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# Editorial: Food safety in low- and middle-income countries

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## Editorial on the Research Topic

### Food safety in low- and middle-income countries

This is the first special edition on food safety in informal markets in low-and-middle income countries (LMICs). Despite their important public health and socio-economic impacts, foodborne diseases have only recently gained the attention of development institutes and initiatives (Grace, 2023). This is the result of growing appreciation of the enormous burden of foodborne disease in LMICs: the health burden is comparable to that of malaria, HIV/AIDS or tuberculosis and the economic cost is more than 100 billion USD a year (Havelaar et al., 2015; Jaffee et al., 2019). Most of the burden is caused by microbial and parasitic infections and most of these are acquired from fresh foods purchased in mass domestic markets in LMICs (Grace, 2015).

These markets are easy to recognize but hard to define. They have been variously called informal, traditional, wet, embedded, and (more recently) territorial markets (Roesel and Grace, 2014; CFS., 2016). They typically include open public markets, kiosks/small shops, butchers, fruit stalls, street food and small-scale eateries. They often lack infrastructure, waste disposal is poor, and pests are common; much of the food sold is fresh, unpackaged, un-processed or traditionally processed and is cheaper than food sold in the modern sector; live animals (especially poultry and fish) may be sold and in some cases wildmeat and traditional foods such as insects; there is an absence of consistent or structured food safety and quality inspection. Informal markets are often supplied by small-scale farmers; workers are not salaried, lack qualifications and training, and often include women and youth; vendors of similar products tend to sell side-by-side with little differentiation of product or price; ready-to-eat food is often available; customers tend to shop frequently, buy in small quantities and be poorer and less educated than customers who patronize the modern food sector. Trust is a major factor in the customer-vendor relation, and vendors may provide added services such as credit or sale in small amounts. The size, variety, and impacts (both positive and negative) of these markets grow in importance as countries develop and urbanize. During this process food safety gets worse before it gets better (Jaffee et al., 2019).

Despite their importance for health, nutrition, livelihoods, equity and the urban environment, these markets have been largely ignored in the research literature (Grace, 2015). Therefore, this Research Topic aimed to bring together studies on foodborne

TABLE 1 Summary of 24 papers on food safety in informal markets.

Study	Methodology	Actor(s)	Product	Place	Hazard(s) or indicator	Key findings	References
<b>Risk assessment</b>							
KAP	Survey; multiple correspondence analysis	Farmers, processors, traders, consumers	Sour milk and local cheese	Benin	n/a	Poor hygiene along the VC; little training for VC actors; many farmers treat their animals without veterinary help. Different categories of farmers and processors, some with better hygiene.	Komagbe et al.
KAP	Survey	Shops slaughtering and retailing	Chicken	Burkina Faso	All hazards	Most informal (60%); 6% birds die during transport; facilities and practices exceptionally poor. Workers have no training.	Assefa et al.
KAP and prevalence	Survey and lab tests	Vendors	Milk	India	Staph.; E. coli; Klebsiella; Shigella	No vendors had received training. Different categories of vendors. 65% of samples had AMR bacteria.	Sharma et al.
KAP	Survey	Growers and vendors	Vegetables	Cambodia	Microbial and chemical hazards	Most concerned about food safety; considered chemical risks more important; 20–50% used at least one risk mitigation practice.	Mosimann et al. (b)
KAP	Survey (online)	Consumers (pregnant women)	Food in (pregnant women)	Jordan	All hazards	Most received food safety information; least awareness of cross-contamination and temperature control. Improved practices during COVID pandemic.	Almanasrah et al.
KAP	Survey	Consumer	Raw and pasteurized milk	Kenya	n/a	98% purchased raw milk and 17% packaged weekly; informal markets key to nutritional requirements of children	Muunda et al.
KAP	Observation, photography, videography	Slaughter, transport	Pork	Vietnam	Meat borne pathogens	Poor hygienic practices and facilities. Difficult to change behavior. Slaughter un-regulated.	Ting et al.
Prevalence	Literature review	Farmer, retailer.	Irrigation water, soil and fresh produce.	Africa	Extended-spectrum $\beta$ -lactamase Enterobacterales	Environmental AMR studies rare outside South Africa. 13 studies found multidrug AMR potential pathogens in irrigation water.	Richter et al.
Challenges to food safety	Literature review	Slaughter, distribution, retail	Edible offals	Kenya	All hazards	Risky practices at slaughterhouse; weak enforcement of transport regulations; lack of hygiene and cold chain throughout VC.	Sirma et al.
Hazard prevalence and food quality	Survey and lab tests	Producers, collectors, vendors	Milk (raw, pasteurized), sour milk, cheese	Congo	E. coli, Staphylococcus Salmonella	All raw and pasteurized milk above coliform limits; Salmonella and Staphylococcus in all products.	Bacigale et al.
Hazard prevalence and health burden	Systematic literature review	Population	All food	Ethiopia	All hazards	High levels of microbial contamination in foods; no studies on health burden in people.	Gazu et al.
Hazard prevalence and health burden (diarrhea) and risk factor	Survey and lab tests	Livestock Farmers	All food	Cambodia	STEC; Staph.; Campy; Salmonella; Shigella	Diarrhea prevalence 9%. E. coli and Shigella in human stool; E. coli and Salmonella in animal samples. Poor hygiene and WASH risk factors. No link between bacteria in livestock and people in livestock-keeping households	Asakura et al.

