PRECOOLING HOT FOOD USING KITCHEN-TEMPERATURE AIR

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Introduction

In 1976, the FDA Food Service Sanitation Manual *(10)* began to specify cooling times and temperatures, because inadequate refrigeration processes had been identified as the major cause of foodborne illness *(2)*. The manual stated that: "Potentially hazardous foods requiring refrigeration after cooking shall be rapidly cooled to an internal temperature of 45ºF or below. --- Methods such as shallow pans, agitation, quick chilling or water circulation external to the food container shall be used so that the cooling period shall not exceed 4 hours." (See §2-302 of the 1976 FDA Food Service Sanitation Manual.) No validated research study was cited to justify the 4-hour recommendation.

Since 1993, the FDA Food Code has recommended that food be cooled from 140 to 70ºF in less than 2 hours, and from 70 to 41ºF or less in 4 hours. (See §3-501-14 of the 1993, 1995, 1997, and 1999 FDA Food Codes *(6, 7, 8, 9)*. The reference for 6 hours is a 1957 research study *(12)*, which really only proves that *Escherichia coli* can grow when food cools too slowly from 110 to 60°F, but says nothing about 140 to 41°F. Again, no scientific research studies were referenced for the 140 to 41°F requirement.

The FDA Food Code gives no recommendations for precooling hot food. The code implies that the cook should put the hot food directly into a refrigeration unit. Many times, this hot food is at temperatures well above 140ºF when removed from a heating device (e.g., kettle, oven, or stove top).

If hot food is immediately put into a walk-in or reach-in refrigerator, an excessive Btu cooling load is placed on the cooling unit. The highest growing temperature for a foodborne pathogen (*Clostridium perfringens*) is 125.6ºF *(13)*. The question is then: "Is it really necessary to begin cooling food directly after cooking, or can part of the cooling be done at kitchen temperatures?"

Most commercial foodservice refrigerators are built to NSF Standard 7 *(1)*. This standard specifies criteria for refrigeration performance in an environment with 90ºF air blowing through the condenser coil, but does not specify standards for the cooling capacity of refrigeration units. When new reach-in refrigerators are tested in the factory, the units are empty, and the door is never opened. If the compressor is on 70% or less of the time, and the temperature within the refrigerator does not rise above 40ºF in a 4-hour test period, the NSF standard is met. NSF-compliant refrigerators have no capacity and are not tested to cool food to 41ºF within 6 hours. Published research *(14)* has shown that a covered pan of food, with a depth of 2 inches, requires 11 to 14 hours to cool in an NSF-compliant refrigerator with an air temperature of 38ºF and typical air flow of 40 to 50 feet per minute.

Walk-in refrigerators do not work any better. These refrigeration units are not tested to conform to NSF Standard 7. However, the compressor capacity of most commercial walk-in units is just enough to balance the heat gain through the walls (door never opened) and operate at 38ºF (±2ºF), which is the same performance standard as NSF Standard 7 refrigerators.

Why, then, do refrigerators work as well as they do to cool food? The reason is that, between approximately 10:00 PM to 8:00 AM (about 10 hours), the door is not opened, and the compressor can reduce the air temperature within the refrigerator to less than 40ºF. Thus, food can be cooled to, perhaps, 35°F. The temperature of the food cannot go much below this, or the evaporator coil of the refrigeration unit will freeze up, because the refrigerant is operating at 15 to 20°F.

In the morning, the cold food acts as a "heat sink," and it slowly warms, absorbing Btu's from door openings and from hot food when it is placed in the refrigeration unit to cool. One hundred (100) pounds of food with a nominal specific heat of 0.75 Btu per pound, warming from 35 to 40ºF, will absorb 375 Btu's of heat. This might cool about 2 pounds of food from 190 to 40ºF (150ºF). This cycling of food temperatures from cold at night to warm during the day is very detrimental to food quality, as well as being inefficient. The growth rate of spoilage microorganisms is about one generation every 15 hours at 35ºF, and one generation every 5.5 hours at 45ºF. So, 45ºF at 8:00 PM is not dangerous if the food was at 35ºF for 10 hours at night. The slow and fast growth rates balance out.

Maintenance of temperature and energy conservation

Bryan et al. *(3)* reported the following example of the effect of warm food on refrigeration temperature: "After cooking, turkeys were deboned and the still-warm meat and stock were put into the reach-in refrigerator. The refrigerator air temperature rose from 34ºF to more than 90ºF and remained above 50ºF for 10 hours." If restaurants do not have to put hot food directly into refrigeration units to meet regulatory requirements, the cold air temperatures of these units can be maintained at a more uniform, low temperature of 45ºF. If refrigerators were allowed to operate at 45ºF vs. 40ºF, there would be an expected power savings of 39% per refrigeration unit *(5)*.

Allowing food to cool at room temperature before it is placed in a refrigeration unit will also conserve energy by decreasing the Btu cooling load on refrigeration units. For example, to cool 1 pound of food with a specific heat of 0.75 Btu / lb. from 190 to 90ºF requires 75 Btu's. To cool the food from 90 to 40ºF requires 37.5 Btu's. Therefore, if the food were to cool to 90ºF before it was placed in a refrigeration unit, there would be a Btu saving of 100%.

