

## REVIEW

# Food safety interventions in low- and middle-income countries in Asia: A systematic review

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## Abstract

Effective and sustainable interventions are necessary for long-term improvement of food safety. This review provides a summary of food safety interventions evaluated in selected low- and middle-income countries in Asia between 2000 and 2020. A systematic screening of published articles from PubMed and CabDirect databases was carried out with the aid of Rayyan QCRI software. A total of 25 studies were considered in the review. A 'before and after' study design was the most frequently used design (64%), while five studies (20%) used a randomized control trial (RCT) design. Interventions applied focused on training to improve knowledge, attitudes, and practices (KAP) towards safe food (60%) or on specific technologies (40%). Nine of the 25 studies were specific on the value chain considered: cattle (1), poultry (1), pigs (4) and fish value chains (3). Except for one study, all interventions reported some level of success; 17 were rated as having a high level of success, defined differently across studies. However, there is a clear evidence gap for the efficacy and cost-effectiveness of food safety interventions in market settings, both consumer- and vendor-facing. A rigorous and standardized assessment of intervention effectiveness and sustainability is recommended, to not only identify areas of improvement, but also to ensure scaling of interventions with demonstrated evidence of success and sustainability.

## KEYWORDS

Asia, consumers, food safety interventions, markets, systematic review, vendors

## 1 | INTRODUCTION

Foodborne diseases (FBD) can be defined as any illness caused by ingesting contaminated food or drink. The most common clinical presentation of foodborne diseases is gastrointestinal symptoms, but foodborne diseases can also lead to chronic, life-threatening symptoms including neurological, gynaecological, or immunological disorders as well as multi-organ failure, cancer and death (Grace, 2015).

Foodborne diseases are a significant threat to public health. Based on the first global study by the World Health Organization, in 2010, 31 FBD caused approximately 420,000 deaths and 600 million illnesses worldwide, resulting in a burden of 33 million Disability Adjusted Life Years (DALYs) lost. A subsequent part of the same study estimated another 56,000 deaths and 9,000,000 DALYs lost from foodborne heavy metals in 2015 (Gibb et al., 2019). The burden of FBD was shown to be disproportional, borne by low- and

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middle-income countries (LMICs), with the continent of Africa leading in terms of per capita burden, seconded by South-East Asia. In the South-East Asian sub-regions, SEAR B and SEAR D, the food-borne disease burden is estimated at 690 and 710 DALYs lost per 100,000 population, respectively (Havelaar et al., 2015). The most affected demographic are children below the age of 5 years, who account for disproportionately more illnesses and deaths (Havelaar et al., 2015). The African and South-East Asian WHO regions also have lowest national food safety scores, just 45% and 51%, respectively in 2021 compared with 78% for the European region (SPAR, 2021 <https://extranet.who.int/sph/spar>).

There is an urgent need to invest in food safety especially in developing countries where most of the health burden accrues, and economic costs are more than USD 100 billion per year (Jaffe et al., 2019). Food safety interventions (FSI) can be categorized by the point within the value chain where they are implemented, moving from farm to fork; pre-harvest interventions may include the use of biocontrol methods in the management of fungal toxins (Ola et al., 2022), or vaccine use in animals (Charlier et al., 2022) or post-harvest activities such as spraying animal carcasses with lactic acid (Lambré et al., 2022) or exposing fresh produce to ultraviolet light (Yemmireddy et al., 2022). Interventions focusing on transport often aim to maintain a cold chain and traceability (Moore et al., 2020). Interventions targeting food processing facilities can mitigate disease risk in processed foods, for example, the pasteurization of dairy products reduces the risk of exposure to consumers (Ruegg, 2003). Apart from upgrading market infrastructure, few interventions have targeted retail (Grace et al., 2018). Education and training interventions can target actors at any level in the value chain (Singh et al., 2016; Takanashi et al., 2013) while awareness creation typically targets consumers (Bass et al., 2022). A recent review of food safety training interventions (Global Alliance for Improved Nutrition (GAIN), 2022) categorized training by the underlying theory, audience, training environment and curriculum. It found the topics, training duration, and learning outcomes were highly variable, and a wide range of media were used (from lectures, to guided practice, to parades, to behavioural nudges).

Attempts to improve food safety especially in LMICs face a number of obstacles including (i) weak public health systems leading to poor disease and pathogen identification; (ii) absence of rigorous epidemiologic investigations to establish source attribution, blurring logical assertions on whether the cause of the illness was unsafe food, drinking water, animals, the environment, people or a combination of factors, and (iii) poor reporting of FBD (Grace, 2017). A plan that aims to address these gaps would provide a good basis for successful implementation of food safety interventions.

National food control systems have been defined as a combination of mandatory regulatory approaches (e.g., inspection) with preventive and educational strategies along the entire food chain that assures the quality, legality, and safety of foods (FAO and WHO, 2019). National food control systems can be considered along four dimensions: inputs (including legal framework and

## Impacts

- This review provides an overview of food safety training and technology-specific interventions that have been evaluated in selected countries in Asia.
- Training interventions to increase knowledge, attitude and practices on food safety were common.
- The review highlights the gaps in designs meant to assess impact or success, cost-effectiveness and sustainability of interventions.

recourses); control (including inspection and surveillance); communication (with domestic and international stakeholders); and evidence (including risk analysis and performance monitoring) (FAO and WHO, 2019). Considering these dimensions, legal frameworks in LMICs are often out-of-date and inappropriate while, by definition, resources are constrained (Grace, 2015). Control relies on food inspection but the limited effectiveness of this is shown by the fact that much or most of the food sampled in LMICs fails to comply with standards (Roesel et al., 2014); moreover, a situational analysis of six African countries found that the chance that a livestock products sold in a mass domestic market would be inspected was never more than one in 2000 and most commonly zero (Jabbar & Grace, 2012). Assessments of food safety in LMICs commonly note the lack of inspectors and inadequate guidance and governance concluding sanitary inspections may contribute little to food safety (Ntawubizi et al., 2020).

