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Research Contributions:

In-depth Interviews with Child Nutrition Directors: Challenges to Food Safety Training

Student Perceptions of Their Student-Operated Restaurant Experience and Confidence with Foodservice Management Competencies

Ventilated and Unventilated Cooling Methods for Tomato Sauce in Onsite Foodservice Operations

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Abstracts

Research Manuscripts

In-depth Interviews with Child Nutrition Directors: Challenges to Food Safety Training

Younger students could have a higher risk of foodborne illness, therefore ensuring safe food handling practices of child nutrition meals is a priority for child nutrition directors. Training of employees on food safety is one approach to decreasing this risk. Understanding challenges to current training is paramount to identifying best practices and mitigating future issues. The aim of this study was to conduct a detailed examination of child nutrition directors' training challenges through in-depth interviews. Identified themes included the role of the director, the training modality, and the effect of behavior change. Further practical implications are identified and discussed.

Student Perceptions of Their Student-Operated Restaurant Experience and Confidence with Foodservice Management Competencies

Student-operated restaurants (SORs) are used by hospitality and dietetics programs to meet curriculum standards. However, research regarding students' perceptions of their SOR experience is limited. The purpose of this study was to explore student perceptions of their SOR experience. Students completed an electronic survey with questions regarding their interpersonal interactions, the use of foodservice and management skills, and the application of nutrition principles during their SOR experience. Students reported that the skills they learned in the SOR would help them in their future careers (M=4.18) and that they gained leadership skills from their SOR experience (M=4.31). Students disagreed with the statement that their SOR experience was negative (M=1.86). Overall, students appreciated their SOR experience and learned valuable skills that they believed would help them in their future careers. Student-Operated Restaurants can be an effective experiential learning tool to be used in both hospitality and dietetics programs.

Ventilated and Unventilated Cooling Methods for Tomato Sauce in Onsite Foodservice Operations

This study investigated whether cooling methods for tomato sauce in a walk-in refrigerator met 2022 FDA Food Code requiring that food be cooled from 135°F (57°C) to 70°F (21°C) within 2 hours and from 135°F (57°C) to 41°F (5°C) within a total of 6 hours. Both covered and uncovered cooling methods were tested, with covered methods taking significantly longer to cool. None of the methods complied with FDA Food Code standards for properly cooling food. Future research should explore cooling liquid foods that are thicker in consistency at shallower depths to improve compliance with FDA Food Code requirements.

Research Manuscript

In-depth Interviews with Child Nutrition Directors: Challenges to Food Safety Training

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ABSTRACT

Younger students could have a higher risk of foodborne illness, therefore ensuring safe food handling practices of child nutrition meals is a priority for child nutrition directors. Training of employees on food safety is one approach to decreasing this risk. Understanding challenges to current training is paramount to identifying best practices and mitigating future issues. The aim of this study was to conduct a detailed examination of child nutrition directors' training challenges through in-depth interviews. Identified themes included the role of the director, the training modality, and the effect of behavior change. Further practical implications are identified and discussed.

Keywords: Food Safety; Child Nutrition Programs; Qualitative Research; Training

INTRODUCTION

Under the National School Lunch Program (NSLP), a vast collective of nearly half a million child nutrition workers are engaged across roughly 100,000 schools, providing daily lunches to about 29.6 million children (USDA, 2024). Though the NSLP's core aim is to deliver low-cost or complimentary lunches that are nutritionally sound to students each day, it's worth noting that the average employee in this sector often lacks advanced education or specialized culinary training, which is critical for preparing meals that are both safe and tasty, as well as compliant with nutritional standards (Stephens et al., 2015). The USDA mandates that all child nutrition staff complete yearly training – six hours for those employed full-time and four hours for part-time workers (USDA, 2015). While child nutrition directors are required to complete a minimum of 12 training hours across various operational areas, including food safety (USDA Food and Nutrition Service, 2023).

Critically, highest risk population for foodborne illness includes children under 5 years of age. However, all school-aged children represent a vulnerable population requiring special consideration for food safety practices. Recent research by Leal et al. (2023) indicates that school-aged children remain susceptible to foodborne illness due to developing immune systems and congregate feeding environments. The CDC (2021) continues to identify schools as significant settings for foodborne illness outbreaks, underscoring the importance of effective food safety training in child nutrition programs.

Studies have surfaced several pressing problems within the current operation of child nutrition programs, including issues such as insufficient time, employee turnover, inadequate utilities for cooking from scratch, and a general shortage of culinary expertise needed to create appetizing and nutritionally

adequate meals (Strohbehn et al., 2014; Tabak & Moreland-Russell, 2015; Stephens, et al., 2015). The outcome is a noticeable drop in the acceptance rate of school meals among students (Yon, et al., 2016). Flure et al. (2021) call attention to the vital role that professional development plays in the success of child nutrition programs. Prior research emphasizes the urgent requirement for training in food hygiene and safety, as well as in culinary techniques (Arendt et al., 2014; Stephens et al., 2015). Reynolds and Dolasinski (2019) have scrutinized foodservice training methodologies, revealing that the widespread preference is lecture-based sessions with simple visual aids. Recent systematic reviews and meta-analyses have demonstrated that while food safety training generally improves knowledge, its impact on sustained behavioral change varies significantly (Insfran-Rivarola et al., 2020; Alkhalidi et al., 2025). This gap between knowledge acquisition and behavior change represents a critical challenge for child nutrition programs. Recent research by Peabody et al. (2024) examined the relationship between food safety training approaches and actual behavior change among child nutrition staff. Their study of 42 school districts found that training programs incorporating hands-on practice components resulted in significantly higher rates of proper food handling behaviors compared to knowledge-based training alone. As Peabody et al. (2024) note, 'The integration of experiential learning techniques with traditional knowledge transfer approaches appears to bridge the persistent gap between food safety knowledge and practice in school nutrition environments' (p. 83). This finding aligns with our focus on understanding the challenges directors face in translating food safety training into consistent behavioral practices. Additionally, research has observed a noteworthy gap when it comes to innovative training strategies which can enhance confidence and motivation, thereby increasing the practical application of knowledge and skills (Stephens et al., 2015).

Addressing the health inspection records of child nutrition programs, Lee and Liu (2020) pinpointed the most frequent critical infractions: controlling temperatures for at-risk foods, inappropriate use of equipment, and mishandling of hazardous substances. They found common non-critical issues as well, particularly associated with the use of equipment and maintaining facilities and equipment for food temperature control. While it is not unprecedented to identify violations of food safety in child nutrition programs, ongoing research spanning several years to determine trends in food safety violations is scarce. Identifying these trends could lead to bespoke training interventions that may reduce the risk of foodborne illnesses.

Moreover, numerous obstacles confront efforts to train child nutrition workers, such as the unavailability of physical space for training. Timing, funding limitations for travel, and extra remuneration are recurrent barriers to training attendance, as identified by Lee, Kwon, and Sauer (2014). Additionally, Tabak and Moreland-Russell (2015) highlighted the exacerbated problem of insufficient time for training due to labor shortages. The CDC reports that incorrect food handling, poor personal hygiene, and cross-contamination are the leading errors contributing to foodborne diseases (CDC, 2021), with school-related outbreaks constituting 8.2% of all reported cases between 2000-2010 (Venuto & Garcia, 2015). A comprehensive review from Jones et al. (2013) outlined the need for food safety training. Similarly, Reynolds et al. (2022) found that nearly 94% of food service directors prefer on-the-job training, typically lasting less than two hours, focusing on food production and safety. An improved understanding of the perceived obstacles to training could greatly aid in creating future training programs.

The primary objective of this research is to delve into the perceived hurdles and barriers that child nutrition directors face regarding their current food safety training practices. This would aid in systematically identifying the training and work support needs of child nutrition workers, which could then be turned into tailored training plans incorporating constructivist teaching methods in subsequent projects. This was completed through in-depth interviews of child nutrition directors.

METHODS

The Research Design

To further understand child nutrition directors' perspectives on challenges to current training practices a semi-structured interview protocol was developed and informed based on previous research (Reynolds et al., 2022), literature review, and input from foodservice, food safety, and training development content experts. A qualitative approach was utilized to better understand the rich contextual data that is often missed in quantitative approaches. With qualitative inquiry, "The key concern is understanding the phenomenon of interest from the participants' perspectives, not the researcher's" (Merriam & Tisdell, 2016, p. 16).

Target Population

The target population of this study was elementary through high school child nutrition directors. Child nutrition directors were selected because of their responsibilities to provide training to staff including the planning, decision making, and execution of the trainings. A total of 50 child nutrition directors were targeted, to provide a national representative convenience sample. This targeted sample size is aligned with previous child nutrition director research ($n=10$) (Yon et al., 2016) and ($n=16$) (Gupta et al., 2025) using a similar method.

Child nutrition directors from each of the seven USDA Food and Nutrition Service regions were targeted (USDA Food and Nutrition Service, 2023). The use of participants from different areas of the country and school sizes helps increase generalizability and credibility (Merriam, 2009). Our approach to recruiting child nutrition directors from diverse geographic regions and district sizes aligns with recent qualitative research (Jowell et al., 2023) which employed purposive sampling to ensure representation across rural, suburban, and urban school districts when examining food service adaptations during the COVID-19 pandemic.

Interview Protocol

A semi-structured interview protocol was developed. The interview protocol was informed by validated measurement scales for food safety culture assessment (Yu et al., 2021), ensuring that questions addressed both technical and cultural aspects of food safety training. The interview protocol contained, first several open-ended questions, then follow-up questions were developed as additional probing questions.

Data Collection

Child nutrition directors were contacted via email as a continuation of a research project conducted by Reynolds et al. (2022) and provided the study purpose and request for inclusion in the current study. Upon completion of informed consent form, interview times were scheduled. All interviews were conducted by a single researcher experienced in qualitative methods. Interviews were conducted in-person or via a video conference call. All interviews were recorded and transcribed verbatim. Interviews ranged from 45-60 minutes in length. Participants were first asked several demographics and descriptive questions: followed by several open-ended questions. An example question was: "Of the food safety training or trainings you conducted last year, what would you consider a major challenge?". Follow-up questions were systematically employed using a predetermined protocol of potential probing questions that were triggered by specific participant responses, enabling deeper exploration of emerging themes while maintaining methodological consistency. This approach (Creswell & Poth, 2023) to follow-up questioning allowed interviewers to delve into directors' experiences with food safety training challenges, encouraging participants to provide concrete examples and elaborate on initial responses while ensuring

all key areas of inquiry were thoroughly addressed. In qualitative research, focus is given to the depth and breadth of the data, not the quantity of data, thus the open-ended, semi-structure interview protocol was used (Creswell, 2013).

Data Analysis

Each interview transcript resulted in a range of 15 to 30 pages of typed, single-spaced text with 12-point font. Following the protocol developed by Arendt et al. (2014) the research team, including three members, independently analyzed manually the transcripts from each interview. The protocol included, reviewing each transcription several times, then identifying coding of segments, followed by, gathering of coding into themes, finally, commonalities between transcripts were explored. After independent review, each member of the research team reached 100% agreement on themes and related codes. NVivo software was used to provide confirmation of the manual qualitative research analysis. A comparison of the manual analysis and the software analysis was conducted for commonalities and differences. The qualitative analysis software allowed for organizing and enriched analysis with visual presentation of the relationships of the findings.

RESULTS AND DISCUSSION

A total of 17 child nutrition directors participated in an interview. Participants in this study were predominantly male (75%) and held the title of child nutrition director (94%). The majority (59%) had over 14 years of child nutrition experience. Finally, participants represented a variety of school district sizes: less than 500 students (12%) to more than 10,000 (18%); as well as oversaw a varying range of full-time child nutrition employees: 1-2 employees (6%) to more than 12 employees (12%), see Table 1.

Table 1: Descriptive Characteristics (n=17)

	<i>n</i>	%
Gender		
Male	13	(76.5)
Female	4	(23.5)
Role in Child Nutrition		
Child nutrition director	16	(94.1)
School administration (superintendent, principal)	1	(5.9)
Years' Experience in School Foodservice		
5-7	2	(11.8)
8-10	2	(11.8)
11-14	3	(17.6)
More than 14	10	(58.8)
Number of Students in School District		
Less than 500	2	(11.8)
501-2,499	4	(23.5)
2,500-9,999	8	(47.1)
More than 10,000	3	(17.6)
Number of Full-time Child Nutrition Employees		
1-2	1	(5.9)
3-5	2	(11.8)
6-8	4	(23.5)
9-12	8	(52.9)
More than 12	2	(11.8)

The following results directly address the food safety training challenges, approaches, and innovations identified by child nutrition directors. Each theme is explicitly connected to training implications, with supporting evidence from participant quotes and relevant literature. Figure 1 provides a visual representation of how these themes interconnect within the broader context of food safety training in child nutrition programs. As recommended by Braun and Clarke (2021) when reporting qualitative research, quantitative representations should be incorporated to balance with the rich qualitative descriptions to maintain the depth of findings. Table 2, illustrated the number and percentage of child nutrition directors that noted each sub-theme as a barrier or challenge.

Table 2: Frequency of Themes and Sub-Themes Mentioned by School Nutrition Directors (n=17)

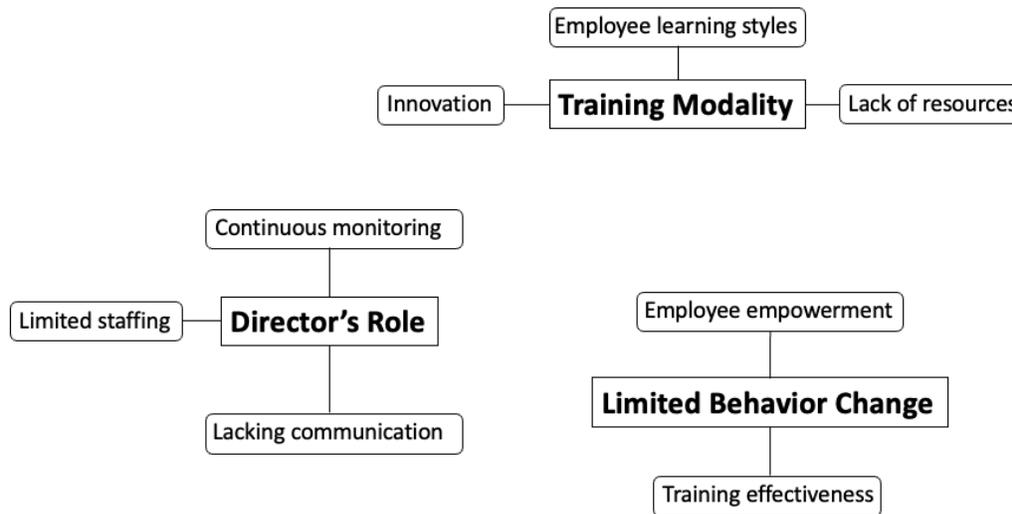
Theme & Sub-themes	Percentage	Number of Directors
Director's Role		
Continuous Monitoring	88%	15/17
Limited Staffing	82%	14/17
Lacking Communication	65%	11/17
Limited Behavior Change		
Training Effectiveness	88%	15/17
Employee Empowerment	47%	8/17
Training Modality		
Innovation	94%	16/17
Lack of Resources	76%	13/17
Employee Learning Styles	59%	10/17

Three main themes were identified, when exploring the main research objective, exploring the perceived hurdles and barriers that child nutrition directors face regarding their current food safety training practices. The main themes, as illustrated in Figure 1, include: The “Director’s Role”; “Limited Behavior Change”; and “Training Modality”. The following sections examine each main theme and subthemes.

