ABSTRACT

EVERHART, SAVANA L. Factors Surrounding the Implementation of Food Safety Management Systems and Their Impact on Food Safety Culture (Under the direction of Dr. Benjamin Chapman).

An estimated 48 million people contract a foodborne illness in the United States each year, causing a large financial burden for food production and service facilities. It is important for these institutions to reduce risks within their establishments. This is often done with the implementation of a food safety management system (FSMS), such as hazard analysis and critical control points (HACCP). This systematic approach allows producers to evaluate their food production or service facilities for biological, chemical, and physical hazards. In order to have a strong FSMS, a positive food safety culture (FSC) must be established throughout all levels of employment. Companies with strong FSC have strong leaders, excellent at communication, that see the value in food safety; however, there are significant barriers to achieving a positive FSC.

The purpose of this thesis was to study the factors surrounding the implementation of food safety management systems (FSMS). A systematic literature review of the factors in implementing a FSMS was conducted. Studies were coded for motivations, benefits, and barriers for implementing a FSMS. It was found that the biggest motivator was improved product safety and/or quality, while the biggest benefit was improved customer satisfaction. The barriers to implementation were cost and employee resistance to change and motivation. Future work should be done to try to reduce costs of implementation, as well as determining what motivates employees to implement a change.

The second study was aimed at determining whether implementing a temperature monitoring FSMS within a university dining hall had an effect on the dining hall’s FSC.
Temperature data were collected. Serving line staff were surveyed on their food safety knowledge and various aspects of FSC, while managers were interviewed about FSC within the dining hall. Dining hall managers that received the intervention technology indicated that the biggest barrier to implementation was training. While data analysis did not show that FSC was different between a dining hall receiving the intervention and one that did not, employees felt that the FSMS was faster, more accurate, and gave more accountability.

Taken together, these studies indicate the need for a positive FSC for the effective implementation of a FSMS. It is important for all food establishments to have a strong FSC in order to prevent outbreaks and avoid losing customer confidence. Future work should be done on discovering what motivates employees to change their behavior when implementing a FSMS.
Factors Surrounding the Implementation of Food Safety Management Systems and Their Impact on Food Safety Culture

by
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A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the degree of Master of Science

Food Science

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2019

APPROVED BY:

_______________________________  _______________________________
Dr. Benjamin Chapman             Dr. Lee-Ann Jaykus
Committee Chair                  

_______________________________
Dr. Anne McLaughlin
DEDICATION

To Momma and Daddy

Thank you for being my original scientific heroes
BIOGRAPHY

Savana Everhart is the daughter of a biologist and a chemist and grew up hearing conversations about science at the dinner table. She was raised in Durham, North Carolina, on a small meat goat farm where she participated in 4-H showing both meat goats and a beef heifer. While in high school, she participated in educational contests and represented the state of North Carolina in national 4-H Livestock Skillathon, Livestock Quiz Bowl, and Horse Bowl contests. These contests and experiences with her own animals sparked an interest in animal health, so Savana began working at Southpoint Animal Hospital in Durham to obtain veterinary experience. She then decided to pursue her Bachelors of Science in Animal Science at North Carolina State University. During her time at NC State, Savana found out about food science and food safety. She also had the opportunity to study abroad in India over winter break. It was there that she first heard about the concept of One Health and realized she could combine her passion for animal health and food safety.

Savana graduated with her Bachelors of Science in both Animal Science and Food Science in 2017. She decided to pursue her graduate studies in food safety communication as she is passionate about protecting both people and animals and educating the public about potential zoonotic risk factors.
ACKNOWLEDGMENTS

First and foremost, I would like to thank Dr. Ben Chapman who gave me a chance when I was an undergraduate with no research experience. Your guidance and support through the last 3 years have meant so much to me. You have encouraged so many people, including me, to ensure their food is a little safer – whether that be washing their hands more frequently or actually measuring the internal temperature of their hamburger. To Dr. Jaykus, thank you for taking me into your lab as one of your own and for showing me that it is possible to be a successful female scientist with a family. The benchtop lab experience I have received has been invaluable to my career, and it has been a pleasure to work as a teaching assistant for you. I have immensely enjoyed your mentorship and our random conversations in your office. To Dr. McLaughlin, thank you for providing your expertise and assistance in conducting this project. You were always willing to help me along the way.

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Thanks to my former roommates, Allison Dixon and Tanvi Tapadia for reminding me to have fun outside of school. To Lindsey Reedy Heck, thank you for being my best friend through everything even if our lives are completely different than they were when we met 6 years ago.

A special thanks to my fiancé, Caleb Nunn. I couldn’t ask for a more supportive partner in life and am so thankful you chose to do this with me. Living apart for the past year has been difficult, but you’ve always understood if I need extra time for school work. Thank you, though,
for reminding me that I don’t need to work all the time and for making me have fun even when I don’t feel like it. I can’t wait to see where life takes us.

To Kinsey, thank you for being the first person I was able to mentor. I know you’ve always looked up to me, and I am so proud of you. You’ve worked so hard to get a job, and I hope you always pursue what you love. To Sierra, you’ve always been able to make me laugh, and it’s been my pleasure to watch you grow up. I’m so proud to see you mentor younger kids in your 4-H program. You truly do an amazing job. I always felt like I had to be the best at everything because both of you looked up to me in everything. You made me push myself, and I appreciate having little sisters to help drive my competitive spirit.

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Lastly, to Momma and Daddy – I can’t even express my gratitude to you both. Daddy, growing up, I can remember random scientific conversations at the dinner table where you’d talk about lyophilization and chromatography. I had no idea what you were talking about, but I always knew you were so passionate about your career. You are a great example of loving what you do. Your satisfaction in your career makes me want to find something I am completely enthralled with. I have also admired your quiet sense of leadership. You don’t have to be a commander, but people still look up to and respect your opinion. Furthermore, you taught me to love traveling and discovering other cultures. I’ve had so many amazing experiences (and hope to have more) around the world. I’m not sure whether the Wanderlust gene is real or not, but your love to seeking new adventures was certainly passed down to me. Momma, you have always been my biggest supporter. You’d listen to me talk at the end of every day whether I was excited about something or just need to vent. I’ve always looked up to you, and you always put your girls first. You drove me all over the state for 4-H, horseback riding and piano lessons, and school functions. You drove me all over the country for 4-H competitions, work opportunities, etc. You sacrificed so all 3 of us could go to schools that were best for each of us. You’ve always had my back, and you always will. I know that whenever I need you, you are just a phone call away. You got me involved in 4-H because agriculture is in my blood, as is my love for animals (Daddy may have given me the Wanderlust gene, but you gave me the Animal People gene). So many of my life choices are because of values you instilled. Both of you are so important to me, and I am who I am because of you. Thank you. I know the only way I can pay you back is to make you proud – I hope to do everything I can to make that happen. I love you.

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INTRODUCTION

Foodborne illness sickens approximately 48 million people in the United States every single year (16). According to Mattia et al., institutions, such as schools or universities, were associated with the third highest rate of outbreak-associated illnesses in a food preparation location, at 13%. Restaurants had the highest rate with 43% and catering or banquet facilities had the second highest with 24%; however, institutions had the highest average number of illnesses per outbreak (11).

Dining hall outbreaks can cause significant burdens to the university. In March 2010, over 70 students at Emerson College became ill with norovirus. The outbreak was suspected to be linked with dining services and related to a large norovirus outbreak in Boston, including the Harvard Faculty Club where as many as 200 people were affected by the virus (14). In another case in 2007, 90 students and staff at the University of Western Ontario were sickened with Salmonella enterica serovar Typhimurium after eating at the university’s food court. This outbreak was later attributed to improper food handling and cross-contamination of raw chicken products (18). In September of 1984, another Canadian institution, the University of Victoria, reported 330 students sickened with Campylobacter jejuni. Improper handling and storage of the salad was thought to be the original source of the outbreak; however, by the end of the outbreak, at least 3 other types of food were implicated in sickening students (1). Poor sanitation, poor handling, and cross-contamination were all attributed to causing the aforementioned outbreaks. University dining halls around the world serve hundreds, if not thousands, of people every single day. It is important that they have a positive food safety culture in order to prevent future outbreaks.
In addition to the burden to victims, outbreaks can cause a significant financial burden to the institutions in which they occurred. Dining hall personnel must spend valuable time answering questions from concerned parents, students, and other patrons. They also receive negative publicity, which can cause a loss of confidence from the public. This can keep new customers away and former customers from returning, furthering the financial burden of the outbreak. Estimates of the cost of a foodborne illness outbreak depends on the outbreak conditions as number of people affected, pathogen of interest, and restaurant structure can all affect the cost. In a study conducted by Bartsch et al., the estimated cost of a single outbreak ranged from $3,968-$1.9 million for a fast food restaurant and $6,330 to $2.1 million for a fast-casual restaurant. The study noted that the most significant cost factors associated with an outbreak are lawsuits and legal fees, the size of the outbreak, and lost revenue (3). This is significant for university dining halls as they serve hundreds to thousands of students every day.

In order to avoid foodborne illness outbreaks, food service facilities need to ensure they have proper food safety protocols in place. The implementation of a good food safety management system (FSMS), such as Hazard Analysis and Critical Control Points (HACCP), has been a way to reduce the risk for an outbreak. A FSMS is defined by Griffith et al. as "all the documented procedures, practices, and operating procedures which influence food safety, preferably consisting of 3 levels – policy, practices and record forms" (7). A singular FSMS does not always work for all business types, and companies should work to ensure their chosen system meets their needs. Managers’ involvement in the implementation and use of the system is also vital for its success (7). In a study conducted by Nayak and Waterson, all food establishments already had pre-set views on food safety, which they tried to instill in their employees (12). As management is also typically responsible for training and motivating new staff members to use
FSMS, their food safety culture – whether positive or negative – will likely be passed onto the personnel they train, again whether it is positive or negative (8).

The concept of food safety culture (FSC) is still relatively new; however, it is an important concept that all food establishments should prioritize. According to Yiannas, FSC is the way employees in an organization view and reflect on food safety (20). Griffith et al. suggested there are six different indicators in FSC: management systems, style, and process; leadership; communication; commitment; environment; and risk awareness, perception, and risk taking behavior (7). In another study, Griffith et al. notes that FSC is the learned and shared attitudes contributing to hygiene behaviors in a food handling establishment (8). Whatever the definition, it is important to note that the culture includes all employees within an organization, from executive management to janitors. Having strong leaders committed to food safety is vital to having a positive FSC (5, 7, 19, 20). Strong leaders are able to implement change and encourage fellow employees to practice positive food safety behaviors. Furthermore, strong leaders do not have to be managers; it is important to have strong leaders within every position. Management often does not have the capacity to see all potential unsafe behaviors, and staff members’ close proximity to others on the floor and may allow them to correct a deviation sooner. Many times, these employees are the first to speak up about a potential food safety problem, so it is important that they are listened to (5). Managers can play an important role by empowering their staff to remind other workers about their organization’s food safety practices (2). Workers also may feel more comfortable asking questions to their peers than managers. Furthermore, it is important for leaders to know and understand food safety risks within their establishment. Leaders should be vigilant in staying up to date with food safety problems and should be trained in mitigating risks before they become issues (15).
Safety climate is another term that needs to be taken into consideration within these institutions. Safety climate nested within safety culture and is more specifically referencing personnel (23). Specifically, food safety climate is defined by De Boeck et al. as “employees’ (shared) perception of leadership, communication, commitment, resources and risk awareness concerning food safety and hygiene within their current work organization” (5, 6). With this definition, food safety climate is seen as just a piece of FSC. This is important as employees are those that drive food safety within any given establishment. Employees perception is a vital component of food safety culture as employees are arguably one of the biggest drivers of an establishment’s positive or negative FSC.

As previously discussed, employee perception is a strong driver to having a positive food safety climate. Communication has been mentioned as a major component for the status of an organization’s food safety culture (4, 7, 15, 20), so it is important for communication to happen frequently and be well thought out. Managers must communicate with staff in order to properly train and correct staff if they are not following proper procedures. They are responsible for training staff in a variety of topics, including food safety and personal hygiene, food quality, and customer service. Establishments with a strong food safety culture often have a strong food safety training program. Barriers to training in food establishments include language and cultural barriers (13). Managers at every level need to have a high standard for communication. As such, even senior level management must communicate with junior managers to discuss topics such as policy updates or new training initiatives. FSC must have a solid foundation amongst all employee ranks and positions, with everyone working together to serve safe food.

The purpose of this thesis was to evaluate the FSC surrounding the implementation of a novel digital FSMS. This evaluation began with a systematic literature review analyzing the gaps
in literature pertaining to the FSC surrounding the implementation of a new FSMS (Chapter 1). There is already a plethora of research analyzing food handlers’ attitudes and consumer towards FSC (17, 21, 22) and FSC evaluation methods (9, 10). The evaluation of FSC pertaining to the adoption of FSMS was chosen since organizations with a positive FSC often have a strong FSMS in place (20). A second study was conducted at a university dining hall to determine the FSC surrounding the implementation of a novel temperature monitoring device (Chapter 2). While there has been an increase in studying FSC in the last 10 years, to date, there has not been a study conducted in a university dining hall specifically looking at the adoption of new food safety technology.
REFERENCES


Operators. United Kingdom.


