Research Contribution

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VENTILATED AND UNVENTILATED COOLING METHODS IN ONSITE FOODSERVICE OPERATIONS

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ABSTRACT
The 2017 Food and Drug Administration (FDA) Food Code states that food shall be cooled from 135ºF (57ºC) to 70ºF (21ºC) within two hours and from 135ºF (57ºC) to 41ºF (5ºC) within a total of six hours or less. This study examined if methods used to cool chili would meet Food Code cooling standards. Chili was cooled covered and uncovered in a walk-in refrigerator. Covered cooling methods took significantly longer to cool than uncovered cooling methods; no method met Food Code standards. Recommendations for future research included cooling chili at shallower depths.

Keywords: cooling; schools; foodservice; FDA; Food Code

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INTRODUCTION

Food safety is a critical issue in the United States (U.S.) and maintaining excellent food safety standards in a foodservice operation is imperative to protect customers and employees from foodborne illness (National Restaurant Association Educational Foundation, 2017). Foodborne illness is estimated to affect 48 million people in the United States annually, along with 128,000 hospitalizations and 3,000 deaths (Centers for Disease Control and Prevention [CDC], 2011). Of these 48 million foodborne illnesses, 20% are attributed to 31 known foodborne pathogens (CDC, 2011; Scallan et al., 2011).

The improper cooling of food products is a significant factor contributing to foodborne illness outbreaks in foodservice operations (Brown et al., 2012; Schaffner et al., 2015; U.S. Food and Drug Administration [FDA], 2018). The potential for outbreaks of foodborne illness exists in environments where food is prepared in large batches. Quantity production of food in a single location is a common process found in institutional foodservice operations, and single locations accounted for 94% of 5,022 outbreak reports in the United States and Puerto Rico from 2009–2015 (Dewey-Mattia, Manikonda, Hall, Wise, & Crowe, 2018). *C. perfringens*, a bacteria associated with improper food temperatures, is estimated to account for 965,958 cases of foodborne illness that occur annually in the United States (Scallan et al., 2011). *Bacillus cereus* (*B. cereus*), another bacteria associated with improper food temperatures, is estimated to cause over 63,400 foodborne illnesses each year (Scallan et al., 2011).

Past studies have identified cooling as a critical control point that school foodservice directors should address while planning food safety programs (Olds, Roberts, Sauer, Sneed, & Shanklin, 2013; Pogostin et al., 2008). From 1998-2006, the third highest contributing risk factor in 16 of 298 school-associated foodborne outbreaks was identified to be inadequate or "slow" cooling of food prepared on school premises (Pogostin et al., 2008). The Centers for Disease Control and Prevention collected data via the Foodborne Disease Outbreak Surveillance System from 2000-2010 pertaining to foodborne illness outbreaks in school settings (Venuto, Garcia, & Halbrook, 2015). The study found that the second highest contributing risk factor for the proliferation of pathogens in food was that no effort was made to control the temperature of food items or the length of time that those food items were not under temperature control (Venuto et al., 2015). The third highest contributing risk factor for the growth of pathogens was improper cold holding caused by faulty refrigeration equipment (Venuto et al., 2015). These two factors above accounted for a total of 38.2% of 105 identified food safety errors contributing to the proliferation of pathogens in this study (Venuto et al., 2015). These factors are of significant importance in school foodservice operations where only breakfast and lunch meals are prepared, and employees typically leave work for the day shortly after the start of cooling procedures, with little or no opportunity for actively monitoring cooling procedures (Roberts, Olds, Shanklin, Sauer, & Sneed, 2013).

The FDA Food Code provides uniform and systematic recommendations to ensure that food offered in foodservice and retail establishments is safe to eat and is presented honestly to customers (FDA, 2017). The FDA Food Code is commonly adopted by government agencies responsible for preventing foodborne illness; these agencies inspect and regulate foodservice operations in restaurants, schools, and hospitals (National Restaurant Association Educational Foundation, 2017).

The FDA Food Code receives input from the Conference for Food Protection , a non-profit organization comprised of members from the foodservice industry, academia, regulatory agencies, and other professional organizations (Conference for Food Protection, 2018; FDA, 2017). Collaboration also occurs between the FDA, the U.S. Department of Agriculture's (USDA) Food Safety and Inspection Service and the Centers for Disease Control and Prevention of the U.S. Department of Health and Human Services in establishing FDA Food Code requirements (FDA, 2017). The input of the Conference for Food Protection, USDA Food Safety and Inspection Service , and the CDC is used to periodically update the FDA Food Code; the Food Code was most recently updated in 2017, with prior updates in 2013, 2009, 2005, 2001, 1999, and 1997 (FDA, 2017).

Section 3-501.14 of the 2017 FDA Food Code states that "cooked time/temperature control for safety food shall be cooled: (1) Within 2 hours from 57ºC (135ºF) to 21ºC (70ºF); and (2) Within a total of 6 hours from 57ºC (135ºF) to 5ºC (41ºF) or less" (FDA, 2017, p. 94). This two-part cooling standard is classified by the FDA as a "priority item", which means that it "contributes directly to the elimination, prevention or reduction to an acceptable level, hazards associated with foodborne illness or injury and there is no other provision that more directly controls the hazard" (FDA, 2017, p. 16). The purpose of

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this cooling standard is to minimize the time that food spends in the "temperature danger zone" (41ºF – 135ºF) to prevent the rapid growth of bacteria, such as *C. perfringens*, in food undergoing cooling (National Restaurant Association Educational Foundation, 2017). Foods can be contaminated with a wide variety of bacteria having a wide range of infectious doses (FDA, 2012). Cooling times exceeding FDA Food Code standards may allow bacteria to multiply to unsafe levels, which may lead to foodborne illness outbreaks (National Restaurant Association Educational Foundation, 2017).

The 2017 FDA Food Code (§ 3-501.15) outlines acceptable cooling methods based upon the type of food product. These cooling methods include: (a) portioning food into shallow pans; (b) dividing food into smaller portions; (c) utilizing specialized rapid-cooling equipment (such as a blast chiller) to cool food quickly; (d) placing food containers in an ice water bath and stirring the food product; (e) using food containers that permit heat to be easily transferred from the food product; (f) adding ice to food as a part of the food preparation process; and (g) utilizing other effective cooling methods (FDA, 2017). An example of an "other effective cooling method" is to place uncovered food at 2 in. depths in a walk-in freezer to cool (Roberts et al., 2013). Section 3-501.15 of the 2017 FDA Food Code recommends that when food is placed in cooling or cold holding equipment, food containers in which food is being cooled shall be arranged to provide maximum heat transfer through the container walls. Food shall also be loosely covered or uncovered during the cooling period to facilitate heat transfer from the surface of the food, if it is protected from overhead contamination as specified under Subparagraph 3-305.11(A)(2) of the 2017 FDA Food Code.

