

TREND AND ASSOCIATED FACTORS OF
FOOD POISONING OUTBREAKS IN SECONDARY
SCHOOLS IN KELANTAN, FROM 2022 TO 2024

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LIST OF ABBREVIATIONS

AOR	Adjusted Odds Ratio
CCP	Critical Control Point
CDC	Communicable Disease Centre
CI	Confidence Interval
DOSM	Department of Statistics Malaysia
GHP	Good Hygiene Practice
HACCP	Hazard Analysis and Critical Control Points
MCO	Movement Control Order
MOE	Ministry of Education
MOH	Ministry of Health
MREC	Medical Research Ethics Committee
NHMS	National Health and Morbidity Survey
NMRR	National Medical Research Registry
OR	Odds Ratio
ProKEM	Program Keselamatan Makanan
ROC	Receiver Operating Characteristics
WHO	World Health Organization

LIST OF SYMBOLS

$>$	More than
$<$	Less than
$=$	Equal to
\geq	More than and equal to
\leq	Less than and equal to
α	Alpha
β	Beta
$\%$	Percentage
p	<i>p</i> -value
$^{\circ}\text{C}$	Degree Celsius

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ABSTRAK

TREND DAN FAKTOR-FAKTOR BERKAITAN WABAK KERACUNAN MAKANAN DI SEKOLAH MENENGAH DI KELANTAN, DARI 2022 HINGGA 2024

Latar belakang: Keracunan makanan masih lagi menjadi cabaran dalam sistem kesihatan awam Malaysia, yang masih tersenarai sebagai lima penyakit berjangkit teratas negara. Di Kelantan, kebimbangan semakin meningkat berikutan peningkatan trend keracunan makanan yang melibatkan persekitaran sekolah.

Objektif: Kajian ini bertujuan untuk menerangkan trend kes wabak keracunan makanan dalam kalangan pelajar sekolah menengah di Kelantan bagi tempoh 2022 hingga 2024, menentukan peratus kes wabak yang melibatkan sekolah menengah, serta menentukan faktor-faktor yang dikaitkan dengan kejadian keracunan makanan dalam kalangan pelajar semasa wabak dalam tempoh yang sama.

Metodologi: Kajian ini menggunakan kaedah hirisan lintang untuk menghuraikan trend dan peratusan wabak keracunan makanan yang dilaporkan dalam kalangan pelajar sekolah menengah di Kelantan dari tahun 2022 hingga 2024. Bagi analisis faktor yang berkaitan, reka bentuk kajian kes-kawalan dengan nisbah 1:3 telah digunakan, di mana pelajar kes daripada wabak terpilih dibandingkan dengan kawalan yang dipadankan. Data diperolehi melalui Borang Siasatan Keracunan Makanan (FWBD/KRM/BG 001), Semakan 2008.

Keputusan: Terdapat peningkatan kes wabak keracunan makanan dari tahun 2022 ke 2023, diikuti keadaan yang mendatar pada 2024. Peratus kes wabak di sekolah menengah adalah 90.9% pada 2022, 44.4% pada 2023, dan 33.3% pada 2024, dengan purata keseluruhan 45.9%. Purata umur pelajar yang terlibat ialah 14.77 tahun (SD = 1.38), dan 62.5% berada dalam kumpulan umur 13-15 tahun. Sekolah di bawah Kementerian Pendidikan Malaysia menyumbang 73.5% kes, manakala 55.9% berlaku di kawasan luar bandar. Kebanyakan (85.3%) kes melibatkan kantin asrama. Ayam itik dikenal pasti sebagai punca utama (50.0%), manakala *Salmonella* spp. adalah agen mikrobiologi yang paling kerap (64.7%). Kegagalan titik kawalan kritikal (CCP) yang paling sering berlaku ialah pemasakan, pemanasan semula dan penyimpanan yang tidak mencukupi (64.7%). Pelajar lelaki mempunyai risiko lebih rendah (AOR = 0.76; 95% CI: 0.60,0.96; p = 0.023) untuk menyebabkan wabak keracunan makanan. Sebaliknya, pengambilan daging merah meningkatkan risiko keracunan (AOR = 4.45; 95% CI: 3.25,6.08; p < 0.001), dan titik kawalan kritikal seperti pemasakan dan pemanasan semula yang tidak mencukupi juga mempunyai risiko lebih tinggi (AOR = 1.50; 95% CI: 1.20,1.89; p < 0.001) untuk menyebabkan wabak keracunan makanan di sekolah menengah.

Kesimpulan: Kajian ini menunjukkan kaitan yang jelas antara wabak keracunan makanan di sekolah menengah di Kelantan dengan amalan pengendalian makanan tertentu. Walaupun faktor yang tidak dapat diubah seperti jantina pelajar mempengaruhi kejadian wabak keracunan makanan, perhatian perlu ditumpukan pada faktor yang boleh dicegah, terutamanya amalan memasak, memanaskan semula, dan penyimpanan makanan berisiko tinggi seperti daging merah. Penemuan ini

menekankan keperluan untuk memperkukuh latihan keselamatan makanan untuk kakitangan kantin, menguatkuasakan pemantauan CCP yang lebih ketat, serta mengintegrasikan literasi kesihatan khusus pelajar untuk mencegah wabak pada masa depan.

Kata kunci: Keracunan makanan, wabak, sekolah menengah, Kelantan.