CHAPTER 1

Food Safety Management Systems and Factors of Implementation:

A Systematic Review

ABSTRACT

Food safety management systems (FSMS) are organized control programs in order to reduce food safety risks and correct food safety deviations. Understanding primary motivators, benefits, and barriers to implementing FSMS is important to continue to improve these systems. A systematic literature review of the factors in implementing a FSMS was conducted. Studies were coded for motivations, benefits, and barriers for implementing a FSMS. It was found that the biggest motivator was improved product safety and/or quality, while the biggest benefit was improved customer satisfaction. The barriers to implementation were cost and employee resistance to change and motivation. Future work should be done to try to reduce costs of implementation, as well as determining what motivates employees to implement a change.

INTRODUCTION

Food safety management systems (FSMS) are systems that are implemented with pre-set hazard control programs in place (36). In the university dining hall system, this may include defined sanitation procedures or a set of corrective actions to follow if a food on the line is found to be within the temperature danger zone for more than 2 hours. These standards are critical for ensuring regulations are followed and that a safe food product is delivered to the consumer; however, research has suggested it is important to take the human aspect into account when discussing FSMS (18), as behavior has to change in order to assure corrective actions are
appropriately taken. Griffith notes that management systems should consist of policies, practices, and record-keeping forms; however, the scale of the system depends directly on the organization (i.e., size and scope of business) (13). Understanding the primary motivators for implementation, as well as the benefits and barriers for implementation may help future training and adoption strategies; furthermore, these factors often can be indicative of an establishment’s food safety culture.

Many current studies do not provide input on the food safety culture and the implementation of a new technology or system. Instead current literature reviews in food safety culture focus on determinants for safe food handling among retail workers (33, 38), but also among consumers (37). Other analyses look at the efficacy of various food safety culture evaluation methods (19, 26). One literature review looked at factors surrounding HACCP implementation from 1994 to 2007 (8); however, increased globalization and new food safety management systems may be different as they have evolved over the last 10 years.

The objective of this literature review was to accumulate and analyze information from the literature to determine what the current applications, impacts, barriers, and limitations of food safety management systems have on food safety culture within food establishments. The following questions were addressed:

Research Question 1: What are the current applications for food safety management systems in the literature?

Research Question 2: According to the conclusions from the studies, what factors affect the implementation of food safety management systems?
METHODS

Article Selection

A systematic review was conducted to investigate the factors, such as motivators, barriers, and benefits of implementing a food safety management system. The review was limited to studies published in English and between 2008 and 2019. A review on the factors surrounding HACCP implementation was conducted between 1994 and 2007. For this reason, studies chosen for our review were limited to those published after 2008 (8).

The North Carolina State University System Library System database was used to search for relevant terms. Search terms were ((barriers OR challenges OR barrier OR difficulties OR difficulty OR challenge)) AND ((implementation OR implementing OR administration)) AND (("food safety management system" OR "food safety management systems" OR "food safety management scheme" OR "food safety management schemes")) NOT (TitleCombined:(review)) NOT (TitleCombined:(halal)) NOT (TitleCombined:(quality)). The search yielded 539 results. Searches from the database were then screened for title and abstract relevance. Relevant articles were then screened for study inclusion (Figure 1.1).
Article inclusion criteria were as follows: a) primary focus on the factors surrounding the implementation of a food safety management system; b) original research; and c) peer-reviewed studies. Exclusion criteria were a) studies not in English; b) literature reviews, dissertation theses, conference proceedings, news and feature articles, blogs, reports, lectures, non-peer reviewed work, working papers, and letters to the editor; and c) studies focused on evaluating the performance of a FSMS. These criteria lead to a total of 23 articles used for analysis. A summary of key findings can be found in Table 1.2.

**Article Analysis**

Articles were coded manually for general characteristics. These included the purpose, implemented system, location, data collection methods, sample size, and key findings from the study. Articles were also coded to determine themes for overall implementation factors. Studies
were coded using NVivo 12 for Mac (QSR International, Melbourne, New South Wales, Australia). Initial codes were analyzed for various patterns. These patterns were then analyzed manually. Ultimately, three themes were established. They included motivations, barriers, and benefits (Table 1.1).

Table 1.1. Main coding themes used to evaluate articles pertaining to the implementation of FSMS

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivators</td>
<td>Article includes information on the main drivers for companies to implement a FSMS</td>
<td>Gain access to foreign markets (32); improved product quality and safety (24); customers require FSMS (6)</td>
</tr>
<tr>
<td>Benefits</td>
<td>Article includes information regarding the positive outcomes of implementing a FSMS</td>
<td>Increased product traceability (6); increased productivity (7); reduction of food waste (30)</td>
</tr>
<tr>
<td>Barriers</td>
<td>Article includes information regarding the challenges from implementing a FSMS</td>
<td>High cost of implementation (7); employee resistance to change (11); poor infrastructure (2)</td>
</tr>
</tbody>
</table>

RESULTS

Characteristics of Reviewed Studies

To address the first research question, studies were placed into groups based on the FSMS they implemented. Of the 23 articles evaluated, 61% of studies (n = 14) surrounded HACCP implementation. Three of the aforementioned studies also looked at implementation of the International Organization for Standardization (ISO) 22000, while another 3 looked at the ISO 22000 system alone. The 3rd party certification system of the British Retail Consortium (BRC) was used in 3 studies.
Most of the data collection was in the form of interviews or surveys. Thirteen studies relied solely on a survey questionnaire, while 4 studies used a combination of surveys with interviews. Nineteen studies surveyed or interviewed individual companies within the population they were targeting. Sample sizes for individual companies interviewed or surveyed ranged from 11 to 223, while focus group samples ranged from 8 to 23. Many studies focused on specific types of processors. These included seafood, dairy, meat, fresh produce, and poultry. Of these, dairy was the most popular with 3 specific studies related to the implementation of FSMS in the dairy industry. Identified articles were from studies conducted all over the world, including developed and developing countries.

To determine factors associated with the implementation of the FSMS, information from articles’ results and discussion sections were used to group factors into three main themes. These themes are motivators, benefits, and barriers to the implementation of a FSMS. Motivators are defined as the drivers for companies to implement a system. Benefits are defined as the positive outcomes from implementing a system, while barriers are seen as the drawbacks from implementing a system. Twenty-one of the articles reviewed identified these specific factors within their studies. A summary of the major motivators, benefits, and barriers from studies reviewed can be found in Table 1.2.
Table 1.2. Motivators, benefits, and barriers to the implementation of FSMS in reviewed literature

<table>
<thead>
<tr>
<th>Factor</th>
<th>Characteristic</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motivators</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to foreign markets</td>
<td></td>
<td>(9, 11, 22, 32)</td>
</tr>
<tr>
<td>Customer requirements</td>
<td></td>
<td>(6, 9, 15, 17)</td>
</tr>
<tr>
<td>Governmental regulations</td>
<td></td>
<td>(17, 31, 35)</td>
</tr>
<tr>
<td>Improved product safety and/or quality</td>
<td></td>
<td>(9, 24, 25, 32, 35)</td>
</tr>
<tr>
<td>Increased accountability</td>
<td></td>
<td>(11)</td>
</tr>
<tr>
<td>Increased marketing capabilities</td>
<td></td>
<td>(35)</td>
</tr>
<tr>
<td>Increased product traceability</td>
<td></td>
<td>(11)</td>
</tr>
<tr>
<td><strong>Benefits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to foreign markets</td>
<td></td>
<td>(1, 24, 25)</td>
</tr>
<tr>
<td>Customer satisfaction</td>
<td></td>
<td>(6, 24, 27, 28, 30, 34)</td>
</tr>
<tr>
<td>Improved communication</td>
<td></td>
<td>(7)</td>
</tr>
<tr>
<td>Improved product safety/quality</td>
<td></td>
<td>(7, 27, 28, 30, 34)</td>
</tr>
<tr>
<td>Increased food safety awareness</td>
<td></td>
<td>(6, 24)</td>
</tr>
<tr>
<td>Increased marketing capabilities</td>
<td></td>
<td>(7, 24, 30)</td>
</tr>
<tr>
<td>Increased product traceability</td>
<td></td>
<td>(6)</td>
</tr>
<tr>
<td>Increased productivity</td>
<td></td>
<td>(7)</td>
</tr>
<tr>
<td>Reduction of food waste</td>
<td></td>
<td>(30)</td>
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<td><strong>Barriers</strong></td>
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<td></td>
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<tr>
<td>Cost</td>
<td></td>
<td>(1, 4, 5, 6, 11, 14, 15, 17, 24, 25, 28, 30, 32)</td>
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<tr>
<td>Employee motivation and resistance to change</td>
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<td>(4, 7, 11, 14, 24, 27, 34)</td>
</tr>
<tr>
<td>High turnover rate</td>
<td></td>
<td>(4)</td>
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<td>Increased paperwork</td>
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<td>Lack of attributable benefits</td>
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<td>(11)</td>
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<tr>
<td>Lack of knowledge</td>
<td></td>
<td>(1, 7, 14, 28, 31)</td>
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<tr>
<td>Legal requirements</td>
<td></td>
<td>(28, 31)</td>
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<tr>
<td>Length of time implementing system</td>
<td></td>
<td>(4, 7, 14, 15, 30, 35)</td>
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<td>Poor infrastructure</td>
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<td>(11, 24)</td>
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Motivators

In this study, the most commonly stated motivator for implementation in the reviewed studies was improved product safety and quality. Twenty-two percent (n = 5) of the articles
specifically mentioned it. Access to foreign markets, governmental regulations, and customer requirements were also seen as major motivators.

Benefits

The benefit most recognized by reviewed literature was customer satisfaction with 26% \((n = 6)\) of reviewed articles mentioning it. Five studies indicated improved food safety/quality as a benefit, while 3 companies each indicated access to foreign markets and increased marketing capabilities were benefits to implementation.

Challenges

The most commonly reported barrier was the cost of implementation. Out of the companies surveyed, 13 (57%), specifically indicated cost as a major barrier. Costs include the cost of training employees, hiring external consultants, fees, and updating or renovating existing infrastructure. Another barrier noted was employee motivation and resistance to change. This was specifically noted as a major barrier in 30% \((n = 7)\) of the included literature. Length of time was noted in 26% \((n = 6)\) of the studies. This could be due the time needed to learn the specific FSMS, update infrastructure, train employees, and get certified. Another barrier was lack of knowledge \((n = 5)\). Many of the studies indicated employees had a lack of food safety knowledge and/or lack of knowledge in the implementation of the FSMS.

DISCUSSION

As food safety becomes more regulated and FSMS become more prevalent, it is imperative for food safety professionals to understand motivators, benefits, and barriers to FSMS
implementation. Motivators and benefits of the implementation of FSMS go hand in hand. As previously discussed, motivators are the drivers for a company wanting to establish a FSMS, while benefits are seen after the system has been established. It makes sense that many of the drivers are also seen as benefits. The biggest motivator and one of the major benefits for the reviewed studies was improved product safety and quality. Major outbreaks have been estimated to cost the respective company between $70 and $160 million dollars (16). Food producers know there is a high cost for outbreaks, and implementing effective FSMS has been shown to decrease the risk of potential food safety hazards (20). Another major motivator and benefit were access to foreign markets. Many governmental regulations require a FSMS to be in place before they will allow products from a different country to be imported. Having an established system allows companies to increase clientele and therefore increase profits. This is especially important for developing countries that want to export products to more developed countries. Another major benefit was the ability to market oneself. This plays into expanding global markets and increasing customer satisfaction. Companies are competitive, so the ability to use food safety as a marketing point is vital (29). Purchasing from firms that have implemented an effective FSMS, especially if it is certified by a neutral third party, is very attractive to many food industry customers. Furthermore, purchasers do not want a risky product, as an outbreak may affect their business as well as yours. Increasing food safety will likely increase their satisfaction with you as a supplier, and they will conceivably continue to purchase from you.

While there are many benefits to implementing a food safety management system, effective execution can be difficult. As seen in this review, there are many barriers to adoption that are not easy to fix. The most common barrier noted was cost of implementation. The Global Food Safety Initiative (GFSI) estimates that the cost of implementing various FSMS, including
ISO 22000 and BRC, ranges from $24,094 for small companies to $45,794 for large companies (12). This cost does not include the infrastructure updates or changes that many companies need in order to become certified. Furthermore, it is important to have employees to be motivated to not only become trained in implementation, but to also adopt the system to their working environment. When implementing any new system, having a positive food safety culture is vital (29). This includes having employees that are willing to take direction. Griffith et al. notes 6 cultural factors that contribute to food safety performance (13). Three of these factors – leadership, commitment to food safety, and communication – are vital to employee motivation. Strong leaders are needed within the entire employment hierarchy for implementation to be effective. A company with a positive food safety culture will have strong leaders committed to food safety and who are good communicators. These leaders should help motivate employees. Further work should be done on identifying a) why employees are resistant to change; and b) what motivates employees to change behavior.

Other barriers noted was the length of time implementing the system. Food companies are busy. Staff may take several days to become properly trained before they can even begin implementing a system. Also, building or equipment updates may be needed, which could limit production, tying back into cost. Companies also may not see the benefits of implementing a FSMS for several months to years after beginning to implement a system. Lastly, lack of knowledge was seen as a barrier. If employees do not have a solid background in food safety, implementing a FSMS could be very difficult. Some FSMS are very new, especially to some of the developing countries identified in this review. Some smaller countries, like Mauritius, lack pertinent information regarding food safety and the implementation of FSMS from their government; however, many of these smaller countries rely on exporting to countries that require
HACCP regulations. Being able to successfully implement a FSMS is vital for the company’s food industry to survive (31).

