Hazard Analysis of Frozen Dinners Prepared at a Catering Establishment

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ABSTRACT

Frozen dinners prepared by a caterer were reported to have been spoiled. Microbiological testing of samples was performed, and a survey of time-temperature exposures (during preparation, storage, delivery and reheating) was conducted of procedures duplicating those at the time the spoiled food was prepared. Growth of spoilage bacteria was not inhibited by freezing a customer's week's supply of packaged meals in cardboard boxes. This growth continued during transit in a precooled insulated truck. Meals reheated in a plywood box oven (furnished by the caterer for this purpose) failed to reach lethal temperatures for vegetative mesophilic bacteria within a practicable time (90 min). Holding the meals in wire baskets or in shallow metal trays during freezing and reheating the frozen meals to 74 C (165 F) in conventional domestic ovens prevented spoilage of the meals.

Large numbers of persons are now being fed in day-care centers, homes for the elderly, half-way houses and centers for children of poverty-level families. These and related feeding activities have increased the demand for catered meals, and small caterers have been attracted to the resulting market. Some of these caterers, however, are ill-equipped to deal with the volumes involved and have unconventional methods for preparing, transporting or serving foods.

An episode concerning such a caterer who had just started marketing frozen dinners led to the study presented here. Dinners were prepared and frozen and subsequently delivered in an insulated truck, precooled for this purpose. On the first day these dinners were heated for meal service, several customers complained to health departments that the food was spoiled. A hazard analysis of the preparation, freezing, transportation, storage and reheating of the dinners was done to detect practices that might have contributed either to the spoilage of the food or to the risk of food poisoning. It is hoped that the results of this study will serve as a warning and a guide to sanitarians and to administrators of feeding programs who must judge the quality of catering operations.

METHODS

Catering operations

The caterer prepared several kinds of dinners, but because the chicken dinners were reported to be spoiled, the investigation was limited to the preparation of these. The sequence of events that led to the spoilage was as follows. Raw, chilled chickens were cut-up and frozen. Several days later the frozen chickens were thawed in a walk-in cooler and put into a pan with barbecue sauce. The pieces of chicken and the vegetables (canned yams and either peas or lima beans) were cooked in separate pans in a stack oven. A fork and an ice cream scoop were used to put the chicken and vegetables into compartmentalized plastic trays, and a clear plastic was heat-sealed over the trays. The sealed trays of food were stacked in cardboard boxes. Each box contained a week's supply for each customer. The boxes were stored overnight in a walk-in freezer and transferred to a precooled, insulated truck the next morning. Several incidents delayed delivery of the food which was stored in freezers on arrival at the destination.

On the day of serving, 15 to 30 frozen dinners were heated in plywood-box ovens (71.2 x 50.8 x 61.0 cm; 28 x 20 x 24 inches). Each box had a rack (made of plywood strips) located 20.3 cm (8 inches) above the bottom. These racks supported the trays. Air was circulated within each box by two, 20.3-cm (8-inches) fans (1/100 hp, 1500 rpm). Heat was supplied by four to seven, 350- to 500-watt, metal-housed, electric heating elements which were located in the bottom of the box. A thermostat with a cut-off temperature of 68 to 82 C (155 to 180 F) was fastened to a plywood partition (with the fans), 7.6 cm (3 inches) from one end of each box. According to the caterer's instructions, the meals were heated for 90 min and then served (unless, as at some establishments, spoilage was observed).

At the catering establishment, each step of the process was simulated, from thawing chickens through the reheating of the frozen meals, as closely as possible to the actual operation. Three modifications of the procedures were also evaluated. These were: (a) meal trays were stored in the freezer either in wire baskets or on metal shelves instead of in cardboard boxes, (b) frozen meals were stored in wire baskets instead of cardboard boxes in a precooled, insulated truck and (c) meals were reheated in aluminum trays in a residential-type oven instead of in the plywood-box ovens.

Temperature recordings

Previous articles describe the attachment and insertion of thermocouples and give specifications for thermocouples and the recording potentiometer (2,3).

