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REVIEW

Microbiological food safety in Malaysia from the academician's perspective

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Abstract

Food safety in Malaysia is not considered an issue yet. From the previous year (2005-2015) records, the incidence rate of food poisoning had been fluctuating and despite that, cases continue to occur especially among school students. As a developing nation, it is high-time that Malaysia begins to emphasize on food safety to reduce the burden of foodborne illness in the socio-economic development of the country, and at the same time, gain benefits in terms of economic returns and trade through food safety enforcement. Most importantly, public health is achieved through food safety implementation and accentuation. The current standing point of the Malaysia's food safety is discussed in this review. In addition, the review will also discuss the role of academicians as intervention contributions in tackling food safety issues. The review is hoped to provide valuable and concentrated information and knowledge to readers in the light to drive Malaysia into ensuring safer food for the public.

1. Introduction

According to Codex Alimentarius Commission (CAC), food safety is the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. The definition embodied three important notions: 1. Harm in which the food is unfit for human consumption without necessarily presenting a danger to health; 2. Assurance as in the concept of food safety and management of the place to produce safe food; 3. Intended use in which the preparation and/or use of a food product by the manufacturer to the consumer and at the consumer phase to ensure safe food. Simple to say; food safety is the assurance of food to be safe chemically, physically and microbiologically for consumption. It is the opposite of food risk.

Food risk contributes to foodborne diseases. According to the World Health Organization (WHO) (2015), foodborne disease burden is estimated to be for a further four bacterial and one chemical hazard. Microbiological food safety remained the main issue worldwide. Diarrhoeal disease agents, especially non-typhoidal *Salmonella* (NTS), were the leading cause affecting countries mostly Africa, South-East Asia sub-regions and the Eastern Mediterranean sub-regions. Additionally, the burden arising from unknown chemical and parasitic contaminants (WHO, 2015). This impacts severely on the public health as it is the cause of morbidity and mortality. Besides that, it significantly affects the socio-economic development and the country's economic.

In Malaysia, food safety is not considered as a real issue today. Malaysia, being truly Asia, is the house of the Southeast Asian cuisine. Most Malaysians prioritize more about the food taste rather than the safety of the food. In Malaysia, home to 30.3 million people (The World Bank, 2017), food is likely to be sold anywhere with little attention being paid to the food hygiene. The reported food poisoning cases increase throughout the years reflects the true food safety situation in Malaysia

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and at the same time increasing the foodborne disease burden. Microbiological food safety is often highlighted due to its onset adverse health effects of food poisoning such as vomiting, diarrhea, nausea, abdominal pain and cramps and if severe could be life-threatening and causing permanent impairment. Unlike chemical food safety which the health effects are observable in long terms but rarely occur in acute conditions. Foodborne pathogens are easily transferred from the soil, feces to hands to food and the transfer can go on as long as the microbes adapt and grow when improper food safety handling is being practiced. To worsen the situation, the pathogens are minute, cannot be seen by a naked eye and it does not give out any odour or food spoilage characteristics. With suitable nutrients and temperature, the pathogens will thrive within minutes even at a minimum amount. Some microorganisms such as the *Bacillus cereus*, Clostridium *perfringens*, Shiga-toxin producing *Escherichia coli* O157 and *Shigella* spp. produce toxins that are heat liable, ensuring the survivability of the toxins throughout the food processing. The food borne pathogens infect and intoxicate humans of all ages and particularly, the children under 5 years of age and the elderly are more susceptible.

The food safety system in Malaysia is characterized by its complexity and diversity; with different authority entrusted with the task of ensuring food safety at different stages of the food chain led by the Malaysian's Food Safety and Quality Division (FoSIM) (Mohamad, 2003). The division has been distinctively playing its role in ensuring the food is against related hazards and fraud to protect the public. It is undeniable that FoSIM has been doing its best, unfortunately with the series of increasing foodborne illness puts the effectiveness and management at question. In a worst-case scenario, if this is not put under control, Malaysia will find it difficult to cope with foodborne diseases in the future. The Malaysian government should consider relying on the research conducted in universities and research institutes for better insights to minimize the data gap and limitations. As policy makers of the country, these research and data collected are necessary to develop food safety policies and manage the food risks. Thus, this review aimed to provide the current standing point of the Malaysia's food safety and the perspective on how researches conducted in universities and research institutes can contribute as a source of intervention.

2. Foodborne disease in Malaysia

2.1 Incidence and mortality rates

Foodborne disease in Malaysia is seeming to fluctuate as observed in Table 1 based on the incidence rates. Based on Table 1, it is undeniable that food poisoning cases hit the highest mark. Most food poisoning cases were from schools and the data has been rising since 2010. Figure 1 represents the food poisoning cases occurred in schools from the year 2012 to 2015, with the highest in 2015 of an average of 8000 cases (Fuentes, 2015). In fact, the outbreaks occurred back to back and at a sudden rose to an alarming level. In 2016, Perak recorded that 887 out of the 1263 victims were students. 45 cases were reported (Asrin and Ismail, 2016) in August 2016 and the number increased to 1015 cases in October 2016 (Astro Awani, 2016). Other states, Terengganu and Kedah, recorded a series of food poisoning episodes from school, however, the number was not as high as Perak which had 39 episodes (Astro Awani, 2016; The Star/Asia News Network, 2016; The Star, 2016).