Overall, implementing FSMS has many benefits and drawbacks. There is a high cost and it can be difficult to motivate employees; however, food outbreaks are expensive, and not many companies can afford to make mistakes. There were several limitations for these studies. Each study had their own way of classifying each of these factors; however, there may have been differences among the ways various studies defined each factor. Furthermore, not all studies looked at motivators, benefits, and barriers. Some studies that did not include motivators may have included the motivators as benefits as many of these are the same.

**CONCLUSION**

Currently, food safety management systems are being utilized around the world, from developing to developed countries. The majority of companies are using HACCP as a FSMS; however, another major FSMS is ISO 22000. The 3 main factors affecting the implementation of FSMS are motivators, benefits, and barriers. Major motivators identified were access to foreign markets, customer requirements, and improved food safety/quality. Benefits of implementation include customer satisfaction and improved food safety/quality. The main barrier to implementation was cost, followed by employee motivation and resistance to change. When developing food safety management systems, professionals should take these factors into account. Future research should be done to find ways to reduce cost of implementation. Other research should be done in determine what motivates employees and how to best motivate them to embrace change so FSMS can be implemented effectively.
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Purpose</th>
<th>Implemented System</th>
<th>Location</th>
<th>Data Collection</th>
<th>Sample</th>
<th>Key Findings</th>
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<tbody>
<tr>
<td>Al-Busaidi et al. 2017 (1)</td>
<td>Investigate the challenges and benefits with the implementation of HACCP and related programs among seafood processors</td>
<td>HACCP and prerequisite programs</td>
<td>Sultanate of Oman</td>
<td>Survey and interviews</td>
<td>HACCP processors: $n = 22$ Non-HACCP processors: $n = 15$ Officials: $n = 15$</td>
<td>Benefits were that HACCP certification allowed for exports to more countries. The main barriers identified for processors was cost; however, regulatory officials indicated there was a lack of training and understanding of HACCP regulations.</td>
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<tr>
<td>Ball et al. 2009 (3)</td>
<td>Investigate factors influencing the implementation of FSMS in small and medium meat processing facilities</td>
<td>HACCP and non-formalized FSMS</td>
<td>Ontario, Canada</td>
<td>Interviews and focus groups</td>
<td>Company interviews: $n = 13$ Company focus groups: $n = 8$</td>
<td>Three main themes of factors for implementing FSMS management systems were proposed: 1) production system, 2) organizational characteristics, and 3) employee characteristics.</td>
</tr>
<tr>
<td>Chaoniruthisai et al. 2018 (4)</td>
<td>Investigate barriers and contextual factors in the implementation of a certification system</td>
<td>British Retail Consortium (BRC)</td>
<td>Thailand</td>
<td>Survey</td>
<td>Companies: $n = 217$</td>
<td>Barriers to implementation included organizational resistance, high cost, high turnover rate and lack of staff motivation, extended length of time and effort to implement system.</td>
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<tr>
<td>Charalambous et al. 2015 (5)</td>
<td>At various points of implementation, evaluate of HACCP in small businesses in Cyprus</td>
<td>HACCP</td>
<td>Cyprus</td>
<td>Audit, survey, and follow-up visit</td>
<td>Companies: $n = 50$</td>
<td>Operators were initially excited to implement HACCP; however, as difficulty and cost increased, operators discontinued implementation.</td>
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<tr>
<td>Chen et al., 2015 (6)</td>
<td>Determine the motivations, barriers, and benefits of using a third-party certification body to implement non-regulatory FSMS in New Zealand</td>
<td>Regulatory and non-regulatory FSMS</td>
<td>New Zealand</td>
<td>Survey</td>
<td>Companies: ( n = 115 )</td>
<td>The most important motivator was buyer requirements. Benefits include a higher product traceability, increased employee food safety awareness, and increased customer satisfaction. Barriers seen were increased paperwork, record keeping, and high cost. Third-party auditors were seen a very helpful in implementing FSMS by a majority of respondents.</td>
</tr>
<tr>
<td>Escanciano and Santos-Vijande 2014 (7)</td>
<td>Investigate barriers, benefits, and overall satisfaction with ISO 22000 implementation in Spain</td>
<td>International Organization for Standardization (ISO) 22000</td>
<td>Spain</td>
<td>Survey</td>
<td>Spanish ISO 22000 certified companies: ( n = 189 )</td>
<td>Barriers include organizational resistance, high cost, large amount of time spent on implementation, and lack of awareness with the standard. Benefits include better control of food safety, increased marketing capabilities, increased productivity, and improved communication among stakeholders.</td>
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<td>Fernando et al. 2014 (9)</td>
<td>Investigate factors leading to the implementation of the Malaysian food safety system (MeSTI)</td>
<td>MeSTI</td>
<td>Northern region of Peninsular Malaysia</td>
<td>Survey</td>
<td>People: $n = 89$</td>
<td>The main motive for implementation was improving the product quality. Other factors include improving customer confidence and the ability to export to other countries. The two major factors for successful implementation of MeSTI are the company’s attributes, such as pre-established programs and procedures and equipment, and personnel, which includes motivation, commitment, and availability. Drivers for implementation include: more accountability, potential to export to new facilities, better traceability. Barriers to implementation include: high cost, apprehension to change, lack of infrastructure and attributable benefits.</td>
</tr>
<tr>
<td>Fotopoulos et al. 2009 (10)</td>
<td>Investigate factors leading to HACCP implementation</td>
<td>HACCP</td>
<td>Greece</td>
<td>Survey</td>
<td>Greek food companies: $n = 107$</td>
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<tr>
<td>Galstyan and Harutyunyan 2016 (11)</td>
<td>Investigate barriers to the adoption of HACCP in a dairy processing system</td>
<td>HACCP</td>
<td>Armenia</td>
<td>Interviews and focus groups</td>
<td>Company interviews: $n = 20$</td>
<td>Company focus groups: $n = 23$</td>
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<td>Grover et al. 2016 (14)</td>
<td>Investigate challenges for small food facilities in implementing Preventive Controls</td>
<td>Hazard Analysis and Risk-based Preventive Controls (HARPC)</td>
<td>Midwest, United States of America (USA)</td>
<td>Interviews</td>
<td>Academia and industry participants: $n = 13$</td>
<td>Barriers identified included difficulty understanding the regulations, high cost, employee motivation and preparation, and long implementation period</td>
</tr>
<tr>
<td>Herath and Henson 2010 (15)</td>
<td>Investigate barrier to HACCP implementation</td>
<td>HACCP</td>
<td>Ontario, Canada</td>
<td>Survey</td>
<td>Companies: $n = 134$</td>
<td>The biggest motivator to implement was customer requirements. Major barriers included high cost and length of time and effort to implement changes.</td>
</tr>
<tr>
<td>Hyde et al. 2016 (17)</td>
<td>Compare HACCP implementation and uses between the European Union (EU) and the USA.</td>
<td>HACCP</td>
<td>EU and USA</td>
<td>Interviews</td>
<td>Companies: USA: $n = 18$ EU: $n = 14$</td>
<td>The main motivators for HACCP implementation in the EU are governmental regulations, while customer requirements are the US drivers. Barriers in both countries include high cost for small businesses to implement specific plans.</td>
</tr>
<tr>
<td>Karaman et al. 2012 (21)</td>
<td>Determine barriers for the implementation of HACCP and other FSMS in the Turkish dairy industry</td>
<td>HACCP and other FSMS systems</td>
<td>Turkey</td>
<td>Surveys and interviews</td>
<td>Companies: $n = 28$</td>
<td>Major barriers include high costs, insufficient knowledge of HACCP, and current plant conditions.</td>
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<td>Kirezieva et al. 2015 (22)</td>
<td>Investigate FSMS implementation at fresh produce companies to determine differences among countries</td>
<td>Various systems</td>
<td>Global</td>
<td>Case Studies</td>
<td>Companies: n = 118</td>
<td>A motivator was the ability to export internationally; however, emerging and developing countries often did not have enough support. Regulations would encourage companies to implement FSMS.</td>
</tr>
<tr>
<td>Kök 2009 (23)</td>
<td>Investigate the implementation of FSMS in the Turkish poultry industry</td>
<td>HACCP and ISO 22000</td>
<td>Turkey</td>
<td>Survey</td>
<td>Companies: n = 25</td>
<td>All firms surveyed indicated the benefits of implementing a FSMS outweighed the cost; however, it was easier for larger companies to adopt the systems.</td>
</tr>
<tr>
<td>Macheka et al. 2013 (24)</td>
<td>Investigate factors influencing the implementation of FSMS in Zimbabwe</td>
<td>HACCP and ISO 22000</td>
<td>Harare Province, Zimbabwe</td>
<td>Survey</td>
<td>Companies: n = 30</td>
<td>The main motivator for implementation was increased product safety and quality. Main barriers include high cost, inadequate infrastructure, and lack of manager commitment. Benefits include increased food safety skills among employees, better image, higher sales, and the ability to export to new markets.</td>
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<tr>
<td>Maldonado-Siman et al. 2014 (25)</td>
<td>Compare factors related to the implementation of FSMS in meat product facilities in China and Mexico</td>
<td>HACCP</td>
<td>Mexico and China</td>
<td>Survey</td>
<td>Chinese companies: $n = 32$ Mexican companies: $n = 42$</td>
<td>Both countries noted the major motivation to implement was improving product quality, the major barrier was the cost of staff training and product testing, and the main benefit was the ability to export to new markets.</td>
</tr>
<tr>
<td>Mensah and Julien 2011 (27)</td>
<td>Investigate the challenges and drivers for FSMS implementation</td>
<td>ISO 22000</td>
<td>United Kingdom</td>
<td>Surveys followed by case study interviews</td>
<td>Company surveys: $n = 120$ Company case studies: $n = 3$</td>
<td>Benefits included supposed confidence in the safety of products and increased transparency. The largest barrier was employees’ reluctance to change. Other barriers included cost and having the proper infrastructure to implement the system.</td>
</tr>
<tr>
<td>Păunescu et al. 2018 (28)</td>
<td>Investigate factors for the implementation of ISO 22000 in Romania</td>
<td>ISO 22000</td>
<td>Romania</td>
<td>Survey</td>
<td>Companies: $n = 43$</td>
<td>The major benefits to implementation were improved food safety, reduced product risk, and improved consumer confidence. Barriers to implementation include high costs, legal requirements, and employee knowledge.</td>
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<td>Qijun and Batt 2016 (30)</td>
<td>Investigate barriers and benefits with implementation of companies in various stages of a third-party certified FSMS implementation</td>
<td>Third-party certified FSMS</td>
<td>Pudong district of Shanghai, China</td>
<td>Survey</td>
<td>Companies: ( n = 204 )</td>
<td>The major barrier for all stages was difficulty setting aside time for implementation and lack of long-term planning. The biggest barrier to implementation for small companies is that it would increase product costs in a highly competitive market. Benefits included improving company image, increase competitiveness, and product quality.</td>
</tr>
<tr>
<td>Ramnauth et al. 2008 (31)</td>
<td>Determine attitudes and knowledge of food safety among managers of fish production-related facilities in Mauritius</td>
<td>Most used HACCP</td>
<td>Mauritius</td>
<td>Interviews</td>
<td>Companies: ( n = 11 )</td>
<td>The main motivator regulatory compliance. In general, respondents had a poor knowledge of hazards and risks pertaining to fish products. Barriers to implementation include a lack of FSMS experts and pertinent information and a lack of communication with government regulators.</td>
</tr>
<tr>
<td>Rincon-Ballesteros et al. 2019</td>
<td>Define barriers and motivations to FSMS implementation among various Latin American countries</td>
<td>BRC</td>
<td>Latin America</td>
<td>Survey</td>
<td>Companies: ( n = 223 )</td>
<td>The main motivator is to have a safe product that can be exported. The main barrier for all countries was high cost of implementation.</td>
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<td>Tomašević et al. 2016 (34)</td>
<td>Investigate costs, difficulties, incentives, and benefits for adopting a FSMS in the Serbian dairy industry</td>
<td>HACCP or ISO 22000</td>
<td>Serbia</td>
<td>Survey</td>
<td>Dairy business operators: (n = 27)</td>
<td>Major benefits for FSMS adoption include increasing product safety and quality and an increased consumer confidence level. The highest costs associated with adoption were product investigation and analysis and external consultants. The biggest difficulty was the attitude and motivation of staff.</td>
</tr>
<tr>
<td>Wilcock et al. 2011 (35)</td>
<td>Investigate barriers and factors motivating HACCP implementation</td>
<td>HACCP</td>
<td>Ontario, Canada</td>
<td>Interviews</td>
<td>Food manufacturing employees: (n = 22)</td>
<td>Motivation for HACCP implementation included the marketing value, avoiding food safety risk, and impending regulations. Managers needed to be committed in order for successful implementation to occur. The biggest barrier among all levels of employees was the time taken to understand and adopt the system.</td>
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Table 1.3. Continued

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</table>
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initiatives: Managers’, food safety coordinators’ and production workers’ perspectives.


CHAPTER 2
Implementation of Novel Technology and Its Implications on Food Safety Culture in University Dining Halls

ABSTRACT
A positive food safety culture (FSC) is vital for the success of any food establishment. University dining halls are a very unique food establishment as many employees are part-time students. They also serve several thousand people every day, so having a strong FSC is essential to reduce the risk of an outbreak. Two dining halls within the same university system were used in this study. One dining hall was given a novel digital food safety management system (FSMS), while the other dining hall did not receive treatment. Temperature data from an intervention dining hall were collected. Serving line staff at both dining halls were surveyed on their food safety knowledge and various aspects of FSC, while managers were interviewed about FSC within their respective dining hall. Dining hall managers that received the intervention technology indicated that the biggest barrier to implementation was training. While data analysis did not show that FSC was different between the dining hall receiving the intervention and the one that did not, employees felt that the FSMS was faster, more accurate, and gave more accountability.

