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Farm-To-Fork Fresh Produce Food Safety: An Evaluation of Perceptions, Knowledge, and Implementation of Good Agriculture Practices in Kentucky

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FARM-TO-FORK FRESH PRODUCE FOOD SAFETY: AN EVALUATION OF PERCEPTIONS, KNOWLEDGE, AND IMPLEMENTATION OF GOOD AGRICULTURE PRACTICES IN KENTUCKY

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Farmers' markets have increasingly become a popular venue for purchase of fresh, locally-grown produce, with the number of farmers' markets in Kentucky reaching an all-time high of 159 in 2016. Good Agriculture Practices (GAPs) is a program created by the USDA's Agriculture Marketing Service to function as a food safety audit for small-scale fresh produce growers, such as those who sell fresh produce at local farmers' markets. However, under the provisions of the Food Safety Modernization Act of 2011, small-scale farmers who sell an average of $25,000 in annual fresh produce sales across the span of three years are exempt from mandatory food safety certification. Many small-scale farmers in Kentucky fall below this threshold, and do not hold food safety certification.

This study had two objectives: to investigate the practices, perceptions, and implementation of GAPs among small-scale Kentucky farmers who sell at farmers' markets; and to create and evaluate the effectiveness of commodity-specific informational factsheets to disseminate food safety knowledge among small-scale Kentucky farmers. Data from the perceptions, practices, and implementation survey were analyzed from 160 completed surveys of small-scale fresh produce growers on-site at farmers' markets in 21 counties across the state of Kentucky (see Appendix A). The

results were mixed, with 90% of participants indicated familiarity with GAPs, but only 47% opting to practice water quality GAPs and 55% choosing to observe soil amendment GAPs. Participants did report slightly 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 a GAPs audit on their farm. Participants also failed to identify many sources of potential microbiological contamination, with soil only being identified as a source of pathogenic contamination by 41% of participants and irrigation water identified by 51% of participants. Even fewer participants believed that contamination could result from ice (26%) or refrigeration and cooling (28%). However, most respondents indicated a desire to undergo further GAPs education, and the factsheet evaluation data indicated that the factsheets were highly effective and had resulted in significant GAPs knowledge increases for participants.

Chapter I: Introduction

Background

The United States Food and Drug Administration (FDA) published the *Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables* in 1998 (U.S. FDA, 1998). 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 (USDA/AMS, 2016). GAPs help to address a major public health concern in the United States, as locally-sourced fresh produce has the potential to act as a vehicle for transmission of harmful pathogens in the food-to-fork process (Quinlisk, 2010). Foodborne pathogenic contamination is estimated to cause approximately 48 million illnesses and 3,000 deaths per year in the United States (CDC, 2011).

Consumption of fresh produce in the United States has increased dramatically in recent years, reflecting an upwards trend of direct consumer purchase from small-scale farmers. According to the United States Department of Agriculture (USDA) Office of Communications, revenues from local food sales exceeded than $7 billion in 2012, a marked increase from the $1 billion value of local food sale revenues in 2005 (USDA/AMS, 2013). Fresh produce sales directly from producers to consumers have increased dramatically, and account for the majority of local food sales (Low & Vogel, 2015). Recent data suggest that fresh produce growers prefer to establish customer bases in the local community by selling face-to-face (Low and Vogel, 2011). Farmers' markets provide an increasingly popular vector for direct sale of fresh produce from growers to consumers. According to the Agricultural Marketing Service (AMS) Division of the United States Department of Agriculture (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 markets in 1994 (USDA/AMS, 2016). In Kentucky, more than 159 farmers' markets now deliver fresh local produce to consumers (Kentucky Department of Agriculture, 2016).

Increased access to local fresh produce has occurred concurrently with an increase in on-farm pathogenic contamination and subsequent foodborne illness outbreaks (DeWaal, Tian, & Bhuiya, 2008). Produce, including fresh produce sold at farmers' markets, causes pathogenic transmission in approximately 46% of yearly foodborne illnesses, and leafy greens are the most common fresh produce type to be linked to produce-related foodborne illnesses (Painter, Hoekstra, Ayers, Tauxe, Braden, Angula, & Griffin, 2013). The potential for pathogenic contamination on farms is highlighted by recent findings in the southeastern United States that small-scale producers engage in a number of practices that are unsafe, including application of non-composted soil amendments and little or no sanitizing of food handling surfaces (Harrison, Gaskin, Harrison, Cannon, Boyer, & Zehnder, 2013). 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 those who did elected to utilize microbial water testing in accordance with GAPs (Bihn, Smart, Hoepting, & Worobo, 2013). Data collected in Delaware and Maryland in 2016 found that three-quarters of small-scale farmers who participated in the study did not conduct microbial testing for *E.coli* in their irrigation water (Marine, Martin, Adalja, Mathew, & Everts, 2016).

Under the provisions of the Food Safety Modernization Act of 2011, many small farms which sell fresh produce at farmers' markets are exempt from mandatory food safety certifications. Small farms which sell a yearly average of $25,000 or less in fresh produce sales across a three-year time frame are not required to maintain a food safety certification, and these farms may sell fresh produce directly to consumers with no food safety audit (21 C.F.R. § 1,227). Because GAPs certification is voluntary, usage of the audit is low among small-scale farmers and many GAPs food safety principles have yet to gain traction (Gravani, 2009). A recent survey of fresh produce growers in Ohio, Michigan, Indiana, and Kentucky found that most participants were familiar with GAPS, but yet were not fully implementing GAPs on their farm, and furthermore did not believe that the majority of pathogenic contamination in fresh produce originated in on-farm practices (Ivey, LeJeune, & Miller, 2012). Similar surveys conducted in Vermont and Oregon found that GAPs certification had only been achieved 22% and 25% of surveyed growers, respectively (Becot, Nickerson, Conner, & Kolodinsky, 2012; Prenguber & Gilroy, 2013). 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 train farm workers in GAPs, indicating a possible success of educational outreach (Marine et al., 2016).

Problem Statement

The Centers for Disease Control and Prevention estimate that harmful pathogens in food cause an estimated 48 million illnesses and 3,000 deaths every year in the United States, and of total reported illnesses, almost half (46%) of yearly incidents are attributed to contamination from produce (Painter et al., 2013). Many of these illnesses are multi-state outbreaks with many victims becoming ill from a single source of contamination. In many cases, outbreaks are traced to farms which had not been GAPs certified, and contamination was potentially preventable if farm managers been trained on risk factors for microbial contamination (Rejesus, 2008). The current food safety practices of fresh produce farmers, their knowledge of safety precaution awareness, and their likelihood of implementing food safety practices such as GAPs are unknown in the state of Kentucky. With many farmers who fail to meet the FDA's $25,000 annual produce sales threshold, many local venders and growers who sell fresh produce at farmers' markets are not required to undergo food safety certification. As a result, these farmers may be unaware of potential risks of microbial contamination in the farm-to-fork process. Thus, the problem concerned in this research is food safety in the local fresh produce supply chain in Kentucky.

Purpose of Research Study

The purpose of this research was to contribute to the body of knowledge regarding fresh produce food safety among small-scale farmers in Kentucky. To accomplish this purpose, the present study had two objectives: 1) to assess current farm management practices utilized by small-scale Kentucky produce farmers, evaluate their knowledge of food safety, and investigate their attitudes towards GAPs. The study collected data on food safety practices through the use of social surveys administered at fresh produce farms and to farmers' market vendors. The survey measured current practices, safety awareness, and the likelihood of implementing GAPs within the state of Kentucky and assessed the desire of small-scale Kentucky farmers to seek GAPs certification, and 2) to create commodity-specific fresh produce safety factsheets on the commodities most likely to cause foodborne illness, and evaluate the effectiveness of the factsheets in conveying food safety knowledge among small-scale farmers in Kentucky. The factsheets contained detailed information on each commodity's growing, harvest, cooling, and storage conditions, as well as information on unique pathogenic behavior on the commodity and a brief history of foodborne illness outbreaks attributed to the commodity.

Significance for the Research Study

The significance of this study was its contribution to the lack of scholarly research regarding fresh produce food safety practices by small-scale farmers in Kentucky. The present project carries implications for food safety in the state of Kentucky and in the local region where Kentucky-grown fresh fruits and vegetables are consumed. The present project can positively impact the implementation of food safety procedures in small-scale farms, leading to mitigation of risk for foodborne illness outbreaks from contaminated produce. This, in turn, can lead to an increased consumer confidence in local farmers' markets, increased economic activity within the state, and increased revenues for Kentucky farmers. Creating educational materials to farmers are vitally important in order to increase knowledge regarding food safety for fruits and vegetables. Furthermore, the present project will serve as an indicator of the future need for further food safety training and research within Kentucky. The data of the present project may be used to influence further educational efforts designed to provide risk mitigation for Kentucky-grown fresh produce.

Hypotheses

In investigating the knowledge, perceptions, and practices of small-scale Kentucky farmers on food safety practices pertaining to fresh produce, three hypotheses were developed for the present study. These hypotheses are detailed below.

1. General awareness of GAPS among small-scale Kentucky farmers is not sufficient to increase locally-grown fresh produce safety, as farmers are unaware of the specific requirements for GAPs audits and the potential sources of microbiological contamination that GAPs are designed to mitigate. Small-scale Kentucky farmers are unaware of all possible routes through which pathogens and other microbiological contamination can infect fresh produce.
2. As a result of their fresh produce safety knowledge deficit, small-scale Kentucky farmers who grow and sell fresh produce at farmers' markets, and are aware of GAPs, engage in a variety of on-farm and at-market food safety practices which are in violation of GAPs requirements.
3. Small-scale Kentucky farmers' knowledge of fresh produce safety can be improved by disseminating food safety knowledge via easily-distributed commodity-specific food safety factsheets.

Assumptions

The present project operates on several assumptions. The present study assumes that participants' responses are honest and truthful. It is also assumed that without GAP audits, farms who sell fresh produce at farmers' markets pose a larger risk for causing foodborne illness outbreaks. Farmers who have not been made aware of the requirements of GAPs compliance are assumed to likely be in violence of one or more GAPs requirements as outlined by the USDA and FDA, and thus more likely to sell pathogenically-contaminated fresh produce to consumers than a farm of comparable size and scope which has been verified for GAPs compliance.

Limitations

One of the limitations with the knowledge and practice survey is that the results cannot be generalized to a larger population because of the non-probabilistic and small sample of participants. However, the purposive sample provided information-rich cases, which allowed a more in-depth analysis of farmers with defined characteristics. 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 the 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 finally, farmers' markets located in rural counties in different regions of the state were included in the sample. The intent of this purposive sampling strategy was to ensure that data was obtained from a sample of farmers who work and grow their produce in different regions in Kentucky and sell their produce in different sized markets.

The factsheet evaluation survey is primarily limited by the limited sample size of the survey. The data from the factsheet survey cannot be generalized to the larger audience of small-scale farmers in Kentucky, because the participants sample was limited to a very small number of fresh-produce growers. However, the data obtained from evaluating the factsheets provides guidance and insight on the effectiveness of the factsheets as educational tools. The evaluation served to both gauge the participants' knowledge on commodity-specific food safety topics and the design and information of the factsheets, and the results serve to guide the design of educational materials in the future as well as identify the greatest needs for information presented in the materials.

Definition of Terms

The following terms will be used in the present study:

Animal husbandry: the keeping and care of farm animals such as cows, pigs, goats, horses, and sheep.

Biosolids: sewage used in compost to produce fertilizer.

CFU: Colony-forming unit, a unit of measurement for quantity of viable bacteria found in a substance. Viable units, if introduced to fruits and vegetables, will reproduce and contaminate the produce.

Factsheet: informational handout with safety information on handling and storage of a type of vegetable or fruit.

Farmers: local producers and sellers of fresh produce who are the subjects of the present study; these individuals often do not sell enough produce in a year to fall under the federally-mandated third-party food safety audit requirement.

Foodborne illness outbreaks: foodborne illness of two or more individuals which can be traced to a common source of contamination.

Foodborne illness: Illnesses caused by pathogens commonly found in fresh produce. These include *Salmonella, E.coli* O157:H7, *Listeria, Shigella, Campylobacter, Toxoplasma gondii,* and Norovirus.

Fresh produce: fresh fruits and vegetables, produced locally (within a 250-mile radius of the consumer) by small-scale farmers who sell produce directly to consumers at farmers markets, roadside stands, and farms.

Good Agriculture Practices (GAPs): audits developed by the Agricultural Marketing Service of the U.S. Department of Agriculture, which detail food safety procedures for farmers on a variety of topics in the entire farm-to-fork process.

Microbial contamination: contamination of produce by pathogens.

Module: training material in the form of a PowerPoint presentation, used to educate participants at a workshop on GAPs.

Pathogens: harmful bacteria such as *Salmonella*, *E.coli* 0157, *Listeria monocytogenes*, and others which can cause illness in humans and commonly contaminate produce.

Third-party audits: GAP audits, conducted by the USDA or another third-party organization.

Chapter II: Literature Review

Despite modern increases in scientific understanding of microbial infection, development of procedures for effective sanitation, and increased ability to trace sources of contamination, foodborne disease continues to be a significant public health concern in the United States. Foodborne disease has the potential to cause considerable illness and even loss of life in some cases. Continuing mitigation training is necessary to minimize risk to consumers. In addition to the large impact on public health and the potential loss of life that may occur from foodborne illness, outbreaks also have a large negative economic impact in terms of medical costs, loss of income, decreased consumer confidence, recall expenses, potential legal costs, and costs of state and federal agency response to outbreaks (CDC, 2013).

2.1 Economic Value of Farmers Markets

Food safety education delivered to local farmers has become more vital than ever, as consumers are increasingly turning to locally-produced fresh fruits and vegetables and an increasingly larger portion of foods consumed in the United States are locally sourced at farmers' markets, roadsides stands, and farms. The market share of locally-sourced foods has soared in recent years; in 2012 the value of local food sales stood at approximately $7 billion, up from $1 billion in 2005 (Agrinews, 2013). Access to locally produced foods has benefited from an increase in venues across the United States: In recent years the number of farmers markets registered in the USDA Farmers Market Directory has increased from 5,274 in 2009 to 8,268 in 2014 (USDA/AMS, 2015). Federal support for nutrition assistance benefits on local produce has contributed to the growing popularity of locally-produced food as well. An increasing acceptance of

Supplemental Nutrition Assistant Program (SNAP) benefits at farmers' markets has caused a dramatic increase in SNAP funds being spent on local foods in recent years, from $4.2 million in benefits spent at farmers' markets in 2009 to $18.8 million in 2014 (Rejto, 2015). Additionally, maturation and development of the local food economy in the United States has grown the scope of the industry beyond simply direct farm-to-consumer sales. Local farmers are now connecting with businesses through food hubs and selling to restaurants and grocery stores directly, as well as providing fresh foods to schools. Growth of food hubs and farm-to-school programs increased by 288% between 2007 and 2012 (Runyon, 2015). Demand for fresh produce has driven market growth. USDA data on food sales from 1982 to 1997 show that in that period of time, consumption of fresh produce per capita rose from 91.6kg to 121.1kg (Harris et al., 2003). Consumption has slightly lessened in recent years, with more recent studies indicating that growth of per capita consumption of fruits and vegetables has slowed; however, fruit and vegetables continue to be a staple of American diets, with fruit consumption projected to grow by 9% from 2015 to 2020, while consumption of fresh vegetables is projected to increase by 8% (Produce for Better Health Foundation, 2015).

Within Kentucky, direct sales from farmers to consumers has increased concurrently with national trends. In 1992, direct sales from producers to consumers in the state were worth $4 million, and by 2007, this number had increased to $15 million. Between 2004 and 2009, the number of farmers markets within Kentucky increased from 96 to 137, and the number of vendors grew from 1,548 to 2,247. There are currently 159 farmers' markets in Kentucky, providing direct sales of fresh produce from farmers to consumers (Kentucky Department of Agriculture, 2016).

2.2 Public Impact and Cost of Foodborne Illness Outbreaks

Localized agriculture has established a strong foothold in the United States, but the continued occurrence of foodborne illness outbreaks highlights the need for education on safe food handling practices in the growing industry. The CDC categorizes an outbreak as an incident where two or more individuals contract the same illness from consumption of a similar food (CDC, 2013). In 2013, the most recent year for which data is available, the Centers for Disease Control and Prevention (CDC) documented 818 reported foodborne illness outbreaks which resulted in 13,360 illnesses and 16 deaths (CDC, 2013). In the previous year, 2012, the CDC documented 831 reported outbreaks with 14,972 illnesses and 23 deaths (Bennett, Manikonda, Mungai Dewey-Mattia, & Gould, 2012). The CDC currently estimates that 1 in 6 Americans will contract a foodborne disease from contaminated food annually, totaling approximately 48 million people per year (CDC, 2015b). Foodborne disease can have especially devastating effects on individuals who fall into high-risk groups. The Food and Drug Administration (FDA) classifies four high-risk group categories: pregnant women, young children, older adults, and those whose immune systems are compromised by disease, or medical treatments (FDA, 2016a). For individuals in these groups, foodborne disease can have even more deadly consequences than the general population, as their immune response may be severely limited.