Several studies have explored the ongoing problems and challenges associated with cooling large quantities of foods within FDA Food Code cooling standards in foodservice operations (Beardall, Paez, Phebus, Watkins, & Gragg, 2019a; Beardall, Paez, Phebus, Watkins, & Gragg, 2019b; Brown et al., 2012; Krishnamurthy & Sneed, 2011; Olds et al., 2013; Olds & Sneed, 2005; Roberts et al., 2013; Schaffner et al., 2015; Watkins, Gragg, Beardall, Phebus, & Paez, 2016). Schaffner et al. (2015) found that during cooling, unventilated (covered) food products were twice as likely to take longer to cool as ventilated (uncovered) food products. Brown et al. (2012) observed cooling practices in foodservice operations and found that in 160 of 466 walk-in refrigerators (34.3%) observed, food being cooled was not ventilated, despite FDA Food Code recommendations that cooling food should be ventilated (FDA, 2017). These studies indicate that unventilated cooling of food is both a common and risky practice in foodservice operations.

Krishnamurthy and Sneed (2011) studied cooling practices used in U.S. schools. From a sample of 411 respondents, 78% reported that food prepared in schools was cooled for reheating and service. Most school foodservice directors (76%) stated that 2 in. stainless steel foodservice pans were utilized for cooling food. Other responses included the use of 4 in. foodservice pans for cooling (39%), 6 in. foodservice pans (9%), and stockpots (6%), all of which increased in cooling time as the depths and/or amounts of food product undergoing cooling also increased. Respondents also indicated that they used chill sticks (37%) and ice baths (38%) while cooling food products in their foodservice operations.

The purpose of this research was to determine if practices commonly used to cool food produced in onsite foodservice operations would meet established 2017 FDA Food Code standards. To the best of the author's knowledge, no study had previously explored the comparisons between ventilated and unventilated cooling of chili con carne with beans in a walk-in refrigerator, while utilizing a variety of sizes of foodservice storage containers, including a 5-gallon high-density polyethylene bucket. This study provided insights into preventing outbreaks of foodborne illness caused by methods that facilitate the improper cooling of food. The main objectives of this study were to: (a) compare the time and temperature differences between ventilated and unventilated cooling methods commonly utilized to cool chili con carne with beans in a walk-in refrigerator; and (b) determine the optimal cooling method(s) for chili con carne with beans from ventilated and unventilated cooling methods tested in this study.

METHODOLOGY

Sample Selection and Preparation

USDA school recipes, available online from the Institute of Child Nutrition, University, Mississippi, were used for preparation of food products. Chili is a food item commonly prepared and cooled in the U.S. National School Lunch Program (Krishnamurthy & Sneed, 2011; Olds & Sneed, 2005; Roberts et al., 2013). For this study, chili was prepared using a standardized recipe (Chili con Carne with Beans, USDA Recipe #D-20) from the *USDA Recipes for Schools* (Institute of Child Nutrition, 2016).

Chili con carne with beans recipe ingredients were procured from local retail food suppliers. Chili was prepared in a modern university residence dining center kitchen using standard foodservice equipment at Bradley University (Peoria, Illinois). The principal investigator was granted exclusive use of the facilities over the summer recess and no other concurrent food production or service activities occurred during data collection procedures. Chili was prepared on a commercial gas range in 26-quart aluminum stockpots. Chili was heated to 212ºF and then transferred while still hot (>135ºF) into selected foodservice storage containers at varying depths/ amounts for testing. Containers used included stainless steel foodservice pans, all with 12 in. widths, varying lengths (10 in. and 20 in.), and varying heights (2 ½ in. and 4 in.). These containers included: 12 in. x 10 in. x 2 ½ in. pans with 2 in. chili depths, 12 in. x 20 in. x 2 ½ in. pans with 2 in. chili depths, 12 in. x 10 in. x 4 in. pans with 3 in. chili depths, and 12 in. x 20 in. x 4 in. pans with 3 in. chili depths. Additional containers used included 20-quart aluminum stockpots and 5-gallon high-density polyethylene buckets, all with 12 in. diameters and varying heights (10½ in. for the stockpots with 3 gallons of chili and 13 in. for the buckets with 5 gallons of chili) (see Table 1).

Comark RF512 Wireless Temperature Transmitters (Comark USA, Beaverton, OR) were connected to Comark RFAX100D thermistors (Comark USA, Beaverton, OR). The thermistors were affixed in the geometric center of the chili to measure the hottest area of the containers during cooling. The 2017 FDA Food Code states that "the geometric center or thickest part of a product are the points of measurement of product temperature particularly when measuring critical limits for cooking" (FDA, 2017, p. 606). The transmitters recorded time and temperature data during cooling. A Comark RF500 temperature monitoring system (Comark USA, Beaverton, OR) was used to download and aggregate the recorded data from the transmitters.

Cooling Procedures

A commercial walk-in refrigerator located in a university residence dining center kitchen at Bradley University (Peoria, Illinois) was used for all cooling procedures. A Comark RF512 Wireless Temperature Transmitter recorded the ambient air temperature of the walk-in refrigerator, which was operated at a mean temperature of 34.6ºF (SD = 1.36ºF). The walk-in refrigerator had 100% free capacity (0% load) prior to foodservice storage containers being placed inside for testing. No other items were present in the walk-in refrigerator while

Table 1. Materials and Methods Used to Cool Chili, Covered or Uncovered, in a Commercial Walk-in Refrigerator from 135ºF to 41ºF

Container Dimensions Width (W), Length (L), Height (H), Diameter (D)	**Depth or Amount of Chili**	**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 a single layer of plastic foodservice film.
**Wrapped tightly with a single layer of aluminum foil.

the covered and uncovered containers of chili were cooling. Containers undergoing testing were placed in the walk-in refrigerator equidistantly apart from one another on standard wire-rack shelving, which facilitated air circulation around all sides of the containers. For all cooling methods tested, the door to the walk-in refrigerator remained closed and locked during cooling, until all containers of chili had reached 41ºF.

Prior studies demonstrated that covered food products cooled slower than uncovered products (Brown et al., 2012; Institute for Food Safety and Health, 2011; Olds, Mendonca, Sneed, & Bisha, 2006; Schaffner et al., 2015). This study expanded upon prior cooling methods used in ventilated (uncovered) chili cooling studies by Olds & Sneed (2005) and Roberts et al. (2013). For this study, chili was cooled using two methods: (a) ventilated (uncovered) containers; and (b) unventilated containers (containers covered with a single layer of plastic foodservice film or a single layer of aluminum foil). Selected foodservice storage containers containing hot chili (>135ºF) were either covered (wrapped with plastic foodservice film or aluminum foil) or left uncovered and both placed in a commercial walk-in refrigerator for concurrent cooling. For each of the six sizes of foodservice containers used in this study, two forms of ventilation (covered or uncovered) were tested, equating to a total of 12 cooling methods (CM1 – CM12). Three replications were conducted for each of the 12 cooling methods tested. For each replication, equal numbers of covered (unventilated) and uncovered (ventilated) containers of identical size were cooled concurrently in the walk-in refrigerator until all containers of chili had reached 41ºF.

