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Risks of Practices, Procedures and Processes that Lead to Outbreaks of Foodborne Diseases

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ABSTRACT

Factors that contributed to outbreaks of foodborne diseases reported in the U.S. from 1977-1982 are identified and classified by disease and place where implicated foods were mishandled. Data for these years are tabulated and combined with data from the years 1961-1976. Inadequate cooling - either leaving foods at room or warm outside temperatures or storing them in large containers while being refrigerated - was associated with most of the outbreaks. Ranking of all factors has changed little over four periods of review, but during the last period numerous outbreaks primarily due to ingestion of raw clams and raw oysters caused an increase in the factors: contaminated raw foods and obtaining foods from unsafe sources. This has been primarily due to raw clam-, oyster- and milk-associated outbreaks. The three most frequently identified factors that contributed to salmonellosis were improper cooling, contaminated raw products, and inadequate heating; to staphylococcal food poisoning were colonized persons handling cooked foods, lapse of 12 or more hours between preparing and eating, and improper cooling; to botulism were inadequate heat processing, improper fermentations, improper room temperature holding; to *C. perfringens* enteritis were improper cooling, lapse of 12 or more hours between preparing and eating, and inadequate reheating (followed closely by improper hot holding); to shigellosis were colonized persons handling implicated foods, improper cooling, and lapse of 12 or more hours between preparing and eating; to *V. parahaemolyticus* gastroenteritis were contaminated raw ingredients, improper cooling, and cross contamination; to typhoid fever were colonized persons handling implicated foods, lapse of 12 or more hours between preparing and eating, and several time-temperature factors tied for third; to *B. cereus* gastroenteritis were improper cooling, lapse of 12 or more hours between preparing and eating, and improper hot holding. The principal factors associated with outbreaks stemming from foods prepared in foodservice establishments were improper cooling, lapse of 12 or more hours between preparing and eating, colonized persons handling implicated foods, inadequate reheating and improper hot holding. Important factors that contributed to outbreaks in homes were contaminated raw foods, inadequate cooking, unsafe source, improper cooling, and lapse of 12 or more hours between preparing and eating. Major contributing factors associated with operations in food processing plants were inadequate heat processing, contaminated raw ingredient, improper cooling, colonized persons handling implicated foods, improper cleaning of equipment, and improper fermentation. Those factors cited above for each category are the vital few items to stress in food safety programs. The many other items that are a part of food protection programs are of lesser importance or trivial.

Accompanying the development of epidemiology and improved surveillance of foodborne diseases, specific factors (faulty practices, procedures and processes) that contributed to the occurrence of outbreaks of these diseases have become apparent. Reviews of such contributory factors have been published for outbreaks that were reported in the United States *(4-7,9)*, England and Wales *(31)*, Canada *(43)*, and New South Wales, Australia *(20)*.

Factors that contribute to outbreaks of foodborne illness reflect hazards. Hence, they aid in establishing critical control points which are operations where measures that will either eliminate or reduce hazards can be exercised. Of further importance, they provide guidance for assessing the probability of occurrence of a hazard (risk) *(12,45)*. They also indicate where verification of the monitoring of critical control points is needed. These contributory factors should set priorities for legislators, program administrators, supervisors and inspectors to use when considering matters related to food safety. Emphasis must be placed on real and proven contemporary problems.

This review updates information about factors (hazardous operations) that contributed to outbreaks of foodborne diseases in the United States and assesses the risk of each factor.

MATERIALS AND METHODS

The present study followed methods that were used in the past *(4-6)*, which consisted of gathering information on factors that contributed to outbreaks of foodborne disease from reports submitted to the Centers for Disease Control (CDC) from health agencies, investigations made by CDC personnel or articles published in public health, medical or food science journals. *Morbidity and Mortality Weekly Reports (19)* and botulism surveillance data (1977-1982) were reviewed to get confirmation and further information. *Index Medicus* (1977-1983), *Excerpta Medica* (1977-1983), *Abstracts of Hygiene* (1977-1983), and Review of the Literature for 1977-1984 in *Food Research Institute Annual*

submitted to the Centers for Disease Control (CDC) from health agencies, investigations made by CDC personnel or articles published in public health, medical or food science journals. *Morbidity and Mortality Weekly Reports (19)* and botulism surveillance data (1977-1982) were reviewed to get confirmation and further information. *Index Medicus* (1977-1983), *Excerpta Medica* (1977-1983), *Abstracts of Hygiene* (1977-1983), and Review of the Literature for 1977-1984 in *Food Research Institute Annual Reports (23)* were searched for listing of articles concerning foodborne disease outbreaks. Outbreaks cited by one source were checked against the other sources to avoid duplication.

This survey, although pointing out many important factors that contributed to outbreaks, has shortcomings that include inadequate reporting of outbreaks and incomplete write-up or abstracting of contributory factors. Omitted from this review were outbreaks of ciguatera, paralytic shellfish poisoning, and mushroom poisoning. Contributory factors to these diseases are ingestion of toxic plankton by fish and shellfish and the toxicogenic nature of the mushrooms. Outbreaks of scombroid (histamine) poisoning were only included when there was clear identification of situations that allowed bacteria to multiply, although this event would have occurred in all cases. Factors were not tabulated, even though obvious, unless the investigator or abstractor presented the information in a narrative format in their reports.