The costs of foodborne illness have a large impact on the US economy, measured by medical costs and also lost income during medical treatment for illness; in 2014, this number was estimated to stand at $15.6 billion (Flynn, 2014). This estimate acknowledges gaps in data, as the estimates “do not include food industry costs, including any loss of consumer confidence in a brand or a business, associated recall expenses, or charges stemming from litigation, nor do they include the cost to taxpayers for local, state, and federal health agencies that respond to outbreaks" (Flynn, 2014, p. 1). Accordingly, the actual cost to the economy is almost certainly significantly larger than the report's estimate. Several diseases stand out for the particularly large costs associated with medical treatment for them. The five top diseases, for negative economic impact by yearly cost, are listed in Table 1:

Table 1

Annual Cost of Foodborne Illness Outbreaks by Pathogen (CDC, 2015b)

Pathogen	Annual cost of outbreaks
Salmonella (nontyphoidal)	$3,666,600,031
Toxoplasma gondii	$3,303,984,478
Listeria monocytogenes	$2,834,444,202
Norovirus	$2,255,827,318
Campylobacter (all species)	$1,928,787,166

In addition to costs of immediate treatment, the costs of diseases can continue long after the initial illness, as chronic conditions may arise which persist for months or even years. The CDC acknowledges that other conditions may arise which are not included in their estimates, but which cause further cost to patients. Examples include consequences of congenital toxoplasmosis and listeriosis which may cause complications for pregnancies as well as permanent mental and physical disabilities; Guillain-Barré syndrome as a result of *Campylobacter*, and possible loss of vision due to *Toxoplasma gondii*, among others (CDC, 2015b). In one notable outbreak of *Listeria* in 1985 detailed by Penner, Aramouni, Blakeless (2006), 140 patients were treated, the majority being pregnant women. 20 miscarriages occurred as a result of the outbreak, with 48 deaths overall. In another outbreak also in 1985, *Salmonella* was confirmed in 16,000 patients in the Chicago region, and many patients later developed reactive arthritis as a result of the microbial infection (Penner, Aramouni, & Blakeless, 2006).

2.3 Trends in Foodborne Illness Outbreaks – 1998-Present

Despite the increased role of local food sales in the US economy and development of food safety guidelines and education, data on outbreak trends indicate that in general, outbreaks have not decreased in the previous decade, but instead has largely increased. Data from a CDC study of common foodborne microbial infections in the period 1996-2014, per 100,000 population found that occurrence of foodborne illness outbreaks from many pathogens was had increased (CDC, 2015) While occurrence of some pathogens such as Yersinia decreased in the eighteen-year span of the data, other pathogens, such as Vibrio, occurred at a much higher rate in 2014 than in 1996. The most impactful diseases largely increased in occurrence. *Salmonella,* the disease with the greatest annual cost to the US economy, increased from 2,064 per 100,000 population in 1996 to 7,452 per 100,000 population in 2014. Infections of *E. coli 0157,* a common pathogen naturally found in the flora of human and animal intestines and commonly spread through feces, increased as well from 374 to 445 per 100,000 population (CDC, 2015).

2.4 Foodborne Pathogens Associated with Fresh Produce

Produce is highly susceptible to microbial contamination. Fresh produce may often be consumed uncooked after purchase from a farmers' market; by skipping the vital step of cooking, consumers allow potential harmful levels of pathogenic contamination to persist in fruits and vegetables (Fischer, Bourne, & Plunkett, 2015). Furthermore, farmers who sell produce to local consumers, stores, and restaurants within a 275-mile radius (or within their home state) and record annual average total produce sales of less than $25,000 during a three-year span are not subject to the same strict control laws that larger producers must abide by (Food Safety Modernization Act of 2011). As a result of the lack of government regulation, small producers often have little training on food safety procedures, and no oversight of their food safety methods (Beecher, 2013). Because many small producers may grow food on farmland that shares usage with animals, composting facilities, ponds, and other sources of pathogens, other concerns arise in fresh produce – for example, manure taken from farm animals and put directly on plants with insufficient composting time, or contaminated water spread by wild animals (Marine et al., 2016). Small scale producers, particularly those with livestock, dairy, poultry, other domestic animals, and wild animals present in the same vicinity as plants, must be cognizant of complex and varied routes of microbial contamination that can occur unless safety awareness is heightened. Of produce-related outbreaks, Norovirus and *Salmonella* account for the majority of annual illnesses, with Norovirus causing 40% of illnesses and *Salmonella* causing 18% (DeWaal, Tian, & Bhuiya, 2006). Recent CDC data corroborates this earlier data, showing that Norovirus and *Salmonella* remain the top two causes of foodborne illness (CDC, 2015b). Outbreaks of both Norovirus and Salmonella are strongly associated with complex foods like salads (Batz, et al, 2011). Some of the most common produce types found at farmers markets are the most likely to be linked to foodborne illness outbreaks. Of all foodborne illness outbreaks that occurred between 1998 and 2008, over half of the outbreaks were incidents of *Salmonella* in tomatoes, sprouts, and cantaloupes (Batz, Hoffman, & Morris, 2011).

2.5 The Growing Burden of Foodborne Illness Outbreaks Due to Contaminated Fresh Produce

Worldwide, foodborne illness causes approximately 2 million deaths every year (WHO, 2014). While many steps have been taken to prevent foodborne illness outbreaks in the United States in recent decades, foodborne illness outbreaks due to fresh produce are on the rise, with leafy green vegetables being the most common source of contamination. Recent major outbreaks demonstrate the burden of foodborne illness from produce. In 2008, 1,442 outbreaks of *Salmonella* linked to fresh peppers and tomatoes occurred in North America (Lynch, Tauxe, & Hedberg, 2009). Fresh leafy green vegetables from Mexico caused an outbreak of *Cyclospora cayetanensis* in 25 states, sickening 631 people (Painter, et al, 2013). In 2014, raw clover sprouts originating from a fresh produce grower in Idaho contaminated with *E. coli* O121 caused 19 illnesses in 6 states (CDC, 2014). Produce accounts for a small but growing portion of overall foodborne illness outbreaks in the United States; from 1990 to 2001, 12% of outbreaks were linked directly to fresh fruits and vegetables, and the amount of outbreaks attributed to small scale growers was 2% (Pennock & Flores, 2006).

2.6 Regulations for Produce Safety

The Food Modernization Safety Act (FSMA) of 2011 drastically changed regulation for farmers in the United States, and key provisions of the law will affect produce. After the legislation was finalized in 2014, all fresh produce growers with an average of more than $25,000 to $250,000 in in annual produce sales were given four years to bring their businesses into compliance with most of the provisions and farmers were granted an additional two years to become compliant with water quality requirements, while businesses with annual produce sales from $250,000 to $500,000 will have three years to become compliant (FDA, 2016b).

The FSMA rule for produce carried a number of changes to food safety practices in the Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption (FDA, 2016b). Among these, audit requirements for USDA GAP specified that water applied to crops was required to meet the standards of the 2012 Environmental Protection Agency's Recreational Water Quality criteria for all produce except sprouts. For water unable to meet the EPA microbial level standards, the allows provisions for irrigation water to be sanitized through a timed process of natural microbial die-off. This option was widely suggested in the comment periods for the rule, and required specific time intervals between irrigation and harvest, and harvest and end of storage (FDA, 2016b).

The FSMA does not require farmers to comply with the 120-day soil amendment application interval before harvest specified by the USDA's National Organic Program, although as of October 2016 further research is being conducted to identify best practices.

The FSMA does require that soil amendments not be allowed to contact covered produce during application, and any potential for subsequent contact is minimized (FDA, 2016b).

The final FSMA rule requires that fresh produce identified as likely having been disturbed by animals must be excluded from harvest. However, the rule allows for animals for intrude into outdoor growing areas, and also does not stipulate a mandatory length of time between animal grazing in fields and harvest of fresh produce (FDA, 2016b). The FSMA rule also established standards for worker health and hygiene management practices, with requirements for proper usage of handwashing and toilet facilities and prevention of contact by sick workers. Workers who handle fresh produce are required to have food safety education, including on-the-job training combined with experience (FDA, 2016b).

Good Agriculture Practices (GAPS)

Good Agriculture Practices (GAPs) are guidelines on agricultural topics which detail how to reduce risk of microbial contamination in produce from small-scale farms. GAPs originated in the late 1990s when President Bill Clinton announced the Produce Safety Initiative, a plan to set safety standards for domestic and imported fruits and vegetables. President Clinton’s initiative was prompted by a report submitted by the EPA, USDA, and Department of Health and Human Services that pinpointed fresh produce as a public health concern (Rogers & Ducharme, 2015). GAPs were first developed by the USDA’s Agricultural Marketing Service as an auditing program for the FDA’s 1998 publication, *Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables* (USDA/AMS, 2016). GAPs certification indicates that a grower is compliant with the recommendations of the FDA to reduce risk of pathogenic contamination in fresh fruits and vegetables, and once certified, fresh produce growers are granted access to sell their produce to wholesalers, schools, and grocery stores (National Sustainable Agriculture Coalition, 2014). The FDA's 1998 guide outlines the criteria for GAPs compliance, covering many topics including safe produce handling, storage, and general safety. In the guide, the FDA defines seven major GAPs topics: water, manure and municipal biosolids, worker health and hygiene, sanitary facilities, field sanitation, packing facility sanitation, and transportation (FDA, 1998).

Several universities have contributed to research into GAPs since the creation of the program, offering other topics that fall outside the scope of the FDA's recommendations. The Joint Institute for Food Safety and Applied Nutrition is one such organization, a joint effort between the University of Maryland and the FDA, which identifies its GAPS training topics as site selection and soil, agricultural water, fertilizers (inorganic and organic) animal exclusion and pest control, and worker health and hygiene (JIFSAN, 2010). For the present study, the topics developed into modules will be the FDA guidance topics, as well as two additional topics: site selection and soil, and animal exclusion and pest control.

Good Agriculture Practice Principles

2.7 Irrigation and Post-Harvest Water

Water plays a constant role in the supply chain of fresh produce. It provides irrigation, cooling, and frost control during the growth period of fresh produce, and after harvest, it is used for cleaning produce. Because of its critical role in agricultural processes, water quality control is a vital component of effective food safety considerations. Risk assessment should be undertaken by local farmers to determine water quality, usage, nd potential sources of contamination, as well as risks in re-use of water and storage. The implications of microbial contamination can be particularly severe for fresh produce. The FDA notes that leafy green vegetables can have an especially high risk for microbial contamination:

> Produce that has a large surface area (such as leafy vegetables) and that with topographical features (such as rough surfaces) that foster attachment or entrapment may be at greater risk from pathogens, if they are present, especially if contact occurs close to harvest or during post-harvest handling (FDA, 1998, p. 10).

At present, there are no national standards for the quantity of microbial contamination in irrigation water. Consequently, farmers must undertake their own risk assessment procedures, and GAPs certification programs have specific guidelines for testing. The USDA GAPs certification requires that irrigation water meet the US Environmental Protection Agency (EPA) Recreational Water Standard for microbial levels, and the EPA Drinking Water Standard must be met for post-harvest water (USDA, 2011).

Depending on the farmers' source of water, testing methods vary. Producers may use municipal water sources, draw water from wells on their farm, or utilize surface water. Each source carries its own risks, and the USDA GAPS program has differing guidelines for effective testing of each type. The USDA (2011) requires that municipal water used for irrigation or cooling be tested annually, with tests results available from the municipal water authority. Well water is required to be tested once during a growing season, although it must be treated and retested if fecal coliforms are detected by the test. Surface water must be tested three times throughout the growing season to ensure that contamination has not infected the surface water source (USDA, 2011).

Water drawn from wells, although drawn from deeper underground than surface water, can still suffer contamination from surface and pathogens in the soil. The USDA (2011) recommends that livestock not be allowed in the vicinity of the well recharge and pump, as surface runoff can carry harmful pathogens from manure. Well casings, particularly in older wells, should be inspected to ensure that cracks or leaks have not allowed surface runoff into the well, and wells should draw water from a sufficient depth to avoid surface contamination (USDA, 2011). Surface water, such as that from rivers, streams, and lakes, is regarded as being more susceptible to contamination than groundwater, as microbial levels can be influences by sources adjacent or upstream that farmers may be unaware of. Rivers can receive runoff from farms, industrial sites, and sewer and storm overflow upstream that introduce pathogens into the water (FDA, 1998).

Post-harvest water usage presents a myriad of risks that can cause contamination, as water is frequently in contact with produce during cleaning. Water is commonly reused during cleaning and packing of fresh produce, thus increasing the risk of spreading contamination if proper safety procedures are not followed. The FDA outlines several methods for preventing microbial contamination during post-harvest procedures (FDA, 1998):

1. Perform periodic water sampling and microbial testing;
2. Change water as necessary to maintain sanitary conditions. Consider developing SOPs (standard operating procedures or sanitary operating plans), including water change schedules, for all processes that use water;
3. Clean and sanitize water contact surfaces, such as dump tanks, flumes, wash tanks, and hydrocoolers, as often as necessary to ensure the safety of produce;
4. Install backflow devices and legal air gaps, as needed, to prevent contamination of clean water with potentially contaminated water (such as between potable water fill lines and dump tank drain lines; and

5. Routinely inspect and maintain equipment designed to assist in maintaining water quality, such as chlorine injectors, filtration systems, and backflow devices, to ensure efficient operation (p. 14).

2.9 Soil Amendments: Manure and Municipal Biosolids

Solomon, Yaron, and Matthews (2002) note that manure and other biosolids are commonly used by farmers to fertilize plants and enrich growing soil, and many small-scale farms, in addition to production of fresh produce, may engage in animal husbandry and use manure to fertilize as part of the farm's agricultural cycle. Such usage is an effective way to maximize production and manage animal waste, but if safety precautions are not observed, dangerous pathogens can easily spread from manure to produce. Runoff from livestock enclosures may spread pathogens into surface water sources or wells; improperly composted manure, or manure composted for an insufficient period of time, may continue to harbor harmful microbial contaminants; and manure placed around plants may be splashed onto low growing crops. Manure and biosolids must undergo controlled composting procedures before they can be applied to soil. Risk of contamination cannot be eliminated, but steps can be taken to minimize potential illnesses. Even with effective handling, common pathogens *E.coli* O157 may survive in compost and infect produce; however, risk mitigation can greatly decrease risk (Solomon, Yaron, & Matthews, 2002).

Common pathogens found in manure include *Escherichia coli* O157:H7, *Salmonella,* and *Cryptosporidium* (USDA, 2011). Outbreaks linked to manure have had tremendous public impact. *E.coli* is a particularly common pathogen found in cattle manure, with measured amounts falling between 3 and 50,000 CFU/gram. This is of particular concern to food producers, as *E.coli* O157 has the smallest infective amount of any common foodborne pathogen: humans become sick after ingesting only 10 CFU of the pathogen (Kirk, 2011). Effective composting of manure is active method by which to eliminate pathogens. Augustin and Rahman (2010) recommend that manure and compost should be collected into a large pile 10-12 feet in width and 4-6 feet in height. The location of the pile should prevent runoff from contaminating nearby water sources, but also facilitate drainage. If piled correctly, within a few days natural decomposition process will cause the manure to reach an internal temperature greater than 120 F, and the pile will stay above this temperature for up to two weeks. Temperature control is critical, as internal temperatures above 160 F will begin to kill beneficial bacteria and will slow the composting process. If temperatures this high are reached, cooling measures may be necessary to revert the pile to the correct temperature range. Once the temperature falls below 110 F, the manure pile should be turned and allowed to reheat and continue composting (Augustin & Rahman, 2010). Varying standards exist for the number of times a manure pile should be turned, with the National Organic Program requiring no fewer than 5 times (The Organic Center, 2006). Compost must then be covered and allowed to cure for a period of 45 days, after which time it can be applied as a fertilizer (Cornell, 2015). USDA GAPs certification requires that raw manure be applied no less than 2 weeks before planting, and at least 120 days must elapse before harvest occurs (USDA, 2011).

2.10 Worker Health and Hygiene

Consistent adherence to hygienic practices by workers can greatly reduce the likelihood of contamination through handling of the produce. The possibility for contamination from transferred fecal matter or other contaminated foods is high during human handling of produce (Harrison et al., 2013). Workers can also spread sickness by handling food while suffering from contagious sicknesses. *E.coli* O157, *Salmonella, Cryptosporidium, Shigella,* and Hepatitis A are among diseases which are excreted by workers who carry the disease, even though they may not show visible symptoms (James, 2006). These diseases can then be easily transmitted into handled food if the worker does not wash their hands routinely. Overall, contamination from food workers is one of the leading causes of illness; in recent examples, a single infected worker has caused regional outbreaks (JIFSAN, 2010). According to the CDC (2015), 86% of foodborne illness outbreaks annually have been traced back to transmission of pathogens from handling by food workers. To prevent transmission of illness, the FDA recommends that food workers should wash their hands after eating, drinking, using tobacco, coughing, sneezing, using tissue, preparing raw animal products, handling dirty equipment, or touching their body (CDC, 2015). Jewelry and hair and beards also can harbor fecal matter and pathogens, and the USDA (2011) recommends that employers develop policies that address these sources of contamination.

The FDA (1998) recommends several measures for minimizing risk from infected workers. These are: establishment of an effective training program to educate workers on sanitation topics, particularly handwashing; encouraging workers to report sickness, and educating managers to recognize the symptoms of sickness in workers; ensuring that any lesion on a workers' body is covered, or if it cannot be, preventing the worker from handling any food or tools that might spread contamination; and potentially including other hygienic measures such as usage of disposable sterile gloves (FDA, 1998).

2.11 Sanitary Facilities

Occupational Safety and Health Act (OSHA) regulations dictate the design of a facility such as those where produce is processed and handled, under 29 CFR 1910.141, subpart J (1974). The FDA focuses heavily on accessibility of toilet facilities in their recommendations, as it is important to encourage the most possible usage of handwashing stations and discourage workers from relieving themselves outside and in fields (FDA, 1998). In addition to keeping the facilities clean and well-stocked, they should also be strategically located in areas where runoff, should it occur in events such as overflow or heavy precipitation, would prevent sewage from contaminating growing areas; furthermore, sewage disposal systems should be up-to-date, within EPA regulations, and properly located (FDA, 1998).