Microbiological Examinations

Samples of raw and cooked food were collected with sterile implements and put into Whirl-Pak bags. Packaged meals were collected after the freezing and reheating steps of the operation. These samples were subjected to tests to indicate mesophilic aerobic counts, coagulase-positive staphylococci, Salmonella and Clostridium perfringens. Four swabs were taken of thawed, raw chickens and four of the utensils that had touched the cooked food. Two of each set of four swabs were put into tubes of thioglycollate broth, one into a tube of tetraphionate brilliant green broth and one into a tube of brain/heart.
HAZARD ANALYSIS OF FROZEN DINNER PREPARATION

10% salt broth. The caterer's hands were also sampled at the times he touched food by having him rub a sterile, 4 x 4-inch gauze pad (moistened with 10 ml of 0.1% peptone water) over his hands. This pad was put into a Whirl-Pak bag. All samples were cooled to 7 C (45 F) in a refrigerator. This temperature was maintained during delivery to the laboratory. Laboratory work was done by the Bacteriology Laboratory, Division of Physical Health, Georgia Department of Human Resources. Procedures followed those cited in the Bacteriological Analytical Manual (4), unless otherwise specified by Bryan and McKinley (2).

RESULTS AND DISCUSSION

Results of microbiological examinations of samples of chicken, utensils, and hand rinses are listed in Table 1.

Thawing

Thawed pieces of raw chicken had mesophilic, aerobic counts nearing the spoilage level. Coagulase-positive staphylococci were isolated from frozen, raw chicken and from the caterer's hands at the time he was filling the trays. C. perfringens was recovered from a rinse of the caterer's hands and from a swab sample of a utensil taken while the meals were being packaged. These recoveries indicated the possibility of post-cooking contamination.

Cooking

All foods that were tested reached temperatures above 93 C (200 F) during cooking. Such temperatures were maintained in the interior of the chicken from 1 h to 1 h and 13 min and in yams and peas for over 50 min (Fig. 1). Most vegetative bacteria, but not necessarily bacterial spores, would have been killed during the cooking of these foods.

FREEZING

The temperature of the freezer was higher than optimum (-23 C; -10 F or below) for freezing (Fig. 2). When meals in plastic trays were put on metal shelves on a rack in the freezer, the chicken cooled to 0 C (32 F)

TABLE 1. Bacteriological findings of samples of chickens at various stages of operations.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Mesophilic aerobic count/gram</th>
<th>Salmonella</th>
<th>Coagulase-positive staphylococci</th>
<th>Clostridium perfringens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freezing chicken pieces</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Thawing chicken</td>
<td>87,000,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Preparing chickens</td>
<td>14,000,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Workers' hands</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cooking chicken</td>
<td>&lt; 300</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Packaging meals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workers' hands</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Utensils</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Freezing meals</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Box</td>
<td>&lt; 300</td>
<td>-</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Basket</td>
<td>&lt; 300</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Tray rack</td>
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<td>-</td>
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<td>Reheating meals</td>
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<tr>
<td>Box 1</td>
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<td>-</td>
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<tr>
<td>Box 2</td>
<td>&lt; 300</td>
<td>-</td>
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<tr>
<td>Box 3</td>
<td>&lt; 300</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 1. Internal temperatures of chicken, yams, and peas during preparation, cooking, and packaging of meals.

Figure 2. Internal temperatures of chicken, peas, and yams in plastic trays in a wire basket, in a tray rack, and in a cardboard box during storage in a walk-in freezer.
throughout in 3 h and 10 min. Chicken in plastic trays in a wire basket cooled to 0°C (32 F) almost as rapidly -- within 3 h and 50 min. When the trays were stored in cardboard boxes, however, chicken in plastic trays cooled slowly; 11 h elapsed before the temperature was reduced to 0°C (32 F). Because of the combined effects of bacterial lag and decreasing temperatures, little bacterial growth would be expected in the chicken pieces in plastic trays stored on the shelves or in the baskets; but considerable bacterial growth could occur in the pieces of chicken in plastic trays in cardboard boxes.

When the spoilage problem occurred, it is likely that the foods stored in the cardboard boxes probably never froze, and the bacteria present multiplied to levels at which the chicken was considered “spoiled.”

Transporting
Routine delivery was simulated by placing frozen or refrigerated meals in a precooled, insulated truck (the same one used to deliver the spoiled food) and leaving the doors open for 2 to 10 min at intervals over a 9-1/2-h period.