INTRODUCTION
Food safety culture (FSC) can be a very complex concept and has been described as a culmination of organizational culture, food science, and social cognitive science (11). The specific structure of a company has a large impact on FSC but the science behind food safety
regulations must also be considered. Powell et al. notes that “Creating a culture of food safety requires application of the best science with the best management and communication systems” (22). Food safety climate is a term that nests under FSC, and is defined as “employees’ (shared) perception of leadership, communication, commitment, resources and risk awareness concerning food safety and hygiene within their current work organization” (5). Favorable food safety climates have often been associated with a strong food safety management system (FSMS), as well as a safe, hygienic product (4).

If a company wants to have a positive FSC, it is important for all levels of management to also have a positive FSC (8, 19, 22, 28). This factor is what makes active managerial control crucial to the successful implementation and maintenance of FSC within an organization. Griffith acknowledges that management effectiveness is one of the most important factors in the service industry to prevent foodborne illness (9). In a study conducted on the implementation of hazard analysis and critical control points (HACCP), an employee noted that if rules were not consistent for everyone within their company, including owners, employees would revert back to old habits practiced before the implementation of the FSMS system (27).

It is critical that a food establishment has a positive FSC to prevent foodborne illness. In the case of university dining halls, thousands of customers are served every day. The majority of their customers are students; however, dining halls also serve university staff and faculty as well as external groups. The majority of college students are under the age of 30 (24), but there may be members of more vulnerable populations, such as those who are very young, old, pregnant, or immunocompromised. This population group has been termed YOPI by Baird-Parker (1). It is estimated that around 0.3% of college students are living with human immunodeficiency virus
(HIV) (24). A foodborne illness can cause serious consequences for people within the YOPI population.

To prevent the risk of foodborne illness, pathogens must be controlled. Pathogens can be controlled using a time and temperature system. Most microbial growth occurs between 40 and 140°F, known as the temperature danger zone (TDZ). Food should not be kept at room temperature for longer than 2 hours (26). In a study done by Lin and Sneed, only 52.1% of student employees in a university dining hall system indicated they had received training on the TDZ, and even one deviation could result in elevated foodborne illness risk (16). It is imperative that employees understand the temperatures they monitor and act upon can mean the difference between a normal meal experience or a potential foodborne illness. These employees are the final line of defense before food is served to a customer, so training them properly is vital.

A pilot study was conducted to determine a baseline for the amount of time it took for university dining hall staff members to take temperatures on the serving line. Time started when employees began taking the first temperature and ended when employees wrote the last temperature on a paper log. It took 11 employees an average of five minutes to take 14 time points. Researchers observed that time points were missed, on average of 1-2 times per shift, and inaccurate temperatures were occasionally recorded. The amount of time it takes to test temperatures is important especially during peak food service hours. The more time that is spent to conduct temperature tests, the less time can be spent on other job aspects, such as replacing food, cleaning, and assisting other personnel or customers; furthermore, the employees may be more willing to take temperatures in a timely manner if the amount of time required to do so is less, i.e., the process is quicker.
Difficulties implementing FSMS, like HACCP, have been noted in school food service facilities before (23). A novel FSMS system that allows employers to monitor temperatures in real-time has been developed by Testo Solutions (Testo SE & Co. KGaA, Lenzkirch, Germany). This system allows management in the dining hall to monitor temperatures taken by employees on the serving line in real-time. It also leads employees through corrective actions if the temperatures fall into the TDZ. The purpose of this study was to determine whether the implementation of a novel digital FSMS would affect the FSC within a university dining hall, measured through surveys and in-person interviews with dining hall serving line members and managers. The hypothesis was that the technology would create a more positive FSC within the dining hall that received the technology intervention.

**METHODS**

**Characterization of the Food Service Operation**

The two university dining halls used in this study were located in Raleigh, North Carolina, within the same university campus. The university has a central dining management team, which consisted of a dining hall director and a general manager for each dining hall. One dining hall was assigned as the intervention dining hall, while the other was assigned to as the control. The dining hall that received the intervention technology was slightly larger than the control dining hall and had 6 line managers. The number of employees fluctuates depending on the time of year and the dining hall’s needs. Anywhere from 50-70 employees are trained to work on the line in the intervention dining hall. Ten to twenty of them were full time employees and/or worked consistently on the line, while the rest were temporary workers or worked in other positions within the dining system. The control dining hall, which did not receive the technology,
had 4 line managers, and 20-40 employees were trained to work on the line in the control dining hall; 5-10 were full time employees and/or worked consistently on the line, while the rest were temporary workers or worked other positions. The hierarchy of management is depicted in Figure 2.1. Both the intervention and control dining halls were open from 7:00am to 9:00pm on weekdays and 9:00am to 9:00pm on the weekend. The timing of meal periods was as follows: Breakfast from the respective opening time until 10:30am; Lunch from 10:30am-4:30pm and was split into “early” and “late” shifts; Dinner was served from 4:30 to 9:00pm. It is important to note that food served during the late lunch shift was typically left over items from the early shift and made-to-order items.

![Figure 2.1. Dining hall system personnel hierarchy.](image)

All items on the line that were labeled as time-temperature controlled for safety (TCS) were foods that are received hot and must be held at or above 135°F according to the North Carolina Food Code, which is an adoption of the United States Food and Drug Administration’s 2009 Food Code (18). Line workers were responsible for taking the temperatures of each pan of
food on the line at 2-hour intervals, previously determined to abide by this code. An example of the serving line setup can be seen in Appendix A.

*Temperature Logging System*

The method of record keeping for temperatures for both dining halls before this study was the use of paper logs. Line workers would handwrite the temperatures for various food items served on a paper log for each service time frame (breakfast, lunch, and dinner). The paper logs would then be collected by line managers and stored in a filing cabinet for record-keeping purposes. An example of the paper log can be seen in Appendix B. During the experimental period, the control dining hall kept this paper log record-keeping procedure, while the intervention dining hall was outfitted with the novel electronic system. Note that paper logs in the intervention dining hall were not being signed off by management before going into the filing cabinet. Paper logs often had been stained, were missing time points, or an average value of two time points were used to make up for a missing one.

*Intervention Temperature Logging System*

An electronic FSMS was implemented within the intervention dining hall and consisted of a Testo FSMS tablet and a multi-function handle with a tip-sensitive thermometer probe (Testo SE & Co. KGaA, Lenzkirch, Germany). Examples of these can be seen in Appendix C. The tablet programming was fully customizable to the needs of the dining hall.

During a preliminary use period, researchers and company support staff worked with the line managers and head manager at the intervention dining hall to determine the best controls. As previously discussed, the regulations for this dining hall state that food must be held at or above
135°F; however, as food safety is not the only concern, managers wanted to ensure that food was also not over 150°F which could yield a lower quality product. Managers also expressed concern that non-native English speakers would not know the names of all the food items served. Pans of food were often switched out if a specific food item ran out, so it could be difficult to keep a consistent list. To combat this concern, employees took a picture of the food item for identification. A final quality control checklist was made for this task. The final steps of using the tablet are as follows in Figure 2.2:
Figure 2.2. Food safety management system FSMS tablet flow
To access the quality control checklist, line staff scanned an NFC tag with the FSMS tablet, which would automatically bring up the quality control checklist (Figure 2.2). The FSMS tablet communicated with the tip-sensitive digital thermometer to upload temperature data in real-time. Once the thermometer user uploaded a thermometer temperature, it was recorded on the FSMS tablet and sent to a website accessible by managers. This dual uploading allowed the user to access temperature logs from previous days, sign off on any violations from those reports, and assess current quality control checklists in process. All management types were given login credentials and allowed to login to this website at their convenience.

**Temperature Data**

Researchers went through information stored on the Testo website’s database for a 12-week period between February 2019 and April 2019. The time taken for each temperature report was noted; furthermore, de-identified information from employees was taken to determine the average length of time individual employees took to complete a temperature report. This allowed for researchers to account for the variability between employees. To determine the length of time, the time noted at the end of the temperature report was subtracted from the time at the beginning of the report.

**Temperature Violations**

To determine the number of food items that were below 135°F, researchers used information stored on the website’s database for a 12-week period, from February 2019 to April 2019, and the number of temperature abuse alerts was calculated. Alerts from non-TCS foods, such as dinner rolls or biscuits, were not included. Alerts were then placed into specific
categories depending on if “Other” or “Stir food and retake temperature” was chosen, along which corrective actions, if any, that were taken (Figure 2.2). Alerts were also categorized based on food type with categories as follows: eggs/dairy, meat/poultry/fish, and vegetables/potatoes/grains. Examples of these food items can be found in Table 2.3.

**Data Analysis**

The temperature data was analyzed using descriptive statistics. Temperature violations were characterized as a percentage of total violations (Number of Specific Violations/Total Violations) based on the category of food they were associated with and on which corrective action, if any, was performed.

**Line Staff Survey**

**Instrument Design**

An online survey containing three sections was developed as a research instrument (Appendix D). The first section consisted of an organizational question and five demographic questions. The organizational question allowed researchers to identify whether the participant worked in the intervention or control dining hall, and the demographic questions were related to age, gender, education level, and first language. They were also asked the length of time in which they had worked for the dining hall. These demographic questions were employed to determine if any of the workers might find it difficult to adopt/adapt the technologies, as previous studies have suggested these might be impediments (3, 7, 13, 15, 21). The second part of the survey was used to measure FSC within the dining halls. This assessed survey participant’s agreements with statements related to FSC on a 7-point Liker-type scale (1 =
Strongly Agree to 7 = Strongly Disagree). The control group’s survey contained 11 Likert-type questions, while the intervention group’s contained 16 questions. These five additional questions evaluated the participants’ thoughts on the Testo equipment used during the intervention period. There were three statement areas, with an additional area for the intervention group, within the Likert-type statements that included: 1) Management support and communication (six statements); 2) Self-commitment to food safety (one statement); 3) Food safety knowledge (four statements); and 4) Ease of equipment use and utility (five statements). Some survey statements were taken from previously validated, published FSC survey instruments by Fatimah et al. (23), Neal et al. (18), and Ulusoy and Çolakoğlu (22), modified to fit the study’s objectives.

The third portion of the survey contained an open-ended question where participants could give any further comments they had concerning food safety within their dining hall. For intervention participants, there were two additional questions asking participants to list the advantages and disadvantages of the Testo technology.

Before the survey was tested, experts in psychology and food safety reviewed it to determine content clarity. A few minor modifications based on the expert feedback were made prior to dissemination.

Data Collection

The research protocol and survey instrument were approved by the North Carolina State University Human Subjects Institutional Review Board prior to distributing the survey (eIRB 16593). After the completion of the 12-week intervention period, the survey was distributed to line staff members at both dining halls via email. The email had a brief message about the survey along with a link to the survey and also contained a flyer with important details regarding survey
participation, such as the study’s purpose and participation requirements (Appendix E). The survey link contained a consent form that documented the study purpose, eligibility information, study protocols, risks and benefits, and confidentiality. The form also noted that participants would receive a $20 gift card upon successful completion of the survey. Furthermore, there was a modified consent in which participants could agree or disagree to continue participating in the survey. A total of three follow-up emails were sent to remind participants about the survey. Researchers were also available in both dining halls with a laptop for potential participants to complete the survey if they did not have access to the survey at home.

**Data Analysis**

Due to a small sample population, demographics of the intervention and control dining halls were combined in order to preserve anonymity of participants. Age survey responses were categorized as 18-34 years, 35-54 years, and 55 years old or older. Education level was consolidated into high school or less, some college, and a 2 or 4 year degree. Lastly, length of time worked in the dining hall became three categories: less than 1 year, 1-3 years, and over 3 years. The percentage of each demographic category was reported.

JMP Pro 14 (JMP, Cary, North Carolina) was used to gather descriptive statistics. The Qualtrics survey software (Qualtrics, Provo, Utah) provided information on variance. Each question was analyzed for differences between the control and intervention groups. Significance for data with two groups was determined by using the nonparametric Wilcoxon rank-sum test, while significance for 3 groups was determined using the nonparametric comparisons for each pair using Wilcoxon method. This was analyzed using JMP Pro 14 using the Wilcoxon one-way test with Chi-square approximation. Likert data was grouped as scale and summed per question
group (Management Support, Communication, and Food Safety Knowledge). The group Self-Commitment to Food Safety was not analyzed, as there was only one question, and participant responses could easily be re-identified. A \( p \)-value of \(<0.05 \) was used to determine significance for all tests. Open-ended questions were coded manually to determine themes.

**Manager Interviews**

*Participant Selection*

At the end of the study, all line managers, general managers, and the dining hall directors for both the intervention and control dining halls were invited via email to participate in a semi-structured interview to discuss their views on FSC within their respective dining hall. Managers associated with the intervention dining hall were also invited to discuss their thoughts on the Testo FSMS. The research protocol and interview script were also approved by the North Carolina State University Human Subjects Institutional Review Board prior to contacting potential participants about scheduling an interview (eIRB 16593). Attached to the email was a flyer indicating the study’s purpose, confidentiality information, compensation, and the principal investigator’s contact information (Appendix F). Three follow-up emails were sent reminding participants about the interview. Once managers reached out, an interview time and place were established for each participant. One participant was not available in-person but was able to participate via a video conference call.

