Exposure Time of Warm Leftovers to Temperatures Suitable for Microbial Growth In a Home-Type Refrigerator

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ABSTRACT

A home-type refrigerator was used to determine the time of exposure of foods of varying solids content to temperatures suitable for microbial growth. The foods were handled using standard recommended public health procedures. Samples were tested with and without supplementary air circulation. The total time in the temperature range of 140°F to 45°F varied from 13 h to over 22 h. Supplementary air circulation had little benefit in reducing cooling times when used indirectly, i.e., when directed away from the test foods at the bottom of the refrigerator compartment. However, when the supplementary air was directed on the test foods from a distance of 4 inches, the cooling time was reduced by approximately one-half. The time of food exposure to a temperature range most favorable to microbial growth (100°F to 70°F) exceeded 5 h without supplementary direct air circulation, but was reduced to less than 2 1/2 h with direct forced air supplementary circulation. Alternate techniques to reduce the temperature of foods to supplement mechanical refrigeration are also discussed.

While the cooling rates of foods in commercial production and using commercial walk-in refrigeration boxes has been studied in the past (1,4,7), less information is available on cooling rates of food in a home-type refrigerator. The purpose of this study was to determine the time required to reduce the temperature of foods of varying solids content from 140°F to 45°F, using a standard home-type refrigerator. Since microorganisms associated with foodborne illness could multiply within this temperature range, the general practice of holding perishable foods within this danger zone beyond 4 h is questionable (3). Air Force Regulation 163-8, Control of Foodborne Illness, prescribes a 3-h cumulative time limit for foods exposed to this temperature range (2). Small satellite food facilities throughout the Air Force frequently use home-type refrigerators. It is not uncommon for these small facilities to store leftover foods in relatively small amounts in this type of refrigerator. Since the major cause of foodborne illness is improper refrigeration, this study was undertaken.

MATERIALS AND METHODS

Food

Three types of foods were selected for their varying solids content to be used in this test. Plain water simulating broth, canned mixed vegetables and water, and creamed beef and gravy, which is also irreverently known in some circles as SOS.

Container

A stainless steel steam table insert pan measuring 11 1/2 x 9 1/2 inches was used. When filled to a depth of 4 inches, the pan contained slightly less than 1 3/4 gal. of food material. Two holes were drilled at right angles in the sides of the pan 2 inches from the bottom, and rubber stoppers were inserted through which two calibrated baby dial thermometers were placed to reach the center of the food mass.

Refrigerator

The refrigerator used was a standard home-type model produced by General Electric. It had an upper freezer compartment and a lower refrigeration compartment of slightly over 8 ft³. The thermostat was set on eight from a scale of one to nine, which maintained an ambient temperature of 42°F within the compartment. At no time was the refrigeration compartment filled to its capacity.

Supplementary air circulation

A small electric fan with an output of approximately 1.3 ft³/min was used in some of the trials to provide supplementary air circulation within the refrigeration compartment. This was designed to prevent air stratification within the compartment when used indirectly, i.e., directed away from the food at the bottom of the compartment. The fan was also used to increase the chill factor when aimed directly at the food from a distance of about 4 inches.

Procedure

All test foods were heated to 140°F and held at that temperature for 30 min. The foods were then placed in the stainless steel insert pan to a depth of 4 inches, covered with aluminum foil, Saran® wrap (Dow Chemical Co., Indianapolis, Indiana) or left uncovered and placed in the refrigerator. The ambient air temperature of the refrigerator and the temperature of the center of the food mass were observed periodically. The temperature of each type of food was recorded, with and without supplementary forced air circulation.
One series of trials tested the samples of food treated by rapid cooling techniques other than a home-type refrigerator. In this series, the pan of food was tested either in a commercial refrigerator, in a freezer compartment or the pan was placed directly on ice. In one sample in this series, the test pan was not used during cooling. The food was placed in a plastic bag which was placed directly on ice.

RESULTS AND DISCUSSION

The ambient air temperature of the refrigerator was raised to the low 50s F soon after introduction of the warmed food and gradually returned to its low setting of 42 F over a period of 4 h or less. While Torrey and Marth (8) demonstrated a wide variation in the air temperature in a home-type refrigerator, Maxcy (5) indicated surprisingly small variations in temperature of the food mass when the food mass exceeded 100 g. In all home-type refrigerator samples tested without supplementary air circulation, the time required to reduce the temperature of the food from 140 F to 60 F exceeded 11 h. The time required to reach 45 F ranged from 13 h to over 22 h. Water cooled in 13 h while the mixed vegetables and the creamed beef required over 20 h to reach 45 F. These cooling rates are surprisingly similar to observations made in large commercial refrigerators, using comparable sized batches (1, 4, 7).