2.12 Field Sanitation

Utilization of containers, crates, baskets, and other packing materials during harvest presents a multitude of opportunities for germs to be spread if routine sanitizing is not enacted. Cross contamination can easily occur if equipment is not sanitized, particularly on small farms where one piece of equipment may be used on a variety of crops. Additionally, workers should be trained to only pick undamaged fruits and vegetables which are not obviously already contaminated by animal feces (Cornell, 2003). Cornell University's National Good Agriculture Practices Program (2003) recommends that farmers establish a strict field sanitation regimen which can be communicated to workers and adhered to throughout the harvest process. Among these recommendations are training workers to not harvest any produce which has visible bruising, animal excrement, or has been dropped on the ground; always washing, rinsing, and sanitizing harvest aids and bins; and using handwashing and sterile gloves in conjunction while also re-washing hands and changing to new disposable gloves any time the worker engages in an action which may disrupt the sanitation of his hands (Cornell, 2003). The USDA audit specifies the following criteria for certification in field sanitation (USDA, 2011):

> • Harvest containers used repeatedly during a harvest should be cleaned on a scheduled basis as outlined in the food safety plan.
> • If the farming operation stores harvest containers outside, proactive steps shall be taken to minimize harboring rodents and other pests in the harvesting containers.
> • Harvesting containers stored outside should be cleaned and sanitized before being used to haul fresh produce.
> • Operations shall also instruct workers to only use harvesting containers for their intended purpose, and not to use them for collecting trash or transporting personal items unless they are designated for that use.
> • Final packing containers used in field pack operations shall be protected from sources of contamination.
> • Only new or sanitized containers are used for packing the product.
> • Operation shall repair or discard damaged harvesting containers.
> • Harvesting equipment and machinery which comes in contact with the product is in good repair.
> • Light bulbs and glass on harvesting equipment are protected and the operation has an SOP in place to address glass or plastic breakage on the equipment during harvest (p. 11).

2.13 Packing Facility Sanitation

After field harvest, fresh produce is transported to a separate location to be readied for shipment or for sale. Produce is at a high risk for contamination during this stage, as improper sanitation procedures within the packing facility can quickly spread microbial infection. Potential sources for contamination include improperly sanitized surfaces, rodent infestation, and worker hygiene. Food contact surfaces, such as tables, counter tops, preparation tables, and containers must be thoroughly cleaned and sanitized routinely. Surfaces should be checked for biofilm after cleaning, as they can hold pathogens on their surface (JIFSAN, 2010). Effective cleanliness may be facilitated by effectively designing the work areas inside the packing facility to best accommodate cleaning, and minimize risk of produce being bruised or damaged (Kirk, 2011). The FDA (1998) advises that workers should remove the maximum amount of dirt from harvests fruits and vegetables before they are brought into the facility. For certification, the USDA mandates that packing facilities develop and implement a schedule for routine cleaning and sanitation of the facility, covering fresh produce handling and contact areas, ductwork, piping, and ventilation fans over produce handling areas, and catwalks which traverse directly above produce areas. (USDA, 2011).

Ice production machinery must be sanitized regularly, as well as the means of transportation for ice to the facility, and supporting documentation must be provided to verify compliance (USDA, 2011). Additionally, should any machinery that directly contacts the food require a lubricant, the USDA (2011) mandates that food grade lubricants be utilized. The USDA also requires measures for pest control as part of GAP certification. As a component of packing facility sanitation, the GAPs audit checklist requires that packing facilities must develop and enact a pest control program. Bait stations and traps must be used, documented, and monitored closely; poisons are not allowed inside the facility, so any traps containing poison must be outside. If pest control is contracted to an outside company, then the outside company must provide documentation of pest control measures that are enacted to verify that they are compliant with USDA requirements (USDA, 2011).

2.14 Transportation

Food can become contaminated during transportation from a packing facility to a store. In the case of fresh produce sold locally at farmers' markets, farmers often own one vehicle that is used for all farm usages, often including transportation of animals and machinery as well as fresh produce. Small scale farmers often engage in animal husbandry and other pursuits along with growing fresh produce, complicating vehicle usage. When a farmer engages in a variety of agricultural pursuits and one vehicle is used for all agricultural needs, precautions must be taken to ensure that the vehicle is sanitized and will not contaminate containers, bins, equipment, or bare food that is exposed to contact surfaces in the vehicle. When considered for small scale agriculture, many recommendations for safe transportation are not applicable, such as those in regards to transport by large refrigerated trucks. The FDA (1998) advises that farmers keep vehicles used for transportation clean, and vehicles should be inspected before use to determine if they need to be cleaned. For USDA GAPs certification, a standard operating procedure for cleanliness must be utilized (USDA, 2011):

Using the same vehicle for transport of produce and also animals, fuels, and compostable materials is inadvisable and can result in contamination (Ilic, LeJune, and Doohan, 2007). However, for many small-scale growers, use of separate vehicles for differing purposes is often impossible, as one vehicle is often used for all farm purposes. Extra attention must be paid to inspection, cleanliness, and routine sanitation to ensure that the risk for contamination is minimized.

2.15 Site Selection and Soil

Site selection is an important first step to establishing a farm and growing fresh produce. For GAPs certification, the USDA requires a documented land use risk assessment that addresses any potential risks that could arise and cause contamination in produce grown on the land (USDA, 2011). The risk assessment must include a consideration of adjacent lands, their usage, and the possible impacts of their usage on the farm being certified, as well as an assessment of the farm's sewage treatment system or connection to municipal sewage infrastructure. Finally, if the farm is subject to flooding, the flooding must be documented, and produce must be evaluated to determine if it suffered from contamination as a consequence of the flooding (USDA, 2011). The FDA (1998) does not address land use and site selection as part of its *Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables*, however, the topic is discussed by other researchers. If the site of a farm was previously employed in animal husbandry or agriculture utilizing application of pesticides, herbicides, or other chemicals and soil amendments, then soil should be tested before use (JIFSAN, 2010). If the land was previously used for industrial sites or waste disposal, then the land may be unsuitable for crop production, as industrial sites may have left heavy metals in the soil and waste disposal may have created a long-term pathogen-rich environment. In either case, testing is necessary to determine the viability of the soil on the farm for food production (JIFSAN, 2010).

2.16 Animal Exclusion and Pest Control

Wild animals such as rodents and birds are hazardous to fresh produce, as these animals can easily spread contamination through feces, cross contamination, saliva, and surface pathogens (JIFSAN, 2010). *Salmonella*, *Staphylococcus*, and *Streptococcus* are pathogens that can be found on animal skin and feathers and can easily be transmitted to plants, fruits, and vegetables via contact (JIFSAN, 2010). Management of risk from animal contamination is a critical component of GAPs certification. In addressing animal exclusion on land used for food production, the USDA (2011) differentiates between wild animals, livestock, and farm service animals. In the GAPs audit for the USDA (2011), livestock are not permitted on crop production land, and neither are pets. While wild animals, including birds, cannot be totally eliminated from farmland, they must be discouraged from entering growing areas and access limited as much as possible, within the confines of local regulation and laws. In the case of service animals such as horses and mules, farmers are required to develop risk assessments and standard operating procedures to accompany their usage (USDA, 2011). The Joint Institute for Food Safety and Applied Nutrition (2010) recommends that farmers consider the usage of buffer zones, control grass height, limit garbage that may attract rodents, drain standing water, and potentially utilize devices like sound cannons to scare away pests.

2.17 Traceability and Recall

Traceability of microbial contamination is vital for determining the source of foodborne illness. Federal agencies utilize traceability measures to identify a source of contamination after a foodborne illness outbreak. As a part of GAPs compliance for certification, the USDA (2011) requires growers to establish at minimum a documented traceability program which tracks “one step back” and “one step forward”; i.e. the location where produce was received from, and the next destination of the produce (p. 10). The USDA (2011) notes that commercial traceability solutions exist, and farmers can receive additional information from local extension offices, trade associations, and state horticultural organizations (p. 10). The Chapman, Kreske, and McReynolds (2013) note that in the event of contamination being discovered in produce, an effective traceability program enables farmers to quickly determine which field the contaminated produce originated from, and what other produce needs to be quarantined to prevent further cross-contamination. A highly documented recall checklist enables farmers to quickly implement recall measures when contamination is discovered in their produce. Checklists should include: customer and buyer contact information; names and phone numbers of authorities, media, legal counsel, and insurance companies; steps for identification of the issue; identification of type of produce and lot numbers associated with the contaminated product; quantities of produce in inventory, shipped, delivered, purchased by consumers, and stock in marketplace; and upon completion of the recall, an assessment of the process for future improvement (Chapman, Kreske, & McReynolds, 2013, p. 13). Chapman, Keske, and McReynolds (2013) recommend a lot code-based system that indicates the date of a produce lot’s harvest and the field it was harvested from, and further recommends that growers stage a mock recall to demonstrate the farm’s preparedness for a food recall; however, it notes that a mock recall is not required for first-time GAPs certification.

Chapter III: Methodology

Research Design

The study was divided into two parts. The first part was developing and administering the food safety practices and knowledge surveys at farmers' markets. The second part of the present study was the development and evaluation of a series of consumer-friendly fact sheets containing GAPs, safe fresh produce handling, and recommended storage guidelines.

Objective I. Small-scale Kentucky Farmers' Knowledge, Practices, and Perceptions Survey

Design and development

The first objective of the present study was to assess and report the food safety knowledge, practices, knowledge of GAPs, and perceptions associated with GAPs certification among small-scale Kentucky farmers who sell fresh produce at farmers' markets. To accomplish this objective, a survey instrument was developed and administered at farmers' markets in 21 counties across the state of Kentucky. The survey consisted of 31 questions that were divided into four main sections: demographics, requirements and current practices, barriers and drivers for adoption, and future participation and interests in GAPs (see Appendix A). The demographic portion of the questionnaire asked the gender of the respondent, the size of their farm, their profile as a producer, water source used for irrigation on their farm, types of products grown and method of sale, and previous or current participation in fresh produce audit requirements. The third portion of the questionnaire 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 ensure that farmers clearly understand 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, and their comments were incorporated into the final document.

Participants Recruitment

To collect data, farmers' markets in 21 counties in the Commonwealth of Kentucky were visited and questionnaires were administered between April and August 2014. The counties were selected to represent different regions of the Commonwealth of Kentucky with varying population size and population 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 the purposive sampling was to assure that data represented a broad spectrum of small-scale Kentucky farmers across the state.
Farmers who attended the farmers' markets during the data collection visits were invited to complete the anonymous questionnaires. 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 using STATA 14 software. Descriptive statistics (mean and standard deviation) were calculated for each variable. Data analysis utilized Chi-square tests of independence, and data were considered to be statistically significant at a 95% confidence level ($\alpha < 0.05$) unless otherwise noted. The unit of analysis of the dependent variable determined the type of quantitative analysis conducted.

Bivariate analyses were used to test the relationship that existed between demographic factors and current farming practices. Using these analyses, the significant demographic differences between farmers currently utilizing GAPs compared to farmers not currently utilizing GAPs was 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.

Objective II. Development and Evaluation of Fresh Produce GAPs Factsheets

The development of effective, commodity-specific informational factsheets was the second objective of the present project. The factsheets were designed to be an easy-to-use educational tool that could quickly and concisely provide readers with critical information related to commodity growing, harvest, handling, storage, and cooling. Each factsheet was approximately two pages in length and included sources for all data used in the factsheet, giving farmers the opportunity to further research food safety for the fruit or vegetable. At the conclusion of the present study, the factsheets will be made available online.

Design and Development

Six factsheets were produced (see Appendix B). The factsheets detailed six fresh produce commodities commonly found at farmers' markets roadsides stands, and other local food venues. These commodities were tomatoes, lettuce, spinach, alfalfa sprouts, squash, cucumbers, and melons. Information on each crop was adapted from USDA and FDA guides, as well as research at universities across the United States. Prior to use, the factsheets were sent to various industry contacts, extension agents, and local small-scale farmers for review to ensure accuracy and effectiveness. Suggestions from these reviews were compiled and used to produce final versions of each factsheet, which were subsequently administered.

The factsheets had a standardized design with 6 major sections in each factsheet. The sections were: general commodity information, pathogenic behavior in commodity, harvest considerations, foodborne illness outbreaks associated with commodity, Good Agricultural Practices, and storage and cooling conditions.

General commodity information, the first section, offered a brief overview of the commodity and included facts and figures related to the commodity. The second section, pathogenic behavior in commodity, related the findings of research on pathogen contamination of the commodity. The commodities featured in the factsheets all have unique routes by which harmful bacteria enters the plant, and relaying this information to fresh produce growers is vital so that growers understand unique precautions which should be taken for each individual commodity. For example, sprout contamination has been shown to usually occur as a result of bacteria collecting on the exterior of the seed, prior to sprouting (Charkowski, 2009). In another example, harmful bacteria can travel through the porous, netted rind of some melons during the melon's growth period (Goetz, 2011). Pathogens adopt a slightly different tactic for attacking each of the six commodities featured in the present project, and as a result, the unique pathways for contamination were detailed on each factsheet. The third section, harvest considerations, was adapted from the FDA Commodity-Specific Guides which are published online. Each of the commodities with a high risk of microbial contamination has an FDA guide for Good Agricultural Practices. The commodity-specific harvest recommendations made by the FDA in each guide have been adapted in the Harvest Consideration section of the factsheet. On the factsheet, this information is presented in the form of a bulleted list. The fourth section, foodborne illness outbreaks associated with the commodity, contained a brief history of recent outbreaks which have been linked to each commodity. This section gave a brief overview of outbreaks linked to each commodity, as well as notable examples. Dates, location of the outbreak, number of states impacted by the outbreak, and the number of illnesses and deaths from each outbreak were included in this section. The fifth section, Good Agricultural Practices, was also adapted from the FDA Commodity-Specific Guides. While many of the GAPs recommended in the Commodity-Specific Guides are common, any recommendations which are unique to a specific commodity are placed in a separate bulleted list in this section. Examples include recommendations for placing melons on new, clean plastic barriers, or cleaning knives used to cut lettuce and spinach. The final section of the factsheets, cooling and storage conditions, was adapted from Fellow (2000) and DeEll (2014). This section provides readers with the specific temperature and humidity levels needed for storage, acceptable methods of cooling, ethylene sensitivity and production information, and storage life.

Participant Recruitment

To administer and evaluate the factsheets, the factsheets were administered at farmers' markets in Kentucky to small-scale farmers who grew and sold fresh produce. The project was explained to small-scale farmers at the farmers' markets, and they were then asked if they were interested in participating by reviewing the factsheets and completing evaluations for them. Participants were provided with permission forms for informed consent and confidentiality in study participation, and the permission forms were collected from each participant when the evaluations were collected. Participation was available to all small-scale farmers present at the farmers' markets. The present study did not exclude participants based on age, sex, ethnic or racial group, sexual orientation, national origin, level of education, socioeconomic status, or language preference. The only demographic information which will was noted and collected in the study was the size of each participant's farm, their GAPs certification status, and whether or not they met the FDA's $25,000 annual produce sales threshold for mandatory food safety certification.

Evaluation Instrumentation

When the factsheets were distributed at farmers' markets, small-scale farmers and vendors who received the factsheets were asked to review them and then complete an evaluation form on the information presented in the factsheet. The evaluation data was collected and used to determine the effectiveness of the factsheets. The objective of the factsheet questionnaire development process was to produce a quantitative self-evaluation tool for factsheet respondents which is easily read and answered in minimal time, but which also accurately measures the effectiveness of the factsheets. The factsheet evaluation questionnaires utilized a 5-point Likert scale: no knowledge, slightly knowledgeable, neutral, moderately knowledgeable, and extremely knowledgeable. The questionnaire asked respondents to rate their knowledge on each of the six factsheet section topics before reading the factsheet, and rate their knowledge again after reading this factsheet. A space was also provided for participants to write in additional comments.

Data Analysis

Data collected from the factsheet evaluation questionnaire was analyzed quantitatively utilizing Microsoft Excel 2016's t-test and standard deviation functions. The mean difference between the evaluation responses from the pre- and post-test sections were used to evaluate the knowledge of farmers before reading the factsheet and measure the gain in commodity-specific knowledge made by farmers by reading the factsheet. The differences in the 5-point Likert scale-based question responses were analyzed using a t-test to compare the pre- and post- data, while the means were reported as descriptive data to indicate the general knowledge increase reported by participants.

Chapter IV: Results and Discussion

Objective I: Small-scale Kentucky Farmers' Knowledge, Practices, and Perceptions Survey

Demographics of fresh produce growers

The survey was distributed to 400 farmers in 21 counties cross the Commonwealth of Kentucky and 160 (40%) survey responses were collected back. The demographic data were collected regarding gender, age, education level, farm county, amount of land used to grow fresh produce and farmers experience are presented in Table 2. Demographics in the study were generally diverse. Respondents were closely split between male and female respondents, at 54.4% and 45.6% respectively. Respondents were most likely to possess a college degree (43%) while respondents with some college experience but no degree closely followed at 40.5%. Respondents with only a high school diploma were the smallest group at 16.5%. Respondents represented a wide variety of ages but were largely middle-aged, with 28.8% of respondents being 50-59, 24.4% being 30-39, and 23.1% being 40-49. Eleven percent of respondents were 60-69 years of age, 7.5% were 75 and above, and 5% were 18-29 years of age. 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. Just over 16% of respondents indicated their home county as Jefferson County, including Louisville, Kentucky's largest metropolitan area. Slightly less than 10% of respondents were located in Hardin County, 8.8% of respondents were located in McCracken County, and 6.3% of respondents were located in

Daviess County. All other counties represented each contributed less than 5% of respondents. Respondents reported a wide variety of land sizes used on their farm. The majority (65.6%) of respondents grow fresh produce on less than 5 acres, followed by 5-10 acres at 24.8%. Only 9.6% of the fresh produce growers reported farming on 10 acres or more.

When respondents were asked to report how many years they had grown produce for sale at farmers' markets, 35.7% of respondents reported growing for 6-10 years, 32.5% for 5 years or less, 21% for 11-20 years, and only 10.8% for more than 20 years.