*Data Collection*

A consent form was signed by each interviewee before proceeding with the interview questions (Appendix G). An interview script, which can be found in Appendix H, was followed.
Participants in the intervention group were also asked questions about the Testo technology. The objective of the interviews was to evaluate FSC and the efficacy of the equipment. Questions about the equipment focused on advantages and disadvantages of the system; ease of use for both themselves and their employees; and barriers to implementation. Relative to FSC, participants were asked about how they viewed FSC and what their role was; how they viewed senior management’s role in FSC; and their thoughts on the amount of support they are getting by senior management. Lastly, participants were asked what improvements they would make to the dining hall’s food safety program. After completion of the interview, participants were then asked if they were still comfortable with sharing the interview data. They were then given their compensation (a $20 Amazon gift card) regardless of their answer.

**Data Analysis**

The researcher conducting the interviews took notes on participant responses to each question. NVivo 12 Mac (QSR International, Melbourne, New South Wales, Australia) was used to code each question for themes. The themes were then analyzed manually.

**RESULTS**

**Temperature Data**

In total, 546 time points were recorded during the 12-week period. At least 41 different employees recorded temperatures during that time, but there were 38 temperature reports that did not include an employee name and were unable to be associated with a specific employee. These unassociated reports were not included in the analysis of the average length of time for employees to conduct temperature reports for any specific employee; however, they were
included in the total overall average for all employees. The average time to take temperatures for all employees was 8 minutes; the longest average time for one employee to take a temperature report was 20 minutes (n=1) while the shortest was four minutes (n=4) (Figure 2.3). Three of the 41 employees only had one temperature report associated with their name, while one employee had 99 reports.

![Graph showing average length of time (mins) for individual employees to conduct temperature report](image.png)

**Figure 2.3. Average length of time (mins) for individual employees to conduct temperature reports**

*Temperature Violations*

There were 4134 original temperature points taken. Descriptive statistics of the values can be found in Table 2.1. A total of 179 temperature abuse alerts occurred during the study
duration. Non-TCS foods (i.e., bread, rolls, biscuits, funnel cake fries) accounted for 33 of the alerts and were therefore excluded from analysis. One food type could not be determined as the picture taken of the food was not discernable; this was also excluded. Thus, there were 145 alerts that could be analyzed, representing 3.5% of the total temperature points gathered. The average temperature for the alerts was 130.9°F.

Table 2.1. Descriptive statistics for temperature values

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Value (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>78.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>207.4</td>
</tr>
<tr>
<td>Average</td>
<td>146.1</td>
</tr>
</tbody>
</table>

Food that fell under the vegetables/potatoes/grains categories received the highest number of violations (57.2%), Meat/Poultry/Fish was the second highest category (37.2%), while eggs/dairy had the least amount of total violations (5.5%) (Figure 2.4).
Figure 2.4. Total number of temperature abuse violations for various categories of TCS foods ($n = 145$)

Table 2.2. Examples of food items that were implicated in temperature abuse violations

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples of Food Items Served</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eggs/Dairy</em></td>
<td>Hard boiled eggs, scrambled eggs, cheese-covered Portobello mushrooms</td>
</tr>
<tr>
<td><em>Meat/Poultry/Fish</em></td>
<td>Bacon, chicken thighs, pulled pork, tilapia</td>
</tr>
<tr>
<td><em>Vegetables/Potatoes/Grains</em></td>
<td>Rice pilaf, steamed mixed vegetables, veggie burgers, hashbrowns</td>
</tr>
</tbody>
</table>

Temperature alert data were further analyzed to determine if proper corrective actions were followed (Figure 2.5). Sixty alerts (41.4%) were followed by a proper corrective action, which include: 1) the food was stirred and the temperature retaken, the temperature was

a) over 135°F
b) under 135°F but the employee replaced the pan, reheated the pan to 165°F, or turned the heat up on the warming pan; or 2) changing the pan automatically; 3) reheating the pan to 165°F; or 4) turning the heat up on the warming pan.

An absence of a corrective action or improper corrective actions accounted for 20.7% of the total violations ($n = 30$). Improper corrective actions included the employees not indicating what they did with the food; a few examples of this were, “turkey sausages under cook[ed]”, “cools fast”, or “burner.” Improper corrective actions also included non-response when prompted by the FSMS tablet to enter what corrective action was taken, as we could not ascertain if the employee followed through with an action. There were 56 instances of temperatures under 135°F being deleted, which is 38.6% of the time (Table 2.3). Since these data points were deleted, there is no way to indicate whether a corrective action was performed or not.

![Figure 2.5. Operator follow-up for temperature abuse violations ($n = 145$)](image-url)
Table 2.3. Temperature abuse violations with operator follow-up

<table>
<thead>
<tr>
<th></th>
<th>Stir and Retake Temperature</th>
<th>Other</th>
<th></th>
<th>Temperature Data Deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2nd Temperature &gt;135°F</td>
<td>2nd</td>
<td>2nd Temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Temperature &lt;135°F, but Proper Corrective Action Taken</td>
<td>Temperature &lt;135°F, but Improper Corrective Action Taken</td>
<td>Proper Corrective Action Taken</td>
</tr>
<tr>
<td>Number of Total Violations</td>
<td>44</td>
<td>9</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Percentage of Total Violations (n=145)</td>
<td>30.3%</td>
<td>6.2%</td>
<td>11.7%</td>
<td>4.8%</td>
</tr>
</tbody>
</table>

Line Staff Survey

**Demographics**

A total of 10 respondents from the intervention dining hall (55.6% response rate) and 10 from the control dining hall (71.4% response rate) completed the survey. The majority of survey respondents were female (80%), under the age of 35 (55%), and had English as a primary language (65%). However, 35% indicated they learned a language other than English first. Education levels of participants varied, but 50% of respondents indicated they had some college education, while 30% indicated they had a high school education or lower. The majority of participants (55%) had worked in the dining hall from 1-3 years; however, 25% had worked in the dining hall for less than 1 year, and 20% had worked for the dining hall for over 3 years. A breakdown of participant demographics can be seen in Table 2.5.
Table 2.4. Survey participant demographics

<table>
<thead>
<tr>
<th>Demographic Category</th>
<th>Number of Participants</th>
<th>Total Percentage from Participants (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-34 years old</td>
<td>11</td>
<td>55%</td>
</tr>
<tr>
<td>35-54 years old</td>
<td>6</td>
<td>30%</td>
</tr>
<tr>
<td>55 years old or more</td>
<td>3</td>
<td>15%</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>4</td>
<td>20%</td>
</tr>
<tr>
<td>Female</td>
<td>16</td>
<td>80%</td>
</tr>
<tr>
<td>First Language Learned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>13</td>
<td>65%</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td>35%</td>
</tr>
<tr>
<td>Education Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school or less</td>
<td>6</td>
<td>30%</td>
</tr>
<tr>
<td>Some college</td>
<td>10</td>
<td>50%</td>
</tr>
<tr>
<td>2 or 4 year degree</td>
<td>4</td>
<td>20%</td>
</tr>
<tr>
<td>Length of Time Worked in the Dining Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 1 year</td>
<td>5</td>
<td>25%</td>
</tr>
<tr>
<td>1-3 years</td>
<td>11</td>
<td>55%</td>
</tr>
<tr>
<td>Over 3 years</td>
<td>4</td>
<td>20%</td>
</tr>
</tbody>
</table>

**Likert-Type Questions**

Table 2.5 shows the mean Likert-type scores (1 = Strongly Agree, 7 = Strongly Disagree) for FSC statements as self-reported by the participants. There was only one significant difference ($p = 0.05$) observed between the responses of the intervention and control groups. The control group had an average of 1.2 when asked about food safety knowledge and the intervention group had an average of 1.6 (1 = Strongly Agree, 7 = Strongly Disagree). While there was only one question with a significant difference between intervention and control, the overall mean for the Food Safety Knowledge area was significantly higher ($p = 0.02$) for the intervention group than the control group, 2.2 and 1.7, respectively.
The Management Support and Communication area was ranked on average at a 2 or above, indicating that employees agreed they were being supported by management. In the Food Safety Knowledge area, participants ranked all but one question above a 3, indicating that most participants were in agreement with the statements. The statement from this section that had a lower average rank was related to how long food can be held at room temperature before serving. The North Carolina Food Code states that food should only be held at room temperature for 2 hours before serving (17), not 3 hours. The statement was specifically written negatively to ensure participants were not just agreeing with all survey statements. It was then reverse coded in order to compare means with other statements in the Food Safety Knowledge area. The variance on this question was also higher than other questions.

The Ease of Equipment Use and Utility area was only pertinent to the intervention group. Participants denoted they felt confident about using the technology; however, the average ranking the length of training was 3.6, indicating that there were mixed thoughts about how long training took. The overall mean for this section was a 2.6, which falls between Agree and Somewhat Agree on the Likert scale given.
Table 2.5. Mean Likert-type (1 = Strongly Agree, 7 = Strongly Disagree) score for food safety culture as self-reported by intervention (n=10) and control (n=10) university dining hall line staff

<table>
<thead>
<tr>
<th>Food safety culture areas and statements</th>
<th>Mean± SD</th>
<th>Variance</th>
<th>X²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Area 1. Management support and communication</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management follows the same practices I am asked to follow</td>
<td>1.6 ± 0.5</td>
<td>1.9 ± 1.0</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Management enforces food safety rules consistently with all employees</td>
<td>1.4 ± 0.5</td>
<td>1.6 ± 0.7</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Employees are disciplined or reprimanded when they fail to follow food safety practices</td>
<td>1.9 ± 0.8</td>
<td>2.0 ± 1.2</td>
<td>0.7</td>
<td>1.4</td>
</tr>
<tr>
<td>My manager generally gives appropriate instructions on safe food handling</td>
<td>1.8 ± 1.2</td>
<td>1.4 ± 0.7</td>
<td>1.4</td>
<td>0.4</td>
</tr>
<tr>
<td>All managers give consistent information about food safety</td>
<td>2.0 ± 1.3</td>
<td>1.4 ± 0.5</td>
<td>1.8</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Overall mean</strong></td>
<td>1.7 ± 0.9</td>
<td>1.6 ± 0.8</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Area 2. Self-commitment to food safety</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food safety is very important to me</td>
<td>1.3 ± 0.5</td>
<td>1.8 ± 1.8</td>
<td>0.2</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Area 3. Food safety knowledge</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food on the serving line kept below 135 degrees Fahrenheit can cause food-borne illness</td>
<td>2.1 ± 1.1</td>
<td>1.6 ± 1.2</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Sanitizing the thermometer probe between uses is very important for food safety</td>
<td>1.6 ± 1.2</td>
<td>1.1 ± 0.3</td>
<td>1.4</td>
<td>0.1</td>
</tr>
<tr>
<td>The most important factors to control the growth of bacteria are temperature and time</td>
<td>1.6 ± 0.5</td>
<td>1.2 ± 0.6</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Cooked foods can be kept at room temperature for 3 hours before serving</td>
<td>3.6 ± 2.3</td>
<td>2.7 ± 1.9</td>
<td>5.2</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Overall mean</strong></td>
<td>2.2 ± 1.7</td>
<td>1.7 ± 1.3</td>
<td>2.7</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Table 2.5. Continued

<table>
<thead>
<tr>
<th>Food safety culture areas and statements</th>
<th>Mean ± SD</th>
<th>Variance</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention</td>
<td>Control</td>
<td>Intervention</td>
<td>Control</td>
<td>X²</td>
<td>p-value</td>
</tr>
<tr>
<td><strong>Area 4. Ease of equipment use and utility</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It took a lot of training for me to understand how to use the Testo handheld thermometers&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.6 ± 2.2</td>
<td>4.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I found the Testo system difficult to use&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.6 ± 1.6</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel very confident using the Testo handheld thermometers</td>
<td>1.4 ± 0.7</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I prefer the handheld Testo thermometers over the old paper logs</td>
<td>2.4 ± 2.0</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The handheld Testo thermometers improve the quality of my job</td>
<td>2.5 ± 1.6</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Overall mean</strong></td>
<td>2.5 ± 1.8</td>
<td>3.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> 7-point Likert-type scale used with 1 = Strongly Agree and 7 = Strongly Disagree

<sup>b</sup> Question was reverse coded

<sup>c</sup> These questions were only asked with intervention group

* Indicates a significant difference at p-value < 0.05
Table 2.6 shows the mean Likert scale (1 = Strongly Agree, 7 = Strongly Disagree) score for different FSC areas among various demographic groups. The Management Support and Communication area had the most variation of the two areas tested. There was a significant difference ($p = 0.02$) for the overall mean for the Management Support and Communication area among the 18-34 year old age group when compared to the 35-54 and 55 years old or more age group. Participants who did not have English as a first language had a higher average score than those whose first language was English. Interestingly, there was a significant difference between respondents that worked 1-3 years and over 3 years. There was no difference among the various education levels for either area tested. Another interesting point was that there was a significant difference between males and females for both FSC areas.
Table 2.6. Mean Likert scale (1 = Strongly Agree, 7 = Strongly Disagree) score for different food safety culture areas among various demographic groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Management Support and Communication</th>
<th>Food Safety Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean(^a, b) ± SD(^a)</td>
<td>p-value</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-34 years old</td>
<td>1.9 ± 1.0(^A)</td>
<td>0.000*</td>
</tr>
<tr>
<td>35-54 years old</td>
<td>1.4 ± 0.7(^B)</td>
<td></td>
</tr>
<tr>
<td>55 years old or more</td>
<td>1.1 ± 0.3(^B)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2.0 ± 0.8(^A)</td>
<td>0.000</td>
</tr>
<tr>
<td>Female</td>
<td>1.5 ± 0.9(^B)</td>
<td></td>
</tr>
<tr>
<td>First Language Learned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>1.8 ± 1.0(^A)</td>
<td>0.029</td>
</tr>
<tr>
<td>Other</td>
<td>1.4 ± 0.6(^B)</td>
<td></td>
</tr>
<tr>
<td>Education Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school or less</td>
<td>1.6 ± 0.6</td>
<td>0.719</td>
</tr>
<tr>
<td>Some college</td>
<td>1.6 ± 0.8</td>
<td></td>
</tr>
<tr>
<td>2 or 4 year degree</td>
<td>1.9 ± 1.3</td>
<td></td>
</tr>
<tr>
<td>Length of Time Worked in the Dining Hall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 1 year</td>
<td>1.6 ± 0.8(^AB)</td>
<td>0.029</td>
</tr>
<tr>
<td>1-3 years</td>
<td>1.8 ± 1.0(^B)</td>
<td></td>
</tr>
<tr>
<td>Over 3 years</td>
<td>1.3 ± 0.6(^A)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) 7-point Likert-type scale used with 1 = Strongly Agree and 7 = Strongly Disagree

\(^b\) Means in a column with a different capital letter indicates there was a significant difference when at a p-value < 0.05

Open-Ended Questions

When intervention line staff were asked an open ended-question about advantages of the system, three themes emerged. These were: 1) accurate; 2) easy; and 3) fast. An example of accurate was “Provides accurate results of the temperatures of the foods;” an example of easy was “Easy to use;” and an example of fast was “Much more accurate and fast! In this job time is not an easy thing to come by, mostly during the dinner time.” Alternatively, when asked about
the disadvantages of the system, two major themes emerged. These were: 1) slow; and 2) difficulties with technology. An example of slow was “Main disadvantage is that it takes more time to complete the process, this can be cumbersome when the dining hall is busy.” While an example of technological difficulties was “Accidentally getting locked out or changing information that was put in on accident is a pain...(Example: Putting in ‘Lunch’ when you meant to press ‘dinner’).”

