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Original Article

Investigation on the trend of food-borne disease outbreaks in Taiwan (1991–2010)

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ABSTRACT

This article summarizes the results of 20 years (1991–2010) of investigation on food-borne disease outbreaks (FBDOs) collected by the Food and Drug Administration of the Department of Health in Taiwan. Among the 4284 FBDOs (82,342 cases) reported, the average annual number of 285 outbreaks during 2001–2010 was substantially greater than the average annual number of 143 outbreaks reported during 1991–2000. The average number of 15.5 cases per outbreak in 2001–2010 was lower than that in 1991–2000, which is 28.5 cases per outbreak. Small-scale FBDOs increased during 2001–2010. Good hygiene practices should be carried out at food service establishments and school kitchens that provide compound cooking food or meal boxes. The three most common bacterial etiology agents involved were *Vibrio parahaemolyticus*, *Staphylococcus aureus*, and *Bacillus cereus*. FBDOs resulting from *B. cereus* and *Salmonella* spp. exhibited an increasing trend during 2001–2010. Increased botulism FBDOs in 2001–2010 had been effectively controlled and reduced after governmental policy intervention. However, natural toxin-associated FBDOs are of concern as they can be fatal, especially the outbreaks associated with eating pufferfish by mistake.

1. Introduction

Food-borne disease outbreak (FBDO) is an important public health issue related to the food safety management in a country. Each year, unsafe food makes at least two billion people ill worldwide, or about one-third of the global population [1]. The United States (US) Centers for Disease Control and Prevention estimate that in each year, roughly 1 in 6 Americans (or 48 million people) falls sick, 128,000 are hospitalized, and 3000 die of food-borne diseases [2].

Outbreak surveillance has served several purposes, including disease prevention and control, knowledge of disease causation, and administrative guidance [3]. The review and statistics of FBDOs are mainly essential for the government to identify the key problems and find solutions to prevent them. US FoodNet has been tracking trends in the most

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common infections transmitted through food since 1996 [4]. In the United Kingdom, the Health Protection Agency has maintained a collaborative surveillance system for foodborne outbreaks in England and Wales since 1992 [5]. Other countries such as France [6], Australia [7], and Malaysia [8] also monitor the trends and causes of FBDOs over time. FBDO statistics have been systemically reported since 1986 by the Department of Health in Taiwan. Pan et al [9] reviewed the FBDOs due to bacteria during 1986–1995 and showed that the most common bacteria involved were *Vibrio parahaemolyticus*, *Staphylococcus aureus*, and *Bacillus cereus*. Bacterial FBDOs in central and northern Taiwan were also discussed for the periods 1991–2000 and 1995–2001, respectively [10,11]. With the exception of the pathogenic microorganisms reported by Pan et al [9], *Salmonella* spp. was one of the main etiologic agents. In the present study, the characteristics and trend of FBDOs during 1991–2010 were investigated. A comparison of two decades, 1991–2001 and 2001–2010, was made. The results of this study provide important insights for the government to improve food safety policy making for the prevention of FBDOs in the future.

2. Methods

2.1. Definition and criteria

A FBDO is defined as the occurrence of two or more cases of a similar illness resulting from the ingestion of a common food. However, only one case of botulism, chemical poison, or natural toxin constitutes an outbreak when laboratory analysis results or epidemiological investigations are proven.

The etiologic agent is confirmed when the agent or toxic substance is identified in at least two or more ill persons or implicated food. The vehicles identified in outbreak investigations that can be classified into a single commodity are grouped into nine major food commodity categories, including seafood, seafood products, meat and meat products, egg and egg products, milk and milk products, cereal and cereal products, vegetable and vegetable products, confectionery, and compound cooking food. Two or more kinds of food categories cooked and serviced together are classified under compound cooking food, such as meal boxes. Reported food vehicles that cannot be categorized are listed as "Others." The incidence of outbreaks and cases (per 100,000 people) were calculated on the basis of data from the statistical yearbook of the Ministry of Interior for the period 1991–2010 in this study[12].

