Investigation of a Staphylococcal Food Poisoning Outbreak in a Centralized School Lunch Program

MARGARET S. RICHARDS, PhD, MPH
MARILYN RITTMAN, RN
THOMAS T. GILBERT, MD, MPH
STEVEN M. OPAL, MD
BARBARA A. DeBUONO, MD, MPH
ROGER J. NEILL, PhD
PETER GEMSKI, PhD

Dr. Richards is a former staff member of the Centers for Disease Control and Prevention's Epidemic Intelligence Service, Division of Field Epidemiology. At the time of the investigation, she was assigned to the Rhode Island Department of Health (RIDH), Division of Disease Prevention and Control (DDPC), where she is now a consultant. Ms. Rittman is the Infection Control Nurse, Office of Communicable Diseases, DDPC. Dr. Gilbert was the Chief of Epidemiology and Communicable Diseases, DDPC; he is now in private practice in East Providence, RI. Dr. Opal is a Staff Physician, Infectious Disease Division, Memorial Hospital of Rhode Island, Pawtucket. Dr. DeBuono is Director of RIDH. Dr. Neill and Dr. Gemski are Senior Research Investigators, Department of Molecular Pathology, Walter Reed Army Institute of Research, Washington, DC.

Ernest Julian, Chief of the Division of Food Protection and Sanitation at RIDH, conducted the environmental portion of the investigation with members of his staff.

Tearsheet requests to Barbara A. DeBuono, MD, MPH; Director of Health, Rhode Island Department of Health, 3 Capitol Hill, 401 Cannon Bldg., Providence, RI; 02908; tel. (401) 277-2231; fac. (401) 277-6548.

Synopsis

The trend in many communities toward centralized school lunch preparation potentially increases the risk of foodborne illness. Foods often are prepared long before serving and may be distributed to satellite schools by persons with little formal training in safe techniques of food preparation or food service.

In May 1990, an outbreak of staphylococcal food poisoning occurred in elementary schools in a Rhode Island community participating in such a program. In the investigation of the outbreak, students in schools that reported cases were interviewed. Food preparation, handling, and distribution were reviewed. At School E, 662 lunches were prepared and distributed to 4 additional schools (schools A-D). Schools A and B accounted for nearly all cases of the food poisoning, with rates of 47 percent and 18 percent. Eating ham increased the risk of illness (62 percent of those consuming ham and 3 percent of those who did not, relative risk = 18.0, 95 percent confidence interval = 4.0, 313.4). Large amounts of Staphylococcus aureus *were cultured, and preformed enterotoxin A was identified in leftover ham.*

A food handler, who tested positive for the implicated enterotoxic strain S. aureus, *reported having removed the casings from two of nine warm ham rolls 48 hours prior to service. Because of improper refrigeration, prolonged handling, and inadequate reheating, the ham was held at temperatures estimated at 10–49 degrees Celsius (50–120 degrees Fahrenheit) for a minimum of 15 hours. The potential for larger outbreaks prompted a statewide training program in safe food preparation for school lunch personnel, which may have applications for other communities.*

STAPHYLOCOCCAL FOOD POISONING (SFP) is the second most commonly reported cause of acute food poisoning in the United States, accounting annually for 14–20 percent of all outbreaks involving contaminated food (*1, 2*).

Although SFP generally is considered to be a mild, self-limited illness, as many as 10 percent of all sufferers visit emergency rooms or are admitted to a hospital for their symptoms (*3, 4*). Infants, children, and elderly persons are likely to have severe illnesses and to require careful observation or inhospital management (*5, 6*).

Because young children are at increased risk for severe illness from SFP, safe food preparation in school lunch programs, particularly elementary schools, is of critical importance. In Rhode Island, 80 school kitchens prepare food for their own school lunch programs, as well as those of 170 satellite schools. Large amounts of food are prepared well in advance of service and are distributed to susceptible populations at remote sites by persons who are not likely to have had formal training in safe food preparation or transport.

We investigated an outbreak of food poisoning

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among elementary school-aged children in Rhode Island. The outbreak resulted from ingestion of staphylococcal enterotoxin A (SEA). The affected children were enrolled in a school lunch program that included one school where the food was prepared and four other schools where it was served. We determined the probable origin and distribution of the contaminated food and defined the staphylococcal strain responsible for the outbreak.