Is there a microbiological hazard?

What is the microbiological hazard from cooling hot food in the kitchen, prior to putting it into the refrigerator? Juneja et al. *(11)* showed that continuous cooling of cooked hamburger from 130 to 45ºF in 15 hours allows about 1 log of multiplication of *Clostridium perfringens*. This study is now used as the performance standard for safe food cooling by the USDA (*4)*. This is a 15-hour continuous cooling period for cooling food from 130 to 45ºF with a 38ºF driving force (refrigeration air temperature). In this cooling, 2 ½ hours is required to decrease the temperature of the food from 130 to 93ºF. If food can be cooled at this rate at kitchen temperatures, it will be safe.

Experimental procedure

The experiment was conducted in a commercial restaurant kitchen. The kitchen air temperature (cooling driving force) ranged from 60ºF when the experiment started at 8:00 AM to about 83ºF when the kitchen heated up by noon.

A simulated sauce was prepared by bringing water to a boil and stirring in a slurry of water and flour to the hot water to achieve a final concentration of 7% by weight flour to water. After heating, the mock sauce was filled 2 inches deep in 12"x 20"x 2 ½" pans. In order to measure the temperature decline in the sauce as it cooled, a 30-gauge chromal-aluminal thermocouple was fastened 1 inch from the bottom of a 1/8-inch-diameter polypropylene rod. The rod was then placed vertically into the pan with the tip resting on the bottom of the pan. With this arrangement, the geometric center temperature in the middle of the 2-inch deep simulated sauce could be accurately measured with a Model 50 Electronic Controls and Design 5-thermocouple-channel data logger (ECD, Beaverton, OR). See Figure 2.

Two methods of cooling at kitchen temperature were measured. One method utilized a $15.00, 20-inch, box floor fan from a discount store. The fan was placed on the side of the rack holding the pan of food and blew kitchen air across the food at about 1,000 feet per minute (Figure 3). For the second method of cooling, the fan was not used (Figure 4). For both methods, the pans of mock sauce rested on 1-pint, plastic inserts so that there was no restriction of air flow across the bottom of the pans. Cooling research *(15)* has shown that about 75% of the heat is extracted from the bottom of the pan, rather than the covered top of the pan. Therefore, there must be free airflow across the bottom of the pan.

Results and Discussion

Comparison of product cooling is shown by the data in Tables 1 and 2. The surrounding kitchen air temperature for the simulated sauce cooled in the presence of a fan ranged from a starting temperature of 60°F at 8:00 AM to 83°F at noon. A graph of the cooling processes is shown in Figure 1.

With no fan, the sauce cooled from 130 to 93°F in about 5 3/4 hours. With a fan, the center temperature of the sauce cooled from 130 to 93°F in about 1 hour.

Juneja et al. *(11)* showed in this study to determine safe cooling of food, that cooked hamburger, inoculated with spores of *C. perfringens,* cooled continuously from 130 to 45°F in 15 hours was safe. In this study, the time to go from 130 to 93°F was 2 ½ hours. (See Figure 1.) Obviously, fan cooling of hot food to 10°F above kitchen temperature is safe.

Conclusion

This experiment shows that hot food can be cooled safely in a commercial kitchen at 83°F if a simple floor fan is used to blow air across the pans of covered food. A simple way to do this is to mount fans to the side of a rack and load the rack with hot food. The hazard is the spores of *C. perfringens* that survive cooking. This hazard is controlled by the rapid cooling between 130 and 93°F. The control point is monitored with a tip-sensitive digital thermistor thermometer, positioned in the middle of the food. The cook reads the thermometer 2 times, about 1 hour apart, and if the slope of the line is faster than that shown on Figure 1 for ***Juneja Safe Cooling***, the cooling is safe.

There is no scientific reason for placing hot food in a refrigeration unit immediately after it has been removed from the heat source. Allowing covered hot food to cool in front of a fan in a kitchen is safe. When the food gets to about 90°F, it should be placed in the refrigeration unit to finish cooling. This procedure has the potential for saving millions of Btu's of refrigeration energy that is currently wasted in food operations to cool hot food above, for example 90°F, without any risk. Inexpensive digital thermometers can now be programmed to sound when a temperature of 90°F is reached in the food. If this type of a thermometer is used, the cook will not forget to put the food in the refrigerator. If the cook were to do the process once with fans and 2-inch pans of food and qualify the process as safe, the temperature of the food does not have to be monitored. The hazard control is monitored simply by verifying that the fans are on and the food is 2 inches deep or less in the pan. The bimetallic coil thermometer cannot be used to monitor this procedure, because it is not tip sensitive.