2.2. Source of data

Investigations on FBDOs were initiated by local health departments after receiving notifications from the public or physicians. Suspicious residual food, stool, vomit, blood, or environmental samples were collected and analyzed by the Taiwan Food and Drug Administration (TFDA) and Centers for Disease Control (TCDC) of the Department of Health. Epidemic investigation was conducted by the TCDC according to standard operating procedures of investigation if necessary. The TFDA was responsible for integrating all the relevant information and statistics. From 1991 to 2010, the data on 4284 FBDOs (82,342 cases) were collected by the TFDA and used for investigation in this study [13].

3. Results and discussion

3.1. FBDOs, cases and incidence

Table 1 showed that from 1991 to 2010, 4284 FBDOs were reported in Taiwan (population: 23,261,747 in 2012) [14], involving 82,342 cases and 15 deaths. The average annual number of outbreaks reported during 2001–2010 was substantially greater than that reported during 1991–2000. However, the average number of 4340 cases in 2001–2010 was only 10% higher than that in 1991–2000, which was 3894 cases. Therefore, the average number of 15.5 cases per outbreak in 2001–2010 was lower than in 1991–2000, which was 28.5 cases per outbreak. The results showed a decrease in large-scale FBDOs and an increase in small-scale FBDOs. With the growing concern on food safety issues and self-care, especially after the incidence of melamine-contaminated milk in China in 2008 [15], more outbreaks were reported. By contrast, as lifestyle changes, people eat out more often. For example, consumers now spend approximately 43% of their food budgets on meals outside the home in the US [16]. There are more than one hundred thousand food service establishments in Taiwan. The Good Hygienic Practice (GHP) was implemented in food industries in Taiwan in 2000. It is important that food service providers have a better understanding of the sanitary procedures and meet the standards of the GHP.

The average incidence of outbreaks per 100,000 people for the periods 1991–2000 and 2001–2010 were 1.2 and 0.7, respectively. The average incidence of cases per 100,000 people for the periods 1991–2000 and 2001–2010 were 19.0 and 18.1, respectively. Although there were no significant differences between the two decades, avoiding the occurrence of death cases resulting from FBDOs should always be an overriding priority.

3.2. FBDOs by month

Taiwan is located in the subtropical area. The average temperature in northern Taiwan (Taipei) is in the range of 25.2 °C to 29.2 °C, whereas that in southern Taiwan (Kaohsiung) is in the range of 27.5 °C to 29.2 °C from May to September [17]. Microorganisms can multiply up to several log values if food is contaminated. The large number of travelers and activities conducted during the summer vacation also contributed to the occurrence of outbreaks. Table 2 shows the increase in the number of FBDOs from May to September in 1991–2010. A similar trend was observed in the two decades (1991–2001 and 2001–2010); however, the number of FBDOs was also substantially higher in October and January in 2001–2010. Despite the cool weather in Taiwan in January and February, an increase in the number of FBDOs was still observed in 2001–2010.

3.3. Vehicles identified

The identified vehicles of FBDOs are shown in Table 3. From 1991 to 2010, compound cooking food (including meal boxes)

Table 1 – Outbreaks, cases, and incidence of food-borne diseases in Taiwan during 1991–2010.

Year	Outbreaks	Outbreak incidence rate × 100,000	Cases	Case incidence rate × 100,000	Cases/outbreaks (mean)	Death (cases)
1991	93	0.5	2378	11.5	25.6	0
1992	88	0.4	3084	14.8	35.0	1
1993	77	0.4	2150	10.2	27.9	1
1994	102	0.5	4276	20.2	41.9	0
1995	123	0.6	4950	23.2	40.2	0
1996	178	0.8	4043	18.8	22.7	0
1997	234	1.1	7235	33.3	30.9	1
1998	180	0.8	3951	18.0	22.0	0
1999	150	0.7	3112	14.1	20.7	1
2000	208	0.9	3759	16.9	18.1	3
2001	178	0.8	2955	13.2	16.6	2
2002	262	1.2	5566	24.7	21.2	1
2003	251	1.1	5283	23.4	21.0	0
2004	274	1.2	3992	17.6	14.6	2
2005	247	1.1	3530	15.5	14.3	1
2006	265	1.2	4401	19.2	16.6	0
2007	248	1.1	3231	14.1	13.0	1
2008	272	1.2	2924	12.7	10.8	0
2009	351	1.5	4642	20.1	13.2	0
2010	503	2.2	6880	29.7	13.7	1
$Total_{1991-2010}$	4284	—	82342	—	—	15
$Mean_{1991-2000}$	143	0.7	3894	18.1	28.5	0.7
$Mean_{2001-2010}$	285	1.2	4340	19.0	15.5	0.8
$Mean_{1991-2010}$	214	1.0	4117	18.6	22.0	0.8