Outbreak

At about 2:45 p.m. on May 31, 1990, the superintendent of a local school district called the Rhode Island Department of Health (RIDH) to report that a number of children at two of the schools in his district had begun vomiting within hours of eating the school lunch. Dozens of children were taken to several area emergency rooms (ERs). At the request of the superintendent, the RIDH's Office of Disease Control (ODC) conducted an investigation. ODC personnel visited four area ERs to recover samples of stool and vomitus from sick students.

The lunch consisted of sliced ham, baked beans, corn, bread and butter, and pudding. The food was prepared at one school (school E) and subsequently distributed to four other schools (schools A–D). A survey of the administrative offices at each of the 5 schools showed that, for 662 lunches sold, there were about 100 reported illnesses. With the exception of one ill food handler, the only food handler who ate the school lunch that day, reports of illness were limited to students, most at schools A and B.

Methods

Epidemiologic investigation. An attack rate of illnesses per lunches sold was calculated for each of the five schools involved in the outbreak. Because school A reported the largest number of sick children, it became the focus of the epidemiologic investigation. On the morning following the outbreak, face-to-face interviews were conducted with all school A children who were in attendance on that day. Children who were at home were interviewed by telephone. For in-school children younger than 7 years, a proxy interview with the child's homeroom teacher was conducted. Similarly, for at-home children who could not be interviewed directly, such as those younger than 7 years or too sick to interview, a proxy interview with a parent or other care provider was conducted. The following data were obtained for each child:

- Sex
- Age
- Body weight
- Purchase of the school lunch
- Time the lunch was eaten
- Foods consumed (ham, baked beans, corn, pudding, bread and butter, and milk)
- Estimate of the amount consumed (for example, for ham: fewer than 2 slices, 2 slices, more than 2 slices)
- Onset and checklist of symptoms, such as nausea, cramps, vomiting, diarrhea, headache, fever, and other symptoms
- Duration of the symptoms (was the student in school the following day)
- Severity of the symptoms (was the student cared for at home, given supportive treatment in an emergency room, treated with IV fluids in an emergency room, or hospitalized overnight)

A case was defined as a person who experienced at least one of the following symptoms within 8 hours of eating the school lunch: cramps, nausea, vomiting, or diarrhea (three or more loose stools in 24 hours or less).

Laboratory investigation. Clinical specimens were collected from students and food handlers, and food samples were obtained. Thirteen emesis, 5 stool, and 4 rectal swab specimens were obtained from 18 sick students. Emesis and stool samples were obtained from one food handler who was sick after eating the school lunch. Premoistened swabs were used to obtain nasopharyngeal cultures from nine asymptomatic food handlers. No food handlers had symptoms suggesting cutaneous infection; however, a surface culture was made from a burn wound on the hand of one of the nine employees.

A total of seven food samples were tested for the presence of *Staphylococcus aureus* using quantitative methods described elsewhere (*7*). Cultures were plated on blood agar plates and phenyl ethyl alcohol plates. *S. aureus* isolates were subcultured and stored at minus 70 degrees Celsius (C) in glycerine for further study.

S. aureus isolates were typed by restriction endonuclease digestion patterns of plasmid dioxyribonucleic acid (DNA) by agarose gel electrophoresis. Plasmid DNA was isolated by a modification of the method of Birnboim and Doly (*8*). Lysostaphin (*A*) at a concentration of 1 milligram per milliliter was substituted for lysozyme in the lysing buffer. The restriction endonuclease enzyme *Eco* R1 was used according to the manufacturer's instructions (*B*).

Phage typing using standard methods (*9*) was performed by Charles H. Zierdt, National Institutes of Health, Clinical Center, Clinical Pathology Department, and by the Centers for Disease Control and Prevention (CDC). Enterotoxin analysis of food samples and *S. aureus* isolates was performed by Reginald W. Bennett, Food and Drug Administration, Center for Food Safety and Applied Nutrition, using enzyme-linked immunosorbent assay methods described elsewhere (*10, 11*). Outbreak strains were subjected to oligonucleotide DNA probe analysis for detection of enterotoxin genotypes as described (*12*).

Environmental investigation. The RIDH conducted a complete kitchen sanitation inspection at all five schools on the day after the outbreak, using field staff members of the Division of Food Protection and Sanitation. The inspection included the refrigeration and food preparation procedures, general cleanliness, and repair of equipment.