Director's Role in Food Safety Culture

Child nutrition directors play a crucial role in establishing and maintaining food safety culture within their organizations. Food safety culture has emerged as a critical factor in preventing foodborne illness outbreaks in institutional settings. Griffith et al. (2010a) identified food safety culture as "an emerging risk factor" requiring proper assessment methods (Griffith et al., 2010b). The importance of organizational culture in supporting training effectiveness is highlighted by Zanin et al. (2022), who developed a roadmap for educational interventions based on food safety culture assessments in institutional foodservice settings. Within the main theme, three sub-themes were identified during data analysis. These sub-themes include: “Continuous monitoring”, “Limited staffing”, and “Lacking communication”. The following section discusses each of the sub-themes with directors’ quotes for context.

Figure 1: Qualitative Themes and Codes



Continuous Monitoring

The most frequently mentioned sub-theme under the director's role, continuous monitoring, was emphasized by 88% (15/17) of directors, who described the ongoing nature of maintaining food safety standards beyond initial training sessions and the need for consistent observation and feedback mechanisms.

"It only takes one slip-up to compromise the health of our students. The pressure is immense." (Director 4)

"We're up against so many challenges – tight budgets, time constraints, staff turnover. It sometimes feels like an uphill battle to maintain food safety standards." (Director 9)

The director's role extends beyond policy creation to active reinforcement through observation and feedback. Reynolds (2020a) emphasizes that the manager (Director) of an operation has a major role in the food safety program, particularly in reinforcing training through direct observation. This ongoing reinforcement is critical, as training and knowledge assessment alone is not enough to fully understand or change food safety behaviors (Reynolds & Rajagopal, 2017a).

Research consistently shows that management commitment significantly influences employee food safety behaviors (Clark et al., 2019). Authority figures serve as "main influencers who create and shape culture" (Clark et al., 2019, p. 189), with management commitment positively affecting food safety training outcomes by motivating employees to adhere to proper practices (Clark et al., 2019).

"...food safety states at the top and trickles down." (Director 2)

Limited Staffing

Limited staffing emerged as a significant barrier to implementing comprehensive food safety training, with 82% (14/17) of directors specifically citing staffing constraints that impacted their ability to schedule training sessions without disrupting daily operations.

"My top priority is ensuring every student has access to safe, nutritious food. That's non-negotiable." (Director 6)

"Food safety is a priority, and we're building a team that prioritizes it every step of the way. However, funding doesn't allow the staffing resources we truly need." (Director 12)

This finding parallels recent research by Jowell et al. (2023), who found that staffing shortages during the COVID-19 pandemic exacerbated existing challenges in maintaining food safety standards in school nutrition programs. Similarly, in a study of Oklahoma child nutrition directors, "limited staffing (63.9%)" was cited as the primary barrier, followed by "concern for student satisfaction (58.1%), and time management (50.3%)" (Peabody et al., 2024). Furthermore, when staffing is limited, employees must manage multiple responsibilities simultaneously, creating what researchers call "role overload" (Clark et al. 2019).

Lacking Communication

Directors are responsible for communicating food safety expectations clearly, consistently, and effectively. Recent research by Martinez-Tome et al. (2022) supports this approach, finding that food handlers with diverse backgrounds benefit from varied communication strategies. We have incorporated this literature and clarified the specific communication challenges and potential solutions identified in our study. Analysis revealed that 65% (11/17) of directors reported communication challenges, primarily related to ineffective communication strategies rather than a complete absence of communication, with many noting the need for multimodal approaches to reach diverse staff.

"Sometimes I feel like a broken record, reminding staff about basic food safety practices. It's a constant struggle."
(Director 13)

"It's frustrating when people don't take food safety seriously. We're talking about the well-being of our children."
(Director 5)

"It's a constant juggling act, trying to balance discussing food safety and daily operations..." (Director 9)

Reynolds and Rajagopal (2017b) found that childcare food handlers perceived a lack of consistency and timeliness of food safety information received from childcare directors. The study also revealed that respondents working in facilities with written food safety policies identified key motivators including written policies and procedures as well as a workplace that does not tolerate unsafe handling behaviors. Similarly, our findings regarding communication challenges echo recent research by Lee et al. (2023), who found significant disconnects between food safety knowledge and actual practices among school canteen handlers, often attributed to communication barriers. "The manager plays a key role in the food safety culture by establishing policies and standards, expecting accountability, serving as a role model, controlling rewards and punishment, providing training, and providing needed resources to follow food safety practices," (Arendt, Paez, & Strohbehn, 2013, p. 126). Furthermore, recent research by Gould et al. (2023) highlights the critical relationship between manager training and food safety outcomes in foodservice establishments. Their study of restaurant managers found that those with comprehensive food safety training were significantly more likely to implement effective monitoring systems and create a positive food safety culture among staff. As Gould et al. (2023) noted, "Manager knowledge and commitment to food safety practices were strongly associated with employee compliance rates and overall establishment performance on food safety inspections" (p. 608). This finding has important implications for child nutrition programs, suggesting that director training may be a key leverage point for improving food safety communication throughout the organization. This aligns with USDA Professional Standards for School Nutrition Professionals, which require a minimum of 12 training hours for directors across various operational areas, including food safety (USDA Food and Nutrition Service, 2023).

Limited Behavior Change

The persistent gap between food safety knowledge and actual practices represents a significant challenge in child nutrition programs. Research consistently demonstrates that knowledge acquisition does not automatically translate to behavior change in food safety practices (Da Cunha et al., 2019). Traditional training approaches often fail to address the underlying factors that influence behavior beyond knowledge deficits. Alcorn et al. (2022) identified salient beliefs of school nutrition employees that impact food safety behavior, highlighting the importance of addressing attitudes and perceptions in training design. Similarly, Roberts et al. (2020) applied the theory of planned behavior to determine that multiple factors influence compliance beyond just knowledge, suggesting that conventional training alone may be insufficient to create meaningful behavior change. This knowledge-behavior gap is influenced by organizational culture, practical implementation barriers, and individual attitudes toward food safety practices (Reynolds & Rajagopal, 2017). Addressing limited behavior change requires comprehensive approaches that improve training effectiveness and increase employee empowerment.

Within the main theme of limited behavior change, two sub-themes were identified during data analysis. These sub-themes include: "Training effectiveness" and "Employee empowerment". The following section discusses each of the sub-themes with directors' quotes for context.

Training Effectiveness

Concerns about training effectiveness and the gap between knowledge acquisition and behavior change were expressed by 88% (15/17) of directors, making this one of the most frequently mentioned challenges, with many directors noting frustration with the "knowing-doing gap" despite substantial investments in training.

"We can provide all the training in the world, but translating that knowledge into consistent daily practices is where we struggle most." (Director 2)

However, many directors emphasized that training doesn't always translate to improved long term food safety practices. The challenge of achieving lasting behavior change following food safety training was a recurring theme among directors in our study. This aligns with findings from Peabody et al. (2024), who documented that only 37% of child nutrition programs achieved sustained compliance with food safety protocols six months after traditional training interventions. Their research suggests that continuous reinforcement strategies, similar to those mentioned by our participants, were associated with significantly higher rates of long-term compliance.

"It's frustrating when training doesn't translate to lasting change. We need to find engaging ways to keep food safety top-of-mind." (Director 11)

"... It's not enough to just teach, we need to inspire lasting change." (Director 12)

"It's like they forget everything they learned the minute they step out of the training session." (Director 4)

Research consistently demonstrates that knowledge acquisition does not automatically translate to behavior change in food safety practices. The challenge of knowledge retention aligns with findings from Hirimuthugoda et al. (2024), who demonstrated that workers receiving biannual refresher courses showed 30% higher compliance with hygiene protocols compared to those receiving only initial training. Traditional training approaches often fail to address the underlying factors that influence behavior. Alcorn et al. (2022) identified salient beliefs of child nutrition employees that impact food safety behavior, highlighting the importance of addressing attitudes and perceptions beyond just knowledge transfer. Similarly, Roberts et al. (2020) used the theory of planned behavior to determine that multiple factors influence compliance beyond just knowledge. This suggests that training alone may not be sufficient to create meaningful behavior change.

Employee Empowerment

Strategies to promote employee empowerment and ownership of food safety practices were mentioned by 47% (8/17) of directors, who sought to develop "food safety champions" rather than mere rule-followers by fostering a culture of accountability and personal responsibility.

"...constantly evaluating our training methods to ensure they're effective, there's always room for improvement."
(Director 10)

"...creating a culture of food safety that extends beyond the training room." (Director 6)

"We're empowering our staff to be food safety champions, not just rule followers. It's about ownership and accountability." (Director 1)

Furthermore, researcher recommends incorporating behavior-based elements into training. Wong et al. (2020) suggest including "motivation, role modeling, mentoring, provision of tools and supplies, and managerial support after training" to enhance effectiveness. Similarly, Alcorn et al. (2022) proposed that intervention strategies could use realistic-event videos focusing on employees' subjective norms and perceived behavioral controls to better influence intentions and behaviors. Self-efficacy interventions, as described by Wong et al. (2020), have shown success in improving selected food safety behaviors among food handlers, supporting our directors' emphasis on building employee confidence through training. These findings collectively suggest that effective behavior change strategies must address the complex interplay of knowledge, attitudes, organizational culture, and continuous reinforcement within child nutrition programs.

Training Modality

Within the main theme of training modality, three sub-themes were identified during data analysis. These sub-themes include: "Innovation", "Lack of resources", and "Employee learning styles". The following section discusses each of the sub-themes with directors' quotes for context.

Innovation

Research indicates a need for innovation in food safety training modalities beyond traditional lecture-based approaches. Visual-based minimal-text training materials have shown promise, particularly for diverse audiences. Beyond traditional educational approaches, integrating behavioral nudges with food safety training has shown promising results in child nutrition programs (Madjdian et al., 2024), supporting our directors' emerging interest in behavioral interventions. Rajagopal et al. (2019) created visual-based minimal-text training materials comprising 10 handouts and one PowerPoint presentation for Chinese-speaking food service workers, noting that these visual aids are an inexpensive educational tool and have been shown to be effective in other foodservice settings.

Innovative approaches to food safety training were described by nearly all directors (94%, 16/17), who discussed implementing new technologies and methods such as microlearning modules, visual aids, and hands-on demonstrations to enhance training effectiveness.

"We're embracing technology to make food safety training more accessible and engaging for our diverse staff."
(Director 8)

"...we offer flexible training options to accommodate different learning styles and schedules." (Director 1)

This aligns with findings from Gupta et al. (2025), who documented how child nutrition directors developed creative solutions to training challenges during the COVID-19 pandemic. Their research identified that directors who implemented hybrid training models—combining self-paced digital modules with targeted in-person demonstrations—reported higher staff engagement and knowledge retention compared to those using traditional approaches.

Emerging technologies are also being explored for food safety training. Some directors expressed interest in emerging technologies for food safety training. This aligns with recent research on AI-enhanced food safety training, which has shown promise in personalizing learning experiences and improving engagement among food handlers (Wang et al., 2025). Recent research by Jeong et al. (2023) demonstrates the significant potential of spatial augmented reality (sAR) in culinary training environments. Their study comparing sAR Kitchen with traditional video tutorials found that augmented reality demonstrations improved learning outcomes by 27% and increased engagement by providing real-time, interactive guidance in the actual work environment. As they note, 'sAR technology creates an immersive learning experience by projecting digital information directly onto physical objects and surfaces in the kitchen, allowing trainees to receive step-by-step guidance while maintaining hands-free operation' (Jeong et al., 2023, p. 768).

Reynolds (2022) suggests that future educational interventions could utilize advanced technology such as augmented reality to educate child nutrition employees in real time on the job. The COVID-19 pandemic accelerated the adoption of virtual training methods. Recent research by Beary et al. (2025) identified significant opportunities for accessible and effective distance learning in food safety education, particularly for reaching geographically dispersed staff in rural school districts.

Clark et al. (2020) assessed perceptions of a video game designed to promote handwashing habits in foodservice, noting that such technology could complement other pillars of habit formation. Wong et al. (2020) described an innovative approach that incorporated real case stories, the use of disgust, and error-based training. This included storytelling about actual food poisoning incidents, visual demonstrations of microbial contamination using GloGerm powder and a handheld UV light, and hands-on activities to demonstrate cross-contamination. This multi-sensory approach engages learners more effectively than traditional methods.

The Spatial Augmented Reality (sAR) Kitchen represents another innovative approach, designed as an sAR tutorial system for culinary training where users are able to watch a pre-recorded, step-by-step tutorial using the sAR system while simultaneously performing the tasks on their end (Ghasemi et al., 2023). This approach has potential benefits for food safety training, as visual and auditory stimuli are easier to understand and using visual cues reduces the cognitive load.

Lack of Resources

Resource limitations, including time, budget, and space constraints, were cited by 76% (13/17) of directors as significant barriers to implementing ideal food safety training programs, forcing many to adapt their approaches within existing constraints.

"It's challenging to find the time and resources to implement engaging training programs. We're often limited by budget constraints." (Director 3)

"With our limited budget, we're forced to use outdated training materials and can't afford the interactive programs that would really engage our staff and make food safety concepts stick." (Director 8)

Resource constraints identified in our study parallel those found in diverse food service settings globally. Gameda et al. (2025) identified inadequate resources as a significant barrier to implementing food safety practices, even when knowledge levels were adequate. Similar challenges have been identified in research pertaining to limited opportunities for training due to time constraints (Tabak & Moreland-Russell, 2015). Additionally, Reynolds and Rajagopal (2017) found that the top four perceived important barriers pertained to time and work limitations: 'too much work to do', 'the work pace', 'too busy', and 'lack of time.' Similarly, Giampaoli et al. (2002) identified time as "one of the greatest challenges" to implementing food safety practices in child nutrition programs.

The challenge of time for training is compounded with the concept of "role overload", which is directly connects time constraints to food safety behaviors. Clark et al. (2019) define role overload in the food safety context as the extent to which food handlers feel they have inadequate time, training, and/or resources to wash their hands as often and as proficiently as they should. They note that role overload reflects organizational culture and often forces employees to spend time on the primary priority, which then dictates that taking short cuts is necessary with lower priority behaviors. Importantly, food safety training programs show mixed results in improving compliance with food safety standards. However, Da Cunha et al. (2013) demonstrated that long-term intervention strategies based on knowledge, attitude, and practice can improve food safety in child nutrition programs. These findings reinforce the need for continued training interventions, though overcoming the identified challenges will require novel approaches.

Employee Learning Styles

The importance of addressing diverse employee learning styles was emphasized by 59% (10/17) of directors, who recognized that standardized training approaches were insufficient for their diverse workforce with varying educational backgrounds, language proficiencies, and learning preferences.

"I've noticed our younger staff learn best from videos and hands-on demonstrations, while our veteran employees prefer written procedures they can reference, which means I'm constantly creating multiple versions of the same training materials to be effective." (Director 9)

"When I switched from lecture-style training to a combination of visual aids, hands-on practice, and short video clips, I saw immediate improvements in comprehension across my staff, especially among those who struggle with English as their second language." (Director 4)

While lecture style was identified in the research as the most common training modality (Reynolds & Dolasinski, 2019), there is growing evidence supporting the effectiveness of multi-modal approaches. Dolasinski and Reynolds (2020) developed a microlearning model for training that utilizes multiple modalities in the design of the training module, including a short video, a scripted pre-shift mini-lecture, a poster providing a visual, and a business card sized companion card. This approach aligns with the finding that using multiple training methods in short training sessions can be effective (Reynolds & Jeong, 2022). Furthermore, The directors' interest in microlearning approaches is supported by recent research comparing microlearning to traditional training methods in child nutrition programs, which found that microlearning resulted in better knowledge retention and application (Maneerat et al., 2024).

