Current Trends in Foodborne Salmonellosis in the United States and Canada

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Abstract

In the United States, Salmonella has been isolated from over 31,000 persons during 1979; this figure is more than 60% higher than isolations made 18 years earlier. In Canada, the change from about 5,000 isolations from humans in 1977 to more than 8,000 in 1979 is also approximately a 60% increase, but over an interval of only 3 years. In the U.S. during 1973-1978, salmonellosis accounted for 40% of reported cases of foodborne disease and 23% of reported outbreaks of foodborne disease. In Canada during 1973-1975, it accounted for 39% of all reported cases of foodborne disease and 25% of reported outbreaks of foodborne disease. Foods most frequently reported as vehicles of salmonellosis in the U.S. were beef, turkey, homemade ice cream (containing eggs), pork and chicken. Turkey was the most frequently reported vehicle in Canada. Factors usually contributing to these outbreaks (in order of importance) are improper cooling, lapse of a day or more between preparation and serving, inadequate cooking or heat processing, ingestion of contaminated raw ingredients, and cross-contamination. Changes in the relative frequency of isolations of particular serovars sometimes indicate spread of foodborne Salmonella by a particular food or the effectiveness of a control measure. Factors that perpetuate the Salmonella problem are Salmonella-contaminated rendered animal byproducts and contaminated feed, concentrating animals in feed lots and brooding houses, spreading Salmonella during animal slaughtering and processing foods of animal origin, national and international distribution of food and feeds, food preparation and storage practices in foodservice establishments and homes and environmental contamination from animal wastes and other sources.

More isolations of salmonellae from human specimens are made each year during the 6-month period of July through November than during the remainder of the year. The significance of this in relation to foods is that this period includes the warmer months when atmospheric temperatures are closer to optimal temperatures for salmonellae to multiply than in the remainder of the year, and this period also includes many holidays when people are apt to prepare large batches of food for family events or outings.

More isolations are made from persons less than 1 year of age than from those of other age groups. Factors contributing to this situation are higher susceptibility of this age group, greater concern by parents to seek treatment for infants, and greater likelihood of physicians to have specimens from infants analyzed for pathogens. Infants less than one year in age also ingest different foods than persons of other age groups.

The number of identified cases of foodborne disease in both countries depends on the occurrence and effectiveness of surveillance programs to detect large outbreaks (Fig. 1). During the 5 years ending in 1978, salmonellosis accounted for 40% of the reported cases of foodborne disease of known etiology in the U.S. (47) and for 39% in Canada for the 3-year period ending in 1975 (30, personal communication, E.C.D. Todd). During these same periods, salmonellosis outbreaks accounted for 23% of reported foodborne disease outbreaks of known etiology in the U.S. and for 25% in Canada.

The number of reported cases and outbreaks of foodborne disease represents only a fraction of the actual number that occurs. Hauschild and Bryan (29) concluded that for every laboratory-confirmed case of salmonellosis, an average of 29.5 other cases are identified when thorough investigations are made. Therefore, for the 10-year period ending in 1978, it is estimated that an average of 150,000 and 740,000 food- or water-borne cases of human salmonellosis occurred annually in Canada and in the U.S., respectively.

Vehicles and Contributory Factors of Outbreaks

Foods of animal origin are the usual vehicles of
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Figure 1. Incidence of isolations of Salmonella from humans and outbreaks and cases of foodborne salmonellosis in the U.S. and Canada.

Foodborne salmonellosis. In the U.S. (1968 - 1977), beef, turkey, and homemade ice cream (the ice cream mix probably contained raw eggs) were the most frequently reported vehicles, but pork and chicken were also identified as vehicles on several occasions (Table 1). In Canada (1973 - 1975), turkey was the most frequently reported vehicle. For comparison, the most frequently identified vehicles in England and Wales were chicken, turkey, milk, and pork. Turkey, a frequently reported vehicle in each of these countries, is oftentimes already contaminated with salmonellae when brought into kitchens, and because of its bulk it is not always adequately cooked; leftovers cool slowly and are seldom adequately reheated (12). Although raw beef is not as frequently contaminated as raw turkey, the cooked meat cools slowly and is seldom reheated adequately (11,12). Both products are subject to cross-contamination in kitchens. Chicken and pork are often mishandled in a manner similar to turkey and beef (11). McCoy (37) associated the high number of outbreaks of pork-borne and chicken-borne salmonellosis to development of intensified farming and meat and poultry processing in Great Britain. When homemade ice cream becomes a vehicle, it is usually contaminated with salmonellae from raw eggs (28). Additionally, large batches of the mix are often kept at room temperature or are cooled in large containers before freezing and also freeze slowly, which can permit the quantity of salmonellae to increase. Raw milk is a vehicle in England and Wales because it is frequently consumed in rural areas.

