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Farmers market food safety: A comprehensive review of training needs in the U.S.

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Abstract

Farmers markets offer an apparently easy way for small-scale or hobbyist food producers to sell fresh produce, meat, and poultry from their farms or distribute value-added products, but they may be unaware of the foodborne illness risks associated with both fresh produce and derivative products, as well as of their local food safety requirements. Food guidance and rules vary from state to state and market to market, making it difficult for individuals to navigate the various regulatory levels.

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Conflicts of Interest

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Even if a local food producer is exempt from these rules due to their amount of sales, they will still benefit greatly from resources and educational tools that increase awareness and knowledge of food safety best practices. This review discusses current knowledge of and guidelines for food safety in farmers markets based on peer-reviewed and grey literature as well as published guidelines and recommendations. We examine facilities and supplies, regulatory measures, education and training, and Good Farmers Market Practices as preventive measures to enhance food safety in farmers markets, which are critical to local and regional food systems. Overall, we identified various barriers to implementing farmers market food safety standards and practices in this scoping review; removing these barriers will require the participation of local regularity authorities, market managers, vendors, and consumers.

Keywords
pathogen, cross-contamination, vendor, manager, value-added, fresh produce, cottage food, local food system, farmers markets, regulations, food safety, education and training, facilities, Good Farmers' Market Practices

Introduction

According to a 2021 U.S. Department of Agriculture (USDA) Economic Research Service (ERS) report, over the previous decade local food sales increased nationwide through a variety of market channels (Martinez & Park, 2021). Despite no uniform USDA definition of the term "local" (Rossano, 2022), local food markets contribute substantially to the economic growth of communities. Rossi et al. (2017) reported that local food sales generate greater regional sales, employment, and gross domestic product when compared to the same dollar value of conventional food sales. According to the National Farmers Market Directory (NFMD), there are a little over 10,000 U.S. farmers markets, more than triple the number recorded in 2000 (2,024). Local food producers most often sell their products at direct-to-consumer venues, including farmers markets, on-farm stores, community supported agriculture (CSA) programs, and pick-your-own operations (Martinez & Park, 2021). The income generated in local and regional food systems provides significant support for many farmers, especially new and beginning farmers and small-scale farmers (Martinez & Park, 2021). In addition, the growth of farmers markets in the past several years helped to fill gaps in the supply chain during the COVID-19 pandemic, with some farmers markets showing their highest sales in 2020, along with helping to renew public interest in local food options (Goldy et al., 2020). Moreover, Thilmany et al. (2021) reported that local and regional food systems responded to the COVID-19 pandemic in more nimble ways compared to the national food supply chain.

Public interest in local food products, such as cottage foods (i.e., homemade goods) and home processing, has risen notably in the last several years (Goldy et al., 2020). Coupled with supply chain disruptions and a shortage of canning supplies, this interest led entrepreneurs to explore alternative home food processing methods during the COVID-19 pandemic, including ones that may not ensure food safety (Niles et al., 2021). Furthermore, in 2021 numerous states passed various forms of food freedom acts that amended cottage food laws to cottage food make selling cottage foods easier for local food producers and farmers market vendors (Farquhar, 2020). Many small-scale growers and food processors who sell directly to retailers are exploring ways to manufacture value-added products that could increase the market value of their raw commodities and yield higher profits. For instance, dairy products such as cheese and yogurt may yield greater profits than the milk itself (Alvarez et al., 2018). Canned low-acid or fermented vegetables can utilize fresh produce gleaned as "seconds," preventing food waste and providing an additional source of income during off seasons. Prepared foods can also increase the income viability of local food producers, though there can be a several year lag without increased income (Clark, 2020).

These value-added foods may present opportunities for economic growth, but key knowledge about risks and best practices is required for safe production of the food. Increased interest in, access to, and ability for producing and selling cottage foods without a proportional increase in dis-

semination of food safety knowledge and best practices could result in unintended consequences. In the last three decades in North America, several confirmed outbreaks in farmers markets have occurred due to contaminated cheese, meat, fruit, and vegetables (Wisconsin Department of Health Services [WDHS], 2022; Young et al., 2017). In retail settings such as farmers markets, foodborne illness risk factors may include food from unsafe sources, inadequate cooking, improper holding or time/temperature controls, contaminated equipment or protection, and poor personal hygiene (National Retail Food Team, 2010). Recommendations for Good Retail Practices for food service and retail establishments are available to facilitate control of basic operational and sanitation conditions under the U.S. Food and Drug Administration (U.S. FDA) Food Code (U.S. FDA, 2022a) which may apply to direct-to-consumer venues depending on products sold. Furthermore, cottage food laws (e.g., food freedom acts) are in place in all states, with various requirements, recommendations, certifications, permits, and guidelines. A comprehensive list of these laws is available at the National Agricultural Law Center.[1]

Nevertheless, lack of handwashing, incorrect glove use, and temperature control issues related to holding foods have been widely reported across farmers market food safety studies (McIntyre, Karden et al., 2014; Miller, 2020; Young et al., 2020). Young et al. (2017) performed a systematic review comparing food safety–related issues and practices for products sold in farmers markets, indicating a small but significant number of problems with unsafe practices and contamination, including two deaths as consequences. Conversely, in the present review, peer-reviewed and grey literature, in addition to guidelines and recommendations by university cooperative extension service and local governments relevant to food safety in farmers markets, were examined to evaluate knowledge gaps in understanding food safety risks related to local food products. Based on the literature review, preventive measures categorized on four main areas (facilities, regulatory, education, best practices) are identified and discussed as strategies to enhance food safety in farmers markets.

