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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.

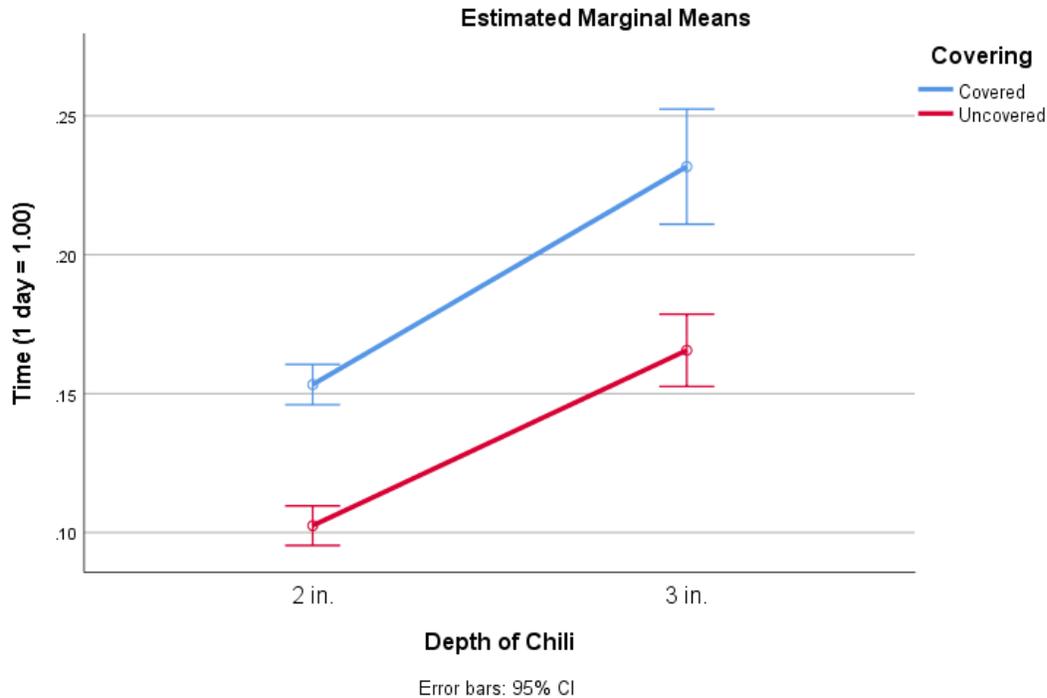
RESULTS AND DISCUSSION

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.

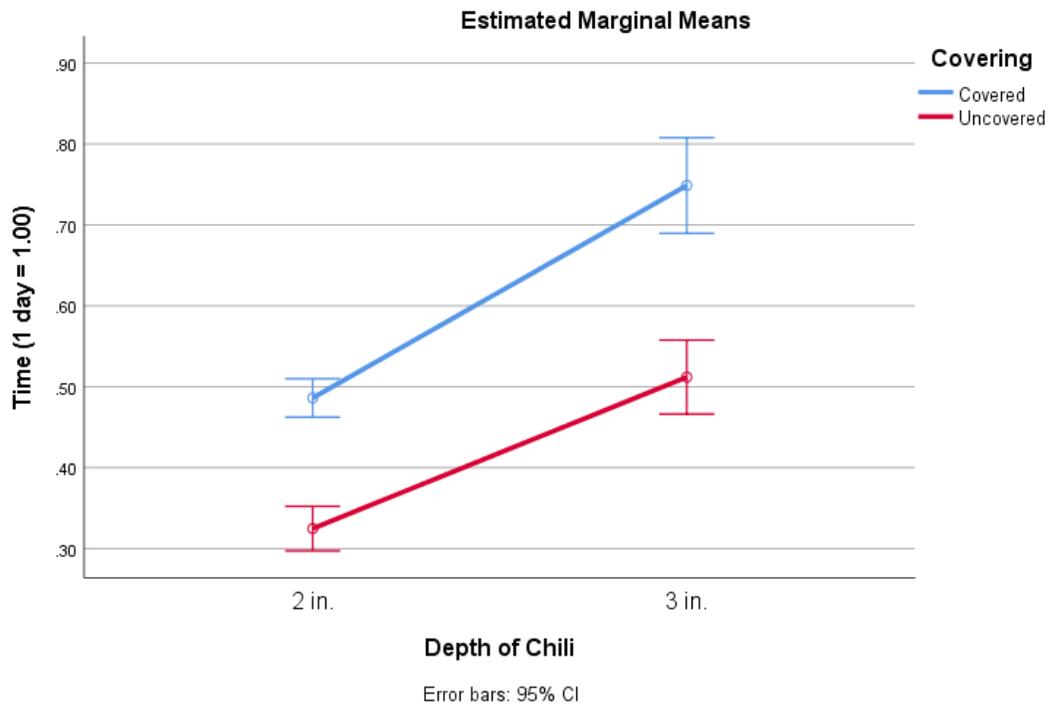
For cooling methods CM9 & CM10, compared with CM11 & CM12, there was a significant main effect of covering method on cooling time ($F(1, 2) = 416.93, p = .002$). Covered containers ($EMM = 0.399, SE = 0.008$) took longer to cool than uncovered containers ($EMM = 0.332, SE = 0.005$). In addition, there 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.