Seven food samples were recovered. Three samples of food were recovered from the dumpster at school E about 3 hours after the outbreak; those samples consisted of ham with an unknown substance, ham with raw chicken skins, and raw chicken skins alone. About 3.5 hours after the beginning of the outbreak, three more samples were recovered from a trash barrel containing leftovers from schools A–D. Those samples consisted of ham with beans and corn, beans and corn, and vomitus with unconsumed ham and corn. Despite an embargo by RIDH of leftover food, all of the surplus was destroyed before field staff members arrived, apparently because of the fear that the entire food supply might be tainted. One sample of frozen, cooked ham was obtained from the supplier's warehouse, but it was not from the lot served on the day of the outbreak.

Table 1. Rates of cases, by schools, of staphylococcal food poisoning among students participating in a Rhode Island school lunch program, 1990

School	Number of lunches	Number reporting illness	Case rate
A	144	67	47
B	153	27	18
C	121	5	4
D	78	1	1
E[1]	166	0	0
Total	662	100	15

[1] School E was the central food preparation site.

Results

Epidemiologic results. The highest reported attack rates of illnesses per lunches sold were for schools A (47 percent) and B (18 percent). Attack rates at each of the remaining schools, C–E, were less than 5 percent (table 1). Interviews were completed with 281 of 345 students (81 percent) at school A who were enrolled for a full day and who attended on the day of the outbreak. Of 132 students interviewed who purchased the school lunch, 67 (51 percent) complained of illness following the meal. Of 149 students who did not purchase the school lunch, only 2 (1 percent) reported illness.

Sixty-five of the 132 children purchasing lunch (49 percent) met the case definition. Symptoms among those 65 children included nausea (90 percent), vomiting (81 percent), cramps (66 percent), headache (51 percent), fever (45 percent), and diarrhea (41 percent). The median incubation period was 2.8 hours. Twelve students (18 percent) were hospitalized overnight, 12 students (18 percent) were discharged following supportive treatment or intravenous fluid replacement in an ER, and 41 (64 percent) were cared for at home. Of the 65 sick students, 31 (48 percent) returned to school on the following day.

Attack rates for boys and girls were similar: 45 percent for males and 56 percent for females (relative risk [RR] = 0.8, 95 percent confidence interval [CI] = 0.6, 1.1). Attack rates were lower among students younger than 10 years (33 percent), compared with those 10 years and older (54 percent) (RR = 0.6, 95 percent CI = 0.4, 1.0). Similarly, attack rates were lower among students weighing less than 77 pounds (52 percent), compared with those weighing 77 pounds or more (80

Table 2. Rates of illness, by specific foods, after an outbreak of staphylococcal food poisoning among students in school A who participated in a Rhode Island school lunch program, 1990

Food	Consumed food			Did not consume food			Relative risk	CI
	Number of students	Number of cases	Rate	Number of students	Number of cases	Rate		
Ham	103	64	62	29	1	3	18.0	4.0, 313.4
Baked beans	27	19	70	105	46	44	1.6	1.2, 2.2
Corn	67	36	54	65	29	45	1.2	0.9, 1.7
Bread and butter	87	44	51	45	21	47	1.1	0.7, 1.6
Chocolate pudding	89	39	44	43	26	60	0.7	0.5, 1.0
Vanilla pudding	5	3	60	102	43	42	1.4	0.5, 2.4
Milk	118	60	51	14	5	36	1.4	0.7, 2.9

Table 3. Characteristics of isolates of *Staphylococcus aureus* cultures obtained from food handlers and students after an outbreak of staphylococcal food poisoning at a Rhode Island school lunch program, 1990