Food Safety Risks of Products Sold in Farmers Markets

The types of products sold in farmers markets varies depending on location, weather conditions, seasonality, demographics, consumption habits, consumer preferences, socio-economic parameters, and individual market rules. In some cases, vendor ingredient preferences and their creativity shape the value-added goods offered with little or no consideration for food safety (Richard et al., 2023). The risks of foodborne illnesses linked to each product type depend on several factors spanning vendor-to-consumer practices and individual farmers market rules and guidelines. Food categories and products sold in farmers markets in 2019 are presented in Table 1, based on a national survey of farmers market managers by the USDA National Agricultural Statistics Service (USDA NASS, 2020). Foods with elevated risks, in the milk and dairy (44.3%) and seafood, meat, poultry, and eggs (84.5%) categories, require time and temperature control for safety. Crops in the category of fruits and vegetables (99.6%) commonly consumed raw are also sold by venders in all farmers markets. The food products and categories in Table 1 were then overlaid with data showing if a food has been linked to confirmed or suspected foodborne outbreaks during 1998–2021 in the U.S. Centers for Disease Control and Prevention (CDC) National Outbreak Reporting System (NORS) (CDC, 2023).

When stored and handled properly, products requiring a kill step to eliminate or reduce harmful microorganisms before consumption (e.g., cooking raw meat to appropriate internal temperature) should not necessarily be of concern as a source of cross-contamination at the point of sale. However, outbreaks of *Salmonella* and *Trichinella* have been associated with pork products and wild boar meat sold in farmers markets in Canada and the U.S., respectively. (Kennedy et al., 2009; National Microbiology Laboratory & Centre for Food-borne Environmental and Zoonotic Infectious Diseases, 2006). Similarly, the risk of foodborne illness is reduced in cottage food products after cooking,

[1] https://nationalaglawcenter.org/state-compilations/cottagefood/

acidification, pickling (Pérez-Díaz et al., 2015), canning (Nichols, 2016), and addition of salt and sugar (Sehrawat et al., 2021) when prepared with basic hygiene rules and best practices (Etzel et al., 2015). However, homemade beverages and ready-to-eat (RTE) food can be at higher risk for foodborne illness transmission due to contaminated ingredients or non-hygienic preparation practices. For exam-

Table 1. Food Categories and Products Sold in Farmers Markets in 2019 Along with the Number of Confirmed or Suspected Outbreaks (1998 to 2021) Linked to Those Types of Food Products in General

Category	Product	Confirmed/ suspected foodborne outbreaks	Searched terms for food vehicle	Sold in farmers market (%)
Milk and dairy				44.2
	Cheese	501	Cheese	92.0[a]
	Yogurt	14	Yogurt	29.3[a]
	Milk	415	Milk	34.6[a]
	Butter	43	Butter	30.6[a]
Bread and baking goods				90.9
	Baked goods	92/129	Bread/Baked	99.8[a]
	Grains/flour	211/7	Grains/Flour	17.6[a]
Fruit and vegetables				99.6
	Fresh fruit	515	Fruit	95.3[a]
	Fresh vegetables	625	Vegetable	99.3[a]
	Fresh and dried herbs	89	Herb	79.6[a]
Seafood, meat, poultry, and eggs				84.5
	Fish and seafood	2,262/93	Fish/Seafood	28.0[a]
	Red meat	345 /227	Meat/Steak	70.2[a]
	Poultry	2,473/707/16/1	Chicken/Turkey/ Duck/Goose	52.5[a]
	Eggs	656	Egg	93.9[a]
Condiments and sauce				94.1
	Honey	26	Honey	93.2[a]
	Canned fruits and preserves	14	Canned	87.8[a]
	Maple syrup	0	Maple/Syrup	38.8[a]
Beverages				60.4
	Alcoholic beverages	12	Alcohol	28.2[a]
	Coffee and tea	10/31	Coffee/Tea	73.6[a]
	Other non-alcoholic	0	-	73.8[a]
Other foods				77.9
	Tofu and/or meat and dairy substitutes	6	Tofu	7.7
	Nuts	51	Nuts (doughnuts excluded)	40.9[a]
	Mushrooms	85	Mushroom	49.0[a]
	Wild harvested and foraged	0	-	17.6[a]
	Prepared foods	2,441	Food Prepared	70.0[a]
	Seed of edible plants	0	-	18.7[a]
	Fermented and pickled foods	5/9	Fermented/Pickle	58.8[a]

[a] Product breakout percent is for respondents reporting sales within the product category.
Data sources: Data are based on a report detailing the results of the National Farmers Market Managers survey published by the Agricultural Statistics Board of the U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS, 2020), and the number of confirmed or suspected local and multistate foodborne outbreaks between 1998 and 2021 listed in the National Outbreak Reporting System (NORS) at the U.S. Centers for Disease Control and Prevention (CDC, 2023).

ple, confirmed outbreaks of *Escherichia coli* O157:H7 and *Salmonella* associated with a guacamole product and apple cider, respectively, sold in farmers markets have been reported (Sun et al., 2010). Artisan cheeses made from raw milk, plus inadequate aging, can also harbor foodborne pathogens such as *E. coli* O157:H7, *Salmonella*, and *Listeria monocytogenes*, and these have been linked to foodborne outbreaks in North America (Ellis et al., 1998; Honish et al., 2005; McIntyre et al., 2015). It has been determined that these outbreaks occurred due to poor handling practices and the use of ingredients from unsafe sources.