RESULTS

The search revealed 766 foodborne disease outbreaks that occurred between 1977-1982 in the United States and met the criteria. They mostly came from reports from states to CDC, but they also included outbreaks described in *Morbidity and Mortality Weekly Reports (19)* and articles in the medical and food science literature (e.g. *1-3,25,27-30, 32,33,36-42,44).*

Factors that contributed to these outbreaks are listed in Table 1. Data are cumulated from 1961 to 1982 in Table 2. Ranking of frequency of the contributory factors remained relative constant over the years covered by the reviews *(4-6)* as shown in Table 3. Data presented in Tables 4-11 are classified by disease - salmonellosis, staphylococcal food poisoning, botulism, *Clostridium perfringens* enteritis, shigellosis, typhoid fever, *Vibrio parahaemolyticus* gastroenteritis, and *Bacillus cereus* gastroenteritis - and grouped according to factors affecting contamination, survival, and growth. They cumulate data from 1961-1982. Data have been classified according to the place where mishandling and/or mistreatment occurred - foodservice establishments (Table 12), homes (Table 13) and food processing plants (Table 14) - from 1973-1982.

TABLE 1. *Factors that contributed to the occurrence of 766 outbreaks of foodborne disease, United States, 1977-1982.*

Contributory factor	Number	Percent[a]
Improper cooling	313	40.9
Holding at room/outside ambient temperature	162	21.1
Large/deep containers in refrigerator	151	19.7
Lapse of 12 or more hours between preparing and eating	193	25.2
Contaminated raw food/ingredient	175	22.8
Obtaining food from unsafe source	138	18.0
Colonized person handled implicated food	116	15.1
Inadequate cooking/canning/heat processing	109	14.2
Inadequate reheating	70	9.1
Improper hot holding	70	9.1
Cross contamination	29	3.8
Improper cleaning of equipment/ utensils	27	3.8
Toxic containers/pipelines	23	3.0
Use of leftovers[b]	19	2.5
Intentional additives	19	2.5
Improper fermentation	12	1.6
Incidental additives	10	1.3
Mistaken for edible varieties	9	1.2
Inadequate/improper thawing	5	0.7
Inadequate acidification	5	0.7
Contaminated water	3	0.4
Slow/inadequate drying	2	0.3
Post processing contamination	2	0.3
Soaking time too short	1	0.1
Flies	1	0.1

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Also lapse of 12 or more hours.

DISCUSSION

Changing situation

Most contributory factors remained rather constant for the four periods of review in the United States (Table 3), and they were not too different from those identified in such reviews that have been made in other countries *(20,31,43).* These data show that important contributory factors have been identified, and they substantiate the relative importance of these factors.

The major changes in ranking between this (1977-1982) review and the earlier reviews *(4-6)* are that ingesting raw foods/incorporating raw ingredients into foods and obtaining these foods from unsafe sources increased considerably. This was primarily due to numerous outbreaks of gastroenteritis (similar to that caused by Norwalk agent) attributed to ingestion of raw clams and oysters, mostly in 1982 *(24).*

Multiple causation

Usually several causal factors happen sequentially to result in foodborne illness. Hence, *(a)* pathogen must reach the food; *(b)* it must survive there until the food is ingested; *(c)* often it must multiply to reach infectious levels or produce toxins, and *(d)* the person who ingests the foods must be susceptible to the levels ingested. For example, under usual circumstances, *Staphyloccus aureus* reaches cooked foods during handling, and time is required for enterotoxin production as the food remains at room temperature or in a large container in a refrigerator. *Bacillus cereus,* for instance, often reaches foods from soil, and its spores survive cooking and multiply during holding, usually at room temperature.

TABLE 2. *Factors that contributed to the occurrence of 1918 outbreaks of foodborne disease, United States 1961-1982.*

Contributory factor	Number	Percent[a]
Improper cooling	839	43.7
Lapse of 12 or more hours between preparing and eating	434	22.6
Colonized person handling implicated food	348	18.1
Incorporating contaminated raw food/ ingredient into foods that received no further cooking	303	15.8
Inadequate cooking/canning/heat processing	298	15.5
Improper hot holding	255	13.3
Inadequate reheating	203	10.6
Obtaining food from unsafe source	192	10.0
Cross contamination	104	5.4
Improper cleaning of equipment/ utensils	103	5.4
Use of leftovers[b]	66	3.3
Toxic containers/pipelines	61	3.2
Intentional additives	46	2.4
Mistaken for edible varieties	33	1.7
Improper fermentation	25	1.3
Incidental additives	24	1.3
Inadequate/improper thawing	7	0.4
Inadequate acidification	5	0.3
Poor dry storage practices	5	0.3
Contaminated water	4	0.2
Post-processing contamination	3	0.2
Slow/inadequate drying	2	0.1
Misbranding	2	0.1
Faulty sealing	1	0.05
Soaking time too short	1	0.05
Growth during seed germination	1	0.05
Improper preservation	1	0.05
Inadequate dishwashing	1	0.05
Contamination by fertilizer or soil	1	0.05
Flies on foods	1	0.05

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Also lapse of 12 or more hours.

