ARTICLES

Food Protection Trends, Vol. 31, No. 9, Pages 560–568

6200 Aurora Ave., Suite 200W, Des Moines, IA 50322-2864

International Association for Food Protection.

Epidemiological Approaches to Food Safety

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ABSTRACT

The literature reveals that milder cases of foodborne diseases are commonly underreported and often undetected through routine surveillance. Outbreaks due to *Staphylococcus aureus* are not under active surveillance, yet they are on the rise. The goal of this retrospective study was to examine the associated risk factors and quantify the impact of foodborne disease outbreaks from secondary data sources collected by the Centers for Disease Control and Prevention and other surveillance bodies. The results of the analysis revealed that during 1997–2007, the leading bacteria to which foodborne disease outbreaks were attributed were *Salmonella* (1,235), *Escherichia coli* (287), *Clostridium* (269), *Staphylococcus* (170), *Campylobacter* (150) and *Shigella* (124). *Listeria monocytogenes* infection resulted in the highest number of deaths (125/100,000 individuals). Methicillin-resistant *Staphylococcus aureus* (MRSA) from animal reservoirs and food products was recently documented to have entered the human population. We conclude that there has been increased isolation of MRSA in food animals. As a result, further studies into the involvement of food in the re-emergence of this pathogen into public knowledge/perception of food safety and handling, and into risks related to food consumption are crucial in reducing the trend of food-related diseases.

A peer-reviewed article

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INTRODUCTION

The incidence of foodborne disease is difficult to estimate, but it has been reported that in 2005, 1.8 million people, mostly children in developing countries died from diarrheal diseases worldwide *(58)*. The majority of diarrheal disease cases can be attributed to contaminated food and bottled drinking water. Although the food supply in the United States is one of the safest in the world, between 250 and 350 million individuals are affected by acute gastroenteritis annually, and about 30% of these cases are believed to be due to foodborne pathogens *(38)*. A foodborne disease outbreak is the occurrence of at least two cases of similar illness resulting from the consumption of a common food.

Furthermore, food contamination creates an enormous social and economic burden on health systems and communities. In the United States, foodborne diseases create an enormous economic burden on health and social systems, costing $152 billion each year *(45)*.

Infections caused by bacteria such as *Campylobacter, Salmonella, Escherichia coli* O157:H7, *Listeria monocytogenes* and Norwalk-like viruses are the most commonly recognized foodborne illnesses and gastroenteritis in humans. Although many foodborne pathogens cause simi-

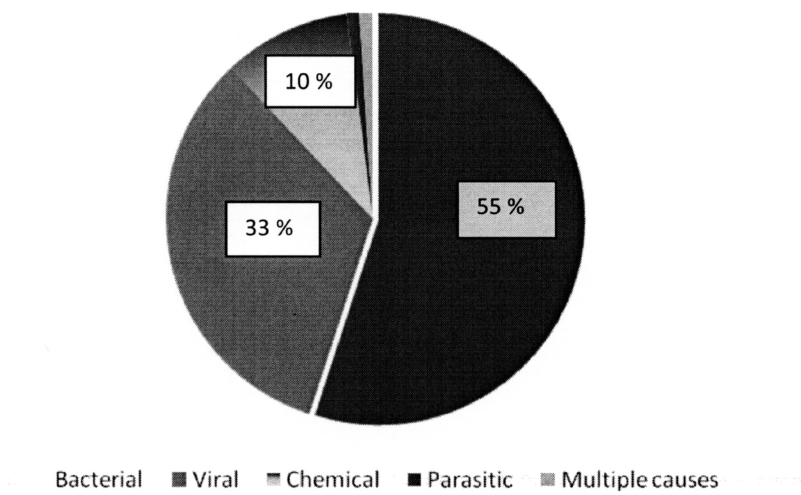


FIGURE 1. Laboratory confirmed etiology of foodborne disease, 1998–2002 in the United States, as reported by Lynch and others *(35)*

lar symptoms, especially diarrhea, abdominal cramps, and nausea, it should be noted that the severity of symptoms depend largely on the type of pathogen and the ability of the pathogen to produce toxins, which can be absorbed into the bloodstream or invade other organs and tissues *(7)*.