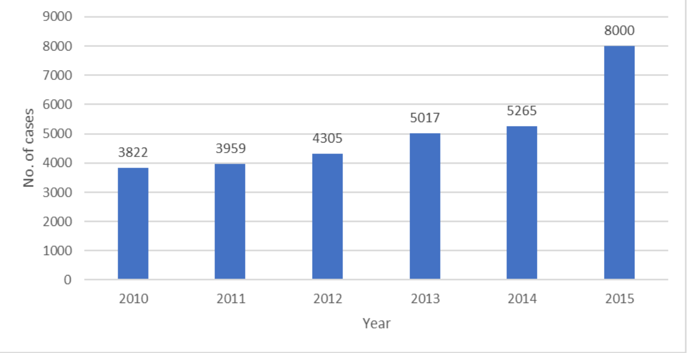

Figure 1. Food poisoning cases occurring in schools according to year

Looking at the available data, students are the highest risk of the population to suffer from food poisoning cases. Most of the episodes occur in boarding schools where a certain population of students are confined to consume the same contaminated food from the school's canteen. The risk of exposure is high which could cause high mortality and morbidity rates as the students are the most vulnerable population. According to the Ministry of Health, Malaysia annual's report (2011), food premises have been checked and food handlers have been trained to practice safe food handling, specifically for schools. In spite that, outbreaks continued to occur. Up till now in 2017, 130 students continued to be affected by food poisoning; 42 students in Balik Pulau, Penang on March 9 and; 99 students and three teachers in Segamat, Johor on March 14. Outbreaks that were reported early will be able to be put under control to minimize the mortality rates (Malaysian Digest, 2017).

Although the morbidity rates were high for food

Table 1. Incidence rate of communicable diseases in Malaysia from the year 2005 to 2015

Diseases	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cholera	1.48	0.89	0.49	0.34	0.98	1.56	2.02	0.96	0.58	0.45	0.8
Dysentery	0.54	0.39	0.54	0.33	0.54	0.37	0.15	0.29	0.28	0.27	0.41
Food poisoning	17.76	26.04	53.19	62.47	36.17	44.18	56.25	44.93	47.79	58.65	47.34
Hepatitis A	ND	ND	ND	0.72	1.07	0.74	1.71	1.58	0.41	0.21	0.36
Typhoid	4.1	0.77	1.2	0.13	0.14	0.14	0.84	0.75	0.73	0.7	1.42

ND = Not detected

Table 2. Mortality rate of communicable diseases in Malaysia from the year 2005 to 2015

Diseases	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cholera	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0	0	0	0.01
Dysentery	0	0	0	0	0	0	0	0	0	0	ND
Food poisoning	0	0	0	0.01	0.01	0	0.03	0	0.04	0.01	0.01
Hepatitis A	ND	ND	ND	0.01	0	0	0	0	0	ND	ND
Typhoid	0	0.02	0.02	0	0	0	0	0	0.01	0	0.03

ND = Not detected

poisoning, the mortality rates were significantly low as shown in Table 2. The highest mortality rate (0.04) was recorded in 2013 with 12 deaths and reduced in the following years to 0.01 per 100,000 population. However, this should not be put to relief as more cases continued to occur affecting many victims, especially students.

Cholera was reported to cause an outbreak in Limbang, Sarawak in 2011. Approximately 111 cases were reported which caused the high incidence rate in 2011 (Table 1). The source of contamination was suspected to originate from contaminated water as traces of *Vibrio cholerae*, the causative agent was found on the chopping board sampled (Veno, 2011). Water has become the major transmission route of diarrhoeal diseases, especially for the bacteria that can survive in water for a certain period such as *V. cholerae* as it was reported to be able to survive in low salinity solutions (Uchiyama *et al.,* 1986), as well as *Salmonella enterica* serovar Typhi and *E. coli*. Using contaminated water for cleaning and processing of food and irrigation purpose will transmit the bacteria to humans when the bacteria adhere itself onto the food surfaces and the kitchen utensils. The access to clean and improved water is a necessity to reduce foodborne disease. In 2011, Cholera was reported to record a mortality rate of 0.04 per 100,000 population as tabulated in Table 2.

Recently, in 2015, Typhoid cases were reported in Malaysia which surged the incidence rate high as shown in Figure 1 compared to the previous years. Typhoid is caused by *S. enterica* serovar Typhi and *S. enterica* serovar Paratyphi A. They are characterized by ulceration of Peyer's patches in the ileum and multiplication of the bacteria in the reticuloendothelial system followed by bacteremia (Christie, 1987; Richens, 2000). The danger of contracting the bacteria is that some victims will develop Typhoid fever and in some cases, victims can be asymptomatic carriers, transmitting the bacteria to another person. In such cases, the hosts are unaware of the presence of the bacteria and often do not take proper preventive measures. Consequently, *S. enterica* serovar Typhi can grow and attain a high transmission rate (Gopinath *et al.,* 2012). Moreover, all food types can be the vehicle of contamination of Salmonella. Three states were involved which include Kuala Lumpur, Selangor, and Kelantan. It was reported by Astro Awani (2015) that Kelantan had the highest number of cases with 151 Typhoid case as of October 2015. Both Kuala Lumpur and Selangor made up a total of 55 cases. Food premise checks were conducted and food handlers were checked to ensure they are not the carriers. The source of contamination was not discovered despite that many summons and fines were handed out to unhygienic food premises and to food handlers who did not receive the Typhoid injection (Zainuddin, 2015). This outbreak had caused the mortality rate to hit 0.03 per 100,000 population (Table 2).

On the other hand, non-typhoidal *Salmonella* (NTS) is the most feared foodborne pathogen in Malaysia as it has caused many outbreaks and deaths during its epidemiology; three people died and sixty-five others were warded after the consumption of food contaminated with *Salmonella* at a wedding in 2013; four lives were claimed and more than 150 students of a boarding school suffered foodborne illness after the consumption of

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Ayam Masak Merah (Chicken in Spicy Tomato Sauce) dish in Kedah (Food Safety News, 2014) in 2014 - the chicken was reported to be contaminated with *Salmonella*; 106 foodborne illness victims and a death of 5-year-old boy due to bacteremia in Dataran Syah Bandar, Terengganu in 2014 (Astro Awani, 2014); and 43 students suffered foodborne illness after consuming *Salmonella* contaminated chicken curry in Tapah, Ipoh in 2016. Apart from that, *E. coli* made the headlines once in 2012 whereby 20 athletes were sickened due to untreated water at Teluk Keke, Terengganu (Latip *et al.,* 2015). Based on the limited available data, it is difficult to categorize which foodborne pathogens are the common constitute of severe risk to the Malaysian community.

3. Data gap and limitations

When there is an outbreak occurred, the source of the outbreak was not reported. This is likely due to the isolation and identification process of the microorganism that is time-consuming and labourious. The source can no longer be identified or it is lost during that period. In addition, the lack of traceability system of the food product contributed as a factor especially for small-medium enterprises (SMEs). Within Malaysia, food is transported freely without barriers. Thus, the route of exposure from a single source exacerbates. The low detection limit of technology used among the laboratories could easily lead to false negative results which eventually led to no conclusive results.