(Continued)

TABLE 1 (Continued)

Study	Methodology	Actor(s)	Product	Place	Hazard(s) or indicator	Key findings	References
Health burden and attribution	Literature and modeling	Population	Animal source Food and vegetables	Ethiopia and Burkina Faso	Campy; ETEC; STEC; Salmonella	Substantial burden of FBD. Campy most cases, Salmonella most deaths and DALYs. Chicken highest burden followed by vegetables.	<a href="#">Havelaar et al.</a>
Health burden	Dietary health risk	Population	Chicken and Fish	Bangladesh	Chromium, Cadmium, Lead	Negligible risk	<a href="#">Begum et al.</a>
Health burden	Quantitative risk assessment	Population	Corn, peanut, rice, soybean, cowpea	Nigeria	Aflatoxin	2.8 cases liver cancer per 100,000 people a year; responsible about 2% of DALYs	<a href="#">Wenndt et al.</a>
Health burden	Quantitative Microbial Risk Assessment	Population	Chicken and pork salads	Cambodia	Salmonella	Around 10–15% fall ill annually from meat salads. Transmission is through cross-contamination not meat.	<a href="#">Rortana et al.</a>
<b>Risk management</b>							
Governance	Survey and KII	Entire value chain	Dairy	Tanzania	All hazards	Government lacks capacity to enforce rules but tolerates the informal sector. Informal actors concerned about safety and mitigate risk.	<a href="#">Blackmore et al.</a>
Governance	FGD, KII and observation	Entire value chain	Meat and Milk	Ethiopia	All hazards	Food safety compliance gap in both formal and informal markets. Government policy of formalization not well suited to food system.	<a href="#">Nyokabi et al.</a>
Interventions that improve safety	Literature review	Entire value chain	Chicken	Kenya	All hazards	Women and youth high participation in poultry VC and hence exposure to hazards but less power. Training, financial support and empowering women can improve food safety.	<a href="#">Garsow et al.</a>
Capacity to implement food safety	Survey	Farmers, distributors and vendors	Vegetables	Cambodia	All hazards	Vendors and distributors has high motivation and capability to improve food safety but less opportunity. Farmers has high motivation and less capability and opportunity.	<a href="#">Mosimann et al. (b)</a>
Technology	Nixtamalization maize and heat treatment soybean	Experiment	Maize, soybean	Democratic Republic Congo	Mycotoxins and antinutrients	Nixtamalization effective at reducing mycotoxins; heat treatment improves flavor of soybean and reduces anti-nutritional factors.	<a href="#">Matendo et al.</a>
Training and simple technology	Before and after milking hygiene intervention	Farmer and Collecting Center	Milk	Uganda	Total bacterial counts (TBC)	Mastitis on farm reduced. 97% of milk samples at MCC below standard because of post-farm contamination.	<a href="#">Sugino et al.</a>
Willingness to pay	BDM experiment	Traditional and upgraded shops	Pork	Vietnam	All hazards	Consumers willing to pay 20% more for pork from upgraded shops, sufficient to pay for the improvements.	<a href="#">Ngo et al.</a>
<b>Risk communication</b>							
	Survey	Consumers in modern and traditional markets	Pork	Vietnam	Microbial and chemical hazards	Received few messages on food safety; television and experts most trusted; wished for information on traceability and how to choose safe food; little concerns about animal welfare.	<a href="#">Le et al.</a>

VC, Value chain; n/a, Not available; Staph, Staphylococcus; Campy, Campylobacter; STEC, Shiga Toxin E. coli; ETEC: Enterotoxigenic E. coli; KAP, knowledge-attitude-practice; QRA, quantitative risk assessment; RA, risk assessment, RC, risk communication; RM, risk management; SLR, systematic literature review; Micr, microbiology.

disease in informal markets at national and sub-national levels with a focus on disease prioritization, risk assessment, management, communication and to develop recommendations for policy, practice and further research.