CONCLUSIONS AND APPLICATIONS

Effective food safety training in child nutrition settings requires a multifaceted approach that addresses not only knowledge gaps but also attitudes, organizational culture, and practical barriers to implementation. Findings will assist in the development of future customized training methods and content. Training programs should be designed with consideration for the specific context of child nutrition programs and should incorporate strategies to bridge the gap between knowledge and practice. Future research should focus on developing and evaluating interventions that address the complex interplay of individual, organizational, and environmental factors that influence food safety behaviors in school settings.

The research clearly demonstrates that directors and managers play a pivotal role in establishing and maintaining food safety culture within child nutrition programs. Management commitment significantly influences employee food safety behaviors (Clark et al., 2019), with authority figures serving as main influencers who create and shape culture (Clark et al., 2019). Directors are responsible for communicating food safety expectations clearly and consistently, as inconsistent messaging has been identified as a barrier to proper food handling practices (Reynolds & Rajagopal, 2017b). The implementation of written

policies and procedures has been shown to be a key motivator for food safety compliance (Reynolds & Rajagopal, 2017b). Furthermore, the director's role extends beyond policy creation to active reinforcement through observation and feedback, as the manager of an operation (childcare director) has a major role in the food safety program (Reynolds, 2020b). This ongoing reinforcement is critical because training and knowledge assessment alone is not enough to fully understand or change food safety behaviors (Reynolds & Rajagopal, 2017).

Traditional food safety training approaches often fail to produce lasting behavior change among child nutrition workers. Research consistently demonstrates a gap between knowledge acquisition and actual practice, with Da Cunha et al. (2019) identifying significant differences between observed and self-reported food safety practices. This knowledge-behavior gap is influenced by multiple factors beyond knowledge deficits, including attitudes, organizational culture, and practical barriers to implementation. Alcorn et al. (2022) identified salient beliefs of child nutrition employees that impact food safety behavior, highlighting the importance of addressing underlying attitudes and perceptions. Resource constraints further complicate behavior change efforts, with limited staffing (63.9%), concern for student satisfaction (58.1%), and time management (50.3%) identified as top challenges faced by child nutrition professionals (Reynolds, Jeong & Nam, 2022).

Emerging research points to the effectiveness of innovative, multi-modal approaches to food safety training. Dolasinski and Reynolds (2020) developed a microlearning model that utilizes multiple modalities in the design of the training module, including a short video, a scripted pre-shift mini-lecture, a poster providing a visual, and a business card sized companion card. This approach aligns with findings that using multiple training methods in short training sessions can be more effective than traditional approaches (Reynolds & Jeong, 2022). Visual-based minimal-text training materials have shown promise, particularly for diverse audiences (Rajagopal et al., 2019). Wong et al. (2020) described an innovative approach that incorporated real case stories, the use of disgust, and error-based training, engaging learners through multiple sensory channels. Emerging technologies such as augmented reality and video games also show promise for enhancing food safety training effectiveness (Reynolds, 2022; Clark et al., 2020).

Finally, future research should address critical gaps in our understanding of how to effectively promote food safety in child nutrition programs. A mixed-methods study examining the effectiveness of various training modalities (in-person, online, microlearning) on both knowledge retention and behavior change among both directors and employees to provide a more comprehensive understanding of training effectiveness, with specific measurement protocols. Another research direction would be longitudinal research tracking the relationship between director leadership training and subsequent improvements in employee food safety compliance, potentially using the Food Safety Climate tool developed by De Boeck et al. (2022). By focusing on the director's role, addressing barriers to behavior change, and developing innovative training approaches, future research can contribute to the development of more effective food safety interventions that protect vulnerable student populations. Another important research agenda would be an intervention study testing innovative approaches to reinforcement and continuous monitoring, such as gamification elements or technology-assisted observation tools, as this was identified as a needed approach for future training. Future research could building on the work of Jeong et al. (2023), who demonstrated sAR's effectiveness in culinary training, studies could examine how this technology might be adapted to address the unique food safety training challenges in school environments. Finally, a comparative analysis of food safety training approaches across different institutional foodservice settings (schools, healthcare, universities) to identify transferable best practices.

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Research Manuscript

Student Perceptions of Their Student-Operated Restaurant Experience and Confidence with Foodservice Management Competencies

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ABSTRACT

Student-operated restaurants (SORs) are used by hospitality and dietetics programs to meet curriculum standards. However, research regarding students' perceptions of their SOR experience is limited. The purpose of this study was to explore student perceptions of their SOR experience. Students completed an electronic survey with questions regarding their interpersonal interactions, the use of foodservice and management skills, and the application of nutrition principles during their SOR experience. Students reported that the skills they learned in the SOR would help them in their future careers (M=4.18) and that they gained leadership skills from their SOR experience (M=4.31). Students disagreed with the statement that their SOR experience was negative (M=1.86). Overall, students appreciated their SOR experience and learned valuable skills that they believed would help them in their future careers. Student-Operated Restaurants can be an effective experiential learning tool to be used in both hospitality and dietetics program.

Keywords: experiential learning; hospitality education; foodservice management; student-operated restaurant

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INTRODUCTION

According to the U.S. Bureau of Labor Statistics (2022), job opportunities for foodservice managers are expected to grow by 10% from 2021-2031. There is a growing need for well-trained and educated foodservice managers to fill these positions. When formally trained, these managers often complete undergraduate hospitality management or dietetics programs. Hospitality programs can be accredited by the Accreditation Commission for Programs in Hospitality Administration (ACPHA), and dietetics programs are required to be accredited by the Accreditation Council for Education in Nutrition and Dietetics (ACEND). Hospitality program curricula typically emphasize foodservice and management skills and include courses to teach these topics (Bartlett et al., 1998; Nies, 1993; Szende et al., 2019). Likewise, dietetics program curricula also require that foodservice and management skills be taught (ACEND, 2022). In both disciplines, these skills and topics may be taught using various educational formats including lectures, laboratory courses, group projects, and presentations.

One educational method, often used in both hospitality and dietetics programs to teach required curriculum skills, is experiential learning. Experiential Learning Theory (ELT), as described by David

Kolb, is based on the works of several scholars and “is a holistic theory that defines learning as the major process of human adaptation involving the whole person” (Kolb & Kolb, 2017, p. 11). ELT emphasizes the role of experience, perception, cognition, and behavior in learning (Kolb, 1984, p. 21). Kolb also describes the experiential learning cycle which includes four learning modes: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984, p. 30). ELT and participating in the experiential learning cycle allows learners to practice real-world applications of their education. Skills essential to effective management such as communication, teamwork, adaptability, and thinking outside the box can all be taught through experiential learning (Yeadon-Lee & Hall, 2013).

Due to the effectiveness of experiential learning, it is often used in both hospitality and dietetics programs to help train future foodservice managers. Kiser and Partlow (1999) surveyed hospitality program directors, deans, and department chairs for the prevalence and use of experiential learning in their programs and, of the 40 programs included in the final analysis, all used experiential learning in some form including industry work experience, internships, practicums, and field projects. Gustafson et al. (2005) reviewed 44 hospitality programs and found that they provided a variety of experiential learning opportunities including foodservice laboratories (n=43) and fine dining courses (n=14) to teach hands-on skills as well as to help students develop critical thinking skills. These results are similar to those of Bartlett et al. (1998) who reported the frequent inclusion of laboratory credits in the curricula of 16 top hospitality programs. In a survey of undergraduate dietetics programs by Short and Chittooran (2004), 87% of respondents indicated using experiential learning methods including having students conduct nutrition education sessions, needs assessments, and educational evaluations.

One form of experiential learning utilized in some hospitality and dietetics programs is the student-operated restaurant (SOR). A SOR is an on-campus restaurant where students can gain hands-on experience in quantity food production and other foodservice management skills while receiving course credit (Josiam et al., 2014; Mathews et al., 2021; Nies, 1993; [blinded for review]). The accrediting bodies for hospitality (ACPHA) and dietetics (ACEND) programs require that foodservice and management principles be taught but do not provide guidelines regarding the use of SORs as an experiential learning tool. These labs are a unique experiential learning tool not utilized by all programs often due to the expense of operating them (Cook et al., 2018). Programs that choose to utilize SORs benefit by being able to manage the teaching and training of students first-hand. This controlled environment allows programs to ensure that required competencies are being properly taught by faculty and met by students (Stokes et al. 2022).

Specific methods of SOR management and use can vary from one program to another. However, Stokes et al. (2022) interviewed managers of SORs and found that there are some similarities in the way that SORs are managed. For example, SORs are typically managed by only one or two academic departments, all programs have a faculty/staff member assigned to oversee the daily operations, and the days and times that SORs are open almost always align with academic schedules. Finally, the overall purpose of SOR's (gain hands-on experience in quantity food production and other foodservice management skills while receiving course credit) is similar across all programs (Stokes et al. 2022).

Some research has been conducted regarding the use of SORs in hospitality and dietetics programs. One of the first studies that focused specifically on the use of SORs in Hospitality Programs, was conducted by Nies and published in 1993. Nies surveyed hospitality program directors regarding their use of SORs and found that half of the programs reported utilizing an SOR. The number of student hours spent in these SORs ranged from 2 to 12 per week, and the majority utilized student management teams. Nies also reported differences between programs with SORs and those without SORs; for example, programs with SORs had fewer academic major options, and their graduates were more likely to be employed in foodservice post-graduation. Cook et al. (2018) surveyed directors of Didactic Programs in Dietetics

(DPDs); a third of the responding directors reported that their students participate in SORs. Programs without SORs taught quantity food production in other ways including restaurant or dining facilities on campus or catering events. The greatest barriers to future SOR use, as rated by DPD directors without SORs, were upfront costs, lack of faculty, and lack of university funding (Cook et al., 2018).

While SORs are a form of experiential learning used in both dietetics and hospitality programs, research regarding SOR use is limited and has focused mainly on customer and management perspectives. Josiam et al. (2014) surveyed customers dining at a SOR run by a university's hospitality management program. Customers ranked various factors of the SOR including food and service quality and motivators or barriers to patronage. Overall, the food and service quality of the SOR were perceived favorably, and customers were generally motivated to eat at the SOR for its perceived value and because they want to support the school and the students who run the restaurant. In a similar study, [blinded for review] (2018) surveyed customers of a SOR run by the university's dietetics program. Quality of food, quality of service, the overall experience, and value for price were all factors rated highly by customers. Customers also valued healthy choices, and the majority (86.6%) reported an expectation that the SOR should "probably" or "definitely" serve foods that meet nutritional guidelines.

Stokes et al. (2022) interviewed SOR managers about the use and operation of SORs, their own experiences with the SOR and how they viewed the experiences of their students and customers. A central objective identified by the SORs managers was developing students' kitchen and management skills. They also described the initial student experience as emotional (anxiety, stress, or anger), but after their SOR experience students typically reported that they had learned valuable career skills.

When assessing the development of skills through an experiential learning tool such as SORs, it is important to consider students confidence/self-efficacy. Bandura's theory of self-efficacy indicates that a person's belief in their ability affects the production of specific outcomes (Bandura, 1997). Similarly, Lorschach & Jinks (1999) summarized theorist's definitions of the theory of self-efficacy as "a sense of confidence regarding the performance of specific tasks." Research has explored self-efficacy and its relationship with learning outcomes. For example, Huang et al. (2020) found that simulation learning improved nursing students' self-efficacy. Specific to learning foodservice learning environments, Sim (1994) explored meal management students' self-perceived foodservice management competencies and found that there was a high correlation between students' actual knowledge and their self-perceived competencies. Niu (2010) similarly found that foodservice employees with high self-efficacy were more committed to their foodservice career. However, at the time of this study, there was no known research related to the perceived confidence/self-efficacy of students participating in SORs.

In summary, accredited hospitality and dietetics programs need to meet foodservice and management competencies delineated by their respective accreditors and both program types use SORs as a form of experiential learning to do so. Self-efficacy and its relationship to student's ability to meet specific competencies is also important to consider. While research on SORs currently includes the perspectives of customers and management, there is no research yet on student's perceptions of their SOR experience or their confidence/self-efficacy related to foodservice and management skills. The purpose of this study was to explore and better understand student perceptions of SORs and their confidence/self-efficacy related to foodservice and management skills through an online survey. The research questions and hypotheses are included below:

Research Question: Do students perceive themselves to be confident in their foodservice and management skills?

Hypothesis 1:

Null: Students do not perceive themselves to be confident in their foodservice and management skills.

Alternate: Students will perceive themselves to be confident in their foodservice and management skills.

Research Question: Will students have a positive perception of their overall SOR experience including their interpersonal interactions, the development and use of skills in the SOR and in the future, and the nutrition focus in SORs?

Hypothesis 2:

Null: Students will have a negative perception of their overall SOR experience including their interpersonal interactions, the development and use of skills in the SOR and in the future, and the nutrition focus in SORs

Alternate: Student will have a positive perception of their overall SOR experience including their interpersonal interactions, the development and use of skills in the SOR and in the future, and the nutrition focus in SORs

Research Question: Will there be differences in students' confidence (with foodservice and management skills) and perceptions related to their SOR experience based on demographic factors (SOR participation status [current, future, or past participation], hours of non-SOR foodservice experience, and other basic demographic factors [major, age, gender, race, ethnicity, or income]).

Hypothesis 3:

Null: There will be no difference in students' confidence (with foodservice and management skills) and perceptions related to their SOR experience based on demographic factors (SOR participation status [current, future, or past participation], hours of non-SOR foodservice experience, and other basic demographic factors [major, age, gender, race, ethnicity, or income]).

Alternate: There will be differences in students' confidence (with foodservice and management skills) and perceptions related to their SOR experience based on demographic factors (SOR participation status [current, future, or past participation], hours of non-SOR foodservice experience, and other basic demographic factors [major, age, gender, race, ethnicity, or income]).

METHODS

Design and materials

Prior to this study, the research team conducted a thorough review of previous studies related to the use of SORs in hospitality and dietetics education (Clark et al. 2023, Cook et al. 2018, Josiam et al. 2014, Kiser & Partlow, 1999, Matthews et al. 2021, Nies, 1993, Stokes et al. 2018). At that time, there were no known studies that had looked at student perspectives of SORs. Because there was no previous study or measure to adapt for this project, the research team needed to develop and validate a new measure that would be appropriate for assessing student perceptions of their SOR experience. The process used to develop and validate the measure for this study is described below.

The research team first conducted a qualitative study where they interviewed multiple students regarding their perspectives of their SOR experience (Clark et al. 2023). Qualitative data from that study served as the basis for developing the survey instrument that was used for this current study. Three researchers independently read the interview transcripts from the qualitative study and identified three themes. Two research assistants then developed survey questions and lists of foodservice and management skills based on the themes identified in the interview transcripts. The survey questions were then entered and formatted in Qualtrics to build the survey. Next, an expert review was conducted to test

the content validity of the survey. Four experts with foodservice management and/or SOR experience rated each survey question on a scale from 1-10 on appropriateness, importance, and phrasing (Mackison et al., 2010). Any items that averaged less than 8, for both appropriateness and importance, were removed. Some survey items removed were: "The SOR customers were dissatisfied with the menu options," "There was too much information already in class for professors to focus too heavily on the nutritious aspect of menu items," and "The SOR did not prepare me to be a better leader in the future."