Source	Origin	Plasmid profile (Kb)[1]	Phage type	Expressed toxin	Toxin genotype
Foodhandler A	Nasopharyngeal	18.5, 6.4	6/7/29/42b	A	A
Foodhandler B	Emesis	18.5, 6.4	6/7/29/42b	A	A
Foodhandler B	Stool	18.5, 6.4	6/7/29/42b	A	A
Student A	Emesis	18.5, 6.4	6/7/29/42b	A	A
Student B	Emesis	18.5, 6.4	6/7/29/42b	A	A
Student C	Emesis	18.5, 6.4	6/7/29/42b	A	A
Student D	Emesis	18.5, 6.4	6/7/29/42b	A	A
Student E	Stool	18.5, 6.4	6/7/29/42b	A	A
Student F	Stool	18.5, 6.4	6/7/29/42b	A	A
Student G	Stool	18.5, 6.4	6/7/29/42b	A	A
Student H	Rectal	18.5, 6.4	6/7/29/42b	A	A
Student I	Rectal	18.5, 6.4	6/7/29/42b	A	A
Student J	Emesis	18.5, 6.4	6/7/29/42b	A	A
	Stool	18.5, 6.4	6/7/29/42b	A	A
Student K	Emesis	18.5, 6.4	6/7/29/42b	A	A
	Stool	18.5, 6.4	6/7/29/42b	A	A
Student L	Emesis	23.0, 6.0	3b/3c/55/71	...	...
	Rectal	18.5, 6.4	6/7/29/42b	A	A
Food[2]	Ham and raw chicken skins	18.5, 6.4	6/7/29/42b	...	A
Food	Ham, beans, and corn	18.5, 6.4	6/7/29/42b	A	A

[1] Kilobase pairs (molecular weight).
[2] Although 5 food samples were positive for *S. aureus*, only 2 of the 5 were subcultured for further study.

percent) (RR = 0.7, 95 percent CI = 0.5, 0.9). The attack rate increased slightly with successive lunch shifts: 42 percent at 11:30 a.m., 47 percent at noon, and 59 percent at 12:30 p.m. (Chi square trend = 1.7, $P = 0.19$).

Having eaten ham markedly increased the risk of illness (RR = 18.0) (table 2), and the risk of illness increased with the amount of ham consumed. Incubation times for the onset of symptoms decreased as consumption of ham increased, from a mean of 3.3 hours among those eating less than two slices, to a mean of 2.6 hours among those eating two slices or more.

Laboratory results. Fifteen of 22 clinical specimens (68 percent) obtained from 12 of 18 children (67 percent) were positive for *S. aureus*, as were both clinical specimens obtained from the single sick food handler. One of nine nasopharyngeal cultures (11 percent) obtained from nine food handlers was positive for *S. aureus*. The surface culture of the burn wound on the hand of one of the nine employees was negative. Five of the seven food samples (71 percent) were positive for *S. aureus*, having more than 2 x 10^6 colony-forming units (CFU) per gram. The two negative food samples were the raw chicken skins and the frozen ham from the supplier's warehouse.

Serologic analysis of food samples revealed evidence of preformed SEA by the enzyme-linked immunosorbant assay (ELISA) method from ham with chicken skins, and ham with beans and corn.

Preformed enterotoxin A was detected in nine emesis specimens from children, including two emesis specimens which did not demonstrate *S. aureus* on culture.

All human and food isolates had identical restriction endonuclease patterns and plasmid profiles, with the exception of one isolate. Student L had positive cultures from both a rectal swab and an emesis specimen. The rectal isolate was identical to other specimens, yet the emesis isolate had a distinctly different plasmid profile (table 3).

Phage typing and DNA probe analysis for enterotoxin of the outbreak-associated isolates confirmed that all but one of the isolates shared the same phage pattern and expressed SEA in culture supernatants. The emesis specimen from student L was a different phage type and did not produce enterotoxin A.

Environmental results. On Thursday, the day of the outbreak, the outside air temperature at 12 noon was 24 degrees C (75 degrees Fahrenheit [F]); temperatures inside the five school kitchens were in the 27–29 degrees C (80.6–84.2 degrees F) range. School E employed nine full-time food handlers, and schools A–D had smaller staffs of four or five food handlers. Food sanitation inspectors found that the kitchen facilities at all five schools were clean and that the equipment was well-maintained, with few exceptions. Some deficiencies were noted.

- No standard operating procedures existed for holding potentially hazardous foods cooked a day or more ahead of time.
- Food thermometers were not present in any of the five kitchens, precluding monitoring of the temperatures of food.
- Half of the hot-holding transport units did not maintain a product temperature of 60 degrees C (140 degrees F) or higher.
- Large volumes of warm food (more than 90 pounds) were stored in closed food cabinets in the refrigerator.

A review of the preparation of the ham revealed that nine 10-pound rolls of frozen, fully cooked ham were delivered to school E on Thursday, May 24, 1 week before the outbreak. They were wheeled into a walk-in refrigerator at 4 degrees C (39.2 degrees F) for thawing.