There is a probability that each causal factor occurs. Hence, the more causal factors that must occur decreases the probability of occurrence of outbreaks. For example, with *Shigella* and the hepatitis virus, only one contributory factor - contamination from an infected person - is necessary. This single factor is a high risk, but not all persons (usually very few) who handle foods are infected, which reduces the risk. Those infected do not always contaminate their hands following defecation or they effectively wash the contaminants off, which further reduces risks. Even when hands are contaminated, they may not touch foods within the duration that the pathogens remain viable, which further reduces risks. The contaminated food may then be heated, which can kill the pathogens and eliminate the risks.

On the other hand, foods that are vehicles of *B. cereus* (e.g. rice) are frequently contaminated with their spores which maintains a high risk. The spores are likely to survive cooking which continues to maintain the risk. Improper storage increases the risk, and as the time of holding is prolonged, the risk continues to increase.

Contributory factors

Contributory factors that accounted for over 1% of the outbreaks are discussed in reference to situations that allowed them to occur and to means to counter them. Relative risks (i.e. high, medium and low) are assigned to each.

Improper cooling. Improper cooling is the most important contributory factor for all periods of review. It was frequently identified in outbreaks of staphylococcal food poisoning, salmonellosis, *C. perfringens* enteritis, *Vibrio parahaemolyticus* gastroenteritis, and *B. cereus* gastroenteritis. It is invariably associated with scombroid poisoning.

Holding foods at room/outside temperature. A major part of improper cooling is keeping foods at room temperature for long durations and sometimes not refrigerating them at all. This is an extremely hazardous practice and the risk of foodborne disease (or spoilage) following such a practice is quite high. It's hard to realize why this practice continues; the problem has been known for decades. Ordinances usually cover this practice, but enforcement of this item is difficult and often lax. This is partly because of the infrequency of inspections and the time at which inspections are made. Retrospective investigations of outbreaks frequently detect that this practice is carried out overnight, at times when inspections are not made. Furthermore, when this poor practice is noticed, food workers often try to justify the situation by stating that the room-temperature holding of potentially hazardous foods is only temporary and that these foods will be put into a refrigerator in a little while, which sometimes never comes.

To add complexities to this issue, room-temperature holding of recently-cooked foods for a short while is essential to complete cooking of some foods having large dimensions (e.g. roast beef and turkeys) or being quite viscous (e.g. chili and pinto beans). During this interval, post-cooking temperature rise due to conduction heating occurs in the interior. In time (which varies with type and thickness of the food and heat-penetration rates that were initiated during cooking), the temperature begins to decrease, and when it reaches 55°C (131°F), cooling in refrigerators, water baths or ice baths should commence.

The importance of this factor demands concerted effort. Prevention is to either eat foods promptly after cooking, hold them hot, or cool them rapidly.

Storing foods in large/deep containers in refrigerators. Foods that have been stored in large/deep containers in refrigerators have been frequently implicates as vehicles in outbreaks of foodborne diseases. This is an extremely high-risk operation. Hazard analyses have also shown that this practice is commonplace (e.g. *11,15-17*).

The Food and Drug Administration's Food Service Sanitation Manual *(22)* stipulates that cooked foods should be cooled from 60°C (140°F) to 7°C (45°F) within 4 h. This is idealistic but if accomplished would make a dramatic impact on prevention of foodborne diseases. It's difficult, however, to achieve such a rapid decrease in temperature

TABLE 3. *Factors that contributed to the occurrence of outbreaks of foodborne disease by rank (1-10) and percent, reported during various intervals in the United States between 1961-1982.*

Contributory factor	Ranking and percent[a] Years Covered and (Number of Outbreaks)									
	1961-70 (493)		1971-72 (232)		1973-76 (427)		1977-82 (766)		1961-82 (1,918)	
Improper cooling	1	(46)	1	(48)	1	(46)	1	(41)	1	(44)
Lapse of 12 or more hours between preparing and eating	4	(21)	2	(23)	2	(20)	2	(25)	2	(23)
Colonized person handled implicated food	3	(22)	4	(19)	3	(18)	5	(15)	3	(18)
Incorporating contaminated raw food/ingredient into foods that received no further cooking	5	(14)	7	(6)	7	(11)	3	(23)	4	(16)
Inadequate cooking/canning/ heat processing	2	(24)	4	(19)	6	(11)	6	(14)	5	(16)
Improper hot holding	6	(13)	3	(21)	4	(16)	7	(9)	6	(14)
Inadequate reheating	7	(9)	6	(9)	5	(16)	7	(9)	7	(11)
Obtaining food from unsafe source	10	(6)	11	(3)	12	(4)	4	(18)	8	(10)
Cross contamination	7	(9)	7	(6)	11	(4)	9	(4)	9	(5)
Improper cleaning of equipment/utensils	9	(8)	9	(6)	8	(6)	10	(4)	10	(5)
Use of leftovers[b]	11	(3)	10	(4)	9	(5)	12	(3)	11	(3)
Toxin containers/pipelines	12	(3)	12	(3)	12	(4)	11	(3)	12	(3)
Intentional additives	13	(2)	13	(2)	10	(5)	13	(3)	13	(2)

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Also lapse of 12 or more hours.

unless either very shallow layers of foods are put into cold environments (such as a rapid-chill refrigerator) or some method of rapid cooling (e.g. ice baths or water baths) is used. Yet, in many foodservice establishments in many communities, it would not be surprising to observe large containers (e.g. 5-gallon plastic containers, stock pots, steam-table deep inserts) used for storage of foods in refrigerators. It does not take much reading of the literature (e.g. *15-17*) or many measurements of temperature and time in foodservice establishments to learn that rapid cooling cannot be achieved in such large containers. Also, it is common to encounter refrigerators within which there is insufficient number and arrangement of shelving to facilitate the holding of very many pans that are 4 or less inches high. Even fewer establishments have devices (e.g. ice baths, water baths, rapid-chill refrigerators) that facilitate rapid cooling.