Under these conditions, the air temperature in the truck gradually rose from 6 to 12°C (42 to 53 F). Frozen chicken in plastic trays in a wire basket did not thaw within 9-1/2 h (Fig. 3). Although the temperature of frozen chicken in trays in a cardboard box were recorded for 4 h only, the chicken had not thawed, and little increase in temperature was observed. The temperature of previously chilled, unfrozen chicken in a plastic tray on the floor of the truck rose in 2 h to within 1°C (2 F) of the air temperature in the truck.

Keeping frozen meals for a 10-h period in a precooled, insulated truck does not appear to cause a risk of bacterial multiplication in the food. Psychrotrophic bacteria would, however, multiply if unfrozen meals were kept in the truck. The food probably spoiled because the bacteria in the unfrozen food continued to multiply during transit, which took considerably more than 10 h at the time of the report of spoilage.

Reheating
When plastic trays containing frozen cooked chicken and vegetables were put in different locations in a 2450-watt plywood-box oven with a 68°C (155 F) thermostat and with fans that pulled air from the heating elements to the top of the box, internal temperatures of pieces of chicken reached 53 to 69°C (127 to 137 F) after heating for 3 h and 35 min (Fig. 4). After 90 min in the oven (the caterer’s recommended time for heating the meals), the internal temperature of the chicken reached only 42 to 44°C (107 to 112 F).

![Figure 3. Internal temperatures of frozen and thawed cooked chicken in plastic trays during heating in 2450-watt, wooden, convection oven (155 F thermostat) with fans pulling heat from elements and circulating hot air to top of unit.](http://www.journaloffoodprotection.com/downloadpii/jfp/article-pdf/43/8/608/1650979/0362-028x-43_8_608.pdf)

In a 1400-watt plywood-box oven with a 77°C (170 F) thermostat and fans that pushed air across the heating elements, internal temperatures of the chicken reached 60°C (140 F) after heating for 2 h and 30 min and stayed at that temperature until heating was terminated, 25 min later (Fig. 5). Frozen peas and thawed chicken heated more rapidly and reached temperatures of 69°C to 70°C (157 F to 158 F) at the end of the heating period. After 90 min in the oven, the internal temperature of the chicken reached 54°C (130 F).

In a 2200-watt plywood-box oven with an 82°C (180 F) thermostat and fans that pulled air from the heating elements, internal temperatures of frozen chicken ranged from 56 to 60°C (133 to 140 F) after 3 h and 30 min (Fig. 6). After 90 min in the oven, the internal temperature of the chicken reached 65°C (150 F).

![Figure 4. Internal temperatures of initially frozen and thawed chicken in plastic trays during heating in 2450-watt, wooden, convection oven (155 F thermostat) with fans pulling heat from elements and circulating hot air to top of unit.](http://www.journaloffoodprotection.com/downloadpii/jfp/article-pdf/43/8/608/1650979/0362-028x-43_8_608.pdf)

![Figure 5. Internal temperatures of initially frozen and thawed chicken and initially frozen peas in plastic trays during heating in 1400-watt, wooden, convection oven (170 F thermostat) with fans pulling heat over heating elements and up around meals.](http://www.journaloffoodprotection.com/downloadpii/jfp/article-pdf/43/8/608/1650979/0362-028x-43_8_608.pdf)
temperatures of chicken ranged from 47 to 54°C (117 to 122°F). In a unit of similar construction but with fans pushing air over the heating elements, internal temperatures of chicken reached 71°C (160°F) in 4 h and 15 min (Fig. 7). After 90 min in the oven, internal temperatures of the chicken ranged from 29 to 54°C (84 to 130°F).

Figure 6. Internal temperatures of initially frozen and thawed chicken in plastic trays during heating in 2200-watt, wooden, convection oven (180°F thermostat) with fans pulling heat from elements and circulating hot air to top of unit.

Figure 7. Internal temperatures of initially frozen and thawed chicken in plastic trays during heating in 2200-watt, wooden, convection oven (180°F thermostat) with fans pushing heat over heating elements and up around meals.

To assure destruction of vegetative bacteria that may be introduced after cooking or that may germinate from heat-resistant spores and multiply during the period required for freezing or during transit, a minimum temperature of 71°C (160°F) must be reached in the interior of foods during reheating. Such a temperature was reached in only one plywood-box oven, and then only after the meals were heated for 4 h and 15 min. Temperatures exceeded those at which mesophilic bacteria would stop growing in only one test of meals cooked in the wooden ovens. In this test, temperatures passed above the upper limits of this growth range only after 1 h and 15 min. Thus if foodborne pathogens had been in the foods, they would have survived and possibly even multiplied.