Five days later, on Tuesday, May 29, 2 days before the outbreak, the fully thawed hams were cooked in a steamer for about 1 hour and 45 minutes. After steaming at 82 degrees C (180 degrees F), the rolls were allowed to cool for 45 minutes so that the casings could be removed by hand. Three employees were involved in removing the casings; none wore gloves. One of the food handlers who removed the casings had a nasopharyngeal culture with the outbreak strain of *S. aureus*. That food handler had peeled two of the nine ham rolls and was then called upon to serve that day's lunch. The remaining seven hams were peeled by the two asymptomatic, culture-negative kitchen employees. After all casings were removed (about an hour later), the rolls were placed in deep pans (three rolls per pan, covered with aluminum foil), and stacked on the shelves of the walk-in refrigerator at 11:30 a.m.

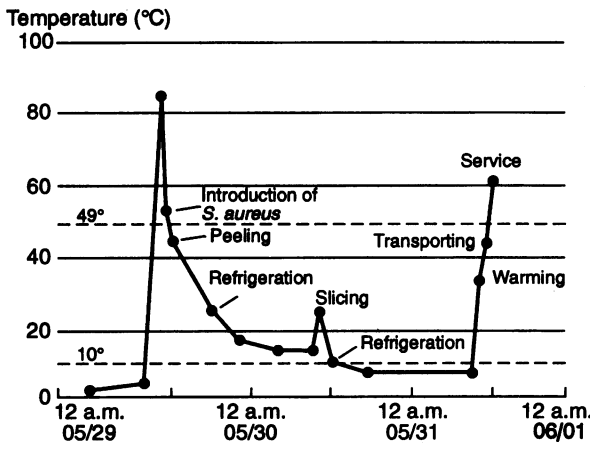
On Wednesday, May 30, the day before the outbreak, at 9 a.m., the rolls were taken out of the refrigerator, sliced, and rolled for serving. The operation lasted slightly more than an hour. Each of the 9 ham rolls produced 150 slices of ham; 2 2-ounce slices constituted 1 serving. The rolled slices were placed in single layers on 12 cookie sheets, which were loaded into an enclosed cart and wheeled into the walk-in refrigerator. At 8:45 a.m. on Thursday, the day of the outbreak, the sheets of ham were removed from the refrigerator and placed (with covers on) into an oven at 64 degrees C (147 degrees F) to warm for 20 minutes. At 9:15 a.m., they were uncovered and placed in eight transport ovens for delivery to the four satellite schools. Four of the eight transport ovens maintained temperatures of 60 degrees C (140 degrees F) or higher; the other units maintained temperatures between 43 degrees C and 50 degrees C (109–122 degrees F).

The driver of the delivery truck reported loading the food onto the truck at 9:45 a.m. He left at 10 a.m., made deliveries to schools D, A, C, and B, in that order, and returned to school E at 11 a.m. All schools, except for school D, received the sliced equivalent of two rolls. Servers at the satellite schools transferred the ham to warming pans for lunch-line service.

Discussion

In many ways, this event represents a classic outbreak of SFP. Nearly all outbreaks of SFP involve a previously cooked, proteinaceous food. Furthermore, in a CDC review of SFP events, ham was the most frequently implicated food, accounting for 24 percent of all outbreaks (*3*). The enterotoxin responsible for the symptoms in the reported event was SEA, the most common entero-

Time and temperatures in the processing of ham rolls implicated in *Staphylococcus aureus* food poisoning in a Rhode Island school lunch program, 1990



NOTE: The dotted lines at 10 and 49 degrees C represent the temperature zone favoring the growth of *Staphylococcus aureus*.
C = Celsius scale.

toxin. The event was unusual, however, in the degree to which the epidemiologic, laboratory, and environmental investigations came together to suggest how the outbreak may have occurred.

Information from the food inspectors shows that contamination probably occurred on Tuesday when the casings were removed from the warm hams. The source of contamination was likely the single nasopharyngeal culture-positive food handler who reported peeling two of the hams. The microbiologic investigation supports this scenario. Despite the fact that there are dozens of phage types of *S. aureus*, the phage types and plasmid profiles of the isolates obtained from the food handler, the students, and the foods were identical, with the exception of one student's vomitus. An estimated 25–50 percent of the population are nasopharyngeal or cutaneous carriers of *S. aureus*; 15–20 percent of the strains are enterotoxigenic (*13*). Student L was apparently a nasopharyngeal carrier of a nonenterotoxigenic type, which was detected in her vomitus.