The use of large containers for storage of foods being chilled should not be tolerated.

Lapse of 12 or more hours between preparing and eating. Time is a primary consideration in determining whether or not many of the foodborne diseases occur. Time is required for spores to germinate into vegetative cells which multiply. It is needed for vegetative cells to progress through the lag and logarithmic growth phases. It is required to permit toxigenic bacteria (e.g. *B. cereus, Clostridium botulinum,* and *S. aureus)* to multiply in foods and to elaborate exotoxins. It is needed for psychrotrophic pathogens to multiply during cold storage. Without sufficient time, none of the above occurs; risks are proportional to time. Given sufficient time, the determination of whether problems occur depends on the type of food (e.g. its pH and a_w) and temperatures at which the foods are held (e.g. kept at room temperature, kept hot or cooled and kept cold) *(11,45).* Risks increase with time between cooking foods or preparing salads that contain cooked ingredients and their serving.

Lapse of 12 or more hours between preparing and eating was frequently identified in outbreaks caused by *B. cereus, C. perfringens, Salmonella, V. parahaemolyticus* and staphylococcal enterotoxin. The occurrence of this factor is far more common than data indicate. This is so because investigators often do not report information about the duration of each preparation step. Furthermore, outbreaks listed under the category of use of leftovers should be added to this category. Such foods are always held 12 or more hours between preparation and reuse. When the time interval between preparation and ingestion exceeds 12 h, risks are quite high. Caution must be taken whenever this interval exceeds 4 h, and concern should increase with each passing hour.

Contaminated raw food/ingredient. Raw clams and oysters, which were vehicles in numerous outbreaks of Norwalk-like gastroenteritis *(24);* raw milk containing either *Campylobacter jejuni* or salmonellae *(14);* and raw pork infested by *Trichinellae spirilis (19)* were primarily responsible for the frequency of occurrence of this factor. Raw foods bring microorganisms that are on them into processing plants and kitchens. Salmonellae and campylo-

TABLE 4. *Factors that contributed to the occurrence of 331 outbreaks of foodborne salmonellosis, United States, 1961-1982.*

Contributory factor	Number	Percent[a]
Factors affecting contamination[b]		
Contaminated raw products	103	31.1
Cross contamination[c]	65	19.6
Colonized person handled implemented food[d]	47	14.2
Improper cleaning of equipment/utensils	42	12.7
Contaminated water	2	0.6
Factors affecting survival		
Inadequate heating (cooking, heat processing)	79	23.9
Inadequate reheating	38	11.5
Factors affecting growth		
Improper cooling[e]	144	42.5
Lapse of 12 or more hours between preparing and eating	63	19.0
Improper hot holding[f]	42	12.7
Use of leftovers[g]	13	3.9
Improper fermentations	2	0.6

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Raw products of animal origin often the source of contamination.
[c]From raw to cooked foods via hands, equipment, utensils, cleaning cloths/sponges/towels to foods not subjected to further cooking.
[d]*Salmonella* isolated from one or more food handlers during the investigation (unknown whether source or victim) or history of food handler touching food incriminated as the vehicle.
[e]Includes leaving foods at room or outside ambient temperature for several hours.
[f]Holding foods at bacterial incubation temperatures for several hours.
[g]Also 12 or more hours.

TABLE 5. *Factors that contributed to the occurrence of 296 outbreaks of staphylococcal food poisoning, United States, 1961-1982.*

Contributory factor	Number	Percent[a]
Factors affecting contamination		
Colonized person handled cooked, implemented foods	144	48.6
Improper cleaning of equipment/utensils	25	8.4
Cross contamination[b]	10	3.4
Factors affecting survival		
Inadequate reheating[c]	17	5.7
Inadequate cooking	9	3.0
Factors affecting growth		
Lapse of 12 or more hours between preparing and eating	136	45.9
Improper cooling[d]	128	43.2
Improper hot holding[e]	52	17.7
Use of leftovers[f]	11	3.7
Improper fermentations	2	0.7
Slow/inadequate drying	1	0.3
Inadequate/improper thawing	1	0.3

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]From raw to cooked foods via hands, equipment, utensils, cleaning cloths/sponges/towels to foods not subjected to further cooking.
[c]Poor practices reported but reheating would not inactivate enterotoxin.
[d]Includes leaving foods at room or outside ambient temperature for several hours.
[e]Holding foods at bacterial incubation temperatures for several hours.
[f]Also 12 or more hours.

bacters are frequently on raw meat and poultry. *Yersinia enterocolitica*, pathogenic *Escherichia coli*, *C. perfringens*, and *S. aureus* are also common contaminants of these raw foods. These microorganisms may be spread during processing and preparation and may survive inadequate heating. Soil-grown cereals, vegetables and fruits are invariably contaminated by bacterial spores (e.g. *B. cereus*, *C. perfringens*, and *C. botulinum*). These remain on the foods during non-heat processing, and many spores survive heating that is less severe than retorting.

