Time-Temperature Survey at a Restaurant that Specializes in Barbecued Food

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(Received for publication December 12, 1979)

ABSTRACT

Temperatures of cuts of beef and pork, beef ribs, chicken, and brunswick stew were recorded during routine operations at a restaurant that specializes in barbecued food. Although surface temperatures reached 74°C (165°F) during barbecuing, internal temperatures did not. Internal temperatures, however, eventually reached 66°C (150°F) and remained above 60°C (140°F) for an hour or more. The meats cooled very slowly and were within a temperature range that would be conducive to bacterial growth on the surfaces as well as in the interiors for several hours. Temperatures attained during reheating and hot-holding of chilled barbecued meat sometimes failed to rise high enough to be lethal to vegetative foodborne bacteria. Measures to prevent foodborne diseases being caused by these products must stress rapid cooling of cooked meats.

RESULTS AND DISCUSSION

Barbecuing

Beef, pork and chicken were heated on a gas-fired grill. Smoke was produced by smoldering hickory wood or sawdust. The temperature of the air near the food and at the level of the grill varied from 38 to 154°C (104 to 310°F) (Fig. 1-5).

Beef cuts. The surfaces of cuts of beef reached 71°C (160°F) in 45 min and 74°C (165°F) in 1 h and 45 min (Fig. 1). The reason for the lengthy lapse of time between 71 and 74°C (160 to 165°F) was that the meat was occasionally turned on the grill; sometimes the thermocouple was at the bottom surface and other times at the top. The temperature near the geometric center progressively increased from approximately 7°C (45°F) to 66°C (150°F) in 2 h and 40 min. A temperature of 71°C (160°F) was not reached until the post-heating period. The period at temperatures above 66°C (150°F), however, would assure destruction of vegetative forms of pathogenic foodborne bacteria.

METHODS

Thermocouples were used to measure temperatures of internal and surface regions of chicken and cuts of beef and pork. Temperatures were taken every few seconds and recorded on a potentiometer chart. Previous articles describe the attachment and insertion of thermocouples and give specifications for the thermocouples and the recording potentiometer (1-3).

Data given in the tables about cooling, hot-holding and reheating include the temperature ranges from 21 to 46°C (70 to 115°F), which is an approximate range within which mesophilic bacteria multiply rather rapidly: from 15.6 to 50°C (60 to 122°F), which is an approximate growth range for Closstridium perfringens; and 7 to 60°C (45 to 140°F), which is the range specified in foodservice code requirements (cold foods should be held at 7°C (45°F) or below, and hot foods should be held at 60°C (140°F) or above) (4).

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Beef ribs. The surface of beef ribs reached a temperature of 68 C (155 F) before the probe was disconnected, and no doubt even higher temperatures later. The internal temperature reached 66 C (150 F) in 1 h and 12 min (Fig. 2). Vegetative bacteria on the surface and in the interior should be killed by these time-temperature exposures during barbecuing.

Pork cuts. The pork reached internal temperatures of 58 C (137 F) in 2 h and 37 min, 66 C (150 F) in 2 h and 55 min, and 74 C (165 F) in 3 h and 35 min (Fig. 3).
These time-temperature exposures would kill parasites and vegetative bacteria.

**Chicken.** A temperature of 74°C (165°F) was reached just under the skin of chicken halves in 2.5 to 17.5 min (Fig. 4 and 5). This time-temperature exposure would assure destruction of vegetative bacteria. Surface temperatures varied because of occasional turning of the chicken during barbecuing. The internal temperature of a chicken leg reached 74°C (150°F) in 50 min in one trial and in 1 h and 32.5 min in another trial. The air temperature near the grill greatly affected the internal temperatures of the chicken.

Although the recommended Public Health Service ordinance (4) specifies that an internal temperature of 74°C (165°F) should be reached during the continuous cooking of poultry, the interval during which the chicken was above 66°C (150°F) should kill *Salmonella* and other vegetative bacterial pathogens.

**Cooling.** During cooling in a walk-in refrigerator, the surfaces and internal regions of cuts of meat were within a temperature range that would be conducive to bacterial growth for considerable periods (Fig. 6; Table 1). A particularly dangerous situation occurred when several cuts of cooked meat were stored in the same covered pan. The value of storing roasts separately can readily be seen in Fig. 6 and in Table 1. If enough pans are not available, the meat can be wrapped in foil, plastic wrap or other similar material. Cutting the meat in smaller portions or chopping and storing it in shallow pans would also speed cooling. Thorough reheating of meat surfaces should be considered to compensate for the slow cooling of the meat.