Passive surveillance of foodborne disease outbreaks began some eighty years ago in the United States, when the roles of milk, food and water were investigated in outbreaks of intestinal illnesses. These surveillance efforts led to the endorsement of important public health measures and regulations that contributed to a decrease in the incidence of enteric diseases, particularly those transmitted by milk and water *(43)*. In 1996, active surveillance was initiated for laboratory confirmed cases of foodborne pathogens in selected states. Although significant progress has been made since then by The Centers for Disease Control and Prevention (CDC), Public Health and Foodborne Diseases Active Surveillance Network (FoodNet), only 15% of the US population in 10 states and a total of nine foodborne pathogens (seven bacteria and two parasites) are currently under active surveillance by this agency *(8)*.

According to The Centers for Disease Control and Prevention, foodborne disease outbreaks can be caused by bacteria, chemicals, toxins, parasites, prions or viruses *(40)*. As reported by Lynch et al. *(36)* in 2006, between 1998 and 2002, over 6,000 foodborne disease outbreaks occurred, of which 67% had no known etiology. As shown in Fig. 1, of the outbreaks with confirmed etiologies, the majority were due to bacterial pathogens (55%), viruses (33%), chemicals (10%), parasites (1%), and multiple causes (1%).

Ultimately, because most foodborne disease reporting systems are voluntary, as pointed out by the International Commission on Microbiological Specifications for Foods, surveillance and monitoring strategies for both the food chain and foodborne disease must be linked at the population level *(22)*. Epidemiological data are important tools in assessing the nature and the enormity of food safety problems. Several studies have concluded that the epidemiology of foodborne disease has changed in the last three decades, because newly recognized pathogens emerge and well-known pathogens reemerge and increase in prevalence or become associated with new food vehicles *(3, 24, 42)*. Foods contaminated with pathogens usually smell, look and taste normal; furthermore, foodborne pathogens and their associated toxins can often survive traditional cooking techniques *(52)*. Currently, foodborne pathogens under active surveillance include bacteria (*Campylobacter, Salmonella, E. coli* O157:H7, *Listeria, Shigella, Yersinia* and *Vibrio*) and parasites (*Cryptosporidium* and *Cyclospora*) in California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New Mexico, New York, Oregon and Tennessee *(4, 8, 9)*.

According to the passive surveillance of foodborne outbreaks Line Listing Annual Report, many causative agents of foodborne disease outbreaks are not reportable in active surveillance systems. Presently, a partial list of these organisms includes noroviruses, *Clostridium perfringens*, *Bacillus cereus*, and *Staphylococcus aureus*. Furthermore, rough estimates of the number of incidences of these non reportable outbreaks were pieced together from past epidemiological data, and an estimate was reported after a multiplying factor was applied *(38)*. According to The Council for Agricultural Science and Technology, over 30 million individuals in the United States are especially susceptible to foodborne diseases. These include the very young, the elderly, pregnant women, and the immunocompromised, as these individuals are more vulnerable to rapid development of dehydration and severity of the gastroenteritis *(15)*.

Several scientists are of the opinion that *S. aureus* is a reemerging foodborne pathogen. In 2001, Jablonski and Bohach *(23)* concluded that *S. aureus* is the most common cause of foodborne illness worldwide, but under-reporting and the self-limiting symptoms of staphylococcal intoxication keeps the number of reported cases low. Humans and animals are the main sources of *Staphylococcus* contamination of food, as a result of direct contact of food, with food preparers or infected persons who may have open sores, cuts or abrasions that can compromise food safety *(20, 44)*. A recent report by the Scientific Opinion of the Panel on Biological Hazards indicated that methicillin resistant *S. aureus* (MRSA) clonal complex CC398 or sequence type 398 prevalence is high in food-producing animals, and people in contact with these live animals face substantial risk of colonization and infection *(46)*. A recent FoodNet report released by The Centers for Disease Control and Prevention showed that the progress against two major foodborne pathogens, *E. coli* O157:H7 and *Salmonella,* has stalled *(14)* and is farthest from reaching its current Healthy People 2010 goal *(56)* and that underlying forces may make foodborne illnesses more of a problem in the years to come *(18)*. The objectives of this paper are to identify and examine the risk factors for foodborne disease and to

TABLE 1A. Description of food categories implicated in foodborne disease outbreaks

