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Bacterial Foodborne Outbreaks in Central Taiwan, 1991-2000

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ABSTRACT

During 1991 to 2000, 274 outbreaks of foodborne illness including 12845 cases and 3 deaths were reported in central Taiwan. Of the 274 reported outbreaks 171 (62.4%) were caused by bacterial pathogens. Chemical and natural toxins appeared to be minor causes. Microorganisms, particularly *Bacillus cereus* (41.2%, 113 of 171 outbreaks), *Staphylococcus aureus* (17.9%, 49 of 171 outbreaks), *Vibrio parahaemolyticus* (15.7%, 43 of 171 outbreaks) were the main etiologic agents. These outbreaks were mainly caused by mishandling of food at home (41.2%) and in school (34.3%). The suspected foods involved in outbreaks were seafood (32.5%), meat & meat-products (23.5%), cereal products (15.6%). 44 enteropathogenic *Escherichia coli* isolates from 20 outbreaks were confirmed by their O serotype. Occurrence of O18 was the most frequently detected. Among the 106 *V. parahaemolyticus* isolates, 55 K-serotype (51.9%) were found. 121 (78%) strains of *S. aureus* can produce enterotoxin. The data further revealed that enterotoxin A-producing strains of *S. aureus* accounted for 76% of all enterotoxigenic strains.

Key words: foodborne, *Bacillus cereus*, *Staphylococcus aureus*, *Vibrio parahaemolyticus*

INTRODUCTION

Foodborne diseases outbreaks have attracted attention in developed countries for a long time, because they provide an excellent opportunity to obtain useful information[1]. Statistical data on foodborne illness in Taiwan have been published annually by the Department of Health since 1981[2-5]. However, the epidemiological data, such as number and size of outbreaks, incubation period, etiology, food vehicles, and location of preparation, were not systemically analyzed until after 1986. A total of 622 outbreaks of Foodborne illness involving 15627 cases were cumulatively reported to the Department during 1981-1989. On average, there were 25 cases per outbreak indicating that only large outbreaks and serious incidents involving hospitalization or death were reported[2]. Taiwan is a subtropical island, and 80% of foodborne disease outbreaks occurred in the warmer months, i.e., between April and October. By the numbers of reported outbreaks, two peaks were found, one in May and the other in October[4]. The low frequency of illness in July and August was mainly due to school holidays and the Chinese Spirit Festival (the 7th lunar month) when local people avoid holding wedding ceremonies and feasts[2].

Diseases are a persistent threat to public health worldwide. The three main causative agents involved were of bacterial, chemical or natural origins. Bacterial foodborne agents play a leading role in all outbreaks. The epidemiological data of the US Centers for Disease Control and Prevention (CDC) between 1973 and 1987 revealed that bacterial pathogens accounted for 66% of outbreaks[1]. From 1981 to 1989, 622 outbreaks of foodborne illness were reported in Taiwan, pathogens accounted for 80% of confirmed incidents[2]. Between 1986 and 1995, 852 outbreaks of foodborne disease were reported in Taiwan. Of the 852 reported outbreaks, 555(65%) were caused by bacterial pathogens. The three most common bacteria involved were *Vibrio parahaemolyticus* 35%, *Staphylococus aureus* 30%, and *Bacillus cereus* 18%[4]. Insufficient heating, improper storage temperature and poor sanitation habits of food processors are the major causes of bacterial foodborne illness[9].

At present, the general isolation of bacterial pathogen in Taiwan includes, *Salmonella spp. V. parahaemolyticus*, *S. aureus*, *B. cereus*, Enteropathogenic *Escherichia coli* (EEC), *Shigella* spp. and *Clostridium botulinum* (especially for the case with symptoms: general weakness, dizziness, double-vision and trouble with speaking, breathing and swallowing, and weak muscles). In USA, Japan and Taiwan, *Campylobacter jejuni/coli* has been recognized as a major cause of bacterial diarrhea and the infection source is chicken [6-7]. Infections caused by *Yersinia enterocolitica*, *E. coli* O157:H7, vibrios, *Clostridium perfringens*, *Aeromonas hydrophila*, *Listeria monocytogenes* and other pathogens were also linked to foods[14] .