Fresh fruits and vegetables generally consumed raw, and products prepared with these commodities, along with foods with time and temperature control for safety (TCS) sold at farmers markets, are considered some of the more high-risk products due to the lack of any pathogen kill step. In 2019, fresh fruit and vegetables were sold at 99% of farmers markets and generated the primary revenue (20–36%) for U.S. vendors (USDA NASS, 2020). While contamination of fruits and vegetables may occur during production, harvesting, and post-harvest handling (Harris et al., 2003; Topalcengiz et al., 2024), pathogen populations still cannot be adequately reduced to undetectable levels on fresh produce with home washing methods like running tap water, soaking in tap water, or using vegetable washing solutions such as 5% vinegar solution or 13% lemon solution (Kilonzo-Nthenge et al., 2006; Uhlig et al., 2017). Contaminated cantaloupe, strawberries, blackberries, and tomatoes—all frequently eaten raw—from farmers markets have caused outbreaks due to contamination with *E. coli* O157:H7, *Salmonella*, and Hepatitis A virus (CDC, 2020; Douglass et al., 2016; Laidler et al., 2013; Smathers, 2012). Shelled peas purchased in farmers markets in Wisconsin and Alaska have also been implicated as outbreak sources of outbreaks of *Campylobacter jejuni* and *Salmonella*, respectively (Gardner et al., 2011; WDHS, 2022). These outbreaks demonstrate that the food safety concerns stated are valid for a variety of food products sold in farmers markets. To some extent, consumers are compelled to accept a potentially higher risk of foodborne illness when they purchase homemade products, fresh produce eaten raw, and raw milk or associated products, regardless of retail venue.

Fate of Pathogens in Farmers Markets

As stated, five primary risk factors for the transmission of foodborne illness have been identified for foodservice, restaurants, and retail settings (Retail Food Program Steering Committee, 2000): unsafe food sources, inadequate cooking, improper holding or time/temperature control, contaminated equipment/protection, and poor personal hygiene. These factors also apply to settings in farmers markets. Pathogens may be introduced to products sold in farmers markets at any stage and can survive for prolonged periods of time, long enough for foodborne pathogens to persist and cause foodborne illnesses (Harrison, 2017; Young et al., 2017). Products having a kill step such as cooking before consumption may not cause foodborne illnesses when properly cooked. However, pathogens in meat, seafood, and poultry can be sources of cross-contamination of RTE food or produce consumed raw at farmers markets due to the use of contaminated equipment or food-contact surfaces or inadvertent cross-contamination between products (e.g., leakage of raw animal protein products onto fresh produce).

Because fruits, vegetables, and leafy greens are frequently consumed raw, they require extra attention, as they may introduce pathogens originating at the farm to the market or become contaminated during transportation, display, preparation, or storage at the farmers market. Possible routes of contamination during the production and harvest of fresh produce include agricultural water, biological soil amendments of animal origin (BSAAO), domesticated and wild animals, workers, and equipment and buildings (USFDA, 2015). When contaminated in the field, produce pathogens can persist until consumption or become a source of contamination at the farmers market. For example, the use of raw manure without waiting between application and harvest and the use of a water source with no microbiological testing are common among the small to medium-sized farms that are often vendors at farmers markets (Harrison et al., 2013). Produce can also become contaminated during the preparation of minimally processed food at

the farmers markets from utensils, aprons, other products for sale, lack of hygiene practices, food-contact surfaces, or customers touching the items in different booths (Acosta et al., 2021; Li et al., 2017).