Following the expert review, cognitive interviews were conducted with five students, who had participated in a SOR, to assess the survey's face validity. The students were female undergraduate students from three different universities; four were majoring in dietetics and one was majoring in hospitality. Feedback from cognitive interviews indicated the need for only minor editorial changes to some items. These changes were made, and the survey was prepared for distribution. The final survey included 32 likert scale items related to student's confidence (1= "Not confident at all" to 5= "Extremely confident") in foodservice (13 items) and management (19 items) skills and 60 likert scale items related to perceptions of their SOR experience (1= "Strongly disagree" to 5= "Strongly agree"). The 60 items were categorized in the following categories; student interactions (4 items), professor interactions (7 items), leadership experiences (4 items), future implications (3 items), positive and negative experiences (21 items), nutrition (7 items), food production skills (6 items), and SOR management skills (8 items). Students were also asked for demographic information including SOR participation status (current, future, or past participation), university, major, career path, age, gender, race, ethnicity, income, and total hours of non-SOR foodservice experience. One free response question invited students to describe their overall SOR experience. With the use of skip logic, future SOR participants were only presented the Likert scale items related to their confidence in foodservice and management skills and demographic questions. Because they had not yet participated in an SOR they did not answer questions pertaining to their perceptions of their SOR experience.

Participants

Students from hospitality and dietetics programs from across the United States were recruited via email. Any students who had participated, were participating, or were planning to participate in a SOR were eligible to complete the survey. However, due to the low number of students who were planning to participate in the future (n=6), after data collection they were removed from all data analysis.

Procedure

First, contact information for program directors was gathered from the following sources: the DPD director list from the ACEND website and a list of hospitality program directors from the International Council on Hotel, Restaurant, and Institutional Education (ICHRIE) website. An email was sent to the directors on these lists and also to a listserv from the Food Service Management Education Council (FSMEC). Directors were asked to forward the email to the relevant SOR manager. SOR managers were asked to complete a short survey regarding the characteristics of their SOR and to distribute the student survey to students in their program via email. As an incentive to participate, SOR managers were offered a \$50 Amazon gift card and students were given the opportunity to enter a drawing for one of 50 \$25 Amazon gift cards. Approval was obtained from the [blinded for review] Institutional Review Board prior to recruiting participants.

Analytic Strategy

The Statistical Package for the Social Sciences (SPSS) Version 28 was used to analyze the data collected from this survey. Basic frequencies were calculated for demographic factors. Means and standard deviations were calculated for each Likert scale question. Lehr's rule of thumb was used to conduct a

power analysis. Using an estimated population variance of 1.5, N=24 was found to be the minimum response necessary for each comparison group in a two-way Independent Samples T-test. The power analysis for ANOVA calculated with SPSS showed a minimum group size of 12 given a conservatively estimated pooled population standard deviation of 1.5 and group means of 2, 3, and 4. These power analyses showed that ANOVA and Independent Samples T-tests would not be appropriate for most demographic factors. For comparison purposes, hours of pre-SOR foodservice experience were grouped into “more than 500 hours” and “500 hours or less.” To adjust for multiple comparisons bias, a p-value of 0.001 was used.

RESULTS

A total of 122 students responded to the survey from 12 different universities across 12 states. Responses with less than 25% of the survey completed (n=10) and those who had not participated in an SOR (n=11) were excluded from the analysis. Of the 101 usable responses, 66 had participated in a SOR and 35 were currently participating in a SOR. Participants were majority female (89.9%) and White (83.1%). Other demographic data are presented in Table 1. Students also indicated their anticipated career path, with the plurality of hospitality students indicating event planning (40.0%), and the plurality of dietetics students indicating clinical nutrition (29.3%), as seen in Table 2.

Testing of hypothesis 1

To test the first null hypothesis (students do not perceive themselves to be confident in their foodservice and management skills), students were asked to rate their confidence (1= not at all confident to 5= extremely confident) in both foodservice and management skills. Results indicated that students had a high level of confidence in both foodservice (mean score range of 3.46 – 4.44) and management skills (mean score range of 3.31 – 4.48) with all scores being above “Moderately Confident.” Current and past SOR students were most confident in their ability to “follow standardized recipes” and “*mise en place* food preparation”, and least confident in recipe conversion and knife skills. In terms of management skills, current and past SOR students were most confident in “teamwork” and “food safety practices,” and least confident in “forecasting,” “recipe development,” and “financial calculations”. Table 3 includes all mean scores for foodservice and management skills by SOR participation (past and current). Based on these results, the first null hypothesis is rejected indicating that students perceived themselves to be confident in their foodservice and management skills.

Testing of hypothesis 2

To test the second null hypothesis stated above (students will have a negative perception of their overall SOR experience...), students were asked to rate their agreement (1=strongly disagree to 5= strongly agree) to several statements regarding their SOR experience. Students agreed that they were able to engage in interactive learning (M=4.56), learn about food production (M=4.46), and gain a greater understanding of the foodservice system (M=4.38). Students disagreed with that their SOR experience was negative (M=1.86). Additionally, students positively rated their interactions with other students and with their instructors. Students strongly agreed that teamwork was critical to their SOR experience (M=4.74) and disagreed that students did not get along with each other (M=2.02). All statements regarding instructor interaction had mean scores higher than neutral with the highest-rated statements showing that students felt their instructors were engaged in the SOR experience (M=4.36) and that they felt comfortable asking their instructors for help (M=4.34).

Table 1: Demographic characteristics of survey respondents (n=101)

	(n) ^a	%
Gender		
Male	8	9.0
Female	80	89.9
Prefer not to say	1	1.1
Age		
18-19	5	5.6
20-21	34	38.2
22-23	31	34.8
24-25	13	14.6
≥26	6	6.7
Race		
White	74	83.1
Black or African American	4	4.5
Asian	5	5.6
Other	6	6.7
Hispanic or Latino Origin		
Not Hispanic or Latino	78	87.6
Hispanic or Latino	6	6.7
Prefer not to answer	5	5.6
Major		
Dietetics	65	73.0
Hospitality	24	27.0
Yearly Income		
< \$5,000	24	27.6
\$5,000 - \$10,000	32	36.8
\$10,000 - \$20,000	19	21.8
\$20,000 - \$30,000	5	5.7
> \$30,000	7	8.0
Pre-Student-Operated Restaurant Hours of Foodservice Experience		
0	6	6.8
Less than 100	13	14.8
101-200	11	12.5
201-300	13	14.8
301-400	11	12.5
401-500	5	5.7
More than 500	29	33.0

^aTotals may not add up to 101 due to missing data

Table 2: Participant's intended career paths based on their academic major

Academic Major	Intended Career Path	n ^a	%
Hospitality (n=24)	Restaurant Management	7	29.2
	Lodging/Hotels	4	16.7
	Event Planning	11	45.8
	Guest Relations	1	4.2
	Other	1	4.2
Dietetics (N=65)	Clinical Nutrition (acute, ambulatory, or long-term care)	19	29.2
	Community and Public Health	14	21.5
	Management, Executive Leadership, and foodservice management	11	17.0
	Consultation, Business & Industry, Entrepreneur	8	12.3
	Education	2	3.1
	Research	1	1.5
	Other	10	15.4

^aTotals do not add up to 101 due to missing data

Regarding the use and development of skills within the SOR, students' mean scores showed general agreement. Students agreed that they learned leadership skills from their SOR experience (M=4.31) and disagreed that there was a lack of communication between the instructors and students (M=2.07). They also learned how to operate commercial kitchen equipment (M=4.32), how to standardize recipes (M=4.09), and cooking skills (M=3.82). Students felt that they became more competent to work in other food production facilities (M=4.34) and that they improved their teamwork (M=4.34) and people skills (M=4.24) after working in the SOR. Students agreed that the skills learned in the SOR would help in their future career (M=4.18) and help them in their everyday life (M=4.03).

When asked about the level of focus on nutrition in the SOR, students agreed that incorporating more nutrition information into the SOR curriculum would be beneficial (M=3.85). They disagreed that the primary focus was on the taste of food not appearance (M=2.07) and that the instructors focused more on nutrition education than foodservice education (M=1.84). Based on these results, the second null hypothesis is rejected indicating that students had a positive perception of their overall SOR experience.

Testing of hypothesis 3

To test the third null hypothesis stated above (there will be no difference in students' perceived confidence with foodservice and management skills and perceptions related to their SOR experience based on demographic factors) comparison of means were calculated. First, Independent Samples T-test and One Way Anova were used to compare mean scores for student's perceived confidence in both foodservice and management skills. Comparisons were calculated based on SOR participation (current and past), age, income, and major (hospitality or dietetics). There were no statistically significant differences based on SOR participation, age, or income. However, there was one statistically significant difference based on academic major (hospitality or dietetics). Hospitality students (M=3.63, SD=.970) rated their confidence in recording of temperatures lower than dietetics students (M=4.38, SD=.744, $t(87)=3.93$, $p<0.001$).

Independent Samples T-test and One Way Anova were also used to compare mean scores for student's perceptions related to their SOR experience. Comparisons were calculated for each of the Likert scale items based on SOR participation (current and past), age, income, major (hospitality or dietetics) and hours of non-SOR foodservice experience. Again, there were no statistically significant differences for any of the items based on SOR participation (current and past), age, income, or non-SOR hours of foodservice experience. However, there was one statistically significant difference based on student's major. Dietetic students ($M=3.71$, $SD=1.01$) had higher expectations that the SOR would be nutrition focused than hospitality students ($M=2.78$, $SD=.951$, $t(86)=3.83$, $p<0.001$).

While not statistically significant, there was a trend towards differences by non-SOR hours of foodservice experience. Students with more than 500 hours of non-SOR foodservice experience tended to have higher confidence in service of food ($M=4.38$, $SD=.728$, $t(86)=2.60$, $p=0.011$), recipe conversion ($M=3.79$, $SD=.940$, $t(86)=2.24$, $p=0.028$), forecasting ($M=3.71$, $SD=.937$, $t(85)=2.55$, $p=0.012$), and understanding of the interaction of foodservice systems ($M=4.21$, $SD=.833$, $t(84)=2.36$, $p=0.020$) than students with 500 or less hours of experience. They also tended to agree less to the following statements than those with fewer hours of experience: "I often felt like the students were running the SOR rather than the instructors(s)" ($M=2.86$, $SD=1.13$, $t(86)=-2.94$, $p=0.004$), "The SOR helped me learn more about food production" ($M=4.21$, $SD=.978$, $t(36.8)=-2.33$, $p=0.025$), "Meeting deadlines in the SOR was often overwhelming" ($M=3.52$, $SD=1.271$, $t(86)=-2.67$, $p=0.009$), "I was surprised by the amount of work it took to create a meal" ($M=3.41$, $SD=1.05$, $t(86)=-2.16$, $p=0.034$), and "I did not know how to batch cook before I was trained in the SOR" ($M=3.14$, $SD=1.41$, $t(47.3)=-2.74$, $p=0.009$). Past SOR participants had lower confidence in implementing and promoting allergy procedures ($M=3.58$, $SD=.925$) than current SOR participants ($M=3.81$, $SD=1.05$, $t(69.99)=1.10$, $p=0.277$), and past participants had higher confidence in recording of temperatures ($M=4.38$, $SD=.791$) than current participants ($M=3.74$, $SD=.891$, $t(72.52)=-3.61$, $p=0.001$). Based on these results, the third null hypothesis is also rejected, indicating that there were differences in both student's perceived confidence and their perception of their SOR experience based on a few demographic factors. However, it is noted that the number of statistically significant differences was very few.

DISCUSSION

Overall, students rated their SOR experience highly. Although the respondents indicated a variety of intended career paths (Table 2), students agreed that they learned valuable skills in the SOR and that they used the skills they learned in the SOR in their everyday life. This may show that the management, leadership, and interpersonal skills learned within the experiential learning environment of a SOR can be widely applicable in a variety of life and career settings. This response supports previous studies that show that experiential learning can be used to teach widely applicable skills such as teamwork, communication, and problem-solving (Doyle, 2014; Yeadon-Lee & Hall, 2013). In addition, Ruhanen (2006), found that students who participated in an experiential learning role-play activity rated the assignment highly for "providing skills for future employment."

Given the effectiveness of experiential learning in skill development, it follows that SORs as a form of experiential learning should produce similar results. Our research shows that students had high levels of confidence in the foodservice and management skills that they learned during their SOR experience and agreed that the skills learned would be valuable to them in the future. This idea is supported by previous research (Huang et al. 2020 & Niu, 2010) that has indicated that students with high self-efficacy/confidence typically perform better on related tasks. However, this study also found that participation in the SOR and hours of previous foodservice experience did not significantly affect students' confidence in foodservice and management skills. This lack of significance may partly be

Table 3: Students' confidence in specific foodservice and management skills by SOR participation status

	SOR Participation Status			
	Current (n=35)		Past (n=66)	
	Mean*	SD	Mean*	SD
<i>Foodservice Skills</i>				
Ability to follow standardized recipes	4.41	0.71	4.47	0.75
Avoidance of cross contamination	4.06	0.91	4.22	0.75
Baking techniques	3.81	0.93	4.09	0.82
Cooking techniques	3.78	0.87	4.00	0.86
Food production	3.77	0.92	4.02	0.89
Knife skills	3.69	1.09	3.78	1.01
Mise en place food preparation skills	4.06	0.98	4.26	0.81
Presentation of food	4.06	0.98	4.02	0.83
Recipe conversion	3.66	0.87	3.34	1.07
Recording of temperatures	3.78	0.91	4.38	0.79
Service from the line	4.00	0.92	4.17	0.96
Service of food	4.00	0.76	4.05	0.96
Temperature control	3.87	0.75	4.02	0.81
<i>Management Skills</i>				
Advertising and promotion	3.65	0.92	3.44	1.18
Collaboration	4.23	0.82	4.19	0.74
Financial calculations	3.42	1.03	3.35	1.06
Food safety practices	4.39	0.76	4.39	0.68
Forecasting	3.39	1.09	3.26	1.03
Implementing and promoting allergy procedures	4.00	0.97	3.58	0.93
Interpersonal skills	4.29	0.69	4.28	0.70
Inventory control	3.58	1.09	3.42	1.10
Leadership	4.35	0.80	4.09	0.89
Menu planning	3.65	0.95	3.74	1.08
Organization	4.29	0.82	4.14	0.83
Planning	4.23	0.81	4.07	0.78
Professionalism	4.35	0.71	4.30	0.71
Recipe development	3.48	1.06	3.21	1.32
Scheduling	3.87	1.02	3.75	0.93
Task delegation	4.35	0.71	4.11	0.88
Teamwork	4.52	0.63	4.46	0.66
Time management	4.06	0.76	3.98	0.86
Understanding of the interaction of foodservice systems	3.94	1.00	3.86	0.88

*Scale of 1 to 5 was used as follows: 1= Not Confident at All, 2= Slightly Confident, 3= Moderately Confident, 4= Very Confident, 5= Extremely Confident

explained by the Dunning-Kruger effect, which is the tendency for inexperienced individuals to overestimate their competence (Kruger & Dunning, 1999). Another contributing factor could be that all participants had either already participated or were currently participating in the SOR experience. The lack of significant differences based on previous foodservice experience could also be explained by the fact that only 6.8% of the participants (n=6) had less than 100 hours of previous foodservice experience. Significant previous foodservice experience likely lead to high levels of confidence in foodservice skills.

