed on small to medium-sized farms in Georgia, Virginia, and South Carolina used manures, and of those, 36% did not compost, or only partially composted, manure before application *(12)*. Properly treated animal manure or biosolids can be an excellent source of fertilizer for production of food crops; however, the use of raw manure on the farm can increase the risk of contamination of fresh produce with pathogens such as *E. coli* O157:H7 and *Salmonella*. Depending on the temperature, *E. coli* O157:H7 can survive up to 150 days or more in soil and up to 70 days in manure, while *Salmonella* can survive up to 300 days or more in soil and up to 159 days in manure *(25)*. The use of biosolids on farms used to produce food crops also increases the risk of contamination from toxic heavy metals. Heavy metals from biosolids can contaminate groundwater and surface water that could be used for crops irrigation or postharvest operations.

Operations with poor sanitation on the field and in the packing facility can increase the risk of contaminating

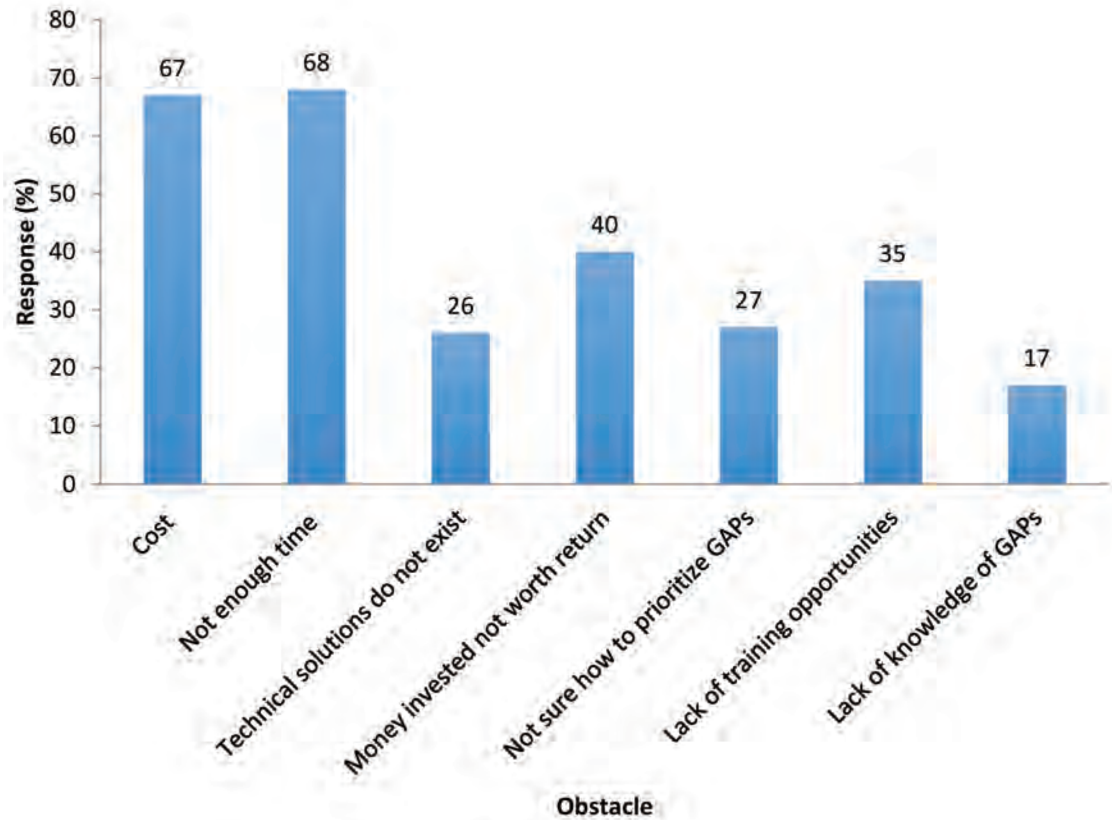

FIGURE 1. Obstacles preventing farmers from implementing GAPs on farm (n = 143). Respondents were allowed to indicate more than one response.

fresh produce and water used on produce. Microbial contamination of fresh produce during pre-harvest and harvest activities can occur from contact with soils, fertilizers, water, workers, and harvesting equipment. Pathogenic contamination can also result from contact with packing facility floors and drains and the surfaces of packing equipment. Operations with proper sanitary facilities (toilets and handwashing stations) can contribute to the reduction of pathogen contamination, because poor management of human and other wastes in the field or packing facility increases the risk of contaminating produce *(9)*. In this study, only 60% of farmers managed packing facility sanitation and 71% managed field sanitation. Seventy-three percent of respondents reported managing sanitary faciltities (e.g., toilets and handwashing facilities). This is consistent with results of a study conducted in Georgia, South Carolina, and Virginia, which found that only 66.8% of surveyed growers provided portable handwashing stations to harvest workers and 66.4% provided portable toilets *(12)*. However, an earlier multi-state survey found that farmers who are aware of GAPs were more likely to provide portable toilet and handwashing facilities to workers in the field, compared with farmers who are unaware of GAPs *(15)*. Lack of appropriate handwashing and toilet facilities may increase the risk of foodborne illnesses caused by pathogens such as norovirus, which are easily spread by unclean hands *(12)*. Without good sanitary practices, operations in the field and packing facilities are a potential source of microbial contamination for fresh produce. Therefore, produce packers should use good sanitation practices as a standard operating procedure to maintain control throughout the field and packing operations.