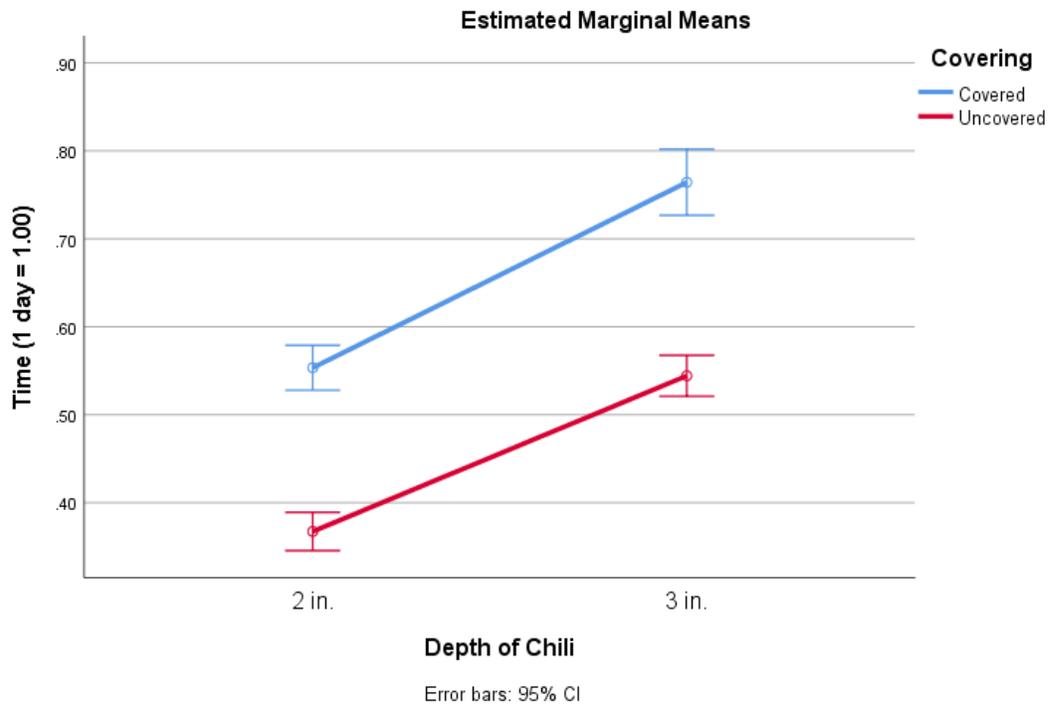


Stainless steel foodservice pans: 12 in. widths x 20 in. lengths.

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.