Supplementary air circulation has been demonstrated to reduce cooling times in large commercial refrigerators (7). However, in this experiment, indirect supplementary air circulation, directed away from the food at the bottom of the refrigeration compartment, did not consistently reduce the cooling time. If the supplementary air circulation fan was aimed directly on the food from a distance of 4 inches, the time required for cooling was reduced by about one-half.

Pre-cooling of product before refrigeration has been shown to be an advantage in reducing total cooling time (4). In this experiment, alternate pre-cooling methods generally reduced the cooling time by about one-half. One notable exception was the holding of the warmed product at room temperature, which simply prolonged the total cooling time. One heated water sample in this trial still was at 100 F after 5 h of cooling at room temperature (70 F).

If the temperature range of 140 F to 45 F is considered a danger zone, we should certainly consider a temperature range of 100 F to 70 F to be a "red alert" zone since this would be the most favorable temperature range for microorganisms associated with foodborne illness. Public health recommendations are that food should not be exposed to this temperature range in excess of 1 h (3). The test foods were exposed to this temperature range for an excess of 5 h without supplementary direct air circulation. However, this time was reduced to 2 1/2 h or less with direct supplementary air circulation. The comparative times for exposure to various temperature ranges under different experimental treatments are presented in Fig. 1. Miller and Smull (6) have demonstrated an increase in the population of staphylococcal food poisoning organisms of over 200 times after 9 h of incubation in a home-type refrigerator. It would appear that there is ample time for the production of gastro-intestinal irritants from a staphylococcal contaminant in any of the refrigerator trials in this experiment.

The time required to reduce a warm leftover food to a safe temperature range in a home-type refrigerator is longer than desirable. Covering the food to prevent airborne contamination also serves as an insulation blanket that retards the cooling process. The geometry of the container, geometry of the product and the thermal properties of the product also influence rates of cooling. The conditions of this study did not simulate the stresses encountered by a home-type refrigerator in commercial use. It would be impossible for home-type refrigerators to provide adequate cooling under stresses of commercial use. Commercial refrigerators are designed to perform better and, in fact, do perform better under temperature stresses. However, it is important to note that in this test, the commercial refrigerator used, which was a design approved by the National Sanitation Foundation, far exceeded the 3-h danger zone time limit of the Air Force Regulation and the 4-h danger zone temperature exposure recommended by public health standards.

It becomes apparent that the hazards associated with cooling of warmed leftover foods are essentially the same whether you are dealing with a large, highly sophisticated food processing plant in California or selling chili dogs at a remote site in Korea. The major issue in this study is the recognition of the prolonged time of exposure to critical temperature ranges even under ideal conditions. Extensive efforts to educate foodhandlers and their supervisors must be undertaken. While many factors influence whether or not conditions for an outbreak of foodborne illness do exist, i.e., degree of contamination, type of organism, nature of the food product, etc., time and temperature do play the critical role. It is conceivable that a bacterial population could increase...
from 100 to 10,000 times or more while stored overnight in a refrigerator. Misguided food handlers who wish to cool the food at room temperatures before placing the food under refrigeration will significantly increase the incubation time. It becomes imperative that all interested parties make every effort to reduce temperature abuse of food products to decrease the potential health hazard.

CONCLUSIONS AND RECOMMENDATIONS

Prevention of food temperature abuse is imperative for any rational program to control foodborne illness. Recognition of the prolonged time required to cool leftover foods to a safe temperature range should play a critical role in management practices. Any method of placing food in the refrigerator studied will allow a greater exposure to danger zone temperatures than is considered acceptable by public health standards. Precooling the food before refrigeration may be effective in reducing total cooling time (Fig. 2). Small food handling facilities should consider methods that might help reduce temperature abuse which would include the following.

1. Replace all home-type refrigerators with commercial models. These are more efficient, but even a conscientious replacement program would take a considerable amount of time and would not solve immediate problems.

2. Provide supplementary direct forced air circulation within the refrigerator compartment. Small electric fans and battery operated fans are commercially available which could favorably increase the rate of cooling when aimed directly on the food product.

3. Place hot foods in the freezer compartment until a temperature of 45°F is achieved. This would require additional handling of the product and the possibility of repeated freezing and thawing may cause greater deterioration of the food than the temperature abuse.

4. Place the pan of hot food in an ice bath before placing in the refrigerator. This would require additional handling and would also require stirring or agitation for best results while in the ice bath. Most food facilities do have adequate amounts of ice available. This practice, if followed, would prevent a temperature increase in the refrigerator from a warmed product.

5. Place hot foods in a plastic bag and immerse the bag in an ice bath. While this method dramatically increases the cooling rate, it also greatly increases the possibilities for contamination of the food product if a leak occurs in the plastic bag. The risk does not outweigh the benefit in these author’s opinion.

Whatever method is used to improve refrigeration techniques, good sanitary practices in handling the food product are still required for prevention of foodborne illness.

REFERENCES