ABSTRACT

A time-temperature and bacteriological survey of roast beef production at a Central Food Processing Facility was undertaken to identify and eliminate food preparation practices which had previously occasionally led to excessive numbers of *Clostridium perfringens* in roast beef at that facility. *C. perfringens* was not detected in the meat or in additives at any stage of the process, but potentially hazardous conditions which would allow its growth, if present, were identified.

During fiscal year 1978, the United States Department of Defense purchased 9,350,200 lb. of boneless beef rounds for roasting, at a cost of 12,070,061.96 dollars, (personal communication; Defense Personnel Support Center, Philadelphia, PA). The frequency with which roast beef is implicated as a vehicle for foodborne disease outbreaks (1,3,5) warrants close surveillance by the Military Food Service to ensure that it is safely prepared and stored. In the United States, roast beef is probably the most frequently reported vehicle for foodborne disease outbreaks (3), including beef-associated salmonellosis (5) and *Clostridium perfringens* food poisoning (1). From 1974 through 1976, *C. perfringens* was responsible for 37 outbreaks, 1,791 cases of foodborne illness and two deaths in the United States (4). In 1976, *C. perfringens* was responsible for 4.5% of confirmed foodborne disease outbreaks and 14.2% of cases in the United States (4). These figures are probably very conservative, considering the number of outbreaks of unknown etiology (4). Therefore, since *C. perfringens* outbreaks usually involve beef (4), precautions must be taken to prevent its growth during preparation and storage of roast beef.

Microbiological analysis of food samples which were collected daily at an Army Central Food Processing Facility (CFPF) had occasionally resulted in condemnations of roast beef due to the presence of excessive numbers of *C. perfringens* (greater than 1000/g in a single sample and/or greater than 100/g in more than two of each five samples collected). A recent (November, 1978) condemnation of roast beef production at this CFPF due to *C. perfringens* counts greater than 10⁵/g prompted the Surgeon General's Medical Advisory Committee on CFPF's to request an investigation which resulted in the following survey.

The purpose of this study was to identify and eliminate food preparation practices that led to excessive numbers of *C. perfringens* in roast beef prepared at the Army CFPF in question. This was accomplished by conducting a time-temperature and bacteriological survey of beef, condiments and other additives at each stage during production of ginger beef pot roasts to determine potential opportunities for contamination, survival and multiplication of *C. perfringens*.

MATERIALS AND METHODS

A time-temperature survey of the thawing, cooking, holding, slicing, panning and freezing processes, and a bacteriological survey of raw and cooked beef roasts, as well as condiments and other additives, during production of ginger beef pot roasts at an Army CFPF were made to determine potential opportunities for contamination, survival and multiplication of *C. perfringens*. Aerobic plate counts (APC) and coliform counts were also made to determine the general microbiological quality of the beef and the effectiveness and sanitation of the process.

Central Food Processing Facility (CFPF)

The Army Base CFPF examined was a 20,558-ft² facility, which prepared, froze and stored, until needed, most food requirements for dining halls on the base including entrees, vegetables and bakery products. Boneless beef rounds were received frozen in cardboard boxes and immediately refrigerated at 2 C (36 F). The entire production of roasts during this survey was carried out in the usual way, and although workers were aware of the survey they were not given any special instructions.

Processing ginger beef pot roast

Approximately 800 lb. of frozen beef rounds, weighing 4 to 6 lb. each, were thawed at 2 C (36 F) for 3 days. Each round was surface-browned in a deep-fat fryer and sprinkled with a mixture of monosodium glutamate, salt and pepper (Fig. 1). Tomato and onion sauce was poured over the surface of each roast just before placing the meat into ovens. Meat was roasted at 176.7 C (350 F) in two convection ovens with rotating shelves. When a roast reached an internal temperature of 62.8 C (145 F), or higher it was removed from the oven and held at ambient temperature (23.9 to 29.4 C) until slicing was completed (up to 190 min). Sliced meat was weighed into foil half steam table trays and covered with hot gravy. Temperature of the gravy ranged from 91.1 C (195 F) initially to 61.7 C (143 F) when added to the last tray of meat. Tray packs were sealed and frozen at -43 C (-45 F) in large walk-in blast freezers.

Temperature measurements

Temperature measurements at each process stage (Fig. 1) were made with sanitized Weston dial thermometers (Weston Instrument Inc. Newark, N.J.) calibrated at regular intervals against certified National Bureau of Standards thermometers.