Ribs stored in a pan with other ribs reached 7°C (45°F) in 12 h and 30 min (Fig. 7). They were within the temperature range of 21 to 46°C (70 to 115°F) for 4 h, the temperature range of 16 to 50°C (60 to 122°F) for 6 h, and 15 min, and within the temperature range of 7 to 60°C (45 to 140°F) for more than 12 h and 20 min.

**Pork.** Pork also cooled slowly. A 1.6-kg (3.5-lb) cut of cooked pork in a pan with other cooked meat was within the temperature range of 21 to 46°C (70 to 115°F) for 6 h and 25 min, within the temperature range of 16 to 50°C (60 to 122°F) for 10 h and 25 min, and within the temperature range of 7 to 60°C (45 to 140°F) for more than 16 h and 15 min (Fig. 8).

**Chicken.** Chicken halves cooled much faster than either the cuts of beef or pork, primarily because of their lesser weight and bulk (Fig. 9 and 10). Chicken halves were within critical temperature ranges as shown in Table 2. Once again, the danger of storing cooked food in bulk during cooling is apparent. Chicken halves should be wrapped individually in foil, plastic wrap or other material and stored separately.

**Reheating and hot-holding.**

**Beef cuts.** The air temperature near a shelf, 12 inches above the grill, varied from 38 to 108°C (100 to 227°F). The temperature of the surface of a roast (roast #1)
Figure 7. Temperatures of geometric center of 2 pounds of cooked beef ribs in a pan of other cooked ribs during storage in a walk-in refrigerator.

Figure 8. Temperatures of geometric center of 3.5-pound cut of cooked pork in a covered (25" x 18" x 9") plastic pan with other meat during storage in a walk-in refrigerator.

Figure 9. Temperatures of geometric center of breast of half a cooked chicken in a covered (25" x 18" x 9") pan with other cooked chicken during storage in a walk-in refrigerator.

Figure 10. Temperatures of geometric center of breast and leg and under skin of half a cooked chicken stored (singly) in a walk-in refrigerator.

TABLE 2. Critical time-temperature ranges of pieces of chicken stored in a walk-in refrigerator in which the temperature fluctuated between 0 C and 6 C (32 F and 42 F).

<table>
<thead>
<tr>
<th>Location of thermocouple and storage situation</th>
<th>Geometric center of breast of chicken half, stored with other cooked chicken</th>
<th>Geometric center of breast of chicken half, stored individually on shelf</th>
<th>Geometric center of leg of chicken half, stored individually on shelf</th>
<th>Under skin of chicken half, stored individually on shelf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minutes at 21 C - 46 C</td>
<td>Minutes at 16 C - 50 C</td>
<td>Minutes at 7 C - 60 C</td>
<td>Minutes at 70 F - 115 F</td>
<td>Minutes at 60 F - 122 F</td>
</tr>
<tr>
<td>Geometric center of breast of chicken half, stored with other cooked chicken</td>
<td>190</td>
<td>315</td>
<td>675</td>
<td></td>
</tr>
<tr>
<td>Geometric center of breast of chicken half, stored individually on shelf</td>
<td>48</td>
<td>80</td>
<td>&gt; 195</td>
<td></td>
</tr>
<tr>
<td>Geometric center of leg of chicken half, stored individually on shelf</td>
<td>37</td>
<td>65</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Under skin of chicken half, stored individually on shelf</td>
<td>30</td>
<td>50</td>
<td>&gt; 112</td>
<td></td>
</tr>
</tbody>
</table>

reached 74 C (165 F) in 45 min while held on this shelf. The temperature of the surface of another roast (roast #2) remained around 50 C (122 F) for a few hours; it did not reach 74 C (165 F) until after 7 h and 20 min (Fig. 11). Surface temperatures varied when the roasts were turned and as the air temperature near the shelf rose and fell. When several pieces of meat were cooked on the grill, the hot air flow was blocked to significantly reduce the temperature near the shelf. The internal temperature of
TEMPERATURE OF BARBECUED FOOD

Figure 11. Temperatures of geometric center and surface of cooked, chilled beef (~7 pounds) during reheating on the upper shelf (12" above grill, 31" above fire) of a gas barbecue grill.

roast #1 reached 69 C (156 F) before serving; the internal temperature of roast #2 reached 71 C (160 F) on two occasions (Fig. 11). Other pieces of beef on a hot-holding shelf where the temperature ranged from 56 C (133 F) to 92 C (198 F) reached only a temperature at the geometric center of 52 C (125 F) and 64 C (147 F) before being served. The cut of beef that reached 64 C (147 F) was perhaps above 60 C (140 F) long enough to kill vegetative bacteria, but the organisms in the cut of beef that reached only 52 C (125 F) would have survived.