ABSTRACT

TREND AND ASSOCIATED FACTORS OF FOOD POISONING OUTBREAKS IN SECONDARY SCHOOLS IN KELANTAN, FROM 2022 TO 2024

Background: Food poisoning is a recurring challenge in Malaysia's public health system, consistently ranking among the nation's top five communicable diseases. In Kelantan, the concern over the increasing trend of food poisoning involving school settings has been growing.

Objective: This study aimed to describe the trend of food poisoning outbreak cases, to describe the proportion of food poisoning outbreak cases and to determine the factors associated with food poisoning cases during outbreaks among secondary school students in Kelantan within the same period.

Methodology: This study conducted a cross-sectional design to describe the trend and proportion of food poisoning outbreaks reported among secondary school students in Kelantan from 2022 to 2024. For the analysis of associated risk factors, a case-control design with a 1:3 ratio was applied, where student cases from selected outbreaks were compared with matched controls. Data were extracted from the final outbreak reports using the "Borang Siasatan Keracunan Makanan (FWBD/KRM/BG 001), Revision 2008".

Result: The findings showed an upward trend in food poisoning outbreaks from 2022 to 2023, followed by a plateau in 2024. The proportion of outbreaks involving secondary schools was 90.9% in 2022, 44.4% in 2023, and 33.3% in 2024, with an overall combined proportion of 45.9% across the three years. The mean age of affected students was 14.77 years (SD = 1.38), with 62.5% in the lower secondary age group (13-15 years). Schools under the Ministry of Education (MOE) accounted for 73.5% of the cases, and 55.9% of outbreaks occurred in rural areas. Notably, 85.3% of incidents were linked to hostel canteens. Poultry was identified as the leading food vehicle (50.0%), while *Salmonella* spp. emerged as the most common microbial agent (64.7%). Inadequate cooking and reheating and improper storage were the most frequent critical control point (CCP) failures (64.7%). Male students were found to have a lower likelihood of being affected (AOR = 0.76; 95% CI: 0.60,0.96; p = 0.023). Conversely, consumption of red meat significantly increased the risk of food poisoning (AOR = 4.45; 95% CI: 3.25,6.08; p < 0.001), as did exposure to inadequate cooking and reheating (AOR = 1.50; 95% CI: 1.20,1.89; p < 0.001).

Conclusion This study revealed a clear link between food poisoning outbreaks in Kelantan's secondary schools and specific operational practices within school. While non-modifiable factors like student's sex influenced susceptibility, the more concerning aspects were preventable factors particularly in cooking, reheating, and storage of high-risk foods such as red meat. These findings highlighted the need for strengthening food safety training for canteen personnel, enforcing strict CCP monitoring, and integrating targeted health literacy for students in preventing future outbreaks.

Keyword: food poisoning, outbreak, secondary schools, Kelantan.

CHAPTER 1

INTRODUCTION

1.1 Overview of food poisoning

Food poisoning, commonly referred to as foodborne illness, constitutes a prevalent concern that impacts individuals across diverse age groups and socio-economic backgrounds. Recent studies indicated that nearly 1 in 10 individuals globally experience foodborne illnesses annually, culminating in approximately 33 million cases each year (Sharif *et al.*, 2018). According to the World Health Organization (WHO), it was estimated that around 600 million individuals suffer from foodborne illnesses each year worldwide, culminating in about 420,000 deaths (WHO, 2024). A particularly susceptible demographic includes children under the age of five, who represent 40% of global foodborne disease cases, culminating in an estimated 125,000 deaths annually (WHO, 2024). In the framework of the United States, it was projected that the annual occurrences of acute gastroenteritis range between 250 and 350 million, with approximately 25% to 30% of these cases being linked to foodborne pathogens (McCabe-Sellers & Beattie, 2004). In developing nations, the incidence of foodborne diseases is frequently exacerbated by restricted access to safe food and healthcare provisions. For instance, in Indonesia, the economic repercussions resulting from food poisoning outbreaks in 2013 were approximated to be around US\$78 million, underscoring the profound implications for both public health and economic stability (Rahayu *et al.*, 2016).

Food poisoning was still a recurring public health issue in Malaysia, with some cases leading to fatalities each year. In Malaysia, food poisoning was the top five communicable disease and historically, statistics in Malaysia showed increasing trend of food poisoning in year 1996 to 1997, and 66.5% of outbreak took place in primary and secondary schools. Other educational institutions like universities, colleges and training centers contributed to the second highest cases and only 0.4% originated from contaminated food sold at various public food courts (Meftahuddin, 2002). Forward to 2020, Malaysia had reported an annual incidence of food poisoning 28.93, 18.4 in 2021, 13.77 in 2022, all per 100,000 population in addition to mortality ranging from 0.003 to 0.02 per 100,000 population (Ministry of Health, 2023). Food poisoning outbreak also reported most of the major outbreaks involved school settings (Ministry of Health, 2023). These numbers showed that schoolchildren were among the most affected victims of food poisoning in Malaysia. Food poisoning cases were usually reported among schoolchildren that were involved in school canteens and hostel kitchens. In recent years of Kelantan, the incidence rate of food poisoning had also increased from 3.47 per 100,000 population in 2021 to 49.8 per 100,000 population in 2022 (Ministry of Health, 2023).