All odd-numbered cooling methods used covered containers and all even-numbered cooling methods used uncovered containers. Covered and uncovered cooling methods that were tested concurrently included: CM1 & CM2, CM3 & CM4, CM5 & CM6, CM7 & CM8, CM9 & CM10, and CM11 & CM12 (see Table 1). Stainless steel foodservice pans were wrapped tightly with a single layer of plastic foodservice film for covered cooling methods CM1, CM3, CM5, and CM7. Twenty-quart aluminum stockpots and 5-gallon high-density polyethylene buckets were wrapped tightly with a single layer of aluminum foil and secured with large rubber bands for covered cooling methods CM9 and CM11. Equipment used to secure the thermistors in the geometric center of the chili did not permit the use of the regular lids for the aluminum stockpots and the 5-gallon high-density polyethylene buckets. It was determined that aluminum foil as covering would be a logical substitute for the aluminum stockpot lid. Aluminum foil was accordingly selected as covering for the buckets as time and temperature data from the stockpots and the buckets were planned for comparison. Thus, a single layer of aluminum foil, secured around the circumference of the stockpots and buckets with large rubber bands, was the method used to ensure the stockpots and buckets remained tightly wrapped while cooling. No plastic foodservice film or aluminum foil was used for uncovered cooling methods CM2, CM4, CM6, CM8, CM10, and CM12 (see Table 1).

For each replication, temperatures of the geometric center of the chili in the containers were measured with Comark RFAX100D thermistors, which were connected to Comark RF512 Wireless Temperature Transmitters. Temperature data were logged at 1-minute intervals and recorded on the transmitters during testing. Upon the completion of each replication, the transmitters were removed from the walk-in refrigerator, disconnected from the thermistors, and transported 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. Data were analyzed using Microsoft

Excel 2013 (Microsoft Corporation, Redmond, WA) and SPSS Statistics version 25 (International Business Machines [IBM] Corporation, Armonk, New York). Means and standard deviations of time and temperature data ranges (135ºF to 70ºF, and 135ºF to 41ºF) for each cooling method were calculated for comparison with FDA Food Code cooling standards. Representative mean time and temperature cooling curves were plotted using Microsoft Excel 2013.

RESULTS AND DISCUSSION

This section outlines the results found from the cooling methods. The main objectives of this study were to compare the time and temperature differences between ventilated and unventilated cooling methods and determine which of those methods successfully met (or did not meet) 2017 FDA Food Code cooling standards. To comply with the 2017 FDA Food Code, these standards must be satisfied when cooked food is cooled.

Mean cooling times for all cooling methods tested in this study are shown in Table 2. None of the 12 uncovered or covered cooling methods tested met 2017 FDA Food Code cooling standards in the walk-in refrigerator. No cooling method cooled chili con carne with beans from 135ºF to 70ºF within two hours and no cooling method cooled chili from 135ºF to 41ºF within a total of six hours.

A two-factor (2x2) repeated measures Analysis of Variance (ANOVA) procedure was used to analyze time and temperature data. To investigate the influence of covering method and chili depth/amount (main effects) on the cooling time, cooling methods with identical container widths and lengths or identical container diameters were compared for time and temperature data ranges of 135ºF to 70ºF and 135ºF to 41ºF. Two independent variables, each with two levels, were tested for effects on the dependent variable: covering method (covered or uncovered), and depth/amount of chili (2 in. or 3 in. depths for pans and 3 gallon or 5 gallon amounts for stockpots/ buckets). Significant interactions between the independent variables were explored using profile plots and related pairwise t-tests to analyze data for comparison at the treatment level. The significance threshold for the effects of the variables and variable interactions was set at $p \leq .05$.

Analysis of chili cooled from 135ºF to 70ºF (see Table 3).

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 ($F(1, 8) = 36.28$, $p < .001$). Covered containers ($M = 0.176$) took longer to cool than uncovered containers ($M = 0.126$). In addition, there was a significant main effect of the depth of chili on cooling time ($F(1, 8) = 121.93$, $p < .001$). Containers at 3 in. depths ($M = 0.177$) took longer to cool than containers at 2 in. depths ($M = 0.126$). No interaction effect was observed between covering method and depth of chili ($F(1, 8) = 0.51$, $p = .497$).

Table 2. Results of Testing Commonly Used Foodservice Storage Containing Hot Chili, Cooled in a Commercial Walk-in Refrigerator, including Mean Cooling Times for Covered and Uncovered Cooling Methods from 135ºF to 70ºF and 135ºF to 41ºF

Container Dimensions Width (W), Length (L), Height (H), Diameter (D)	Depth or Amount of Chili	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 135ºF to 70ºF* *2017 FDA Food Code Standard: ≤ 2:00 hr	Mean Cooling Time Hr : Min ± Standard Deviation 135ºF to 41ºF** **2017 FDA Food Code Standard: ≤ 6:00 hr	Mean Difference in Cooling Method Times (CM Covered - CM Uncovered) Hr : Min ± Standard Deviation 135ºF to 70ºF	Mean Difference in Cooling Method Times (CM Covered - CM Uncovered) Hr : Min ± Standard Deviation 135ºF to 41ºF
Stainless Steel Food-service Pan 12 in. W x 10 in. L x 2 ½ in. H	2 in.	34.9 ± 1.20	CM1	Covered	3:33 ± 0:14	9:41 ± 0:47	1:07 ± 0:32	3:05 ± 1:27
			CM2	Uncovered	2:26 ± 0:10	6:36 ± 0:31		
Stainless Steel Food-service Pan 12 in. W x 20 in. L x 2 ½ in. H	2 in.	34.6 ± 1.36	CM3	Covered	3:54 ± 0:14	10:42 ± 0:33	1:33 ± 0:35	4:19 ± 1:20
			CM4	Uncovered	2:21 ± 0:09	6:23 ± 0:30		
Stainless Steel Food-service Pan 12 in. W x 10 in. L x 4 in. H	3 in.	34.5 ± 1.32	CM5	Covered	4:53 ± 0:26	13:23 ± 1:09	1:16 ± 0:41	3:37 ± 1:45
			CM6	Uncovered	3:37 ± 0:15	9:46 ± 0:46		
Stainless Steel Food-service Pan 12 in. W x 20 in. L x 4 in. H	3 in.	34.6 ± 1.30	CM7	Covered	4:54 ± 0:34	13:40 ± 1:25	1:07 ± 0:16	3:25 ± 0:34
			CM8	Uncovered	3:47 ± 0:25	10:15 ± 1:31		
20-quart Aluminum Stockpot 12 in. D x 10½ in. H	3 Gallons	34.8 ± 1.50	CM9	Covered	7:21 ± 0:12	20:17 ± 1:00	1:28 ± 0:07	4:05 ± 0:38
			CM10	Uncovered	5:53 ± 0:09	16:12 ± 1:03		
5-gallon High-Density Polyethylene Bucket 12 in. D x 13 in. H	5 Gallons	34.5 ± 1.44	CM11	Covered	12:25 ± 0:18	34:47 ± 1:13	2:58 ± 0:12	9:35 ± 1:44
			CM12	Uncovered	9:27 ± 0:07	25:12 ± 0:32		