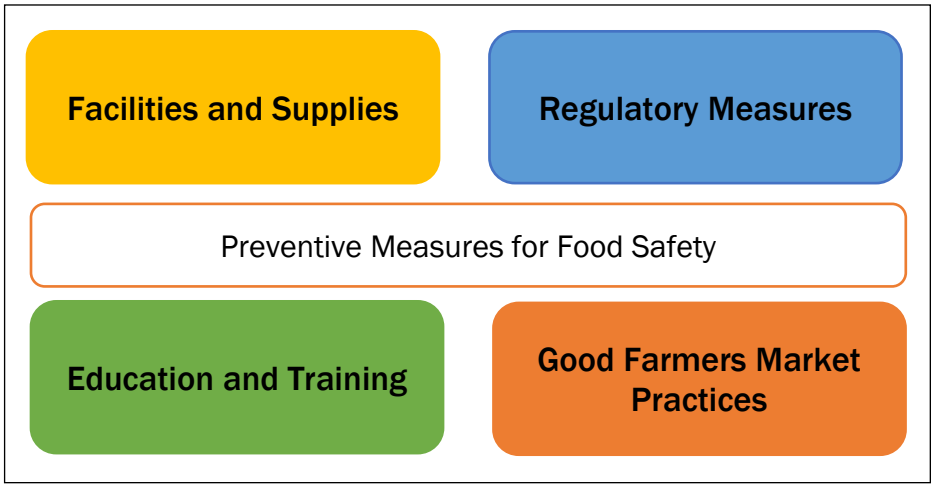
A greater risk of pathogen presence and higher microbial loads have been reported in farmers markets for various food items compared to conventional retail counterparts (Roth et al., 2018; Scheinberg et al., 2013; Soendjojo, 2012). For instance, Roth et al. (2018) reported that total coliform concentration in leafy greens and spinach were approximately 2.1 and 3.4 times higher at farmers markets than at retail supermarket counterparts. Whole, raw chickens (N = 100) sold in farmers markets in Pennsylvania were 90% and 28% positive for *Campylobacter* and *Salmonella* spp., respectively, compared to 8% and 52% in conventionally processed, nonorganic chicken, respectively (Scheinberg et al., 2013). Vendors' limited food safety knowledge regarding TCS foods (e.g., fresh-cut fruits, sprouts, ready-to-eat salads, eggs, milk products, and raw, cooked, or partially cooked meat, poultry, and seafood) combined with the lack of cooling, refrigeration, and freezing available at farmers markets may compound the risk of foodborne illnesses (Harrison et al., 2013; Scheinberg et al., 2018; Teng et al., 2004). Thus, the fate of pathogens in farmers markets depends on several factors, including lack of food safety knowledge of both vendors and market managers, limited or no refrigeration, and uncontrolled parameters such as consumer behaviors (e.g., running additional errands before taking products home for proper storage), weather conditions such as heat, and food from unsafe sources.

Literature Search Criteria

The most recent literature review of farmers markets studies was published in 2017 by Young et al. However, that scoping review did not specifically focus on food safety at farmers markets, and additional studies have been published in the past five years that should be considered. In the present study, we performed a realist review of the farmers market food safety literature to identify contextual elements that promote or impede the act of receiving and implementing knowledge during knowledge dissemination. To identify these elements, a variety of data sources were used in addition to empirical studies, including grey literature (e.g., reports, white papers), commentaries, and theoretical papers (Jagosh, 2019). This realist review approach to identify context-mechanism interactions to inform food safety training has not been widely used (Yeargin et al., 2021), yet it holds the potential to address the current research-practice gap—between knowledge reception and actually putting knowledge into practice—in food safety training interventions. In this review, we focused specifically on preventive measures to enhance food safety in farmers markets in the four areas: (a) facilities and supplies, (b) regulatory measures, (c) education and training, and (d) Good Farmers Market Practices (Figure 1).

In addition, we conducted a search for farmers market food safety resources to determine the quantity and topic areas of resources available through university cooperative extension and state health and agriculture departments. All resources

Figure 1. Areas for Preventative Food Safety Measures in Farmers Markets



were collected that resulted from a Google search for "[State] Cooperative Extension Famers Market Food Safety" and compiled in a spreadsheet with the following information: state, type of resource (video, factsheet, webpage, legislation, etc.), key word(s), topics covered, author(s), date published, and link.

Results and Discussion

Preventive Measures to Enhance Food Safety in Farmers Markets

Minimizing food safety hazards in farmers markets is more challenging than in retail food settings as the temporary market settings, operated by managers and vendors on a part-time basis, are hard to control (Boys & Fraser, 2019; Mack & Tong, 2015). Preventive approaches with all parties collaborating may reduce the risk of foodborne illnesses. Facilities and supplies, regulatory measures, education and training, and development of Good Farmers' Market Practices (Chapman & Sain, 2017) have been identified as the four main areas of preventive measures to enhance food safety in farmers markets (Figure 1).

Facilities and supplies

Properly designed and well-maintained facilities with enough supplies for both customers and vendors are essential to reduce contamination risk at farmers markets. To support this need, facility and design recommendations and guidelines to enhance food safety practices have been published by governmental agencies (CDC, 2014), nonprofit organizations, and university researchers and cooperative extension services (Boyer & Yang, 2017). Despite current knowledge and efforts, sufficient facilities and supplies at farmers markets are often inadequate and remains a food safety risk (Harrison, 2017). Handwashing facilities and supplies, proper storage of TCS foods, and appropriate food-contact surfaces and materials represent the main food safety concerns. The presence of companion animals can also be a food safety concern and is generally not recommended by food safety professionals (Boyer & Yang, 2017).

Adequate handwashing and using gloves properly are essential during the preparation and handling of food to avoid transferring pathogens to the final product. As reported by Behnke et al. (2012), access to handwashing stations affects the handwashing frequency of farmers market vendors and customers. However, little to no access to well-maintained handwashing facilities and insufficient supplies have been observed in farmers markets, possibly affecting vendors' ability to practice handwashing in most circumstances (Behnke et al., 2012; Harrison et al., 2013; McIntyre, Karden et al., 2014; Smathers, 2012; Worsfold et al., 2004). Handwashing facilities should be convenient, unobstructed, and within a manageable and easily accessible distance (e.g., some recommend within 25 feet/7.6 meters) from vendor booths or tables. These handwashing stations should also include adequate supplies such as potable water, catch basins for wastewater, liquid soap, paper towels, and trash cans.