Table 2

Demographics of fresh produce famers and vendors (N = 157)	N	%
Gender		
Male	54.4	87
Female	45.6	73
Education		
High School or Less	16.5	26
Some College	40.5	64
College Degree	43	68
Age		
18-29 Years	5	8
30-39 Years	24.4	39
40-49 Years	23.1	37
50-59 Years	28.8	46
60-69 Years	11.3	18
70 and Over	7.5	12
Amount of Land Used to Grow Crops for Farmer's Market		
1 Acre or Less	12.7	20
2 Acres	21.7	34
3 Acres	15.3	24
4 Acres	15.9	25
5-10 Acres	24.8	39
More than 10 Acres	9.6	15
Years Growing Produce for Farmer's Market		
Less Than 5 Years	32.5	51
6-10 Years	35.7	56
11-20 Years	21	33
More Than 20 Years	10.8	17

Food Safety Practices, Perceptions, and Knowledge On-farm Survey Responses

Food Safety Practices and Perceptions On-farm Among Participants

Table 3

Relationship between awareness of GAPs and currents farming practices

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

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 3). A significant relationship ($x^2 = 7.72$, $p < .01$) was observed between awareness of GAPs and use of transportation GAPs, with 64% of participants who were aware of GAPs indicating management of transportation. Sanitary facilities and field sanitation were the most likely GAPs to be utilized by participants who were aware of GAPs, at 73% and 71%, respectively. Participants were most likely to engage in sanitary facilities and field sanitation GAPs. Sixty-one percent of participants chose to engage in worker health and hygiene GAPs, and 60% reported engaging in packing facility sanitation GAPs. Reported packing facility sanitation GAPs compliance in the current study compared to a study conducted in Georgia, South Carolina, and Virginia that found that only 66.8% of surveyed growers provided portable handwashing stations to harvest workers and 66.4% provided portable toilets (Harrison et al., 2013). However, an earlier multi-state survey found that farmers who are aware of GAPs are more likely to provide portable toilet and handwashing facilities to workers in the field than farmers who are unaware of GAPs (Jackson et al, 2007).

Reported adherence to water quality management was found to be low, with less than half of respondents (45%) choosing to mitigate microbiological contamination in farm use water with GAPs. Just under 29% of participants used tested well water on their farm, while less than 6% used untested well water. 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.

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 infect produce (Bihn, Smart, Hoepting, & Worobo, 2013). Marine, Martin, Adalja, Mathew, & Everts (2016) reported 48.5% of 2010 growers and 23.4% of 2013 growers using surface water (including ponds, rivers and streams) at least some of the time. The same survey also found that more than 76% of growers did not test their irrigation water at least once a year for indicators of fecal contamination (Marine et al., 2016). Bihn et al. (2013) reported 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 (Bihn et al., 2013). Another previous study found that only 18% tested groundwater (Cohen et al., 2005).

Participants in the current study indicated mixed usage of composted manure and municipal biosolids. When asked about manure use and source, 54% of the growers reported using composted manure, and the majority (82%) reported using manure from chicken. Manure usage by participants was comparable to other recent data that found that 60.4% of surveyed growers in Maryland apply manure, compost or bio-solids to their farm (Marine et al., 2016). However, not all growers had on-farm sources of manure or compost. Harrison et al. (2013) found more than 56% (n = 128) 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.

Table 4

GAPs awareness by acres farmed, years of selling produce at farmers' markets, and education

	Aware of GAPs		
	Yes	No	Chi 2
	% (N)	% (N)	
Acres			
1 acre or less	11 (16)	25 (4)	8.46
2 acres	21 (29)	31 (5)	
3 acres	16 (22)	13 (2)	
4 acres	18 (25)	0 (0)	
5-10 acres	26 (37)	13 (2)	
> 10 acres	9 (12)	19 (3)	
Total (N)	100 (141)	100 (16)	
Years of selling produce			
< 5 years	30 (42)	56 (9)	5.19
6-10 years	38 (53)	19 (3)	
11-20 years	22 (31)	12 (2)	
> 20 years	10 (15)	12 (2)	
Total (N)	100 (141)	100 (16)	
Education			
High school or less	16 (23)	19 (3)	4.62
Some college education	38 (54)	63 (10)	
College degree	46 (65)	19 (3)	
Total (N)	100 (142)	100 (16)	

* = p < .05
** = p < .01
*** = p < .001

The relationship between awareness of GAPs, years of selling produce at farmers' markets, and level of education among farmers is reported in Table 4. Among size of acreage used on participants' farms, farmers who utilized 5-10 acres of land for growing produce were most likely to be aware of GAPs, at 26%. Twenty-one percent of farmers who used 2 acres of land were aware of GAPs, 18% of farmers who used 3 acres of land were aware of GAPs, and 16% of farmers who used 4 acres were aware of GAPs. Only 11% of farmers who used 1 acre or less were aware of GAPs, while a mere 9% of farmers who utilized 10 acres or more were aware of GAPs.

In investigating the correlation between years of selling produce and awareness of GAPs, it was observed that 38% of farmers who had sold produce between 6 and 10 years were aware of GAPs, followed by farmers who had sold produce for 5 years or less and 11-20 years at 30 and 22%, respectively. Only 10% of farmers who had sold produce at farmers' markets for more than 10 years were aware of GAPs.

Slightly less than half (46%) of farmers who held a college degree were aware of GAPs. About 38% of farmers who had some college education but had not graduated were aware of GAPs. Only 16% of farmers who held a high school diploma or less were aware of GAPs.

Reported farm size appeared to have little bearing on GAPs awareness, with awareness distributed across the spectrum of farm land size categories. When considering time spent farming correlated with GAPs awareness, the distribution peaked at 6-10 years and declined to its lowest point at >20 years. The findings of the current survey are similar to Jackson et al. (2013), who found that participants' age, the size of their farm, and length of time spent farming had no significant impact on awareness of GAPs in a multi-state survey (Jackson et al., 2013).

Relationship between size of land used for locally grown produce and GAPs practices

Table 5

Relationship between size of land used for locally grown produce and GAPs practices

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

* = p < .05
** = p < .01
*** = p < .001

Among respondents who were aware of GAPs, a significant relationship ($\chi2$ (1) = 19.1, p < 0.001) existed between the amount of land used on participants' farms for growing produce and practice of managing worker health and hygiene (Table 5). 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 ($\chi2$ (1)

= 15.8, $p < 0.01$) observed 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 the practice. When asked about management of manure and municipal biosolids, significantly more farmers utilizing 3 acres for growing produce responded in the affirmative than other land amounts ($\chi 2$ (1) = 12.7, $p < 0.05$). The survey indicated that farmers who utilize 2 acres or less for produce are least likely to engage in GAPs, with the majority of categories reporting compliance less than half of the time. At 3 acres, response increased somewhat, with a range of 63 – 88%. A majority of respondents with 4 acres reported compliance in all categories as well. Interestingly, compliance with several GAPs categories once again fell into the minority among respondents with 5-10 acres, these categories being water quality (41%) and worker health and hygiene (49%). At >10 acres, worker health and hygiene and manure and municipal biosolids GAPs compliance were indicated less than half of the time, at 40% and 33% respectively. A majority of respondents indicated compliance in all other GAPs areas at this farm size.

Farmers' Knowledge of On-farm Sources of Contamination

Table 6

Sources of microbiological contamination on farm identified by local farmers

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

^Respondents were allowed to indicate more than one response

Respondents were given a list of microbiological contamination sources, and asked to select all that they believed were a risk on a small 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 6). 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 respondent identified transport containers, irrigation water (51%), and cross-contamination in storage, display, or preparation (51%) as possible vectors for microbiological contamination. Less than half (45%) of respondent believed transport vehicles, inadequately composted manure (44%), harvesting equipment (42%), or soil (41%) to be possible sources of microbiological contamination. Only 36% of respondents believed produce wash and rinse water to be capable of causing microbiological contamination. Furthermore, a relatively small number of respondents indicated that microbiological contamination could come from refrigeration or cooling (28%) and ice (26%).

Survey results present a complex reality for awareness of microbiological contamination vectors among small-scale farmers in Kentucky. 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 (Heaton & Jones, 2007), the results indicates that most small-scale Kentucky farmers are unaware of contamination risks associated with soil. Ice was the lowest-reported source of microbiological contamination in the current study. Wild animal intrusion was identified by a majority of participants, similar to a 2013 survey of growers in Maryland and Delaware in which 76% of participants reported awareness of wild animal intrusion and exclusion efforts, with only 18% of participants choosing to not attempt any type of wild animal exclusion (Marine et al., 2016). 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 (Parker et al., 2012). A second 2012 survey of growers in the Midwest United States found that growers often believed that wild animal exclusion required too large of an economic investment for them to implement it on their farm (Ivey, LeJeune, & Miller, 2012)

Table 7

Sources of microbiological contamination on farm identified by education

Source of contamination	High School or Less	Some College	College Degree	Total	Chi2
	% (N)	% (N)	% (N)	% (N)	
Soil	50 (10)	36 (19)	44 (27)	42 (56)	1.48
Irrigation water	45 (9)	53 (28)	52 (32)	51 (69)	0.40
Animal manure	65 (13)	68 (36)	62 (38)	65 (87)	0.39
Inadequately composted manure	35 (7)	49 (26)	43 (26)	44 (59)	1.21
Wild and/or domestic animals walking through your farm	60 (12)	70 (37)	84 (51)	75 (100)	5.51
Workers clothing and hands	40 (8)	60 (32)	62 (38)	58 (78)	3.25
Harvesting equipment	30 (6)	45 (24)	43 (26)	42 (56)	1.43
Transport containers	30 (6)	58 (31)	54 (33)	52 (70)	4.88
Produce wash and rinse water	15 (3)	36 (19)	43 (26)	36 (48)	5.00
Ice	15 (3)	26 (14)	30 (18)	36 (35)	1.65
Refrigeration or cooling	20 (4)	28 (15)	31 (19)	38 (38)	0.92
Transport vehicles	25 (5)	51 (27)	46 (28)	45 (60)	4.01
Cross-contamination in storage, display or preparation	30 (6)	53 (28)	57 (35)	51 (69)	4.58

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

The relationship between the respondents' knowledge of microbiological contamination vectors and education was investigated (Table 7). Soil was rarely identified as a possible source of microbiological contamination, being selected by only 50% of respondents with a high school diploma or less, 36% of respondents with some college, and 44% of respondents with a college degree. Forty-five percent of respondents with a high school diploma or less identified irrigation water as a possible route for microbiological contamination, while 53% of respondents with some college and 52% of respondents with a college degree identified this risk. Awareness of animal manure as a vector of microbiological contamination was slightly higher, 65% of respondents with a high school diploma or less, 68% of respondents with some college experience, and 62% of respondents with a college degree identifying the risk of microbiological contamination from this source. Less than half of respondents in all categories believed improperly composted manure to be a source of microbiological contamination, with this source being identified by only 35% of respondents with a High School diploma, 49% of respondents with some college experience, and 43% of respondents with a college degree. For contamination by wild or domestic animals intruding into production areas, 60% of respondents with a high school diploma or less identified the risk of microbiological contamination, while 70% of respondents with some college experience and 84% of respondents with a college degree did the same. Workers' clothing and hands were identified as a potential sources of contamination by 40% of respondents with a high school diploma or less, 60% of respondents with some college experience, and 62% of respondents with a college degree. Only 30% of respondents with a high school diploma or less identified harvest equipment as a source of microbiological contamination, compared to 45% of respondents with some college experience and 43% of respondents with a college degree. About 30% of respondents with a high school diploma indicated that they believed transport containers could be a source of microbiological contamination, while 58% of respondents with some college experience and 54% of respondents with a college degree identified the risk. A minority of respondents in all categories indicated a belief that produce wash and rinse water could transmit microbiological contamination to produce, with only 15% of respondents with a high school diploma or less, 36% of respondents with some college experience, and 43% of respondents with a college degree. Even less respondents believed cooling ice to be a source of microbiological contamination, and only 15% of respondents with a high school diploma or less, 2% of respondents with some college experience, and 30% of respondents with a college degree identified this risk. Refrigeration and cooling was believed to be a risk of microbiological contamination by only one-fifth of respondents (20%) while slightly less than a third of respondents (28%) with some college experience and respondents with a college degree (31%) believed refrigeration and cooling to be a source of contamination. Transport vehicles were implicated as a potential vector for microbiological contamination by 25% of respondents with a high school diploma or less, 51% of respondents with some college experience, and 46% of respondents with a college degree. Lastly, cross-contamination in storage, display, or preparation was identified as a source of contamination by 30% of respondents with a high school diploma or less, 53% of respondents with some college experience, and 57% of respondents with a college degree.

In investigating the relationship between education level and awareness of vectors of microbiological contamination, no clear association emerged. Although sources of contamination were generally identified by a larger percentage of respondents with a college degree than 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 8 and continue to suggest that small-scale Kentucky farmers are inadequately informed on the risks of pathogenic transmission present on their farm operation.

Affect of education level on GAPs practices

Table 8

Relationship between level of education and GAPs practices

GAPs Practice	High School or Less	Some College	College Degree	Total	Chi2
	% (N)	% (N)	% (N)	% (N)	
Managing water quality	54 (13)	46 (28)	46 (29)	47 (70)	0.54
Managing manure & municipal biosolids	46 (11)	52 (32)	57 (36)	53 (79)	0.93
Managing worker health & hygiene	50 (12)	54 (33)	65 (41)	58 (86)	2.31
Managing facilities sanitation	63 (15)	64 (39)	81 (51)	71 (105)	5.35
Managing Field sanitation	79 (19)	66 (40)	71 (45)	70 (104)	1.59
Managing Packing facility sanitation	38 (9)	54 (33)	70 (44)	58 (86)	8.15*
Managing Transportation	54 (13)	61 (37)	62 (39)	60 (89)	0.45
I choose not to implement GAPs	0 (0)	5 (3)	0 (0)	2 (3)	4.37

* = p < .05
** = p < .01
*** = p < .001

Table 8 shows the relationship between level of education held by participants and their GAPs usage. A significant relationship ($\chi2$ (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 some college practices packing facility GAPs. Those with high school or less came in lowest, with only 38% reporting management of packing facility GAPs. For management of water quality GAPs, a slight majority (54%) of respondents with a high school diploma or less engaged in the practice, while less than half (46%) of those with some college and a college degree (46%) used water quality GAPs. For management of manure and municipal biosolids GAPs, respondents with a high school diploma or less were GAPs compliant 46% of the time, while respondents with some college were compliant 52% of the time and college graduates were compliant 57% of the time. Half of respondents (50%) with a high school diploma or less chose to manage worker health and hygiene on their farm, while slightly more than half of respondents (54%) with some college did the same and a majority of respondents (65%) with college degrees engaged in the practice. A majority of respondents in all categories managed facilities sanitation GAPs on their farm, accounting for 63% of respondents with a high school diploma or less, 64% of respondents with some college experience, and 81% of respondents with a college degree engaging in the practice. Only 54% of respondents indicated that they managed transportation GAPs on their farm, while 61% of respondents with a high school diploma or less indicating management and 62% of respondents with a college degree indicating management. No participants with a high school diploma or less or a college degree declined to implement GAPs on their farm, while 5 respondents with some college experience declined to implement GAPs on their farm.

Obstacles in GAPs Implementation

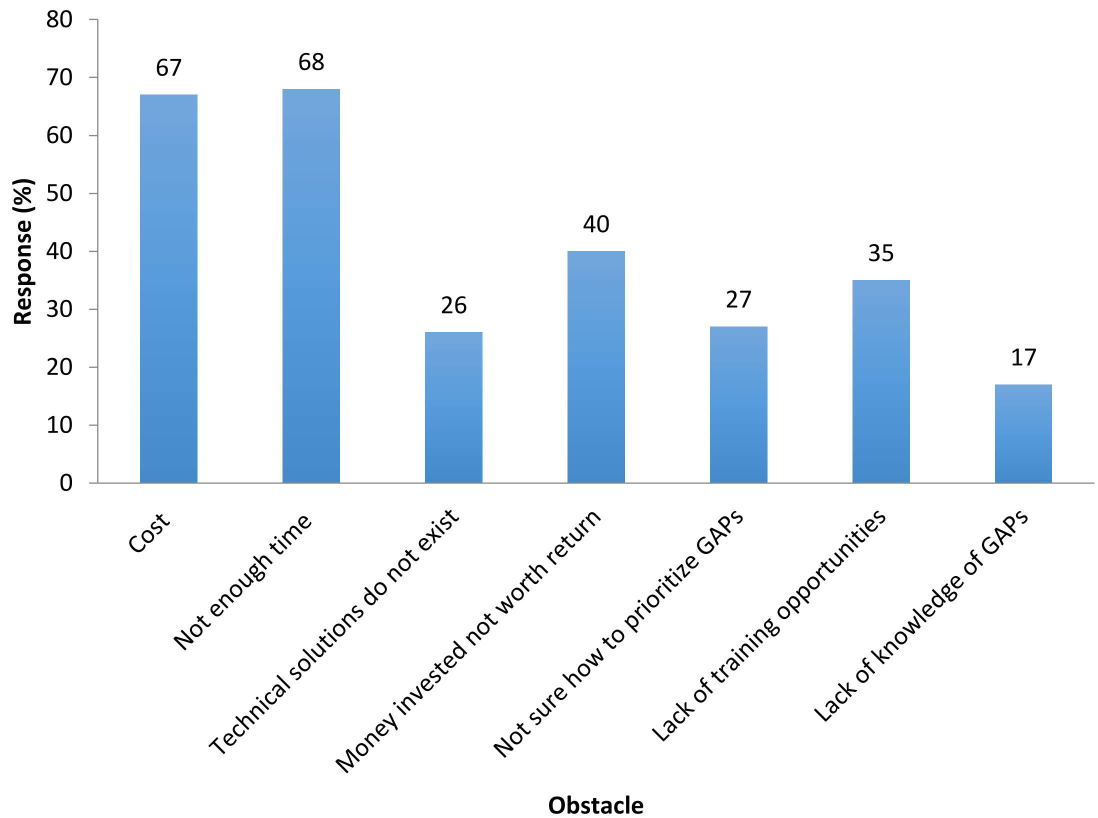

Figure 1. Obstacles to preventing farmers from implementing GAPs on farm (n=143).