Table 3. Two-way (2x2) Repeated Measures ANOVA – Analysis of Data for Chili Cooled from 135ºF to 70ºF

Cooling Methods (CM) Compared	Main Effect of Covering Method	Mean of Covered (*SE*)*	Mean of Uncovered (*SE*)*	Main Effect of Depth of Chili	Mean of 2 in. Depth (*SE*)*	Mean of 3 in. Depth (*SE*)*	Interaction of Covering Method & Depth of Chili
CM1 & CM2 (12 in. x 10 in. x 2 in. chili depths) CM5 & CM6 (12 in. x 10 in. x 3 in. chili depths)	*F*(1, 8) = 36.28, *p* < .001	0.176 (0.006)	0.126 (0.003)	*F*(1, 8) = 121.93, *p* < .001	0.125 (0.003)	0.177 (0.004)	*F*(1, 8) = 0.51, *p* = .497
CM3 & CM4 (12 in. x 20 in. x 2 in. chili depths) CM7 & CM8 (12 in. x 20 in. x 3 in. chili depths)	*F*(1, 8) = 70.86, *p* < .001	0.184 (0.007)	0.128 (0.004)	*F*(1, 8) = 94.74, *p* < .001	0.130 (0.004)	0.181 (0.006)	*F*(1, 8) = 5.52, *p* = .047**

Cooling Methods (CM) Compared	Main Effect of Covering Method	Mean of Covered (*SE*)*	Mean of Uncovered (*SE*)*	Main Effect of Amount of Chili in gallons	Mean of 3 gallon Amount (*SE*)*	Mean of 5 gallon Amount (*SE*)*	Interaction of Covering Method & Amount of Chili
CM9 & CM10 (12 in. diameter x 3 gallons chili) CM11 & CM12 (12 in. diameter x 5 gallons chili)	*F*(1, 2) = 989.70, *p* = .001	0.412 (0.005)	0.320 (0.003)	*F*(1, 2) = 2027.63, *p* < .001	0.276 (0.004)	0.456 (0.005)	*F*(1, 2) = 108.97, *p* = .009***

*Mean times are reported in days (1.000 = one day), *SE* = standard error.
** See Figure 1 for interaction profile plot.
*** See Figure 2 for interaction profile plot

Stainless steel foodservice pans: 12 in. widths x 20 in. lengths.
For cooling methods CM3 & CM4, compared with CM7 & CM8, a significant interaction effect was observed between covering method and depth of chili (*F*(1, 8) = 5.52, *p* = .047) (see Figure 1). Related pairwise t-tests for covering method revealed a significant difference between covered (*M* = 0.16, *SD* = 0.02) and uncovered (*M* = 0.10, *SD* = 0.01) cooling methods for 2 in. depths of chili (*t*(8) = 8.54, *p* < .001), and a significant difference in covering method between covered (*M* = 0.20, *SD* = 0.02) and uncovered (*M* = 0.16, *SD* = 0.02) cooling methods for 3 in. depths of chili (*t*(8) = 5.96, *p* < .001). Related pairwise t-tests for depth of chili revealed a significant difference between 2 in. depths of chili (*M* = 0.16, *SD* = 0.02) and 3 in. depths of chili (*M* = 0.20, *SD* = 0.02) for covered cooling methods (*t*(8) = -5.00, *p* = .001), and a significant difference between 2 in. depths of chili (*M* = 0.10, *SD* = 0.01) and 3 in. depths of chili (*M* = 0.16, *SD* = 0.02) for uncovered cooling methods (*t*(8) = -14.83, *p* < .001).

Aluminum stockpots and high-density polyethylene buckets: 12 in. diameters.
For cooling methods CM9 & CM10, compared with CM11 & CM12, a significant interaction effect was observed between covering method and depth of chili (*F*(1, 2) = 108.97, *p* = .009) (see Figure 2). Related pairwise t-tests for covering method revealed a significant difference between covered (*M* = 0.31, *SD* = 0.01) and uncovered (*M* = 0.25, *SD* = 0.01) cooling methods for 3 gallon amounts of chili (*t*(2) = 19.98, *p* = .002), and a significant difference in covering method between covered (*M* = 0.52, *SD* = 0.01) and uncovered (*M* = 0.39, *SD* = 0.01) cooling methods for 5 gallon amounts of chili (*t*(2) = 24.26, *p* = .002). Related pairwise t-tests for amount of chili revealed a significant difference between 3 gallon amounts of chili (*M* = 0.31, *SD* = 0.01) and 5 gallon amounts of chili (*M* = 0.52, *SD* = 0.01) for covered cooling methods (*t*(2) = -33.50, *p* = .001), and a significant difference between 3 gallon amounts of chili (*M* = 0.25, *SD* = 0.01) and 5 gallon amounts of chili (*M* = 0.39, *SD* = 0.01) for uncovered cooling methods (*t*(2) = -46.70, *p* < .001).

Analysis of chili cooled from 135ºF to 41ºF (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) = 44.49, *p* < .001). Covered containers (*M* = 0.481) took longer to cool than uncovered containers (*M* = 0.341). In addition, there was a significant main effect of the depth of chili on cooling time (*F*(1, 8) = 127.06, *p* < .001). Containers at 3 in. depths (*M* = 0.483) took longer to cool than containers at 2 in. depths (*M* = 0.339). No interaction effect was observed between covering method and depth of chili (*F*(1, 8) = 0.74, *p* = .416).

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) = 101.33, *p* < .001). Covered containers (*M* = 0.508) took longer to cool than uncovered containers (*M* = 0.347). In addition, there was a significant main effect of the depth of chili on cooling time (*F*(1, 8) = 103.69, *p* < .001). Containers at 3 in. depths (*M* = 0.498) took longer to cool than containers at 2 in. depths (*M* = 0.356). No interaction effect was observed between covering method and depth of chili (*F*(1, 8) = 2.84, *p* = .13).