and seafood accounted for 46% and 20% of identified vehicles in a total of 773 outbreaks, respectively. A similar trend in vehicles identified in FBDOs was observed in the two decades (1991–2001 and 2001–2010). Other vehicles, except cereal and cereal products, had decreasing trends.

The number of outbreaks associated with compound cooking food increased to over 50% in 2001–2010 compared to 1991–2000. Various ingredients, including vegetables, meat, seafood, and cereal, are involved in compound cooking food; mishandling these ingredients with cross contamination or improper storage could increase the chances of an FBDO occurrence. In the US, complex vehicles accounted for 27.2-32.9% of FBDOs from 1998 to 2002 [1]. Good hygienic practice and sanitary management, including employee training in food service establishments and meal box factories, are mainly important for food safety improvement. Furthermore, meal box factories usually provide 10,000–60,000 meal boxes each time. If an FBDO occurs, hundreds or thousands of consumers may become sick. For these reasons, the Hazard Analysis and Critical Control Point (HACCP) system has been promoted and implemented voluntarily in the meal box industry in Taiwan since July 1998 [18]. In 2007, the Department of Health (DOH) in Taiwan announced that the HACCP shall be carried out in the meal box industry after September 2010. The

Table 2 – FBDOs by month in Taiwan, 1991–2010.

Month	Mean temperature (°C) (1981–2010)		Outbreaks		
	North (Taipei city)	South (Kaohsiung city)	1991–2010	1991–2000	2001–2010
Jan	16.1	19.3	305	54	251
Feb	16.5	20.3	253	42	211
Mar	18.5	22.6	238	69	169
April	21.9	25.4	262	96	166
May	25.2	27.5	459	193	266
June	27.7	28.5	440	202	238
July	29.6	29.2	442	193	249
Aug	29.2	28.7	441	153	288
Sept	27.4	28.1	526	174	352
Oct	24.5	26.7	373	123	250
Nov	21.5	24.0	313	80	233
Dec	17.9	20.6	232	54	178

FBDOs = food-borne disease outbreaks.

Table 3 – Vehicles identified in FBDOs in Taiwan, 1991–2010.

Vehicles	1991–2010	1991–2000	2001–2010
Seafood	153 (20)[a]	79 (21)	74 (18)
Seafood products	16 (2)	12 (3)	4 (1)
Meat and meat products	72 (9)	46 (12)	26 (6)
Eggs and egg products	10 (1)	8 (2)	2 (<1)
Milk and milk products	2 (<1)	1 (< 1)	1 (<1)
Cereal and cereal products	56 (7)	27 (7)	29 (7)
Vegetable and vegetable products	46 (6)	24 (6)	22 (5)
Confectionery	45 (6)	29 (8)	16 (4)
Compound cooking food (including meal box)	358 (46)	137 (37)	221 (55)
Others	15 (2)	8 (2)	7 (2)
Total	773	371	402

FBDOs = food-borne disease outbreaks.
[a] Data are presented as *n* (%).

number of FBDOs decreased by 25% for these meal box factories performed HACCP in 2010 but not in 2009 (data not shown). However, efforts should be made continuously, especially the involvement of professional staffs in food manufacturing.