Participants were asked about the obstacles that preventing them from implementing GAPs (Fig. 1). Lack of time (68%) to undergo auditing was identified as the greatest barrier by respondents, while cost of certification was the second-most salient perceived barrier (67%). Less than half of respondents (40%) believed that the investiture in GAPs certification would not provide a worthwhile return on investment, while 35%

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 participants (27%) believed that being unsure of how to prioritize GAPs would be a barrier to certification, while 26% of participants 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 participants (17%).

Participants perceived cost and lack of time to be considerable obstacles to GAPs certification on their farm. This finding is shared by a 2007 multi-state survey of growers in the United States that also found cost and lack of time to be the two most commonly perceived barriers to audit completion (Jackson et al, 2007). 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 instead either 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 (Marine et al., 2016). Additionally, a 2012 survey conducted across the Midwestern United States found that the majority of participants did not perceive costs to be a barrier (Ivey, LeJeune, & Miller, 2012). 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 (Nickerson, Becot, & Conner, 2012). 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 smaller economic impact than a non-GAPs certified farm, raising the possibility that further education on the benefits of GAPs certification may encourage auditing (Rejesus, 2009). 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 (Ribera, Palma, Paggi, Knutson, & Masabn, 2012).

Willingness to Attend Further Education by Study Participants

More than 85% of participants indicated they are interested in training opportunities to enhance their knowledge of GAPs (Figure 3). When asked what types of training they preferred, more than 90% of participants indicated that they would like online training on a website or videos, and about 65% of participants indicated that interested in workshops (Figure 4). Results support the need for development of educational materials and practical training for small-scale producers. Similar findings were reported by Harrison et al. (2013), who discovered that 40% of surveyed farmers wanted food safety education materials which they could give to their workers.

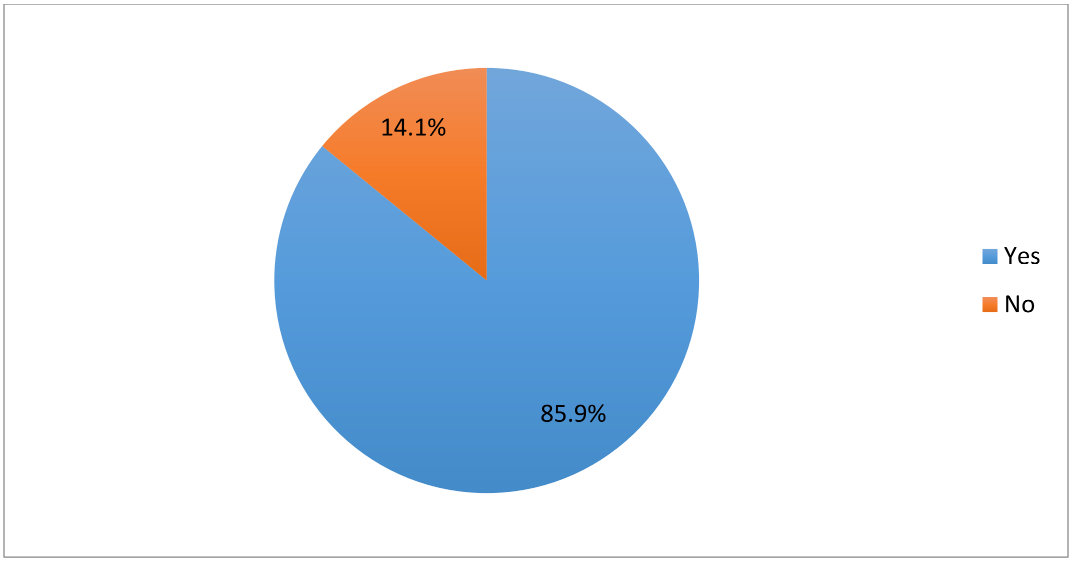

Figure 3. Percent of farmers who are interested in training opportunities on GAPs) or other on-farm food safety practices (N = 156)

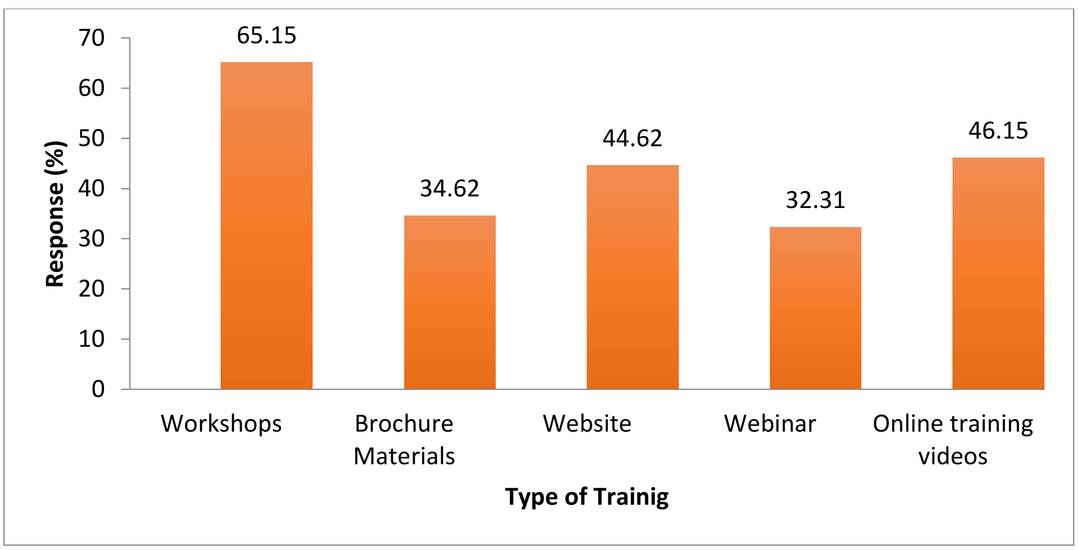

Figure 4. Types of Educational or Training Materials Preferred by Farmers (N = 130)

Food Safety Practices and Perceptions at Farmers' Markets Among Participants

In addition to investigating farmers' safety practices on-farm, farmers' food safety knowledge, practices, and perceptions at farmers' markets was also investigated as part of the present study. Participants were questioned on their usage of display and transport containers at farmers' markets, their washing practices, storage methods, and perceived sources of microbiological contamination at farmers' markets. Types of container used by participants for presentation and transport, and washing and sanitizing of containers by participants, are reported in Table 10.

Container use and container washing practices at farmers' market

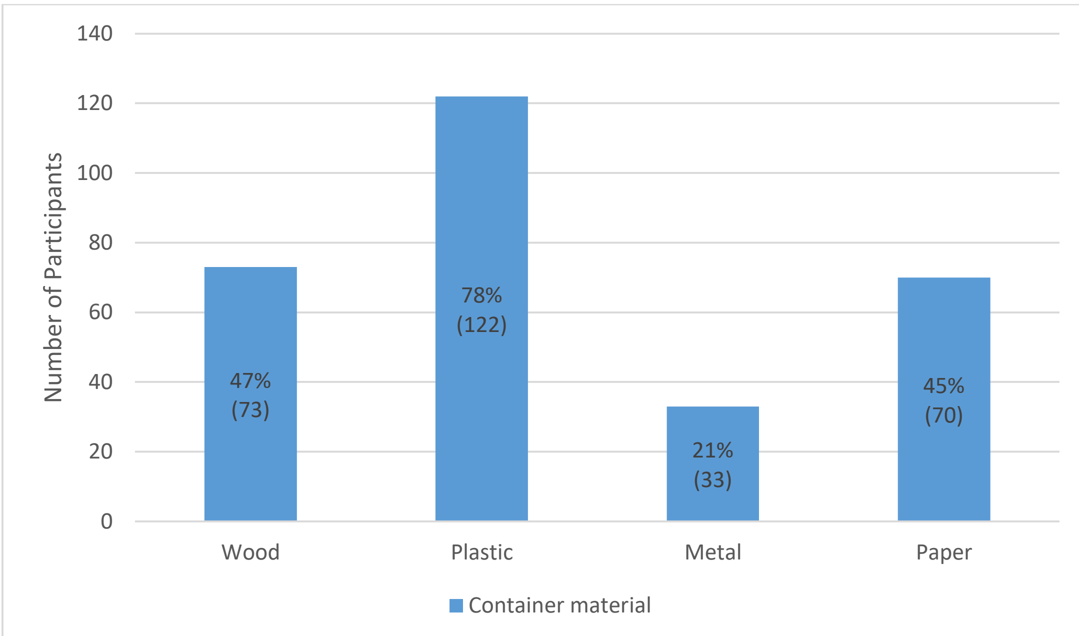

Figure 3. Type of container used by small-scale farmers to present fresh produce at farmers' markets (N=156)

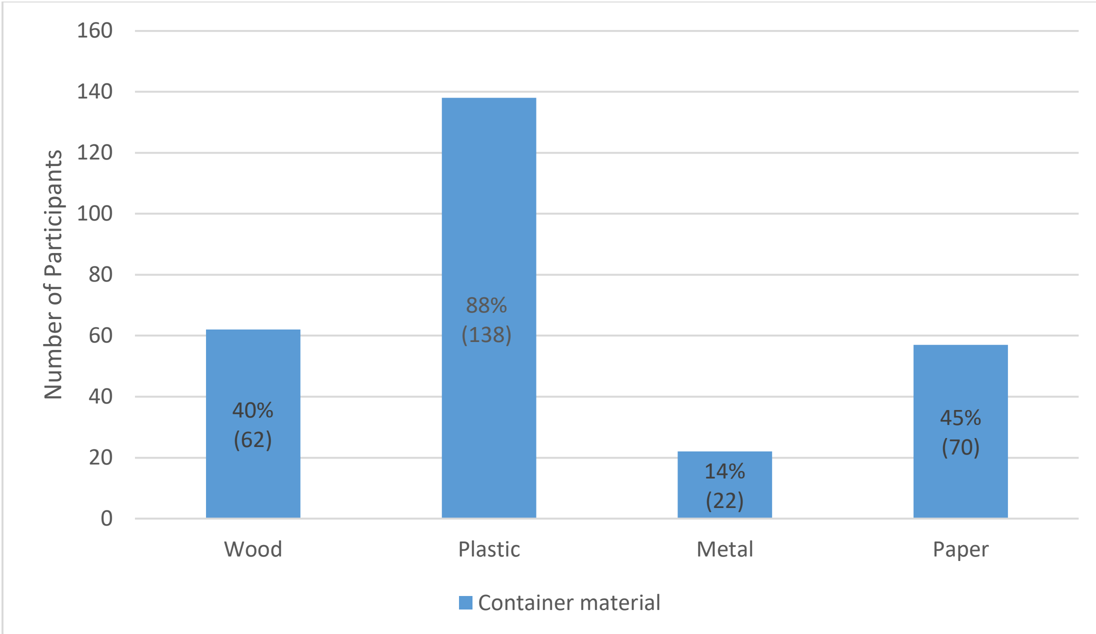

Figure 4. Type of container used by small-scale farmers to transport fresh produce to farmers' markets (N=156)

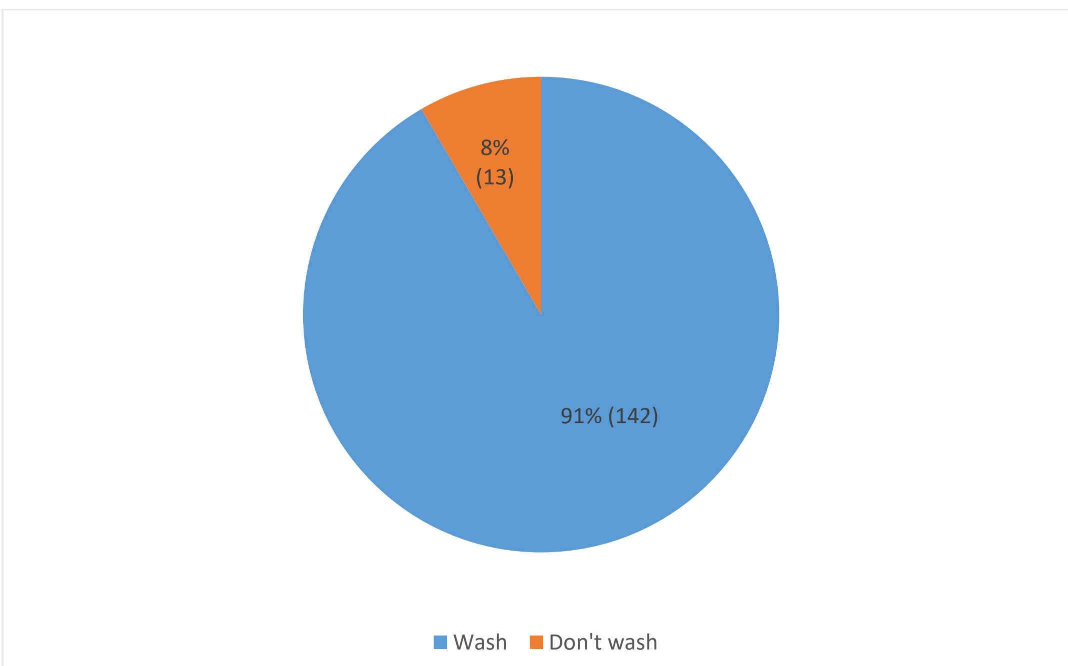

Figure 5. Participants' reported washing of fresh produce prior to sale (N=156)

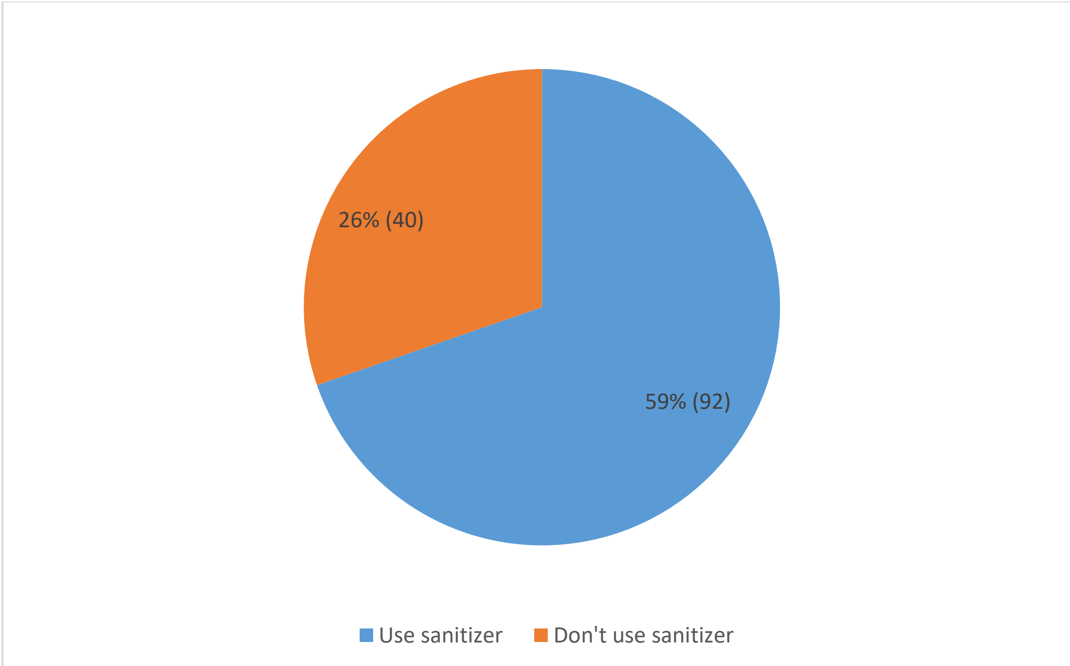

Figure 6. Participants usage of sanitizer in wash water for fresh produce prior to sale (N=156)

As a portion of the survey questioned devoted to food safety practices at farmers' markets, participants were asked about what type of container they used to present fresh produce when selling at farmers' markets (Figure 3). Most participants chose to use plastic containers for presentation of fresh produce at farmers' markets (77.22%). Wood containers were the second-most popular option (73%), paper was the third most popular choice (44.30%) and metal containers were the least popular option for presentation container (20.89%). Participants were also asked to identify what type of container they used for transport of fresh produce to farmers' markets (Figure 4). About 88% of participants preferred plastic containers for transport, 62% preferred paper containers, 36.54% used wood containers, and only 14.10% of participants used metal containers for transport. Interestingly, the vast majority of participants (91.61%) reporting cleaning their containers between usage (Figure 5), and 69.70% reported using a sanitizing agent mixed in with the water to sanitize containers between usage (Figure 6).

Participants were also asked about their storage practices at the market. Two questions of the survey were devoted to storage at market and investigated the means of storage (Figure 7) as well as length of time that fresh produce was kept in storage before sale at market (Figure 8). Participants were allowed to select more than one response when indicating storage method.