References:

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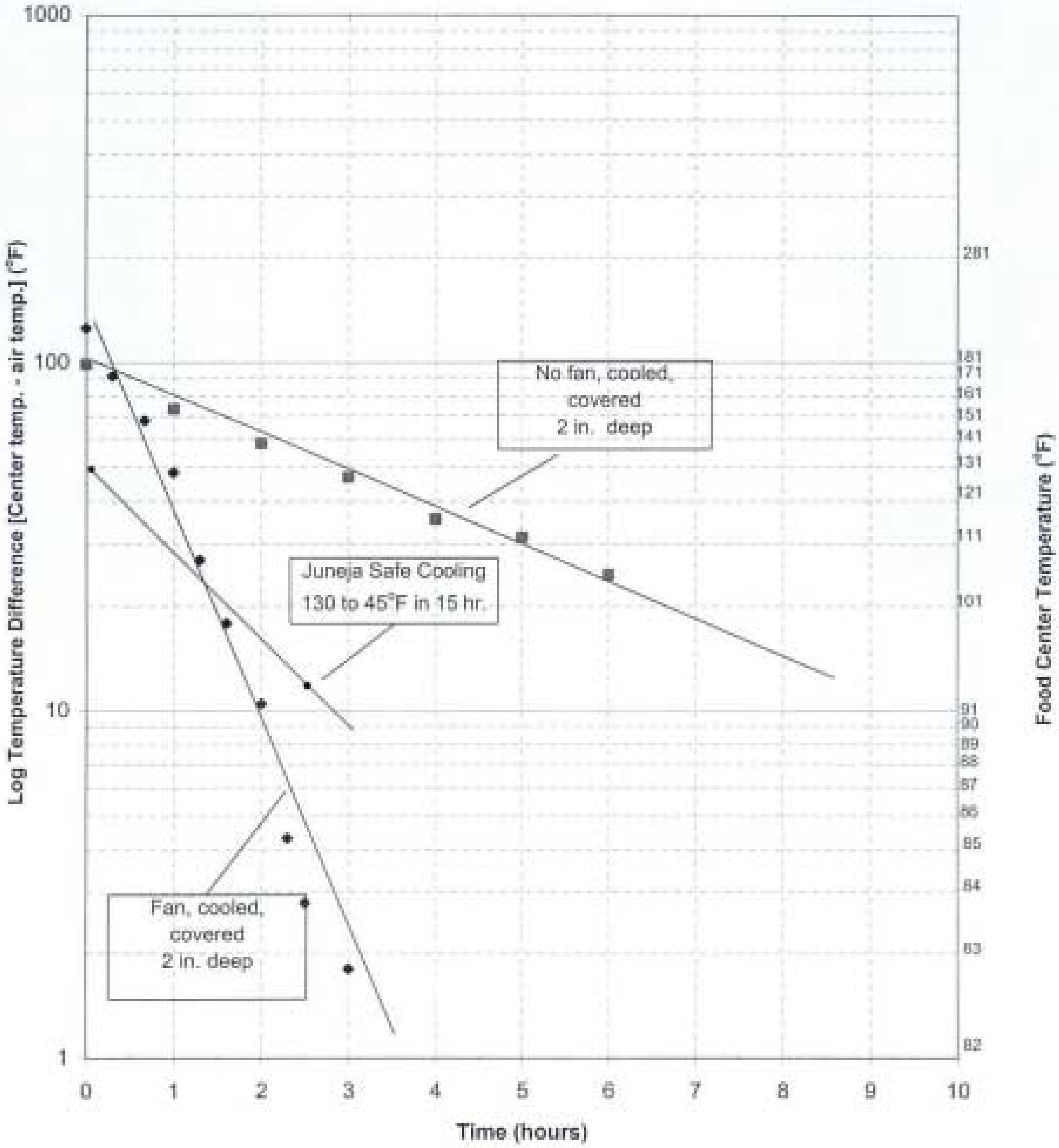
Figure 1. COOLING PANS OF SAUCE

Cooling sauce (flour-thickened water) in 12"x20"x2-1/2" pans (2" depth)
at kitchen temperature, using a fan, and no fan
compared with the Juneja 15 hour-cooling curve.



Tables 1 and 2. COOLING PANS OF FLOUR-THICKENED WATER AT ROOM TEMPERATURE USING A 1,000-FT./MIN. FAN AND NO FAN

Table 1. With Fan

Time (h)	Center Temp (°F)	Air Temp. (°F)	Temp Difference (°F)
0	185.8	60.1	125.7
0.3	158.0	66.5	91.5
0.67	134.8	66.8	68.0
1	117.1	68.9	48.2
1.3	105.0	77.9	27.1
1.67	97.0	79.1	17.9
2	91.5	81.0	10.5
2.3	87.4	83.1	4.3
2.5	86.0	83.2	2.8
3	82.8	81.0	1.8
4	79.8	79.0	0.8

Table 2. Without Fan

Time (h)	Center Temp (°F)	Air Temp (°F)	Temp Difference (°F)
0	179.0	80.0	99.0
1	154.1	80.5	73.6
2	137.6	79.1	58.5
3	125.0	78.3	46.7
4	115.2	79.7	35.5
5	107.5	76.0	31.5
6	101.3	76.7	24.6

Figure 2. 2-1/2-inch stainless steel pan with 2-inch, flour-thickened water rigged for cooling

Figure 3. Rack with fan and 2" pan for cooling

Figure 4. Rack with no fan set up for pan cooling