Food category	Type of foods in the category
Beef stew	steak, ground beef, hamburger, goat, beef jerky, beef
Poultry	eggs, chicken, turkey, guinea pig, rabbit jerky
Pork	ham, pork (roasted, barbecue)
Rice/pasta	macaroni and cheese
Seafood	oyster, crab cake, shrimp
Produce	fruits, vegetables, beans, nuts
Multiple Food	casseroles, chicken dishes, turkey and stuffing, lasagna, salads, sandwiches, sauces
Dessert	ice cream, pie, cake, pudding
Beverage	milk, juice (pasteurized and unpasteurized)
Unknown	unknown foods, others, unidentified

TABLE 1B. Definition of the location of foodborne outbreaks

Location	Types of places
School	Schools and day care centers
Cafeteria/Workplace	Cafeteria, workplace, office, camps, picnic, fair, church, halls, grocery stores, others
Restaurant	Restaurant/delicatessen, hotel, banquet, reception
Private home	Private homes/kitchen
Institution	Nursing homes, prison, juvenile facility, hospital
Unknown	Unknown, unidentified

quantify the effect of bacterial foodborne disease from outbreak statistics.

METHODS

Existing literature reviews and the criteria used are outbreak data published annually by CDC from 1997 to 2007, which were obtained and extracted from various surveillance bodies, including: Line Listings *(12)*, Foodborne Disease Active Surveillance Network (FoodNet) *(13)*, and the Active Bacterial Core (ABC) surveillance systems *(10, 11)*. Line Listings *(12)* provides passive surveillance of yearly foodborne outbreaks data between 1997 and 2005 that contains the etiology, state, month of outbreak, year, number of individuals who become ill, food vehicle and location; the 2006–2007 listings include additional information on the number of hospitalizations and deaths due to foodborne disease. Table 1a and 1b describes the food categories and locations of the outbreaks. FoodNet is an active population-based surveillance system. Data were retrieved from the summary tables and graphs report (part II), which contained foodborne outbreak information about the nine foodborne pathogens in the ten specific locations of interest, including rates of infection, age, gender, and numbers of hospitalizations and deaths.

Statistical analysis

Based on the output of descriptive statistics with use of SPSS *(50)*, a coefficient of variation was computed on the leading bacterial causes of foodborne outbreaks.

ABC report *(10)*

The ABC report is a population-based surveillance system for invasive bacterial pathogens of public health importance, including MRSA. MRSA invasive disease cases are classified into three epidemiologic classifications: hospital-onset if the MRSA infection was identified more than 48 hours after hospital admission; healthcare-associated-community-onset if the MRSA infection was identified less than 48 hours after admission; and community-associated (CA). This ABC report was used to assess the prevalence of *S. aureus* infections and deaths not recorded as part of the national notifiable diseases. Nine states are in the catchment areas of ABC: California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New York, Oregon and Tennessee.

TABLE 2. Coefficient of variation (CV)[a] for bacteria associated with foodborne diseases

Causative Agent	Mean	Std. Deviation	CV	Rank
Salmonella	205.83	324.33	1.575	1
E. coli	47.66	75.36	1.581	2
Clostridium	44.83	70.89	1.581	2
Shigella	20.67	32.69	1.582	3
Staphylococcus	28.33	44.86	1.583	4
Campylobacter	25.00	39.81	1.592	5
Vibrio	7.83	12.86	1.642	6

[a]Coefficient of variation is calculated as Std. Deviation/mean.

FIGURE 2. Number of foodborne outbreaks due to bacteria, recorded in CDC Line Listing passive surveillance, 1997–2007 (data extracted from CDC)