1.2 Problem statement and study rationale

Food poisoning outbreaks had increased significantly in Malaysia, with a 94% rise in cases from 2021 to 2022 following the reopening of schools. Of the 392 episodes reported in 2022, 45.9% occurred in schools (Ministry of Health, 2023). Despite this, there is a limited number of studies that had focused exclusively on secondary school students in Kelantan, a population known to be vulnerable (Meftahuddin, 2002; Abdullah & Ismail, 2021; Ministry of Health, 2023). Existing studies offer limited insights into the factors contributing to these outbreaks, especially given recent changes in food consumption patterns. This study aimed to address these gaps by identifying the trends, etiological causes, specific food vehicles, and critical control points (CCPs) related to food poisoning outbreaks among secondary school students in Kelantan.

The findings of the study would provide empirical evidence on contributory factors linked to outbreaks in secondary school settings, including commonly implicated food vehicles and deficiencies in food safety protocols. In relation to third Sustainable Development Goals (SDG 3) which focuses on reducing preventable health risks and promoting well-being, the findings would guide tailored interventions, enhanced food safety regulations, and improved food handler training. The goal was to strengthen public health systems, reduce outbreak frequency, and create healthier learning environments, ultimately contributing to sustainable public health outcomes in the region.

1.3 Research questions

- 1.3.1 What is the trend of food poisoning outbreak cases among secondary school students in Kelantan from 2022 to 2024?
- 1.3.2 What is the proportion of food poisoning outbreak cases among secondary school students in Kelantan from 2022 to 2024?
- 1.3.3 What are the factors associated with food poisoning cases among secondary school students in Kelantan from 2022 to 2024?

1.4 Objectives of study

1.4.1 General:

To study the trend and factors associated with food poisoning outbreaks among secondary school students in Kelantan from 2022 to 2024.

1.4.2 Specific:

- 1.4.2.1 To describe the trend of food poisoning outbreak cases among secondary school students in Kelantan from 2022 to 2024.
- 1.4.2.2 To describe the proportion of food poisoning outbreak cases among secondary school students in Kelantan from 2022 to 2024.
- 1.4.2.3 To determine the factors associated with food poisoning cases during outbreaks among secondary school students in Kelantan for 2022 to 2024.

1.5 Hypothesis

1.5.1 N_0 : There are no significant associated factors with food poisoning cases during outbreaks among secondary school students in Kelantan.

1.5.2 N_A : There are significant associated factors with food poisoning cases during outbreaks among secondary school students in Kelantan.

CHAPTER 2

LITERATURE REVIEW

This literature review was compiled from multiple databases, such as Scopus, PubMed, Web of Science, and Science Direct. Using Boolean operators (AND, OR, NOT) to combine relevant terms, some keywords included “Foodborne Diseases”, “School”, “Food Poisoning”, “outbreak”, “epidemics”, “HACCP”, “Hazard Analysis Critical Control Point” and “Food Safety Analysis”.

2.1 Definition of food poisoning

Food poisoning could be defined clinically by acute onset of vomiting, diarrhea, or other sudden symptoms following ingestion of contaminated food or drinks. Neurological symptoms, such as tingling, muscle weakness, and even paralysis, can also occur. Any reported case meeting this clinical description is classified as a confirmed instance of food poisoning paralysis (Health, 2017). In Malaysia, various food and waterborne diseases, including food poisoning, hepatitis A, dysentery, typhoid/paratyphoid fever and cholera are recognized under the Prevention and Control of Infectious Diseases Act 1988 (Act 342) as substantial public health risks linked to contamination and these diseases were mandatory to be notified (Health, 2017). While for the food poisoning outbreak, it was defined as two or more people with illness associated with a common food or meal, which was epidemiologically related either by time, place, or person (Organization, 2008; Health, 2017).

2.2 Epidemiology of food poisoning outbreak

Through decades, foodborne illnesses remained a significant global health challenge, responsible for substantial mortality and socioeconomic impacts. Food poisoning had a significant impact on public health, resulting in a substantial burden of disease worldwide. According to the World Health Organization (WHO), an estimated 600 million people fall ill each year due to the consumption of contaminated food, leading to 420,000 deaths annually (Shrivastava *et al.*, 2016). In the United States alone, foodborne illnesses were responsible for approximately 128,000 hospitalizations and 3,000 deaths each year (Wesley, 2009). The economic impact of food poisoning was substantial, affecting both individuals and society. In the United States, the annual economic burden of foodborne illnesses was estimated to be between 20 and 43 billion, including costs associated with medical care, lost wages, and legal fees (Wesley, 2009). Globally, the economic losses due to foodborne diseases were estimated to be in the billions of dollars, with significant implications for public health systems and national economies (Shrivastava *et al.*, 2016).

Since 2020, Malaysia had reported an annual incidence of food poisoning 28.93 per 100,000 population, followed by an incidence rate dropped in 2021 to 18.4 per 100,000 population due to the COVID-19 pandemic (Ministry of Health, 2022). However, in 2022, the MOH reported a 94% increase in episodes of food poisoning from 2021 to 2022 with an incidence rate of 43.77 per 100,000 population of food poisoning, in addition to a mortality rate of 0.01 per 100,000 population after the opening of schools and workplaces in April 2022 (Ministry of Health, 2023). Food poisoning outbreak even ranked second among major outbreaks in 2022 after Hand, Foot, and Mouth Disease (Ministry of Health, 2022). A similar trend was seen in

Kelantan state which had experienced a rising incidence rate in recent years, increasing from 3.47 per 100,000 population in 2021 to 49.8 per 100,000 population in 2022 (Ministry of Health, 2023).