Raw meat during thawing at 2 C (36 F) for 3 days was checked by inserting thermometers into one or two roasts in each of 16 cases of meat. Roasts on the outside edge of each case were checked because they were expected to represent the worst case (highest temperature).
Measurements during cooking were made whenever ovens were opened to turn the roasts or to determine doneness. Internal and external temperatures of 5 to 15 roasts selected at random were taken at each time period. During the holding period at ambient temperatures, thermometers were inserted into five roasts selected at random and remained in place until the roasts were sliced. These five roasts were the last to be sliced so that a temperature profile of the entire holding period could be obtained. Temperature readings were made every 15 to 30 min. After slicing and weighing the meat into trays, temperature readings were made at 15- to 20 min intervals. Temperature of the gravy, which was ladled over sliced meat, was measured every 15 to 20 min. Temperature measurements of sliced, meat during the freezing stage were made at 30- to 60-min intervals by inserting a thermometer into the corner of five pans selected at random on the freezing racks.

Microbiological analyses

Microbiological quality of beef roasts and additives was determined at each process stage (Fig. 1) by analyzing five 50- to 100-g samples for aerobic plate count (APC), total coliforms (TC) and C. perfringens (CP) according to standard procedures (7). Samples from five roasts or pans, as appropriate, were collected aseptically, placed in sterile Whirl Pak bags (Scientific Products, Bedford, MA) and refrigerated on ice until tested. Surface samples extending an inch or two into the meat were collected from raw and cooked whole roasts and entire slices were collected from sliced roasts. Swab samples of equipment surfaces were collected by swabbing five, 8-in.² areas, as recommended by the U.S. Public Health Service (8). Swabs were analyzed for APC, coliforms, Staphylococcus aureus and C. perfringens.

Media

All media were purchased from Difco Laboratories, Detroit, Michigan. Plate Count Agar was used for APC. Violet Red Bile Agar was used for counting total coliforms and egg yolk Tryptose Sulfate-Cycloserine (TSC) Agar was used for counting C. perfringens (7). Swabs were placed directly into cooked meat medium for primary recovery of C. perfringens and then subcultured in TSC agar. Baird-Parker agar was used for recovery of S. aureus from equipment.

RESULTS

Figure 1 (flow diagram) shows each stage of the beef pot roast production in the CFPP. Figure 2 is a composite curve of the average internal temperatures of the beef roasts during the entire process. Elapsed time and major stages in the process are denoted by different symbols in the curve. The danger zone (temperature range 7.2 to 60 C, in which the hazard of bacterial growth is greatest) is indicated by the lined area. The shaded area within this zone indicates the temperatures which could support growth of C. perfringens. During the thawing stage at 2 C (36 F), for 3 days, the internal temperature of the roasts never exceeded 0 C (32 F). Surface temperature ranged from 0 to 4 C (32-40 F). Browning the surface of roasts by frying each roast for a few minutes was completed in 1 h and did not raise the internal temperature. During the cooking stage in dry rotary ovens set at 176.7 C (350 F), the average internal temperatures increased gradually to 62.8 C (145 F), at which time roasts were removed from the oven. All roasts were cooked and removed from ovens within 220 min. After cooking and during the holding and slicing period at ambient temperatures (75-85 F), average internal temperatures of the roasts were within the danger zone, 7.2-60 C (45-140 F), for approximately 4 h which is the maximum time period considered to be safe for cooling foods (6). However, the roasts were in the temperature range for most rapid bacterial growth, 15.6 C (60 F) to 48.9 C (120 F), for 2.5 h, which is not recommended (6).

Average internal temperatures of the roasts during holding and slicing were also in the temperature range which supports growth of C. perfringens, 18 C (65 F) to 50 C (122 F), for 140 min. The optimum growth temperature for C. perfringens is 46 C (114.8 F). Average surface temperatures (not shown) of roasts were within the bacterial growth range in less than 20 min after removal from ovens, and for more than 5.5 h. Sliced meat and gravy, in foil half steam table trays, reached freezing temperatures within 2.5 h after entering the blast freezer (Fig. 2).