A review of available interventions, their efficacy and cost-effectiveness, is needed to inform decisions on what can be scaled up and what modifications may be needed to suit use in different contexts. We had previously conducted a systematic literature review (SLR) on food safety interventions in Africa, the region with the highest per capita FBD burden (Grace et al., 2018), and following from this, wished to conduct a SLR on food safety interventions in Asian low- and middle-income countries, the region with the second highest per capita FBD. The review was undertaken as part of a donor-funded project 'EatSafe; Evidence and Action Towards Safe, Nutritious Food' with the findings expected to inform the design of interventions to implement as part of the program, as well as to inform future programming decisions. Ethical approval was not sought as the study only involved review of existing literature. No human subjects were interviewed.

## 2 | MATERIALS AND METHODS

### 2.1 | Selection of studies (search process)

The study was designed to capture food safety interventions conducted in Asia. The studies had to have been reported between the year 2000 and 2020 and published in English to be included in the

review. We limited the literature search to 2000 because we needed to put temporal bounds on the study, and based on our knowledge of the enormous changes in SE Asian food systems over the last two decades, we believed that studies before 2000 would be less relevant. A total of 20 Asian countries were purposively considered in the review: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka, Cambodia, Laos, Myanmar, Thailand, Vietnam, Brunei, Indonesia, Malaysia, Papua New Guinea, New Guinea, Philippines, and Timor-Leste. Observational studies, secondary data sources, or field experimental studies on interventions aimed at improving food safety or evaluation of food hazards or health impacts were included.

## 2.2 | Exclusion criteria

Exclusion criteria included: interventions not related to foodborne hazards, those only conducted in laboratories or controlled research farm settings (on-farm trials), those focused on prevalence or risk factor analysis instead of interventions, or those not implemented in the selected Asian countries, or those published before 2000 or after 2020.

## 2.3 | Keywords and publication search

Search strategies were developed using the population, intervention, comparison and outcome (PICO) format using Medical Subject Headings (MeSH). Keywords were defined and combined into appropriate syntaxes (Table 1). Searches were done in PubMed and CabDirect databases, on the 4 November 2020 and outputs exported to Rayyan QCRI software (Ouzzani et al., 2016) from where duplicates were sought and removed.

TABLE 1 Databases searched, and search syntax used in the review.

Database	Syntax	No. of hits
PubMed	((foodborne OR "food safety" OR "safety label" OR "food hygiene" OR "food-borne" OR "food borne" OR "kitchen hygiene" OR "street food" OR abattoir OR slaughter* OR "willing* to pay" NOT "organic" NOT "indigenous" NOT "GMO" NOT "exotic") AND ("cluster random" OR Random OR "clinical trial" OR intervention OR trial OR experiment OR impact OR evaluation OR effect OR control* OR manag* OR improve OR achiev*) AND ("South Asia" OR "South East Asia" OR Afghanistan OR Bangladesh OR Bhutan OR India OR Maldives OR Nepal OR Pakistan OR Sri Lanka OR Cambodia OR Laos OR Myanmar OR Thailand OR Vietnam OR "Viet Nam" OR Brunei OR Indonesia OR Malaysia OR "Papa New Guinea" OR "New Guinea" OR Philippines OR "Timor-Leste") AND ("2000/01/01"[PDat]: "2020/08/01"[PDat]))	3150
CabDirect	(title: (foodborne OR "food safety" OR "safety label" OR "food hygiene" OR "food-borne" OR "food borne" OR "kitchen hygiene" OR "street food" OR abattoir OR slaughter* OR "willing* to pay" NOT "organic" NOT "indigenous" NOT "GMO" NOT "exotic") OR ab: (foodborne OR "food safety" OR "safety label" OR "food hygiene" OR "food-borne" OR "food borne" OR "kitchen hygiene" OR "street food" OR abattoir OR slaughter* OR "willing* to pay" NOT "organic" NOT "indigenous" NOT "GMO" NOT "exotic")) AND (title: (intervention OR trial OR experiment OR impact OR evaluation OR effect OR control OR manag* OR improve OR achiev*) OR ab: (intervention OR trial OR experiment OR impact OR evaluation OR effect OR control OR manag* OR improve OR achiev*)) AND (("South Asia" OR "South East Asia" OR Afghanistan OR Bangladesh OR Bhutan OR India OR Maldives OR Nepal OR Pakistan OR Sri Lanka OR Cambodia OR Laos OR Myanmar OR Thailand OR Vietnam OR "Viet Nam" OR Brunei OR Indonesia OR Malaysia OR "Papa New Guinea" OR "New Guinea" OR Philippines OR "Timor-Leste"))yr:[2000 TO 2020]1175	1175

## 2.4 | Article selection and screening process

Screening of articles was done in Rayyan QCRI software. The search results including the publication title, author list, journal, year, issue, page numbers, abstract and Digital Object Identifier (DOI) numbers, when available, were downloaded and uploaded to Rayyan®. After the duplicate removal was done, the articles were subjected to title and abstract screening against predefined inclusion and exclusion criteria. The screening was done independently by two reviewers. The included articles were then subjected to full-text screening. Reasons for the full-text exclusion have been provided (Figure 1). Any discordance in the classification of articles was resolved by a third reviewer.

## 2.5 | Quality assessment

Quality assessment of individual papers was based on the Cochrane assessment of bias criteria (Higgins et al., 2022). The included articles were classified as good, medium or poor quality. Articles that had an unbiased selection of subjects, had methods that were judged by the reviewers to be scientifically sound, with appropriate data analysis and complete results that articles were classified as good quality articles. Medium quality articles acknowledged and accounted for selection bias of subjects, limitations in data analysis, had methods that the reviewers understood, and had results that were valid.

## 2.6 | Data extraction and analysis

Table 2 presents a summary of the data extracted from the relevant articles. The data was summarized as proportions and presented in tables and figures.