Most of the affected persons especially if the cases are not serious, do not seek treatment at the hospitals probably that foodborne illness is indeed a self-limiting disease. Not only it occurs in Malaysia, but it is common to other countries too. In addition, a complex chain called population exposure must occur first before a case can be reported to the authority in Malaysia (Soon *et al.,* 2011). This could delay the investigation of the outbreak cases and limit of the surveillance data. Indeed, the paucity of good surveillance data is a challenge worldwide due to this (WHO, 2015). Without good surveillance data, the foodborne disease burden will be difficult to estimate and the appropriate corrective actions to be taken.

Till now, there is no best and standardized method of surveillance for foodborne disease in Malaysia (FAO, 2004). Evidently, this greatly depended on the economic status, infrastructure, availability of resources (manpower and laboratory facilities) and technical expertise of the country.

3.1 Economic status

As of 2015, the gross domestic product (GDP) of Malaysia is 296.3 billion USD, showing a decline compared to 2014 with a GDP of 338.1 billion USD. The GDP growth rate was reportedly declined from 2014 to 2015 (The World Bank, 2017). In 2016, it was reported that Malaysia had a steady growth rate, but more risks to come.

On the latest Malaysian Budget 2017, most of the RM 25 billion budget allocated for healthcare will be channeled for upgrading hospital facilities and building new hospitals and clinics (New Straits Times, 2016). The budget allocated was 10% lesser compared to last year due to the economic status. To ensure that the welfare and health of the citizens are taken care of, more budget was used to address the overcrowding of hospitals and catering to the underprivileged people by building more conservative and mobile clinics. Despite that, minimal funds are allocated to purchase consumables and reagents for laboratory investigations carried out by hospitals. This disrupts most of the investigation processes related to health as well as surveillance data collection from outbreak cases.

3.2 Infrastructure

Malaysia has no issues on infrastructure as it is a developing country. According to Damodaran (2016), Malaysia ranks number two in terms of its attractiveness for infrastructure investment in Asia. The strong economic performance and continued long-term investment in infrastructure brought Malaysia to have the best network of highways, efficient seaports, international airports, developed industrial parks and specialized parks catering for high-tech telecommunications (EBM, 2017).

However, in food safety, the quality infrastructure should be aligned with the food safety regulatory framework. Support for the development of a sustainable and targeted quality infrastructure should be provided (Calzadilla-Sarmiento, 2014) by the government. Available food safety infrastructure should be improved in its quality by the government. However, this important point is slowly taking the importance due to lengthy administrative works. A certain period is needed to have the food safety regulatory framework to be approved by a certified board of technical expertise. The lost in time certainly had caused a loss of economic return.

More importantly, the adherence and compliance are considered a cost to most food manufacturers. To most manufacturers, safety is a cost that they need to spend on which does not guarantee a specific economic return. Hence, this led to the reasons of incomplete compliance due to over expenditure, especially in small medium enterprises (SMEs).

3.3 Availability of resources (manpower and laboratory facilities)

Human resources such as food inspectors, researchers, and laboratory assistants are also important in running the system. These special group of personnel should have a strong scientifically based qualification. Additionally, the personnel must be trained and evaluated at periodic checks to ensure competency. Coordination of a surveillance system is necessary within the several parties that are involved in the system.

Due to the limited resources and the cost of providing training, relevant fees may be imposed to recover the cost of implementing food safety controls based on the principle. The current inspection approach of most South-East Asia countries emphasizes on visual inspection of food facilities and end-product testing, followed by sanctions on responsible parties when the rest results contravene the provisions of the food law (Othman, 2007). Such approach is reactive rather than preventive therefore should be considered for revision.

Laboratories require infrastructures to enable the monitoring, surveillance and enforcement activities. i.e.; labs should be segregated for chemical, residue and micro labs; all labs should have controlled environmental conditions (temperature/humidity); constant and ready power back up; good laboratory practice; and safety measures well-taken care (Bhajekar, 2011). Proper equipment and human capabilities should be complemented with the implementation of the Quality Assurance System that meets the international standards to support the credibility of the assessment. In addition, laboratories should be accredited with International Organization for Standards (ISO) certification, specifically MS ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories to produce reliable data and proven to be technically competent. In today's modern era, the rapid advancement of analytical technology has placed a different impact on the detection limit on prohibited substances. Apart from that, the rapidness and the robustness of the analytical technology takes into account. All these require further investments in newer technologies in multiple labs in the country and thus, increasing the cost of surveillance.

3.4 Technical Expertise

The available technical expertise in food safety in Malaysia are considered moderate and Malaysia is continuously generating capacity. As such, most of the technical expertise available are academicians in Malaysia, hence this causes a gap between the academicians and the food industries. The gap between academicians and the food industries should be minimized as both parties are interdependent to be able to benefit from both sides. Acting solely and independently by either party will cause a waste of resources leading to higher economic burden. Additionally, academicians usually gain an advantage to the first insight of food safety issues, especially in emerging foodborne pathogens. Ineffective solutions will be taken to tackle food safety challenges when there is a lack of cooperation.

4. Consumer awareness

The public awareness on food safety in Malaysia is in considered low. Consumers are considered as the end users in a food chain and less attention is often paid to them on how they eat and prepare the food. When there is an outbreak on a certain food, the immediate portrayal of the food in the media will create a stereotype that food associated with the outbreak will be avoided completely. This could be due to some false information exaggerated and spread through social media in which most consumers are now completely engage in. As a result, the impact brings a downfall to the food industry due to the loss of consumers' trust in purchasing the food products.