The risk of ingesting contaminated raw shellfish is linked with where they have been harvested. If they are harvested from sewage-contaminated waters, the risk is quite high. If, on the other hand, they are harvested from sewage-free waters, the risk is low. Hence, a program featuring strict monitoring of shellfish waters, patrolling closed areas and checking tags and certification listings is essential for ensuring that shellfish are free of contamination *(8,24)*.

The risk of acquiring illness from ingesting raw milk, whether certified or not, or cheese made from raw milk is high *(14)*. The risk of acquiring trichinosis from ingesting raw or rare pork is low, but precautions should still be taken.

Unsafe source. Shellfish from sewage-polluted waters, raw (including certified raw) milk, and wild mushrooms are examples of foods that are obtained from unsafe sources. Risks are similar to those stated in the above section.

Contamination by persons who handle foods. Most outbreaks of staphylococcal food poisoning follow the handling of cooked foods by persons who carry enterotoxigenic staphylococcal strains in their nares or skin. Risk of foods becoming contaminated by staphylococci as they are handled with bare hands are high, and risk of food poisoning resulting from the contaminated, cooked, moist, protein-rich foods are high when they are kept for several hours without refrigeration or stored in large containers.

Although some persons who handled the foods which were incriminated as vehicles were found during investigations to be infected with *Salmonella*, their carrier state could have been caused by either eating or handling the implicated foods. So they may have been victims rather

TABLE 6. *Factors that contributed to the occurrence of 147 outbreaks of botulism, United States, 1961-1982.*

Contributory factor	Number	Percent[a]
Factors affecting contamination[b]		
Factors affecting survival		
Inadequate heat processing	117	79.6
Inadequate acidification	4	2.7
Inadequate reheating	2	1.4
Factors affecting growth		
Improper fermentations	18	12.2
Improper room temperature holding	15	10.2
Lapse of 12 or more hours between preparing and eating	3	2.0
Improper hot holding[c]	3	2.0

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Raw product or ingredient likely source of spores from soil or mud.
[c]Holding foods at bacterial incubation temperatures for several hours.

TABLE 7. *Factors that contributed to the occurrence of 141 outbreaks of* Clostridium perfringens *enteritis, United States, 1961-1982.*

Contributory factor	Number	Percent[a]
Factors affecting contamination[b]		
Cross contamination[c]	2	1.4
Improper cleaning of equipment/utensils	2	1.4
Factors affecting survival		
Inadequate reheating	60	42.6
Inadequate cooking[d]	10	7.1
Factors affecting growth		
Improper cooling[e]	111	78.8
Lapse of 12 or more hours between preparing and eating	79	56.0
Improper hot holding[f]	55	39.0
Use of leftovers[g]	15	10.6

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Raw product or ingredient likely source of spores.
[c]From raw to cooked foods via hands, equipment, utensils, cleaning cloths/sponges/towels to foods not subjected to further cooking.
[d]Poor practices observed but probably would not have altered outcome because *C. perfringens* spores survive most heat processes short of autoclaving/retorting.
[e]Includes leaving foods at room or outside ambient temperature for several hours.
[f]Holding foods at bacterial incubation temperatures for several hours.
[g]Also lapse of 12 or more hours.

than sources of salmonellae. The source is more likely to be incoming raw foods of animal origin (e.g. poultry, meat, egg shells). Risks of direct contamination from food handlers are low compared to cross contamination from foods of animal origin.

Since shigella and *S. typhi* are host-adopted to human beings, a carrier is usually found to have contaminated the implicated foods. Risks of acquiring these diseases from foods are low, however, because carriers of these bacteria are not very common in the United States anymore.

The virus of hepatitis A and apparently the Norwalk virus are host-adapted to humans or primates. Thus either foods are contaminated when handled by infected persons who fail to effectively wash their hands after defecation or water-grown foods are contaminated by sewage. These diseases and perhaps other viral infections are probably more common than epidemiological data currently indicate. At this time, however, the risks are classified as medium to low.

Streptococcal pharyngitis may follow ingestion of foods that are contaminated by persons with sore throats or infected skin lesions. This disease is not commonly foodborne, so it would be classified as being a low risk.

Risks of contamination are increased whenever persons who have infected skin lesions, diarrhea, sore throats, or jaundice handle foods.

Insufficient cooking/canning/heating. This contributory factor is frequently identified in outbreaks of trichinellosis and botulism and sometimes implicated in outbreaks of salmonellosis. Retorting or heating in pressure cookers must be sufficiently long to inactivate spores of *C. botulinum*. Otherwise, heat-processed foods must have a pH value below 4.6 or be acidified to this level or below and then heated sufficiently to inactivate these spores. Pork, bear meat and walrus meat must be heated sufficiently long to kill cysts of *T. spirilis*. Other cooked foods must be heated to time-temperature values (e.g. 165°F/73.9°C for a few seconds; 150°F/65.5°C for a minute or longer, depending on quantity of microorganisms present and type of foods) to kill parasites and vegetative forms of bacterial pathogens. If such heating is done effectively, risks are low; otherwise, risks that unheated or insufficiently-heated foods serve as vehicles of foodborne disease are high.