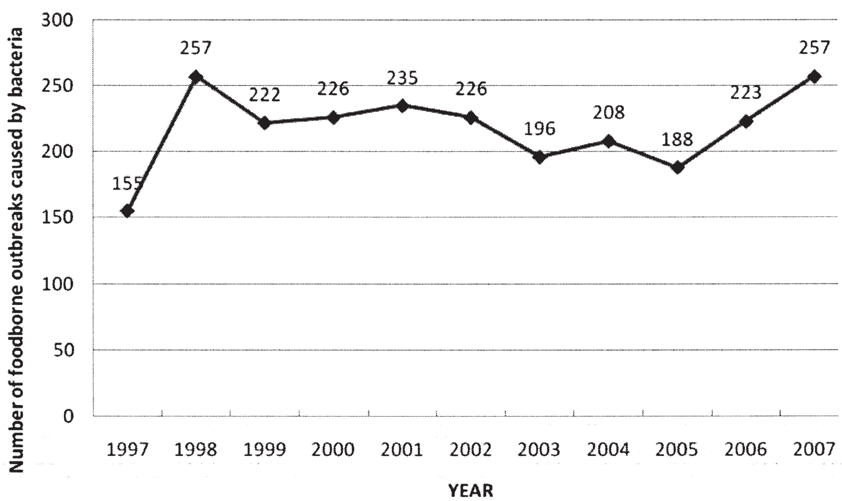
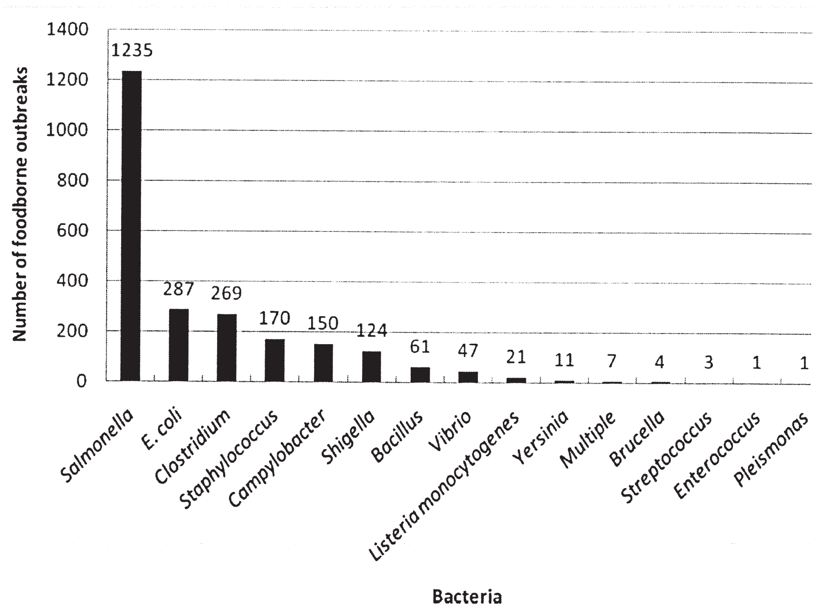


FIGURE 3. Leading bacterial foodborne pathogens implicated in outbreaks as recorded by CDC Line Listing, 1997–2007 (data extracted from CDC)



RESULTS

Published epidemiology data and literature from 1997 to 2007 line listing reports were analyzed. The results revealed that there has been a slight but steady increase in the number of foodborne outbreaks caused by bacteria in the United States (Fig. 2). Although several bacteria were confirmed as the causative agents of the outbreaks, according to the results in Fig. 3, the majority of laboratory confirmed bacterial pathogens were *Salmonella, Escherichia coli* serovars, *Staphylococcus* spp., *Campylobacter* spp., *Clostridium* spp., *Shigella* spp. and *Vibrio*. Statistical analysis of the number of outbreaks caused by each bacterial foodborne pathogen from line listing data revealed that there were only slight differences in the coefficient of variation among the common bacteria implicated in the reported foodborne outbreaks (Table 2). Therefore, five pathogens under active surveillance and *Staphylococcus*, which are not under surveillance for foodborne disease outbreaks, were selected for further analysis. *Staphylococcus* spp. were selected because they are among the most common causes of nosocomial infections *(30)*, they are very important as foodborne pathogens *(23, 26)*, and, according to the National Institute of Allergy and Infectious Diseases (NIAID), they are considered to be class II reemerging pathogens *(39)*.