Although large amounts of *S. aureus* (more than 2×10^6 CFU per gram) were recovered from food samples, those samples were not leftover, refrigerated samples (which had been destroyed), but were samples recovered from trash containers hours after the outbreak. As a result, colony counts may not reflect the dose in the ham at the time it was served, but rather intervening bacterial multiplication.

Nonetheless, we believe that there was ample opportunity for *S. aureus* growth and subsequent elaboration of toxin. As shown in the figure, food inspectors estimated by simulating outbreak conditions that the contaminated ham was held at temperatures of 10–49 degrees C (50–120 degrees F) for a minimum of 15 hours as a result of a combination of improper procedures, including lack of refrigeration, prolonged handling, and inadequate reheating.

Specifically, bacterial growth would have occurred following the peeling operation 2 days before the outbreak while the hams were cooling. The inspectors estimated that a single 10-pound ham roll requires more than 10 hours to reach refrigerator temperature following steaming. It can be assumed that three stacked rolls, covered with aluminum foil, would take at least 10 hours to cool to refrigerator temperature. Bacterial growth may have occurred on Wednesday, the day before serving, during the slicing and rolling operation, when the hams, which would not have cooled to refrigerator temperature, would have warmed to room temperature in about an hour. Growth may have continued when those slices were placed in pans and loaded into a closed food wagon before being wheeled into the refrigerator. Storing 90 pounds of warm ham in a closed wagon would slow refrigeration considerably, possibly for about 2 hours. Finally, growth continued when the slices were warmed for transporting on the day they were served, possibly for about 2 hours. The supervising cook stated that the ham was heated to 64 degrees C (147 degrees F); however, it is unlikely that the ham reached this temperature in 20 minutes.

Although half of the transport units used for the ham were deficient, we were unable to show that they were the units used for the most affected schools. The question remains of why the outbreak was limited largely to two of five schools. We believe that only two of the nine rolls were contaminated: the two rolls peeled by the culture-positive food handler. We know that the rolls were processed in batches of three, such that the two contaminated rolls appear to have stayed together throughout processing and distribution, in all likelihood contaminating the third roll in turn. We know that each of the schools, except for school D, received the sliced equivalent of two rolls. Although aggregate preparation and waste disposal prohibited our tracing the final destination of the nine ham rolls, we hypothesize that school A received primarily the two contaminated rolls, and school B received the third.

For a foodborne outbreak to occur, two conditions are necessary: introduction of the outbreak organism and time and temperature abuses that

facilitate its growth. Because some contamination of food is inevitable, most preparation sites emphasize measures to control the growth of organisms. Foods need to be handled to a minimal extent, prepared as often as possible on the day they are to be served, promptly refrigerated, and adequately reheated.

A centralized school lunch program potentially promotes the introduction and growth of bacteria into foods, because the distribution process necessitates additional warming and handling. Moreover, the fact that hundreds or thousands of lunches are served daily requires that the foods be prepared well in advance of service. In this regard, the Rhode Island program differs little from other large scale operations. Together with considerations of scale, however, is the increased susceptibility of children, and the lack of formal training of food handlers. The food inspectors who conducted a training program for kitchen personnel 8 days after the outbreak reported that some kitchen staff members were unaware that inadequate cooling and reheating of foods is a major cause of foodborne illness.

Although centralization in the school lunch preparation process undoubtedly contributed to this outbreak, it can also provide opportunities to decrease the risk of foodborne illness through improved standards, training, and supervision of staff persons. To that end, RIDH made recommendations that included the development of standard operating procedures for high-hazard foods, the use of food thermometers throughout food processing and transport, and the use of narrow shelving in refrigerators to prevent the stacking of deep containers filled with warm food. Closed food wagons were not to be used to store cooked food in the refrigerator. Transport ovens were not to be used unless proven to maintain product temperatures of 60 degrees C (140 degrees F) or higher.

Most importantly, a yearly training program was mandated. In August 1990, the Rhode Island Department of Education held a statewide training program in safe food preparation for school lunch personnel. States with centralized school lunch programs, or those planning or moving toward centralization, need to consider a similar training program.

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Equipment

A. Sigma Chemical Co., Inc., 3050 Spruce St., St. Louis, MO 63103.

B. New England Biolabs, Inc., 32 Tozer St., Beverly, MA 01915.