Most of the food handlers or operators in food manufacturing companies in Malaysia now are colonized by migrants and they originate from underdeveloped countries such as Nepal, Myanmar, and Vietnam. A survey conducted by Woh *et al.* (2016) reported that migrant food handlers in Peninsula Malaysia had poor knowledge on food safety with average knowledge on food handling practices. The most probable reasons are the low education level of the migrants and language barriers. Due to that, there is a low level of participation of them in food training programs and constantly not being highlighted on the importance of food safety. Due to that, there is a higher possibility of them not to comply with good manufacturing practice. Lee *et al.* (2017) reported that most food handlers had low performance in maintaining hygienic hands. This does not only include the migrants but also the local food handlers as the respondents in the survey reported that the food handlers had a moderate level of food safety knowledge with a good attitude, and self-reported practices. Hands are the main transmission route for cross-contamination at higher rates when improper food handling is being practiced (New, Wong, Usha *et al.,* 2017). Food handlers find washing hands as an additional task and a waste of time. The survey concludes that food handlers were not highlighted of the hazard that is transmittable via hands to the food.

On the other hand, Nee and Sani (2011) indicated that food handlers who operates the residential colleges and canteen on the main campus of Universiti Kebangsaan Malaysia (UKM) had a low level of knowledge on food storage and preparation temperature to control the growth of microorganisms. This explained and substantially proven the main root cause of most outbreaks occurred in canteens of boarding school dormitories and residential colleges. Temperature and time are the two main important keys in controlling the growth of microorganisms. Jeopardizing either one of the factors will lead to unforeseen food safety hazards, causing foodborne illness outbreaks. The preventive key points in controlling the growth of microorganism should constantly be reminded to the food handlers during training and surveillance cleanliness checks. These food handlers should be regularly trained and educated to ensure these practices are applied in real life situations.

Food handlers' attitude is the answer to preserving food safety. To ensure food safety is being practiced, the attitude of food handlers must be coordinated into having a thought of the consequences of having food risks in their daily meal and why it is important to keep the food safe. There is a strong relation of the attitude of compliance to safe food handling in terms of adherence to food operational management and this is supported by Saidatul and Hayati (2013) in which their study was related to the school canteen management. Following the increasing school foodborne illness outbreaks, Ministry of Health Malaysia began to conduct more surveillance checks on the school canteen management. Many of them were reported being fined and closed as they do not meet the food safety standards.

Safer food brings better business and this should be kept in mind for food manufacturing companies. The adherence to food safety frameworks such as Hazard Analysis Risk Based Critical Control Points, International Standards and Good Manufacturing Practices will trade in more business than rejection. But this point is far beyond outreach if there are different groups operating the food manufacturing management does not come to the same terms on the magnitude and distribution of food safety benefits and losses.

To date, consumers are beginning to realize the importance of food safety. A consumer survey conducted by New, Thung, Premarathne *et al.* (2017) indicated moderate levels of food safety knowledge a random group of Malaysian consumers. Surprisingly, Norazmir *et al.* (2012) reported high levels of food safety knowledge among secondary school students in Johor. This could due to food safety was brought into the limelight when the outbreak cases involving students were on the rise and the school students were educated on the essential points of food safety and keeping personal hygiene. Nevertheless, the action had become a stepping stone to preserving food safety and public health. Future of such implementation will increase the awareness of the consumers on food safety as this will engage the consumers to complement the public effort.

5. Academicians' role in food safety surveillance

5.1 Risk Assessors

Food scientists majoring in food safety holds the role of being the risk assessors. This includes data collection on the foodborne pathogens. The quantitative data collected from the prevalence studies will be used to assess the risk and estimate the burden of foodborne disease through simulation models mimicking the food consumption practice. Table 3 indicates the prevalence studies conducted in Malaysia. As observed in Table 3, numerous prevalence studies have been conducted. On the contrary, the studies were often focused on high-risk foods and did not vary in other types of food. High-risk foods are often sampled to observe any characteristic changes of the foodborne pathogens genotypically and phenotypically. Other food types will depend on how the food scientists would link to the current food safety issues. Nevertheless, the data collected will provide a stepping stone in observing the contamination rate of the foodborne pathogen and identify possible food as a vehicle of exposure. The data collected, however, will remain insufficient as Malaysia has a vast food source. Many foods are created and developed according to the needs and taste of the Malaysian community. Hence, prevalence data should be collected continuously to cater to the changes and adaptation of foodborne pathogens' survivability.

This, however, has several disadvantages. Prevalence studies require numerous sample collection to reflect the actual scenario of the microbial distribution in the sample. It is difficult to be able to estimate the microbial distribution in food samples due to high sample variation which puts the available data into the paucity of reliability. Different detection methods also could limit and falsify the data. As detection methods are advancing towards rapidness (e.g. nucleic acid based detection, immunoassays, and biosensors based detection), the data collected should be treated with validity to create an actual scenario in risk assessment, especially in the viable bacterial cells. The traditional method of aerobic plate counting remains the best in estimating the viable bacterial cells, however, it is often extensively labourious, time-consuming and with various limitations such as media limitations, bacteria falling into the category of Viable but non-culturable state (VBNC), and technical skills.

In risk assessment, other factors (i.e. temperature, a holding time of the food, etc.) that contribute to the growth of microorganisms should be recorded based on the simulation models - these are necessarily important. As the current risk assessment employs stochastic statistical method, it is possible to calculate the risk by performing large numbers of simulations based on the range of available data. Eventually, the burden of foodborne disease can be estimated and the point where high contamination rate occurs can be pin-point to design the corrective actions.

5.2 Identifying emerging food safety issues

5.2.1 Rise of antimicrobial resistance in foodborne pathogens

Antimicrobial resistance has become a global epidemiology. The increase of antimicrobial resistance had reduced the efficacy of antibiotics. While the cause of it is complex to determine due to many factors, the continuous rise and minimal prevention had caused the emergence of resistant clones such as Methicillin-resistant *S. aureus* (MRSA), *E. coli* ST131 and *Klebsiella* ST258. Foodborne pathogens are no less the same, especially when the source of exposure is wide. Food scientists isolated foodborne pathogens that are highly antimicrobial resistance, indicated the widespread of antimicrobial resistance and a compromise of effective treatment of infectious disease in humans and in animals (European Food Safety Authority, 2014)

Resistant bacteria can spread through many routes (European Food Safety Authority, 2017). What is feared most is the ingestion of these high resistance pathogens from food, leading to colonization in the intestines. As such, these infections will be a difficult treatment. Most health care associates usually opt for prolonged antibiotic use and more expensive and broad-spectrum antibiotics if the current antibiotic is ineffective anymore. However, this requires high cost due to the costly production of antibiotics and it becomes a burden to low-income and middle-income countries resulting high mortality rate, high hospitalization rate and high prevalence of hospital infections (Laximanarayan *et al.,* 2013). The inability to rely on antibiotics to prevent infection will terrorize the globe with longer illness duration and higher mortality in patients with resistant infections.