Insufficient reheating. The situation related to this factor is similar to that described for cooking. The risk of the hazard may be greater, however, because cooked and chilled foods are frequently just warmed up rather than thoroughly heated. Also, more microorganisms of concern will be on foods that have been subjected to time-temperature abuse than would be present on raw foods. A raw chicken, for example, may have from 10 to 100 salmonellae spread over the carcass. These pathogens are likely to be killed over the carcass. These pathogens are likely to be killed during cooking. On the other hand, if some survived or if there was cross contamination followed by storage at temperatures conducive to multiplication for sufficient time, then millions or billions may be present. These mi-

TABLE 8. *Factors that contributed to the occurrence of 47 outbreaks of foodborne shigellosis, United States, 1961-1982.*

Contributory factor	Number	Percent[a]
Factors affecting contamination[b]		
Colonized person handled implicated food	43	91.5
Contaminated raw ingredient	1	2.1
Flies	1	2.1
Factors affecting survival		
Inadequate reheating	2	4.3
Factors affecting growth		
Improper cooling[b]	18	38.3
Lapse of 12 or more hours between preparing and eating	9	19.1
Use of leftovers[c]	1	2.1

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Includes leaving foods at room or outside ambient temperature for several hours.
[c]Also lapse of 12 or more hours.

TABLE 9. *Factors that contributed to the occurrence of 27 outbreaks of* Vibrio parahaemolyticus *gastroenteritis, United States, 1961-1982.*

Contributory factor	Number	Percent[a]
Factors affecting contamination[b]		
Contaminated raw ingredients	12	44.4
Cross contamination[c]	6	22.2
Improper cleaning of equipment/utensils	1	3.7
Sea water contaminated cooked foods	1	3.7
Factors affecting survival		
Inadequate reheating	2	7.4
Inadequate cooking	1	3.7
Factors affecting growth		
Improper cooling[d]	12	44.4
Lapse of 12 or more hours between preparing and eating	3	11.1

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Raw seafood or seawater likely source of contamination from seawater.
[c]From raw to cooked foods via hands, equipment, utensils, cleaning cloths/sponges/towels to foods not subjected to further cooking.
[d]Includes leaving foods at room or outside ambient temperature for several hours.

TABLE 10. *Factors that contributed to the occurrence of 17 outbreaks of typhoid fever, United States, 1961-1982.*

Contributory factor	Number	Percent[a]
Factors affecting contamination		
Colonized person handled implicated foods	14	82.4
Factors affecting survival		
Inadequate cooking	1	5.9
Inadequate reheating	1	5.9
Factors affecting growth		
Improper cooling[b]	2	11.8
Lapse of 12 or more hours between preparing and eating	1	5.9

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Includes leaving foods at room or outside ambient temperature for several hours.

crobes would have to be killed during reheating or face the likelihood that the chickens become a vehicle for salmonellae.

Improper hot holding. Foods that are allowed to remain in steam-tables, bains Marie, hot-air cabinet, thermotainers, or overs set at low temperatures or to stay under heating elements where the ambient temperature is below the maximum-growth temperature for pathogenic bacteria for long durations are frequently implicated as vehicles in outbreaks of foodborne disease. The lowest temperatures of foods in cabinets and ovens are usually at the geometric center. The temperatures of foods in steam tables and bains Marie, however, are usually lowest near the top, unless they are stirred frequently *(15)*. Lids on either steam tables or pans in hot-water baths, however, aid in maintaining a higher temperature at the surface, but their use is not always practicable. Risks are related to the temperature of the foods being held and the duration of the holding; they are higher with lower temperatures and usually with longer durations of holding.

Cross contamination. Cross contamination is either direct or indirect contamination froma contaminated food to other foods. Indirect cross contamination occurs when a contaminated (e.g. raw) food is handled by persons or when it contacts surfaces of utensils or equipment, and subsequently the contaminated hands of the person or surface contacts a previously uncontaminated or cooked food. Since cross contamination is a series of sequential events, it occurs over time; hence, it is difficult to detect during routine inspections of short duration or during retrospective epidemiologic investigations. Nevertheless, potential risks are high. By just watching food processing and particularly preparation of raw foods of animal origin, the high probability of its occurrence becomes readily apparent. Washing hands and cleaning surfaces between raw and cooked food handling are often neglected.

Improper cleaning of equipment/utensils. Procedures to effectively clean and disinfect utensils and equipment are well established. Short cuts, sloppiness or carelessness and lack of supervision by managers, however, contribute to contaminants remaining on "cleaned" surfaces. Risks would have to be classified as medium, but they would be low with improved supervision.

Toxic containers and pipelines. Defective backflow values on soft-drink dispensing lines or in vending machines and conditions conducive to back siphonage have resulted in outbreaks of copper poisoning. Risks are low

TABLE 11. *Factors that contributed to the occurrence of 11 outbreaks of* Bacillus cereus *gastroenteritis, United States, 1961-1982.*

Contributory factor	Number	Percent[a]
Factors affecting contamination[b]		
Factors affecting survival		
Inadequate reheating[c]	2	18.2
Factors affecting growth		
Improper cooling[d]	11	100.0
Lapse of 12 or more hours between preparing and eating	6	54.5
Improper hot holding[e]	1	9.1

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Raw product or ingredient likely source of spores from soil.
[c]*B. cereus* emetic toxin is not inactivated by reheating.
[d]Includes leaving foods at room or outside ambient temperature for several hours.
[e]Holding foods at bacterial incubation temperatures for several hours.