Both intervention and control staff were asked if they had any further comments on the dining hall operation in general. A majority of the participants responded with no, but two (10%) respondents indicated that they would like to see more training for line staff employees, and two respondents (10%) indicated that servers should remember personal hygiene is essential and very important to food safety. A line worker also noted “Food safety for the hot lines is rigorous but food safety for cold lines is lackluster at best, poor at worst.”

Manager Interviews

Both the control and intervention dining halls had 5 managers participate in the interviews, with a 100% and 83.3% response rate, respectively.

Questions Related to the Digital Food Safety Management System (Intervention Managers Only)

A recurring theme among all intervention managers when asked about the advantages of the Testo FSMS was that they appreciated its accuracy in measuring temperatures. One statement that supports this is: “..., I liked that it took pictures and that employees couldn’t fudge answers. The amount of times I’ve seen employees just writing down random temperatures is crazy and they couldn’t do that with this technology.” This was especially true when comparing the new
system with the paper-log system. Furthermore, 60% of the managers indicated that the digital logs were more efficient. An example of this is: “There is no typing up logs, no checking the time, and no waste of paper, so overall is has really just made the whole process and serving much more efficient.” While the previous manager indicated the digital system saved time when typing up and printing logs, some managers specifically mentioned that it was faster than the paper system to take temperatures on the line.

When discussing disadvantages of the system, the intervention managers noted mechanical problems. Examples of this include: “… [tablets] not making it back to the stand to charge overnight”; “Keeping track of the disc [NFC tag] that goes with it was a little difficult at times…”; and “…we only had two but we have six lines so at times I had to designate one person who would take temperatures and use the technology, but we really don’t have enough employees for that.” However, 40% of the managers indicated they could not think of any improvements that should be made to the system.

Managers also indicated the largest barrier to the technology’s implementation was training, specifically because of 1) language; and 2) receptiveness to change. An example supporting language barriers was, “Training the staff and getting them on board with using it mostly because of the language barrier, it was just harder for them to pick it up and figure it out.” They also pointed out that it was difficult for people to accept the new technology, for both line staff and other managers. The following are statements from two different managers supporting this: “If we had a more cohesive management system it might have gone better, but it seemed like not all of our supervisors were on board”; and “They [line staff] were not all receptive of the change and they are not all computer savvy, so getting used to the technology took time.” Even though managers indicated that training was the biggest barrier to
implementation, when they were questioned on a scale of 1 to 7 (1 being very difficult, 4 being neutral, and 7 being very easy) about how easy it was to teach the system, the average reply was a 5.8 (minimum value = 4, maximum value = 7), indicating that training was on the easier end of the scale. One manager declined to respond to this question as they had not personally taught this system. An example of a 4 was as follows: “Just because of the variety of people, backgrounds, and languages I was teaching it to. I mean they definitely all got it eventually but it just took time and practice.” An example of a 7 was as follows: “Just had to work with them and train them but they got used it and how it works. New things are hard at first but once you know how to do it it’s easy.”

When managers were asked on a scale of 1 to 7 (1 being very difficult, 4 being neutral, and 7 being very easy) about how easy it was for them personally to learn the Testo system, the average reply was 5.8 (minimum value = 5, maximum value = 7), indicating managers felt the system was relatively easy to use. An example of a manager that gave the system a 5 rating is as follows: “Because I am always doing something and very busy so I had to take the time to learn it, but once I got the hang of it, it was a breeze, it just took me an extra week after that first initial week to really get comfortable with it.” An example of a manager that ranked the system a 7 is as follows: “When we were trained we were given a clipboard with notes and step by step instructions, we were allowed to play with the technology and get accustomed to it, and then we were able to give it a test run before we had to use it.”

Only one manager indicated he/she had been checking the electronic temperature logs, while the rest indicted they had not been reviewing the online records. Even so, the manager indicated records were only being checked about three times a week. Another manager indicated
“I’ve never really felt the need to [personally check the online website for alerts and violations] because the tablet lets me know right away what is going on.”

Overall, intervention managers were in agreement that using the Testo FSMS improved the FSC in the dining hall as it had increased awareness in food safety and accountability. Managers indicated that people do not have to be reminded of taking temperatures and that “Food safety and temperature logging just comes more naturally.” One manager even noted using the technology not only brought awareness about food safety, but also potential equipment failures as it guided employees through corrective actions before they could move on with taking other temperatures – “if we took the temperature and it was under temperature, we would investigate and see that the well was off or the well was broken. So maybe we might not have noticed these things otherwise- we had to respond to the issue if it was presented and recorded.” They appreciated the technology increasing efficiency, accuracy, and including more data when compared to the paper log system.

**Food Safety Culture Questions (Control and Intervention Managers)**

The major theme in both the intervention and control dining halls when managers were asked about what FSC meant to them was serving people food that was safe to eat. One definition of FSC was: “Serving safe food, so that includes keeping food at safe temperatures, cooking foods to the correct temperatures, food handling, food storage temperatures, dating food, labeling food, knowing the difference between raw and ready-to-eat foods, and then understanding how necessary each of these tasks are in order to keep people safe. Food safety culture means all of this should come second nature to employees handling and serving food.” Another manager indicated that “…alerting managers if there are issues or discarding the food if
we see something go wrong. It is also about holding others accountable to this standard” was part of FSC. Sixty percent of managers at both dining halls indicated temperature control during their response.

There was a difference between the dining halls when managers were asked how they saw their personal role in food safety. While intervention managers saw their role as more of an accountability checker, control managers indicated their role was to lead by example. Examples of this include: “Being an example, teacher, and trainer. So that means not doing anything wrong, staying vigilant, and making sure food safety actions come as second nature...” and “To be a role model. The cooks look to me and ask me for guidance so I need to be mindful of what I am doing in order to lead by example in the best possible way. That means I am following all of the food safety guidelines we have in place such as washing my hands, wearing gloves, changing gloves when I should, storing food properly, and so much more.”

Ninety percent of managers indicated they felt that senior management was committed to food safety. A common theme for both dining halls was that senior management holds people accountable for food safety. One employee noted that if a deviation is observed, management “will say something and bring it to the employees’ attention.” A few managers indicated that one of the reasons senior management is committed to food safety is that “it is a liability issue and a legal issue” as it could cause “patrons to lose trust in us.”

When asked to rank how committed the dining hall was to food safety on a scale between 1 being not committed at all to 7 being very committed, all managers ranked their dining hall a 6 or 7. Managers that ranked the dining hall at a 6 all indicated they did so because there is always room for improvement. In general, managers felt that their food safety efforts were supported by upper level management; however, managers did indicate wanting more support in certain areas.
These areas include: 1) training – “Ideally, we should take the time to show each employee the correct methods of food preparation, distribution, cooling, etc., then take the time to answer their questions, provide them with a mentor who will oversee them as they begin to work to correct their actions and teach them in a hands-on way without any pressure or time constraint” and “more training with new employees but also refresher trainings with old employees”; 2) equipment updates – “[I would like to see] upgrading equipment and staying committed to the dangers of old and broken equipment”; and 3) more open-mindedness towards new ideas – “there is low approval of our new ideas”.

DISCUSSION

Temperature Data

The average length of time for an employee to record temperatures of all food served on the line was three minutes longer than recorded in the preliminary data, but there are several potential reasons for this increase in time. The pilot study only sampled 11 employees at 14 different time points, while the intervention study was conducted over 12 weeks and included at least 41 different employees and 546 time points. There is inherent variability between the length of time it takes employees to record temperatures, as seen in this study (Figure 2.3). Furthermore, the lunch and dinner services typically have more food items than breakfast, which may result in a longer recording time for the latter. While the previous paper-based system was only recording information on the temperature of the food products, the intervention FSMS gave dining hall managers more information, such as pictures of the food items and alerts based on food safety (when a food item was under 135°F) and quality (when a food item was over 150°F).
While there were a relatively small percentage of temperature violations from the total number of points taken, it is important to note that even just one deviation could result in a foodborne disease outbreak if conditions were right, and because so many people are served from one single pan in university dining hall venues. It was concerning that such a high percentage of the total violations came from meat, poultry, or fish products as there are typically only one or two of these items on the line during any given service, while much of the rest typically fall under the vegetables, potatoes, and grains category. Eggs are usually served exclusively during the breakfast period, and dairy only products are uncommon on the hot serving line; therefore, it was expected that these products would not often be implicated in alerts.

In regard to corrective actions and their proper implementation, it is important to consider the data with just the corrective actions that required the employee to input what they did. If the deleted temperature data and the alerts that were above 135°F are removed, 46 violations remain. Of those, 65.2% had improper or no corrective action taken. This lack of action indicates employees may not have understood what was expected from them during this step, had forgotten or not wanted to document what they did, or decided not to do anything. When cultivating a FSC, it is imperative for dining hall employees to understand why following through with proper corrective actions is important and why documentation is needed. Managers should follow through with employees that do not properly follow corrective action steps in order to address the aforementioned concerns and retrain if necessary. Creating a positive, strong FSC takes work from everyone in the establishment.
Line Staff Survey

Participant demographics were as expected; however, there were only 4 male respondents, which may skew the demographic results. The overall mean for the Management Support and Communication area (Table 2.5) was similar to what Fatimah et al. reported. (6). Similar answers were also given in the Self-Commitment to Food Safety area (23). Other related questions from a study by Neal et al. provided similar results (18).

The control and intervention groups’ overall means for the Food Safety Knowledge area were significantly different ($p = 0.02$). This difference could be due to various training practices between the two locations. There was a higher standard deviation of intervention responses when compared to the control group, which indicates that answers were more variable among the intervention group. This variation could be due to a plethora of reasons, such as a training difference or a wider difference in knowledge among the intervention group.

When breaking down the Management Support and Communication area by demographics, there were significant differences between many of the demographic groups. When breaking down the Food Safety Knowledge area, there was only a significant difference between gender. On average, females scored 1.7 while males scored 2.3 (Table 2.5). This could be due to a low sample size from males when compared to females. In a study by Ulusoy and Çolakoğlu, there was no significant difference in food safety knowledge when comparing men and women; however, these authors did see a difference between employees’ educational level and length of time worked in foodservice (22). These differences may be attributed to differences within the sampled populations. The Ulusoy and Çolakoğlu study sampled kitchen employees among restaurants, hotels, catering companies, and school food service facilities in Turkey (22), while our study focused on a university dining hall system in the United States. Furthermore,
most employees surveyed in this study had some college-level education, while most of the
employees in the Turkish study had a high school education or less. Most of the Turkish
employees surveyed also had 5 or more years in the food service industry, while most in our
study had 3 or less.

In relation to the open-ended questions, it should be noted that only 10 participants were
able to answer the two questions on the advantages and disadvantages of the FSMS since there
were only 10 intervention group respondents. An advantageous theme that emerged was that
using the digital FSMS was faster than the paper system; however, a theme emerging from the
question concerning the disadvantages of the digital system was that it was slower. Due to these
conflicting statements, it is clear that employees had different thoughts on whether the Testo
system was faster or not. As previously discussed in the Temperature Data section, the length of
time required for complete temperature recording in the pilot study was shorter than the time
using the new system. Nonetheless, there was significant variation in the average time it took
employees to record temperatures. As previously discussed, while the dining hall used to only
receive information on the temperature of the food when manually recording, the Testo FSMS
provides picture information as well. While this study did not look at the differences in
compliance with corrective action steps before and after the new system was implemented,
employees were guided through corrective action steps in the Testo system. An increase in time
could potentially be due to more employees following through on changing out a food pan or
asking a chef to reheat it. This is certainly an area for future research. Another advantage cited
for the Testo system was accuracy. Dining hall management could see exactly when a
temperature was taken. They also know that the number is accurate since the data were uploaded
in real time. This takes out human error in inaccurately recording numbers or purposefully
falsifying data. Since employees must enter corrective actions for temperature alerts, managers can also use the system to determine if an employee is properly recording corrective action steps. If they observe deviations from corrective action protocols, they can address retraining immediately.