Hence, the prevalence of antimicrobial resistance in foodborne pathogens should be monitored and characterized via genomic sequencing whenever possible to identify the antimicrobial resistance genes. These data are important to conduct risk assessment and scientific assistance. Most Food Safety Authorities are focusing on *Salmonella* and Campylobacter as these two pathogens are gaining resistance rapidly. Moreover, both pathogens showed increasing resistance towards ciprofloxacin, a critically important antibiotic for the treatment of human infections and most widely used. This infers that we have little knowledge of the antimicrobial spread and to the extent that it is unknown if the available antibiotics are still effective in inactivation. According to EFSA (2017), multi-drug resistant *Salmonella* bacteria continue to spread across Europe. Center for Disease Control and Prevention (CDC) (2017) estimated that 400,000 people of the United States are sickened with resistant Campylobacter or *Salmonella* every year. However, the National Antimicrobial Resistance Monitoring System (NARMS) developed under the partnership of Food Drug and Administration (FDA), CDC and United States Department of Agriculture (USDA) reported that there was a decrease in the prevalence of antibiotic resistance of non-typhoidal *Salmonella* (FDA, 2011). Yet, antimicrobial resistance Salmonella serotypes for third-generation cephalosporins rose between 2008 to 2011 (FDA, 2014). The current research reports an increase resistance of *E. coli* which became a concern as it is commonly present in humans and the top most common cause of foodborne illness and urinary tract infections. It was also observed by NARMS and put under surveillance.

5.2.2 Emerging foodborne pathogens

The occurrence of emerging foodborne pathogens puts us at risk as there is little information available on

Table 3. Prevalence of foodborne pathogens in foods in Malaysia

Genus	Species	Serovars/ Biovars/ Strains	Sample/Source	Prevalence [a]	References
Vibrio	*vulnificus*		cockles	25/100 (25.0%)	Radu, Elhadi, Hassan *et al.* (1998)
	parahaemolyticus	kanagawa-negative strains	cockles	27/100 (27.0%)	Son, Nasreldin, Zaiton *et al.* (1998)
	cholerae	O139 Bengal	surface water	4/60 (6.7%)	Son, Rusul, Samuel *et al.* (1998)
	cholerae		street foods	(0.7%)	NPHL/MOH (2005a)
	cholerae		frozen squids	2/146 (1.4%)	NPHL/MOH (2005b)
			frozen prawn	ND[b]	
	parahaemolyticus		frozen squids	ND	
			frozen prawn	42/455 (9.2%)	
	parahaemolyticus		cultured Tiger Prawn	49/60 (81.7%)	Zainazor (2006)
	parahaemolyticus		cultured Tiger Prawn		MOH (2007)
	cholerae		Catfish (*Pangasius hypophythalmus*)	32/100 (0.32%)	Norshafawati *et al.* (2017)
		O139	Catfish (*Pangasius hypophythalmus*)	7/100 (0.07%)	
	parahaemolyticus		Retail shrimp	185/320 (57.8%)	Letchumanan *et al.* (2015)
	parahaemolyticus		Raw salad vegetables	57/276 (20.65%)	Tunung *et al.* (2010)
	parahaemolyticus		Crabs and clams	200/450 (44.4%)	Letchumanan *et al.* (2015)
		trh+	Crabs and clams	13/450 (2.8%)	
	parahaemolyticus		Bloody clams, surf clams and shrimps	229/232 (98.7%)	Malcolm *et al.* (2015)
		tdh+		16/232 (6.9%)	
		trh+		77/232 (33.1%	
	parahaemolyticus		Shrimp farm (Water)	132/264 (50%)	Pui *et al.* (2014)
			Shrimp	11/27 (41%)	
	vulnificus		cockles	32%	Kurdial-Dulaimi *et al.* (2016)
Escherichia	*coli*	O157:H7	retail beef	9/25 (36.0%)	Radu, Mutalib, Rusu *et al.* (1998)
	coli	O157:H7	milk	312/930 (33.5%)	Chye *et al.* (2003)
	coli		street foods	7/76 (9.1%)	NPHL/MOH (2005a)
	coli		RTE (pork dishes)	3/20 (15%)	NPHL/MOH (2005a)
			RTE (beef dishes)	5/99 (5.1%)	
			RTE (mutton dishes)	12/81 (14.8%)	
			RTE (chicken dishes)	10/102 (9.8%)	
	coli		RTE (open market)	18/155 (11.6%)	NPHL/MOH (2005b)
	coli		cooked foods (school canteens)	10/408 (2.5%)	Hodate, 2003
	coli	O157: H7	Beef and beef products	54/99 (54.54%)	Premarathne *et al.* (2017)
	coli		RTE (popiah)	23/30 (76.6%)	Elexson *et al.* (2017)
	coli	VTEC	Pig Farms	7/345	Ho *et al.* (2013)
		O157:H7	Organic vegetables and chickens	12/230 (5.2%)	Chang *et al.* (2013)