Table 4. Two-way (2x2) Repeated Measures ANOVA – Analysis of Data for Chili Cooled from 135 ºF to 41 ºF

Cooling Methods (CM) Compared	Main Effect of Covering Method	Mean of Covered (*SE*)*	Mean of Uncovered (*SE*)*	Main Effect of Depth of Chili	Mean of 2 in. Depth (*SE*)*	Mean of 3 in. Depth (*SE*)*	Interaction of Covering Method & Depth of Chili
CM1 & CM2 (12 in. x 10 in. x 2 in. chili depths) CM5 & CM6 (12 in. x 10 in. x 3 in. chili depths)	*F*(1, 8) = 44.49, *p* < .001	0.481 (0.015)	0.341 (0.009)	*F*(1, 8) = 127.06, *p* < .001	0.339 (0.010)	0.483 (0.009)	*F*(1, 8) = 0.74, *p* = .416
CM3 & CM4 (12 in. x 20 in. x 2 in. chili depths) CM7 & CM8 (12 in. x 20 in. x 3 in. chili depths)	*F*(1, 8) = 101.33, *p* < .001	0.508 (0.015)	0.347 (0.012)	*F*(1, 8) = 103.69, *p* < .001	0.356 (0.010)	0.498 (0.016)	*F*(1, 8) = 2.84, *p* = .13

Cooling Methods (CM) Compared	Main Effect of Covering Method	Mean of Covered (*SE*)*	Mean of Uncovered (*SE*)*	Main Effect of Amount of Chili in gallons	Mean of 3 gallon Amount (*SE*)*	Mean of 5 gallon Amount (*SE*)*	Interaction of Covering Method & Amount of Chili
CM9 & CM10 (12 in. diameter x 3 gallons chili) CM11 & CM12 (12 in. diameter x 5 gallons chili)	*F*(1, 2) = 98.06, *p* = .01	1.147 (0.022)	0.863 (0.017)	*F*(1, 2) = 448.58, *p* = .002	0.760 (0.023)	1.250 (0.009)	*F*(1, 2) = 75.30, *p* = .013**

*Mean times are reported in days (1.000 = one day), *SE* = standard error.
** See Figure 3 for interaction profile plot.

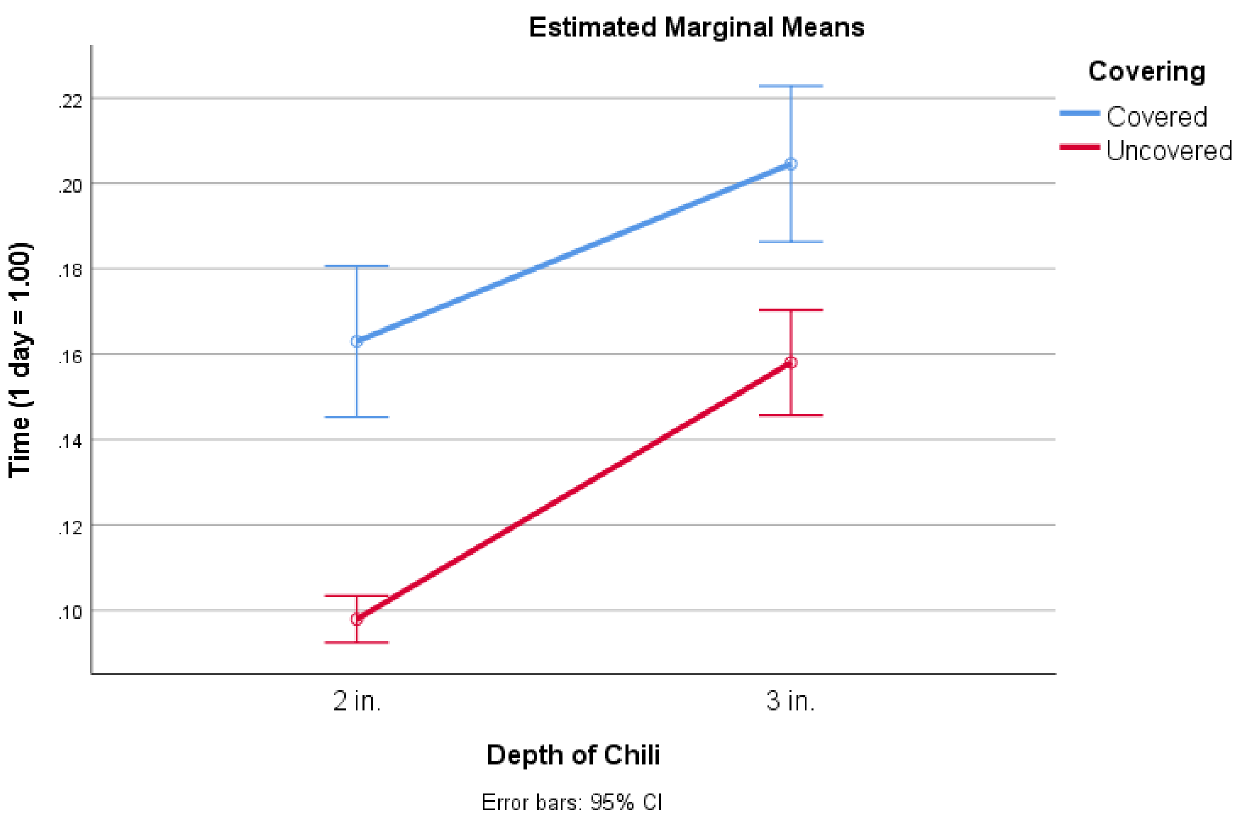

Figure 1. Interaction Profile Plot for Cooling Method 3 (Covered, 2 in.) and Cooling Method 4 (Uncovered, 2 in.); Compared to Cooling Method 7 (Covered, 3 in.) and Cooling Method 8 (Uncovered, 3 in.) for chili cooled from 135ºF to 70ºF.