In addition to practical skills, SORs provide students the opportunity to practice interpersonal or “soft” skills. The relationships that students developed with both instructors and other students within the SOR were rated as a positive aspect of their SOR experience. Teamwork within SORs was valued by the students, and instructors were viewed as an active part of building a safe and comfortable environment for learning. SOR participants were able to get help from fellow students and instructors, showing that SORs allow for the development of mentoring relationships. These relationships are essential for students as mentoring, both formal and informal, has been shown to benefit both the mentor and mentee, resulting in improved academic outcomes; development of critical thinking, organizational, and leadership skills; and improved career advancement (Bynum, 2015; Marshall et al., 202; Schmidt & Faber, 2016).

Of the skills and topics taught within SORs, students felt that nutrition was not a focus, but that they would like more nutrition education in their SOR experience. Customer perspectives on SORs also support incorporating nutrition information in SORs. The majority (86.6%) of respondents to a survey by [blinded for review] on the perspectives of SOR customers reported that the SOR should “probably” or “definitely” serve foods that meet nutritional guidelines. Additionally, “healthy choices” was one of the highest-ranking factors that influenced where SOR customers chose to eat. Alternatively, some consumers may view eating out as an occasional indulgence, and the healthfulness of the food may not be as important (Allman-Farinelli, 2019). This dichotomy between indulgent menu options and the inclusion of healthy choices is discussed in research by Mathews et al. (2021). They interviewed SOR managers who described their nutrition philosophy as one of two opposing views: nutrition as an important factor in running the SOR, or that nutrition was not a focus.

Despite this dichotomy, there is a potential for students and customers alike to benefit from additional focus on nutrition education within SORs. In the United States, consumers spent almost as much of their disposable personal income on food away from home (FAFH) (5.11%) as food at home (FAH) (5.16%) in 2021 (ERS, 2022). With increased intake of FAFH, diet quality tends to be poorer including lower Healthy Eating Index scores for greens and beans, total fruits, whole fruits, and whole grains (Nagao-Sato & Reicks, 2022). Future foodservice managers need to have an understanding of nutrition guidelines to better provide healthful options for those who eat FAFH frequently.

CONCLUSIONS AND APPLICATIONS

Experiential learning in the form of SORs in hospitality and dietetics education has not been well-studied with previous research mainly focused on customer and manager perspectives of SORs. This study, for the first time, gathers student perspectives of their SOR experience. From their responses, it is clear that students have a positive perspective of their SOR experience, they learn important management, foodservice, and leadership skills, and they agree that increased nutrition education may be beneficial to their experience. Hospitality and dietetics programs with SORs should continue utilizing them as an experiential learning tool and those programs without one should consider adopting this model in the future. Although not significant, participants with more than 500 hours of previous foodservice experience tended to have higher levels of confidence and a more positive perception of the overall SOR experience. Programs could consider requiring students to have increased amounts of previous foodservice experience prior to participating in a SOR, though the benefit of this change would need to be weighed against impacts on enrollment in these programs. This research clearly indicates that this kind of immersive experiential learning opportunity enhances student learning and benefits students overall.

Limitations of the Present Study

Some limitations of this study include the low number of participants of male gender or underrepresented races. These groups may have different perspectives on their SOR experience than white, non-Hispanic, or female participants, but there was insufficient power to make these comparisons.

There was also an unequal distribution of participants across universities, with some SOR programs having more respondents to the survey than others. Program level differences in SOR management could also affect students' responses. Due to the lack of program level data, we were not able to control for these differences amongst participants responses. Only six participants who had not yet participated in a SOR completed the initial survey. Unfortunately, based on the power analysis this number was insufficient to include these participants in comparisons based on SOR participation so these data were not reported in this manuscript. With the heterogeneity of SOR programs, this research may not be representative of students from all programs. However, one strength of this study is that it included student perspectives from 12 different universities and states and not simply one individual university/program.

Future Research

Future research in this area could include prospective studies to better determine skill growth in SORs, interventions to improve student perceptions, or surveys that focus on SOR perceptions of students from underrepresented groups. Repeating surveys of this type in the future could also show how student perceptions of SORs change over time. Gathering perspectives of students who have not yet participated in a SOR would give educators an idea of baseline confidence in skills of incoming students which may improve how SORs are utilized as an experiential education tool. Recruiting more students who had not yet participated in an SOR to identify differences in confidence between those who have participated and those who have not would be important. Having baseline data from students who have not yet participated in a SOR would be invaluable for future longitudinal studies that could identify changes in confidence and perceptions as well as the overall effectiveness of SORs as a beneficial experiential learning opportunity. Lastly, comparisons of practicing foodservice managers who participated in a SOR and those who did not may show the impact of SORs on long-term education outcomes.

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Research Manuscript

Ventilated and Unventilated Cooling Methods for Tomato Sauce in Onsite Foodservice Operations

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ABSTRACT

This study investigated whether cooling methods for tomato sauce in a walk-in refrigerator met 2022 FDA Food Code requiring that food be cooled from 135°F (57°C) to 70°F (21°C) within 2 hours and from 135°F (57°C) to 41°F (5°C) within a total of 6 hours. Both covered and uncovered cooling methods were tested, with covered methods taking significantly longer to cool. None of the methods complied with FDA Food Code standards for properly cooling food. Future research should explore cooling liquid foods that are thicker in consistency at shallower depths to improve compliance with FDA Food Code requirements.

Keywords: cooling; schools; foodservice; FDA Food Code

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INTRODUCTION

Food safety is a vital concern in the United States, requiring stringent standards in foodservice operations to safeguard customers and employees from foodborne illnesses (National Restaurant Association Educational Foundation, 2022). Foodborne pathogens cause foodborne illness, resulting in approximately 9.9 million illnesses, 53,300 hospitalizations, and 931 deaths in 2019 (CDC, 2025; Scallan Walter et al., 2025). Norovirus accounted for the highest number of illnesses (~5.5 million), while *Salmonella* caused the most deaths (238). These statistics help inform food safety policies and interventions.

Improper cooling is a significant contributor to foodborne illness outbreaks in institutional settings, such as schools, where large quantities of food are prepared and stored (Brown et al., 2012; FDA, 2023; Hedeem et al., 2022; Hedeem & Smith, 2020; Holst et al., 2025; Igo et al., 2021; Koreen et al., 2024; Lipcsei et al., 2019; Schaffner et al., 2015). According to the CDC's National Outbreak Reporting System (NORS) data from 2014–2022, improper cooling accounted for 17.3% of foodborne outbreaks in the later years, an increase

from earlier periods (Holst et al., 2025). This issue is particularly critical in schools, where foods like chili, taco meat, and rice are commonly prepared and cooled in large volumes (Olds, 2019; Olds et al., 2013).

Cooling is a critical control point (CCP) for many menu items produced in school foodservice operations that directors must prioritize when developing food safety programs (Olds, 2019; Olds et al., 2013). After the lunch shift, staff and managers typically leave, making it difficult to actively monitor cooling processes effectively (Roberts et al., 2013). According to Krishnamurthy and Sneed (2011), 78% of 411 U.S. school foodservice directors cooled food for reheating, primarily using 2-inch stainless steel pans (76%). Other cooling methods included 4-inch pans (39%), 6-inch pans (9%), stockpots (6%), chill sticks (37%), and ice baths (38%), with cooling times increasing as pan depth and food volume increased.

The 2022 U.S. Food and Drug Administration (FDA) Food Code offers consistent, systematic guidelines to ensure food in foodservice and retail settings is safe and accurately represented to consumers (FDA, 2022). It is widely adopted by government agencies tasked with preventing foodborne illnesses, who use it to regulate and inspect foodservice operations in restaurants, schools, and hospitals (National Restaurant Association Educational Foundation, 2022).

The 2022 FDA Food Code, Section 3-501.14, mandates that cooked time/temperature control for safety (TCS) food must be cooled: (1) from 57°C (135°F) to 21°C (70°F) within 2 hours, and (2) from 57°C (135°F) to 5°C (41°F) or below within a total of 6 hours (FDA, 2022). Classified as a “priority item,” this two-stage cooling standard directly reduces hazards linked to foodborne illness by limiting time in the “temperature danger zone” (41°F–135°F), where bacteria like *Clostridium perfringens* can rapidly multiply (FDA, 2022; National Restaurant Association Educational Foundation, 2022). Prolonged cooling times beyond these standards may allow bacteria to reach unsafe levels, increasing the risk of foodborne illness outbreaks due to varying infectious doses of contaminants (FDA, 2012; National Restaurant Association Educational Foundation, 2022).

Section 3-501.15 of the 2022 FDA Food Code specifies cooling methods tailored to food types, including: (a) portioning food into shallow pans, (b) dividing food into smaller portions, (c) using rapid-cooling equipment like blast chillers, (d) placing food containers in ice water baths with stirring, (e) using containers that facilitate heat transfer, (f) incorporating ice into food preparation, and (g) employing other effective methods, such as placing uncovered food at 2-inch depths in a walk-in freezer (FDA, 2022; Roberts et al., 2013). The code recommends arranging food containers in cooling or cold-holding equipment to maximize heat transfer through container walls. During cooling, food should be loosely covered or uncovered to enhance surface heat transfer, provided it is protected from overhead contamination (FDA, 2022).

Multiple studies have investigated challenges in meeting FDA Food Code cooling standards for large quantities of food in foodservice operations (Beardall et al., 2019a, 2019b; Brown et al., 2012; Krishnamurthy & Sneed, 2011; Olds, 2019; Olds et al., 2013; Olds & Sneed, 2005; Roberts et al., 2013; Schaffner et al., 2015; Watkins et al., 2016). Schaffner et al. (2015) found that unventilated (covered) food took almost twice as long to cool compared to ventilated (uncovered) food. Brown et al. (2012) observed that 34.3% of 466 walk-in refrigerators (160 units) contained unventilated cooling food, despite FDA Food

Code recommendations for ventilation during cooling (FDA, 2022). These findings highlight that unventilated cooling is a common and risky practice in foodservice settings.

This study aimed to evaluate whether common cooling practices in onsite foodservice operations complied with 2022 FDA Food Code standards. No prior research had compared ventilated versus unventilated cooling of tomato sauce in a walk-in refrigerator using various foodservice storage containers, including the use of a 5 gallon high-density polyethylene bucket. The study sought to provide insights into preventing foodborne illness outbreaks caused by improper cooling methods. Its primary objectives were to: (a) compare time and temperature differences between ventilated and unventilated cooling methods for tomato sauce in a walk-in refrigerator, and (b) identify the most effective cooling method(s) from the ventilated and unventilated methods tested.

METHODS

Sample Selection and Preparation

This study's methodology was closely adapted from a former study by Olds (2019), which used a similar research design to study methods used to cool chili prepared in a university residence dining center kitchen. Tomato sauce was prepared using a standardized recipe (Tomato Sauce USDA Recipe for Schools) from the USDA Standardized Recipe Project, sourced from the Institute of Child Nutrition website (Institute of Child Nutrition, 2019). Tomato sauce is a commonly prepared and cooled item in the U.S. National School Lunch Program (Krishnamurthy & Sneed, 2011; Olds & Sneed, 2005; Roberts et al., 2013).

Ingredients for the tomato sauce recipe were obtained from local retail food suppliers. The sauce was prepared in a university residence dining center kitchen at Bradley University (Peoria, Illinois), using standard foodservice equipment. The principal investigator had exclusive access to the facilities during summer recess, with no other food production or service activities occurring during data collection. The sauce was cooked on commercial induction burners in 20-quart stainless steel stockpots, heated to $\geq 165^{\circ}\text{F}$, and then transferred into various foodservice storage containers at different depths and volumes for testing. Containers included stainless steel pans, all 12 inches wide, with lengths of 10 or 20 inches and heights of 2½ or 4 inches: specifically, 12 × 10 × 2½-inch pans filled with tomato sauce to 2-inch depths, 12 × 20 × 2½-inch pans filled with tomato sauce to 2-inch depths, 12 × 10 × 4-inch pans filled with tomato sauce to 3-inch depths, and 12 × 20 × 4-inch pans filled with tomato sauce to 3-inch depths. Additional containers were 20-quart aluminum stockpots (12-inch diameter, 10½-inch height) filled with 3 gallons of tomato sauce and 5 gallon high-density polyethylene buckets (12-inch diameter, 13-inch height) filled with 5 gallons of tomato sauce (see Table 1).

Comark RF512 Wireless Temperature Transmitters (Comark USA, Beaverton, OR) were paired with Comark RFAX100D thermistors (Comark USA, Beaverton, OR), which were placed in the geometric center of the tomato sauce—the hottest area of the containers—to measure temperature during cooling, as specified by the 2022 FDA Food Code for monitoring critical limits (FDA, 2022). The transmitters recorded time and temperature data throughout the cooling process, and a Comark RF500 temperature

monitoring system (Comark USA, Beaverton, OR) was used to download and compile the data from the transmitters.

Cooling Procedures

All cooling procedures were conducted in a commercial walk-in refrigerator located in the university residence dining center kitchen at Bradley University (Peoria, Illinois). A Comark RF512 Wireless Temperature Transmitter monitored the refrigerator's ambient air temperature, maintained at an average of 37.7°F (SD = 1.26°F). The refrigerator was completely empty (0% load) before the foodservice storage containers were placed inside for testing, with no other items present during the cooling of covered and uncovered tomato sauce containers. The containers were positioned equidistantly on standard wire-rack shelving to ensure optimal air circulation around all sides. The refrigerator door remained closed and locked throughout the cooling process until all tomato sauce containers reached 41°F.

Previous research has shown that covered food products take longer to cool than uncovered ones (Brown et al., 2012; Institute for Food Safety and Health, 2011; Olds, 2019; Olds et al., 2006; Schaffner et al., 2015). This study built on methodologies from Olds (2019), Olds & Sneed (2005), and Roberts et al. (2013) to investigate cooling tomato sauce using two methods: (a) ventilated (uncovered) containers and (b) unventilated containers (tightly covered with plastic foodservice film or aluminum foil). Hot tomato sauce (>165°F) was placed in selected foodservice storage containers, either covered (with plastic film or aluminum foil) or left uncovered. Covered and uncovered containers were cooled concurrently in a commercial walk-in refrigerator. The study tested six container sizes, each with two ventilation conditions (covered or uncovered), resulting in 12 cooling methods (CM1–CM12). Each of the six container sizes was tested exclusively, without any different container sizes or other items in the walk-in refrigerator during cooling. Three replications were performed for each cooling method, with equal numbers of covered (unventilated) and uncovered (ventilated) containers of the same size cooled concurrently in the walk-in refrigerator until all containers reached 41°F.