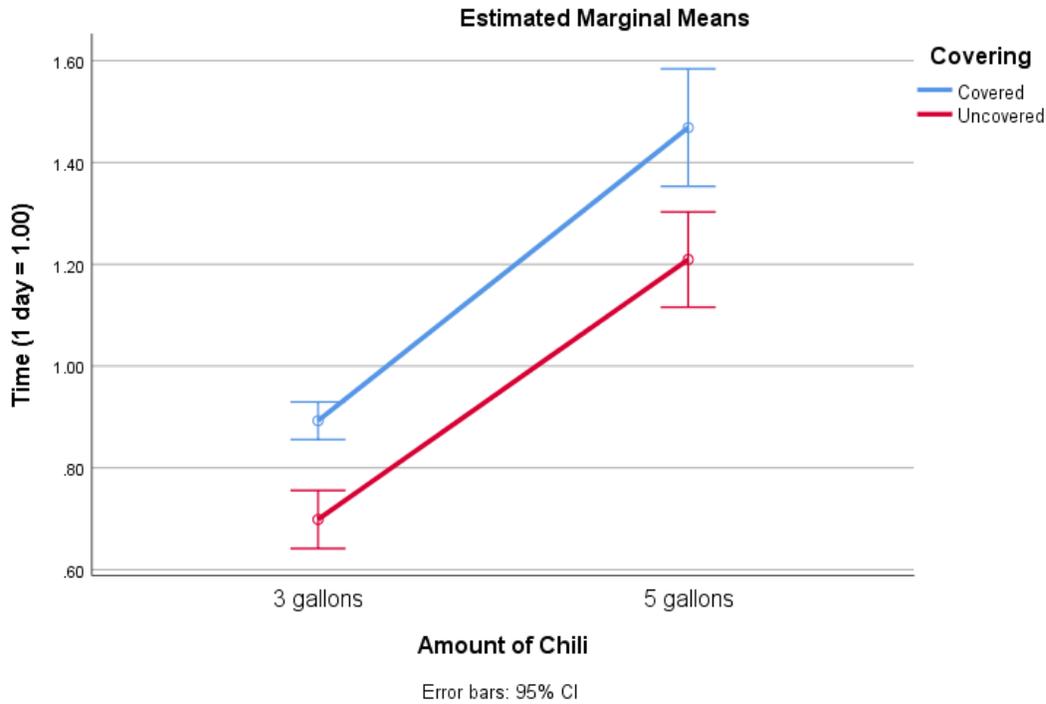


Aluminum stockpots and high-density polyethylene buckets: 12 in. diameters.

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.

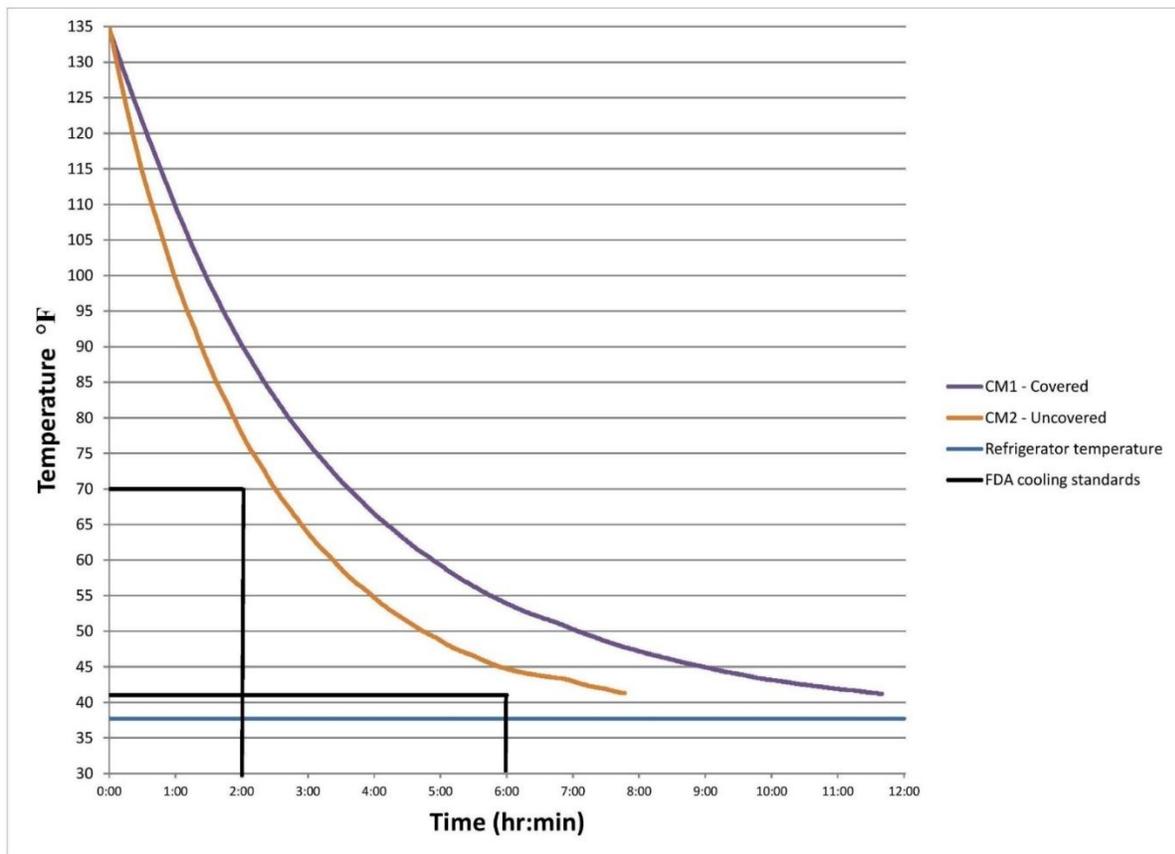
This study's results mirrored results from a former study by Olds (2019), which used a similar methodology to evaluate cooling methods for chili prepared in a university residence dining center kitchen.