Changes in agricultural practices, food processing and packaging could facilitate bacterial contamination and growth; hence food contamination can occur anywhere along the food chain *(48)*. Definitions of the food vehicles and locations involved in outbreaks are listed

TABLE 3A. Food categories and outbreaks for top six bacteria from Linelist outbreak data, 1997–2007

Food category	Number of foodborne outbreaks (%) and cases (%)						
	Salmonella	*E. coli*	*Staphylococcus*	*Campylobacter*	*Shigella*	*Vibrio*	Total
Beef	19(1.5); 500(1.5)	58(20);1131(16)	7(4); 111(2)	1(1); 34(1)	2(1.6); 9(0.14)	- [a]	87; 1785
Poultry	108(8.7);2403(7.0)	2(0.7);38(0.54)	9(5); 118(2)	12(8.7);100(3)	5(4.0); 215(3)	1(2);47(3.9)	137; 2921
Pork	27(2);769(2)	2(0.7);56(0.8)	30(17.6);1099(22)	-	-	-	59; 1924
Seafood	27(2); 434(1)	2(0.7); 26(0.4)	4(2); 20(0.4)	4(2.7); 13(0.4)	4(3);61(1.0)	43(93); 1365(96)	84; 1919
Rice/Pasta	18(1.5);1007(3)	3(1); 29(0.41)	3(1.8); 74(1.5)	-	1(0.8); 30(0.5)	-	25; 1140
Produce	89(7); 3216(9)	34(11.8);1792(25.5)	3(1.8); 50(1.0)	6(4.0); 368(12.7)	10(8); 1749(27)	-	142; 7175
Multiple	399(32);14976(44)	64(22); 2082(29.6)	89(52); 2993(60)	32(20); 754(26)	33(27);1775(28)	-	617; 22580
Dessert	50(4); 1210(3.5)	3(1); 79(1)	5(2.9); 253(5)	3(2); 15(0.52)	1(0.8); 50(0.8)	-	62; 1607
Beverages	16(1); 1118(3)	12(4); 299(4)	1(0.59); 36(0.7)	42(28); 923(32)	1(0.8); 7(0.1)	-	72; 2383
Unknown	482(39); 8483(24.8)	107(37); 1502(21)	19(11); 210(4)	50(33); 697(24)	67(54); 2484(39)	3(4.7); 8(0.5)	728; 13384
Total	1235; 34116	287; 7034	170; 4964	150; 2904	124; 6380	47; 1420	2013; 56,818

[a]None reported.

TABLE 3B. Location of outbreaks for top six bacteria from Linelist outbreak data, 1997–2007

Location	Number of foodborne outbreaks (%) and cases (%)						
	Salmonella	*E. coli*	*Staphylococcus*	*Campylobacter*	*Shigella*	*Vibrio*	Total
School/Daycare	32(2.6); 1096(3)	16(5.6); 45 (6)	14(8); 728(14.7)	2(1); 64(2)	10(8); 292(4.6)	-	74; 2632
Caf/Wk[1]	203(16); 6488(19)	59(20.6); 1664(23.7)	72(42); 2558(51.5)	35(23); 850(29)	16(12.9); 1483(23)	6(12.8); 439(30.9)	391; 3482
Rst/Hotel[2]	548(44); 14886(43.6)	97(33.8); 2497(35.5)	43(25); 968(19.5)	46(30.7); 819(28)	63(50.8); 2299(36)	31(66); 733(51.6)	828; 22202
Private home	237(19); 4949(14.5)	66(23); 1558(22)	23(13.5); 236(4.8)	38(25); 444 (15)	17(13.7); 835(13)	8(17); 37(2.6)	389; 8059
Institution	58(4.7); 2871(8)	15(5); 340(4.8)	8(4.7); 298(6)	3(2); 423(14.6)	-	-	84; 3932
Unknown	157(12.7); 3826(11)	34(11.8); 523(7)	10(5.9); 176(3.5)	26(17); 304(10.5)	18(14.5); 1471(23)	2(4); 211(14.9)	247; 6511
Total	1235; 34116	287; 7034	170; 4964	150; 2904	124; 6380	47; 1420	2013; 56,818

[1] Caf/Wk = Cafeteria/Workplace; [2] Rst/Hotel = Restaurant/Hotel.