Genus	Species	Serovars/ Biovars/ Strains	Sample/Source	Prevalence [a]	References
Salmonella	*enterica*	(predominant serovars were *S. enteritidis*, *S. muenchen*, *S. kentucky* and *S. blockley*)	retail poultry	158/445 (35.5%)	Rusul *et al.* (1996)
			poultry (pocessing plant)	52/104 (50.0%)	
			litter	8/40 (20.0%)	
			poultry farm (environmental)	2/10 (20.0%)	
			milk	13/930 (1.4%)	Chye *et al.* (2003)
	enterica		street foods	12/129 (9.3%)	Tunung *et al.* (2007)
		Biafra	fried chicken	1/18 (5.6%)	
		Braenderup	Kerabu jantung pisang (salad)	3/5 (60.0%)	
		Biafra and Weltevreden	Sambal fish	6/9 (6.7%)	
		Biafra	mix vegetables	2/5 (40.0%)	
			street foods	1/76 (1.4%)	NPHL/MOH (2005a)
			RTE (pork dishes)	4/20 (5.0%)	NPHL/MOH (2005a)
			Frozen squids	6/146 (4.1%)	NPHL/MOH (2005b)
			frozen prawn	2/455 (0.4%)	
	enterica		Ducks and Environmental	125/531 (23.5%)	Adzitey *et al.* (2012)
		Typhimurium		29.6%	
		Enteritidis		12.0%	
		Gallinarum		2.4%	
		Braenderup		12.0%	
		Albany		11.2%	
		Hadar		20.8%	
		Derby		6.4%	
		Weltevreden		1.6%	
		Newbrunswick		3.4%	
		London		0.8%	
	enterica	Albany, Agona, Corvallis, Stanley, Typhimurium, Mikawashima, Bovis-mobificans	Catfish (Clarias gariepinus), Tilipia (Tilapia Mossambica) and environmental	9/32 (28.1%)	Budiati *et al.* (2013)
		Agona, Braenderup and Corvallis	Ducks and duck eggs	16%	Nor Faiza *et al.* (2013)
	enterica		Fruit juices	34%	Diana *et al.* (2012)
		Typhi		20%	
		Typhimurium		10%	
	enterica		Sliced fruits	23.3%	Pui *et al.* (2011)
		Typhi		7.6	
		Typhimurium		3.8%	
	enterica		Raw chicken meat	25/120 (20.8%)	Thung *et al.* (2016)
		Typhimurium		8/120 (6.7%)	
		Enteritidis		3/120 (2.5%)	
Aeromonas	genus		retail fish	60/87 (69.0%)	Son *et al.* (2003)
	veronii	*Sobria*		48/87 (55.0%)	
	hydrophila			10/87 (11.5%)	
	caviar			2/87 (2.3%)	

Genus	Species	Serovars/ Biovars/ Strains	Sample/Source	Prevalence [a]	References
Bacillus	*cereus*		cooked canteen food	17/28 (60.7%)	Rusul and Yaakob (1995)
			dried rice noodle	3/3 (100.0%)	
			wet wheat noodle	2/2 (100.0%)	
			dried wheat noodle	10/10 (100.0%)	
			spices	8/8 (100.0%)	
			grains	4/4 (100.0%)	
			legumes	11/11 (100.0%)	
			legume products	3/3 (100.0%)	
	genus		processed cereal products	105/111 (95.0%)	Lee *et al.* (2009)
	cereus			84/111 (76.0%)	
	cereus		street foods	11/76 (14.7%)	NPHL/MOH (2005a)
	cereus		RTE (pork dishes)	6/20 (30.0%)	NPHL/MOH (2005a)
			RTE (beef dishes)	8/99 (8.1%)	
	cereus		RTE (open market)	2/155 (1.3%)	NPHL/MOH (2005b)
	cereus		cooked foods (school canteens)	7/408 (1.7%)	Hodate (2003)
	cereus		RTE cooked rice	38/54 (70.4%)	Sandra *et al.* (2012)
	thuringiensis			19/54 (35.2%)	
	cereus		Raw rice	5/5 (100%)	
	thuringiensis			ND	
	cereus		RTE cereal products	4/30	Lesley *et al.* (2013).
Campylobacter	*jejuni*		broiler chicken (farm)	(72.6%)	Saleha (2002)
	genus		ulam (fresh vegetable salad)	(29.4% - 67.7%)	Chai *et al.* (2007)
	jejuni			(25.5% - 67.7%)	
	coli			(22.6% - 65.7%)	
	fetus			(0.0% - 1.9%)	
	genus		retail sushi	40/150 (26.6%)	Tan *et al.* (2008)
	jejuni			33/150 (22.0%)	
	coli			ND	
	jejuni		chicken parts (wet market)	65/92 (70.7%)	Tang *et al.* (2009)
	coli			19/92 (20.7%)	
	jejuni		chicken parts (hypermarket)	85/93 (91.4%)	
	coli			32/93 (34.4%)	
	genus		Ducks and duck eggs	9/75 (12%)	Nor Faiza *et al.* (2013)
	jejuni			2/75 (2.7%)	
	coli			7/75 (9.3%)	
	genus		chickens	68/90 (75.6%)	Mansouri-najand *et al.* (2012)
	coli			46/90	
	jejuni			41/90	
	genus		Chicken Carcasses and Slaughterhouse	220/360 (61%)	Rejab *et al.* (2012)
	genus		Chicken meat and chicken-based products	57/151	Nur Ilida and Faridah (2012)
	genus		Beef and farm environment	66/248 (26.6%)	Aung *et al.* (2015)