## FOOD SAFETY INTERVENTIONS IN ASIA

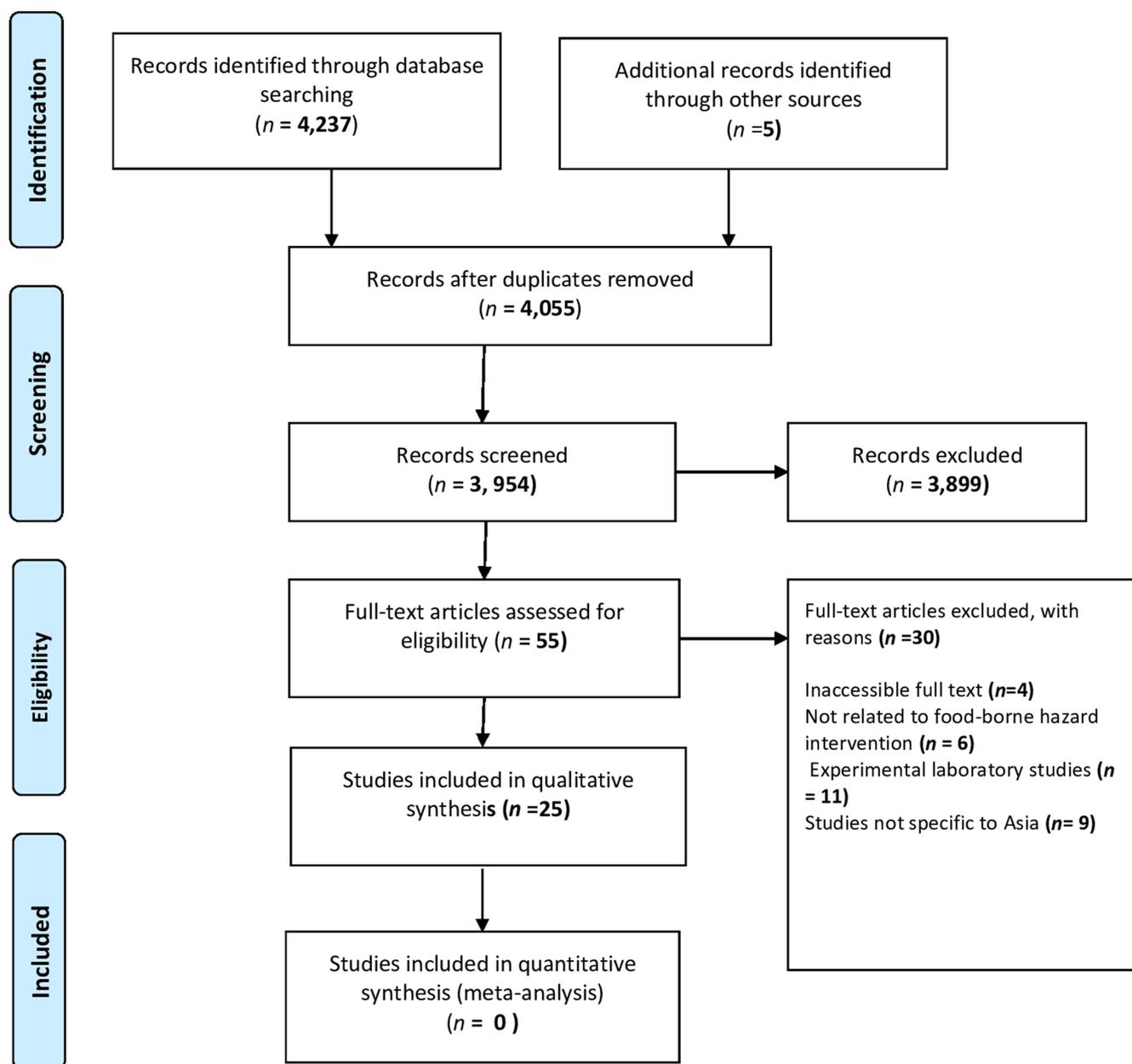


FIGURE 1 PRISMA flow diagram of article screening process. From: Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., The PRISMA Group. (2009). Preferred Reporting items for systematic reviews and Meta-analyses: The PRISMA statement. *PLoS Med*, 6(7), e1000097. 10.1371/journal.pmed1000097. For more information, visit [www.prisma-statement.org](http://www.prisma-statement.org).

### 2.7 | Impact assessment criteria

Three main categories of indicators were used to assess the effectiveness of the studied interventions and included: (a) the effect of the interventions on knowledge, attitudes, and practices (KAP), (b) reduction of the hazard prevalence, and (c) health outcomes. These were chosen based on a previous SLR for food safety interventions in Africa (Grace et al., 2018) which found that KAP was the most commonly measured outcome but least informative of impact, whereas health outcomes were least measured but most relevant to impact, with hazard prevalence intermediate other outcomes

identified in the review were less relevant to FBD (livelihoods, infrastructure, quality).

## 3 | RESULTS

### 3.1 | Outcome of the systematic screening

The PRISMA flow diagram showing the study selection process is presented as Figure 1. A total of 4237 articles were found after database search: 3049 from PubMed and 1188 from CabDirect.

Five more studies were found through reference screening (these were added later in the review process) and underwent the same screening process. Two hundred and eighty-eight (288) articles were duplicates and were thus removed. The total number of articles subjected to title and abstract screening was 3954. Fifty-five (55) of the 3954 met the inclusion criteria and were considered in the next stage of review. Twenty-five (25) articles were selected from the full paper review. The remaining articles (30) were excluded for the following reasons: experimental laboratory studies (11), did not specify the study country ( $n = 9$ ), the interventions were not related to improving food safety (6), or the full-text articles were inaccessible (4). Six of the articles were scored as having moderate quality and 19 as good quality. No article was judged to be of poor quality. Data were extracted from these 25 articles and subjected to qualitative analysis (see Tables 3 and 4 for a summary of the 25 articles). Sufficient data were not available to conduct a meta-analysis.

### 3.2 | Characteristics of the selected studies

The 25 publications were from studies done in India (7), Vietnam (4), Indonesia (6), Bangladesh (2), Laos (2), Malaysia (2) Thailand (1)

and Nepal (1). Most of the papers (60%) were published in 2016 and after (Figure 2).