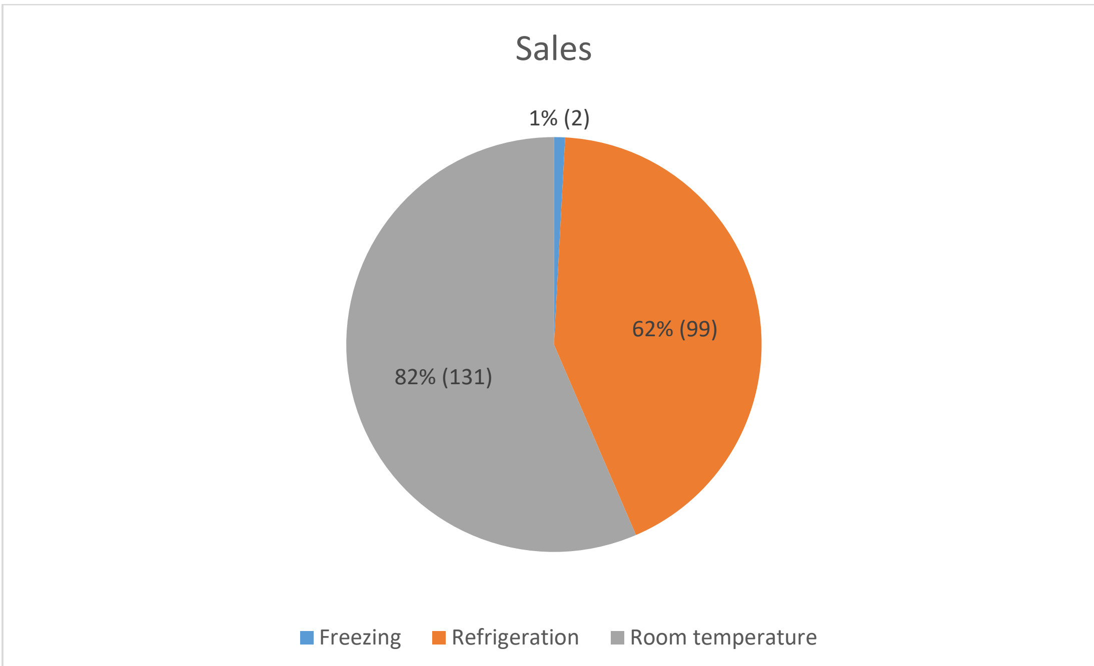

Figure 7. Fresh produce storage method before sale (N=159)

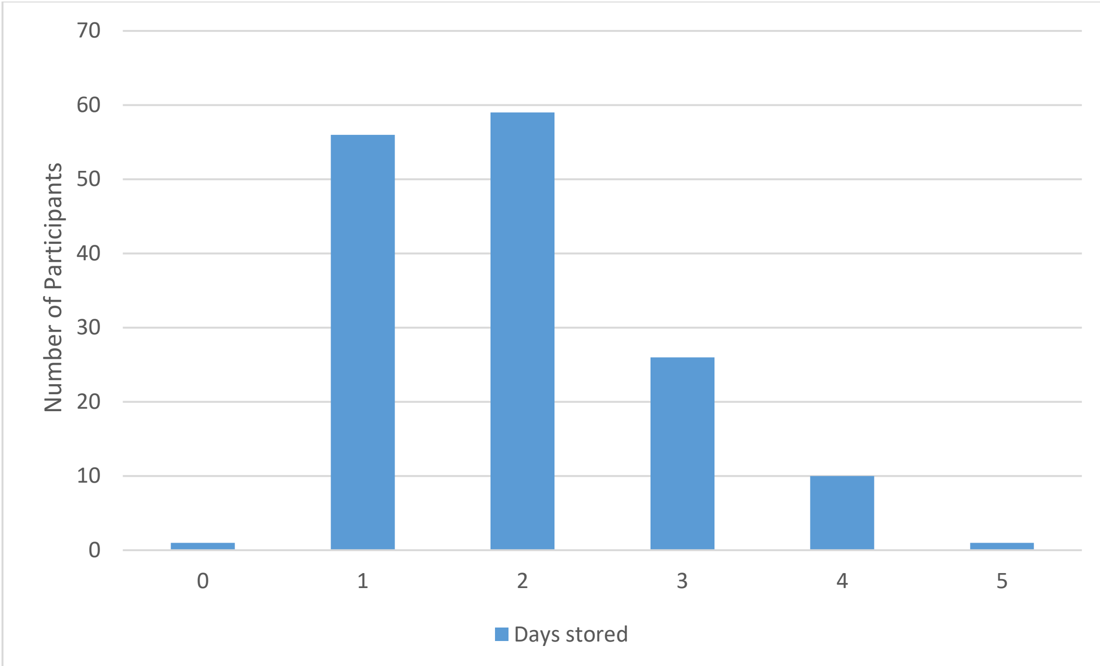

Figure 8. Number of days fresh produce stored before sale (N=159)

Participants were most likely to store fresh produce at room temperature, with 82.39% of participants reporting this means of storage. About 62% of participants reported refrigerating fresh produce before sale, while slightly more than 1% of participants chose to freeze produce before sale at farmers' markets. Fresh produce was most commonly stored for two days before sale at farmers' markets (38.56%), closely followed by 1 day (36.60%) and 3 days (16.99%). Participants who stored fresh produce for 1, 4, or 5 days together only accounted for just 7.84% of participants.

Participants in the current study were surveyed on their awareness of potential sources of contamination at farmers' markets (data not shown). Reported awareness of contamination sources at farmers' markets bore similarities to reported awareness of contamination sources on-farm in the current study. Of participants aware of GAPs, 69.6% correctly identified animals, 82.4% of participants identified workers' hands and clothing, 68.0% identified transport containers, and 76.8% of participants identified cross-contamination in storage, display, or preparation as possible sources of contamination at farmers' markets. A mere 38.4% of participants identified rinse and wash water, 34.4% identified ice, 32.8% identified cooling and refrigeration, and 58.4% identified transport vehicles as possible sourced of contamination at farmers' markets, raising concern that fresh produce grown on GAPs-compliant farms may still suffer contamination before sale to consumers.

Participants' Produce Washing Practices

Washing practices were highly utilized among respondents across all categories of land size (Table 9). Almost all respondents with 4 acres of land used for growing engaged in produce washing practices prior to sale at farmers' markets (96%), while this practice declined slightly for respondents who used 5-10 acres (85%) and of respondents who used more than 10 acres for growing (86%). Similarly, 83% of farmers who used 3 acres were likely to engage in washing practices, 85% of farmers who used 2 acres washed produce, and 79% of farmers who used 1 acre or less washed produce prior to sale. Washing practices were even higher in education categories, with 92% of respondents with a high school diploma or less reporting that they washed produce prior to sale, 83% of respondents with some college experience reporting that they washed produce prior to sale, and 85% of respondents with a college degree reporting that they washed produce prior to sale. Of the participants in the current study, only 33.9% chose to soak produce in a tub or container, while, 63.6% chose to spray produce with a hose, and 70.3% chose to rinse produce in a sink.

Rinsing and soaking fresh produce assist in preparing food for safe consumption, although they have not been shown to result in a complete removal of bacterial presence on the surface of fresh produce (Bolton, Crowe, & El-Begearmi, 2013). The findings of the current study compare with results from a 2013 survey of small-scale fresh produce growers in Maryland, in which 39.2% of participants washed produce by hand in a sink, with 47% of participants using pure water, just over 22% of participants washing produce with water containing a disinfectant, and almost 25% reporting not washing produce at all prior to sale (Marine et al, 2016).

Participants' Produce Washing Practices Correlated with Education Level

Table 9

Relationship between produce washing practices, education, and land used for growing.

	Land Used for Growing Produce							
GAP Practice	1 acre or less	2 acres	3 acres	4 acres	5-10 acres	> 10 acres	Total (n=150)	Chi2
Wash produce before selling at farmers' market	79 (15)	85 (29)	83 (20)	96 (23)	85 (33)	86 (12)		2.87

	Education				
	High School or Less	Some College	College Degree	Total	Chi2
	% (N)	% (N)	% (N)	% (N)	
Wash produce before selling at farmers' market	92 (23)	83 (52)	85 (56)	85 (131)	1.27

* = p < .05
** = p < .01
*** = p < .001

Table 10

Relationship between produce washing practices and education

Produce washing practice	High School or Less	Some College	College Degree	Total	Chi2
	% (N)	% (N)	% (N)		
Soak produce in tub or container	58 (14)	30 (16)	36 (21)	38 (51)	5.67
Spray produce with hose	58 (14)	62 (33)	69 (40)	64 (87)	1.02
Rinse produce in sink	50 (12)	70 (37)	76 (44)	69 (93)	5.33

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

Fifty-eight percent of respondents who had a high school diploma or less engaged in the practice of soaking produce in a tub or container, compared to 30% of respondents with some college experience and 36% of respondents with a college degree who engaged in the practice (Table 10). Fifty-eight percent of respondents reported washing produce by spraying it with water from a hose, 62% of respondents with some college experience utilized a hose, and 69% of respondents with a college degree washed produce with a hose. Washing produce in a sink was a more commonly practice, being reported by 50% of respondents with a high school diploma or less, 70% of respondents with some college experience, and 76% of respondents with a college degree.

Objective 2: Development and Evaluation of Fresh Produce GAPs Factsheets

Factsheet Evaluation Demographics

The factsheet evaluation was conducted at 2 farmers' markets in Barren and Warren County, Kentucky, and included 7 participants (Table 11). Two of the participants (29%) had some college education but did not hold a college degree, while 5 of the participants (71%) held a Bachelor's degree. Women were slightly more represented than men, with 4 female participants (57%) and 3 male participants (43%). A wide range of ages were represented among the participants, with 3 participants between 25 and 30 years of age, 2 participants between 40 and 50 years of age,

One participant was between 50 and 60 years of age, and 1 participant was 60 years of age or older. The demographic sample was overwhelmingly in favor of uncertified participants: Six of the participants (86%) did not hold GAPs certification, while 1 participant (14%) held certification. Participants were mixed on reported interest in further education on GAPs, with 3 participants (43%) indicating interest in further training while 4 participants (57%) indicated that they had no further interest in GAPs education. Five of the participants (71%) reported utilizing 2 acres of land for growing produce, and 2 participants (29%) reported utilizing 1 acre or less for growing.

Table 11

Demographics of Factsheet Survey Participants

Sex	**N**	**%**
Male	3	43
Female	4	57
Age		
18-25	0	0
25-30	3	43
30-40	0	0
40-50	2	29
50-60	1	14
60+	1	14
Highest Level of Education Completed		
Less than High School Diploma	0	0
High School Graduate/GED	0	0
Some College Credit, but no degree	2	29
AA/AS Program Graduate	0	0
BA/BS Program Graduate	5	71
Post-Graduate Education	0	0
Are you currently certified in GAPs?		
Yes	1	14
No	6	86
Would you be interested in training opportunities on GAPs or other on-farm food safety practices?		
Yes	3	43
No	4	57
How much land do you devote to growing produce sold at farmers' markets?		
1 acre or less	2	29
2 acres	5	71
3 acres	0	0
4 acres	0	0
5-10 acres	0	0
10+ acres	0	0

Each factsheet was evaluated using a survey with a series of knowledge questions. Participants were asked to self-report their knowledge in six areas on each commodity: general information, foodborne illness outbreak history associated with the commodity, knowledge of pathogenic behavior, harvest considerations, applicable Good Agriculture Practices, and storage and cooling conditions for the commodity. Participants were asked to complete the questions before reviewing the commodity factsheet, and asked to complete the questions again after reviewing the factsheet. Questions were answered on a 5-point Likert scale, with 1 = no knowledge, 2 = slightly knowledgeable, 3 = neutral, 4 = moderately knowledgeable, and 5 = extremely knowledgeable.

Factsheet Survey Responses

Survey data indicated that participants overwhelmingly found the factsheets informative, with knowledge gains indicated for all six commodities. Among responses for cucumbers, the greatest significant relationship ($p < .001$) was observed in the knowledge increase for harvest consideration (Table 12). Knowledge of foodborne illness outbreaks, pathogenic behavior, and Good Agricultural Practices also had significant increases ($p < .01$) as did general knowledge ($p < .05$). Melons (Table 13) saw a greater impact on participants, with significant increases ($p < .001$) for both pathogenic behavior and Good Agricultural Practices. A significant increase ($p < .01$) also emerged in foodborne illness outbreak history knowledge, while general commodity knowledge, harvest considerations, and storage and cooling condition knowledge increased at a smaller but still significant rate ($p < .05$). Spinach factsheets greatly increased participants' food safety knowledge, with significant increases ($p < .001$) in participants' knowledge in general commodity information, pathogenic behavior, harvest considerations, and Good Agricultural Practices (Table 14). Participants' knowledge on foodborne illness outbreaks associated with spinach also significantly increased ($p < .05$), as did their knowledge on storage and cooling conditions. Similar to the spinach factsheet, the sprout safety factsheet achieved notable knowledge increases among participants (Table 15). Foodborne illness outbreak history associated with sprouts, harvest considerations for sprouts, and storage and cooling conditions were the areas in which participants recorded the most significant increases ($p < .001$), while general commodity knowledge, pathogenic behavior on the commodity, and Good Agricultural Practices areas of knowledge also increased significantly ($p < .01$). Lettuce factsheets imparted the most significant increases ($p < .001$) in knowledge on Good Agricultural Practices, and further significant increases ($p < .01$) in knowledge on general commodity information, foodborne illness outbreak history, and pathogenic behavior were observed (Table 16). Harvest considerations and storage and cooling conditions for lettuce were two areas in which lesser but still significant knowledge increases ($p < .05$) emerged. Finally, tomato commodity knowledge among participants was also increased from the factsheets (Table 17), with foodborne illness outbreaks associated with tomatoes and Good Agricultural Practices for tomatoes being the two areas in which participants reported the most significant knowledge increases ($p < .001$). Survey data also showed significant knowledge gains ($p < .01$) among participants in pathogenic behavior on tomatoes and storage and cooling conditions for tomatoes, as well as general commodity information ($p < .05$).

Table 12

Cucumber Factsheet Evaluation Responses Before and After (N=7)

Survey Question	Mean Before	Mean After	Mean Difference
Q1: Please rate your knowledge on general information about the commodity.	3.57±.79	4.14±.69*	0.57
Q2: Please rate your knowledge on foodborne illness outbreaks associated with the commodity.	2.14±1.17	3.71±.95**	1.57
Q3: Please rate your knowledge of pathogenic behavior on the commodity.	1.71±1.11	3.57±1.27**	1.86
Q4: Please rate your knowledge on harvest considerations for the commodity.	2.71±1.11	3.85±1.07***	1.14
Q5: Please rate your knowledge on Good Agricultural Practices related to the commodity.	1.85±.76	4.00±1.00	2.15
Q6: Please rate your knowledge on storage and cooling conditions for the commodity	3.57±1.15	4.57±.53	1.00

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

Table 13

Melon Factsheet Evaluation Responses Before and After (N=7)

Survey Question	Mean Before	Mean After	Mean Difference
Q1: Please rate your knowledge on general information about the commodity.	3.14±1.35	4.14±.69*	1.00
Q2: Please rate your knowledge on foodborne illness outbreaks associated with the commodity.	2.71±1.11	4.29±.49**	1.58
Q3: Please rate your knowledge of pathogenic behavior on the commodity.	2.29±1.25	4.29±.49***	2.00
Q4: Please rate your knowledge on harvest considerations for the commodity.	2.71±1.25	4.00±.58*	1.29
Q5: Please rate your knowledge on Good Agricultural Practices related to the commodity.	2.14±.90	4.29±.49***	2.15
Q6: Please rate your knowledge on storage and cooling conditions for the commodity	3.14±1.35	4.29±.76*	1.15

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

Table 14

Spinach Factsheet Evaluation Responses Before and After (N=7)

Survey Question	Mean Before	Mean After	Mean Difference
Q1: Please rate your knowledge on general information about the commodity.	2.71±1.11	3.57±.69***	0.86
Q2: Please rate your knowledge on foodborne illness outbreaks associated with the commodity.	2.57±1.51	4.00±1.00*	1.43
Q3: Please rate your knowledge of pathogenic behavior on the commodity.	1.71±.49	4.00±.58***	2.29
Q4: Please rate your knowledge on harvest considerations for the commodity.	2.14±.69	3.86±69***	1.72
Q5: Please rate your knowledge on Good Agricultural Practices related to the commodity.	2.00±.82	3.86±.69***	1.86
Q6: Please rate your knowledge on storage and cooling conditions for the commodity	3.43±1.13	4.29±.76*	0.86

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

Table 15

Sprouts Factsheet Evaluation Responses Before and After (N=7)

Survey Question	Mean Before	Mean After	Mean Difference
Q1: Please rate your knowledge on general information about the commodity.	2.00±1.15	3.86±.90**	1.86
Q2: Please rate your knowledge on foodborne illness outbreaks associated with the commodity.	1.71±1.11	4.14±.90***	2.43
Q3: Please rate your knowledge of pathogenic behavior on the commodity.	1.86±1.07	3.71±.49**	1.85
Q4: Please rate your knowledge on harvest considerations for the commodity.	1.43±.79	4.00±.58***	2.57
Q5: Please rate your knowledge on Good Agricultural Practices related to the commodity.	1.57±1.13	4.00±.58**	2.43
Q6: Please rate your knowledge on storage and cooling conditions for the commodity	1.57±.79	4.00±.82***	1.43

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

Table 16

Lettuce Factsheet Evaluation Responses Before and After (N=7)

Survey Question	Mean Before	Mean After	Mean Difference
Q1: Please rate your knowledge on general information about the commodity.	2.86±1.22	3.57±.69**	0.71
Q2: Please rate your knowledge on foodborne illness outbreaks associated with the commodity.	2.71±1.11	4.29±.49**	1.58
Q3: Please rate your knowledge of pathogenic behavior on the commodity.	2.43±1.13	4.14±.38**	1.71
Q4: Please rate your knowledge on harvest considerations for the commodity.	2.57±1.27	4.14±.38*	1.57
Q5: Please rate your knowledge on Good Agricultural Practices related to the commodity.	2.00±.82	4.14±.38***	2.14
Q6: Please rate your knowledge on storage and cooling conditions for the commodity	2.86±1.35	4.29±.76*	1.43

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

Table 17

Tomatoes Factsheet Evaluation Responses Before and After (N=7)

Survey Question	Mean Before	Mean After (P-value)	Mean Difference
Q1: Please rate your knowledge on general information about the commodity.	3.14±.90	4.14±.38*	1.00
Q2: Please rate your knowledge on foodborne illness outbreaks associated with the commodity.	2.29±1.11	4.00±.82***	1.71
Q3: Please rate your knowledge of pathogenic behavior on the commodity.	2.29±.95	3.57±.79**	2.28
Q4: Please rate your knowledge on harvest considerations for the commodity.	3.14±1.07	4.29±.49	1.15
Q5: Please rate your knowledge on Good Agricultural Practices related to the commodity.	2.57±.98	4.14±.69***	1.57
Q6: Please rate your knowledge on storage and cooling conditions for the commodity	3.14±1.07	4.14±.69**	1.00

* = p < .05
** = p < .01
*** = p < .001

Chapter V: Conclusion and Recommendations

The present survey of food safety knowledge and on-farm practices returned mixed results, indicating a wide range of food safety practices and perceptions among small-scale Kentucky farmers. The conclusions of the present study are divided based on hypothesis.