3.4. FBDO-associated locations

To compare the locations of FBDOs, we collected data from outbreaks during 1991–2010 for analysis as given in Table 4. The top two locations where foods consumed were implicated in FBDOs were food service establishments and schools during the past two decades (1991–2001 and 2001–2010). Furthermore, more cases occurred in schools, which accounted for 44% and 51% of cases in 1991–2001 and 2001–2010, respectively. Because most children have school meals, the number of cases is usually significantly higher in schools if FBDOs should happen. For example, 295 students fell sick from food poisoning involving a bacterial etiology agent after having lunch prepared at a school kitchen in Tainan city in 2010 [19]. Therefore, more efforts to prevent FBDOs should be made in these locations.

3.5. Etiology agents

Etiology agents, including bacterial, natural toxin, and chemical agents, accounted for 48%, 2.3%, and 0.8% of outbreaks, respectively, during 1991–2010 as shown in Fig. 1. For bacterial agents, the most predominant organisms were *V. parahaemolyticus* (28.8%), *S. aureus* (7.3%), *B. cereus* (5.4%), and *Salmonella* spp. (4.0%). Fig. 2 shows the trend of outbreaks caused by bacterial agents in Taiwan. *V. parahaemolyticus* has played a leading role since 1995 and reached a peak of 160 outbreaks in 1997, followed by a tendency to decrease gradually. However, it still stands in the first place. *V. parahaemolyticus* exists in warm coastal areas and is the main etiological agent in seafood and ready-to-eat foods. By contrast, the number of outbreaks caused by bacterial agents such as *B. cereus*, *S. aureus*, and *Salmonella* spp. increased in 2001–2010.

B. cereus, which is a Gram-positive, spore-forming bacteria, should be the most noticeable one because of its toxin producing ability and a minimum growth temperature of 4 °C. Two distinct food-borne disease types, emetic (vomiting type) and diarrheal, are associated with *B. cereus*. The emetic syndrome was first identified after several outbreaks caused by eating cooked rice in the United Kingdom in the early 1970s [20]. The vomiting-type outbreaks have generally been associated with rice products [21]. In recent years, there has been increased awareness of the potential risk of emetic food poisoning caused by *B. cereus* in Korea [22]. The consumption of rice by the Taiwanese people is 42.6 kg/year/person [23]. Although the contamination of *B. cereus*, especially with spores, could not be avoided, appropriate cleaning, cooking, and preservation could still effectively reduce FBDOs.

Clostridium botulinum is an anaerobic, Gram-positive, spore-forming bacterium that produces a potent neurotoxin. The disease called botulism sometimes causes fatal cases. Eight outbreaks, eight and 11 cases of FBDOs caused by *C. botulinum* in 2007 and 2010, respectively, occurred during 2001–2010 as shown in Fig. 3. Eleven infected cases and one fatal case were

Table 4 – Locations of food mishandling in FBDOs in Taiwan, 1991–2010.

Location	1991–2010		1991–2000		2001–2010	
	Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases
Home	28 (13)	181 (4)	18 (12)	154 (4)	39 (14)	207 (5)
Food service	84 (39)	914 (22)	42 (29)	800 (21)	125 (44)	1027 (24)
School	43 (20)	1956 (48)	27 (19)	1707 (44)	59 (21)	2206 (51)
Office	20 (9)	418 (10)	19 (13)	507 (13)	21 (7)	329 (8)
Hospital	2 (1)	21 (<1)	2 (1)	29 (1)	1 (<1)	12 (<1)
Transportation	2 (1)	33 (1)	2 (1)	35 (1)	2 (1)	32 (1)
Army	4 (2)	80 (2)	3 (2)	80 (2)	4 (1)	79 (2)
Outdoors	1 (1)	32 (1)	1 (1)	38 (1)	1 (<1)	26 (1)
Snack booth	4 (2)	17 (<1)	2 (1)	11 (<1)	7 (2)	24 (1)
Catering	23 (10)	377 (9)	25 (18)	484 (12)	18 (6)	269 (6)
Other	6 (3)	104 (3)	4 (3)	63 (2)	8 (3)	141 (3)

Data are presented as mean (%).
FBDOs = food-borne disease outbreaks.