Because the plywood-box ovens failed to heat foods to internal temperatures that would minimize the opportunity for bacterial growth and kill any post-cooking contaminants, frozen meals were reheated in a residential-type oven at settings of 93, 163 and 218°C (200, 325 and 425°F). Internal temperatures of frozen chicken (in aluminum trays of the same dimensions used by the caterer) reached 71°C (160°F) in 25 min when reheated at the 163°C (325°F) setting (170 to 199°C, 338 to 390°F, temperature fluctuation) and in 20 min at the 218°C (425°F) setting (229 to 257°C, 445 to 498°F, temperature fluctuation) (Fig. 8). Reheating meals at 93°C (200°F) (96 to 148°C, 205 to 300°F fluctuation) showed a wide temperature variation and could not be recommended for reheating frozen meals.

Figure 8. Internal temperatures of cooked, initially frozen chicken pieces, TV dinner-type trays, when reheated in home-type oven with setting at 200°F (205-300), 325°F (338-390) and 425°F (445-498). *Only two layers tested (24 meals). **Three layers tested (30 meals).

Later, frozen foods in plastic trays were cooked in a modified version of the plywood-box ovens that had heating elements totaling 4400 watts and fans that pushed air across the elements. The oven had a wire rack and was lined with stainless steel. Two, 82°C (180°F) thermostats regulated the air temperature. Frozen chicken reached an internal temperature of 71°C (160°F) within 80 min (Fig. 9). Lima beans, the food which had the slowest penetration, did not reach an internal temperature of 71°C (160°F) until 90 min had elapsed. Some of the plastic trays which were located at the bottom and middle levels away from the fans, however, warped or melted as a result of heating. Although this oven was capable of heating foods so that they reached 71°C (160°F) within a reasonable time (90 min), the heating period was prolonged compared to heating (for 20 to 30 min) in a residential-type oven that was operated at temperatures of 190 to 232°C (375 to 450°F). Under these time-temperature conditions, foods reheated in the plywood-box ovens would be overcooked, compared to foods reheated in residential-type ovens. An obvious fire hazard existed whenever the wooden ovens were used.

Serving

According to the Food Service Sanitation Manual (5), the minimum temperature for holding hot foods is 60°C (140°F). The preferred eating temperature for foods is usually 63°C (145°F) or higher; for entrees and meats,
preferred temperatures range from 57 C (135 F) to more than 71 C (160 F) (1,6). Food temperatures fall below preferred eating temperatures rapidly after the foods are served. This drop in temperature usually necessitates holding foods above the preferred eating and holding temperatures. Therefore, an experiment was carried out to determine the cooling rates for chicken thighs that were cooked to 60 C (140 F), 66 C (150 F), 71 C (160 F) or 77 C (170 F) and served. Thighs at a temperature of 60 C (140 F) cooled to 57 C (135 F), the minimum satisfactory eating temperature for meats, in 4.5 min (Fig. 10). Thighs at 66 C (150 F) were within an optimal eating temperature range for 3 to 3.5 min and within the satisfactory eating temperature range for approximately 15 min. Thighs at 71 C (160 F) were in optimal temperature range for 3 to 5 min and within the satisfactory eating temperature range for approximately 10 min. Thighs at 71 C (160 F) were in optimal temperature range for 8 to 10 min and in the satisfactory range for approximately 15 min.

Thus, besides killing most of the vegetative bacteria that may have multiplied during undesirable practices of storage or prolonged heating, raising the temperature of foods to 71 C (160 F) or above gives a greater latitude for serving before the temperature of the foods falls below the optimal eating level.

**SUMMARY**

Two major faults were noted in the operation: (a) failure to freeze prepared meals rapidly, and (b) failure to reheat frozen foods rapidly to an internal temperature that would kill vegetative bacteria.

**REFERENCES**


Figure 9. Internal temperatures of initially frozen foods in plastic trays during heating in a 4400-watt, wooden (stainless steel-lined), convection oven (180-F thermostat) with fans pushing heat over heating elements and up around meals.

Figure 10. Internal temperatures of chicken thigh in metal tray when put on a table after removal from an oven (excluding post-oven temperature rise or lag of 2 to 4 min). **From Blaker et al. (1) and Thompson and Johnson (6).**