Genus	Species	Serovars/ Biovars/ Strains	Sample/Source	Prevalence [a]	References
Listeria	genus		retail raw vegetables	5/280 (1.8%)	Tang *et al.* (1994)
	monocytogenes		chicken portions	19/32 (59.4%)	Arumugasamy *et al.* (1994)
			liver	10/17 (58.8%)	
			gizzard	12/18 (66.7%)	
			beef	6/12 (50.0%)	
			beansprout	7/16 (43.8%)	
			prawn	7/16 (43.8%)	
			dried oyster	1/3 (33.3%)	
			beancake	2/8 (25.0%)	
			satay (uncooked)	11/23 (47.8%)	
			raw vegetables	5/22 (22.7%)	
			RTE (satay)	11/29 (37.9%)	
			RTE (prawns, squids, clams, chicken dishes)	6/22 (27.3%)	
			RTE (cucumber slices)	4/5 (80.0%)	
			RTE (peanut sauce)	1/5 (20.0%)	
	genus		frozen beef	17/23 (73.9%)	Hassan *et al.* (2001)
			local beef	10/23 (43.5%)	
			fermented beef	14/25 (56.0%)	
	monocytogenes		frozen beef	15/23 (65.2%)	
			local beef	6/23 (26.1%)	
			fermented beef	3/25 (12.0%)	
	genus		milk	41/930 (4.4%)	Chye *et al.* (2003)
	monocytogenes		retail poultry	23/49 (46.9%)	Tan *et al.* (2007)
			retail seafood	13/40 (32.5%)	
	monocytogenes		Chicken meat	42/210 (20%)	Goh *et al.* (2012)
	monocytogenes		Chicken liver	18/216 (25.0%)	Kuan *et al.* (2013)
			Chicken heart	15/216 (20.83%)	
			Chicken gizzard	24/216 (33.33%)	
	monocytogenes		Beef burger patties (Frozen)	8/35 (22.9%)	Wong *et al.* (2012)
			Chicken burger patties (Frozen)	13/39 (33.3%)	
			Fish Patties (Frozen)	4/38 (10.5%)	
	monocytogenes		Raw and RTE food samples	12/140 (8.57%)	Marian *et al.* (2012)
	monocytogenes		Ducks and environment	15/531 (2.8%)	Adzitey *et al.* (2013)
	genus		RTE foods	71/396 (17.9%)	Jamali *et al.* (2013)
	monocytogenes			45/396 (11.4%)	
	monocytogenes		Beef offal	21/63 (33.33%)	Kuan *et al.* (2014)
Enterococcus	*faecium*	Vancomycin-resistant	tenderloin beef	10/75 (13.3%)	Son *et al.* (1999)
Enterobacter	*cloacae*		Street foods	7/78 (9.0%)	Haryani *et al.* (2008)
Cronobacter	genus		Powdered Infant Formulas and foods	ND	Abdullah Sani *et al.* (2013)
	sakazakii		Powdered infant formula	9/72 (12.5%)	Abdullah Sani *et al.* (2014)

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Genus	Species	Serovars/ Biovars/ Strains	Sample/Source	Prevalence [a]	References
Staphylococcus	*aureus*		street foods	15/76 (19.6%)	NPHL/MOH (2005a)
	aureus		RTE (pork dishes)	1/20 (5.0%)	NPHL/MOH (2005a)
			RTE (beef dishes)	4/99 (4.0%)	
			RTE (mutton dishes)	6/81 (7.4%)	
			RTE (chicken dishes)	4/102 (3.9%)	
	aureus		RTE (open market)	18/155 (11.6%)	NPHL/MOH (2005b)
	aureus		cooked foods (school canteens)	51/408 (12.5%)	Hodate (2003)

[a] number of positive samples/ total samples tested (percentage)
[b] ND: not detected

the unknown hazard to combat. Additionally, it takes the time to acquire the key data, but this can be reduced to a specific time by targeting at addressing critical knowledge gaps (Buchanan, 1997). Researchers often share their work and knowledge in meetings and conferences and thus, they are often the earliest to receive an insight on the unknown/emerging hazards. The following reports on some of the emerging foodborne pathogens that are currently under research.

Hepatitis E Virus (HEV) are commonly associated with swine and any other domestic meat that serves as animal-human reservoirs even shellfish. The virus is reported to cause acute hepatitis by infecting the liver due to the consumption of undercooked meat. Individuals with cirrhosis are at higher mortality rates if they become infected with the virus.

Clostridium difficile is the leading cause of antibiotic -associated diarrhea and colitis (Moono *et al.,* 2016). Infecting hospital and health-care patients, this anaerobic spore-forming rods release exotoxins knowns as TcdA and TcdB (Moono *et al.,* 2016) causing the patients to suffer *C. difficile* associated diarrhea (CDAD). *C. difficile* is widely disseminated in the environment, thus it has a wide host range. Most are infected through the consumption of contaminated meat and produce or food prepared unhygienically by a *C. difficile* carrier. It was reported that *C. difficile* is gaining antibiotic resistance, recording high mortality rate; in May 2010, 14 people were killed in Victoria, Australia while in May 2011, 26 people were killed in Ontario, Canada due to *C. difficile* infection.

Arcobacter butzleri and Arcobacter cryaerophilus are the two identified foodborne pathogens under the *Arcobacter* genus. It was reported by Douidah *et al.* (2012) in a prevalent study on pre-cut ready-to-eat vegetables that *A. butzleri* and *A. cryaerophilus* carries virulence-associated genes that are common with those of *Campylobacter jejuni* that contribute to host-cell invasion. The similarity suggested that *Arcobacter* and *Campylobacter* could be homologous pathogenically.

Apart from discovering emerging foodborne pathogens, researchers will also be on the look-out of re-emerging foodborne pathogens and this requires continuous monitoring to gather any information of genetic mutation of the foodborne pathogens. Also, as food technology advances, there is a risk that the foodborne pathogens will adapt rendering them difficult to be inactivated. Such cases will leave the community a direct exposure to risk. A great example is the *Salmonella* outbreak in peanut butter. It was a shocking evidence to discover that *Salmonella* had higher heat tolerance (Shachar and Yaron, 2006; He *et al.,* 2013) in low water activity and high-fat content food. 600 cases were reported in the Salmonella outbreak in peanut butter (Crum-Cianflone, 2008).

In addition, *E. coli* and *L. monocytogenes* were also becoming heat tolerant. (Flynn, 2016) reported that there are *E. coli* strains that survive throughout the grilling of meat patties. It was also discovered that *Salmonella* had a higher tolerance to acid stress and it is greatly dependent on the strains (Linaou *et al.,* 2017). The developed food technologies have to be constantly assessed to ensure that the technology effectively inactivates the foodborne pathogen apart from applying food safety practices at all times.

5.2.3 Strategic rapid foodborne detection for surveillance

Food products are often released without knowing the bacteria test results due to the time consuming and labourious microbiological test. Hence, it is often a drive for researchers to produce accurate and rapid foodborne methods. Detection methods for food safety surveillance should be specific, sensitive, high throughput and reliable. Whenever possible, the method should also be inexpensive. A selective number of methods are recommended for in-field and routine foodborne pathogens detection.