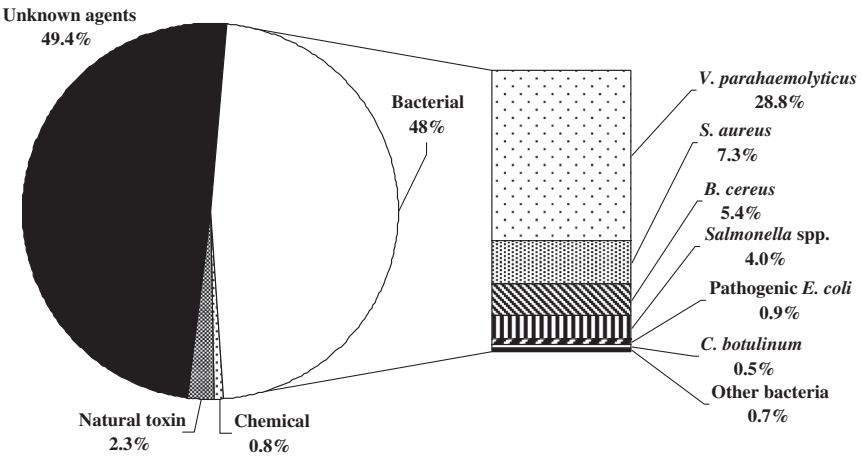

Fig. 1 – Etiology agents of FBDOs in Taiwan, 1991–2010. FBDOs = food-borne disease outbreaks.

reported in 2010. The investigation by the TFDA in 2010 found that vacuum-packed ready-to-eat soybean food was the most suspected vehicle and *C. botulinum* was proven to be the etiology agent by the TCDC. To avoid the recurrence of FBDOs caused by *C. botulinum*, new regulations, including "Good Hygiene Practice for Vacuum-Packed Food" [24], "Regulations of Labeling for Vacuum-Packed Food" [25], and "Registration Requirements for Vacuum-Packed Ready-to-Eat Soybean Food" [26] were promulgated and brought into force to regulate food producers to take necessary actions and use proper labels to guarantee food safety. Recent statistics showed there have been no botulism cases caused by vacuum-packed ready-to-eat soybean food in 2011 and 2012 [13].

Natural toxin and chemical agents accounted for 2.3% and 0.8% FBDOs, respectively. The trend in natural toxin-associated FBDOs increased around 2010 as shown in Fig. 4. Although the frequency of FBDOs caused by natural toxin was low, the symptoms were usually very serious and even life threatening in severe cases. For example, the consumption of pufferfish containing tetrodotoxin is very dangerous. Tetrodotoxin is heat-stable and not destroyed by cooking or freezing. Therefore, pufferfish is not used as a food in Taiwan. From 1991 to 2010, however, 11 people died from eating pufferfish by mistake. Recently, a report showed that there were 58 cases for tetrodotoxin poisoning from 1988 to 2011 and resulted in intoxication in 192 people and 22 deaths. Most cases were caused by puffer fish, followed by gastropod (snail) and goby [27]. In order to educate consumers and fishermen on recognizing poisonous marine species, the TFDA published a guidebook in 2012 that teaches one to recognize poisonous pufferfish [28].

Some wild plants containing toxic substances, such as poisonous mushrooms (also known as toadstools) may be mistaken as edible plants. Five people came down with food poisoning after eating *Chlorophyllum molybdites* (Meyer: Fr.) Massee, which looks similar to the edible mushroom named *Macrolepiota procera*, and one person had throat ache and swallowing difficulty after eating *Alocasia macrorrhiza* (L.) Schott & Endl., which is one of the most popular wild plants that looks like edible taro, in Taiwan in 2010 [19]. The toxins in wild mushroom are not destroyed by washing, cooking, freezing, or canning. The best way to avoid getting sick from eating wild mushrooms is not to eat them and purchase mushrooms from grocery stores that sell products planted and grown in professional mushroom farms [21].

