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Review
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Review

Food quality and safety in Singapore: microbiology aspects

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Abstract

BACKGROUND: Singapore's status as a first world island city-state which relies chiefly on food imports to meet the demand for consumption presents unique challenges in terms of microbial food safety and quality. Despite the efforts of the Ministry of Health in Singapore, in conjunction with the Agri-Food & Veterinary Authority of Singapore and the National Environment Agency actively collaborate together to promote safety in Singapore, foodborne diseases are still a major public health issue.

OBJECTIVE: The aim of the review was to summarize the various foodborne diseases reported in Singapore in the past few years as well as to give an account of all the currently available microbiological findings indicating safety and quality of poultry, vegetables, fruits, and seafood sold in Singapore.

Keywords: Singapore; Food safety; Food quality; Foodborne disease.

Introduction

Despite constant advancements in technology and our knowledge of food safety, foodborne illness due to consumption of unwholesome food remains a critical problem worldwide. One challenge in food safety is the prioritization of food commodities to be tested given the limited time and resources (Batz *et al.*, 2005). Considering the limitations, the ability to efficiently establish the relationship between the illness and the contaminated food is an important factor that can promote food safety along the entire food supply chain.

As an island city-state with scarce land for agriculture, Singapore relies predominantly on food imports to meet more than 90% of consumption (AVA, 2015a). Agri-Food & Veterinary Authority of Singapore (AVA) plays a very active approach in safeguarding public health by setting and enforcing food safety standards for all foods being imported from the point of production to retail in a series of comprehensive monitoring, surveillance, and enforcement programmes. As a result, residents of Singapore enjoy food of good quality, diversity, affordability, and most importantly safety (Ludher, 2015).

Despite Singapore enjoying among the safest food in the world, foodborne diseases, as succinctly summarized by Kondakci and Yuk (2012), are still a major health burden. To minimize the risk of foodborne illnesses, it is necessary to assess and estimate the extent of the contribution of different food commodities to the foodborne disease burden in Singapore. This review article aims to summarize and compile the currently published findings regarding the microbial safety and quality of retail poultry, vegetables, fruits, and seafood in Singapore as well as give a summary of foodborne disease cases and notable outbreaks in Singapore in the past few years.

Foodborne Diseases in Singapore

The Ministry of Health (MOH) in Singapore publishes communicable diseases surveillance report on an annual basis and epidemiological news bulletin articles on a quarterly basis. Information such as number of cases and incidence rates of all reported cases of food-/water-borne diseases in Singapore is available in the former while the latter covers information on specific outbreaks in Singapore.

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Table 1. Annual incidence of reported food-/water-borne diseases in Singapore between 2006 and 2015.*

Year	No. of cases (Incidence rate/100 000 population)								
	Campylobacteriosis	Cholera	Hepatitis A	Hepatitis E	Listeriosis	Non-typhoidal salmonellosis	Paratyphoid	Shigellosis	Typhoid
2006	236 (5.3)	0 (0.0)	146 (3.3)	31 (0.7)	9 (0.2)	380 (8.5)	23 (0.5)	19 (0.4)	60 (1.3)
2007	170 (3.7)	7 (0.2)	88 (1.9)	35 (0.8)	6 (0.1)	307 (6.7)	33 (0.6)	13 (0.3)	67 (1.2)
2008	176 (3.6)	1 (0.0)	107 (2.2)	54 (1.1)	5 (0.1)	718 (14.9)	29 (0.6)	29 (0.6)	84 (1.7)
2009	261 (5.2)	4 (0.1)	89 (1.8)	90 (1.8)	—**	1144 (22.9)	28 (0.6)	—	69 (1.4)
2010	320 (6.3)	4 (0.1)	68 (1.3)	112 (2.2)	—	1480 (29.2)	38 (0.7)	—	82 (1.6)
2011	372 (7.2)	2 (0.04)	57 (1.1)	95 (1.8)	—	1374 (26.5)	30 (0.6)	—	61 (1.2)
2012	443 (8.3)	1 (0.02)	94 (1.8)	99 (1.9)	—	1499 (28.2)	51 (1.0)	—	79 (1.5)
2013	397 (7.4)	2 (0.04)	77 (1.4)	53 (1.0)	—	1735 (32.1)	17 (0.3)	—	71 (1.3)
2014	435 (8.0)	2 (0.04)	67 (1.2)	63 (1.2)	—	1883 (34.4)	17 (0.3)	—	50 (0.9)
2015	420 (7.6)	3 (0.05)	45 (0.8)	58 (1.0)	—	1988 (35.9)	24 (0.4)	—	43 (0.8)

*All data are obtained from the Ministry of Health Singapore (MOH, 2007–2016).
**Data are not available.