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.



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.

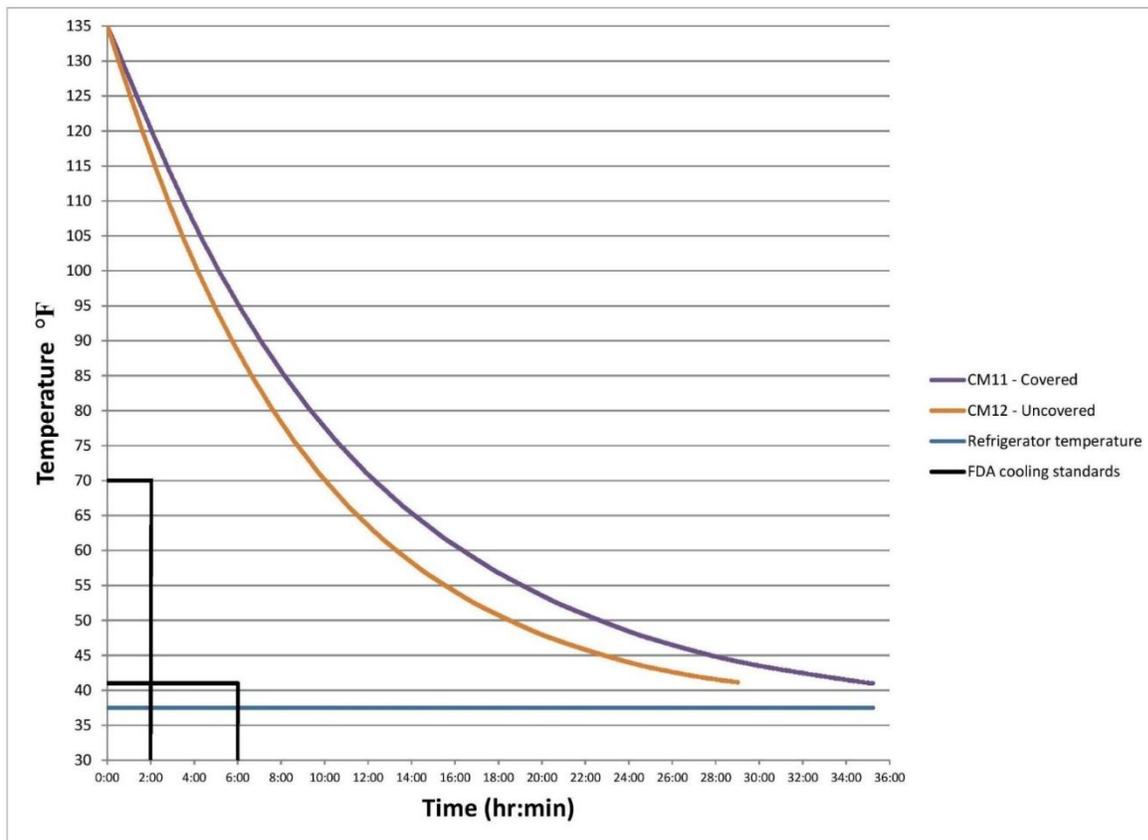
This study has several limitations. First, since only tomato sauce was tested, the findings may not apply to other high-viscosity sauces. Additionally, the experiment took place in a highly controlled setting: the refrigerator contained no other items during cooling, and its door stayed closed and locked 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.