Proper and effective storage of TCS foods requires refrigeration to control the growth of pathogens. TCS foods should be held below 5°C (41°F) and above 57.2°C (135°F) for cold and hot storage, respectively (Chapman & Sain, 2017; USDA, 2019). However, the display and storage of TCS products such as eggs and processed fruits and vegetables without refrigeration has been observed in farmers markets, especially during months with warmer ambient temperatures (Harrison, 2017; Li et al., 2017; McIntyre, Herr et al., 2014; McIntyre et al., 2015; Scheinberg et al., 2018; Teng et al., 2004). For example, only 60% of vendors selling TCS foods were observed to be in compliance with the food temperature control requirement at Canadian farmers markets (McIntyre, Herr et al., 2014). Other studies suggest that the use of thermometers to verify temperature control is not always followed (Teng et al., 2004). In the U.S., only 12.7% of vendors selling TCS food at Pennsylvania farmers markets were observed (i.e., under direct concealed observation) with a thermometer on site or in the cold storage unit at the farmers markets (Scheinberg et al., 2018). These types of circumstances may occur due to both a lack of knowledge or training by both managers and vendors (Mohammad et al., 2020), and a lack of onsite storage facilities and cooling units. To address the lack of cold storage at farm-

ers markets, Scheinberg et al. (2018) reported that some vendors selling temperature-sensitive foods used portable coolers with ice (16.9%) and without ice (9.9%). However, these cold storage solutions can still be susceptible to temperature fluctuations.

The transfer and survival of pathogens between food-contact surfaces and produce have been demonstrated at farmers markets. Surface types include reusable and single-use gloves (Brar & Danyluk, 2013), clean and dirty cloths (Beiza et al., 2021; Sreedharan et al., 2014), new, used, and dirty corrugated fiberboard boxes (cartons) (Topalcengiz et al., 2023), plastic (Zhu et al., 2020), and stainless steel (Xie et al., 2023). The cleanliness of surfaces in contact with food at farmers markets has been widely reported as deficient. Specifically, signs of dirt and lack of cleanliness ranged 10.8%–81% across multiple studies for vendors observed handling foods such as poultry, cheese, and produce (Scheinberg et al., 2018; Teng et al., 2004; Vandeputte et al., 2014). The considerable percentage gap among observed unclean food-contact surface materials can be explained by the subjective nature of the observation, type of data collection, type of food handled, and the time during a given farmers market operating hours that the observation was made, which may result in more or less frequent business transactions.

The use of easy-to-clean surfaces is another important factor to reduce risk of foodborne disease transmission. For example, using plastic containers is suggested rather than those made of porous materials, primarily because porous materials such as pressed cardboard, molded pulp fiber, and wood have slower reduction of pathogens including *E. coli* O157:H7, *Salmonella*, and *L. monocytogenes* at refrigerated and room temperature (Beiza et al., 2021; Li et al., 2017). Thus, the use of cleanable materials is recommended and often required by farmers market managers and local authorities (Boyer & Yang 2017; Harrison, 2017).

Regulatory measures

Regulations pertaining to farmers markets food safety practices are not established at the federal level and thus are not enforced by governmental agencies such as the U.S. FDA or USDA Food Safety Inspection Service (FSIS). Regulations and rules for the sale of food products at farmers markets are established at the state level by departments of health and/or farmers market associations, and often differ across states and even between counties within a state (Smathers, 2012). Regarding value-added food sales at farmers markets, 19 states have enacted their own cottage food or food freedom legislations, legislation summaries, or additional resources for regulatory compliance on easily accessible sites such as university cooperative extension services and state government webpages. Other states may have regulations and related published resources, but they could not be found with the search criteria used. Individuals looking for them would have to tailor their search to find legal guidance in states where these resources are not easily accessible.

Some states also require retail food licenses in order to operate food facilities at farmers markets. Responsible state health or agriculture departments may issue permits and licenses to market vendors as a regulatory tool (Hoffman et al., 2007). Although intact, unprocessed fruits and vegetables and similar products are not regulated, state-level departments generally have regulatory authority over processed food items sold in farmers markets. In contrast, foods covered by cottage food laws may or may not require registration, licensing, and permitting, and may be inspected by responsible state departments with little or no regulatory oversight in general (see compilation by The National Agricultural Law Center[2]).

The model policy known commonly as the "Food Freedom Act" was finalized in 2018 and recognizes the right of individuals to produce and consume homemade foods with no unnecessary and competitive regulations.[3] The term food freedom act may have various names and versions for similar legislative purposes by state governments. The act led to updates of cottage food rules where the sale of cottage food had previously been illegal, such as in the state of New Jersey. Depending on

[2] https://nationalaglawcenter.org/state-compilations/cottagefood/
[3] https://alec.org/model-policy/food-freedom-act/

state law, cottage food products may or may not be limited to a prescribed list and may or may not allow for direct or indirect sales to end consumers. Limits on annual revenue and labeling requirements vary in each state's cottage food law. In some states, cottage foods are classified based on type of foods, direct sale, certifications, degree of risk, and producing location, e.g., at home or on farm. Common elements of state cottage food laws include types of food products allowed, limits on where these food products can be sold, required registration, licenses, inspections, and/or permits, limits on total sales, and required labeling. These state food laws have been compiled for comparison by the Harvard Law School Food Law and Policy Clinic[4] and are also available at the National Agricultural Law Center as noted above.