A report published by Kondakci and Yuk (2012) gave an overview of foodborne diseases in Singapore in the past decade from 2001 to 2010. The report found a significant rise in non-typhoidal salmonellosis from an incidence rate/100 000 population of 3.9 at the start of the decade to 29.2 at the end. As shown in Table 1, in the new decade starting 2011, the incidence rate of salmonellosis/100 000 population has been on the rise every year from 26.5 in 2011 to 35.9 in 2015 (MOH, 2012, 2016). Other notable disease of interest reported was campylobacteriosis which was largely caused by *Campylobacter jejuni* with an incidence rate/100 000 population of 1.2 in 2002 and an average rate of 7.7 from 2011 to 2015 (MOH, 2016).

An epidemiological news bulletin article published in the last quarter of 2016 investigated the link between the Group B *Streptococcus* (GBS) and the consumption of raw fish dishes. A joint investigation between the MOH, National Environment Agency (NEA), and AVA found a significant association between the GBS serotype III ST283 infections and the consumption of the Chinese raw fish dish *Yu Sheng* (Tan *et al.*, 2016). Swift measures to ban the consumption of raw freshwater fish in ready-to-eat (RTE) raw fish dishes and stepped up measures to closely monitor the microbiological safety of salt water fish intended for raw consumption, were also reported.

Poultry

Poultry production in 2016 is forecasted to be at 116.2 million tons; accounting for more than 36% of the forecasted total global meat production at 320.7 million tons with Asia at the helm followed by North and South America according to the Food & Agriculture Organization (FAO) (Global Poultry Trends, 2016). These statistics suggest that poultry is one of the most important food categories to be monitored for its wholesomeness and safety; especially with respect to *Salmonella* contamination, since poultry has been associated with *Salmonella* outbreaks (Foley *et al.*, 2011). The Centers for Disease Control and Prevention (CDC) in the USA has reported a total of 611 cases of human salmonellosis linked to live poultry in eight multistate outbreaks spanning 45 states in the United States in 2016 alone (CDC, 2016).

In Singapore, the definition of poultry encompasses domestic fowl or chickens, ducks, turkey, geese, quails, pigeons, etc. (AVA, 2016). AVA has stringent regulations regarding the import of live poultry into Singapore meant for slaughter and consumption to uphold the wholesomeness of the poultry consumed in Singapore. In spite of that, a small-scale study conducted by Zheng *et al.* (2014) revealed that 10% (n = 60) of raw duck wing samples purchased from local supermarkets were contaminated with *Salmonella* spp. while Lim *et al.* (2015) reported 33.3% (n = 30) of raw duck wing samples being *Salmonella* positive (Table 2). The discrepancy in the prevalence of *Salmonella* between the two studies could be attributed to their small sample sizes. Combining the results from both studies, the overall prevalence of *Salmonella* spp. in duck wings in Singapore might be around 18% (n = 90).

Despite salmonellosis (typhoidal and non-typhoidal) accounting for more than 66% of all food- and waterborne diseases reported in Singapore from 2001 to 2010 (Kondakci and Yuk, 2012) and poultry being a well-known reservoir of *Salmonella* spp., there is a lack of published information in the literature on prevalence of *Salmonella* spp. in various types of poultry and its role in contributing to the disease burden of salmonellosis in Singapore. More prevalence studies involving different types of poultry such as chicken, quail, and turkey in large enough sample sizes are needed to properly assess the microbiological safety and quality of poultry in Singapore.

Fruits and Vegetables

The Center for Science in the Public Interest (CSPI) reported that fresh produce (fruits, vegetables and their dishes) such as cucumber, cilantro, cantaloupe, and peppers was the cause of most foodborne illnesses in the United States with almost 20 000 illnesses over 629 outbreaks between 2004 and 2013 (CSPI, 2015). Moreover, various surveillance studies have previously described *Salmonella* spp., *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Staphylococcus aureus*, *Bacillus cereus*, and *Aeromonas* spp. being isolated from fresh produce (Beuchat, 1996; Johnston *et al.*, 2006; De Giusti *et al.*, 2010).