Specific factors that have contributed to outbreaks of salmonellosis in the U.S., Canada, and England and Wales are listed in Table 2. The U.S. data are categorized by outbreaks in which foods were mishandled in foodservice establishments, homes, and food processing plants (8). Improper cooling, inadequate cooking or thermal processing, ingestion of contaminated raw products and cross-contamination are frequently identified as contributory factors.

It is discouraging that, despite the identification of many vehicles associated with outbreaks (e.g., eggs and precooked roast beef) and despite the implementation of certain control measures (pasteurization of eggs and beef) in both countries, the number of isolations from human specimens not only has failed to decrease, but, as pointed out, has increased, and the rate of increase is growing with each passing year. Pasteurization of eggs may have had an effect, because pasteurized frozen and dried eggs have seldom been identified as vehicles in recent years. Homemade ice cream, containing raw eggs, however, is still an occasional vehicle, as it was in the past. Likewise, cooking beef to internal time-temperature exposures that are lethal to salmonellae may reduce...
the number of outbreaks involving precooked roast beef prepared in meat-packing plants (27), that is if contamination during repackaging does not nullify the results, and if there is strict control of cold-storage temperatures in the plant, during distribution and by those who cater or serve the beef. These cooking standards, however, will have little impact on beef roasted in foodservice establishments (the core of the problem), because contamination with and multiplication of salmonellae - during hot holding, storage at room temperature, or cooling - occurs after cooking, and these contaminants are not always killed by reheating (11,13).

### SEROVARs ASSOCIATED WITH FOODS AND OUTBREAKS

Serotyping can help to detect an increasing problem caused by a specific serovar, particularly rare serovars. The number of isolations of certain serovars from humans in the U.S., annually from 1969-1977, are given in Table 3. These were selected to show changing trends and associations with certain foods. The number of isolations of some serovars is remarkably constant from year to year (Salmonella cerro, Salmonella gallinarum, Salmonella montevideo, Salmonella newport, for example). Every year Salmonella typhimurium is isolated more often than any other serovar. In 1977, there were 9,690 isolations of S. typhimurium and its variety copenhagen; there were 2,187 isolations of S. newport, the second most common serovar. Some serovars (such as S. gallinarum) are rarely isolated from humans, gallinarum is more or less host-adapted to chickens and apparently large numbers are required to cause infection in humans. Some serovars, such as Salmonella thompson, have declined over this 9-year period. This serovar has, in the past, frequently been isolated from unpasteurized egg products; pasteurization of eggs, which was required for egg products in the late 1960's, could have influenced this decline. But, after a serovar has been seeded throughout a country, declines are often slow. Other serovars, such as Salmonella agona, have appeared and then have been found with increasing frequency each year. The first isolation of S. agona, both in the U.S. and in England, was made from fish meal and apparently this serovar subsequently spread to animals, then to foods of animal origin, and finally to humans (18, 26). Other serovars, such as Salmonella berta, Salmonella bovis-morbificans and Salmonella eastbourne, have been isolated infrequently, then with increased frequency for a few weeks, and then have fallen back to their original levels. Single, common-source outbreaks account for such situations; turkey eggs were the source of S. berta (52), imported beef the source of S. bovis-morbificans (16), and imported cocoa the source of S. eastbourne for chocolate candy (21,22,24). Sudden increases in frequency of isolations of a particular serovar can indicate the existence of a common-source outbreak (19). Obtaining such information is one of the advantages of having surveillance of Salmonella.

The serovars that are frequently isolated from humans are usually the same serovars that are frequently isolated from animals (15). For instance, S. typhimurium, the most frequently isolated serovar from human specimens, is commonly isolated from cattle, swine, and turkeys. Salmonella heidelberg, usually in the top five serovars found in human specimens in the U.S. and Canada, is frequently isolated from chickens and turkeys. The same is true of Salmonella saint paul. Salmonella infantis is a common isolate from specimens from both man and chickens. On the other hand, certain serovars, such as Salmonella dublin, Salmonella johannesburg, and Salmonella choleraesuis are commonly isolated from cattle, chickens and swine, respectively, but are not commonly isolated from human specimens.