in Tables 3a and 3b. Results indicated that during 1997–2007, overall, unknown or unidentified foods caused the largest number of outbreaks, resulting in approximately 728 outbreaks. In these outbreaks, the consumers could not recall what had been consumed. The second largest outbreak was from multiple foods/ingredients, indicating that more than one type of food resulted in a total of 616 outbreaks. Consumption of rice or pasta resulted in 25 outbreaks, the lowest number recorded among the six bacteria reviewed. The analysis of each pathogen showed that *Salmonella* was implicated as the cause of outbreaks in the following food vehicles: unknown or unidentified food (482), multiple foods (399), poultry (108), produce (89), dessert (50), pork (27), seafood (27) beef (19) and beverages (16). Outbreaks caused by *E. coli* serovars in unknown foods, multiple foods and beef were 107, 64 and 58, respectively, while produce (34), beverages (12) and the remaining food categories caused low numbers of outbreaks. Cows are normal carriers of *E. coli*. Therefore, large numbers of outbreaks due to consumption of raw or undercooked beef are expected. *Staphylococcus* spp. were implicated in several outbreaks; 89 outbreaks were due to the consumption of multiple foods, and consumption of pork, unknown food, and poultry were confirmed in 30, 19, and 9 staphylococcal outbreaks, respectively. Outbreaks due to *Campylobacter* were confirmed in unidentified foods (50), beverages (42) particularly unpasteurized milk, multiple foods (31), and poultry (12). *Shigella* was the causative agent in outbreaks of unknown food origin (67), multiple foods (33), and produce (10), while seafoods were involved in 43 *Vibrio* outbreaks.

Table 3b shows that 827, 384, and 380 outbreaks occurred from foods consumed in restaurants or delicatessens, private homes, and cafeterias, respectively. In the case of all of the causative agents, except for *Staphylococcus* spp., restaurants were the most common locations of outbreaks, whereas, in the case of staphylococcal intoxication, cafeterias resulted in the highest number of outbreaks. Inspections of restaurants have led to improved efforts in optimal holding temperatures of foods and should be incorporated with routine collection of samples for laboratory testing and intensive education of the public. Food safety education will go a long way in reducing the trend of foodborne illnesses, whether foods are prepared on a small or large scale for picnics, camps or fairs.

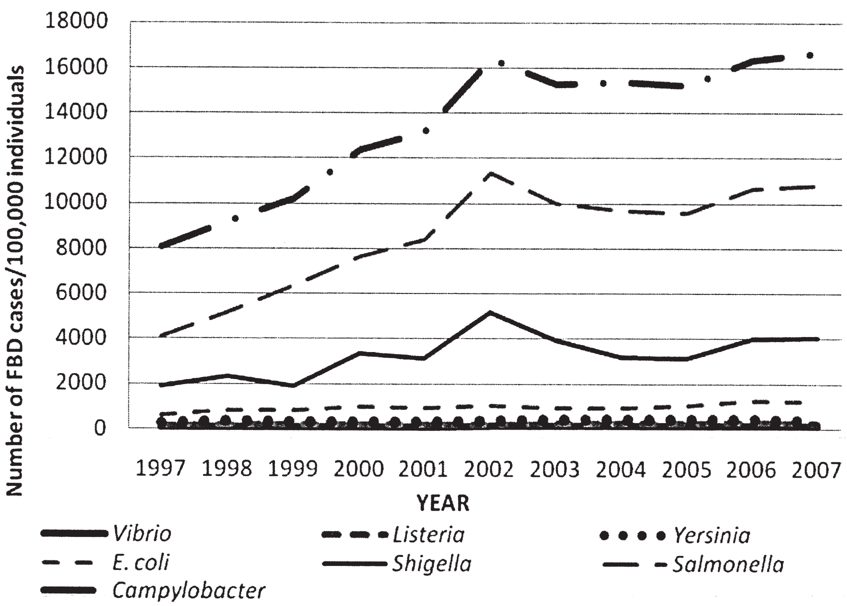
Other than restaurants, locations associated with high number of outbreaks were homes and cafeterias. According to Kaferstein *(27)*, several factors contribute to outbreaks of foodborne illness in the home. These factors include a raw food supply that is frequently contaminated, a lack of awareness among the general public, improper food handling and food preparation, and intentional consumption of raw and undercooked foods of animal origin, described as risky eating behavior. Fur-

TABLE 4. Prevalence of *Staphylococcus aureus* infections, 2005–2006

Methicillin Resistant *Staphylococcus aureus* (MRSA)	Cases[a]	Deaths
Hospital-onset (HO)	3025	787
Healthcare-associated community-onset (HACO)	6845	1062
Community-associated (CA)	1568	162

[a]Cases per 100,000 individuals in ABCs areas.