The study designated odd-numbered cooling methods (CM1, CM3, CM5, CM7, CM9, CM11) for covered containers and even-numbered methods (CM2, CM4, CM6, CM8, CM10, CM12) for uncovered containers. Covered and uncovered cooling methods tested concurrently included CM1 & CM2, CM3 & CM4, CM5 & CM6, CM7 & CM8, CM9 & CM10, and CM11 & CM12 (see Table 1). For covered methods CM1, CM3, CM5, and CM7, stainless steel foodservice pans were sealed tightly with plastic foodservice film. For covered methods CM9 and CM11, 20-quart aluminum stockpots and 5 gallon high-density polyethylene buckets were covered with aluminum foil, secured with large rubber bands, as the equipment used to position thermistors in the geometric center of the tomato sauce prevented the use of standard lids. Aluminum foil, secured with large rubber bands, was chosen as a suitable substitute for the stockpot and bucket lids to ensure consistency in comparing time and temperature data across these containers. For uncovered methods (CM2, CM4, CM6, CM8, CM10, CM12), no plastic film or aluminum foil was used (see Table 1).

For each replication, Comark RFAX100D thermistors, connected to Comark RF512 Wireless Temperature Transmitters, measured the temperature at the geometric center of the tomato sauce in the containers. Temperature data were recorded at 1-minute intervals by the transmitters during testing. After each

replication, the transmitters were removed from the walk-in refrigerator, disconnected from the thermistors, and transferred from the dining center kitchen to a computer laboratory for data analysis.

Data Analysis

Time and temperature data from the Comark RF512 Wireless Temperature Transmitters were downloaded to the Comark RF500A wireless monitoring gateway. The data were analyzed using Microsoft Excel 2019 (Microsoft Corporation, Redmond, WA) and SPSS Statistics version 26 (IBM Corporation, Armonk, NY). Means and standard deviations for cooling times and temperatures (from 135°F to 70°F and from 135°F to 41°F) were calculated for each cooling method to compare with FDA Food Code standards. Representative mean time and temperature cooling curves were generated using Microsoft Excel 2019. A two-factor (2x2) repeated measures Analysis of Variance (ANOVA) was performed to provide additional insights into the time and temperature data.

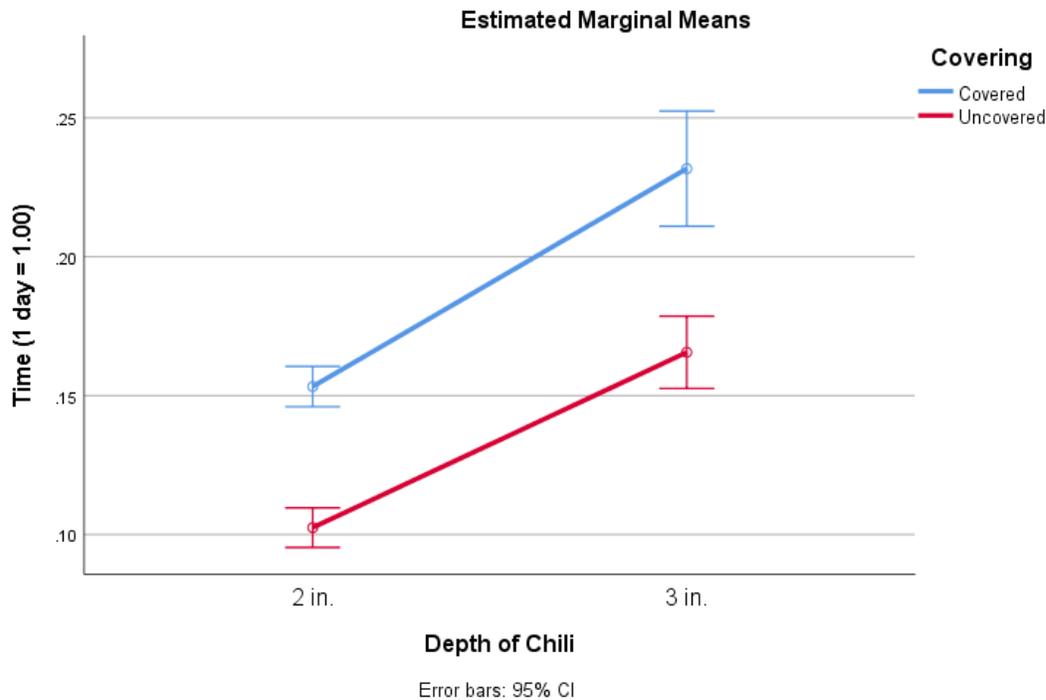
RESULTS AND DISCUSSION

This section presents the results of the cooling methods evaluated. The primary goals of the study were to compare time and temperature differences between ventilated and unventilated cooling methods and to assess which methods met or failed to meet 2022 FDA Food Code standards. Compliance with these standards is required when cooling cooked food.

Table 2 presents the mean cooling times in hours and minutes for all cooling methods tested. Two independent variables were analyzed – covering method (covered or uncovered) and tomato sauce depth/amount (2-inch or 3-inch depths for pans; 3 gallon or 5 gallon amounts for stockpots/buckets). Cooling times for the temperature ranges of 135°F to 70°F and 135°F to 41°F were recorded. Comparisons of covered versus uncovered cooling times were calculated for cooling methods with identical container dimensions (CM1 & CM2, CM3 & CM4, CM5 & CM6, CM7 & CM8, CM9 & CM10, CM11 & CM12). None of the 12 cooling methods (covered or uncovered) met the 2022 FDA Food Code standards in the walk-in refrigerator, as no method cooled tomato sauce from 135°F to 70°F within 2 hours or from 135°F to 41°F within a total of 6 hours.

A two-factor (2x2) repeated measures Analysis of Variance (ANOVA) was conducted to further analyze time and temperature data. Tables 3-4 present the main effects and interaction effects of compared cooling methods. Pairwise t-tests and estimated marginal means (EMM) plots (see Figures 1-4) were used to evaluate significant interaction effects between the covering methods and the depths/amounts of tomato sauce. Estimated marginal mean cooling times are reported in days (1.000 = one day). The significance threshold for all statistical tests was set at $p \leq .05$. For analysis of tomato sauce cooled from 135 °F to 70 °F see Table 3.

Figure 1 – Interaction profile plot for Cooling Method 1 (covered, 2 in.) and Cooling Method 2 (uncovered, 2 in.); compared to Cooling Method 5 (covered, 3 in.) and Cooling Method 6 (uncovered, 3 in.) for tomato sauce cooled from 135 °F to 70 °F.



Stainless steel foodservice pans: 12 in. widths x 10 in. lengths.

For cooling methods CM1 & CM2, compared with CM5 & CM6, there was a significant main effect of covering method on cooling time ($F(1, 8) = 875.62, p < .001$). Covered containers ($EMM = 0.192, SE = 0.006$) took longer to cool than uncovered containers ($EMM = 0.134, SE = 0.004$). In addition, there was a significant main effect of the depth of tomato sauce on cooling time ($F(1, 8) = 252.65, p < .001$). Containers at 3 in. depths ($EMM = 0.199, SE = 0.007$) took longer to cool than containers at 2 in. depths ($EMM = 0.128, SE = 0.003$).

A significant interaction effect was observed between covering method and depth of tomato sauce ($F(1, 8) = 13.36, p = .006$) (see Figure 1). Related pairwise t-tests for covering method revealed a significant difference between covered ($M = 0.15, SD = 0.01$) and uncovered ($M = 0.10, SD = 0.01$) cooling methods for 2 in. depths of tomato sauce ($t(8) = 36.13, p < .001$), and a significant difference in covering method between covered ($M = 0.23, SD = 0.03$) and uncovered ($M = 0.17, SD = 0.02$) cooling methods for 3 in. depths of tomato sauce ($t(8) = 17.28, p < .001$). Related pairwise t-tests for depth of tomato sauce revealed a significant difference between 2 in. depths of tomato sauce ($M = 0.15, SD = 0.01$) and 3 in. depths of tomato sauce ($M = 0.23, SD = 0.03$) for covered cooling methods ($t(8) = -12.36, p < .001$), and a significant difference between 2 in. depths of tomato sauce ($M = 0.10, SD = 0.01$) and 3 in. depths of tomato sauce ($M = 0.17, SD = 0.02$) for uncovered cooling methods ($t(8) = -22.07, p < .001$).

Stainless steel foodservice pans: 12 in. widths x 20 in. lengths.

For cooling methods CM3 & CM4, compared with CM7 & CM8, there was a significant main effect of covering method on cooling time ($F(1, 8) = 370.80, p < .001$). Covered containers ($EMM = 0.209, SE = 0.005$) took longer to cool than uncovered containers ($EMM = 0.147, SE = 0.002$). In addition, there was a significant main effect of the depth of tomato sauce on cooling time ($F(1, 8) = 2324.38, p < .001$). Containers at 3 in. depths ($EMM = 0.213, SE = 0.004$) took longer to cool than containers at 2 in. depths ($EMM = 0.143, SE = 0.003$). No interaction effect was observed between covering method and depth of tomato sauce ($F(1, 8) = 1.93, p = .203$).

Aluminum stockpots and high-density polyethylene buckets: 12 in. diameters.

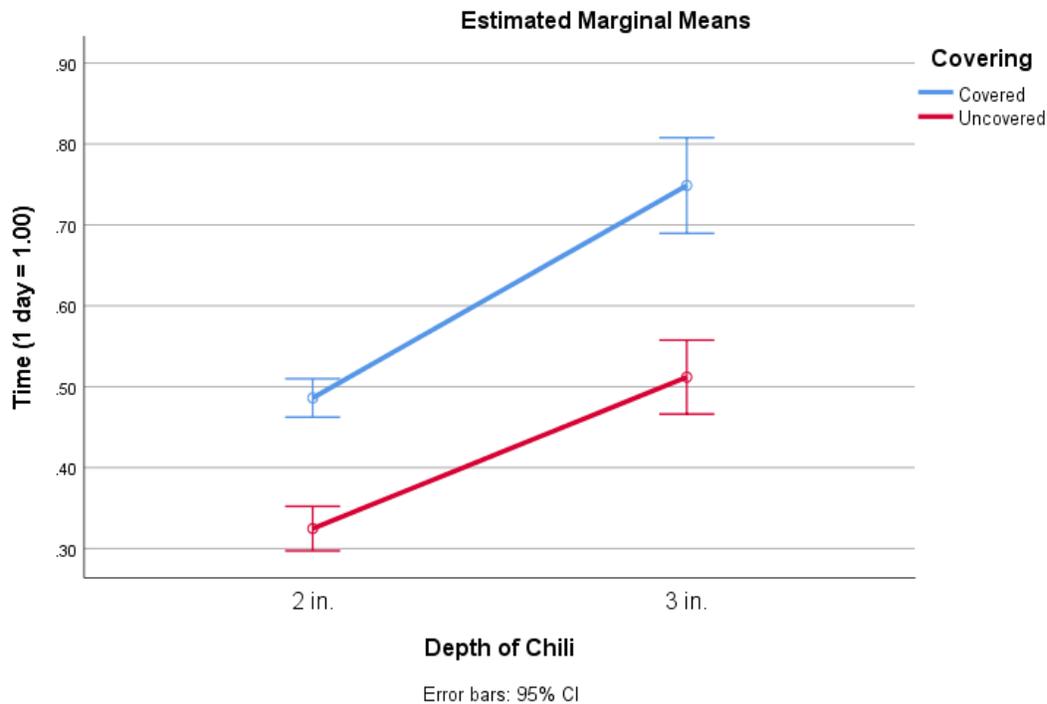
For cooling methods CM9 & CM10, compared with CM11 & CM12, there was a significant main effect of covering method on cooling time ($F(1, 2) = 416.93, p = .002$). Covered containers ($EMM = 0.399, SE = 0.008$) took longer to cool than uncovered containers ($EMM = 0.332, SE = 0.005$). In addition, there was a significant main effect of the amount of tomato sauce on cooling time ($F(1, 2) = 1323.98, p = .001$). Containers at 5 gallon amounts ($EMM = 0.453, SE = 0.006$) took longer to cool than containers at 3 gallon amounts ($EMM = 0.278, SE = 0.008$). No interaction effect was observed between covering method and amount of tomato sauce ($F(1, 2) = 2.276, p = .270$). For analysis of tomato sauce cooled from 135 °F to 41 °F see Table 4.

Stainless steel foodservice pans: 12 in. widths x 10 in. lengths.

For cooling methods CM1 & CM2, compared with CM5 & CM6, there was a significant main effect of covering method on cooling time ($F(1, 8) = 3811.51, p < .001$). Covered containers ($EMM = 0.617, SE = 0.018$) took longer to cool than uncovered containers ($EMM = 0.418, SE = 0.016$). In addition, there was a significant main effect of the depth of tomato sauce on cooling time ($F(1, 8) = 347.49, p < .001$). Containers at 3 in. depths ($EMM = 0.630, SE = 0.023$) took longer to cool than containers at 2 in. depths ($EMM = 0.405, SE = 0.011$).

A significant interaction effect was observed between covering method and depth of tomato sauce ($F(1, 8) = 81.87, p < .001$) (see Figure 2). Related pairwise t-tests for covering method revealed a significant difference between covered ($M = 0.49, SD = 0.03$) and uncovered ($M = 0.32, SD = 0.03$) cooling methods for 2 in. depths of tomato sauce ($t(8) = 59.33, p < .001$), and a significant difference in covering method between covered ($M = 0.75, SD = 0.08$) and uncovered ($M = 0.51, SD = 0.06$) cooling methods for 3 in. depths of tomato sauce ($t(8) = 34.17, p < .001$). Related pairwise t-tests for depth of tomato sauce revealed a significant difference between 2 in. depths of tomato sauce ($M = 0.49, SD = 0.03$) and 3 in. depths of tomato sauce ($M = 0.75, SD = 0.08$) for covered cooling methods ($t(8) = -16.72, p < .001$), and a significant difference between 2 in. depths of tomato sauce ($M = 0.32, SD = 0.04$) and 3 in. depths of tomato sauce ($M = 0.51, SD = 0.06$) for uncovered cooling methods ($t(8) = -21.06, p < .001$).

Figure 2 – Interaction profile plot for Cooling Method 1 (covered, 2 in.) and Cooling Method 2 (uncovered, 2 in.); compared to Cooling Method 5 (covered, 3 in.) and Cooling Method 6 (uncovered, 3 in.) for tomato sauce cooled from 135 °F to 41 °F.

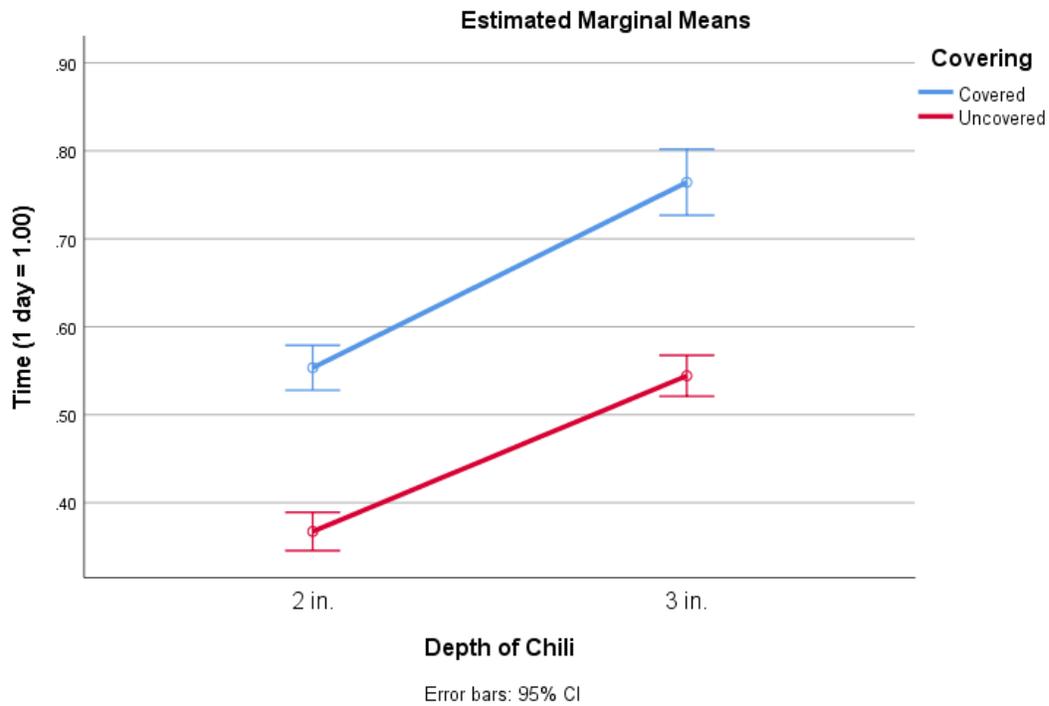


Stainless steel foodservice pans: 12 in. widths x 20 in. lengths.