Food poisoning outbreaks typically occurred due to the consumption of contaminated food or water, with symptoms ranging from mild gastrointestinal distress to severe illness. Several studies reported frequent foodborne outbreaks in school canteens, mass gatherings, and religious events, highlighting vulnerabilities in food preparation and storage practices (Ayob *et al.*, 2018; Bajaj *et al.*, 2019; Rajakrishnan *et al.*, 2022). Outbreaks were commonly linked to improper temperature control, incorrect storage, cross-contamination, and infected food handlers (Abdullah & Ismail, 2021). In Malaysia, of the 392 episodes reported in 2022, 45.9% occurred in schools (Ministry of Health, 2022). Additionally in Ethiopia, outbreaks at religious events and public gatherings were linked to unsafe catering practices and overwhelmed food handlers who failed to maintain proper hygiene (Kassahun *et al.*, 2019). In a study from Selangor, Malaysia, mass events increased the risk due to high volumes of prepared food and logistical challenges related to food safety enforcement (Rajakrishnan *et al.*, 2022).

2.3 Etiological agents of food poisoning outbreak

The most common pathogens in food poisoning outbreaks include bacteria such as *Bacillus cereus*, *Salmonella* spp., and *Staphylococcus aureus*. For example, *Bacillus cereus* was a common cause of foodborne illness, as seen in outbreaks in Malaysia and China (Bujang *et al.*, 2023; Li *et al.*, 2023). This bacterium was known for producing toxins that cause vomiting and diarrhea. While *Salmonella* spp. and

Staphylococcus aureus were responsible for most cases at 52.4% and 19% respectively in Terengganu (Abdullah & Ismail, 2021). *Salmonella* spp. and *Clostridium perfringens* were additional bacterial agents responsible for food poisoning outbreaks in schools. Salmonellosis outbreaks had been reported in Malaysia and China, often linked to contaminated food items such as salads and cooked dishes (Liu et al., 2016; Ayob et al., 2018). *Clostridium perfringens* had been associated with outbreaks in Greece and Ghana, where it was identified in food samples and stool specimens (Ameme et al., 2016; Papanikou et al., 2023).

Other etiological agents, such as *Enteroaggregative Escherichia coli* (EAEC), *Cronobacter sakazakii*, and *Vibrio parahaemolyticus*, had also been implicated in school outbreaks. For example, an outbreak in South Korea was caused by EAEC, which was detected in both food and stool samples (Shin et al., 2015). Also in South Korea, *Escherichia coli* had been reported for 53.8% of outbreaks (Lee et al., 2019). Similarly, *Vibrio parahaemolyticus* had been reported with the highest frequency (58.41%) in school-related outbreaks in Zhejiang, China (Chen et al., 2022). In addition, *Cronobacter sakazakii* was also identified in a high school outbreak in China as the causative agent, highlighting the diversity of pathogens involved in these incidents (Yong et al., 2018). In terms of *Shigella* spp., a study which analyzed acute gastroenteritis outbreaks in the United States from 2009 to 2020, reported that most reported etiologies were *Shigella* spp. (7.7%) and second only to norovirus (64.4%) during this period (Mattison et al., 2022).

For viruses, norovirus was another prevalent cause of food poisoning in schools. Outbreaks in Spain, Japan and China had been linked to norovirus, with the virus often transmitted through contaminated food or person to person contact (Godoy

et al., 2016; Somura *et al.*, 2017; Guo *et al.*, 2018). In addition, rotavirus had also been implicated in school outbreaks, as seen in Thailand, where it was identified as the causative agent in a gastroenteritis outbreak (Thanasitthichai *et al.*, 2023).

While some parasites, like fish-borne trematodes, were transmitted solely through food. Others, such as *Echinococcus* spp. and *Taenia* spp., infected humans via contaminated food or direct contact with animals. Parasites like *Ascaris*, *Cryptosporidium*, *Entamoeba histolytica*, and *Giardia* could enter the food chain through polluted water or soil, contaminating fresh produce (WHO, 2024).

Regarding food poisoning by chemicals, environmental pollutants such as persistent organic pollutants (including dioxins) could accumulate in the food chain, harming reproduction, immunity, and hormone systems. Heavy metals (lead, cadmium, mercury) primarily contaminate food via polluted water and soil, leading to neurological and kidney damage. Other chemical risks involve radioactive materials, food allergens, and drug residues (WHO, 2024).

2.4 Mode of transmission

The mode of transmission in food poisoning outbreaks in schools was often multifaceted, involving both foodborne and person to person transmission. Contaminated food and water were the primary sources of infection, with outbreaks often linked to school canteens or cafeterias. For example, a *Bacillus cereus* outbreak in China was traced to contaminate rice noodles served in the school canteen (Li *et al.*, 2023). Similarly, a norovirus outbreak in Spain was associated with exposure to foods or drinks from the school canteen (Godoy *et al.*, 2016). Person to person transmission also played a significant role in the spread of illness, particularly in closed settings

such as schools. Norovirus outbreaks in China had been attributed to both foodborne and person to person transmission, with the virus spreading rapidly among students and staffs (Guo *et al.*, 2018). In some cases, symptomatic food handlers had been identified as potential sources of infection, as seen in a norovirus outbreak in China where a symptomatic server was considered the possible source of infection (Guo *et al.*, 2018).