Improvement of food safety at farmers markets is supported with direct and indirect local and national funding sources. Local governments grant state-specific farmers market and local food promotion programs, in addition to technical, consulting, licensing, certification, and educational and training services. USDA grants available to enhance food safety in farmers market include the Local Food Promotion Program,[5] Organic Agriculture Research and Extension Initiative,[6] and Beginning Farmer and Rancher Development Program.[7] All other possible grants, loans and funding support are listed under various services.[8]

Education and training

Food safety training programs and certification are among the backbones of the effort to prevent foodborne illnesses. Effective training programs are essential for both protection of public health and the survival of food companies. From nationwide companies with bulk production to vendors selling locally grown and processed foods, food safety knowledge delivery requires the cooperation of all parts of a food business, including employees, managers, and trainers. The extent and content of the food safety knowledge provided is typically based on type of products, processes, knowledge level, and the responsibilities of the trainee.

Food safety knowledge and awareness in farmers markets continue to lag based on published studies in different locations. Harrison et al. (2013) reported that risky on-farm practices could lead to pathogen contamination of produce sold in farmers markets across three southeastern states. This survey-based study indicated that a lack of compliance with applying soil amendments as well the use of untested surface water sources for agricultural and cleaning purposes (Harrison et al., 2013). However, these reported on-farm practices occurred prior to the enactment of the Produce Safety Final Rule (USFDA, 2015). Another survey-based study in Arkansas and Texas found that only about 37% of vendors and farmers market managers received formal food safety training, and only half of market managers provided food safety educational materials to vendors (Mohammad et al., 2020). In Rhode Island farmers markets, 81% of vendors were observed to have unsanitary conditions, such as visible dirt on clothes and nails and improper hygiene practices including handling money or touching the body and then produce with no hand washing in between (Vandeputte et al., 2014). Another direct observational study at 18 farmers markets in Indiana revealed that proper food safety practices were rarely followed by vendors, with handwashing regulation compliance observed only twice in 417 transactions (Bhenke et al., 2012).

More positive observations, however, have been reported as well regarding food safety knowledge and awareness at markets. In Pennsylvania, both direct and concealed observations and a state sanitarian survey showed low percentages of unclean clothing and unclean stalls at farmers markets, despite some important gaps in vendor food safety behavior, such as insufficient hand washing and cross-contamination (Scheinberg et al., 2018).

[4] https://chlpi.org/wp-content/uploads/2013/12/FLPC_Cottage-Foods-Report_August-2018.pdf
[5] https://www.ams.usda.gov/services/grants/lfpp
[6] https://www.nifa.usda.gov/grants/funding-opportunities/organic-agriculture-research-extension-initiative
[7] https://www.nifa.usda.gov/grants/funding-opportunities/beginning-farmer-rancher-development-program
[8] https://www.ams.usda.gov/services/local-regional/food-sector/grants

Chen et al. (2022) reported that 82% of small-scale produce growers in Indiana selling in farmers markets declared themselves knowledgeable about food safety. In California, over two-thirds of surveyed farmers market managers claimed that food safety standards (which are under their responsibility on-site) are in place (88.2%) and in compliance with local and environmental health department regulations (Pires et al., 2020). Nevertheless, food safety knowledge and awareness are highly variable in U.S. farmers markets despite educational efforts and regulatory requirements and guidance documents.

Resources for educational materials

Many educational materials and training resources from governmental agencies and university cooperative extension services are available to fill food safety knowledge gaps, reduce the risk of foodborne illnesses at farmers markets. Written recommendations, guidelines, and training resources have been developed and published in many states through cooperative extension services or health departments, with varying depth and detail (CDC, 2014). Visual, auditory, and interactive educational materials to enhance food safety are also available for managers, food vendors, and growers, including general and product-specific information about safe handling practices, avoiding cross-contamination, temperature monitoring, hot holding, cleaning and sanitation, personal hygiene, washing stations, proper cooking, storage, and labeling. All vendors and market managers are expected to comply substantially with relevant rules and regulations by customers and regulatory authorities. To improve product the safety, some state and local governments require certification of vendors and permits to sell at the farmers markets (see Education and Training, above).

Rules and safety guidelines with similar handling and storage recommendations have been published in each state by university cooperative extension service, state programs and divisions, or farmers market coalitions for market managers and vendors. The guidelines may include food safety knowledge and best practices for different types of foods. The same guidelines used in multiple states may also be recommended by different extension services or state government websites. We found resources from 47 of the 50 states, with topics varying little. While this may seem repetitive, most university cooperative extension programs aim to gain trust from local communities as a source of reliable information. Therefore, many programs will repost other state's resources or paraphrase the same concepts using their own branding.

Using the methods that were used for this review to search for these materials, 197 unique resources were identified online: 100 were factsheets, webpages, or presentations generated by university cooperative extensions; 51 were from state government webpages; and the remaining 46 were from interest entities, such as state farmers market associations or personal blogs. The most common topics were hygiene and handwashing; sanitation; permit and other regulatory requirements; holding and storage temperatures; and guidance on included or excluded foods based on potential hazards. Other materials provided information about production (farm, slaughter, transportation, GAPs), processing (acidifying, dehydration, cooking, canning, handling), and selling (labeling, sampling, temperature control). Additionally, six resources provided through cooperative extension specifically provided self-evaluation checklists and toolkits.