For cooling methods CM3 & CM4, compared with CM7 & CM8, there was a significant main effect of covering method on cooling time ($F(1, 8) = 949.33, p < .001$). Covered containers ($EMM = 0.659, SE = 0.013$) took longer to cool than uncovered containers ($EMM = 0.456, SE = 0.009$). In addition, there was a significant main effect of the depth of tomato sauce on cooling time ($F(1, 8) = 1156.00, p < .001$). Containers at 3 in. depths ($EMM = 0.654, SE = 0.013$) took longer to cool than containers at 2 in. depths ($EMM = 0.460, SE = 0.010$).

A significant interaction effect was observed between covering method and depth of tomato sauce ($F(1, 8) = 14.40, p = .005$) (see Figure 3). Related pairwise t-tests for covering method revealed a significant difference between covered ($M = 0.55, SD = 0.03$) and uncovered ($M = 0.37, SD = 0.03$) cooling methods for 2 in. depths of tomato sauce ($t(8) = 32.19, p < .001$), and a significant difference in covering method between covered ($M = 0.76, SD = 0.05$) and uncovered ($M = 0.54, SD = 0.03$) cooling methods for 3 in. depths of tomato sauce ($t(8) = 22.78, p < .001$). Related pairwise t-tests for depth of tomato sauce revealed a significant difference between 2 in. depths of tomato sauce ($M = 0.55, SD = 0.03$) and 3 in. depths of tomato sauce ($M = 0.76, SD = 0.05$) for covered cooling methods ($t(8) = -24.17, p < .001$), and a significant difference between 2 in. depths of tomato sauce ($M = 0.36, SD = 0.03$) and 3 in. depths of tomato sauce ($M = 0.54, SD = 0.03$) for uncovered cooling methods ($t(8) = -32.95, p < .001$).

Figure 3 – Interaction profile plot for Cooling Method 3 (covered, 2 in.) and Cooling Method 4 (uncovered, 2 in.); compared to Cooling Method 7 (covered, 3 in.) and Cooling Method 8 (uncovered, 3 in.) for tomato sauce cooled from 135 °F to 41 °F.

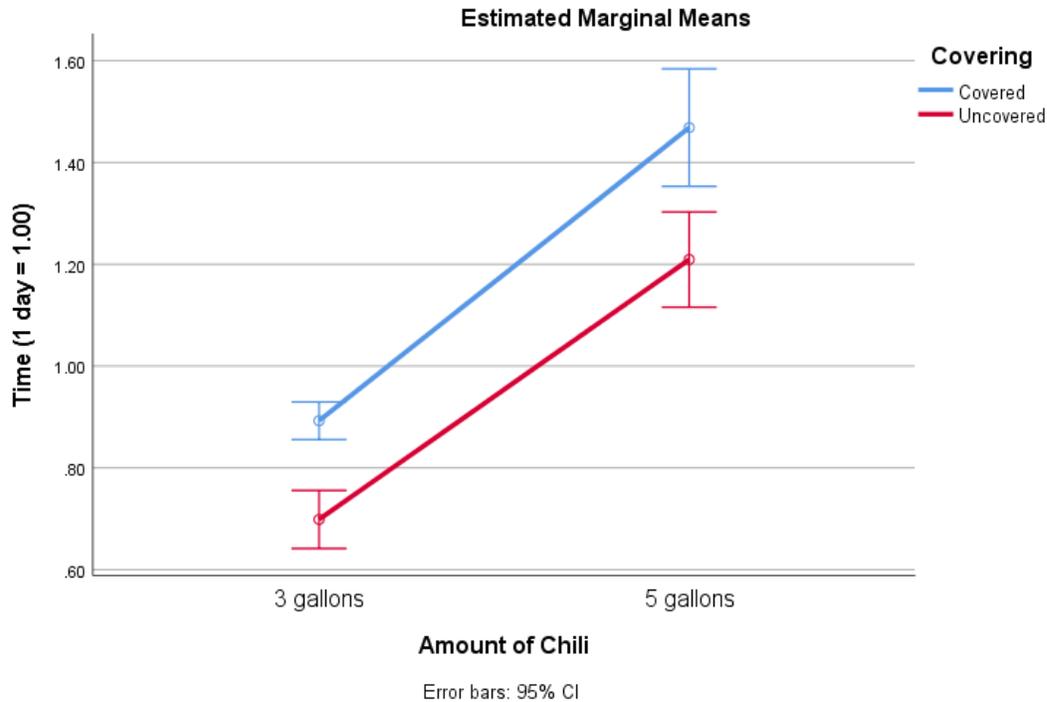


Aluminum stockpots and high-density polyethylene buckets: 12 in. diameters.

For cooling methods CM9 & CM10, compared with CM11 & CM12, there was a significant main effect of covering method on cooling time ($F(1, 2) = 981.26, p = .001$). Covered containers ($EMM = 1.181, SE = 0.018$) took longer to cool than uncovered containers ($EMM = 0.954, SE = 0.017$). In addition, there was a significant main effect of the amount of tomato sauce on cooling time ($F(1, 2) = 1619.05, p = .001$). Containers at 5 gallon amounts ($EMM = 1.339, SE = 0.024$) took longer to cool than containers at 3 gallon amounts ($EMM = 0.796, SE = 0.011$).

A significant interaction effect was observed between covering method and amount of tomato sauce ($F(1, 2) = 28.66, p = .033$) (see Figure 4). Related pairwise t-tests for covering method revealed a significant difference between covered ($M = 0.89, SD = 0.01$) and uncovered ($M = 0.70, SD = 0.02$) cooling methods for 3 gallon amounts of tomato sauce ($t(2) = 26.66, p = .001$), and a significant difference in covering method between covered ($M = 1.47, SD = 0.05$) and uncovered ($M = 1.21, SD = 0.04$) cooling methods for 5 gallon amounts of tomato sauce ($t(2) = 23.09, p = .002$). Related pairwise t-tests for amount of tomato sauce revealed a significant difference between 3 gallon amounts of tomato sauce ($M = 0.89, SD = 0.01$) and 5 gallon amounts of tomato sauce ($M = 1.47, SD = 0.05$) for covered cooling methods ($t(2) = -30.55, p = .001$), and a significant difference between 3 gallon amounts of tomato sauce ($M = 0.70, SD = 0.02$) and 5 gallon amounts of tomato sauce ($M = 1.21, SD = 0.04$) for uncovered cooling methods ($t(2) = -55.84, p < .001$).

Figure 4 – Interaction profile plot for Cooling Method 9 (covered, 3 gallons) & Cooling Method 10 (uncovered, 3 gallons); compared to Cooling Method 11 (covered, 5 gallons) & Cooling Method 12 (uncovered, 5 gallons) for tomato sauce cooled from 135 °F to 41 °F.



Summary of results.

Although the FDA's recommendations to cool food uncovered and reduce food depths/volumes improved cooling efficiency, none of the methods tested in this study met the 2022 FDA Food Code standards. No cooling method achieved the required cooling of tomato sauce from 135°F (57°C) to 70°F (21°C) within 2 hours or from 135°F (57°C) to 41°F (5°C) within a total of 6 hours. Unventilated (covered) cooling methods took significantly longer to cool than ventilated (uncovered) methods across all tested conditions ($p < .05$). Although these findings were significant, they did not replicate the results of a former study by Schaffner et al. (2015), which found that unventilated (covered) food took almost twice as long to cool compared to ventilated (uncovered) food.

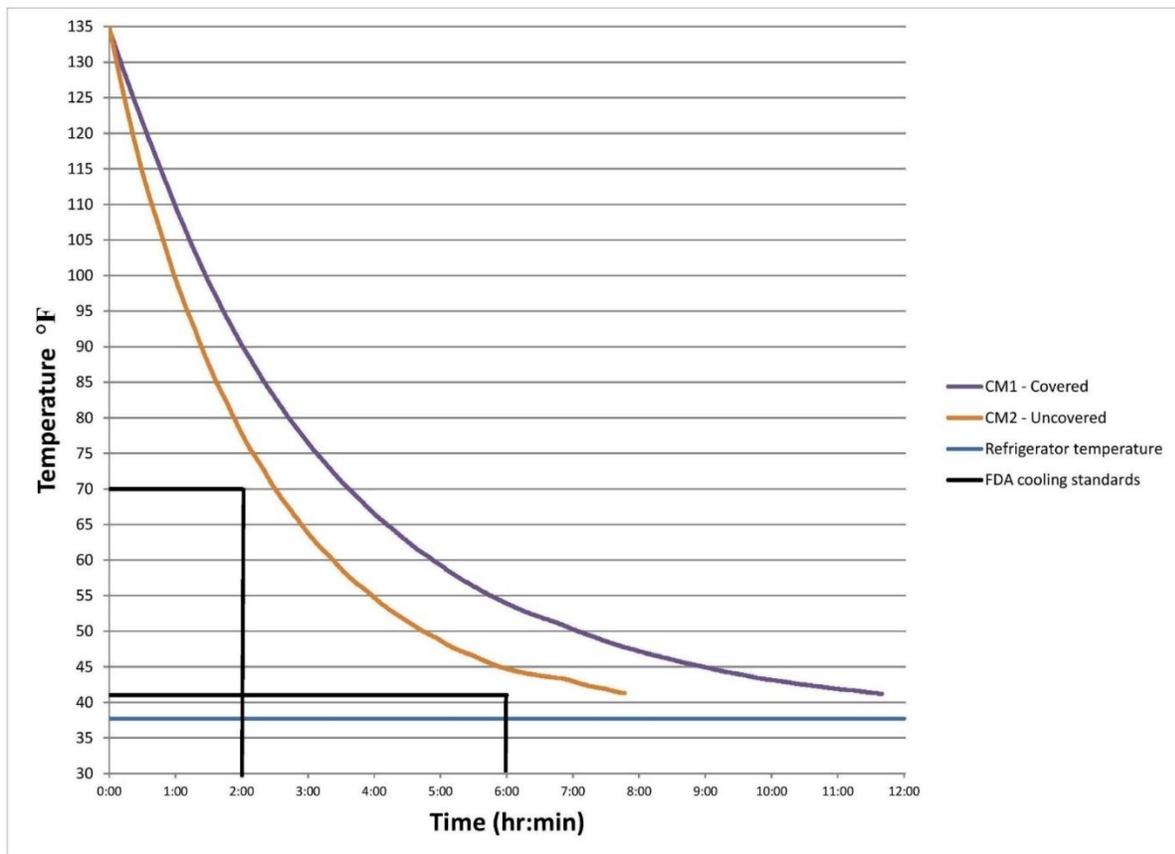
This study's results mirrored results from a former study by Olds (2019), which used a similar methodology to evaluate cooling methods for chili prepared in a university residence dining center kitchen.

In contrast, the slowest cooling method was the covered 5 gallon high-density polyethylene bucket with a 5 gallon amount of tomato sauce, averaging 35 hours and 14 minutes ($SD = 1$ hour 6 minutes). This method did not meet 2022 FDA Food Code standards, is clearly an unacceptable cooling method, and should not be used in any foodservice operation (see Figures 7 & 8).

Figure 5 – Covered and Uncovered 12 × 10-inch stainless steel foodservice pans with a 2 in. depth of tomato sauce.



Figure 6. Cooling Curves for Cooling Method 1 (covered) and Cooling Method 2 (uncovered); both utilizing a 12 in. x 10 in. x 2½ in. foodservice pan with a 2 in. depth of tomato sauce and cooled in a walk-in refrigerator from 135 °F to 41 °F.



ice pan with a 2-inch tomato sauce depth, averaging 7 hours and 47 minutes ($SD = 51$ minutes). Although this was the fastest cooling method, it still did not meet 2022 FDA Food Code standards (see Figures 5 & 6).

Figure 7. Uncovered and Covered 5 gallon high-density polyethylene buckets with 5 gallons of tomato sauce.



The 2022 FDA Food Code recommends cooling methods such as portioning food into shallow pans and cooling food uncovered. This study confirmed that uncovered tomato sauce at 3-inch depths took longer to cool than at 2-inch depths. Of all methods tested, cooling tomato sauce uncovered at 2-inch depths (methods CM2 and CM4) came the closest to meeting FDA standards, as shown in Table 2. A proposal at the 2023 Biennial Meeting of the Conference for Food Protection suggested amending the FDA Food Code to allow cooling foods uncovered at depths of 2 inches or less in refrigeration without mandatory time and temperature monitoring (Hedeem & Shelton, 2023). Furthermore, a study by Koreen et al. (2024) stated that there was minimal pathogen growth risk for food cooled at food depths of 2 inches or less.

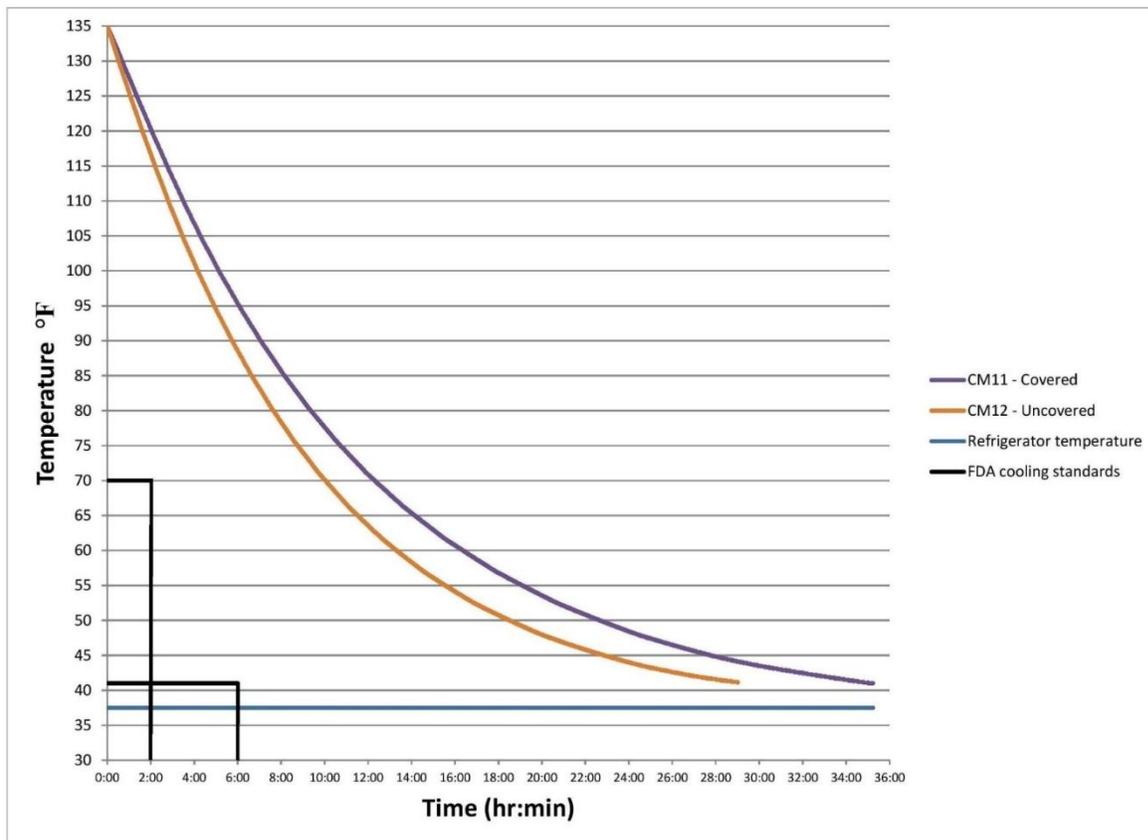
This study has several limitations. First, since only tomato sauce was tested, the findings may not apply to other high-viscosity sauces. Additionally, the experiment took place in a highly controlled setting: the refrigerator contained no other items during cooling, and its door stayed closed and locked the entire time—conditions that differ from typical foodservice operations where doors are frequently opened.