Cross-contamination was another critical factor in the transmission of foodborne illnesses in schools. Inadequate food handling practices, such as improper thawing and storage of food, had been reported in outbreaks. For example, a *Bacillus cereus* outbreak in Malaysia was attributed to cross-contamination and inadequate storage temperatures (Bujang *et al.*, 2023). Similarly, a salmonellosis outbreak in China was linked to cross-contamination via a storage bucket used for raw ingredients (Liu *et al.*, 2016).

2.5 Food poisoning outbreak in schools

Food poisoning outbreaks in schools represented a significant public health concern, particularly in Malaysia, where a considerable proportion of such incidents were linked to educational institutions. In 2022, 45.9% of food poisoning outbreaks in Malaysia was associated with schools, indicating a critical area for intervention and research (Abdullah & Ismail, 2021; Ministry of Health, 2022). The trend of food poisoning outbreaks in Malaysia had shown alarming statistics over the years. In Terengganu, for instance, the incidence of school-related outbreaks was notably high at 63.6% in 2016 (Abdullah & Ismail, 2021). Comparatively, data from China indicated that school cafeterias were responsible for 13% of foodborne cases from

2003 to 2008, which increased to 19.93% in Zhejiang province from 2010 to 2020 (Wu *et al.*, 2018; Chen *et al.*, 2022). In contrast, Switzerland reported a much lower incidence with only 6.5% of outbreaks involving schools from 2007 to 2021 (Lüthi and Fridez, 2023). Among school-aged populations, secondary school students were particularly vulnerable, representing a significant portion of cases, with 81% of incidents in Terengganu occurring among this age group (Abdullah & Ismail, 2021).

This highlighted the importance of targeted interventions in school settings to mitigate foodborne illnesses among students. In addition, timely investigation and the implementation of control measures were critical in mitigating the impact of food poisoning outbreaks in school settings. A study in Greece emphasized the importance of timely investigation and sample collection in identifying the source of an outbreak and implementing effective control measures (Papanikou *et al.*, 2023). As an example, a salmonellosis outbreak in China which was introduced via cross-contamination from an unclean storage bucket. Following the identification of contaminated food sources, the interventions of hygiene practices able to be implemented including discarding contaminated food, enforcing strict hygiene, disinfecting utensils, and separating raw and cooked food storage (Liu *et al.*, 2016).

2.6 Hazard Analysis and Critical Control Point (HACCP)

For decades, studies had recommended to incorporate the HACCP approach in managing food poisoning outbreaks. HACCP was a systematic, preventive approach to food safety that identifies, evaluates, and controls hazards in the food production process. It was widely recognized as an effective tool for preventing foodborne illnesses. However, its implementation in school food service systems remains

inconsistent. For instance, a study in Luzon Island, Philippines had shown that many high schools fail to meet HACCP compliance requirements, with average compliance rates as low as 2.9% (34 public schools) and 11.8% (17 private schools) (Salvador *et al.*, 2024). This lack of compliance was often attributed to inadequate training, insufficient resources, and a lack of awareness of the benefits of HACCP (Kwon, 2003; Pun and Bhairo-Beekhoo, 2008).

Several case studies highlight the importance of HACCP in preventing food poisoning outbreaks in schools. For example, in boarding schools in Zaria, Nigeria, microbial contamination and inadequate food handling practices were identified as major contributors to foodborne illnesses. The implementation of HACCP was recommended to address these issues (Solomon *et al.*, 2007). Similarly, in the United States, food safety violations in urban schools were linked to a lack of temperature control and inadequate food handling practices, emphasizing the need for HACCP training and certification programs (Kwon, 2003; Reynolds, 2022).

2.7 Factors associated with food poisoning outbreaks in schools

2.7.1 Sociodemographic factors

Literature indicates that school-aged students, particularly in secondary schools, were more susceptible to food poisoning. In Terengganu, Malaysia, secondary school students (ages 13-17) comprised 81% of cases, while primary school students (ages 7-12) accounted for 19%. Previous studies had similarly identified students as a high-risk group for foodborne illnesses (New *et al.*, 2017; Abdullah & Ismail, 2021). Younger individuals, particularly those in the 11 to 15 age group, were more susceptible to such outbreaks due to their developing immune systems and potential

lack of awareness about food safety practices. For instance, in a study conducted in a rural area of Perak, Malaysia, half of the cases (52%) were aged between 11 and 15 years, highlighting the vulnerability of this age group (Halim *et al.*, 2024). A study in Nigeria found that while students had good food safety knowledge and practices, their understanding was influenced by their mothers' education levels, suggesting that socioeconomic factors also play a role in shaping food safety awareness (Aluh *et al.*, 2019).

For the sex, patterns showed an increase among female students. In a study conducted in Negeri Sembilan, a *Bacillus cereus* outbreak affected more female students, linked to consumption of beef rendang (a dry curry), rice, rice cubes and vermicelli, while in India, a staphylococcal outbreak also impacted female high school was associated with unhygienically prepared milk (Vyas & Pandya, 2019; Bujang *et al.*, 2023). Similarly, in the USA, females exhibited a marginally higher incidence (54%) compared to males (46%) where they were more likely to be involved in grains-beans, nuts-seeds, fruits, sprouts and vegetable row crops outbreaks (Strassle *et al.*, 2019). Furthermore, in a study from Indonesia, 53.22% of the cases were female students, with the outbreak linked to contaminated meatballs and *Salmonella* spp. As the main sources. Contributing factors included bulk storage in refrigerators, inadequate reheating, and cross-contamination. These findings suggesting that gender-specific factors such as dietary preferences or exposure to contaminated food sources might vary by context (Iskandar *et al.*, 2024). However, in some cases, male students had been more affected. Several studies had reported a higher incidence of foodborne illnesses among male students compared to their female counterparts. For example, in a study conducted in Ghana, 51.47% of the cases were male students, with *C.*

perfringens identified as the most likely agent and contaminated canteen water as the vehicle of transmission (Ameme *et al.*, 2016). Similarly, in a rural village in Perak, Malaysia, 68% of acute gastroenteritis cases occurred among male students, suspected to be linked to drinking water contaminated with chemicals such as carbofuran (Halim *et al.*, 2024). This pattern suggested that male students might be more exposed to risky food handling practices or may have different eating habits that increase their susceptibility to foodborne illnesses.