In all, 32 papers were submitted to the special edition and 24 were accepted. The papers were diverse in topic and geographical focus. Most were from Africa (14), which has the highest per capita burden of foodborne disease, followed by Asia (8), which has the highest overall burden of foodborne disease (Havelaar et al.; Gibb et al., 2019). Most studies were on animal source foods (17) followed by vegetables (5). These fresh products are high risk. Animals are reservoirs for many zoonotic pathogens and both animal source foods and fresh produce provide suitable matrices for pathogen survival and growth: as a result they are important sources of foodborne disease (Hoffmann et al., 2017). There were relatively fewer papers on parasites (but these have been perhaps over-represented in the literature) and chemical hazards (but in terms of human health impacts these are both more difficult to study and overall, less important than biological hazards).

Risk assessment predominated (16 papers), followed by risk management (seven papers) and only one paper focused on risk communication. Among risk assessment papers, seven reported knowledge-attitude-practice (KAP) studies, three microbiological prevalence findings, three were quantitative risk assessment (of which two included laboratory analysis), three were literature reviews, and two were on population disease burden. As such, the papers drew more on risk analysis and food science than on medical epidemiology. The eight papers on risk management included two focused on technologies, two on governance, and one on willingness-to-pay for safer food as an incentive for vendor behavior change. The importance of foodborne disease as a development issue has only been recognized in the last few decades, and it is natural that initial research focuses on understanding the problem and its extent. However, as more and more studies corroborate the importance of food safety, more emphasis on risk management and communication would be welcome.

The CGIAR was the first international research organization to have a major program on food safety in informal markets of LMICs. This started in 2006, and as of 2023, more than 8,000 outputs on food safety in informal markets are listed in the CGIAR repository (CGSpace, 2023). Most of the authors in this edition have links to this program (18 out of 24) as well as all four editors, which may also have contributed to the strong CGIAR representation.

## Key findings

While the special edition called for papers on food study in informal markets, some also looked at formal markets either as a comparator or to situate the informal market in the context of food systems. These studies confirmed the predominance of informal markets in Africa and much of Asia. For example, in Kenya 98% of household purchased unprocessed fresh milk at least once in the 7 days prior to the survey, while only 17% purchased packed pasteurized milk (Muunda et al.) and in Tanzania 95% of marketed milk passes through informal

channels (Blackmore et al.). Informal and formal markets co-exist and attract different clients. For example, in Vietnam, modern urban consumers trusted less in traditional wet markets whereas traditional urban consumers trusted more in them (Le et al.).

Informal markets are often seen as undifferentiated, yet detailed investigation reveal considerable segmentation. A study on the dairy chain in two Indian states identified five categories of milk vendor (Sharma et al.) while in Benin Komagbe et al. differentiated dairy farmers and producers of local cheese into different categories reflecting different practices. A study in Uganda illustrated the (often) porous boundaries between formal and informal markets: of nine licensed Milk Collection Cooperatives that sold milk to processing plants, seven also sold raw milk to shops and vendors and even individual customers (Sugino et al.). The characterization of different types of actors and customers can help in understanding risk and targeting interventions.

As previous studies have found, “if you look for hazards you will find them” (Roesel and Grace, 2014) and all the studies that conducted microbiological studies found hazards were present. Earlier work had also found that while hazards are often present, they are not always at high levels, and hazards may be present yet health risk not high. Several studies assessed disease burden. Three of these were quantitative risk assessments, the gold standard for prediction of disease risk from food. Heavy metals are of consumer concern in Bangladesh, but the risk assessment found there was currently low health risk from consumption of fish and chicken (Begum et al.). A risk estimate for hepatocellular carcinoma from consumption of five commonly eaten foods, estimated 2.8 cases per year per 100,000 people: a significant public health problem but only 2% of the total estimated burden of foodborne disease in the region (Wenndt et al.; Havelaar et al., 2015). This study assessed risk for five different commodities leading to more reliable estimates as there was an upper limit on the total burden. Finally, a quantitative microbial risk assessment from Cambodia established 10%–15% of consumers of chicken and pork salad became ill each year from salmonellosis (Rortana et al.). Importantly, the exposure route was not through the well-cooked meat but from cross-contamination within the household.

Previous studies had also concluded “informal sector food is not always dangerous and formal sector not always safe” (Roesel and Grace, 2014). One study on dairy products in the Congo found that both raw and pasteurized milk exceeded the relevant standards and both contained *Salmonella* spp. and *Staphylococcus* spp. and another in Uganda found only 13% of milk sampled from in the Milk Collecting Centers (formal sector) met standards, confirming the difficult of ensuring food safety even in formal markets (Bacigale et al.; Sugino et al.).