### CONSTITUENTS OF THE FOODBORNE SALMONELLOSIS PROBLEM

The following factors have contributed to outbreaks of foodborne salmonellosis and to maintenance of the endemicity of salmonellosis.

**Virulence of Salmonella strains and susceptibility of hosts.**

Different serovars and different strains of any given...
TABLE 2. Factors that contributed to outbreaks of salmonellosis in the United States, Canada and in England and Wales (by percent).

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<tr>
<td>Improper cooling</td>
<td>68</td>
<td>47</td>
<td>41</td>
<td>63</td>
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<td>Improper hot holding</td>
<td>25</td>
<td>14</td>
<td>5</td>
<td>15</td>
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<td>Lapse of day or more between preparation and serving</td>
<td>46</td>
<td>21</td>
<td>18</td>
<td>52</td>
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<td>Use of leftovers</td>
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<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Faulty fermentations</td>
<td></td>
<td></td>
<td>17</td>
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<td>Inadequate thawing</td>
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Factors affecting growth

Factors affecting survival

Factors affecting contamination


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<td>agona</td>
<td>0</td>
<td>4</td>
<td>44</td>
<td>524</td>
<td>864</td>
<td>1037</td>
<td>1333</td>
<td>1461</td>
<td>1229</td>
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<td>berta</td>
<td>40</td>
<td>70</td>
<td>101</td>
<td>48</td>
<td>24</td>
<td>17</td>
<td>16</td>
<td>31</td>
<td>30</td>
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<tr>
<td>bovis-morbificans</td>
<td>10</td>
<td>33</td>
<td>26</td>
<td>29</td>
<td>19</td>
<td>60</td>
<td>33</td>
<td>115</td>
<td>142</td>
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<td>cerro</td>
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<td>23</td>
<td>23</td>
<td>19</td>
<td>25</td>
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<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
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<td>375</td>
<td>363</td>
<td>464</td>
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<td>1700</td>
<td>1722</td>
<td>2201</td>
<td>2058</td>
<td>1634</td>
<td>1550</td>
<td>1336</td>
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<tr>
<td>thompson</td>
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<td>958</td>
<td>834</td>
<td>675</td>
<td>533</td>
<td>400</td>
<td>331</td>
<td>246</td>
<td>218</td>
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<tr>
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<td>5640</td>
<td>6525</td>
<td>6460</td>
<td>8348</td>
<td>7003</td>
<td>6576</td>
<td>7493</td>
<td>9380</td>
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Serovars are capable of exhibiting different degrees of virulence. Data from a few outbreaks (23) suggest that lower numbers of salmonellae can cause salmonellosis than was observed by McCullough and Eisele (38, 39). The lower dose may be linked with the chemical composition of the food, such as fats, that protect these pathogens during passage through the stomach (22). Improper cooling or improper hot storage of foods is found to be a contributory factor in many outbreaks, however, and these practices suggest the probability of multiplication of salmonellae resulting in large quantities of the organism in the implicated food.

Segments of the population are more susceptible than others to salmonellosis. The very young, the elderly, the malnourished and those suffering from other infections are the most highly susceptible (15, 44, 46). Smaller numbers of salmonellae than usual can make these more susceptible persons sick. This may, in part, account for many sporadic cases of salmonellosis that are identified.

Feed ingredients and feeds

Offal, dead animals, processing plant wastes and meat- and fish-market scraps are frequently contaminated with salmonellae. Fish caught in the open seas do not harbor salmonellae, but they sometimes become contaminated either on fishing boats, apparently during storage in holds or from harbor water used to flush fish into storage vats (41). The higher temperatures attained during rendering of meat scraps or fish kill salmonellae. The rendered products, however, are often cross-contaminated by (a) aerosols created by grinding, (b) workers who move from processing areas for raw materials into rendered product areas, (c) equipment that comes into contact with raw materials and then with rendered products and (d) birds, insects and vermin; particularly when they have access to both raw materials and rendered products (36).