A complex reality for awareness of microbiological contamination sources among farmers in Kentucky was found. Of 13 categories of potential sources of microbiological contamination, only 6 categories were identified by a majority of respondents. Although soil has been identified as one of the top vehicles for transmission of microbiological contamination in fresh produce *(13)*, the results indicate that most Kentucky farmers are unaware of contamination risks associated with soil. Fruits and vegetables are usually grown in an open environment, where there are many opportunities for exposure to chemical and microbiological hazards due to the application of compost, raw manure or biosolids on the land, as well as use of pesticides, soil amendments or other chemicals. Ice was the lowest-reported source of microbiological contamination in the current study. Wild animal intrusion was identified as a source of contamination by a majority of participants, similar to the results of a 2013 survey of growers in Maryland and Delaware, in which 76% of participants reported awareness of the implications of wild animal intrusion and exclusion on their farms *(18)*. Previous research has indicated that growers may possess a fatalistic attitude about wild animal intrusion on farm land, with surveyed growers in a 2012 study reporting that they believed they could not control the presence of wild animals on their farm *(21)*. A second 2012 survey of growers in the Midwest United States found that growers often believed that wild animal exclusion required too great an economic investment for them to implement it on their farm *(14)*.

Respondents perceived cost and lack of time to be considerable obstacles to GAPs certification on their farm. This finding is in agreement with findings of a 2007 multistate survey of growers that also found cost and lack of time to be the two most commonly perceived barriers to audit completion *(15)*. Surprisingly, surveys conducted in Delaware and Maryland in 2013 reported that cost of auditing was believed to be a barrier by less than 10% of participants, with the majority of participants believing that their farm was too small to qualify for a GAPs audit or that they did not possess enough knowledge to satisfy the GAPs criteria *(18)*. Additionally, a 2012 study conducted across the Midwestern United States found that the majority of participants did not perceive costs to be a barrier *(14)*. Previous case studies of the cost of GAPs certification in the Northeastern United States found that the mean cost of certification was $3,268 for each crop certified, with a mean of 322 hours of labor per year needed for GAPs-related labor *(2)*. The third most highly reported perceived barrier to GAPs certification was the belief that money invested in GAPs would not provide a useful return on investment to the farmer. However, previous case studies have indicated that in the event of a foodborne illness traced to a GAPs-certified farm, the farm suffers significantly less economic impact than a non-GAPs certified farm, raising the possibility that further education on the benefits of GAPs certification may encourage auditing *(23)*. However, market volatility in the aftermath of a foodborne illness outbreak linked to produce sold at a farmers' market may nullify the positive effects of GAPs certification *(24)*.

More than 85% of participants indicated interest in training opportunities to enhance their knowledge of GAPs. When asked what types of training they preferred, more than 90% indicated that they would like online training on a website or videos, and about 65% indicated that they were interested in workshops. Results support the need for development of educational materials and practical training for producers. Similar findings indicated that 40% of surveyed farmers wanted food safety education materials that they could give to their workers *(12)*. Increasing training programs for farmers who are not GAPs certified but are selling their produce directly to consumers could enhance the safety of locally grown produce.

This study has some strengths and limitations. One limitation is that these results cannot be generalized to a larger population because of the relatively low overall response rate and non-probability sampling technique employed to gather data from participants. However, our use of purposive sampling design provided information-rich cases, which allowed for the examination of patterns among farmers included in our analysis. The farmers' markets were selected from different regions in Kentucky with varying degrees of population size and density. For example, farmers' markets in Louisville and Lexington were included in our sample as these two cities represent the largest metropolitan areas in Kentucky; farmers' markets in Bowling Green, Elizabethtown, Owensboro, and Paducah were included because they represent medium-sized metropolitan areas surrounded by rural counties; and farmers' markets located in rural counties in different regions of the state were included. The intent of this purposive sampling strategy was to ensure that we obtained data from a sample of farmers who work and grow their produce in different regions in Kentucky and sell their produce in markets of different sizes.

CONCLUSION

This survey research returned mixed results, indicating a wide range of food safety practices and attitudes present on Kentucky farms. In general, respondents appeared to have a relatively little understanding of food safety practices. Results indicated that respondents possessed relatively little understanding of behavior of pathogens in environments found on farm operations, including sources of contamination in water, soil, and manure; during transportation, and by other means. The utilization of GAPs reported by respondents in the survey indicated relatively little general usage of GAPs, with some severe deficiencies, particularly in water usage and soil safety practices. The study also found that the obstacles perceived by farmers to GAPs certification are cost and lack of time, suggesting that food safety educators in Kentucky must overcome these perceptions to increase acceptance of GAPs among Kentucky farmers. The findings support the conclusion that further educational outreach to Kentucky farmers is needed to ensure safer fresh produce in the farmers' market farm-to-fork supply chain in Kentucky.

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