The amount of vegetables produced locally in Singapore only accounts for 8% of consumption (AVA, 2015c). Hence, a staggering 92% of all vegetables consumed in Singapore are imported from countries such as Australia, China, and Malaysia. A total of 388 364 tons of fruits such as watermelons, bananas and oranges were shipped to Singapore from countries such as Malaysia, China, and the United States in the year 2012 (AVA, 2013, 2015c). Although no major fresh produce-related foodborne outbreaks has been recently reported in Singapore, recent shift in tastes and preferences towards high fibre diets due to increased health consciousness (Good, 1998)

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and the tendency to consume vegetables as RTE food warrants proper assessment of microbial safety and quality of fresh produce sold in Singapore.

A study carried out by Seow *et al.* (2012) characterizing the microbial quality of a total of 125 common fresh fruit and vegetable items sold in Singapore showed that the highest mean aerobic mesophilic count and coliform counts were found in bean sprouts among all tested items at 8 and 5.7 log CFU/g, respectively (Table 3). RTE salad was found to have a mean aerobic mesophilic and coliform count of 6.5 and 4.9 log CFU/g, respectively (Table 3). Neither *E. coli* O157:H7 nor *Salmonella* spp. was isolated from any of the samples in the study.

Two other separate studies by Lim *et al.* (2015) and Zheng *et al.* (2014) reported a prevalence of *Salmonella* spp. in bean sprouts as 6.7% (n = 30) and 3.3% (n = 60), respectively. Based on these previous studies, the prevalence of *Salmonella* spp. in bean sprouts sold in Singapore might be around 4% (n = 104). However, more comprehensive studies covering more varieties of produce and presence of other significant pathogens like pathogenic *E. coli* and *L. monocytogenes* are needed to paint a fuller picture of the microbial quality and safety of fruits and vegetables in Singapore.

The microbial quality of fruits sold in Singapore is relatively better as compared to that of vegetables, with 4.0 and 1.1 log CFU/g being the highest counts found in fruits (mango) for aerobic mesophilic count and coliform count, respectively, as compared to 8.0 and 5.7 log CFU/g in bean sprouts for the two parameters described above, respectively (Table 3) (Seow *et al.*, 2012). Fruits are generally expected to have low microbial counts due to the fruits' peel acting as a good biological barrier against microorganisms. Furthermore, fruits hang high on their trees, keeping them safe from contact with soil or irrigation water. Under such environments, the numbers of microorganisms would be expected to be smaller than other produce

Table 2. Prevalence of foodborne pathogens in various food items sold in Singapore.

Sample	No. of samples	% (No.) of confirmed positive samples			References
		Salmonella spp.	*Escherichia coli* O157:H7	*Vibrio* spp.	
Poultry					
Duck wings	30	33.3 (10)	—*	—	Lim *et al.* (2015)
	60	10.0 (6)	—	—	Zheng *et al.* (2014)
Vegetables					
Carrot	12	0.0 (0)	0.0 (0)	—	Seow *et al.* (2012)
Lettuce	13	0.0 (0)	0.0 (0)	—	Seow *et al.* (2012)
Tomato	13	0.0 (0)	0.0 (0)	—	Seow *et al.* (2012)
RTE salad	13	0.0 (0)	0.0 (0)	—	Seow *et al.* (2012)
Bean sprouts	14	0.0 (0)	0.0 (0)	—	Seow *et al.* (2012)
	30	6.7 (2)	—	—	Lim *et al.* (2015)
	60	3.3 (2)	—	—	Zheng *et al.* (2014)
Fruits					
Apple	14	0.0 (0)	0.0 (0)	—	Seow *et al.* (2012)
Mango	10	0.0 (0)	0.0 (0)	—	Seow *et al.* (2012)
Orange	11	0.0 (0)	0.0 (0)	—	Seow *et al.* (2012)
Seafood					
Prawn	40	0.0 (0)	—	2.5 (1)	Huang *et al.* (2012)
Shellfish	31	3.2 (1)	—	0.0 (0)	Huang *et al.* (2012)
Fishball	32	0.0 (0)	—	3.1 (1)	Huang *et al.* (2012)
	30	23.3 (7)	—	—	Lim *et al.* (2015)

*Not performed.

Table 3. Aerobic mesophilic and coliform counts of various fruits and vegetables sold in Singapore (Seow, 2012).