Thousands of people were ill from foodborne disease outbreaks every year in Taiwan. The prevention of it becomes an important task. In addition to the annual statistical data on foodborne illness in Taiwan published by the Department of Health, there are also various essays issued on the subject, such as Chiou *et al.*, 1991[2], Chen, 2000 [3], Pan *et al.*, 1997[4]. Beginning in 1989, the three divisions (Central, Southern, Eastern) of the National Laboratories of Foods and Drugs simultaneously accepted samples to identify pathogens of local foodborne outbreaks to improve the

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detection efficiency. The objectives of this study were to review and compare the statistical data of the foodborne illness between the central region and the whole Taiwan area (1991-2000). The foods associated with foodborne illness, O serotype of EEC, K-serotype of *V. parahaemolyticus*, *S. aureus* and its typing of enterotoxin, distribution and the tendency of foodborne outbreaks in central regions were analyzed and compared with the islandwide results.

MATERIALS AND METHODS

I. *Sources of Data*

From 1991 through 2000, data on 274 foodborne illness outbreaks were collected from public health authority in central Taiwan. Areas covered are Miou Li County, Taichung County, Taichung City, Chang Hwa County, Yulin County and Nan Tou County.

II. *Methods*

(I) *Detection of B. cereus*[10]

Twenty-five grams of sample was added to 225 mL sterilized normal saline to prepare tenfold dilutions. 0.1 mL of the dilution was transferred and spread to mannitol-egg yolk-polymyxin agar (MYP) (Merck, Darmstadt, Germany). Inoculated the MYP plate at 37˚C for 24 hours and the suspected colonies were cultivated in nutrient agar (NA) (Difco Lab, Detroit, Michigan, USA) at 37˚C for another 24 hours before performing Gram stain and microscopic inspection. Using API 50CHB (BioMerieux, Inc., USA) or Vitek JR systems for biochemical tests and bacterial counts (CFU/g).

(II) *Detection of S. aureus*[11]

Twenty-five grams of sample was added to 225 mL sterilized normal saline to prepare tenfold dilutions. Apply solution to Baird-Parker agar (BP) (Merck) and cultivate at 37˚C for 48 hours. The suspected colonies were cultivated in trypticase soy agar (TSA) (Merck) and brain heart infusion broth (BHI) (Merck) at 37˚C for another 24 hours before performing Gram stain and microscopic inspection. The BHI broth was used to perform coagulase testing, then using API 20 staph (BioMerieux, Inc., USA) or Vitek JR systems for analysis and bacterial counts (CFU/g).

(III) *Detection of the types of S. aureus enterotoxin*

The cultured BHI broth was centrifuged at 3000 rpm for 20 minutes and the supernatant is used as sample. Dropped 25 µL of sample into the four wells of the V-type. Using a dropper, add 25 µL sensitized latex anti-A, B, C, D to each well for reaction. 25 µL control latex was also added to 25 µL enterotoxin standard solution for reaction. Observed the results after leaving the microplate at room temperature for 18 hrs. The pink agglutination in V-type showed a negative result, and positive reaction did not find pink agglutination.

(IV) *Detection of S. aureus enterotoxin in food*[11]

Ten grams of food sample was add to 90 mL normal saline to make a tenfold dilution. The dilution was centrifuged in 3000 rpm for 20 minutes and use the supernatant as sample. 25 µL enterotoxin standard solution (positive control) and 25 µL of the above sample solution were dropped into the four wells of the V-type, then test the sample following the steps described previously.

(V) *Detection of V. parahaemolyticus*[12]

Twenty-five grams of sample was added to 225 mL 3%NaCl to make a tenfold dilution. 1 mL of the dilution was added to glucose salt teeple broth (GSTB) (Difco) or alkaline peptone water (APW) (Difco) and inoculated at 37˚C for 18 hrs. The above broths were streak-cultured on a thiosulfate-citrate-bile salts-sucrose agar (TCBS) (Merck), and inoculated at 37˚C for 18 hrs. A typical colony was cultured into triple sugar iron agar (TSI) (Merck) that contained 3% NaCl and 3% TSA at 37˚C for 18 hrs, before Gram stain and microscopic inspection. API 20E or Vitek JR system was used for biochemical tests. The bacterial number (MPN/g) was calculated and serological typing for K antigen was confirmed.