CONCLUSIONS AND APPLICATIONS

This study evaluated whether common cooling practices in onsite foodservice operations aligned with the 2022 FDA Food Code cooling standards. This study's results mirrored results from a former study by Olds (2019), which used a similar methodology to evaluate cooling methods for chili prepared in a university residence dining center kitchen. Both the current study and the former study by Olds (2019) came to the following conclusions:

1. No cooling method cooled tomato sauce from 135°F to 70°F within 2 hours or from 135°F to 41°F within a total of 6 hours.
2. Unventilated (covered) cooling methods took significantly longer to cool than ventilated (uncovered) methods across all tested conditions ($p < .05$ for the current study, $p < .05$ for the 2019 study by Olds).

Figure 8. Cooling Curves for Cooling Method 11 (covered) and Cooling Method 12 (uncovered); both utilizing a 12 in. diameter x 13 in. HDPE bucket with 5 gallons of tomato sauce and cooled in a walk-in refrigerator from 135 °F to 41 °F.



3. For containers with identical widths and lengths, cooling methods with 3-inch tomato sauce depths took significantly longer to cool than those with 2-inch depths across all tested conditions ($p < .001$ for the current study, $p < .005$ for the 2019 study by Olds).

4. For containers with identical diameters, cooling methods with 5 gallon tomato sauce amounts took significantly longer to cool than those with 3 gallon amounts across all tested conditions ($p < .05$ for the current study, $p < .005$ for the 2019 study by Olds).

5. None of the cooling methods tested met 2022 FDA Food Code cooling requirements. Non-compliance with FDA Food Code cooling standards increases the risk of foodborne pathogens multiplying to unsafe levels.

6. Future research should further evaluate FDA-recommended cooling methods and identify implementable methods that comply with FDA requirements. For example, a future study could investigate whether cooling tomato sauce uncovered at depths of less than 2 inches in a walk-in refrigerator would comply with the 2022 FDA Food Code cooling standards.

This study's findings can help educate foodservice professionals on the safety risks of cooling potentially hazardous foods, potentially reducing dangerous practices and preventing foodborne illness outbreaks

from improper cooling. Proper food cooling is challenging and poses safety risks, particularly for large volumes of food without prior portioning. While reducing food volume accelerates cooling, space constraints in foodservice refrigerators may make it impractical to achieve compliance solely this way. This study tested cooling methods commonly used in onsite foodservice operations. The tested methods represented a "best-case" scenario for cooling tomato sauce and excluded real-world variables that could have extended cooling times, such as frequent refrigerator door openings or a full load of other food products stored in the refrigerator impeding air flow. Based upon the cooling methods used in this study, the results showed that cooling tomato sauce under standard refrigeration was inadequate to meet FDA Food Code standards. Thus, other methods need to be considered in order to cool food properly.

Blast chillers effectively meet FDA Food Code standards using forced air, but their high cost limits availability in many onsite foodservice operations. If investing in a blast chiller is not feasible, operations must adopt alternative effective techniques to achieve rapid cooling. Previous studies have shown that cooling tomato sauce uncovered in 2-inch deep stainless steel pans in a walk-in freezer met FDA Food Code standards (Beardall et al., 2019b; Roberts et al., 2013). However, Roberts et al. (2013) found that school foodservice operations typically have only about 20% available freezer space, posing a barrier to using freezers for cooling. Moreover, introducing hot foods risks defrosting existing frozen items, compromising their safety and quality. In addition, this cooling method may also hinder next-day service due to the need for reheating food from a frozen state.

Affordable tools like chill sticks can reduce cooling times for liquids (e.g., sauces or soups), though this increases labor demands and may require staff oversight that is not always feasible. Chill sticks are designed for active use with stirring and ice needs to be replaced when it has melted. However, if chill sticks are used passively (i.e., incorrectly), then their effectiveness to cool food properly is reduced. Similarly, ice baths can be used to reduce cooling times for liquids, but this method also require active stirring and monitoring of the ice to effectively cool food.

Further depth reductions for uncovered refrigerator cooling could potentially meet FDA Food Code standards. This approach could be tested on other liquid foods with a thicker consistency than tomato sauce. If confirmed in future research, this approach could become a valuable standard operating procedure, especially for operations without feasible access to walk-in freezers/blast chillers or the ability to actively cool food with chill sticks/ice baths. Findings of this study can apply broadly to onsite foodservice operations to enhance cooling practices.

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Table 1 – Materials and methods used to cool tomato sauce, covered or uncovered, in a commercial walk-in refrigerator from 135 °F to 41 °F.

Container Dimensions Width (W), Length (L), Height (H), Diameter (D)	Depth or Amount of Tomato sauce	Cooling Method (CM)	Ventilation During Cooling	Number of containers used per replication	Number of replications
Stainless Steel Foodservice Pan 12 in. W x 10 in. L x 2 ½ in. H	2 in.	CM1	Covered*	3	3
		CM2	Uncovered	3	3
Stainless Steel Foodservice Pan 12 in. W x 20 in. L x 2 ½ in. H	2 in.	CM3	Covered*	3	3
		CM4	Uncovered	3	3
Stainless Steel Foodservice Pan 12 in. W x 10 in. L x 4 in. H	3 in.	CM5	Covered*	3	3
		CM6	Uncovered	3	3
Stainless Steel Foodservice Pan 12 in. W x 20 in. L x 4 in. H	3 in.	CM7	Covered*	3	3
		CM8	Uncovered	3	3
20-quart Aluminum Stockpot 12 in. D x 10½ in. H	3 gallons	CM9	Covered**	1	3
		CM10	Uncovered	1	3
5 gallon High-Density Polyethylene Bucket 12 in. D x 13 in. H	5 gallons	CM11	Covered**	1	3
		CM12	Uncovered	1	3

*Wrapped tightly with plastic foodservice film. **Wrapped tightly with aluminum foil.

Table 2 – Results of testing commonly used foodservice storage containing hot tomato sauce, cooled in a commercial walk-in refrigerator, including mean cooling times for covered and uncovered cooling methods from 135 °F to 70 °F and 135 °F to 41 °F.

Container Dimensions Width (W), Length (L), Height (H), Diameter (D)	Depth or Amount of Tomato sauce	Mean Walk-In Refrigerator Ambient Air Temperature in Degrees Fahrenheit ± Standard Deviation	Cooling Method (CM)	Covering Method During Cooling	Mean Cooling Time Hr : Min ± Standard Deviation 135 °F to 70 °F* *2022 FDA Food Code Standard: ≤ 2:00 hr	Mean Cooling Time Hr : Min ± Standard Deviation 135 °F to 41 °F** **2022 FDA Food Code Standard: ≤ 6:00 hr	Mean Difference in Cooling Method Times (CM Covered - CM Uncovered) Hr : Min ± Standard Deviation 135 °F to 70 °F	Mean Difference in Cooling Method Times (CM Covered - CM Uncovered) Hr : Min ± Standard Deviation 135 °F to 41 °F
Stainless Steel Foodservice Pan 12 in. W x 10 in. L x 2 ½ in. H	2 in.	37.7 ± 1.11	CM1	Covered	3:40 ± 0:13	11:40 ± 0:44	1:13 ± 0:04	3:52 ± 0:08
			CM2	Uncovered	2:27 ± 0:13	7:47 ± 0:51		
Stainless Steel Foodservice Pan 12 in. W x 20 in. L x 2 ½ in. H	2 in.	38.1 ± 1.07	CM3	Covered	4:07 ± 0:17	13:16 ± 0:47	1:24 ± 0:06	4:28 ± 0:07
			CM4	Uncovered	2:43 ± 0:11	8:48 ± 0:40		
Stainless Steel Foodservice Pan 12 in. W x 10 in. L x 4 in. H	3 in.	37.9 ± 1.12	CM5	Covered	5:33 ± 0:38	17:58 ± 1:50	1:35 ± 0:16	5:41 ± 0:29
			CM6	Uncovered	3:58 ± 0:24	12:17 ± 1:25		
Stainless Steel Foodservice Pan 12 in. W x 20 in. L x 4 in. H	3 in.	37.8 ± 1.45	CM7	Covered	5:52 ± 0:26	18:20 ± 1:10	1:30 ± 0:18	5:08 ± 0:29
			CM8	Uncovered	4:19 ± 0:05	13:03 ± 0:43		
20-quart Aluminum Stockpot 12 in. D x 10½ in. H	3 gallons	37.0 ± 1.32	CM9	Covered	7:21 ± 0:16	21:25 ± 0:21	1:22 ± 0:07	4:39 ± 0:18
			CM10	Uncovered	5:59 ± 0:22	16:46 ± 0:33		
5 gallon High-Density Polyethylene Bucket 12 in. D x 13 in. H	5 gallons	37.5 ± 1.48	CM11	Covered	11:47 ± 0:27	35:14 ± 1:06	1:49 ± 0:23	6:13 ± 0:28
			CM12	Uncovered	9:57 ± 0:03	29:01 ± 0:54		

Table 3 – Two-way (2x2) repeated measures ANOVA – Analysis of data for tomato sauce cooled from 135 °F to 70 °F.

Cooling Methods (CM) Compared	Main Effect of Covering Method	Estimated Marginal Mean Cooling Time of Covered (SE)*	Estimated Marginal Mean Cooling Time of Uncovered (SE)*	Main Effect of Depth of Tomato sauce	Estimated Marginal Mean Cooling Time of 2 in. Depth (SE)*	Estimated Marginal Mean Cooling Time of 3 in. Depth (SE)*	Interaction Effect of Covering Method & Depth of Tomato sauce
CM1 & CM2 (12 in. x 10 in. x 2 in. tomato sauce depths)	$F(1, 8) = 875.62,$ $p < .001$	0.192 (0.006)	0.134 (0.004)	$F(1, 8) = 252.65,$ $p < .001$	0.128 (0.003)	0.199 (0.007)	$F(1, 8) = 13.36,$ $p = .006^{**}$
CM5 & CM6 (12 in. x 10 in. x 3 in. tomato sauce depths)							
CM3 & CM4 (12 in. x 20 in. x 2 in. tomato sauce depths)	$F(1, 8) = 370.80,$ $p < .001$	0.209 (0.005)	0.147 (0.002)	$F(1, 8) = 2324.38,$ $p < .001$	0.143 (0.003)	0.213 (0.004)	$F(1, 8) = 1.93,$ $p = .203$
CM7 & CM8 (12 in. x 20 in. x 3 in. tomato sauce depths)							
Cooling Methods (CM) Compared	Main Effect of Covering Method	Estimated Marginal Mean Cooling Time of Covered (SE)*	Estimated Marginal Mean Cooling Time of Uncovered (SE)*	Main Effect of Amount of Tomato sauce	Estimated Marginal Mean Cooling Time of 3 gallon Amount (SE)*	Estimated Marginal Mean Cooling Time of 5 gallon Amount (SE)*	Interaction Effect of Covering Method & Amount of Tomato sauce
CM9 & CM10 (12 in. diameter x 3 gallons tomato sauce)	$F(1, 2) = 416.93,$ $p = .002$	0.399 (0.008)	0.332 (0.005)	$F(1, 2) = 1323.98,$ $p = .001$	0.278 (0.008)	0.453 (0.006)	$F(1, 2) = 2.276,$ $p = .270$
CM11 & CM12 (12 in. diameter x 5 gallons tomato sauce)							

Estimated marginal mean cooling times are reported in days (1.000 = one day). *SE = standard error. ** See Figure 1.

Table 4 – Two-way (2x2) repeated measures ANOVA – Analysis of data for tomato sauce cooled from 135 °F to 41 °F.

Cooling Methods (CM) Compared	Main Effect of Covering Method	Estimated Marginal Mean Cooling Time of Covered (SE)*	Estimated Marginal Mean Cooling Time of Uncovered (SE)*	Main Effect of Depth of Tomato sauce	Estimated Marginal Mean Cooling Time of 2 in. Depth (SE)*	Estimated Marginal Mean Cooling Time of 3 in. Depth (SE)*	Interaction Effect of Covering Method & Depth of Tomato sauce
CM1 & CM2 (12 in. x 10 in. x 2 in. tomato sauce depths)	$F(1, 8) = 3811.51,$ $p < .001$	0.617 (0.018)	0.418 (0.016)	$F(1, 8) = 347.49,$ $p < .001$	0.405 (0.011)	0.630 (0.023)	$F(1, 8) = 81.87,$ $p < .001^{**}$
CM5 & CM6 (12 in. x 10 in. x 3 in. tomato sauce depths)							
CM3 & CM4 (12 in. x 20 in. x 2 in. tomato sauce depths)	$F(1, 8) = 949.33,$ $p < .001$	0.659 (0.013)	0.456 (0.009)	$F(1, 8) = 1156.00,$ $p < .001$	0.460 (0.010)	0.654 (0.013)	$F(1, 8) = 14.40,$ $p = .005^{***}$
CM7 & CM8 (12 in. x 20 in. x 3 in. tomato sauce depths)							
Cooling Methods (CM) Compared	Main Effect of Covering Method	Estimated Marginal Mean Cooling Time of Covered (SE)*	Estimated Marginal Mean Cooling Time of Uncovered (SE)*	Main Effect of Amount of Tomato sauce	Estimated Marginal Mean Cooling Time of 3 gallon Amount (SE)*	Estimated Marginal Mean Cooling Time of 5 gallon Amount (SE)*	Interaction Effect of Covering Method & Amount of Tomato sauce
CM9 & CM10 (12 in. diameter x 3 gallons tomato sauce)	$F(1, 2) = 981.26,$ $p = .001$	1.181 (0.018)	0.954 (0.017)	$F(1, 2) = 1619.05,$ $p = .001$	0.796 (0.011)	1.339 (0.024)	$F(1, 2) = 28.66,$ $p = .033^{****}$
CM11 & CM12 (12 in. diameter x 5 gallons tomato sauce)							

Estimated marginal mean cooling times are reported in days (1.000 = one day). *SE = standard error. ** See Figure 2. *** See Figure 3. **** See Figure 4.