The MOH's 2022 report indicated that 35.9% of outbreaks occurred in Ministry of Education (MOE) schools, however, in other studies non-MOE schools had a higher risk with an adjusted odds ratio of 3.62 (95% CI:2.37,5.54) reported in Terengganu (Abdullah & Ismail, 2021; Ministry of Health, 2022). Boarding schools also faced elevated risks, with a 25.5% attack rate noted in a Negeri Sembilan outbreak due to confined dining (New *et al.*, 2017; Bujang *et al.*, 2023). Study from Terengganu reported that 76.2% of outbreaks were related to hostel canteens (Abdullah & Ismail, 2021). Similarly, a study in India, reported a 70.1% attack rate in girls' hostels, which was linked to issues in food preparation at the hostel canteen (Prajapati *et al.*, 2020).

Differences in urban and rural settings could also influence outbreak patterns. In predominantly urban areas such as Petaling district, Selangor, outbreaks were often associated with mass gatherings and public events. In contrast, rural areas like Batang Padang, Perak, reported outbreaks linked to challenges in traditional food preparation methods (Ayob *et al.*, 2018; Rajakrishnan *et al.*, 2022). Urban schools often had more diverse food sources, which could increase the risk of contamination if food safety regulations were not strictly enforced. For example, a study in Terengganu found that urban district (57.1%) schools were more likely to experience

food poisoning outbreaks compared to rural schools (Abdullah & Ismail, 2021). In contrast, rural schools may face challenges related to inadequate food safety infrastructure and limited access to clean water, which could increase the risk of contamination. A study in North West province, South Africa also highlighted that poor storage and preparation of food in local public primary day school contributed to a salmonellosis outbreak linked to contaminated was samp (processed maize meal) (Motladiile *et al.*, 2019).

2.7.2 Food Vehicle

Various food vehicles contributed to food poisoning outbreaks in secondary schools. Studies reveal that certain foods were key contributors to school food poisoning outbreaks. This section examines the proportion of outbreaks associated with specific food vehicles, including poultry, red meat, rice/grain, desserts, eggs, and fish/seafood, based on from relevant studies.

Poultry was one of the most common food vehicles associated with food poisoning outbreaks in secondary schools. In a study conducted in Terengganu, Malaysia, poultry was implicated in 61.9% of food poisoning outbreaks involving schoolchildren (Abdullah & Ismail, 2021). Similarly, in the United States, although outbreak related schools only amounted to 13%, poultry emerged as a major food vehicle, accounting for 18.9% of outbreaks with confirmed etiologies reported to the Foodborne Disease Outbreak Surveillance System during 2009 to 2015 (Dewey-Mattia *et al.*, 2018). *Salmonella* spp. was the most common microbial etiological agent associated with poultry-related outbreaks, contributing to 52.4% of cases in the Malaysian study (Abdullah & Ismail, 2021). In another study focusing on salmonella outbreaks in Australia that used national register of foodborne outbreaks, poultry meat

was identified as a significant food vehicle, although the trend showed a decreasing proportion of outbreaks associated with poultry over time (Ford *et al.*, 2018). However, the study not specifically focused on school children.

Red meat, particularly beef, has also been implicated in food poisoning outbreaks in school settings. In Negeri Sembilan, beef rendang had a strong association with outbreaks (AOR= 20.54; 95% CI: 4.89,86.30), while a study in Terengganu reported only 9.5% of outbreaks related to red meat (Abdullah & Ismail, 2021; Bujang *et al.*, 2023). In addition, according to study from United States, beef was the third most common food vehicle, accounting for 11.9% of outbreaks with known etiologies (Dewey-Mattia *et al.*, 2018). A systematic review of bacterial foodborne outbreaks related to red meat and meat products found that *Escherichia coli* and *Salmonella* spp. were the most common pathogens associated with red meat, causing 33 and 21 outbreaks, respectively (Omer *et al.*, 2018). In China, livestock meat was the most implicated food category in foodborne disease outbreaks, accounting for 28.67% of all outbreaks (Zhao *et al.*, 2022). From several studies, red meat has been shown to be linked to *Salmonella* spp., *Staphylococcus aureus* and *Escherichia coli* (Angkititrakul *et al.*, 2013; Ain Auzureen *et al.*, 2017; Shafini *et al.*, 2017; Omer *et al.*, 2018; Al-Hilu & Al Shujairi, 2020).