Training programs

Delivering knowledge and establishing proper food safety practices to farmers market vendors, managers, and growers is not an easy task. For example, 78% of Indiana small-scale produce growers agree that food safety is one of the top parameters in a value-added business, but time limitation and the large amount of necessary expertise are identified as the two main barriers for growers to learn more about food safety (Chen et al., 2022). Chen et al. also reported that growers tend to receive more educational materials about increasing sales and communicating with regulators and inspectors compared to food safety information.

Significantly related to food safety knowledge and attitudes are the ways educators adapt and disseminate food safety information to local food producers selling direct-to-consumers. Jan et al. (2021) investigated the impact of visual-based, minimal-

text educational tools on the food safety knowledge and attitude of farmers market vendors. There was a positive difference in knowledge between vendors who saw the visual learning tools and those who did not, indicating that the vendors are receptive to training but need to be provided with the right tools to learn effectively. Previous studies (Plakias et al., 2020; Schmit et al., 2020) and anecdotal evidence (e.g., conversations with growers) have shown that food safety training programs are more effective when presented as part of a comprehensive approach to enhancing the success of producers. For example, Schmit et al. (2020) demonstrated that it is important to engage growers by showing a direct link between investing in food safety practices and enhanced sales growth.

Although educational and training resources are available, farmers market managers may not have access to farmers market–specific training that can be disseminated to their vendors. For example, in some cases food safety training may be provided through state cooperative extension service; however, Pollard et al. (2016) showed that within the same state some market vendors go through training while others do not. This is further complicated by the reality that each state and perhaps each city and county may have different sets of guidelines. There are several American National Standards Institute (ANSI)-certified commercial options for handler and manager food safety training programs and certifications; Mohammad et al, (2020) showed that only about 37% of farmers market vendors pursued these types of training programs. However, these programs are based on the U.S. FDA Food Code and contain task-specific information for foodservice and retail operation employees and managers, which are not contextually applicable to farmers markets and other direct-to-consumer venues.

Good Farmers Market Practices

The food supply chain can consist of multiple nodes, including growers, processors, packagers, manufacturers, distributors, and retail markets through to consumer purchase. Food safety practices are often designed for each node of the chain under various food safety management systems, depending on specific risk factors. Some systems include Good Agricultural Practices (GAPs) (Center for Food Safety and Applied Nutrition, 1998) in the field, Good Manufacturing Practices (GMPs) (U.S. FDA, 2020), and Hazard Analysis and Critical Control Points (HACCP) principles with the support of Sanitation Standard Operating Procedures (SSOPs) for processing and manufacturing food (U.S. FDA, 2022b). Even product-specific food safety practices such as Tomato-GAPs (TGAPs) (Florida Administrative Code & Florida Administrative Register, 2016), California Leafy Green Marketing Agreement (2023), and juice HACCP standards (U.S. FDA, 2004) have been developed requiring compliance of growers and processors with local or nationwide alliances and authorities. Good Hygienic Practices and Good Retail Practices (GRPs) have also been defined for foodservice and retail establishments by the U.S. FDA (Retail Food Program Steering Committee, 2000; USFDA, 2022a).

For vendors selling in farmers markets, food safety decision trees, self-assessment forms, and best practices have been defined and developed by university extension specialists and local authorities. In general, the defined best practices are built on the previously described five risk factors likely to cause foodborne illness transmission in retail settings (Retail Food Program Steering Committee, 2000). The Good Farmers Market Practices (GFMPs) developed by North Carolina State University Cooperative Extension (NCSUCE) (Chapman & Sain, 2017; NCSUCE, 2023) is a curriculum that covers food safety practices under three areas: food safety principles, personal health and hygiene, and food sampling (NCSUCE, 2023). Food safety principles focus on basic definitions and knowledge about types of hazards, five factors contributing to foodborne illnesses, high-risk populations, and key parameters for pathogen growth. Personnel health and hygiene covers proper handwashing and gloves use, restrooms, facilities, and required supplies. Finally, the food sampling section mentions different food safety considerations during preparation, thawing, storage, and transportation, which include cross-contamination, use of food-grade containers, and use of thermometers.

Multiple food safety management systems may be required in farmers markets to ensure product

safety depending on the types of products. There are challenges for both vendors and market managers. For example, produce that is frequently consumed raw represents the majority of products sold and displayed at the vendor booths. It does not seem to be affordable and realistic for small-scale growers to invest in food safety knowledge and apply GAPs on farms with tight budgets. Another issue is the allowable list of cottage foods, which varies state to state. In most states, non-TCS foods are unrestricted or do not require inspection and permits by responsible authorities. However, the large variety of ingredients, potential lack of food safety knowledge, and careless individual behavior can limit establishing good practices in home kitchens. Insufficient infrastructure and settings, lack of facilities and supplies, and the absence of refrigeration and electricity are observed limitations for food safety in farmers markets. Although GFMPs are intended to be in place, all these aforementioned factors cannot be reliably in place in most farmers markets.