(VI) *Detection of Enteropathogenic E. coli*[13]

Twenty-five grams of sample was added to 225 mL BHI to make a tenfold dilution. 1 mL of the dilution was added to 9 mL BHI and inoculated at 44˚C for 18 hrs enrichment. Suspected BHI enrichment was spread-cultured in Levine's Eosin-Methylene blue agar (L-EMB) (Merck) at 37˚C for 18 hrs. A typical colony was cultivated to TSA and TSI at 37˚C for 18 hrs before performing Gram stain and microscopic inspection. API 20E or Vitek JR system was used for biochemical tests. The bacterial number (MPN/g) was calculated and serological typing for O antigen was confirmed.

(VII) *O Serological identification of Enteropathogenic E. coli*

The suspected colonies of Enteropathogenic *E. coli*, following biochemical tests and microscopic inspection, were inoculated from TSA to BHI and cultured at 37˚C for another 24 hours. Then added it into a 5mL solution containing 0.5% saline water, shook well, and added equal volume of suspension into two sterilized tubes. Performed *E. coli* O anti-serum testing on one tube and heated anti-serum testing on the other tube. The procedure is as follows. Draw a line on a slide with a crayon to divide it into two sections, each at about 1 × 2 cm. Mix one drop of *E. coli* O

anti-serum and a few drops of solution containing 0.5% saline water on one section, and put a few drops of saline water on the other section for comparison. Added a loop suspension fluid to each section, shook the slide, let it sit for three minutes before observing. Agglutination represents positive reaction. The other tube of suspension was heated at 100˚C for one hour or at 121˚C for 15 minutes to destruct the capsule before performing another test. Agglutination indicated a positive reaction. Serological typing for O antigen was confirmed.

(VIII) *Detection of Salmonella* spp. [15]

Mixing 225 mL of sterilized lactose broth (LB) (Merck) with 25 g specimen into a tenfold enrichment broth. The broth was inoculated at 35˚C for 18 hours. 1 mL LB was added to tetrathionate broth (TT) (Merck) and selenite cystine broth (SC) (Merck) for secondary enrichment at 37˚C for 18 hours. The suspected colony was isolated to TSI, TSA for cultivation at 35˚C for 18 hours before performing Gram stain and microscopic inspection. API 20E or Vitek JR system was used for biochemical tests, and serological typing for O antigen was confirmed.

(IX) *O Serotype Testing of Salmonella* spp.

Suspected colonies from TSI, confirmed by biochemical tests and microscopic inspection, were taken a loop to mix with two loops' amount of saline water on the slide to formulate suspension. Draw a line on a slide with a crayon divide it into two sections, each at about 1×2 cm. Mix one drop of *Salmonella* O anti-serum and a few drops of solution containing normal saline on one section, and put a few drops of saline water on the other section for comparison. Added a loop suspension broth to each section, shook the slide, let it sit for three minutes before observing. Agglutination represents positive reaction.

RESULTS AND DISCUSSION

Table 1 summarized the statistical data of 274 foodborne outbreaks, reported by central Taiwan public health authorities. They were processed by the Central Division of NLFD from 1991 to 2000. During those ten years, the average number of outbreaks per year was 27 (excluding foodborne outbreaks without food samples). The outbreaks increased dramatically and reached a peak of 46 in 1997. The numbers of outbreaks decreased to 39 in 1998, 25 in 1999 and 30 outbreaks in 2000. There were three deaths, all in Chang Haw County. All three deaths resulted from ingesting pufferfish. The most commonly found bacteria was *B. cereus* (113/274, 41.2%), followed by *S. aureus* (49/274, 17.9%) and *V. parahaemolyticus* (43/274, 15.7%) (Table 1). This result was different from Chiou *et al.*, which reported that the most frequently identified bacteria from 1981 to 1989 was *V. parahaemolyticus*, *S. aureus* and Entreopathogenic *E. coli*. This result was also different from Pan *et al.* who pointed out *V. parahaemolyticus* played a leading role (35%) from 1986 to 1995. It could be due to the fact that seafood consumption in central region was less than that in northern and southern regions. In 1995, 1997 and 1998, the percentage of *B. cereus* found in foodborne outbreaks were as high as 58.3%, 56.5% and 53.8%, respectively, and dropped to 16.7% in 2000. The detection rate of *B. cereus* in central region was higher than the 18% reported by Pan *et al.*[4]. Regional differences of food variety and preparation habit require further study. *B. cereus* can be found in nature, especially in soil and plants. It is also often isolated from rice products, seafood, chicken and dairy products (Todd, 1992)[16]. The detection rate of *S. aureus* fluctuated over the ten years, the highest detection rate was in 1992 and 1993, both at 40%, and the lowest was in 1998 at 2.6%. For *V. parahaemolyticus*, the highest detection rate was 28.2% in 1998 and the lowest was 5.0% in 1992 and 1993.