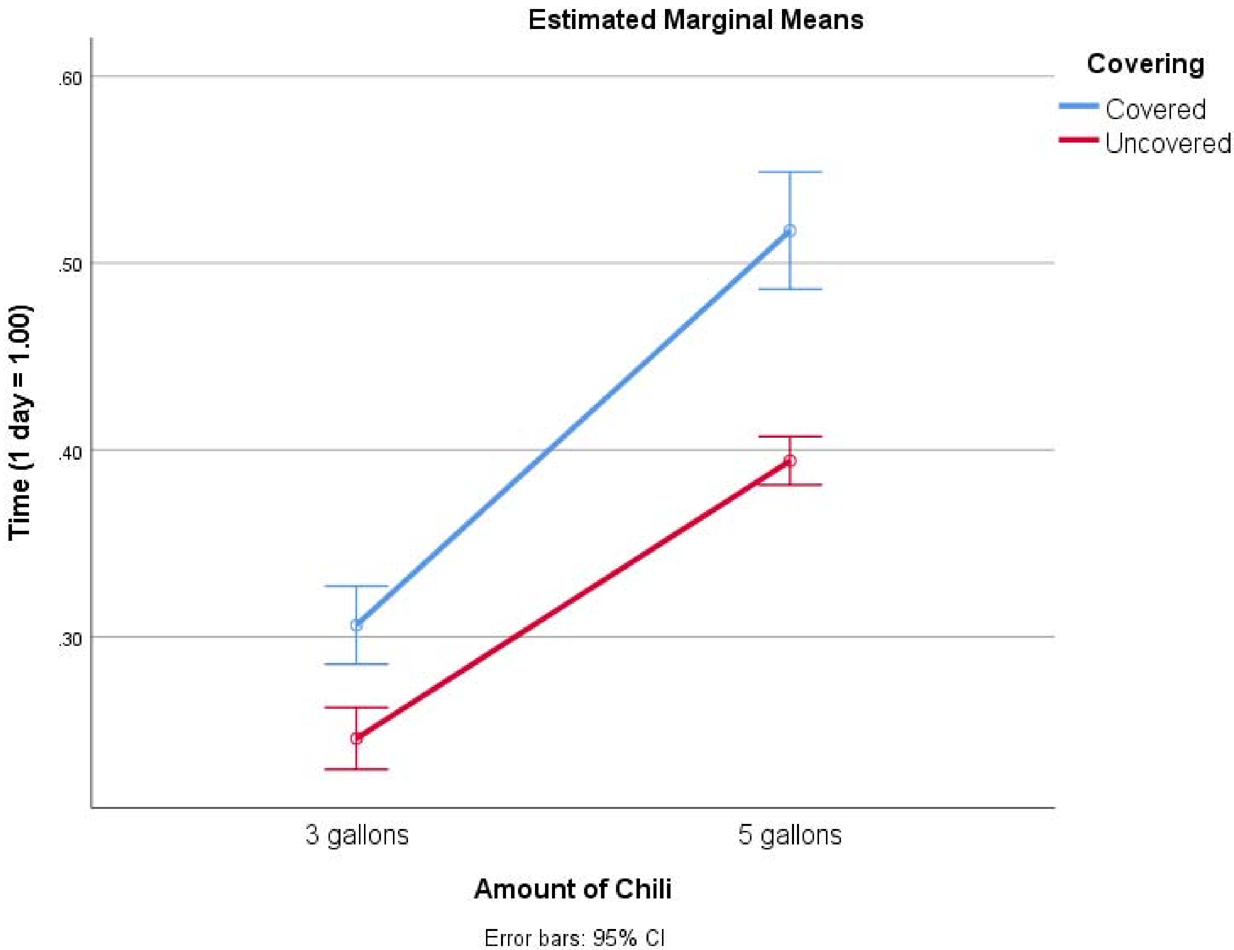

Figure 2. Interaction Profile Plot for Cooling Method 9 (Covered, 3 Gallons) & Cooling Method 10 (Uncovered, 3 Gallons); Compared to Cooling Method 11 (Covered, 5 Gallons) & Cooling Method 12 (Uncovered, 5 Gallons) for Chili Cooled from 135ºF to 70ºF.

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

For cooling methods CM9 & CM10, compared with CM11 & CM12, a significant interaction effect was observed between covering method and amount of chili ($F(1, 2) = 75.30$, $p = .013$) (see Figure 3). Related pairwise t-tests for covering method revealed a significant difference between covered ($M = 0.85$, $SD = 0.04$) and uncovered ($M = 0.68$, $SD = 0.04$) cooling methods for 3 gallon amounts of chili ($t(2) = 10.94$, $p = .008$), and a significant difference in covering method between covered ($M = 1.44$, $SD = 0.05$) and uncovered ($M = 1.05$, $SD = 0.02$) cooling methods for 5 gallon amounts of chili ($t(2) = 9.52$, $p = .011$). Related pairwise t-tests for amount of chili revealed a significant difference between 3 gallon amounts of chili ($M = 0.85$, $SD = 0.04$) and 5 gallon amounts of chili ($M = 1.45$, $SD = 0.05$) for covered cooling methods ($t(2) = -19.39$, $p = .003$), and a significant difference between 3 gallon amounts of chili ($M = 0.68$, $SD = 0.04$) and 5 gallon amounts of chili ($M = 1.05$, $SD = 0.02$) for uncovered cooling methods ($t(2) = -17.76$, $p = .003$).

SUMMARY OF RESULTS

While the FDA's recommendations of cooling food uncovered and reducing the depths/amounts of food products did improve the cooling processes, the 2017 FDA Food Code standards were still not met in this study. No cooling method tested in this study cooled chili from 135ºF (57ºC) to 70ºF (21ºC) within two hours and from 135ºF (57ºC) to 41ºF (5ºC) within a total of six hours or less.

The cooling method requiring the shortest cooling time from 135ºF to 41ºF (M = 6 hr 23 min, SD = 33 min) was the uncovered 12 in. x 20 in. stainless steel foodservice pan at a 2 in. food product depth (see Figure 4). The cooling method requiring the longest cooling time from 135ºF to 41ºF (M = 34 hr 47 min, SD = 1 hr 13 min) was the covered 5 gallons of chili in a high-density polyethylene bucket (see Figure 5), which is clearly an unacceptable cooling method that should never be considered for use in any type of foodservice operation.

Past studies have demonstrated that chili which was cooled uncovered in stainless steel foodservice pans at 2 in. depths in a walk-in freezer met FDA cooling time and temperature standards (Beardall et al., 2019a; Roberts et al., 2013; Watkins et al., 2016). However, available freezer space in school foodservice operations has been measured on average to be about 20% and this could be a barrier to cooling food in the freezer (Roberts et al., 2013). In addition, the safety and quality of frozen food normally stored in a walk-in freezer may be compromised if it is permitted to defrost while hot food products are cooling.

A prior study by Olds and Sneed (2005) explored ventilated cooling of chili con carne with beans using the following methods: (a) 12 in. x 10 in. stainless steel foodservice pans at 2 in. and 4 in. food product depths, cooled in a walk-in refrigerator; (b) 12 in. x 10 in. stainless steel foodservice pans at 2 in. and 4 in. food product depths, cooled in a blast chiller; (c) a stockpot containing 3 gallons of chili cooled in a