The 'before and after' was the most frequently (64%, 16/25) used study design. In this case, the outcome of interest was measured before and after implementation of the intervention but with no randomization or control groups. Five studies reported the use of randomized control trials (RCT). In this case, two groups were considered, one group received the intervention while the other group did not and acted as a control. Two studies introduced a new approach to food safety intervention and measured adoption, while for the remaining two studies, the design as described by the authors does not fit into a RCT or a 'before and after' design.

Training to improve knowledge, attitude, and practice (KAP) towards safe food (60%), and technology-specific interventions (40%) were the main categories of interventions reported. Each of these interventions is described in the following sections. Most of the interventions (72%, 18/25) were applied at the household or food vendor level and focused on consumer safety. Sixteen (64%) studies involved informal food vendors; 7 (28%) were applied in the formal sector settings. Two (8%) were non-specific.

Nine of the 25 studies were specific on the value chain considered: cattle (1), poultry (1), pigs (4) and fish value chains (3). The value chain-specific interventions were applied at the household/vendor

TABLE 2 Type of information extracted from the most relevant papers.

Variable name	Additional description
Paper description/details	Paper ID, author, title, year of publication, year study was done
Country where study was done	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka, Cambodia, Laos, Myanmar, Thailand, Vietnam, Brunei, Indonesia, Malaysia, Papua New Guinea, New Guinea, Philippines, Timor-Leste
Did the intervention target specific value chains? If yes, which value chains	Yes, no Livestock, fish, cereals, vegetables, other
Describe the intervention	Description of what was done
Hazard group addressed	Biological, chemical
Specific hazard	Name of the hazard
Study design	RCT, before and after, with and without, adoption, review, conjoint, ex-ante, diagnostic validation
Sector of intervention	Formal, informal, not clear, NA
Level where intervention was applied	Farm/production, processing, human population, transport, market/retail, consumption, product storage
Outcome measured	Knowledge attitude and practice, hazard level or presence, health, compliance, willingness to pay, quality attribute, infrastructure, livelihoods, economic impact
Health outcome observed	Describe
If self-reported	Yes, no
Sample size used	Number
If the intervention was successful	Yes, no, partially (at least significance reported for one outcome), inconclusive
Measure of success and confidence interval	Number and CI estimate
Quality of the paper	Good, moderate, poor

TABLE 3 Description of approaches used to deliver food safety training.

Authors and year of publication	Description of approach used	Sample size (n)	Observed outcome
Bhattacharya et al., 2019	Video-based interactive sessions, designed booklets, continuous supply of logistics needed for personal hygiene and use of flip chart were offered to food handlers working in a medical college to improve their knowledge and practice on food safety	103	Improvement in personal hygiene of food from Score-1 (23.76) to Score-3 (42.57)
Choudhury et al., 2011	Street food vendors (mobile food vendors, owners of small restaurants and food handlers) from schools, colleges, marketplaces were trained on food handling practices using charts, flip charts, posters, motivational video films, role plays, demonstration, puppet shows and handouts	80	Increase in knowledge of food vendors from 24.35% to 66.2% after training interventions. The overall performance rating of full adoption increased from 37.5% to 50.8%
Dudeja et al., 2017	Use of an intervention package comprising of a Self-Instructional Manual in Hindi for food handlers working in eating establishments of hospital, short film for sensitization of food handlers on food safety titled 'Gravy Extra', and a documentary titled 'Food Safety from Farm to Fork'	280	Significant improvement in food safety knowledge and practice score of food handlers ( $p < 0.05$ ). Their attitude towards food safety changed in a positive direction ( $p < 0.05$ )
Dudeja & Singh, 2017	Use of monthly food safety inspection coupled with corrective suggestions as an intervention geared towards improving food safety practices by food vendors operating in eating establishments within/around hospital premises (These were mainly central hospital kitchen, cafeterias for hospital employees, restaurants, kiosks, canteens, and messes.)	36	Increase in food safety knowledge, attitude and practice scores of Eating Establishments ( $p = 0.000$ )
Islam et al., 2013	Four-week field training on how to attain the critical control point conditions during preparation of pre-weaning foods for children under five in 30 households	60 (30 intervention group, 30 control group)	Reduction in counts of faecal coliforms by 0.76 log <sub>10</sub> cfu/g and faecal streptococci by 1.24 log <sub>10</sub> cfu/g
Malhotra et al., 2008	Health education provided using posters and interactive sessions using a flip chart to improve knowledge and attitudes of food handlers working in Medical College in Delhi, India	18	Increase in knowledge on washing hands before handling food by 41.9% and keeping nails cut and clean 23.7%
Riaz et al., 2016	Use of courtyard counselling meetings to increase household knowledge and practices on food handling and preparation among selected households	194	Increase in food handling scores by 1.6% ( $p < 0.001$ ), Increase in knowledge about safe food by 24% and Mean scores increase on knowledge by 1.9 and practice (1.6) on food safety necessity to cook by 13%
Riyanto et al., 2017	Use of schoolbook covers and videos to provide food safety education to Public Elementary School students in Cimahi City to improve knowledge, attitude, and practice of street food safety	224 (112 intervention, 112 controls)	KAP of street food safety was improved. Knowledge improved by 85.7%, attitude by 27.7%, and practice by 38.4%
Riyanto et al., 2018	Use of an education program to improve the bacteriological and chemical safety of the food served by vendors in public elementary schools. Sanitation officer educated the vendors on food handling and preparation for 20–30 min a week for 6 months	54 (27 intervention, 27 groups)	Increase in food that is chemically safe by 29.6% increase in food that is bacteriologically safe by 59.3%
Nik Rosmawati et al. (2018)	Use of a Food Safety Education Programme in a community-based intervention to improve handwashing practices of food handlers at selected primary school canteens	79 (33 intervention group, 46 control group)	Improved handwashing practices among food handlers by 21.8%

TABLE 3 (Continued)