Rendered meat, bone and fish meal are the major sources of salmonellae in feedstuffs; however, sal-
Salmonellae can also get into feedstuffs by way of contaminated grains and other ingredients (1). The salmonellae that get into these ingredients can also come from boxcars previously used to transport animals or contaminated materials, or fertilizers. The hopes of eradicating salmonellosis in humans and in other animals will never materialize without elimination of salmonellae from animal feedstuffs.

**Intensive animal raising**

Years ago, the potential for outbreaks of salmonellosis was often confined to a farm, slaughter house or a butcher shop, and to persons in their vicinity. Times have changed, and so has the epidemiology of salmonellosis. Contaminated feed or feed ingredients bring salmonellae to farms. Animals become infected either by eating the feed or from an environment that has become contaminated, conceivably, at least in part, by salmonellae in feed and in the feces of infected animals. Large-scale, intensive fowl or stock raising confines many fowl, cattle or other animals in houses or feed lots in crowded areas where they have continued, intimate contact with many animals and share food and water with them. They walk, and sometimes lie, in feces. The feces can also get into their feed and drinking water. Salmonellae introduced by feed or any other source can spread rapidly by cross-infection. McCoy (37) feels that the cessation of rationing in Great Britain and the reestablishment of pig and poultry stocks and intensive farming contributed greatly to the present problem of salmonellosis in that country. Successful production of Salmonella-free pigs and poultry has been demonstrated (25,53). Control must be based on feeding animals a ration free of Salmonella, on proper husbandry and on monitoring feed, animals and the farm environment for Salmonella.

**Slaughtering and processing**

Large-scale processing evolved for economic reasons and out of the necessity created by intensified animal raising and because of the high demand for animal protein. Traditional slaughtering methods and meat and poultry processing practices spread salmonellae from one carcass or cut of meat to another. Animals are the main source of salmonellae in slaughtering houses (2,14,35). Although only a small percentage of animals are infected on farms, the infection rate increases as the animals travel to market and stay in holding pens before slaughter. As the number of infected animals slaughtered and processed daily increases, the risk of cross-contamination increases. Once introduced into a plant, even after the original source is gone, salmonellae can survive on improperly cleaned equipment or in the plant environment (in filters, drains, dust, scraps, sweepings) and can subsequently contaminate food. Solid wastes from slaughter houses are rendered into feed, and therefore contribute to the cyclic spread of salmonellae.

Foods that have been prepared in food processing plants are sometimes identified as vehicles of salmonellosis. When this happens, contamination has usually occurred in the plant. Contamination often comes in with the animals to be slaughtered or with raw meat or poultry and is spread by equipment or workers’ hands that previously touched a contaminated product. Heat processes sometimes fail to kill salmonellae, if the level of contamination is high, if the cooker is overfilled, if the temperature is too low or if the processing time is too short. Improper cooling of the processed product in the plant and inadequate temperature control during delivery or storage allow the surviving salmonellae to increase, sometimes to quantities sufficient to cause illness (6,8).

**Hazard analysis of food processing operations**

Identification of critical control points at potentially hazardous stages of the operation and establishment of a system to monitor these points are essential for control of Salmonella (4,6,42,43). The analysis should be augmented by sampling and testing for Salmonella after each significant processing step and by testing for physicochemical attributes (temperature, pH, a_w) of the food. Management must be informed of the hazards and the workers trained in specific preventive and control measures.

**National and international spread**

There is a potential for national and international spread of salmonellae by contaminated feeds and foods. Processed meat and bone meal and fish meal that harbor salmonellae can take these organisms with them wherever their distribution channels lead -- even into other countries. Contaminated fish meal from Peru, for instance, apparently introduced S. agona into Great Britain and the U.S., where it had previously been rarely isolated. The same source introduced S. agona into Israel and the Netherlands, where it had never before been isolated. After its introduction, livestock became infected, and human cases began to appear after ingestion of contaminated poultry or pork (18). This serovar is now among the five most commonly isolated in the U.S. and Great Britain and among the top 10 serovars from certain other countries. (51).

Before World War II, Salmonella panama was unknown in the United Kingdom, but during the war it was introduced with dried eggs. These eggs were fed to pigs, and afterwards this serovar was isolated from the pigs. During the next two decades, this serovar was implicated as the cause of several human cases of salmonellosis, and since that time has become one of the major causes of salmonellosis in the United Kingdom (46).

Corned beef, processed in Argentina and subjected to Salmonella typhi in cooling water, brought this organism into Great Britain. Several outbreaks resulted (3,32).