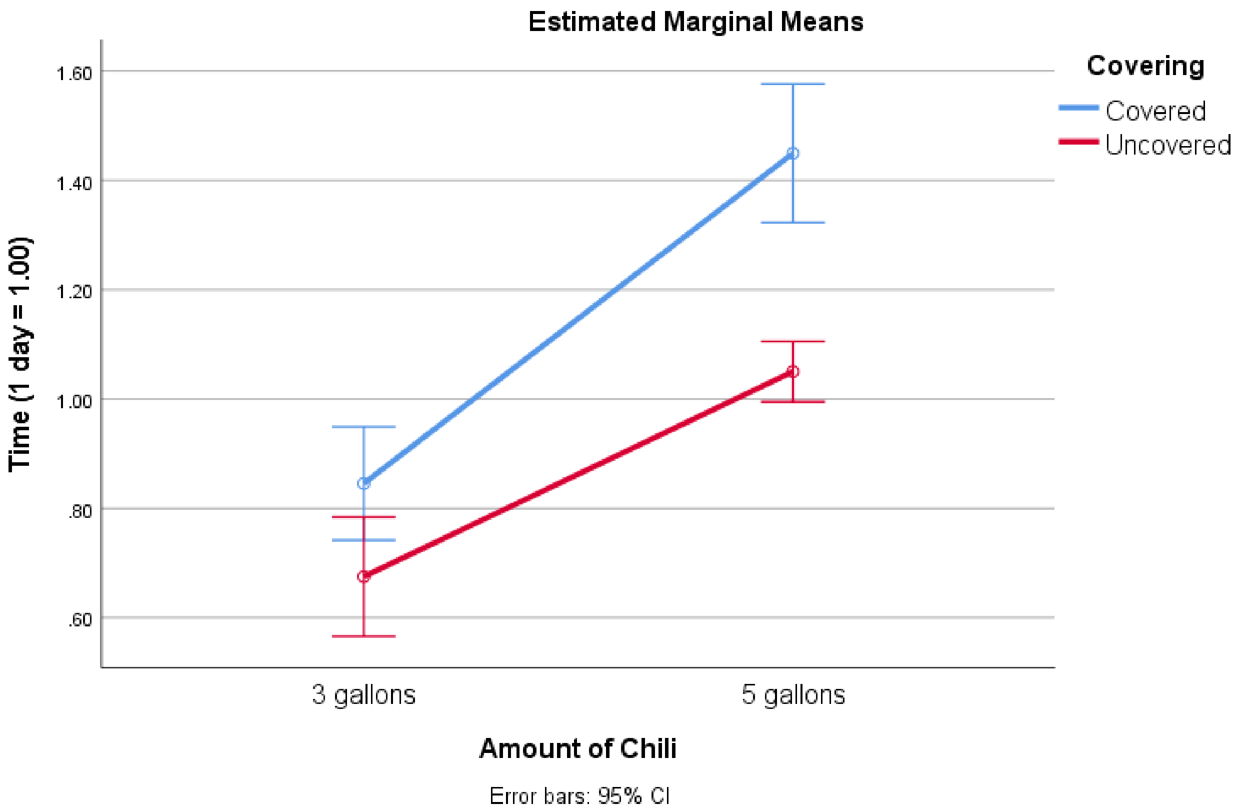

Figure 3. Interaction Profile Plot for Cooling Method 9 (Covered, 3 Gallons) & Cooling Method 10 (Uncovered, 3 Gallons); Compared to Cooling Method 11 (Covered, 5 Gallons) & Cooling Method 12 (Uncovered, 5 Gallons) for Chili Cooled from 135ºF to 41ºF.

walk-in refrigerator; and (d) a chill stick used in a stockpot containing 3 gallons of chili, while cooling in a walk-in refrigerator. The only methods that satisfied FDA Food Code cooling standards were those that utilized the blast chiller, which rapidly cooled chili at both 2 in. and 4 in. food product depths within the recommended times. Blast chillers are effective for rapidly cooling food products, but it has been estimated that only about 8% of onsite foodservice operations actually utilize them during food production (Krishnamurthy & Sneed, 2011). However, blast chillers can be prohibitively expensive to procure and thus may not be a feasible alternative for some onsite and retail foodservice operations, given the financial barriers (Olds et al., 2013).

According to the 2017 FDA Food Code section, "Holding Hot Food Without Temperature Control," food held without temperature control should meet the performance standard of no more than 1 log growth of *C. perfringens* and *B. cereus* spores (FDA, 2017). Meeting FDA Food Code cooling standards helps to ensure that spore-forming bacteria such as *C. perfringens* and *B. cereus* do not multiply to unsafe levels and cause foodborne illness. *C. perfringens* spores can be found in chili, a food item commonly prepared and served in onsite foodservice operations (Blankenship, Craven, Leffler, & Custer, 1988; Krishnamurthy & Sneed, 2011). The 2017 FDA Food Code (§ 3-501.15) outlines acceptable cooling methods based upon the type of food product. These cooling methods include portioning food into shallow pans. This study demonstrated that chili cooled uncovered at 3 in. depths took longer to cool, as expected, than chili cooled uncovered at 2 in. depths. As shown in Table 2, chili cooled uncovered at 2 in. depths (cooling methods CM2 & CM4) only slightly exceeded Food Code standards. Further reduction of the depths of chili, while being cooled uncovered in a walk-in refrigerator, could potentially meet 2017 FDA Food Code cooling standards. If this was confirmed in a future research study, it could become a useful standard operating procedure for foodservice operations where walk-in freezers and blast chillers are not feasible options for cooling food.

CONCLUSIONS AND APPLICATIONS

The purpose of this research was to determine if practices commonly used to cool food produced in onsite foodservice operations would meet established 2017 U.S. FDA Food Code cooling standards.

The following conclusions were made based on the results of this study:

1. None of the cooling treatments tested in this study met 2017 FDA Food Code cooling standards.
2. For all cooling methods tested in this study, unventilated (covered) cooling methods took significantly longer to cool than ventilated (uncovered) cooling methods ($p < .05$).
3. For all cooling methods tested in this study on containers of identical widths and lengths, cooling methods with 3 in. depths of chili took significantly longer to cool than cooling methods with 2 in. depths ($p < .005$).
4. For all cooling methods tested in this study on containers of identical diameters, cooling methods with 5 gallon amounts of chili took significantly longer to cool than cooling methods with 3 gallon amounts of chili ($p < .005$).
5. Because FDA Food Code cooling standards were not met, the potential existed for spore-forming bacteria, such as *C. perfringens*, to multiply to unsafe levels.
6. Future research could help determine if cooling chili uncovered at depths less than 2 in. in a walk-in refrigerator would meet 2017 FDA Food Code cooling standards.