The foodborne outbreaks in Taiwan are illustrated in Table 2. There were 679 outbreaks from 1981 to 1990, with an average of 70 outbreaks per year. In the past decade, the growing economy led to an increase of dining-out population. Statistics showed that foodborne outbreaks climbed up to 1433 during the period of time with an average of 140 cases per year, while the number of outbreaks increased twice. The total cases were 17405 and 38742,

Table 1. Foodborne outbreaks in central Taiwan, 1991- 2000

Year	No. of outbreaks	No. of cases	No. of deaths	No. of outbreaks caused by foodborne pathogen		
				Bacillus cereus	*Staphylococcus aureus*	*Vibrio parahaemolyticus*
1991	16	789	0	4	5	2
1992	20	981	0	7	8	1
1993	20	705	0	8	8	1
1994	18	1166	0	5	4	1
1995	24	976	0	14	3	2
1996	36	1433	0	16	2	6
1997	46	2753	1	26	5	9
1998	39	1681	0	21	1	11
1999	25	1281	1	7	6	4
2000	30	720	1	5	7	6
Total	274	12845	3	113	49	43

Table 2. Foodborne outbreaks in Taiwan

Year	No. of outbreraks[a]	No. of cases[a]	No. of deaths[a]	Cases / Outbreak
1981-1990	679	17405	39	26
1991-2000	1433	38742	7	27

a: data from Department of Health (Taiwan).

Table 3. Location of food mishandling in foodborne outbreaks in central Taiwan, 1991-2000

Location	No. of outbreaks (%)		No. of confirmation
Home	113	(41.2)	77
School	94	(34.3)	57
Food service	33	(12.0)	16
Offices	21	(7.7)	15
Others	13	(4.7)	6
Total	274		171

Table 4. Causative agents of foodborne outbreaks in central Taiwan, 1991-2000

Agents	No. of outbreaks (%)	No. of deaths
Bacterial[a]	171 (62.4)	0
Bacillus cereus	113 (41.2)	
Staphylococcus aureus	49 (17.9)	
Vibrio parahaemolyticus	43 (15.7)	
Enteropathogenic *Escherichia coli*	25 (9.1)	
Salmonella spp	3 (1.1)	
Staphylococcal enterotoxin in food	4 (1.5)	
Chemical and unknown agent	103 (37.6)	3
Total	274	3

a: In some outbreaks, more than one agents were identified.

also indicated a twofold increase. However, the average cases in each outbreak were about the same (26 and 27), and death numbers decreased from 39 to 7. Chiou *et al.*,[2] reported that there were totally 39 deaths in Taiwan from 1981 to 1989, 3 deaths due to *C. botulinum*, 4 deaths by chemical poisoning, 6 deaths by natural toxin and 26 deaths died of unknown causes. The fatality rate by ingesting hazardous foods at home was the highest (32/39). There were 7 deaths from 1991 to 2000, 1 deaths caused by ingesting pesticides and 6 deaths by tetradotoxin. In the USA, the highest fatality rate in foodborne outbreaks was caused by *Salmonella* spp. (88/247), followed by *Listeria* (70/247), and *C. botulinum* (47/247) (Bean, 1990)[1]. The outbreaks ratio between the central region and the whole Taiwan was 274/1433 (19.1%), and the cases ratio was 12845/38742 (33.2%) from 1991 to 2000, indicating the larger magnitude of foodborne outbreaks in central region (Table 1 & Table 2).