Authors and year of publication	Description of approach used	Sample size (n)	Observed outcome
Samaan et al., 2011	Provision of information to market stakeholders (finance and operations staff of the municipal market authority, general managers and sanitation teams of the live bird market, and members of the non-governmental organization (NGO), CHF International) on Avian Influenza A (H5N1) WHO guideline recommendations for visual inspection, cleaning, and poultry-holding practices, as well as infrastructural requirements for zoning and water supply and utilities	22	Market stakeholders' knowledge about the avian influenza A(H5N1) virus improved. They began to conform to the WHO guideline
Sesanelvira 2019	Use of mind map methods to improve knowledge, attitude, and practice on food safety behaviours among school going children	88 (44 intervention, 44 control group)	Improve in knowledge, attitude, and skills on food safety behaviours among school-going children (p-value = 0.000)
Sheth & Obrah, 2004	Food safety education imparted on mothers of underprivileged children to reduce the incidence of diarrhoea and improve knowledge attitude and practice of food safety. The food safety education package incorporated three messages: washing hands with soap and water, avoid feeding leftover food and keep surrounding clean. The messages were communicated through lectures, slogans, posters, charts, flash cards, role-play. Calendars and leaflets were also handed over to the mothers as education materials	200	Reduction in diarrhoea prevalence in children by 52% and improved KAP of mothers safe feeding practices
Singh et al., 2016	Use of customized counselling for each vendor in phase one, and laminated posters in Hindi on do's and don'ts of food safety displayed in phase two to improve food hygiene and safety of street vendors	20	Improvement in hygienic practices mean score from 4.75 to 5.15 Personal hygiene and habits mean score from 7.4 to 8.3
Takeuchi et al., 2017	Food safety education provided through use of pamphlets given to healthcare volunteers and local residents, use of public display banners in government offices, schools, markets, some villages and posters pinned in hospitals	Not determined	Decrease in the number of FBD cases to 13 and 10 in 2011 and 2012 respectively. Annual incidence decreased from 6.4/100,000 2.0/100,000 in 2012
Takanashi et al., 2013	Use of community-based information, education and communication activities on food hygiene and food safety behaviours. The educational messages were linked to diarrhoea. The main message was handwashing of children after toilet and before meals, and proper food handling practices	120	Reduction in diarrhoea prevalence from 21.6% to 7.6% after year one of intervention and 5.9% at the end of year two

TABLE 4 Description of approaches used to deliver technology-specific interventions.

Author & year of publication	Description of the intervention	Sample size (n)	Outcome observed and success of the intervention
Ash et al. (2017)	Implementing a One Health intervention covering both pigs and humans to control <i>Taenia solium</i> and soil-transmitted helminths. This included two Mass drug administrations (MDA1 and MDA2) for village residents using a triple dose albendazole 400mg treatment regime	Pretreatment-190, Post-treatment-185	The level of taeniasis decreased by 79.4% after the first mass drug administration, remained steady during the 5-month inter-treatment interval and decreased again by 100% after the second mass drug administration. The prevalence of STHs decreased by 65.5% and 62.8% after first and second drug administration respectively
Clausen et al. (2013)	Effectiveness of final host drug treatment and pond management strategies for the prevention of zoonotic metacercariae infection in cultured fish	Three farm groups each with five fish ponds	The intensity of metacercariae in fish from ponds receiving management interventions was reduced by 91.7% compared with before interventions
Fagerli et al. (2017)	Comparing the effectiveness of boiling drinking water and chlorination using Air RahMat on microbial quality of stored water, and effects on diarrhoea prevalence in children under five	281	Lower risk of <i>E. coli</i> in stored water treated with Air RahMat than boiling (risk ratio (RR) 0.75, lower risk of diarrhoea in households using Air RahMat (RR 0.43) than boiling
Lier et al. (2014)	Use of chemotherapy (50mg/kg praziquantel, split in two doses on the same day) as an intervention to curb fish zoonotic trematodes	539	The intervention was not successful. There was an increase in hazard prevalence (Fish trematode eggs in human stool)
Madsen et al. (2015)	Two-year on-farm intervention to control of fish-borne zoonotic trematodes in giant gourami ( <i>Osphronemus goramy</i> ) and striped catfish ( <i>Pangasianodon hypophthalmus</i> ) in nursery ponds	Intervention-5 farms for each fish species Control-5 similar farms for each species	Decrease in the odds of infection for giant gourami, odds of infection from 0.13 (95% CI:0.09–0.20; $p < 0.001$ ) to 0.07 (0.08–0.35; $p < 0.001$ ) in the intervention group. For striped catfish, the odds decreased from 0.17 (0.04–0.15; $p < 0.001$ ) ponds free from infection. Metacercariae intensity in giant gourami decreased from 0.16 (0.11–0.23; $p < 0.001$ ) to 0.07 (0.04–0.15; $p < 0.001$ ) while for striped catfish, the intensity decreased from 0.18 (0.09–0.36; $p < 0.001$ ) to 0.00 after intervention
Okello et al. (2017)	Impact of a joint human-porcine intervention package for control of <i>Taenia solium</i> through drug administration with a three-day albendazole 400mg protocol to humans and anti-cysticercosis TSOL18 vaccination and an oral dose of oxfendazole anthelmintic to pigs	Pretreatment -190, Post-treatment-185	78.7% decrease in crude prevalence of <i>Taenia solium</i> was reported
Siagian et al. (2015)	Assessed effect of irradiation of food taken by immunocompromised patients on body mass index and haematological parameters	45	An increase in albumin levels and maintained lymphocyte count was observed in the patients that took irradiated food
Poudel et al. (2019)	Implementation of a 3-monthly vaccination and medication program to reduce the prevalence of porcine cysticercosis	279 (Intervention area) and 218 (Control area)	Reduction in <i>Theridion solium</i> prevalence of 34.5% to 0 in the Intervention area
Wardhana and Soepraniondo (2019)	Study assessed effect of halal slaughtering on total plate count values of beef meat	60	Low level of hazard – All samples from slaughterhouses that used the Halal method lower total plate count than the maximum recommended

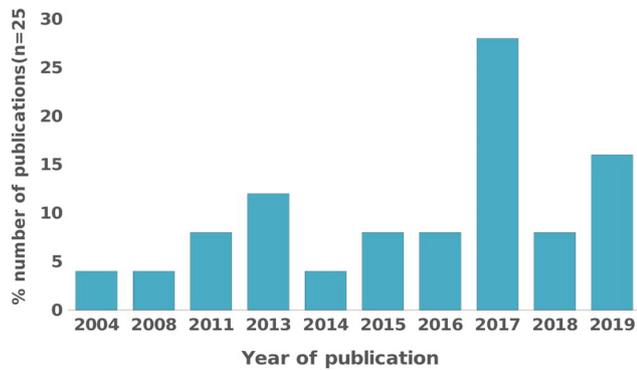


FIGURE 2 Year when the reviewed publications were published.

level (4), market/retail level (1), farm/production level (3) or at the level of the processing stage (1).