A systematic literature review found studies on hazards and burden of foodborne disease in Ethiopia. High levels of microbial contamination in different food value chains were often seen in the small, *ad-hoc*, observational studies that dominated the literature, but there were no reports on the incidence of foodborne disease or its health burden (Gazu et al.). Empirical evidence on foodborne disease is difficult to obtain in LMICs, so risk assessments are a useful tool in estimating health burden. Another study took

a different approach to estimating health burden by updating the World Health Organization Global Burden of Foodborne Disease study and complementing with a dedicated Structured Expert Judgement study to estimate the burden attributable to specific foods in Ethiopia and Burkina Faso. In both countries, the burden of foodborne disease was high and highest burdens were attributable to poultry, followed by vegetables (Havelaar et al.).

Seven studies focused on Knowledge, Attitude and Practice (KAP) of different value chain actors (Table 1). Four looked at more than one node on the “farm to fork” chain although only one took a whole chain approach considered best for understanding where risk is introduced, amplified and mitigated. In general, these KAP studies found low levels of knowledge, poor hygienic practices and that most value chain actors received little or no training. However, studies from Cambodia, Kenya and Tanzania also reported that informal value chain actors are concerned about food safety and actively implement risk mitigation (Blackmore et al.; Garrow et al.; Mosimann et al. (a)). This confirms the hypothesis that many actors are “well-intentioned but ill informed” and therefore benefits may be attained by increasing awareness. As found in other studies, there are misperceptions about risk. Especially chemical hazards tend to be feared more than biological (e.g., study on vegetables in Cambodia). The seven KAP studies developed their own instruments and while this allows contextualization, it raises the question as to whether better validity and comparability could be achieved by greater uses of standardized instruments, an instance of the toothbrush problem: “no self-respecting psychologist wants to use anyone else’s” (Elson et al., 2023).

Some papers also reported methodological innovation. A study of slaughterhouses in Vietnam study used videos and photographs to assess hygiene and sanitation (Ting et al.); a study in Jordan used an online questionnaire to investigate food safety knowledge among pregnant woman (Almanasrah et al.); a Cambodian study used the COM-B framework which considers capability (C), opportunity (O), and motivation (M) as three key factors capable of changing behavior (B) (Mosimann et al. (b)); a study in Benin used multiple correspondence analysis (MCA) to identify different categories of farmer and processor (Komagbe et al.); a study in Vietnam used a Becker-DeGroot-Marshak (BDM) experiment to collect data on WTP for pork from typical and upgraded pork shops (Ngo et al.).

Although food safety is a quintessential One Health issue spanning different sectors and populations, few studies used explicitly the One Health approach. One was a study in Cambodia, which cultured fecal and swab samples from livestock and stool samples from humans in the same livestock-keeping households (Asakura et al.). Another literature review, which took a One Health approach, was the only study to consider environment samples along with water and food commonly sampled (Richter et al.).

Six studies focused on risk management. The emerging “three legged stool” approach to improving food safety in informal markets has been developed by the CGIAR and partners and posits that food safety can be cost-effectively improved if and only if three essentials are met. These are (a) an enabling environment (meaning authorities on-board and minimally acceptable infrastructure); (b) appropriate training and technology for value chain actors; (c) incentives for behavior change (Grace, 2023). Two studies

looked at governance and found government lacked capacity to enforce regulations (Nyokabi et al.; Blackmore et al.). Two studies tested training and technology (both effective); two studies looked at incentives (price premium and motivation- both effective). However, none of the studies combined all three aspects and none investigated long-term sustainability and scalability of solutions.

## Conclusion

In the last decades, much information has been generated confirming the large health and economic burden of foodborne disease and that most of this burden comes from fresh foods sold in traditional (informal, territorial) markets (Grace, 2023). Knowledge is being generated that allows a better understanding of these risks and ways to manage them within their specific social, cultural, technical and infrastructure contexts. The Research Topic highlights the diversity of informal markets and the differing needs of stakeholders in these value chains, which is a challenge in terms of scalability. Successful interventions are emerging and future research should focus more on solutions especially in terms of scale and sustainability.

## Author contributions

DG: Conceptualization, Writing – original draft, Writing – review & editing. BB: Writing – original draft, Writing – review & editing. BH: Writing – original draft, Writing – review & editing. HN-V: Writing – original draft, Writing – review & editing.

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## Conflict of interest

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