Conclusions and Future Research Needs

Local and regional food systems provide substantial income for many farmers and food entrepreneurs. In 2015, local food producers sold US$8.7 billion of edible farm products directly to consumers, retailers, institutions, and local distributors (Martinez & Park, 2021), equal to 2.2% of agricultural sales in 2017. Approximately 35% of local foods are sold through direct-to-consumer market channels, including farmers markets, and 69% of local food farms (114,801 out of 167,009) sell directly to consumers (Martinez & Park, 2021). Overall, local and regional food systems provide significant support for many farmers, especially new and beginning farmers and small-scale farmers, which in turn contributes to the sustainability of U.S. agriculture.

Microbiological safety of products sold at farmers markets is generally not the primary concern of consumers, many of whom believe that foods sold at farmers markets are inherently safer than those sold in supermarket retail stores (Crandall et al., 2011; Worsfold et al., 2004; Yu et al., 2017). Freshness and taste have been rated as an important to extremely important reason for shopping at farmers markets by more than 93% of consumers (Khouryieh et al., 2019; Shen et al., 2022). Despite consumer beliefs, habits and preferences, outbreaks linked to products sold in farmers markets are an indicate significant food safety issues, as discussed in the section Food Safety Risks of Products Sold in Farmers Markets, above.

State regulators and educators confirm the lack of food safety knowledge, awareness, capital, and training in small and very small food businesses selling risky products in farmers markets (Harrison et al., 2016). Numerous observational studies have been published on the food safety practices of local food producers and vendors at farmers market venues as reviewed by Young et al. (2017). One practice that was consistently low across 14 studies was "adequate hand washing when required." While this may be in part due to deficient knowledge about and attitudes towards food safety practices, often the resources for handwashing were not available, particularly in smaller, outdoor markets. Another key area of concern for farmers markets is the lack of proper refrigeration of potentially hazardous foods and the absence of thermometers for monitoring temperatures. Again, both inadequate knowledge and access to necessary resources may be preventing the implementation of key food safety practices related to temperature control. To enhance market food safety, preventive measures should be considered under the four main areas of facilities and supplies, regulatory measures, education and training, and GFMPs (Figure 1).

Aside from infrastructure barriers, the biggest challenge is the effective delivery of knowledge produced by university extension specialists and local authorities to vendors and managers to improve food safety awareness and behaviors. Transformative and engaging food safety training seems to be critical to increasing the food safety knowledge of local food producers, eliciting behavior change, and preventing food safety issues within direct-to-consumer venues. Educational games and interactive modules have the potential to create meaningful learning experiences for a wide range of subjects and ages (Hsiao et al., 2020; Trujillo et al., 2016; Ulery et al., 2020). For example, open-access online food safety education con-

tent to improve safe food-handling skills in the kitchen (e.g., Ninja Kitchen) and interactive modules for growing microgreens, developed through collaborative education and training projects, represent some active and user-friendly computer-based or mobile-responsive resources.[9] Research overwhelmingly indicates that interactive multimedia learning tools can help audiences understand concepts better than traditional education practices, and they are powerful mechanisms to elicit behavioral change (Dede, 2009; Gee, 2003). Multimedia learning theory suggests that people learn better when words and images are used together, the multimodal approach (Clark & Lyons, 2011). This is an opportunity to engage via educational games with local food producers about acquiring the resources needed to implement best safety practices.

Technology can be adapted to farmers markets to improve food safety in addition to the alternative training methods discussed previously. Many vendors are small-scale farmers who grow, handle, and sell their commodities at farmers markets with tight budgets. Dhillon and Moncur (2023) concluded that small-scale farmers may benefit from a combination of smart sensors, automation, solutions from the internet of things (IoT), smartphone applications for decision making, and traceability for both productivity and food safety as a part of value-added food production. For example, low-cost smartphone-based infrared cameras are practical, easy to use, and cost-effective for monitoring the temperature of produce and assessing cooling and storage efficiency (Yang et al., 2022). Further research and practical applications in the use of technology to address the identified gaps in food safety knowledge and practices at farmers markets should be prioritized. These efforts could focus on supply chain transparency and food traceability via the implementation of already available low-cost technologies such as GPS receivers, radio frequency identification (RFID), and QR code methods (Dhillon & Moncur, 2023).

The establishment of nationally accepted preventive food safety measures in farmers markets could play a crucial role in reducing the risk of foodborne illness transmission, in addition to producing economic impacts through conceptual strategies and practical interventions. First, scientific and data-driven evidence is needed to reduce the risk of contamination in market facilities and supplies. Prevention and early intervention methods that reduce risk of contamination from farm to fork should be studied and specifically designed for vendors growing high-risk food commodities (Table 1). Second, vendor-oriented and encouraging regulatory measures are important as an inclusive approach for all stakeholders to take responsibilities for food safety in the farmers markets. For example, state cottage food laws could be easily updated with nationwide cottage food laws targeting high-risk food categories while also considering each vendor's level of experience, which could be based on training received or the scale of their business based on the total revenue (i.e., local food sales). By considering these characteristics, a more customized or tiered approach to compliance and training could be developed. Third, providing accessible educational materials and training to vendors, managers, and customers through a variety of delivery forms is essential, as discussed above. Fourth, implementation of GFMPs should be encouraged in all states for overall success in food safety.

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