### 3.3 | Training and information-sharing interventions

There were 16 interventions on training and information sharing. A summary of the approaches used in delivery of food safety trainings is given in Table 3.

Nik Rosmawati et al. (2018) studied the effects of food safety training on handwashing behaviours of food handlers at school canteens. The mean percentage of hand washing practices of food handlers performing correct hand washing method significantly increased from 29% ( $\pm 24.17$ ) at baseline to 50.8% ( $\pm 30.58$ ) after the intervention; the mean for the control group was 35.06 ( $\pm 29.23$ ) at baseline and 37.59 ( $\pm 33.99$ ) after the intervention. With food safety intervention, mean percentage of handwashing practices increased by 21.8% (from 29% to 50.8%). Sesanelvira et al. (2019) studied how education using mind map methods influenced food safety behaviour of school-age children. Significant changes were reported in the scores, for the intervention, before and after the training, the mean values for knowledge (5.6), attitude (10.2) and skills (3.5), compared with the control group whose differences were  $-0.9$  (knowledge),  $-1.1$  (attitude) and  $0.5$  (skills). Singh et al. (2016) rated the hygiene and sanitation of 20 urban street vendors before and after a health education intervention. A health education intervention was carried out in two phases. In the first phase, two sessions of one-to-one counselling tailored to suit requirements of each vendor were held for 30 min. In the second phase, laminated posters in Hindi on do's and don'ts of food safety were displayed. The authors did not find any improvement in the overall score although significant changes ( $p < 0.05$ ) were observed for some of the domains (personal habits, hygiene, and food handling practices). Bhattacharya et al. (2019) studied food handler behaviour in a hospital setting and reported significant changes in hygiene scores;  $23.73 \pm 1.71$  (baseline),  $34.01 \pm 2.01$  (after 1 month of training) and  $42.5 \pm 1.80$  (after 2 months of training). The use of video-based training and administrative measures improved food handling scores significantly

( $p < 0.05$ ). Islam et al. (2013) identified control measures for critical control points in the preparation of food (at cooking, cooling, and feeding) at home and trained mothers for 4 weeks on how to minimize contamination. The findings revealed a reduction in faecal coliforms counts by 0.76 log<sub>10</sub>cfu/g and faecal streptococci by 1.24 log<sub>10</sub>cfu/g respectively after the intervention.

Samaan et al. (2012) reports on the provision of information to market stakeholders on Avian Influenza A (H5N1) WHO guideline recommendations for visual inspection, cleaning, and poultry-holding practices, as well as infrastructural requirements for zoning and water supply and utilities. The study reports an increase in knowledge attitude and practice and compliance to WHO guidelines after the intervention. Takeuchi et al. (2017) studied the use of education and information to healthcare volunteers and residents, display of public banners and posters to offices, schools and hospitals. The banners and posters contained message on behavioural change in slaughterhouses, restaurants and at home, that is, wear gloves while handling pigs, wash hands after handling pigs, do not consume raw pigs or pork, The intervention significantly reduced the annual incidence of *Streptococcus suis* from 6.4/100000-persons in 2010 to 2.0/100000 in 2012. The intervention was only effective in the first 2 years after the intervention. The increase in the incidence is attributed to existence of deep-rooted cultural behaviours and the necessity of continuous public health intervention. Riaz et al. (2016) studied the relationship between courtyard counselling meetings (CCM) on household food safety knowledge and practices. Participants were taught about food safety and good practices using the WHO's 5-keys to safer food and the 10 golden rules for safer food preparation. After intervention, mean scores of knowledge and practice on food safety were significantly increased by 1.9 and 1.6, respectively.

Sheth and Obrah (2004) assessed the impact of food safety training on KAP of mothers on safe feeding and reduction of diarrhoea in children aged 6–24 months. The training focused on aetiology of diarrhoea, personal hygiene, and environmental sanitation. The total reduction in the incidence of diarrhoea was 52% following the intervention. The severity of diarrhoea decreased from a baseline level of 24% to 19% after the intervention. Takanashi et al. (2013) studied the long-term impact of a community-based education program on food hygiene and food safety behaviours of caregivers of children aged 6 months to 4 years. The authors reported significant reduction of diarrhoea incidence in children aged between 6 months and 4 years (from 21.6% at baseline to 7.6% and 5.9 at first and second evaluation respectively). Riyanto et al. (2017) assessed the effects of food safety education using book covers and videos on knowledge, attitude, and practice of elementary school students. Following the intervention, significant positive changes were reported; increase in knowledge from 5.4% to 91.1%, increase in attitude scores from 69.6% to 97.3% and improved practices on food safety from 21.4%–59.8%.