1) Concerning the present study's first hypothesis that small-scale farmers in Kentucky did not understand the specifics of GAPs beyond a general awareness, the data was conclusively supportive. In general, respondents appeared to have a limited understanding of food safety practices. Survey responses indicated that respondents possessed a limited understanding of pathogenic behavior in environments found on small-scale farm operations, including vectors of contamination in water, soil, manure, transportation, and other sources. Additionally, most participants were unaware of portions of GAPs, such as water quality and manure and biosolids management. The study also found that obstacles perceived by small-scale farmers to be barriers to GAPs certification that prevented wider acceptance of food safety practices. The reported perception of cost and time as barriers to certification suggest that food safety educators in Kentucky must overcome these perceptions to increase acceptance of GAPs among small-scale Kentucky farmers. The findings support the conclusion that further educational outreach to small-scale Kentucky farmers is needed to ensure safer fresh produce in the farmer's market farm-to-fork supply chain in Kentucky. The data supports the conclusion that the present study's hypotheses relating to

small-scale Kentucky farmers' knowledge on food safety is correct: While general awareness of GAPs was high among respondents, there was a considerable lack of knowledge about GAPs compliance and requirements, as well as fresh produce safety on-farm and while for sale at farmers' markets. Thus, this hypothesis was supported by the research.

2) The utilization of GAPs reported by respondents in the survey indicated limited general usage of GAPs with some severe deficiencies, particularly in water usage and soil safety practices. While most participants did report usage of portable sanitary facilities, for example, a majority of the participants did not manage water quality by engaging in regular testing and irrigation and post-harvest water. Combined with participants' insufficient knowledge of potential routes of microbiological contamination on-farm and at the market, the data supports the conclusion that small-scale farmers in Kentucky are unknowingly engaging in a wide variety of farm management practices that are failing to mitigate microbiological contamination in fresh produce.

3) The success of the factsheet evaluation in the present study demonstrated the potential success that free, easily-distributed educational handouts can have among farmers who are receptive to education on GAPs. Among the study sample, the factsheets were highly effective at conveying important commodity-specific food safety facts, and the factsheets are cheaply produced and easily distributed online or in printed form, making them an effective response to farmers' reported interest in educational materials. The data collected from the factsheet evaluation survey indicates that commodity-specific factsheets are a

highly effective and efficient way to educate small-scale Kentucky farmers on fresh produce safety and GAPs.

Future Research

While the present study sheds light on small-scale Kentucky farmers' practices throughout the farm-to-fork practice, food safety practices must continue after the sale of fresh produce to ensure minimal foodborne illness risk. However, at present consumer safety practices in handling, storage, and consumption of fresh produce are unknowns in the state of Kentucky. Further research could address the deficit of knowledge regarding consumer perceptions, practices, and knowledge of safe fresh produce handling.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD
OFFICE OF RESEARCH INTEGRITY

DATE:	August 13, 2013
TO:	Hanna(John) Khouryieh
FROM:	Western Kentucky University (WKU) IRB
PROJECT TITLE:	[500751-1] An Integrated Approach to Enhance the Safety of Locally Grown Fresh Produce Through Research and Extension
REFERENCE #:	IRB 14-022
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	August 13, 2013
REVIEW TYPE:	Exempt from Full Board Review

Thank you for your submission of New Project materials for this project. The Western Kentucky University (WKU) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Exempt from Full Board Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by an *implied* consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Paul Mooney at (270) 745-2129 or irb@wku.edu. Please include your project title and reference number in all correspondence with this committee.

- 1 -

Generated on IRBNet

Hello:

We are conducting a short, 10 minute survey on **good agricultural practices** used by farmers who sell produce at local farmers' markets. We would greatly appreciate your time and efforts completing our short survey. Completing this questionnaire is completely voluntary, and you may withdraw your participation at any time without penalty. To protect your anonymity, please do not write your name on the survey instrument. By completing this survey instrument, you are providing your informed consent to participate in this research and you also are affirming that you are at least 18 years of age. If you have any questions, please do not hesitate to let us know. Thank you again for your assistance.

1. Have you heard of good agricultural practices (GAPs)?

☐ Yes
☐ No

2. What is the location/source of the produce you have with you at the farmers' market today:

☐ All of the produce was grown on my farm

☐ Some of the produce was grown on my farm

☐ None of the produce was grown on my farm (if this option is selected, please skip to question 16)

3. In which county is your farm located?

☐ Jefferson ☐ McCracken
☐ Fayette ☐ Floyd
☐ Warren ☐ Jackson
☐ Hardin ☐ Rowan
☐ Daviess ☐ Lewis

☐ Other: Please specify___________________

4. Approximately how much land do you devote to growing produce sold at farmers' markets?

☐ 1 acre or less
☐ 2 acres
☐ 3 acres
☐ 4 acres
☐ 5-10 acres
☐ More than 10 acres

5. How many years have you been growing produce to sell at farmers' markets?

☐ Less than 5 years
☐ 6 to 10 years
☐ 11 to 20 years
☐ More than 20 years

6. What type of produce do you grow? (please place a check mark next to all items that apply)

☐ Leafy vegetables (such as lettuce, spinach)

☐ Fruits grown on bushes or trees (such as blueberries, blackberries, and apples)

☐ Root vegetables

☐ Fruits grown on or near the ground (such as cantaloupe, strawberries, and other melons)

☐ Other vegetables (such as tomatoes, cucumbers)

☐ Others: **If others please specify:**

____

7. What type of fertilizer(s) do you use? (check all that apply)

☐ Synthetic fertilizer
☐ Non-composted manure
☐ Composted manure
☐ Mixture of composted & non-composted manure
☐ Other natural fertilizers

8a. Do you use composted manure?

☐ No: If "no" – skip to question 9
☐ Yes: If "yes", please answer 8b, 8c & 8d

8b. For how many months do you compost it?

Specify number of months: ________________

8c. What is the source of your manure?

☐ Chicken
☐ Horse
☐ Cattle
☐ Pigs
☐ Others, please specify___________.
☐ I do not use livestock manure

8d. After manure has been applied, how many months do you wait before harvesting your produce?

Specify number of months: ________________

9. Do you use insecticides to kill bugs on your farm?

☐ Don't know
☐ No
☐ Yes: **If yes, what kinds?**

____

10. What is your source of irrigation water?

☐ Tested Well Water
☐ Untested Well Water
☐ Municipal/Water District
☐ Surface Water
☐ Rainwater
☐ Other: Please write: ____________

11. Do you have employees working on your farm?

☐ Yes: If yes, go to question 12.
☐ No: If no, go to question 13.

12. Do your employees have access to the following facilities near the harvesting area on your farm?

a. Toilet Facilities
☐ Yes
☐ No

b. Hand-washing facilities
☐ Yes
☐ No

c. Soap or other sanitizers at hand-washing facilities
☐ Yes
☐ No

13. Which of the following good agricultural practices (GAPs) do you use on your farm? (check all that apply)

☐ Managing Water Quality
☐ Managing Manure & Municipal Bio-Solids
☐ Worker Health and Hygiene
☐ Sanitary Facilities
☐ Field Sanitation
☐ Packing Facility Sanitation
☐ Transportation
☐ I choose not to implement GAPs

14. What are some obstacles which may prevent you from implementing GAPs on your farm? (check all that apply)

☐ Cost
☐ Not enough time
☐ Technical solutions do not exist
☐ Money invested not worth return
☐ Not sure how to prioritize GAPs
☐ Lack of training opportunities
☐ Lack knowledge of GAPs
☐ Other (please write): ______________

15. Which of the following do you think are potential sources of microbiological contamination on your farm? (please check all sources that apply)

☐ Soil
☐ Irrigation water
☐ Animal manure
☐ Inadequately composted manure
☐ Wild and/or domestic animals walking through your farm
☐ Workers clothing and hands
☐ Harvesting equipment
☐ Transport containers
☐ Produce wash and rinse water
☐ Ice
☐ Refrigeration or cooling
☐ Transport vehicles
☐ Cross-contamination in storage, display or preparation

16. How many years have you been selling produce at farmers' markets?

☐ Less than 5 years
☐ 6 to 10 years
☐ 11 to 20 years
☐ More than 20 years

17. Do you usually wash produce before selling it at the farmers' market?

☐ No – if no, please skip to question # 21
☐ Yes

18. Which method(s) do you use to wash your produce? (check all that apply)

☐ Soak produce in a tub or other container
☐ Spray produce with a hose
☐ Rinsing in a sink
☐ Other: ____________________

19. Do you add sanitizer to your wash/rinse water?

☐ No
☐ Yes: **If yes, what kind? Please write on the line below.**

____

20. How often do you change your sanitized water during produce washing/rising?

☐ Never
☐ Within 4 hours of first use
☐ Between 4 and 12 hours of first use
☐ Between 13 and 24 hours of first use

21. What kind(s) of containers do you use to <u>present your produce</u> at the market? (check all that apply)

☐ Wood
☐ Plastic
☐ Metal
☐ Paper
☐ Other: (Please write: ______________)

22. What kind(s) of containers do you use for <u>storage/transport of your produce</u>? (check all that apply)

☐ Wood
☐ Plastic
☐ Metal
☐ Paper
☐ Other: please write: _____________

23. Do you wash your storage containers between visits to the farmers' market?

☐ No
☐ Yes - **If yes, do you sanitize your containers?**

☐ No
☐ Yes: **If yes, please specify the type(s) of sanitizer you use:**

____

24. How do you store your produce before transporting it to the farmers' market? (check all that apply)

☐ I freeze my produce
☐ I store my produce at refrigerated temperatures
☐ I store my produce at room temperature

25. How many days do you keep your produce in storage before selling it at the farmers' market?

Specify number of days: ___________

26. Which of the following do you think are potential sources of microbiological contamination at the market? (please check all sources that apply)

☐ Wild and/or domestic animals walking through the market
☐ Workers clothing and hands
☐ Transport containers
☐ Produce wash and rinse water
☐ Ice
☐ Refrigeration or cooling
☐ Transport vehicles
☐ Cross-contamination in storage, display or preparation

27. Which of the following bacteria do you think can be transmitted from fresh fruits and vegetables? (check all that apply)

☐ Shiga Toxin Producing E. coli
☐ Salmonella
☐ Listeria monocytogenes
☐ Staphylococcus aureus

28. Would you be interested in training opportunities on good agricultural practices (GAPs) or other on-farm food safety practices?

☐ No
☐ Yes. **If yes, which types of educational or training materials do you prefer?**

☐ Workshops
☐ Brochure Materials
☐ Website
☐ Webinar
☐ Online training videos
☐ Other (please specify):

____

29. What is your gender?

☐ Male
☐ Female

30. What is your highest degree or level of education that you have completed?

☐ Less than High School Diploma
☐ High School Graduate / GED
☐ Some College Credit, but no Degree
☐ AA/AS Program Graduate
☐ BA/BS Program Graduate
☐ Post-Graduate Education

31. In what year were you born?

____

Thank you for completing our survey.

APPENDIX B

Fresh Produce Safety Factsheet Evaluation

Western Kentucky University

Thank you for participating in the 2016 Western Kentucky University study on GAPs knowledge among small-scale Kentucky farmers. We greatly appreciate your time and efforts. As part of this study, informational factsheets have been developed on fresh produce commodities. The objective of the present project is to administer the informational factsheets to small-scale farmers and vendors in Kentucky farmers markets, and gain feedback to assess the effectiveness of the factsheets. Your participation in this objective is appreciated.

Please complete the complete the assessment questions below and the demographic questions on the reverse side of this evaluation form. To protect your confidentiality, **please do not write your name on this form**. Your participation in the present study will be entirely confidential and you will not be identified in any way throughout the study. You may withdraw your participation at any time without penalty. By completing this survey instrument, you are providing your informed consent to participate in this research, and you affirm that you are at least 18 years of age.

Please check the appropriate box.

1. **What is your age?**

☐ 18 – 25
☐ 25 – 30
☐ 30 – 40
☐ 40 – 50
☐ 50 – 60
☐60+

2. **What is your gender?**

☐ Male
☐ Female

3. **What is your highest degree or level of education that you have completed**

☐ Less than High School/Diploma
☐ High School Graduate/GED
☐ Some College Credit, but no Degree
☐ AA/AS Program Graduate
☐ BA/BS Program Graduate
☐ Post-Graduate Education

4. **Approximately how much land do you devote to growing produce sold at farmers' markets?**

☐ 1 acre or less
☐ 2 acres
☐ 3 acres
☐ 4 acres
☐ 5-10 acres
☐ More than 10 acres

5. **Are you currently certified in Good Agricultural Practices (GAPs)?**

☐ Yes
☐ No

6. **Would you be interested in training opportunities on GAPs or other on-farm food safety practices?**

☐ Yes
☐ No

Please circle the commodity factsheet you are evaluating:

Tomatoes · Spinach · Lettuce · Melons · Cucumbers · Sprout

Please answer the following questions BEFORE reading the factsheet. For each question, place a check in the appropriate box.	1 No Knowledge	2 Slightly Knowledgeable	3 Neutral	4 Moderately Knowledgeable	5 Extremely Knowledgeable
Please rate your knowledge on general information about the commodity.					
Please rate your knowledge on foodborne illness outbreaks associated with the commodity.					
Please rate your knowledge of pathogenic behavior on the commodity.					
Please rate your knowledge on harvest considerations for the commodity.					
Please rate your knowledge on Good Agricultural Practices related to the commodity.					
Please rate your knowledge on storage and cooling conditions for the commodity					

Please answer the following questions AFTER reading the factsheet. For each question, place a check in the appropriate box.	1 No Knowledge	2 Slightly Knowledgeable	3 Neutral	4 Moderately Knowledgeable	5 Extremely Knowledgeable
Please rate your knowledge on general information about the commodity.					
Please rate your knowledge on foodborne illness outbreaks associated with the commodity.					
Please rate your knowledge of pathogenic behavior on the commodity.					
Please rate your knowledge on harvest considerations for the commodity.					
Please rate your knowledge on Good Agricultural Practices related to the commodity.					
Please rate your knowledge on storage and cooling conditions for the commodity					

Do you have any additional comments?

____

____

Good Agriculture Practices for Cucumbers

Western Kentucky University

General Information

Cucumbers, a member of the same family as pumpkins and gourds, are primarily eaten raw or pickled. A native of India, cucumbers were grown in North America as early as the 16th century by European settlers.

Cucumbers grow best during summer and cannot tolerate cold. For best flavor, cucumber harvest should occur when they are 6-8 inches long and 1-2 inches in diameter.

Harvest Considerations

Because cucumbers are pollinated by bees are differing times, multiple harvests will occur during a growing season.

A clean, sterilized knife should be used to harvest cucumbers. After cutting, cucumbers should be moved to a cool environment immediately.

Workers should wash hands regularly during the harvest. If possible, workers should also use sterile disposable gloves while handling cucumbers. Any workers who display symptoms of illness, such as fever or coughing, should be immediately removed from the cucumber production area. Additionally, any worker with open wounds, cuts, or bruises should be excluded from handling fruit.

Use of single-use containers should be avoided, if possible. Disposable container liners are preferable. If containers are reused, they should be cleaned and sanitized after each use.

Foodborne Illness Outbreaks

Several large-scale foodborne illness outbreaks have been attributed to cucumbers. In 2015, an outbreak of *Salmonella* from imported cucumbers sickened 767 consumers. The outbreak caused 157 hospitalizations occurred and 4 deaths. In 2014, cucumbers contaminated with *Salmonella* caused 275 illnesses in 29 states, with 1 death.

Bacteria	Year	Food Vehicle	Location	States Affected	Illnesses	Deaths
Salmonella	2015	Cucumbers	US	36	767	4
Listeria	2014	Cucumbers	US	29	275	1
Non-O157 STEC	2013	Cucumbers	US	9	84	1

Table 1. Selected Foodborne Illness Outbreaks Attributed to Cucumbers, 2013-Present (Outbreak Database, 2015

Cooling and Storage Conditions:

Cucumbers are best stored at approximately 12°C (55°F) with high humidity. Cucumbers should be chilled immediately to remove all field heat, to protect flavor and shelf life. Cucumbers should not be washed before being stored. They may be stored in plastic bags or wrapped in plastic to help preserve moisture content.

Produce	Optimal Storage Temp., °C	Optimal Humidity (%)	Cooling with top ice acceptable	Cooling with water sprinkle acceptable	Ethylene Production	Ethylene Sensitivity to	Storage Life
Cucumbers	10-15	95	No	Yes	Very Low	Yes	10-14 Days

Table 2. Storage and Cooling Conditions for Cucumber (Fellow, 2000)

Good Agriculture Practices

- Cool cucumbers immediately after harvesting to remove field heat.
- If pruning of cucumber plants is necessary, green trimmings should be removed from field.
- Regularly inspect cucumber plants for signs of wildlife intrusion.
- Use a clean and sanitized knife to cut ripe cucumbers from vine.
- Ensure water used is of sufficient microbial quality level (e.g. EPA drinking water standards).
- Inspect seedlings for signs of disease before planting.

Pathogenic Behavior

Feces in a cucumber production field can easily transfer pathogens to cucumber plants and fruits, contaminating the cucumbers. Exclusion of domestic and wild animals from the field is critical to prevent transmission of pathogens. Irrigation water is another leading cause of cucumber contamination, particularly where feedlots or concentrated animal feeding operations may be in the vicinity of the cucumber field. Unsanitary conditions also contribute heavily to cucumber contamination, as human pathogens can easily be transferred from workers to fruit. All workers must observe hygienic and sanitary practices.