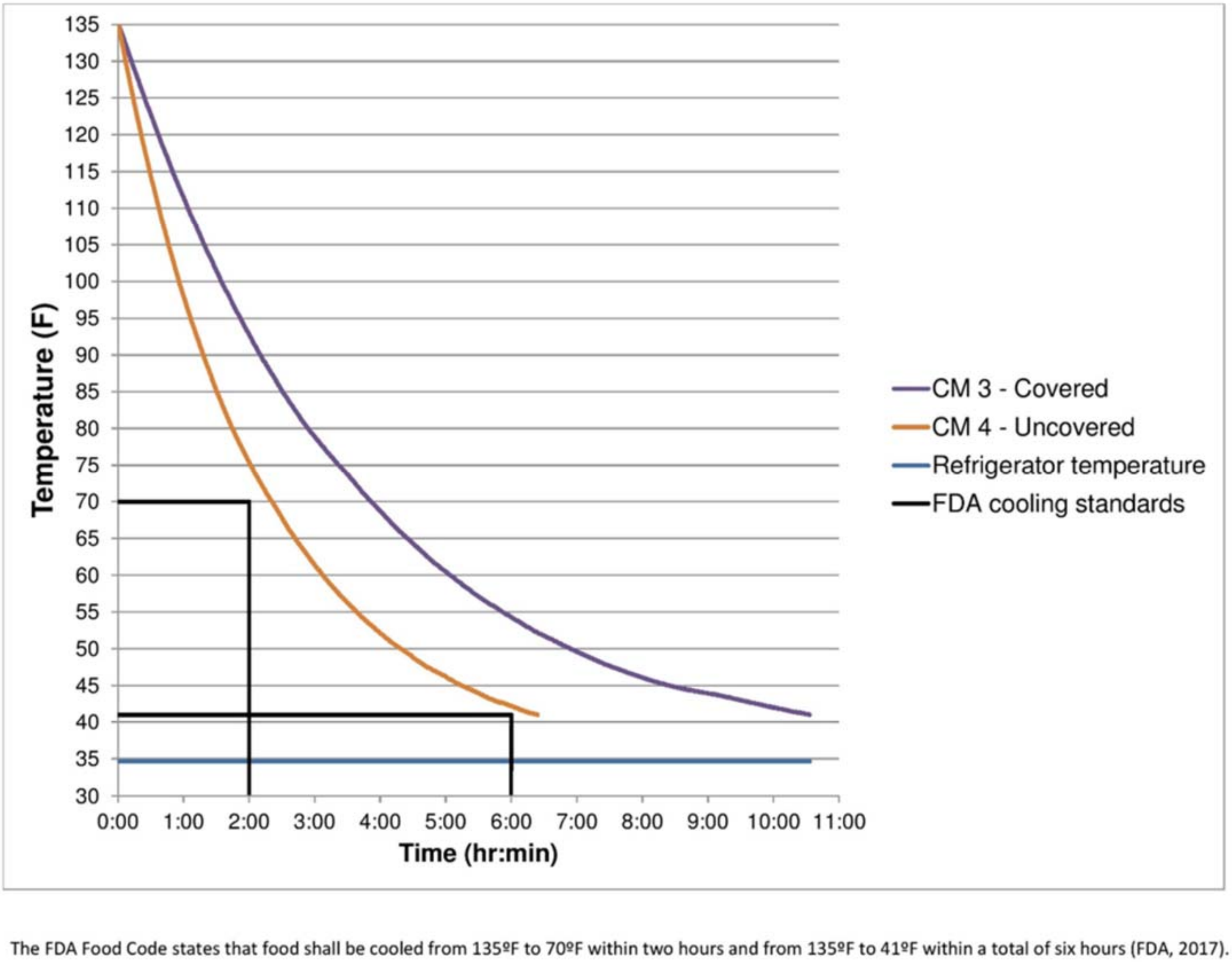

Figure 4. Cooling Curves for Cooling Method 3 (Covered) and Cooling Method 4 (Uncovered); Both Utilizing a 12 in. x 20 in. x 2½ in. Foodservice Pan with a 2 in. Depth of Chili and Cooled in a Walk-in Refrigerator from 135ºF to 41ºF.

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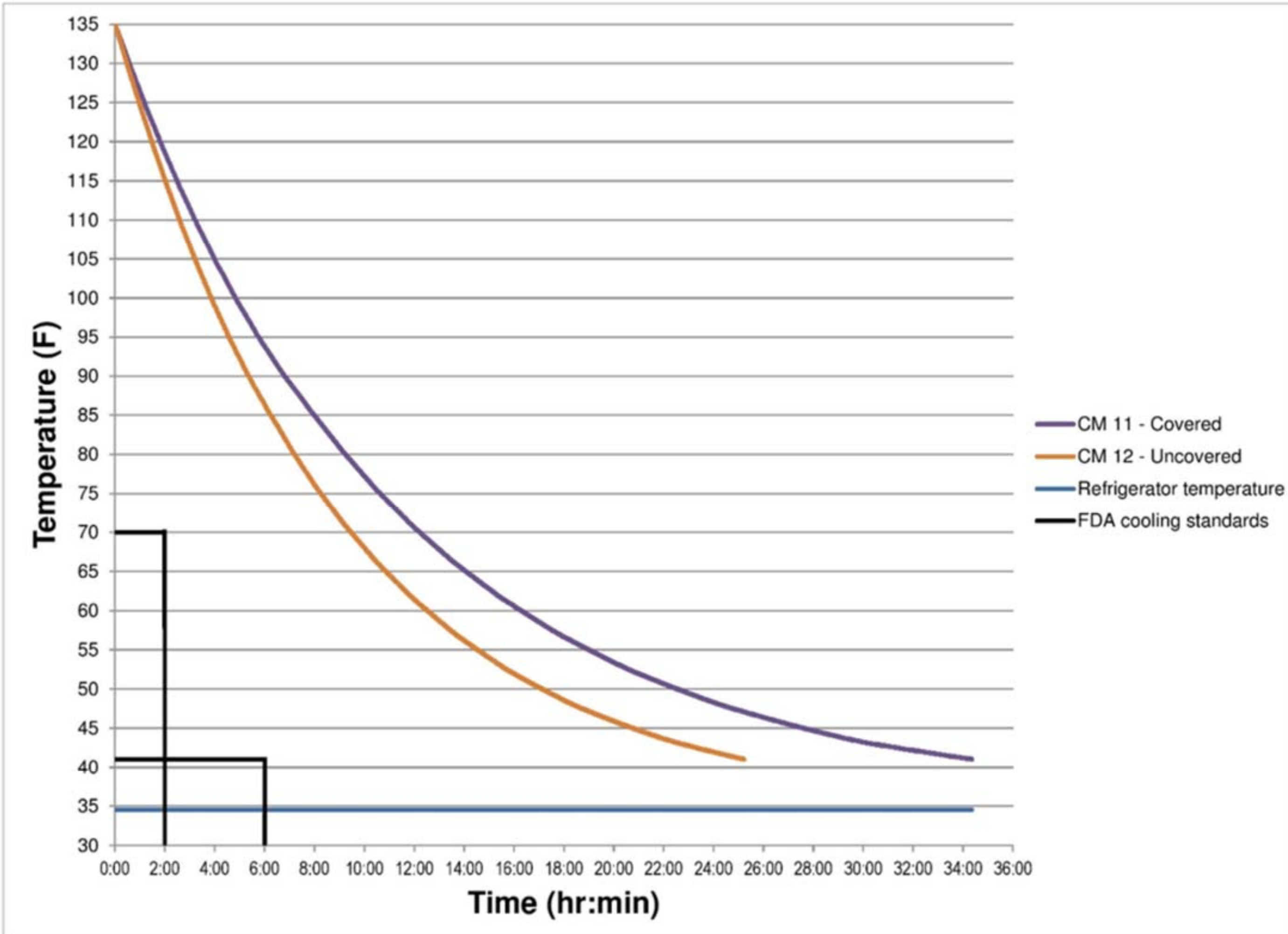

The FDA Food Code states that food shall be cooled from 135ºF to 70ºF within two hours and from 135ºF to 41ºF within a total of six hours (FDA, 2017).

Figure 5. 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 Chili and Cooled in a Walk-in Refrigerator from 135ºF to 41ºF.

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