Rice and grain products have also been associated with food poisoning outbreaks in schools. Rice and grain-based dishes, such as "nasi kuning" and net pancakes or "roti jala" had a relative risk of 3.8 (95% CI: 2.19,6.56) to 10.5 (95% CI: 2.7,40.0) respectively in Sabah and Perak related to outbreaks occurrence (Jeffree *et al.*, 2016; Packierisamy *et al.*, 2018). Furthermore, in a study conducted in Terengganu, rice/grain contributed 14.3% of food poisoning outbreaks (Abdullah &

Ismail, 2021). On the other hand, a study in United States reported that grains/beans were implicated with 8.6% of outbreaks (Dewey-Mattia *et al.*, 2018). A study on foodborne disease outbreaks in France found that cereals were among the food categories contributing to the burden of foodborne infectious diseases, although the proportion was relatively low compared to meats and dairy products (Augustin *et al.*, 2020).

Desserts have been implicated in food poisoning outbreaks, particularly those involving dairy products. An outbreak-related restaurant in Umbria, Italy with 63% attack rate (affecting 24 of the 42 customers) related to cream desserts were reported (Ercoli *et al.*, 2017). A national register study from United States revealed that desserts were among the food categories associated with foodborne disease outbreaks, although the proportion was relatively low compared to other food vehicles (Dewey-Mattia *et al.*, 2018). In addition, study on foodborne disease outbreaks in Australia found that desserts, particularly those containing raw egg products, were associated with salmonella outbreaks (Ford *et al.*, 2018). While in France, sweet foods, including desserts, were estimated to contribute approximately 5 to 20% to the foodborne disease burden (Augustin *et al.*, 2020).

Eggs were another significant food vehicle in food poisoning outbreaks in schools. A study from Terengganu reported egg consumption was 4.6 times more likely to be associated with food poisoning outbreaks compared to rice/grain consumption (AOR= 4.63;95% CI:1.78,12.04) (Abdullah & Ismail, 2021). In addition, report from the United States also implicated eggs in 5.3% of outbreaks with known food vehicles (Dewey-Mattia *et al.*, 2018). A study on salmonella outbreaks in Australia found that eggs and egg-containing foods were the most frequently identified

food vehicles, although the trend showed a decreasing proportion of outbreaks associated with eggs over time (Ford *et al.*, 2018).

Fish and seafood had also been associated with food poisoning outbreaks in schools. Seafood contributed to 9.5% of outbreaks in Terengganu, and there were tetrodotoxin poisoning cases from horseshoe crabs reported in Sabah (Suleiman *et al.*, 2017; Abdullah & Ismail, 2021). A study from United States also reported 18.6% of outbreaks related to fish and seafood (Dewey-Mattia *et al.*, 2018). A study on foodborne disease outbreaks in France also reported that fish and seafood were estimated to contribute approximately 5 to 20% to the foodborne disease burden (Augustin *et al.*, 2020).

To conclude, poultry, red meat, rice/grain, desserts, eggs, and fish/seafood were all significant food vehicles in food poisoning outbreaks, both in school settings and in other environments such as restaurants. Poultry and fish/seafood were the most common food vehicles, while eggs and desserts were also notable contributors. Understanding the proportion of outbreaks associated with each food vehicle was crucial for developing targeted interventions to reduce the burden of foodborne diseases in school settings.

2.7.3 Critical Control Point (CCP)

Food poisoning outbreaks were often linked to inadequate cooking and reheating, incorrect storage, cross-contamination, and infected food handlers. CCPs were points in a food production process where control can be applied to prevent, eliminate, or reduce food safety hazards to an acceptable level. In the context of school food service, CCPs were crucial for ensuring that food was prepared, stored, and served safely. The failure to identify and manage CCPs could lead to food poisoning

outbreaks, making it essential to understand and address these points effectively.

One of the most common CCP violations in school food service was inadequate cooking and reheating (Michino & Otsuki, 2000; Wu *et al.*, 2018; Abdullah & Ismail, 2021; Holst *et al.*, 2025). This could occur due to a lack of proper training among food handlers or the use of inadequate equipment (Suryani *et al.*, 2021; Reynolds, 2022; Kaugi *et al.*, 2024). In a study from Terengganu, inadequate cooking and reheating contributed to 57.1% of outbreaks, while similar patterns were observed in China, where improper cooking was a primary factor across 2,190 outbreaks (Wu *et al.*, 2018; Abdullah & Ismail, 2021).

Incorrect storage practices also played a significant role. This could include storing raw and cooked foods together, not maintaining proper refrigeration temperatures, and not using food within the recommended time frame (Michino & Otsuki, 2000; Daniels *et al.*, 2002; Motladiile *et al.*, 2019; Reynolds, 2022). These practices could lead to bacterial growth and contamination, making food unsafe for consumption. For example, incorrect storage temperatures contributed to outbreaks in Negeri Sembilan and accounted for 23.8% of cases in Terengganu (Abdullah & Ismail, 2021; Bujang *et al.*, 2023). Furthermore, it was reported in China that improper storage was a factor in 13% of outbreaks (Wu *et al.*, 2018). Cross-contamination was another critical factor, particularly in environments where raw and cooked foods were prepared and stored in proximity (Ayob *et al.*, 2018; Wu *et al.*, 2018; Abdullah & Ismail, 2021). This could occur due to inadequate cleaning and sanitizing of utensils, equipment, and surfaces. The factor had contributing to 14.3% of outbreaks in Terengganu and being common in China, where it accounted for 22% of cases (Wu *et al.*, 2018; Abdullah & Ismail, 2021). Infected food handlers with foodborne pathogens could also be a source

of contamination. If food handlers do not follow proper handwashing and hygiene practices, they can transfer pathogens to food, leading to outbreaks. Ensuring that food handlers were trained in proper hygiene practices and free from illness was a critical control point in food safety management (Dudeja and Singh, 2017). Infected food handlers were responsible for 4.8% of cases in Terengganu and 4% in China (Wu *et al.*, 2018; Abdullah & Ismail, 2021). Furthermore, unsanitary food handling procedures accounted for over 50% of poisoning episodes in Malaysia (Soon *et al.*, 2011).