Another important note from the open-ended questions supports the second theme relative to disadvantages. Some employees did not like that they could not go back and change an item once it was selected; however, this system was put in place to prohibit people from making changes that could allow them to override the system or falsify data.

**Manager Interviews**

Overall, managers had strongly positive feelings about the implementation of the Testo FSMS. They indicated that it was more accurate and held greater accountability of those using it. Most indicated that the system was also more efficient; however, as mentioned previously, the pilot study with the paper logs had a shorter average time dedicated to data collection when compared to the digital system. Nonetheless, the digital system may still save managers time when taking into account that they previously had to type and print the paper logs daily; whereas, the new system completely eliminates that need. While almost all intervention managers indicated they had not been checking the online database, they may ultimately also save time by being able track the data on their own computers as opposed to reviewing a paper log.

Other studies have also shown differences in language as a barrier towards training in the food service industry (13, 16). Since almost one-third of the dining hall’s current employees first learned a language other than English, it is important to remember them when developing training methods. Managers specifically requested adding in the picture-taking option for
employees that may not know the English names of certain types of food, but more could be done to facilitate training process in this population, especially since managers indicated they would like to have more training initiatives on food safety. Nonetheless, when managers were asked to rank how easy it was to learn the system for themselves and teach the technology to staff, on average, both questions were ranked a 5.8 (scale of 1 = very difficult, 4 = neutral, 7 = very easy). This number indicated that even though language was a barrier, training was still perceived as fairly easy. The second training barrier noted was apprehension to change. When implementing the HACCP system, studies have also shown that lack of staff motivation to implement technology was seen as a barrier to the system’s implementation (11, 19). Efforts in increasing staff and manager awareness about the potential benefits of adopting the technology could prove to be useful; furthermore, everyone in the adoption process from senior management all the way down to line staff needs to be willing to accept a new process. It is also important for staff to feel they are having appropriate level of support when adopting a new system. Managers need to be allowed time to train employees and change should be measured in order for it to be successful.

When comparing the intervention and control dining halls, there were not many significant differences between responses. Both locations had similar definitions on what they believed FSC meant. The one big difference between the dining halls was when participants were asked how they saw their role in food safety. While intervention managers indicated they saw their role as holding staff accountable, managers at the control dining hall saw their role as being a role model for their staff, exemplifying food safety standards. Managers indicated they felt their dining hall was very committed to food safety; however, they would like more support
from upper level management on training, updating old or broken equipment, and being more receptive to new ideas.

As so many managers requested training for their employees, an area for future research should be in the best training and communication tools and methods for food service employees in university dining halls. While some work has been done in communication tools for food service workers, such as the Chapman et al. food safety infosheets (2), university dining halls are unique as they often serve thousands of people every day and many of their employees are part-time student workers. As such, the turnover rate is high, and employee retention can be difficult.

Further work should be done at other dining halls across the country to see if any differences can be seen institutionally or geographically. This would also potentially allow for broader conclusions to be made concerning this area of research. While this study primarily focused on temperature monitoring, other aspects of FSC, such as handwashing, should be analyzed in university dining halls. University food handlers have reported frequent hand washing; however, handwashing was not observed in the same frequencies as what employees reported (9).

**Limitations**

Several limitations are recognized in this study’s design. The study sample was limited to one university in North Carolina; therefore, inferences from this study cannot be generalized to other states that may have different food safety laws or practices. Also, employee demographics and characteristics could differ between universities and regions.

Since the surveys were self-reported measurements of food safety, a social desirability bias may have occurred. This is especially true, even after the guarantee of confidentiality, as
respondents may have felt like their job was at risk if they did not answer questions pertaining to their workplace’s FSC favorably. They may also have been concerned that unfavorable responses would reflect poorly on the dining hall’s reputation. The aforementioned limitations should be taken into account and any broader inferences on findings should be made with caution.

The employment of several intervention dining hall line staff and one intervention manager was terminated before the survey was administered. The reason for termination was not given to the researchers. Since researchers sent information about the survey/interview and the link to complete the survey or to schedule an interview via the employees’ university email, these terminated employees could not be contacted. This may have impacted intervention results for both the survey and the interview as sample sizes were smaller than originally intended.

**CONCLUSION**

Using a mixed methods study, the hypothesis that implementing a digital FSMS into a university dining hall would create a more positive FSC was tested, although the association was found to be statistically insignificant. Data analysis for both managers and line staff members within the intervention and control groups showed few statistical differences. The few differences that could be quantified were actually in favor that the control dining hall, which had a higher understanding of food safety knowledge and managers that were better at indicating their role in FSC. While significant differences were not seen upon data analysis, managers that received this technology said they believed there to be improved FSC within the dining hall that received the intervention. Employees receiving the intervention technology indicated it made their jobs quicker, more accurate, and gave them a higher level of accountability.
REFERENCES


Health 75:38–46.


CONCLUSIONS

The current literature on the implementation of FSMS indicates that firms have multiple barriers to adopting FSMS (Chapter 1). While the most significant barrier is cost, other barriers are more focused on behavioral aspects, such as employee resistance to change. In order for a system to be effective, employees from all levels within the company need to embrace the change. In order to do this, companies must keep their employees engaged and strong leaders that are passionate about food safety. Another limitation is lack of food safety knowledge. Employers must train their employees about why food safety is important and the consequences of a foodborne illness.

The second study indicated that while there was no evidence for a shift in FSC among intervention staff, managers believed that more people were aware of food safety and that when prompted by the digital system, were forced to follow through with a corrective action (Chapter 2). Literature has shown that adopting FSMS, like HACCP, has been difficult for food service establishments, so similar digital systems like the one used in this study could be helpful to manage risks. Managers and employees alike did like the system overall, and felt it made their jobs more efficient and accurate. While cost was not evaluated in this study, future cost analysis should be conducted to determine if the systems is feasible for this particular sector.

In this project, we were successful in determining the benefits and barriers to implementing a novel FSMS. While a difference in FSC was not clearly demonstrated as a consequence of use of the digital system, its utility was supported by interview data. There is a plethora of future research projects that can be done in university dining halls, particularly due to their unique position. Dining halls have many part-time student employees, but also serve thousands of customers every day. It is important that food safety training and educational
materials are geared towards this population of employees. The system was successfully piloted in this study, and employees commented that it made them more efficient, accurate, and accountable when recording temperatures.
APPENDICES
Appendix A:
Example Serving Line Setup

The following picture is an example of one of the serving lines in the university dining hall.
## Appendix B:

Examples of Paper Temperature Logs

**Food Temperature Log**

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Prepared By</th>
<th>Time placed in hot box</th>
<th>Cook Temp</th>
<th>Temp when placed on line</th>
<th>7:30</th>
<th>8:00</th>
<th>8:30</th>
<th>9:00</th>
<th>9:30</th>
<th>10:00</th>
<th>Corrective Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Boiled Eggs</td>
<td>6:45</td>
<td>/60</td>
<td>161</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scramble Eggs</td>
<td>6:45</td>
<td>/60</td>
<td>158</td>
<td>159</td>
<td>157</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grits</td>
<td>6:00</td>
<td>170</td>
<td>160</td>
<td>160</td>
<td>159</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tator Tots</td>
<td>6:15</td>
<td>155</td>
<td>155</td>
<td>153</td>
<td>150</td>
<td>151</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sausage Egg/</td>
<td>6:22</td>
<td>158</td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tornado</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biscuits</td>
<td>6:30</td>
<td>158</td>
<td>159</td>
<td>142</td>
<td>140</td>
<td>142</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sausage Gravy</td>
<td>6:30</td>
<td>170</td>
<td>170</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacon</td>
<td>6:30</td>
<td>155</td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sausage Patty</td>
<td>6:15</td>
<td>158</td>
<td>157</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oatmeal</td>
<td>6:15</td>
<td>165</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- All food items must be labeled with completed cooking time.
- All food items must be at least 135 degrees.
- Any food under 135 degrees must be reheated to 165 degrees and then held above 135 degrees.
- Any food item held under 135 degrees for more than 2 hours must be discarded.

**Corrective Action Steps**

- Stir food item & retake temperature.
- Check to make sure wells are turned on.
- Check to see if hot box is working.

Any food item under 135 degrees must be reheated to 165 degrees.
<table>
<thead>
<tr>
<th>Food Item</th>
<th>COOK temp</th>
<th>Time placed in hot box</th>
<th>5:00</th>
<th>5:30</th>
<th>6:00</th>
<th>6:30</th>
<th>7:00</th>
<th>7:30</th>
<th>8:00</th>
<th>8:30</th>
<th>Corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roasted redskin</td>
<td>167</td>
<td></td>
<td>154</td>
<td>145</td>
<td>138</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>potatoes</td>
<td></td>
<td>160</td>
<td>160</td>
<td>150</td>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green peas</td>
<td>160</td>
<td></td>
<td>160</td>
<td>150</td>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honey carrots</td>
<td>162</td>
<td></td>
<td>160</td>
<td>150</td>
<td>139</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herb crusted fish</td>
<td>164</td>
<td></td>
<td>160</td>
<td>150</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasta primavera</td>
<td>164</td>
<td></td>
<td>160</td>
<td>150</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black bean burger</td>
<td>170</td>
<td></td>
<td>170</td>
<td>160</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black forest chicken</td>
<td>165</td>
<td></td>
<td>165</td>
<td>140</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soup</td>
<td></td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- All food items must be labeled with completed cooking time.
- All food items must be at least 135 degrees.
- Any food under 135 degrees must be reheated to 165 degrees and then held above 135 degrees.
- Any food item held under 135 degrees for more than 2 hours must be discarded.

Corrective Action Steps
- Stir food item & retake temperature.
- Check to make sure wells are turned on.
- Check to see if hot box is working.

Any food item under 135 degrees must be reheated to 165 degrees.

Temperature Under 135°F
Appendix C:
Testo Equipment

The following are depictions of the FSMS tablet, multi-function handle for the digital thermometer, and tip-sensitive thermometer probe.

*Pictures were used with permission from Testo North America.*
Appendix D:
Line Staff Member Online Survey

Implementing Novel Technology and Its Implications on Food Safety Culture in Dining Halls

INFORMED CONSENT FORM for RESEARCH

Title of Study: Implementing Novel Technology and Its Implications on Food Safety Culture in Dining Halls, eIRB 16593
Principal Investigator: Savana Everhart, sleverh2@ncsu.edu, (919) 451-2214
Faculty Point of Contact: Benjamin J. Chapman, bjchapma@ncsu.edu, (919) 515-8099

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate and to stop participating at any time without penalty. The purpose of this research study is to gain a better understanding of food safety culture in dining halls surrounding the adoption of a new technology. We are also interested in learning more about your opinions on the technology in general. We will do this through online survey questions.

You are not guaranteed any personal benefits from being in this study. Research studies also may pose risks to those who participate. You may want to participate in this research because knowledge may be gained that can provide more useful implementation of new technologies in dining halls across campus. You may not want to participate in this research because you may be uncomfortable sharing your thoughts about the food safety culture in the dining hall.

In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above or the NC State IRB office (contact information is noted below).

What is the purpose of this study?
The purpose of the study is to investigate the food safety culture surrounding the adoption of new technology in a university dining hall setting.

Am I eligible to be a participant in this study?
There will be approximately 40-70 number of participants in this study.

In order to be a participant in this study you must be over the age of 18 and work for NC State Dining in Fountain Dining Hall or Clark on the serving line.
You cannot participate in this study if you are under the age of 18, do not work for NC State Dining in Fountain or Clark Dining Hall, and do not work on the serving line.

**What will happen if you take part in the study?**
If you agree to participate in this study, you will be asked to do all of the following: fill out a 3-part study. Part 1 will ask you about demographic information. During Part 2, you will be asked to fill out a multiple choice form based on your agreements or disagreements to certain statements. During Part 3, you will be asked open-ended questions regarding food safety culture and/or the advantages and disadvantages of the new technology.

The survey should be taken in a private location; however, as it is an online survey, you may take it in any location you choose.

The total amount of time that you will be participating in this study is 10-15 minutes. This is not a requirement of your employment with NC State Dining. Data from this survey will be shared with your employer; however, your name will not be attached to any data and employers will only see data combined with the data of other survey respondents.

**Risks and benefits**
There are minimal risks associated with participation in this research. There is a potential risk for re-identification of your response based off the demographic information you share. We plan on presenting the data to your employer in such a way as to minimize this risk. There are no direct benefits to your participation in the research. The indirect benefits are potentially increasing the work efficiency in the dining halls.

**Right to withdraw your participation**
You can stop participating in this study at any time for any reason. In order to stop your participation, please contact Savana Everhart at the above information. If your choose to withdraw your consent and stop participating you can expect to have all your data destroyed.

**Confidentiality**
The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely on an NC State managed computer with password protection. This data will be shared with your employer; however, no names will be directly associated with your data. Only data compiled from all survey participants will be shared. Nonetheless, this does have a possibility of re-identification from the data. Individual data with identifiable details removed may be made available to the public as required by a professional association, journal, or funding agency.

**Compensation**
For participating in this study you will receive a $10 Amazon gift card electronically. At the end of the survey you will be redirected to a different survey so that you can provide contact information for compensation without your identity being linked with your responses. Your
survey responses are anonymous.