FIGURE 4. Number of foodborne cases in the catchment areas: California, Connecticut, Georgia, Maryland, Minnesota, New York, New Mexico, Oregon and Tennessee (data extracted from CDC)



thermore, Scott *(47)* concluded in her study that the 21st century home is the last line of defense against foodborne diseases and that public education is an essential factor in improving food safety practices.

According to the FoodNet surveillance data in the area of catchment, the number of foodborne cases per 100,000 individuals indicated a steady increase in the number of reported cases from 1997 to 2007, of infection caused by *E. coli, Campylobacter, Salmonella, Shigella,* and *Yersinia*, as indicated by the time series analysis shown in Fig. 4. The increased number of foodborne disease cases may be due to population increase, deliberate focus on the selected pathogens, and development of more sensitive laboratory-based detection methods. It is also possible that cases of *Staphylococcus* foodborne outbreaks are increasing in the United States, as has been documented in other countries, because of globalization *(6)*. In the 2007 Line Listing data, besides the eleven confirmed staphylococcal outbreaks reported, ten more suspected outbreaks were associated with this pathogen.

Several foodborne pathogens are known to infect both animals and humans *(5, 51)*. In addition, cases of MRSA in animals used for food production appear to be emerging. There is no information in the FoodNet data about outbreaks caused by *Staphylococcus* spp., particularly MRSA, even though some researchers have documented that MRSA from animal reservoirs have recently entered the human population in Europe *(54)*. Pigs have recently been shown to be major reservoirs for MRSA 398 (ST398) worldwide in the Netherlands, Korea, Japan, Canada, Singapore and the United States of America *(21, 28, 49, 55)*. Other reservoirs include poultry products *(33, 34, 41, 54)*, cattle *(34)*, dairy herds *(17)*, and pets *(5, 53)*.

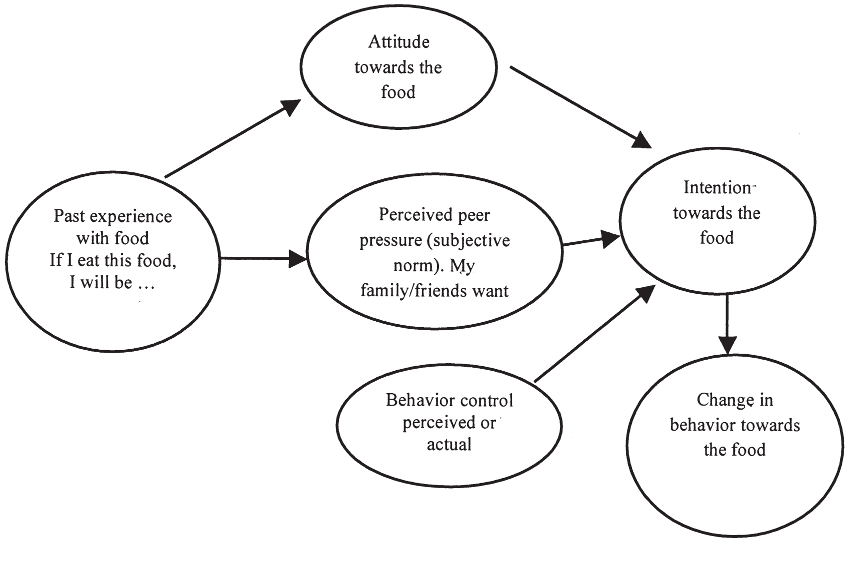
Furthermore, Active Bacterial Core (ABC) Surveillance Report Emerging Infections Program data (Table 4) show that in the year 2005–2006, 11,438 cases of MRSA and 2,011 deaths were recorded in the nine-state catchment areas. Klevens and others *(29)* reported that the percentage of MRSA isolates increased from 35.9% in 1992 to 64.4% in 2003 and further estimated that 94,000 infections and more than 18,000 deaths were attributed to MRSA in 2005 for US hospitals in the National Nosocomial Infections Surveillance System *(30)*.

While it is not clear how many, if any, of these hospital-onset, healthcare-associated community onset and community associated infections were a result of foodborne outbreaks, according to Lee *(33)*, transmission through food products has not been fully investigated. Food safety issues are public health concerns, particularly because there is an increased risk of MRSA isolated from food-producing animals. There have been documented reports of other outbreaks of community-acquired foodborne illnesses caused by MRSA *(25, 31)*. A more recent report by the Scientific Opinion of the Panel on Biological Hazards indicated that MRSA CC398 prevalence is high in food-producing animals and that the public in contact with these live animals face a substantial risk of colonization and infection. The risk to human health from different levels (dose response) of MRSA during carriage in animals (and in the environment) is not well-known *(46)*.