Multi bacteria simultaneous detection via multiplex polymerase chain reaction (PCR) targets multiple bacteria in a single tube. The simultaneous detection is a consistent and reliable method which is useful for rapid screening in routine diagnostic laboratories (Chen *et al.,* 2012). To ensure the feasibility of the method, the primer design should be specific and does not interact with one another. The optimization of the method requires detailing in each primer concentration to achieve the best results. Chen *et al.* (2012) successfully developed a rapid multiplex PCR method to detect five major foodborne pathogens; *S. aureus*, *L. monocytogenes*; *E. coli* O157; *S. enterica* serovar Enteritidis and *Shigella flexneri*. On the other hand, Kupradit *et al.* (2016) developed a simultaneous detection on B*acillus cereus, E. coli, L. monocytogenes, Salmonella* spp., and *S. aureus* at a low detection level of at least 100 ng of mixed extracted genomic DNA. Having able to detect at low detection level, the method is sensitive and specific. However, it has the inability to distinguish between viable and non-viable cells, thus producing false positive results. This brought the researchers to develop methods such as biological dyes such as ethidium monoazide (EMA) and propidium monoazide (PMA), preferably compared to EMA, to pretreat samples before DNA extraction (Zeng *et al.,* 2016). Therefore, this reduced the shortcomings of molecular assays used for foodborne pathogen detection. Coupled with Most Probable Number (MPN) assay, the available data can be quantified for foodborne pathogen surveillance.

Lateral flow immunoassays have been popularly preferred to perform in-field and routine foodborne testing as the assays are rapid, low cost, easy to operate, sensitive and specific (Zhao *et al.,* 2014). Dipsticks and immunochromatographic assays are examples of lateral flow immunoassays. There are two basic formats of the current lateral flow immunoassays; 1. Competitive assay for single epitope analyte testing and 2. Sandwich assay for several epitopes analyte testing (Ngom *et al.,* 2010; Zhao *et al.,* 2014). Jung *et al.* (2005) developed an assay on to detect *E. coli* O157. Besides that, Niu *et al.* (2014) detected *S. aureus* while Xu *et al.* (2013) detected *C. jejuni.* Detection of toxins such as brevetoxins and staphylococcal enterotoxin B was also possible with lateral flow immunoassay (Zhou *et al.,* 2009; Rong-Hwa *et al.,* 2010). Recently, Zhao *et al.* (2016) developed a ten-channel up-converting phosphor technology-based lateral flow (TC-UPT-LF) to perform ten simultaneous detections within 20 minutes. Despite that, the quick detection method was unable to provide quantitative assessment data needed to estimate the foodborne illness. However, this method is rather suitable for preliminary screening before conducting the further sophisticated downstream analysis. The assay is also suitable for food industries to evaluate the presence of any foodborne pathogen present in the product in advance before releasing the product to the market.

The current rapid in-field detection of foodborne pathogens revolves around by combining nanotechnology and molecular biology, producing a new method called 'Direct solid-phase polymerase chain reaction'. It is designed to perform simultaneous different PCR reactions on a chip with minimal interference, fast and accurate screening of food products is feasible (Larsen, 2016). The only disadvantage of this product is the high cost needed to design the suitable platform for in-field detection. Nonetheless, cheaper, accurate and rapid detection method of foodborne pathogens are often sought after. This often requires creative and innovative as well as sustainable method development from the researchers in which is hoped to see in the future. With such created method, foodborne surveillance can be carried out proactively, tackling all knowledge gaps and securing the public health.

6. Bridging knowledge gaps in food safety

As risk assessors, we play a role in performing the scientific assessment in evaluating the present hazard. However, there is no significant meaning of conducting the scientific assessment if it is not well-communicated to the appropriate authorities for action and thus, not benefiting the public. It becomes a responsibility of the risk assessors to convert their findings into a communicable language to the risk managers, often the policy makers, who are not scientists. The communication held should be in a two-way direction, and not a one-way direction for both benefits.

On the other part, policy makers should also take the proactive action to approach academicians to gain insights of the current food safety issues and solutions. This can be done by attending conferences, meetings and also liaising with researchers who are food risk assessors. The risks of food safety and their impact on public health should be the main purpose and drive of the policy makers towards food safety improvement. Being the leaders of the food chain, it is their role to gather and use the best available data from all parties, i.e. the food risk assessors, food manufacturing companies. The synergetic effect will then improve the development of domestic food system and food export industries.

It is also important for policy makers to align their standards according to the current international food safety standards efficiently. This puts the country's standards a par with the international food safety

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standards and allowing the flexibility of complying Malaysian food industries an upper hand in economic and trade objectives internationally. It is worth noting that the quality infrastructure for food safety improvement is through standardization food safety standards and this should be made clear. The incorporation of such action as a performance standard within the food industries will also instill the attitude of understanding food safety's importance.

Also, the current food safety knowledge among consumers are not well-understood by the consumers in depth based on the surveys conducted by the researchers. The differences in public perception and scientific assessment of food risk remain a challenge. Malaysia, similar to the many of the countries from South East Asia has lack of exposure to assessment data, conducting the risk assessment as well as the needed laboratory infrastructure and the know-how to analyze a wide range of contaminants. Education and campaigns to increase awareness on foodborne require information, communication channels, and approaches that are specifically designed for the audiences particularly the consumers. These national food control programs are coordinated by officials which are required to attend ongoing training to update themselves with the international advances in science and technology, trends and food trade and other developments in food safety problems. Not only that, the right information should also be channeled correctly. What is observed today is that; minimal specific and detailed information on microbiological food safety and when there is an outbreak and; certain news reported the wrong information causing misleading among the consumers. It is essential to educate the consumers on microbiological food safety, emphasizing on the cause and consequences. Eventually, consumers will begin to understand and practice food safety.

Food safety is commitment and responsibility of those involved in the food supply chain from farm to fork. Practically, it should be everyone's responsibility as we, humans, need to survive with food and water. On the contrary, food safety is an economichh burden to be maintained to Malaysia and all other emerging economy countries. It is worth noting that the impact of not practicing food safety will severely affect the welfare and the economy of the country. The benefits of practicing food safety will definitely provide higher returns, trade and public health conservation will be achieved.

Conflict of Interest

The authors declare no conflict of interest.

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