If you withdraw from the study prior to its completion, you will not receive compensation.

**What if you are an NCSU student?**
Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

**What if you are an NCSU employee?**
Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.

**What if you have questions about this study?**
If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Benjamin J. Chapman, bjchapma@ncsu.edu, (919) 515-8099.

**What if you have questions about your rights as a research participant?**
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NC State IRB (institutional Review Board) Office via email at irb-director@ncsu.edu or via phone at 1.919.515.8754. An IRB office helps participants if they have any issues regarding research activities.

You can also find out more information about research, why you would or would not want to be a research participant, questions to ask as a research participant, and more information about your rights by going to this website: [http://go.ncsu.edu/research-participant](http://go.ncsu.edu/research-participant)

*Please remember to take this survey in a private location. Individual’s names should not be included when answering open-ended questions.*

---

Q1

**Consent To Participate** “I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose
not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.”

**Electronic Consent:** Please select your choice below. You may print a copy of this consent form for your records. Clicking on the "I agree" button indicates that:
- You have read and understand the above information
- You voluntarily agree to participate in this 3-part study
- You are 18 years of age or older
- You work as a server in Fountain or Clark Dining Hall

- [ ] I agree. (1)
- [ ] I disagree. (2)

*Skip To: End of Survey If Consent To Participate “I have read and understand the above information. I have received a copy... = I disagree.*

End of Block: Block 1

Start of Block: Default Question Block

Page Break
**Q Demographics**

**Q2 In which dining hall are you currently employed?**

- [ ] Fountain Dining Hall (1)
- [ ] Clark Dining Hall (2)
- [ ] I have not worked in either dining hall (3)

*Skip To: End of Survey if In which dining hall are you currently employed? = I have not worked in either dining hall*

**Q3 What is your age?**

- [ ] 18-24 years old (1)
- [ ] 25-34 years old (2)
- [ ] 35-44 years old (3)
- [ ] 45-54 years old (4)
- [ ] 55-64 years old (5)
- [ ] 65 years old or older (6)

**Q4 What is your gender?**

- [ ] Male (1)
- [ ] Female (2)
- [ ] Non-binary/Third gender (3)
Q5 What was the first language you learned to speak?

- [ ] English (1)
- [ ] Other (2)

Q6 What is the highest degree or level of school you have completed? If currently enrolled, highest degree received.

- [ ] Less than high school (1)
- [ ] High school graduate (2)
- [ ] Some college (3)
- [ ] 2 year degree (4)
- [ ] 4 year degree (5)
- [ ] Professional degree (6)
- [ ] Doctorate (7)
Q7 How long have you worked at Fountain or Clark Dining Hall?

- [ ] Less than 3 months (1)
- [ ] Less than 1 year (2)
- [ ] 1-3 years (3)
- [ ] 3-5 years (4)
- [ ] 5-10 years (5)
- [ ] Over 10 years (6)
Q Likert Questions

Display This Question:

If In which dining hall are you currently employed? = Fountain Dining Hall

Q8 Please read the following statements and select the response that accurately describes your answer choice.
<table>
<thead>
<tr>
<th>Strongly Agree (1)</th>
<th>Agree (2)</th>
<th>Somewhat Agree (3)</th>
<th>Neither Agree nor Disagree (4)</th>
<th>Somewhat Disagree (5)</th>
<th>Disagree (6)</th>
<th>Strongly Disagree (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management follows the same practices I am asked to follow (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management enforces food safety rules consistently with all employees (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employees are disciplined or reprimanded when they fail to follow food safety practices (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My manager generally gives appropriate instructions on safe food handling (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All managers give consistent information about food safety (5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Food safety is very important to the dining hall

Food safety is very important to me

Food on the serving line kept below 135 degrees Fahrenheit can cause food-borne illness

Sanitizing the thermometer probe between uses is very important for food safety

The most important factors to control the growth of bacteria are temperature and time

Cooked foods can be kept at room temperature for 3 hours before serving
It took a lot of training for me to understand how to use the Testo handheld thermometers (12)

I found the Testo system difficult to use (13)

I feel very confident using the Testo handheld thermometers (14)

I prefer the handheld Testo thermometers over the old paper logs (15)

The handheld Testo thermometers improve the quality of my job (16)
Q9 Please read the following statements and select the response that accurately describes your answer choice.
<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree (1)</th>
<th>Agree (2)</th>
<th>Somewhat Agree (3)</th>
<th>Neither Agree nor Disagree (4)</th>
<th>Somewhat Disagree (5)</th>
<th>Disagree (6)</th>
<th>Strongly Disagree (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management follows the same practices I am asked to follow (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management enforces food safety rules consistently with all employees (2)</td>
<td></td>
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</tr>
<tr>
<td>Employees are disciplined or reprimanded when they fail to follow food safety practices (3)</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Food safety is very important to the dining hall (6)

Food safety is very important to me (7)

Food on the serving line kept below 135 degrees Fahrenheit can cause food-borne illness (8)

Sanitizing the thermometer probe between uses is very important for food safety (9)

The most important factors to control the growth of bacteria are temperature and time (10)

Cooked foods can be kept at room temperature for 3 hours before serving (11)
Q22 Please list disadvantages of using the Testo system.

________________________________________________________________________

Q15 Please list advantages of using the Testo system.

________________________________________________________________________

Q16 Do you have any further comments about food safety in the dining hall?

________________________________________________________________________

Page Break

End of Block: Default Question Block
Appendix E:
Line Staff Member Recruitment Flyer

Participants Invited To Participate In Research Study With N.C. State University

Participate in a 15 minute 3-part online survey interested in your thoughts on food safety culture and technology in the dining halls

Study Purpose: This study aims to determine the food safety culture surrounding the implementation of a new technology.

Participation in this study is not a requirement for your employment with NC State Dining. De-identified data will be shared with NC State Dining and Testo.

Participation Criteria:
• Must be 18 years or older
• Must work as a server on the line at either Fountain or Clark Dining Halls

Interested participants should email Savana Everhart (sleverh2@ncsu.edu) to set up a time to participate in this study. You will receive a $20 gift card to Amazon for your participation.

Research Under the Direction of:
Benjamin Chapman
Professor, Agriculture and Human Sciences
512 Brickhaven Dr., 220E
bichapman@ncsu.edu
(919) 515.8099

Anyone who has questions or is interested in participating should contact:
Savana Everhart
Email: sleverh2@ncsu.edu
Appendix F: 
Manager Recruitment Flyer

Participants Invited To Participate In Research Study With N.C. State University

Participate in a 30 minute interview interested in your thoughts on food safety culture and technology in the dining halls

Study Purpose: This study aims to determine the food safety culture surrounding the implementation of a new technology.

Participation in this study is not a requirement for your employment with NC State Dining. De-identified data will be shared with NC State Dining and Testo.

Participation Criteria:
• Must be 18 years or older
• Must work as a manager at either Fountain or Clark Dining Halls

Interested participants should email Savana Everhart (sleverh2@ncsu.edu) to set up a time to participate in this study. You will receive a $20 gift card to Amazon for your participation.

Research Under the Direction of:
Benjamin Chapman
Professor, Agriculture and Human Sciences
512 Brickhaven Dr., 220E
bjchapma@ncsu.edu
(919) 515.8099

Anyone who has questions or is interested in participating should contact:
Savana Everhart
Email: sleverh2@ncsu.edu
Appendix G:
Manager Consent Form

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Title of Study: Implementing Novel Technology and Its Implications on Food Safety Culture in Dining Halls, eIRB 16593

Principal Investigator: Savana Everhart, sleverh2@ncsu.edu, (919) 451-2214

Faculty Point of Contact: Benjamin J. Chapman, bichapma@ncsu.edu, (919) 515-8099

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate and to stop participating at any time without penalty. The purpose of this research study is to gain a better understanding of food safety culture in dining halls surrounding the adoption of a new technology. We are also interested in learning more about your opinions on the technology in general. We will do this through online survey questions.

You are not guaranteed any personal benefits from being in this study. Research studies also may pose risks to those who participate. You may want to participate in this research because knowledge may be gained that can provide more useful implementation of new technologies in dining halls across campus. You may not want to participate in this research because you may be uncomfortable sharing your thoughts about the food safety culture in the dining hall.

In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above or the NC State IRB office (contact information is noted below).

What is the purpose of this study?
The purpose of the study is to investigate the food safety culture surrounding the adoption of new technology in a university dining hall setting.

Am I eligible to be a participant in this study?
There will be approximately 5-12 participants in this study.

In order to be a participant in this study you must be over the age of 18 and work for NC State Dining as a director or general or line manager at either Fountain or Clark Dining Halls.

You cannot participate in this study if you are under the age of 18, do not work for NC State NC State Dining as a director or general or line manager at either Fountain or Clark Dining Halls.

What will happen if you take part in the study?
If you agree to participate in this study, you will be asked to do all of the following: schedule a 30-minute in-person interview with Savana Everhart. This interview will be scheduled between the hours of 7:30-4:30.

Questions asked will be open-ended and related to technology adoption and food safety and workplace culture. Example questions may ask about your feelings towards technology implemented in the dining hall, your role as a manager to food safety culture, if you are getting enough support from upper level management.
The total amount of time that you will be participating in this study is 30 minutes.

Risks and benefits

There are minimal risks associated with participation in this research. Anytime questions are asked about culture in the workplace, there is an increased risk to employment based off answers to questions. The likelihood of re-identification can be high, especially depending on your answers. If you feel uncomfortable with any question, you do not have to answer. Please ensure that you are not using any names or situations that could directly identify a person. Only data compiled from all participants, with identifiable details removed, will be shared and we will keep each answer as anonymous. Because there are relatively few individuals in this study, please take care to not identify yourself with your answers.

There are no direct benefits to your participation in the research. The indirect benefits are potentially increasing the work efficiency in the dining halls.

Right to withdraw your participation

You can stop participating in this study at any time for any reason. In order to stop your participation, please contact Savana Everhart. If your choose to withdraw your consent and stop participating you can expect to have all your data destroyed.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely on an NC State managed computer with password protection. This aggregated interview data will be shared with your employer; however, no names will be directly associated with your data. Only data compiled from all participants will be shared. Nonetheless, this does have a possibility of re-identification from the data. You may choose not to answer any question. Individual data with identifiable details removed may be made available to the public as required by a professional association, journal, or funding agency.

Compensation

For participating in this study you will receive a $10 Amazon gift card electronically. At the end of the interview you will be given a $10 Amazon gift card.

If you withdraw from the study prior before the interview, you will not receive any compensation. If you decide to withdraw from the study during or after the interview, you will still receive the $10 Amazon gift card.

What if you are an NCSU student?
Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

What if you are an NCSU employee?
Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.

What if you have questions about this study?

If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Benjamin J. Chapman, bjchapma@ncsu.edu, (919) 515-8099.
What if you have questions about your rights as a research participant?
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NC State IRB (institutional Review Board) Office via email at irb-director@ncsu.edu or via phone at 1.919.515.8754. An IRB office helps participants if they have any issues regarding research activities.

You can also find out more information about research, why you would or would not want to be a research participant, questions to ask as a research participant, and more information about your rights by going to this website: http://go.ncsu.edu/research-participant

Consent To Participate

“\'I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.”
Appendix H:
Manager Interview Script

“Thank you for agreeing to speak with me today. Before we begin, I need you to read and agree to the consent form. Please let me know if you have any questions or concerns. You will receive a copy of the form to take home.”

Consent form given to participant.

The purpose of this interview is to get your feedback on food safety culture within the university dining hall system. We are also interested in your thoughts on the Testo technology. As a manager, you can oversee food safety within the dining hall and have also helped implement the adoption of the technology.

This interview will last about thirty minutes, and I will be taking notes to ensure that I am recording your responses efficiently. You may choose not to answer any question. Please remember to not use any individual’s names during this interview.

Do you have any questions before we begin?

1.1 Testo Technology (excluded from control interviews)

1. What are some advantages of using the Testo handheld FSMS tablet and thermometer?
2. What are some disadvantages of using the Testo handheld control unit and thermometer?
3. Can you think of any improvements you could make to make the system more efficient?
4. How often are you personally checking the online website for alerts and violations?
5. What were the biggest barriers in implementing this technology?
6. How do you think the new technology compares with the paper logs?
7. On a scale of 1 to 7, with 1 being very difficult, 4 being neutral, and 7 being very easy, how was the process of learning the Testo system for you?
8. Why do you think that?
9. On a scale of 1 to 7, with 1 being very difficult, 4 being neutral, and 7 being very easy, how was the process of teaching the Testo system?
10. Why do you think that?

1.2 Food Safety Culture

1. What does food safety culture mean to you?
2. What do you think your role as a manager is to food safety culture?
3. Do you feel like the senior management is committed to food safety?
4. Why do you feel that way?
5. On a scale of 1 to 7, with 1 being not committed at all, 4 being neutral, and 7 being very committed, how committed to food safety is the dining hall?
6. Why do you say that?
7. Do you feel like the Testo technology has changed food safety within the dining hall?
8. Why do you think that?
9. Do you feel like you are getting enough support from upper level management?
   a. If yes: Proceed to next question.
   b. If no: What other forms of support would you like to have?
10. Are there any improvements to the dining hall’s food safety you would make?

I’d like to confirm that you understand the focus of our study and that you wish to maintain as a participant.

   If no: Thank you so much for your time. We will remove your data from our dataset and destroy any records.

   If yes: Thank you for your time and participation in our study today. Are there any questions that you have for me?

Here is your $20 Amazon gift card.

*Have participant sign they received their card.*