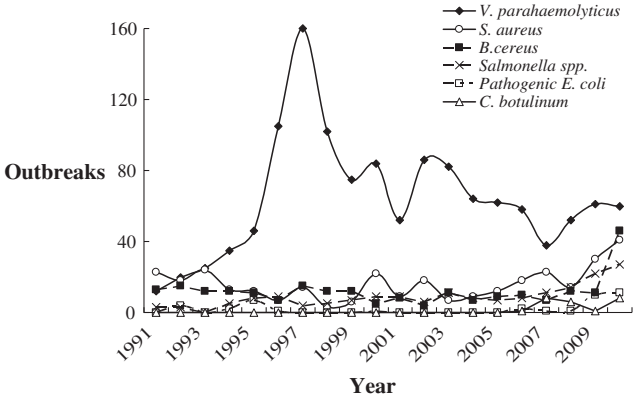

Fig. 2 – The trend of outbreaks caused by bacterial agents in Taiwan, 1991–2010.

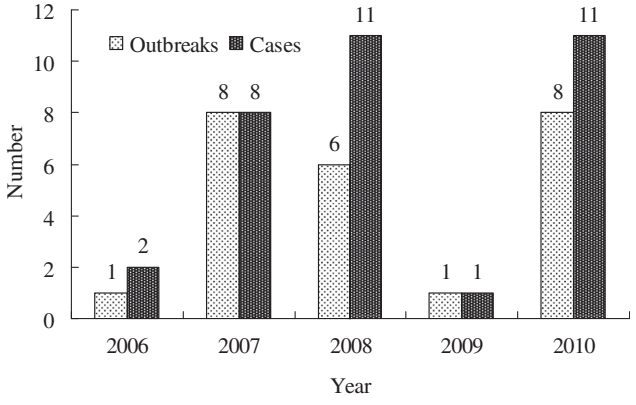

Fig. 3 – The outbreaks and cases of *Clostridium botulinum* in Taiwan, 2006–2010.

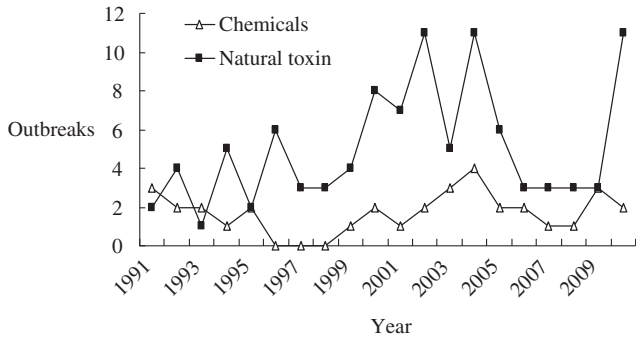

Fig. 4 – The trend of outbreaks caused by chemical and natural toxin agents in Taiwan, 1991–2010.

Hydrogen peroxide (H_2O_2) in processed food, such as fish-balls, noodles, and soybean curd, had been found to cause chemical poisoning. Fifteen FBDOs associated with H_2O_2 caused symptoms of illness in 1999 and 2010 [19], and the investigation showed all the vehicles were noodles. Hydrogen peroxide was used to reduce microorganisms by mistake. Proper preservation of wet noodles at low temperature could inhibit the growth of microorganisms and prolong the shelf life. Information on proper and safe food handling should be given to the related food vendors.

Unknown agents made up 49.4%, which leave room for improvement in the future, including investigations on FBDOs, sampling timing, sampling accuracy, and analytical techniques.

4. Conclusion

Studies on the FBDOs provide information for the government and the directions in the future. Because small-scale FBDOs had become the majority in 2001–2010, food service establishments providing compound cooking food should strengthen the sanitary management by carrying out GHP. Furthermore, the schools and meal box providers should perform HACCP carefully to control the critical points for eliminating the possible hazards. *B. cereus* and *Salmonella* spp. should be regarded as important etiology agents, and intervention policies should be made to reduce possible FBDOs in the future. Information on the correct and careful use of additives should be made available to food processors to avoid chemical intoxication. The best way to avoid natural toxins from wild plants and unsafe seafood such as pufferfish is not to eat them. Finally, the prevention of FBDOs is always an important goal for the government.

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