The temperature at the geometric center of a 7-lb cut of cooked, chilled beef during reheating directly on a barbecue grill is shown in Fig. 12. A temperature of 60 C (140 F) was reached in 1 h and was maintained until the beef was served 3 h later. Meat should be reheated on a barbecue grill for at least 1 h before being shifted to the upper shelf. The meat should be turned a number of times during reheating, and care should be taken not to block the flow of air rising to the shelf used for holding the cooked meat.

Pork. During reheating on a barbecue grill, cuts of pork reached temperature of 58 C (137 F) in 45 min, 66 C (150 F) in 52 min and 74 C (165 F) in 60 min (Fig. 12). These time-temperature exposures would assure destruction of parasites, salmonellae and other vegetative forms of pathogenic bacteria.

Sliced beef. During steaming of 57 g (2 oz) of barbecued beef in a bun in a small steamer which generated temperatures that varied from 83 C (181 F) to 97 C (207 F), the internal portions of the beef reached 74 C (165 F) in 15 sec and remained above this temperature for more than 30 sec and above 66 C (150 F) for more than 1 min (2). Such treatment should kill vegetative pathogenic foodborne bacteria.

Chicken. Chilled, cooked chicken was reheated in a microwave oven for approximately 2 min. Shortly after this exposure, the temperature at the geometric center of the breast was 66 C (150 F) to 71 C (160 F) and rose to 81 C (178 F) and to 84 C (183 F); it remained above 71 C (160 F) for at least 5 min (Fig. 13). Such time-temperature exposure should kill vegetative pathogenic foodborne bacteria.

Figure 12. Temperatures of geometric center of beef and pork and surface of beef during reheating on a barbecue grill (19" above fire) heated by gas.

Stew. Chilled stew was reheated in a small steam table. The temperature reached 74 C (165 F) in 1 h and 10 min on one occasion. On another occasion it reached only 66 C (150 F) after 6 h and 20 min (Fig. 14). A considerable amount of inadequately heated stew would have been served during this 6-h period. Although the steam table was capable of reheating stew rapidly and holding it at an acceptable serving temperature, the stew was not always heated to a satisfactory temperature because of either a low thermostat setting or a short period of heating. To prevent this problem, either the steam table’s thermostat should be set to provide higher temperatures — so that the stew can reach 74 C (165 F) within 1 h — or the stew should be heated to this temperature on a range and then transferred to a steam table. The steam table’s thermostat should be set to hold the stew at a temperature above 60 C (140 F) so that the stew would be at or above the optimal eating temperature at the time of serving.

SUMMARY

Barbecued meat and poultry are cooked slowly and do not always reach high internal temperatures which often result from other modes of cooking. However, they usually undergo sufficiently high temperatures for long
enough periods to kill vegetative forms of pathogenic foodborne bacteria. The primary microbiological hazards occur during slow cooling, slow reheating and holding at insufficiently high temperatures, often for long periods. Measures to prevent foodborne diseases must stress rapid cooling and thorough reheating of cooked meat. Whole chickens, half chickens and cuts of meat should be wrapped individually in foil or plastic wrap or each individual item put in a separate pan. It is also recommended that, whenever practical, roasts be precooled before refrigeration (2). If reheating is to be done on barbecuing grills, the food should be placed so that air is not impeded by other items being cooked or reheated between them and the heat source. They should also be turned frequently while being reheated. Stew should be heated by a heat source that is sufficient to cause its temperature to reach 74 C (165 F). During such heating, the stew should be stirred occasionally.

REFERENCES


AIB's Sanitation AV Programs Complete

Volumes five and six in the American Institute of Baking's (AIB) audio-visual training series on basic sanitation principles for the food industry have been completed and are ready for distribution.

"Good Cleaning Practices", volume five outlines elements of a good housekeeping program, as well as the types of equipment and supplies necessary for such a program. Information is also presented on the training of employees for the cleaning operation.

"Preventive Maintenance", volume six, concerns essential elements required for preventive maintenance of equipment as viewed from a sanitation viewpoint. An explanation of the financial benefits of a good preventive maintenance program is pointed out, along with a discussion of the organizational responsibilities of production, sanitation and maintenance personnel and the training of these employees.

The first four volumes in the sanitation series are: "Introduction to Sanitation", "Sanitation Program Development", "Pest Control Programs", and "Operational Methods and Personnel Practices".

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