Table 1 shows bacterial counts of raw and cooked meats at different stages in the process. Cooking reduced the APC by more than 99.9% from an average of 22,000/g on the raw meat to only 160/g before slicing. Coliforms on raw meat were destroyed by cooking, but were detected in panned meat after slicing, indicating post-cooking contamination. However, only two of the five samples of panned meat tested contained coliforms; one had a coliform count of 500/g and one had a count of 100/g. The remaining three samples had fewer than 100 coliforms per gram (no count at the 1:100 dilution). Freezing reduced the APC to only 40/g, and the average coliform count to only 2/g. Only one out of five frozen samples tested had coliforms and at a count of only 10/g. C. perfringens was not detected in the meat at any stage of the process at the lowest dilution counted, and was thus <100/g in raw and cooked panned meat and <10/g in cooked frozen meat.

Table 2 shows counts obtained in additives to the ginger beef pot roast and on the slicer. The tomato and onion sauce and the salt-pepper-mono-sodium-

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TABLE 1. Microbiology of ginger beef pot roast during processing.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Microorganisms per gram</th>
<th>Range</th>
<th>Averagea</th>
<th>Range</th>
<th>Averageb</th>
<th>Range</th>
<th>Averageb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aerobic plate count</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Raw pot roast (Thawed 3 days)</td>
<td>2200 to 24000</td>
<td>22000</td>
<td>&lt; 100 to 160</td>
<td>400</td>
<td>200 to 460</td>
<td>&lt; 100 to 40</td>
</tr>
<tr>
<td></td>
<td>Cooked pot roast</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Before slicing</td>
<td>&lt; 100 to 100</td>
<td>1200</td>
<td>&lt; 100 to 100</td>
<td>120</td>
<td>&lt; 100 to 100</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Panned after slicing</td>
<td>&lt; 100 to 100</td>
<td></td>
<td>&lt; 100 to 100</td>
<td></td>
<td>&lt; 100 to 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frozen</td>
<td>&lt; 100 to 100</td>
<td></td>
<td>&lt; 100 to 100</td>
<td></td>
<td>&lt; 100 to 100</td>
<td></td>
</tr>
</tbody>
</table>

aAverage of 5 samples.

TABLE 2. Microbiology of additives to ginger beef pot roast and of slicer surfaces.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Average count^a</th>
<th>Range</th>
<th>Average</th>
<th>Range</th>
<th>Average</th>
<th>Range</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aerobic plate count</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomato and onion sauce</td>
<td>1.8000/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
</tr>
<tr>
<td>Salt-pepper-MSG^b mixture</td>
<td>50000/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
<td>&lt;100/g</td>
</tr>
<tr>
<td>Gravy</td>
<td>&lt;100/g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slicer blade</td>
<td>0.75/ln.</td>
<td>&lt;0.25/ln.</td>
<td>0.40/ln.</td>
<td>&lt;0.25/ln.</td>
<td>&lt;0.25/ln.</td>
<td>&lt;0.25/ln.</td>
<td>&lt;0.25/ln.</td>
</tr>
<tr>
<td>Slicer platform</td>
<td>(cutting surface)</td>
<td>1.0/ln.</td>
<td>&lt;0.25/ln.</td>
<td>0.40/ln.</td>
<td>&lt;0.25/ln.</td>
<td>&lt;0.25/ln.</td>
<td>&lt;0.25/ln.</td>
</tr>
</tbody>
</table>

^aAverage of 5 samples.
^bMSG = Monosodium glutamate.
^cCounts preceded by the symbol "<" were negative at the lowest dilution cultured.
^dSwabs were cultured directly in cooked meat medium.
^eNot tested.

The bacteriological quality of both raw and cooked beef, and the overall sanitation of the roast beef production in the CFPF was good. Although C. perfringens was not detected, the meat was held within its optimum growth range long enough to be potentially hazardous if the organism had been present in large numbers. With a generation time of 8-12 min at its optimal growth temperature, C. perfringens could increase 1000 to 30,000-fold in 3 to 4 h (1). Therefore, the major weakness in the operation at the CFPF investigated was the practice of holding cooked meat at ambient temperatures above 21.1°C (70°F). During the last outbreak of C. perfringens at this facility, the temperature of the roast beef was reportedly within the bacterial growth range for 18 h before slicing, at which time the temperature of the meat was 15-16°C (59-60.8°F). This long time at temperatures suitable for bacterial growth was undoubtedly a major factor in finding excessive numbers of C. perfringens at that time. Inadequate refrigeration and warm holding for long periods are the two most important factors that contribute to C. perfringens foodborne illness outbreaks (2). Recommendations made included quartering of cooked roasts to speed cooling, and refrigeration during the holding period before slicing. Slicing of meat when it is cold will not only inhibit bacterial growth but will also increase yield of the meat.

ACKNOWLEDGMENTS

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REFERENCES