Name of sample	Aerobic mesophilic count*			Coliform count*		
	n	Mean	Range	n	Mean	Range
Vegetables						
Carrot	16	4.8	2.6–6.9	12	2.7	1.4–4.9
Lettuce	17	5.8	3.4–7.0	13	4.2	1.6–5.5
Tomato	18	4.2	2.4–5.5	13	2.1	0.3–3.0
Bean sprouts	19	8.0	7.3–9.1	14	5.7	4.1–6.3
RTE salad	13	6.5	5.8–7.3	13	5.2	4.2–5.9
Fruits						
Apple	18	3.4	2.1–5.1	14	0.1	ND**–1.2
Mango	11	4.0	3.0–5.1	10	1.1	ND–2.5
Orange	13	3.4	1.6–4.4	11	0.9	ND–2.1

*All units are in log CFU/g.**Not detected.

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commodities. It was also suggested that the higher surface area of vegetables as compared to fruits made the former more susceptible to bacterial contamination and adhesion (Aycicek *et al.*, 2006). No *E. coli* O157:H7 and *Salmonella* spp. contamination were found in the 35 fruit items sampled in the study (Table 2).

Seafood

Seafood is an important food source for a large segment of the world population and is widely consumed as a delicacy in many parts of Asia (Huang *et al.*, 2012; Yaashikaa *et al.*, 2016). Seafood is susceptible to microbial contamination and pathogens may be present in low levels at harvest while more may be introduced during handling and processing. Risk of foodborne illness by consumption of seafood increases further if the food is mishandled by unsanitary practices where pathogens can multiply exponentially due to temperature abuse conditions (Adams and Moss, 2000; Badrie *et al.*, 2006; Espiñeira *et al.*, 2010; Bakr *et al.*, 2011).

In Singapore, seafood is defined as including any variety of fishes, crustaceans, aquatic mollusks, marine sponges, and any other form of aquatic life including their young and eggs harvested from brackish, marine, or fresh water (AVA, 2015b). Seafood-borne disease has received increased attention ever since the 2009 *Vibrio parahaemolyticus* outbreak associated with consumption of Indian Rojak from cross contamination with seafood resulting in many cases of illness, hospitalization, and two deaths (MOH, 2009).

A study on microbial quality of 116 seafood samples sold in Singapore reported that the mean aerobic mesophilic counts for prawns, shellfish, and fishballs ranged between 4.6 and 6.6 log CFU/g (Table 4). A significant finding from the study was that by comparing the bacterial load between the frozen shellfish and the frozen-thawed shellfish, it was found that the thawing process increased the bacterial load even when the process was carried out at refrigeration temperatures. It was suggested that the water and nutrient released from the ruptured cells during freezing might have encouraged the growth of organisms during the subsequent thawing process.

Huang *et al.* (2012) reported the isolation of *V. parahaemolyticus* from a sample of both shrimp meat and commercial fishball, establishing a prevalence of 2.5% (n = 40) and 3.1% (n = 32), respectively. *Salmonella* spp. was isolated from one shellfish sample, establishing a prevalence of 3.2% (n = 31). However, in a separate study by Lim *et al.* (2015), *Salmonella* prevalence in fishball samples was found to be at 23.3% (n = 30). The discrepancy could be due to the different preparation procedures of fishball (handmade or machine processed) and differences in the type of market the samples were purchased from (wet markets or supermarkets). The overall prevalence of *Salmonella* spp. in fishball sold in Singapore might be around 11.3% (n = 62) based on these two studies.

Table 4. Aerobic mesophilic count of various seafood in Singapore (Huang *et al.*, 2012).

Name of sample	Aerobic mesophilic count*		
	n	Mean	Range
Fresh prawn	31	6.1	5.2–7.7
Shrimp meat	10	5.8	5.0–6.5
Frozen-thawed shellfish	23	6.6	4.7–7.2
Fresh shellfish	14	6.5	4.8–7.7
Frozen shellfish	6	4.6	3.9–5.0
Handmade fishball	16	5.7	3.6–6.5
Commercial fishball	16	4.7	ND**–6.8

*All units are in log CFU/g.
**Not detected.

Conclusion

Despite continuous efforts by the government to curb foodborne illnesses, it still remains as one of the most pressing public health issues to be solved. Based on currently published data, a high overall prevalence of *Salmonella* spp. was found in duck wings (18%) followed by fishballs (11%) and bean sprouts (4%) but no *Salmonella* spp. and *E. coli* O157:H7 were isolated from fruits and vegetables. Although some previous studies indicated that foods being sold in Singapore are contaminated with some pathogenic bacteria, additional prevalence and characterization work should be performed to further establish and determine the significance of this exposure to the national disease burden. Meanwhile, continuous efforts are needed to educate food handlers and consumers on proper handling and thorough cooking of food to prevent the risk of foodborne illnesses.

Conflict of interest statement. None declared.

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