Location of food mishandling was illustrated in Table 3. The occurrence happened mostly at homes, including catering services, which was 41.2% followed by schools at 34.3%. Restaurants and work places were at 12.0% and 7.7%, respectively. This result was similar to Chiou *et al.*,[2] indicating that homes (including catering) accounted for almost half of reported outbreaks (44%), followed by schools (31%). In Canada, restaurants were the leading outbreak locations (52%), followed by fast food stands (25%) and private residence (19%) (Todd, 1992)[16]. Results showed that the difference of food preparation style between Taiwan and Canada. In Taiwan, the numbers of outbreak were mainly at homes because food samples were easy to obtain. However, the numbers of outbreak in restaurants might be higher than reported because some food samples were not purchased. The confirmation fractions of etiological agent were over 60% in offices (15/21, 71.4%), homes (77/113, 68.1%) and schools (57/94, 60.6%), but it was low in food service (16/33, 48.5%).

Table 4 illustrated the causative agents of foodborne outbreaks in central Taiwan. Among the 274 outbreaks, 171 were due to bacterial pathogens (62.4%) and the other 37.6% were due to chemical or unknown agents. The most significant organisms isolated in foodborne outbreaks were *B. cereus* (41.2%), *S. aureus* (17.9%), *V. parahaemolyticus* (15.7%), Enteropathogenic *E. coli* (9.1%), *Salmonella* spp (1.1%), and *S. aureus* enterotoxin (1.5%). Pan *et al.*, 1997[4] pointed out that the outbreaks caused by *Salmonella* spp in Taiwan did not occur as often as in the USA and Japan. From 1983 to 1993, 10 types of *Salmonella* serovars were the most frequently isolated in Taiwan. The major serovars were *S. typhimurium*, and *S. virchow. S. enteritidis* was found as the new serovar in recent years.

E. coli is a Gram negative bacilli, a normal flora in human intestine. Some of the *E. coli* serotypes could induce foodborne outbreaks, those serotypes are called Enterovirulent *E. coli* and can be divided into six subgroups: Enterotoxigenic *E. coli* (ETEC), Enteropathogenic *E. coli* (EPEC), Enteroinvasive *E. coli* (EIEC), Enterohemorrhagic *E. coli* (EHEC), Enteroadherent *E. coli* (ETEC) or Enteroaggregative *E. coli* (EAggEC), and Diffusely adherent *E. coli* (DAEC)[14,22,23]. From 1994 to 2000, 15 O serotypes of *E. coli* were isolated from Enteropathogenic *E. coli* with distribution shown in Table 5. Among the 44 isolates of Enteropathogenic *E. coli* O serovar recovered from 20 outbreaks, O18 serovar was the most common, 11 isolates were obtained from 3 outbreaks. The minor serovars were O78, O144 and O169 found in two different outbreaks. According to Wang *et al.*,[13], the contamination rate of Enteropathogenic *E. coli* from lunch box was 15% in northern Taiwan. From 1995 to 1996, 23 isolates of Enteropathogenic *E. coli* were identified from 147 foodborne outbreaks, and the most common serovar was O55. In central region, on the other hand, 20 isolates of Enteropathogenic *E. coli* were obtained in all 218 outbreaks during 1994 to 2000, and the O18 serovar was the most often found. *E. coli* O157:H7 was firstly identified from an outbreak of diarrhea with hemorrhagic colitis due

Table 5. The O serotypes of EEC strains isolated from the foodborne outbreaks of central Taiwan, 1994-2000