Although further studies are ongoing, it is likely that MRSA CC398 is pervasive primarily in the pig, cattle and possibly poultry populations, most likely in all European countries. Hence, animals in food production and their products are a potential source of community-acquired MRSA *(46)*.

Risk factors identified as increasing foodborne diseases include aging of the population, high probability of communicable diseases among young, old and immune-compromised individuals,

FIGURE 5. Theory of Planned Behavior (TPB) model, modified from Ajezen *(1)*



increased international travel, willingness to try new exotic cuisines, ingredients from different parts of the world, and transportation of raw and finished products *(2)*. The desire to consume undercooked or raw foods has become increasingly popular in the United States, which minimizes the risk perception of foodborne diseases. Based on the Theory of Planned Behavior (TPB) model *(1)* (Fig. 5), public behavioral beliefs can be shaped by educating consumers on the ease of association of foodborne pathogens with foods such as leafy greens, meat, dairy, poultry and ready-to-eat meals and by discouraging the acceptance of consuming raw and unpasteurized milk and juices. According to Lobb et al. *(35)*, this model can explain how consumer purchasing intentions are influenced by their levels of risk perceptions and trust in food safety information from diverse sources. TPB has been used successfully in the analysis of a wide range of behaviors, especially those associated with risky or health related activities such as smoking *(35)*. Information on the epidemiology and microbial load at every stage of food production (farm to fork), including pre and post-harvest, storage, transportation, and manufacture, is becoming increasingly important. Equally important, the lack of awareness of the seriousness of foodborne diseases needs to be addressed with consumers of all ages. This could ultimately stem the tide of the increasing foodborne disease trend and improve food safety.

DISCUSSION

Surveillance, either passive or active, is difficult and has numerous confines. Some outbreaks are never recognized, those recognized are often underreported, and the likelihood that public health authorities are alerted about an outbreak depends on many factors such as the size, since the outbreaks most likely to be brought to the attention of public health authorities will be those that are large, interstate, and restaurant-linked or that result in hospitalization or death. According to the line listing during 1997–2007 passive foodborne outbreak surveillance, *Salmonella, E. coli, Clostridium, Staphylococcus, Campylobacter, Shigella* and *Vibrio* were the leading bacterial causes of gastroenteritis. At least 170 foodborne outbreaks were caused by *Staphylococcus* from 1997 to 2007. The recent documentation of MRSA in various food animals (pigs, poultry) is cause for concern. Cases of MRSA in animals used for food production and reports of sporadic cases in dairy cattle, and the isolation of a new clone, CC398, from pigs, appears to be emerging *(21, 26, 28, 49, 55)*. Nevertheless, sources of contamination could include the infected food animals, handlers, environment, slaughterhouses and subsequent contamination of foods by colonized food preparers *(54)*. Epidemiological studies show that the behavior of food workers is a major factor contributing to staphylococcal foodborne disease outbreaks *(19)*. Furthermore, according to Jones *(25)*, MRSA may not be recognized as the cause of foodborne outbreaks because isolates obtained from outbreak investigations may not be analyzed for their antibiotic resistance profiles. In addition, as explained by Walls, there might be concern for public reaction to unfavorable findings, which could lead some groups (industries, government or countries) to keep some data private *(57)*.

Although several risk factors, including holding temperature of food, inadequate cooking, personal hygiene *(32, 59)* and more, have been identified and discussed in the literature, the single thread that runs through them all is the need for education and awareness of food safety. In order to reduce or prevent foodborne diseases, the principles of food safety must become concrete practical steps in food production *(16)*. The role of MRSA as the cause of clinical and community infections has been established. Furthermore, the role of *S. aureus* as a foodborne pathogen has been demonstrated and should not be ignored *(42)*. We conclude that further studies on MRSA, the involvement of food in the re-emergence of this pathogen, the public's knowledge/perception of food safety and handling and of risks related to food consumption, are crucial in reducing the trend of food-related diseases.

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