TABLE 12. *Factors that contributed to the occurrence of 660 outbreaks of foodborne disease that resulted because of mishandling and/or mistreatment of foods in foodservice establishments, United States, 1973-1982.*

Contributory factor	Number	Percent[a]
Improper cooling	366	55.8
Lapse of 12 or more hours between preparing and eating	203	30.8
Colonized person handled implicated food	160	24.2
Inadequate reheating	130	19.7
Improper hot holding	107	16.2
Contaminated raw food/ingredient	58	8.8
Obtaining food from unsafe source	42	6.4
Improper cleaning of equipment/ utensils	38	5.8
Cross contamination	31	4.7
Use of leftovers[b]	31	4.7
Inadequate cooking	29	4.4
Toxic containers/pipelines	23	3.5
Intentional additives (e.g. MSG)	13	2.0
Incidental additives	9	1.4
Inadequate/improper thawing	6	0.9
Contaminated water	2	0.3
Improper dishwashing/ contamination afterwards	1	0.2
Mistaken for foods	1	0.2

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Also lapse of 12 or more hours.

TABLE 13. *Factors that contributed to the occurrence of 345 outbreaks of foodborne disease that resulted because of mishandling and/or mistreatment of foods in homes, United States, 1973-1982.*

Contributory factor	Number	Percent[a]
Contaminated raw food/ingredient	145	42.0
Inadequate cooking/canning/heat processing	108	31.3
Obtain food from unsafe source	99	28.7
Improper cooling	77	22.3
Lapse of 12 or more hours between preparing and eating	44	12.8
Colonized person handled implicated food	34	9.9
Mistaken for foods	24	7.0
Improper fermentations	16	4.6
Inadequate reheating	12	3.5
Toxic containers	12	3.5
Improper hot holding	11	3.2
Cross contamination	11	3.2
Use of leftovers[b]	9	2.6
Intentional additives	8	2.3
Incidental additives	3	0.9
Contaminated water	2	0.6
Inadequate acidification	2	0.6
Improper cleaning of equipment/ utensils	1	0.3
Poor dry storage practices	1	0.3
Inadequate preservation	1	0.3
Inadequate drying	1	0.3
Faulty sealing	1	0.3
Flies contaminated food	1	0.3

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Also lapse of 12 or more hours.

because the combination of events that are necessary to result in this situation do not commonly line up.

Zinc poisoning has resulted from highly-acid foods (e.g. lemonade) being stored in galvanized containers. Practices of storing such foods in containers that contain toxic metals (e.g. copper pots and kettles, cadmium-containing trays, gray-enamelware containing antimony) are not common anymore because there are so many other types of containers (e.g. stainless steel, aluminum, plastic) that are available and more popular to use for storing foods.

Intentional additives. Chemical substances that are intentionally added to foods are often overemphasized as a cause of foodborne illness. Most of the outbreaks involving these substances occur most frequently in homes; but sometimes foodservice establishments are involved. Risks vary from time-to-time and place-to-place and with the knowledge of persons using the additives.

Inadequate/improper thawing. The process of thawing individual frozen items is not particularly hazardous. If, however, thawed foods remain at room temperature or in water baths for a long time after they have thawed, microorganisms can multiply. If raw foods are involved, spoilage will more likely be the outcome. Risks that illnesses will occur as a result of improperly thawing raw foods are low. This is not necessarily true, however, when cooked foods are thawed.

The primary hazard associated with thawing is that foods (e.g., large turkeys) that are incompletely thawed are

TABLE 14. *Factors that contributed to the occurrence of 75 outbreaks of foodborne disease that resulted because of mishandling and/or mistreatment of foods in food processing plants, United States, 1973-1982.*

Contributory factor	Number	Percent[a]
Inadequate heat processing	20	26.7
Contaminated raw ingredient	14	18.7
Improper cooling	11	14.7
Colonized person handled implicated food	8	10.7
Improper cleaning of equipment/utensils	8	10.7
Improper fermentation	8	10.7
Incidental additives	6	8.0
Intentional additives	5	6.7
Obtaining food/ingredient from unsafe source	5	6.7
Post-process contamination	3	4.0
Improper hot holding	2	2.7
Cross contamination	1	1.3
Inadequate drying	1	1.3
Toxic containers/pipelines	1	1.3
Contaminated water	1	1.3
Lapse of 12 or more hours between preparing and eating	1	1.3
Use of leftovers[b]	1	1.3
Soil/fertilizer contamination	1	1.3
Microbial growth during germination of seeds	1	1.3

[a]Percentage exceeds 100 because multiple factors contribute to single outbreaks.
[b]Also lapse of 12 or more hours.

sometimes cooked insufficiently to kill pathogens that are on or in them. The consequences and risks associated with this are discussed under the section on inadequate cooking.

Other factors. Contributory factors discussed in this section must be considered as low risks because they occur in less than 1% of foodborne disease outbreaks. Insufficient concentrations of acids have been added to acidified foods which allowed microbial growth. Water was the vehicle of pathogens in three outbreaks. Slow or otherwise inadequate drying of meat products (jerky) resulted in a few outbreaks as did post-processing contamination. Soaking too short a time was cited as a contributing factor. Flies from a sewage-treatment plant were possible vectors that contaminated food with shigellae. Soiled dishes after washing was implicated only once, and this was questionable. Other low risk factors are listed at and near the bottom of Table 2. Items not listed, but yet cited as requirements in ordinances, are even rarer contributory factors if indeed they even contributed to outbreaks.