Serovar	No. of isolates (no. of outbreaks)							Total no.of isolates
	1994	1995	1996	1997	1998	1999	2000	(no. of outbreaks)
O18		3(1)			3(1)	5(1)		11(3)
O20					4(1)			4(1)
O26			2(1)					2(1)
O27		4(1)						4(1)
O28ac		1(1)						1(1)
O55		1(1)						1(1)
O78			1(1)	3(1)				4(2)
O114		2(1)						2(1)
O115	1(1)							1(1)
O125				1(1)				1(1)
O128		2(1)						2(1)
O143				1(1)				1(1)
O144	1(1)				1(1)			2(2)
O159		4(1)						4(1)
O169			4(2)					4(2)
Total	2(2)	17(7)	7(4)	5(3)	8(3)	5(1)	0	44(20)

Table 6. The K serotype for *Vibrio parahaemolyticus* strains isolated from the foodborne outbreaks of central Taiwan, 1991-2000

Serovar	No. of isolates (no. of outbreaks) in (yr)										Total no.of isolates
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	(no. of outbreaks)
K6							14(3)				14(3)
K7			4(1)				2(1)				6(2)
K8								1(1)			1(1)
K13						1(1)					1(1)
K15										1(1)	1(1)
K19										4(1)	4(1)
K26									2(1)		2(1)
K28						1(1)		2(1)		5(2)	8(4)
K30										1(1)	1(1)
K33										1(1)	1(1)
K34							1(1)	1(1)			2(2)
K36					3(1)						3(1)
K46								1(1)			1(1)
K48							1(1)			1(1)	2(2)
K54							8(2)				8(2)
Nontypeable	3(2)	2(1)	0	4(1)	1(1)	13(4)	4(2)	11(7)	6(3)	7(4)	51(25)
Total	3(2)	2(1)	4(1)	4(1)	4(2)	15(6)	30(10)	16(11)	8(4)	20(11)	106(49)

to ingesting improperly cooked beef hamburger, occurred in USA, 1982. In 1996, over 10,000 people in Japan's Osaka area were infected with the disease, and resulted in 3 deaths. The first outbreak in Taiwan was reported in 2001. A six-year-old American boy visiting Taiwan showed symptoms in August and bacterial culture confirmed the pathogen to be intestinal hemorrhagic *E. coli* combining with hemolytic uremic syndrome. Although *E. coli* O157:H7 outbreaks have not widely occurred in Taiwan, the health authorities have already paid great attention to it.

Taiwan and Japan are two countries with high consumption of seafood products. *V. parahaemolyticus* is identified as a leading cause in foodborne outbreaks[12]. The Vp-TDH produced by *V. parahaemolyticus* is considered to be the major virulent agent and related to Kanagawa reaction. Most of the *V. parahaemolyticus* isolated from the patients' feces dissolves red blood cells indicating Kanagawa positive reaction[17,18]. Shih et al (1997) reported that the identification rate on *V. parahaemolyticus* was 13.3% from 120 samples of fresh fish and shell fish in Taiwan. Table 6 showed the isolation rate of K serotype *V. parahaemolyticus* in central Taiwan from 1991 to 2000. 106 strains of *V. parahaemolyticus* were isolated from 49 outbreaks. 55 strains could be identified with K serotype (51.9%) while the other 51 strains could not (48.1%). At present, the identification of *V. parahaemolyticus* in foodborne outbreak is mainly based on biochemical test, some of the strains cannot be confirmed with the marketed K serotype. It could be that the isolated strain was a new type or an environmental type and that no relevant K serotype could be used for identification. Confirmation with TDH analysis or other virulent agent could identify whether the isolates of *V. parahaemolyticus* were pathogenic or not. As

isolated stains, there were 14 strains of K6, 8 strains of K28 and K54 and 6 strains of K7. The foodborne outbreaks increased dramatically in 1996 and mostly related to the high isolation rate on *V. parahaemolyticus*, especially serotype O3:K6. In 1997, 83.8% of the *V. parahaemolyticus* serotype found in Taiwan was O3:K6 (Chiou, 2000)[8]. In central Taiwan, the highest isolates of *V. parahaemolyticus* was 30 in 1997, and 26 of them could be typed with K serotype.