An outbreak of S. eastbourne, considered to be a rare serovar in the U.S. and Canada, was spread by contaminated chocolate candy that was prepared in a processing plant in Canada. S. eastbourne came into the
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plant with cocoa beans imported from Africa (21, 24).

Upon arrival in a country, samples of each lot of feed or food can be examined for Salmonella. A protocol for sampling plans and specifications is given by the International Commission on Microbiological Specifications for Foods (33, 34). Contaminated feeds or foods that ordinarily will not receive any further heat treatment should be rejected or reprocessed. Information on the hazards of cross-contamination and the need to thoroughly cook contaminated raw products should be given to health agencies, to the segment of the food industry that uses the product and, if applicable, to the public.

Foodservice

Raw foods of animal origin are the major sources of salmonellae in kitchens of restaurants, institutions and homes. Salmonellae can survive in these foods if lethal time-temperature exposure is not provided during cooking. Foodservice workers who do not wash their hands after handling raw foods of animal origin can transfer salmonellae either back to the same food after it has been cooked or to other foods. Salmonellae can also be transferred from contaminated raw foods to equipment surfaces and then from the equipment to previously uncontaminated foods. Such contaminated foods are then sometimes kept at room temperature, held in warmers at temperatures within the growth range for salmonellae or refrigerated in large, deep containers for several hours. The chances that these events will occur are greater in establishments that prepare large volumes of food and hold them for several hours before they are served. The chances are even greater if the food is prepared for serving a day or more later.

Populations of most countries are expanding, and people are congregating in urban areas. Every year, more women are employed in business, manufacturing and commerce. These trends have brought about a change in eating habits; more and more meals are eaten in foodservice establishments. Many such establishments are not aware of the potential for spreading salmonellae from water courses after minimal treatment or after runoff from spray-irrigated fields. Fish, shellfish and aquatic plants can become contaminated by salmonellae from these sources (7). Furthermore, wildlife can acquire salmonellae from water courses and transfer them to other streams, farm lands, feed or animals.

These organisms, however, have been isolated also from spring water within a few meters of its emergence from the earth. They were also found on aquatic vegetation and stream-bed sediment, but not with nearby soil, forest litter, aquatic vertebrates, or aquatic or terrestrial invertebrates. Salmonellae may have a free-living existence apart from animal hosts (17). If this is so, the possibility of achieving the goals of preventing infection in animals and contamination of foods and the eventual eradication of human salmonellosis become remote.

SOLUTIONS OF THE FOODBORNE SALMONELLOSIS PROBLEM

The foodborne salmonellosis problem can be solved by
one of three undertakings -- (a) eradicate salmonellae from feed, farm environments and animals, (b) eliminate salmonellae from the raw foods of animal origin by pasteurization, thorough cooking or radicidation or (c) educate people to the dangers of salmonellosis, the sources of salmonellae and the ways to prevent foods that are prepared in food processing plants, foodservice establishments and in home kitchens from transmitting disease-producing quantities of salmonellae.

Eradication of salmonellae from animals would patently by a task of overwhelming magnitude, and under prevailing economic conditions would be an insupportable expense. Elimination of salmonellae from rendered animal byproducts and animal foodstuffs is, however feasible and would significantly contribute to patently by a task of overwhelming magnitude, and under prevailing economic conditions would be an insupportable expense. Elimination of salmonellae from food processing plants, foodservice establishments and in home kitchens from transmitting disease-producing quantities of salmonellae.

Use of pasteurization and radicidation is limited to certain foods and subsequent cross-contamination can nullify their effects. Although these processes kill salmonellae, they are selective and permit survival of other foodborne pathogens such as Clostridium perfringens.

To train personnel in the food industry, and to educate the populace will be a long-term, but practicable, undertaking. Although training per se will not eradicate the salmonellosis problem, it can have significant impact in preventing foodborne outbreaks. Training must start with public health and regulatory personnel and managers of the food industries, but it must reach the persons who actually process, prepare or store foods (5, 10). Education of the public must start with teachers and students who are preparing to teach, and progress to pupils in primary and secondary schools (45).

If we intensify actions to train managers and food workers and begin to educate the populace now, the impact of change may be seen in the next decade and a half. But, if we wait, we risk becoming (or remaining) stagnant because of our continued or intensified frustration brought about by observations of an increased incidence of salmonellosis.

REFERENCES