Vital versus trivial factors associated with operations

There is a principle, sometimes referred to as the Pareto Principle, in quality control (planning and analysis) and management that in effect states: A few (the 'vital few') contributors to a problem account for most (perhaps 90%) of the total size of the problem, and the remaining many contributors (the 'trivial many') account for only a small proportion (perhaps 10%) of the total *(26,35)*. The factors that contribute to outbreaks of foodborne diseases (as shown in the tables) fit this principle. In this regard, a few factors (e.g. improper cooling and lapse of 12 h or more between preparing and eating) occur more frequently than others and hence are vital. Many items in regulations (e.g. dirty walls, floors, and ceilings) relate to aesthetics and are trivial in regard to contributing to outbreaks of foodborne disease. Hence, efforts toward food safety should not be deployed equally on all operations or on all items in a regulation, but emphasis must be put on high-risk operations. Those factors or operations that frequently contribute to outbreaks (which have been presented in the tables and discussed above) define priorities for preventive and control programs and indicate critical control points.

Foodservice establishments. Foods prepared in foodservice establishments account for most of reported outbreaks of foodborne disease *(10,13)*. Four of the top five contributory factors associated with foodservice establishments relate to time and temperature situations and, hence, their prevention and control are vital to food safety. Preparing food in advance of serving is integral to certain foodservice systems (e.g. cool/chill, cook/freeze, cook/hold), and, therefore, pose high risks. The risk must be reduced by preventing microbial multiplication during the interval foods are held after preparation. Handling cooked foods is another vital factor that leads to contamination. Reheating is quite a bit more important than initial cooking because higher numbers of pathogenic microorganisms must be killed.

These and other vital operations to food safety (critical control points) in foodservice operations can be readily identified from these data. Health agencies must verify that effective control measures are in effect in foodservice establishments and that monitoring of critical control points is being carried out effectively.

Homes. Data about contributory factors of home-associated outbreaks show the need for informing the public about hazardous situations that are unique to home preparation of foods in the region of concern. For example, in shellfish-harvesting regions, the public should be warned about hazards associated with harvesting shellfish from sewage-polluted waters or closed areas, from waters having red tides, or from purchasing shellfish from unknown sources (e.g. untagged or non-coded products); in cities that have certified raw-milk dairies and in rural areas, the hazards of ingesting raw milk should be stressed; in forested regions, warnings about toxic species of mushrooms should be given. Although it is not high on the list of contributing factors associated with home-prepared foods, many situations prevail that make the possibility of cross contamination quite likely. Hence, procedures to reduce its occurrence along with proper heating and cooling procedures should be stressed in educational efforts.

Food processing plants. Many of the animals that enter abattoirs are either infected or contaminated with foodborne pathogens, and further spread occurs during processing. Hence, abattoirs and raw-product processing plants must

accept some of the blame of spreading salmonellae and other pathogens to many carcasses and pieces of meat. These products are major sources of pathogens for food-service establishments and homes where further abuse (e.g. inadequate cooking or cross contamination) leads to outbreaks of foodborne illness. Other ingredients used in processed foods (e.g. coco beans) may harbor salmonellae and spices contain bacterial spores. These may survive certain forms of processing unless the hazards are realized and measures taken to eliminate or at least reduce them. Strict monitoring of critical control points is essential.

CONCLUSION

The information base on the factors that contributed to foodborne diseases has grown to a point that it significantly indicates hazards and predicts risks that are associated with food production, processing, transportation, storage, retailing and preparations. Continued investigations, however, are needed to evaluate, expand and up-date this base.

In the United States with its abundance of electrical power, availability of equipment to cool and heat foods and relatively high education level of its populous, it's surprising that a significant foodborne disease problem exists. It's even more surprising that these illnesses continue after the causes have been detected and the abundance of evidence that indicates the major roles of certain contributory factors. Some of the past efforts to cause change in behavior of the persons who handle and process foods and those who supervise them, however, have apparently failed because outbreaks are still common. Inspection as carried out in the past and presently being done in many jurisdictions has not solved this problem. Although, no doubt, some of the hazards that have been described have been observed from time-to-time and corrections made. Other hazardous situations are apparently missed because either certain operations are not happening at the time of inspection or the duration of the inspections are too short to evaluate some operations (e.g. cooling rates). Furthermore, during inspections sanitarians do not always emphasize operations that epidemiological data have repeatedly shown to lead to outbreaks. Education of food workers and the public so far has not yet solved these problems either. This is partly so because neither health/regulatory agencies nor the food industry is sufficiently motivated and financed to take the necessary action to educate and train the multitudes of persons who must be aware of the hazards and means of prevention and control.

A few operations are vital to food safety. (these are listed in the upper portions of the tables.) They may also be referred to as critical items and relate to critical control points. High priority must be given to these operations to ensure that they are carried out in a safe manner. Other operations and inspectional items are of lesser consequence.

Many of these hazards could be prevented, controlled or alleviated with a high degree of assurance by implementation of a hazard analysis critical control point system. With this system, specific hazards are identified (before the occurrence of outbreaks), critical control points are determined, criteria for control are established, critical control points are monitored, and immediate corrective action is taken whenever monitoring results indicate that the criteria at a critical control point is not met *(11,34,* and *45).*

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