S. aureus can produce one or more types of pyogenic exotoxins including Staphylococcal enterotoxins (SEs), toxic shock syndrome toxin 1 (TSST-1), and exofoliative toxin A and B[19]. Enterotoxin can be divided into A, B, C, D, and E, five types based on serotypes, and C type can further be divided into C1, C2 and C3. Enterotoxin is a group of protein molecule with a molecular weight between 26,000 and 34,000 Da and is able to resist high temperature and multiple protein dissociation enzyme[20,21]. Table 7 illustrated the isolation rate of *S. aureus* and the enterotoxin type found in central Taiwan outbreaks. 121 of 155 strains of *S. aureus* (78.0%) were able to produce toxin while 34 strains (22.0%) could not. The isolated *S. aureus* enterotoxins was divided into seven types: A, B, C, D, A&B, A&D, A&B&C. *S. aureus* enterotoxins type A was the most frequently isolated among 92 strains (76.0%), followed by type B with 17 strains (14.0%). Type D and type A&B&C were found only in one case. This result matched with Ko *et al.*, (1995) study on *S. aureus*, which was isolated from 169 samples of foodborne outbreaks in Taiwan[11]. The report indicated 78% of *S. aureus* strains were able to produce enterotoxin, and type A was the most commonly found (81%).

The food groups were divided into six categories: fish and shell fish, meat and meat products, cereal products, vegetable and fruits, boxed meal and others. The relationships between food vehicles and isolated pathogenic bacteria are listed in Table 8. In the six categories, seafood products were the main identified vehicles of transmission (32.5%), followed by meat and meat products (23.5%), cereal (15.6%), others at 11.3%, boxed meal (9.8%) and vegetables and fruits (7.4%). This result was similar to Chiou *et al.*, (1991)[2] which reported that many of the outbreaks (68%) could not link to specific food categories. Seafood products were the main identified vehicles of transmission, followed by mixed dishes and meat and meat products. Unlike western countries, milk and dairy products were very minor causes of outbreaks in Taiwan. In USA, the food vehicles in the order of frequency of outbreaks are finfish (15%), beef (9%), pork (7%), shellfish (6%), vegetable and fruit (5%), Chinese food (4%) and dairy products (3%) (Bean, 1990)[1]. In central Taiwan, *B. cereus* was frequently isolated from seafood (40/178), meat and meat products (37/178) and boxed meals (28/178). Otherwise, *S. aureus* is most frequently found in cereal (25/67), less in meat and meat products (18/67) and even less in seafood (11/67). In addition, *V. parahaemolyticus* is often isolated from seafood (55/86), meat and meat products (17/86). The highest isolation rate on Enteropathogenic *E. coli* were in seafood (17/45) and meat and meat products (14/45), and all *Salmonella* spp. strains were found in all meat and meat products (100%). The study of Todd *et al.* (1992) (15) showed that, foodborne illnesses associated with food categories did not change much from 1975 to 1984, and that different pathogenic bacterium were found in various food vehicles.

Investigation and analysis of foodborne disease outbreaks play a key role in isolating new emerging pathogens and evaluating hazards. However, in many outbreaks, the bacterial pathogens were not isolated due to delay or incomplete investigations, lack of relevant expertise of the laboratories, or inability to identify the pathogenic bacteria immediately. A fast and complete investigation could provide the information of epidemiological data within the first hours to enable appropriate prevention and control.

Table 7. Enterotoxin production by *Staphylococcus aureus* from 155 samples of foodborne outbreaks in central Taiwan, 1991-2000

Enterotoxin	No. of isolates	(%)
A	92	(76.0)
B	17	(14.0)
C	3	(2.5)
D	1	(0.8)
A&B	3	(2.5)
A&D	4	(3.3)
A&B&C	1	(0.8)
None detected	34	
Total	155	

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Table 8. Number of foodborne outbreaks by pathogens in central Taiwan, 1991-2000

Pathogen	Fish/Shellfish	Meat/Meat products	Cereal products	Vegetable & fruits	Boxed meal	Others	Total
B. cereus	40	37	27	21	28	25	178
S. aureus	11	18	25	2	5	6	67
V. parahaemolyticus	55	17	6	1	1	6	86
Enteropathogenic *E. coli*	17	14	1	4	3	6	45
Salmonella	0	3	0	0	0	0	3
Total (%)	123(32.5)	89(23.5)	59(15.6)	28(7.4)	37(9.8)	43(11.3)	379

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