Despite the existing literature on food poisoning outbreaks involving schools in Malaysia, there remained a notable gap in understanding the trend, etiological agents, specific food vehicles and critical control points related to food poisoning outbreaks among secondary school students in Kelantan especially given recent developments in food safety. Furthermore, investigating the role of specific food vehicles and critical control points will be essential for developing comprehensive prevention measures tailored to the unique environments of schools in Kelantan. Addressing these gaps will enhance public health responses and improve safety standards within school cafeterias across Kelantan and beyond.

2.8 Conceptual framework

Figure 2.1 illustrates the conceptual framework of this study. There were many factors that led to food poisoning outbreak at secondary schools based on literature findings. In the sociodemographic factor, the variables studied were age, sex, school category, premises type, geographical area (urban or rural area). For the etiological agent, the studies agents were *Salmonella* spp., *Staphylococcus aureus*, *Bacillus cereus*, *Escherichia coli*, *Shigella* spp. and *Vibrio Parahaemolyticus*. Other etiological agents such as viruses, parasites or chemicals were not included in this study. The food vehicles studied were poultry, red meat, eggs, rice/grain, fish/ seafood and desserts. All critical control points listed in the conceptual framework were studied.

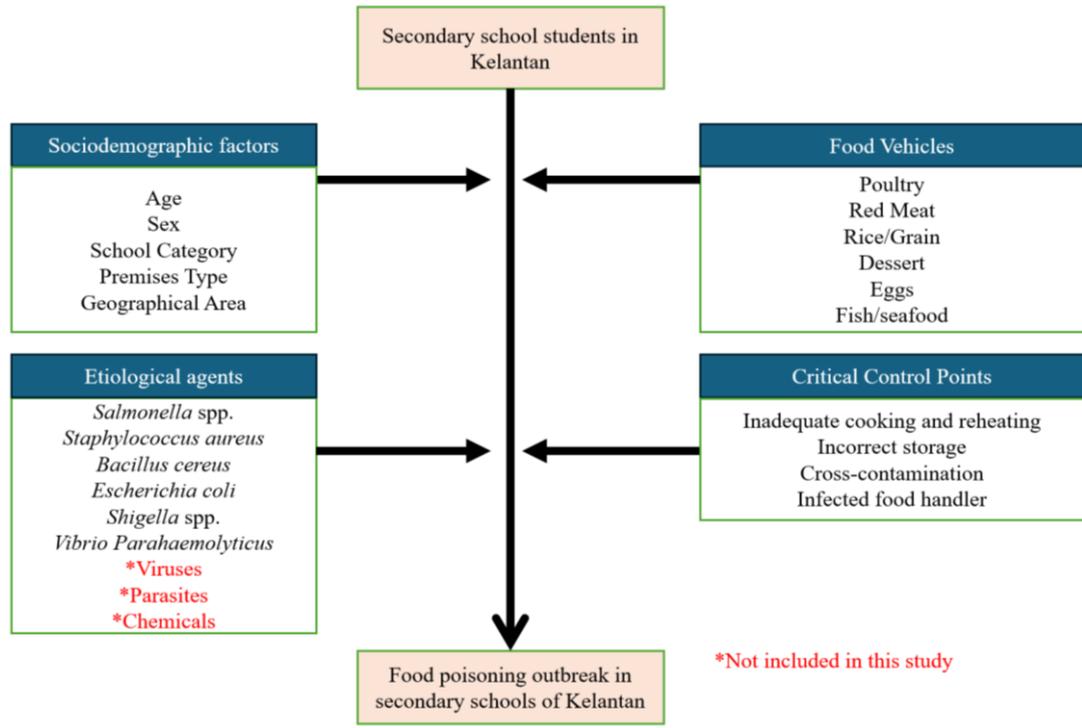


Figure 2.1: Conceptual framework of study

CHAPTER 3

METHODOLOGY

3.1 Study design

This study consists of two parts, which consist of descriptive cross-sectional study and case-control study within the outbreak population.

3.2 Study duration

This study was done from 1 January 2025 to 30 June 2025 (6 months).

3.3 Study location

The study involved all districts in state of Kelantan, Malaysia. Kelantan is located at the north-eastern coast of Peninsular Malaysia. Kelantan is bordered by Narathiwat province of Thailand to the north, Terengganu to the south-east, Perak to the west and Pahang to the south. It has eleven districts namely Bachok, Gua Musang, Jeli, Kecil Lojing, Kota Bharu, Kuala Krai, Machang, Pasir Mas, Pasir Puteh, Tanah Merah and Tumpat. Kota Bharu is the capital town of Kelantan. The estimated total population in Kelantan was about 1,792,600 in 2020. The children aged 10-19 years old population was about 385,100 and made up 21.5% of total population in Kelantan (DOSM, 2020). In Kelantan, there were approximately 418 secondary schools (78.1%) and 177 primary schools, indicating that the majority were secondary institutions (Ministry of Education, 2023).