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This document was prepared by: Daniel Sinkel, Graduate Student, John Khouryien, Assistant Professor of Food Processing and Technology, Martin Stone, Associate Professor of Horticulture, Western Kentucky University, Bowling Green, KY 42101.

This food safety factsheet can be downloaded at http://www.wku.edu/agriculture/index.php

Good Agriculture Practices for Lettuce

Western Kentucky University

WKU

General Information

- Two categories: Head (iceberg) and leaf
- Lettuce is third-most consumed vegetable in United States
- Americans consume more than 14 pounds of head lettuce and 10 pounds of leaf lettuce per capita annually

Harvest Considerations

• Growers should implement sanitation policies for knives used in cutting lettuce, as well as for knife scabbards and other tools.

• Consider using single-use liners for containers.

• Soiled containers should not be stacked on top of another.

• Cut surfaces on lettuce should never be allowed to contact soil or other unsanitized surfaces.

• Harvesters should immediately wash cut surfaces of lettuce with FDA-approved sanitizing agent, not chlorine.

• Workers harvesting lettuce should have access to handwashing stations, and also use clean gloves during harvest.

Foodborne Illness Outbreaks

Microbial contamination of leafy green vegetables, including lettuce, is attributed to 22% of foodborne illness outbreaks in the United States annually. Lettuce has been responsible for a number of recent large foodborne illness outbreaks, including a 2013 case in Arizona which caused 59 illnesses. In 2010, 114 consumers in Illinois were sickened by *Salmonella* after consuming lettuce. Table 1 shows notable foodborne illness outbreaks attributed to lettuce since 2010:

Bacteria	Year	Food Vehicle	Location	States Affected	Illnesses	Deaths
E.coli O157:H7	2013	Lettuce	Arizona	1	35	0
E.coli O157:H7	2012	Lettuce	International	1	28	0
E.coli O157:H7	2011	Lettuce	Missouri	5	58	Unknown
Norovirus	2010	Lettuce	International	Unknown	260	0

Table 1. Selected Foodborne Illness Outbreaks Attributed to Lettuce, 2010-Present (Outbreak Database, 2015)

Storage and Cooling Conditions

Lettuce is best maintained as close to 0°C as possible. Because of lettuce's large water content, a high humidity level is preferable. Lettuce is highly sensitive to ethylene and will decay if not isolated from high ethylene-producing produce in storage. Figure 2 indicates ideal storage conditions:

Produce	Optimal Storage Temp., °C	Optimal Humidity (%)	Cooling with top ice acceptable	Cooling with water sprinkle acceptable	Ethylene Production	Ethylene Sensitivity to	Storage Life
Lettuce	0	98-100	No	Yes	No	Yes	2-3 Weeks

Table 2. Storage and Cooling Conditions for Lettuce (Fellow, 2000)

Good Agriculture Practices (FDA, 2006)

- Develop and implement procedures for preventing pest infestation in irrigation pipe and drip tape.
- Ensure that water used in all pre- and post- harvest applications meets microbial water standards. This includes water used for hydrovac cooling.
- Any cooling equipment used on lettuce should be cleaned and sanitized regularly.
- Never use raw animal manure on or near lettuce.
- Chlorine is insufficient to kill pathogens in lettuce latex after cutting and coring. A stronger FDA-approved sanitizing agent should be used.

Pathogenic Behavior in Commodity

Typical cleaning practices are incapable of completely eliminating bacteria from surface-contaminated produce. The only way to eliminate contamination is to prevent pathogens from coming into contact with lettuce during the entire farm-to-fork process. Pathogens can easily be splashed onto plants from soil or transferred by human or animal contact. Dried manure can also be wind-blown onto plants, and *Salmonella* has been shown to be resistant to drying. Noroviruses are another concern for lettuce. Noroviruses are the most common foodborne disease and are often found in lettuce. Norovirus is significantly smaller than bacteria, and has been shown to be capable of transferring up into the lettuce plant from the roots.

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Good Agriculture Practices for Melons

Western Kentucky University

WKU

General Information

Commonly consumed melons include cantaloupe, honeydew, and watermelon. Melons have a rich, vibrant taste and great nutritional benefits, making them a popular fresh produce that is often eaten raw in salads, desserts, or by themselves.

Melons are highly susceptible to microbial contamination, particularly varieties of melons with netted rinds. Extra caution must be taken during all stages of growth, harvest, and storage of melons to ensure that contamination is prevented.

Harvesting Tips

Melons which appear to have been disturbed by animals should be excluded from harvest. Additionally, any melons which have been exposed to pooled water should also be excluded from harvest, as pooled water can collect pathogens and allow bacteria to transfer to fruit.

Because melons have a high weight, the rind is vulnerable to machine damage or damage from being dropped. If pathogens have collected on the rind, they can easily enter the fruit if the rind is cracked. Extra care should be taken to ensure that fruit are carefully harvested with no damage, and damaged fruit should be excluded.

Cleaning the rind of melons is important for removing any pathogens which may have been transferred to the surface of a melon. Surface dirt should be first removed, after which a melon should be scrubbed with a clean produce brush. Water used for cleaning melons, including scrubbing, should be in accordance with GAPs post-harvest microbial quality. All tools, surfaces, containers, brushes, and other equipment used for the harvesting of melons should be sanitized between uses to prevent spread of bacteria.

Notable Foodborne Illness Outbreaks Linked to Melons, 2006-Present (Outbreak Database, 2015)

Between 1996 and 2008, 507 illnesses and 2 deaths were attributed to contaminated melons. Several notable foodborne illness outbreaks caused by melons occurred in 2011. A *Salmonella outbreak* severely affected the state of Kentucky, causing 8 deaths. A *Listeria* outbreak in the same year from melons produced in Colorado resulted in 133 illnesses, 33 deaths, and 1 miscarriage, making it one of the deadliest recorded foodborne illness outbreaks in American history.

Bacteria	Year	Food Vehicle	Location	States Affected	Illnesses	Deaths
Salmonella	2012	Cantaloupe	Indiana	11	261	3
Listeria	2011	Cantaloupe	Colorado	12	147	33
Salmonella	2011	Cantaloupe	Guatemala	6	20	0
Norovirus	2008	Melons	California	1	23	0
Salmonella	2008	Cantaloupe	International	8	53	0
Salmonella	2007	Honeydew	New Jersey	4	26	0
Salmonella	2006	Melons	International	6	41	0

Table 1. Selected Foodborne Illness Outbreaks Attributed to Melons, 2006-Present (Outbreak Database, 2015)

Good Agriculture Practices for Spinach

Western Kentucky University

General Information

Spinach is a leafy green vegetable commonly consumed in the United States as a raw agricultural commodity, and is found in raw form in many salads and sandwiches. Spinach is classified into three categories: Smooth leaf, savoy, and red veined. Spinach grows quickly and prefers cool temperatures between 45° - 75°F.

Harvest Considerations

- Workers harvesting lettuce by hand should always have access to handwashing facilities, and should wash their hands regularly to prevent cross-contamination.
- The use of sterile disposable gloves is advisable.
- Cut surfaces of spinach should be never allowed to directly contact soil.
- Tools, knives, knife scabbards, and containers should be sanitized between cuts of spinach.
- Any spinach displaying signs of bruising, decay or contamination should be excluded from harvest.

Foodborne Illness Outbreaks

Of all fresh produce, leafy green vegetables, including spinach, cause the most illnesses in the United States. In 2006, an outbreak of *E.coli* from uncooked spinach caused 3 deaths, 31 cases of kidney failure, and 199 cases of dehydration due to diarrhea, across 26 states. In 2012, an outbreak of *E.coli* 0157:H7 from spinach produced in Massachusetts sickened 33, 2 of whom developed hemolytic uremic syndrome.

Bacteria	Year	Food Vehicle	Location	States Affected	Illnesses	Deaths
E.coli O157:H7	2008	Spinach	US	N/A	13	0
Salmonella	2007	Spinach	US	N/A	76	Unknown
E.coli O157:H7	2006	Spinach	International	14	238	5
E.coli O157:H7	2003	Spinach	California	1	46	2

Table 1. Selected Foodborne Illness Outbreaks Attributed to Spinach, 2010-Present (Outbreak Database, 2016)

Pathogenic Behavior on Commodity

Like most produce, damaged skin on spinach can lead to greater risk of contamination. Pathogen cells prefer to collect on portions of spinach leafs which are damaged, as pathogens thrive off of nutrients leaked from the interior tissue of the leaf. Additionally, when pathogenic cells have access to damaged portions of leafs, they can spread to the interior of the leaf and render postharvest cleaning procedures ineffective. Water splash, direct soil contact, uncleaned preparation surfaces, and human touch are the greatest contamination risks to spinach. Studies have shown that bacteria multiply on damaged leafs at optimal growing temperatures, but do not grow on undamaged leafs.

Cooling and Storage Conditions for Commodity

Spinach is extremely perishable and will deteriorate quickly in warm conditions, with an accelerated loss of the folate and carotenoid content which contributes to its nutritional value. Spinach is ideally maintained in storage close to 32°F or 0°C, with high humidity levels. Cooling with top ice is permissible.

Produce	Optimal Storage Temp., °C	Optimal Humidity (%)	Cooling with top ice acceptable	Cooling with water sprinkle acceptable	Ethylene Production	Ethylene Sensitivity to	Storage Life
Spinach	0	95-100	-	-	No	-	10-14 Days

Table 2. Storage and Cooling Conditions for Spinach (Fellow, 2000)

Good Agriculture Practices

- Test water periodically to assure that it is of appropriate microbial quality (e.g., meets U.S. EPA or WHO microbial standards for drinking water).
- Monitor and minimize domestic animal and wildlife activity in lettuce/leafy greens fields.
- Clean and sanitize ice-making equipment routinely
- Sanitize and clean cooling equipment on regular basis.
- Spinach placement and storage should not facilitate cross-contamination.
- Ensure workers follow sanitation protocol and never allow sick workers to handle spinach.
- Inspect all equipment in spinach production to ensure that no biofilm accumulation has occurred.

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Good Agriculture Practices for Sprouts

Western Kentucky University

WKU

General Commodity Information

Sprouts are a common fresh produce to be consumed raw. Sprouts are used to add flavor to complex foods like salads, soups, and other dishes. Additionally, sprouts contain a wide variety of essential nutrients. However, unless proper equipment and procedures are used to grow sprouts, microbial contamination can easily occur. The FDA recommends the sprouts should always be cooked before consumption. Furthermore, the FDA advises that sprouts should not be consumed by the very young, the very old, or anyone with a compromised immune system.

Harvesting Considerations

Growers should clean and sanitize any surfaces that sprouts may come into contact with, and growers should always wash their hands before and after handling the plants. After germination, sprouts should be handled carefully. Growers should not touch sprouts directly with bare hands, but instead use sanitary disposable gloves. Adequate sanitary facilities and bathrooms should be provided to all workers so that handwashing can be performed adequately. Workers who are sick or exhibit symptoms of sickness should be excluded from handling sprouts. When the sprouts are packed and prepared for transport, food grade packing materials should be used, and lot/batch numbers with grower's contact information should be placed on packaging. If sprouts are stored after harvest, they should be stored at a temperature of 41°F/5°C or less, although 32 °F/0 °C is ideal.

Foodborne Illness Outbreaks

Sprouts present a unique risk to consumers, because they require humidity and warmth to grow. These same conditions are ideal for pathogens such as *Salmonella, Listeria*, and *E.coli* O157:H7. Bacteria can infect internally infect seeds and multiply to high levels during sprouting. In one notable outbreak in 2009, *Salmonella* Saintpaul in alfalfa sprouts sickened 235 consumers in 14 states. A 1996 outbreak of *E.coli* in Japan from sprouts sickened 10,000, primarily students and teachers who consumed the sprouts in school meals. 12 of the sickened consumers later died. With more than 30 foodborne illness outbreaks occurring from sprouts between 1996 and 2009, alfalfa sprouts are a produce of concern to small-scale farmers.

Bacteria	Year	Food Vehicle	Location	States Affected	Illnesses	Deaths
Salmonella	2014	Sprouts	US	11	115	0
Listeria	2014	Sprouts	US	2	5	2
Non-O157 STEC	2014	Sprouts	US	5	19	0

Table 1. Selected Foodborne Illness Outbreaks Attributed to Sprouts, 2014 (Outbreak Database, 2015)

Cooling and Storage Conditions:

Immediately after harvesting, sprouts should be cooled to 32 °F, or 0 °C. Sprouts are an extremely perishable raw agricultural commodity and should be sold and consumed within 10 days of harvest. Hydro-cooling, forced-air, and vacuum cooling are permissible, but misting is not.

Produce	Optimal Storage Temp., °C	Optimal Humidity (%)	Cooling with top ice acceptable	Cooling with water sprinkle acceptable	Ethylene Production	Ethylene Sensitivity to	Storage Life
Sprouts	0	95-100	No	Yes	Minimal	N/A	5-10 Days

Table 2. Storage and Cooling Conditions for Sprouts (DeEll, 2014)

Good Agriculture Practices

- Sprout producers should conduct microbiological testing of spent irrigation water from each production lot to ensure that contaminated product is not distributed.
- Any workers who handle sprouts should routinely wash hands and/or use disposable sterile gloves.
- During seed treatment, prior to sprouting, seeds should be cleaned with water which has been tested for microbial quality.
- Just prior to sprouting, seeds should be subjected to one or more treatments that can effectively reduce or eliminate pathogenic bacteria (e.g. 20,000 ppm calcium hypochlorite).
- Raw materials and other ingredients should be inspected upon receipt to ensure they are clean and suitable for processing into food. Bags of seed which have been contaminated with rodent urine will glow when viewed using a blacklight.

Pathogenic Behavior in Commodity

Growing conditions contribute to the risk of microbial contamination in sprouts. Pathogens can enter sprout seeds through small cracks, contaminating the interior. To sprout and grow, sprout seeds require a combination of humidity and warmth comparable to ideal growing conditions for harmful bacteria. Consequently, sprouts often harbor pathogens which grow internally in the plant and are later consumed with the produce. According to the FDA (2015), contaminated seeds are responsible for the vast majority, if not all, of foodborne illness outbreaks attributed to sprouts. Microbial contamination of sprouts is difficult to eradicate, however, as pathogens can endure months of dry storage, which is common for sprout seeds.

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Good Agriculture Practices for Tomatoes

Western Kentucky University

WKU

General Information

- United States is world's largest tomato producer, with $2 billion in annual receipts
- Tomatoes are produced in every state
- 25% of tomato consumption is in unprocessed form

Tomato skin should appear bright, with a strong amount of color consistent with the type of tomato. The skin of the fruit should be firm, and should not wrinkle when a finger is ran over the surface. Fruit with visible dark bruises should be avoided as they may have been mishandled. Damaged fruit will spoil quicker than undamaged fruit and potentially spread microbial contamination.

Harvest Considerations

Tomatoes which have fallen off the vine to the ground should not be harvested, and any fruit which has contacted fecal matter or appears to have been disturbed by animals should also be excluded from harvest. Additionally, fruit with visible bruising or decay should not be harvested and transported with good fruit, as microbial contamination can be spread from damaged fruit. After harvest, produce should always be stored off the floor. Whole fresh tomatoes should be stored in areas without other produce, meats, or poultry, to prevent cross-contamination. If tomatoes are refrigerated, separate storage racks should be used to keep tomatoes separate from other fresh produce which may be stored in the same area.

Foodborne Illness Outbreaks Linked to Commodity

Tomatoes are a common produce to suffer from microbial contamination, often causing foodborne illness outbreaks. Salmonella is a particularly common pathogen to contaminate tomatoes, with 15 multistate outbreaks reported 1973 and 2010; these outbreaks resulted in 2,000 sicknesses and 3 deaths. In 2005 and 2006, tomatoes from a farm in Virginia were linked to foodborne illness in 21 states.

Bacteria	Year	Food Vehicle	Location	States Affected	Illnesses	Deaths
Salmonella	2009	Tomatoes	Michigan	1	21	0
Salmonella	2008	Tomatoes	California	1	9	0
Salmonella	2008	Tomatoes	US	Unknown	61	0
Salmonella	2008	Tomatoes	Iowa	Unknown	12	0
Salmonella	2007	Tomatoes	Minnesota	1	23	0

Table 1. Selected Foodborne Illness Outbreaks Attributed to Tomatoes, 2007-2009 (Outbreak Database, 2015)

Cooling and Storage Conditions:

Tomatoes harvested when ripe maintain well under cool conditions, with 4° - 10°C being ideal. Tomatoes harvested before ripening (green) must be stored above 12°C to prevent injuries from chilling. Ripe tomatoes prefer high humidity in storage. Green tomatoes are sensitive to ethylene and will begin ripening if exposed; however, ripe tomatoes are not highly sensitive to ethylene.

Produce	Optimal Storage Temp., °C	Optimal Humidity (%)	Cooling with top ice acceptable	Cooling with water sprinkle acceptable	Ethylene Production	Ethylene Sensitivity to	Storage Life
Tomatoes, ripe	4-10	90-95	No	No	Medium	No	4--7 Days

Table 2. Storage and Cooling Conditions for Tomatoes (Fellow, 2000)

Good Agriculture Practices (FDA, 2008)

- Remove dirt, stems, and leaves from tomatoes to the degree practicable in the field, in a manner that does not pose a risk of contamination.
- Ensure that containers used for field packing are not stored in the field unless protected from potential contamination.
- Apply extra care to cull and remove any damaged tomatoes during field packing because such packing of tomatoes generally occurs with mature ripe tomatoes.
- Prohibit the reuse of single-use containers, e.g., corrugated boxes, for the field packing of tomatoes.
- Protect containers from direct contact with the ground.

Pathogenic Behavior in Commodity

The vectors of contamination in tomatoes are still largely unknown. When washing tomatoes, it is inadvisable to use detergent or soap. Fresh fruit should be washed with clean potable water which is changed between every batch of produce, and washing water should be 10°F warmer than the temperature of the fruit being washed. Any surface which has direct contact with tomatoes should be regarded as a food contact surface, and cleaned and sanitized.

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