Riyanto et al. (2018) reports the use of food preparation safety education of street food vendors around public elementary schools, 20–30 min a week for 6 weeks to improve bacteriological and chemical safety of food. This intervention led to a reduction in the

prevalence of food hazards (coliform, *Escherichia coli*, sodium borate/borax, formaldehyde, rhodamin B and yellow methanol), and an increase in food that is chemically safe by 29.6%, bacteriologically safe by 59.3% respectively, after the intervention. For the trained group, the number of vendors selling safe products significantly increased from 11%–70% for bacteriological safety and 70.4%–100% for chemical safety. No significant change was reported for the non-trained group and chemical quality was better for foods handled by the intervention group. Dudeja et al. (2017) assessed the effect of an educational intervention on knowledge, attitude and practices of food handlers in a hospital setting. Significant changes in the scores following the intervention were reported. Malhotra et al. (2008) assessed the effect of a health education on food handler's knowledge, attitude, and practices. Significant changes in the knowledge of foodborne diseases and hand hygiene practices were reported. Dudeja and Singh (2017) studied the use of monthly food safety inspections coupled with corrective suggestions to improve the safety practices of food vendors operating within/around hospital premises. Significant changes in the scores of the establishments were reported post the intervention. Choudhury et al. (2011) studied the impact of training on food handling practices knowledge, attitude, and practice of food vendors. The training programme comprised of 15 sessions on personal hygiene, food hygiene, health and nutrition, and environmental hygiene. After the training, the knowledge level of the food vendors increased from an average 24.35% to 66.2%.

### 3.4 | Technology- specific interventions

A summary of the nine technology-specific interventions is given in Table 4. The interventions used 'before and after' design (6/9) and mostly measured hazard presence (7/9). The studies demonstrated some level of success except one study that failed to demonstrate the success of the intervention. Siagian et al. (2015) analysed the effects of irradiated ready-to-eat foods on the health of immunocompromised residents of the National Narcotic Board in Bogor, Indonesia. Safe traditional ready-to-eat foods were irradiated at an irradiation facility and the process maintained under cryogenic conditions to protect essential dietary nutrients from free radical attack. The food was then given to immunocompromised people in the intervention group over a period of 21 days. No effect was found on body mass index, but increased albumin levels were reported in the group that consumed irradiated foods.

Poudel et al. (2019) reported a reduction in the prevalence of *Taenia solium* from 34.5% to 0 in the intervention area following a 3-monthly porcine vaccination and anthelmintic program. The intervention involved vaccinating pigs with the TSOL18 recombinant vaccine (Cysvax, IIL) every 3 months, and an oral treatment with 30mg/kg oxfendazole (Paranthic10% MCI, Morocco) given at the same time. Ash et al. (2017) investigated the impact of a triple-dose albendazole regime on controlling *Taenia solium* and soil-transmitted helminth infections. Participants (190 and 185 in pre- and post-treatment respectively) were treated with two mass drug administration with

triple dose albendazole 5 months apart. This intervention achieved a significant reduction in the level of taeniasis by 79.4% and 100% after the first and second mass drug administration. The prevalence of soil-transmitted helminths was also reduced by 65.5% and 62.8% after the first and second mass drug administration, respectively. Okello et al. (2017) assessed the impact of a joint human-porcine intervention package for the control of *Taenia solium*. It involved mass drug administration with a 3-day albendazole 400mg protocol to humans and anti-cysticercosis TSOL18 vaccination and an oral dose of oxfendazole anthelmintic to pigs. Following the intervention, a 78.7% decrease in crude prevalence of *Taenia solium* was reported.

Madsen et al. (2015) studied the effectiveness of on-farm interventions on control of fish-borne zoonotic trematodes in juvenile striped catfish and giant gourami. The interventions included reduction in fish trematode egg contamination through treatment of infected people and domestic animals, reduction in snail density through mud removal from aquaculture ponds prior to fish stocking, and various other measures. The study comprised of five intervention farms for each fish species as well as five similar control farms for each species. Following intervention, the odds of infection for giant gourami decreased from 0.13 (95% CL:0.09–0.20;  $p < 0.001$ ) to 0.07 (0.08–0.35;  $p < 0.001$ ) and from 0.17 (0.04–0.15;  $p < 0.001$ ) to ponds free from infection for striped catfish. Metacercariae intensity in giant gourami decreased from 0.16 (0.11–0.23;  $p < 0.001$ ) to 0.07 (0.04–0.15;  $p < 0.001$ ) and 0.18 (0.09–0.36;  $p < 0.001$ ) to 0.00 for striped catfish.

Lier et al. (2014) reports on the use of chemotherapy in people as an intervention to curb fish zoonotic trematodes although the intervention is not successful as there is an increase in fish trematode eggs in human stool. It involved 396 people with history of consuming raw fish. Stool samples were taken 2, 16, 29, and 60 weeks after the intervention and examined for the presence of the parasites. High rates of re-infection were reported. Preventive chemotherapy alone is not sufficient to curb transmission of zoonotic trematodes. Animal reservoirs and farm management practices must be targeted to achieve sustainable control of zoonotic trematodes.

Clausen et al. (2013) report on the effectiveness of final host drug treatment and pond management strategies for the prevention of zoonotic metacercariae infection in cultured fish. Although the prevalence of fish-borne zoonotic trematodes in fish was not significantly reduced, the study demonstrated a reduction in the intensity of metacercariae by 91.7% in fish from ponds receiving management interventions. The intensity of fish-borne zoonotic trematodes was also significantly lower in the pond management group, compared with the drug treatment group and the control group, implying that improving farm and pond management practices can be effective in reducing fish-borne zoonotic trematodes infections without using drug treatment. Fagerli et al. (2017) compared the effectiveness of boiling drinking water and chlorination using Air Rah Mat on *E. coli* and effects on diarrhoea prevalence in children under 5 years. The findings showed a lowered risk of *E. coli* in stored water treated with Air RahMat than boiling, and a reduced prevalence of diarrhoea in children from households using Air RahMat.

## 4 | DISCUSSION

This study reviews food safety interventions conducted in selected Asian countries and illustrates a variety of interventions and their observed outcome on knowledge, attitude and practice, hazard presence and effects on health outcomes. Most of the interventions were done at the household or community level, with food handlers in different contexts, or with caregivers, where the studies involved children.

An increase in knowledge through training and provision of food safety information was the commonest outcome measured in most of the studies. Most training activities impacted on knowledge, which in some cases was shown to lead to improved food handling practices mediated by increase in knowledge and a reduction in the occurrence of foodborne hazards. Several studies have reported an increase in knowledge, attitude and practice related to food hygiene and handling practices following training (Dudeja et al., 2017; Malhotra et al., 2008; Riaz et al., 2016; Samaan et al., 2012). A meta-analysis of studies on training interventions to increase knowledge and attitude of food vendors on food handling practices produced a significantly higher summary effect than those without the training (Soon et al., 2012). World Health Organization. (1999) and Sivaramalingam et al. (2015) recommend that food safety interventions should focus on the dissemination of knowledge that leads to change in behaviour theories and engaging the targeted population in research. Training may be more feasible logistically and financially compared with other interventions since it requires fewer resources. Soon et al. (2012) recommends that refresher training and long-term reinforcement of food handling behaviours, which may be beneficial for sustainability of practices such as adequate hand washing.

The training activities in the studies reviewed employed a wide range of approaches and media tools like printed materials and videos. In-person training or assessment visits were most reported in the review. This agrees with a scoping review by Sivaramalingam et al. (2015) which reported trainings through sessions and workshops as the commonest mode of delivery. Advanced information technology involving the use of the internet and mobile phones were historically not common hence most studies did not use these media channels. Singh et al. (2016) noted that the contribution from other stakeholders and food systems is critical in improving the levels of food safety since education and training alone is not adequate. Availability of government services like provision of potable water, relevant infrastructure, and transport services impacts food safety levels (Gabriël et al., 2018).

Nearly twice as many training interventions (16) were identified as compared with technology interventions (9), suggesting that training may be more feasible. Among the training interventions, most evaluated changes in KAP with only two measuring changes in hazard and three in health outcomes; all the technology interventions measured hazard outcomes (4), health outcomes (4) or hazard and health outcomes. As changes in knowledge, and even practice are intermediate outcomes, they provide less evidence of impact than changes in hazards or health parameters. It is well established

that learning decays with time and hence requires refreshment; in contrast, new technologies, once adopted can be integrated into normal working. In terms of costs and complexity, technologies showed greater range, from much simpler and cheaper than training (e.g., administering a worm tablet) to more complex and expensive (pond management and fish health).

Most of the reported food safety interventions were general and did not target a specific value chain and pathogen. However, a few targeted specific hazards, including: *Taenia solium*, *E. coli*, zoonotic fish trematodes, faecal coliforms, and faecal *Streptococcus*. Unsurprisingly, training was more general (15 out of 16 interventions), while technologies were more likely to target specific hazards (six out of nine interventions).

All interventions focused on specific pathogens targeted zoonotic foodborne pathogens. These may require different types of interventions at different stages of the value chain. The control effort can either be directed to controlling the pathogens in live animals or humans or both (Gabriël et al., 2018). More specific interventions are needed to control specific pathogens for various value chains. Effective control of fish-borne zoonotic trematodes in a community requires repeat treatments, for 1 year or more, to reduce risks of reinfections (Clausen et al., 2015). Single chemotherapy of reservoir hosts or humans, or both does not change the reproduction ratio whereas continuous chemotherapy of reservoir hosts or humans led to a decreased reproduction ratio of respectively 1.69 and 1.30, respectively (Boerlage et al., 2013). A practical and sustainable approach to controlling fish-borne zoonotic trematodes in aquaculture can be achieved through identification of critical control points in the fish production system, and protection of fish ponds from contamination by fish-borne zoonotic trematodes eggs (dos Santos & Howgate, 2011). Clausen et al. (2015) recommends adoption of an integrated approach based on education, improvement of infrastructure and farm management practices, targeting critical control points in the aquaculture.

The interventions in the review did not provide sufficient information to evaluate the cost-effectiveness of the programs. Several societal and economic factors may affect the adoption and sustainability of interventions (Grace et al., 2018; Hoffmann & Jones, 2021; Stepman, 2018) indicated that cost may be a big limitation to scaling up mitigation measures. Studies in Africa have discussed other factors that influence the uptake of interventions including acceptance by local communities (Hobbs et al., 2020), lack of relevant and appropriate facilities (Donkor et al., 2009) bias in the delivery of the intervention (Simiyu et al., 2020) and societal events like civic unrest (Rosenthal, 2019). More studies are needed to assess the cost-effectiveness of different food safety intervention strategies and factors influencing uptake and sustainability of such interventions in Asia.

This review identified very few interventions fitting the inclusion criteria. All identified studies utilized different definitions of success, not always based on clear indicators. Only five randomized controlled trials were identified of food safety interventions in the selected countries which provide high-level evidence. A similar

research gap in the number of controlled randomized trials has been reported by Sivaramalingam et al. (2015). Due to the lack of standardized measures or indicators of efficacy and lack of data on the costs incurred or avoided, no evaluations can be made of the relative cost-effectiveness of different studies. The main limitation of this review is the availability of very few food safety intervention articles. The success of the interventions was subject to the reviewer's judgement.

This review provides an overview of food safety interventions that have been evaluated and demonstrated some level of success in Asia. The relatively small number of published studies in the Asian countries included in the review shows the paucity of published evidence on effective food safety interventions in Asia. Most of the interventions provided generalized advice on food safety with a few focusing on specific pathogens and value chains. Majority of the studies assessed changes in knowledge, attitude, and practice as indicators through trainings. Training is the most common approach applied in the reviewed studies; reasons for this choice are usually not stated. It is possible that trainings, compared with other interventions, are more feasible logistically and financially for organizations with less resources. Training studies employed a broad range of approaches and media tools, from printed materials to videos and songs. In-person training or assessment visits were most common. Sophisticated information technology (e.g., mobile phones, internet) were historically not as widespread, so these media channels were not covered in the studies.

The review noted the absence of comprehensive project design in food safety interventions, the initiatives did not highlight high, medium and low-level outcomes anticipated upon implementation nor clearly defined 'impact' or 'success'. There is a clear evidence gap for food safety interventions in market settings, for both consumers and vendors. Food safety interventions need to leverage existing social networks to improve the dissemination and sustainability of such interventions. There is need for rigorous assessments of intervention effectiveness and sustainability as well as the identification of foreseeable impediments to inform the design of food safety interventions.

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#### CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

#### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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