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Review Article

Food safety challenges related to meat, fish, and poultry handling and processing in developing countries

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Abstract

Animal-derived proteins, mainly coming from meat, fish, and poultry, are vital for ensuring nutrition security, especially in many developing countries. However, poor handling practices throughout the supply chain pose serious risks of foodborne illnesses. This review explores the safety challenges related to the handling and processing of these items in developing nations. It highlights key shortcomings in pre-harvest management, such as weak veterinary oversight and limited disease control at the primary production stage. It also points out processing and distribution as potential contamination points, often worsened by poor temperature control, inconsistent application of Hazard Analysis Critical Control Point (HACCP) systems, and infrastructural issues. Globally, contaminated food causes about 10% of yearly illnesses, leading to roughly 420000 deaths. Therefore, strengthening quality and safety management systems at all stages—from production and processing to distribution and consumer handling—is crucial so stakeholders along the supply chain can effectively reduce these risks and protect public health. This review stresses the need for better veterinary services, improved disease management protocols, and strict safety practices to tackle these ongoing issues. Governments, companies, and NGOs should work on upgrading infrastructure, hygiene standards, and training, along with implementing regulations, to improve food safety management from farm to fork.

Keywords: Developing countries, Fish, Foodborne illness, Food safety, HACCP, Meat.

Introduction

Meat, fish, and poultry are recognized as main sources of animal protein worldwide, including in developing countries (Delgado et al., 2017; Gul et al., 2016). They provide sufficient amounts of amino and fatty acids, which are essential for body maintenance and functions, especially in vulnerable groups at risk of protein-energy malnutrition (Delgado et al., 2017; Leroy & Frongillo, 2019). According to Ritchie et al. (2018), the consumption of animal-derived protein foods is crucial for meeting daily dietary requirements across different populations. However, there is a public health concern related to consuming these animal-based foods due to their high risk of foodborne illness, particularly in developing countries. For example, WHO (2022) reported that nearly 1 in 10 people worldwide become ill after

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eating contaminated food, resulting in about 420000 deaths each year.

The high risks of contracting the illness are mostly due to contamination caused by poor handling, inadequate processing, and improper temperature control during storage (Kamboj et al., 2020; Sharif, et al., 2018). The study conducted by Newell et al. (2010) highlighted the leading epidemic foodborne diseases caused by bacterial contamination. Some of the most significant foodborne illnesses include salmonellosis, campylobacteriosis, and listeriosis. These foodborne illnesses are more harmful in developing countries because of the weak healthcare systems. The fragile healthcare infrastructure in these developing countries increases the burden on public health protection (Grace, 2015; Havelaar et al., 2015).

The social and economic consequences of unsafe food, particularly from meat, fish, and poultry, are severe in developing countries. This is due to multiple factors, including loss of productivity, medical expenses, loss of consumer confidence, food recall costs, and regulatory challenges (Focker & van der Fels-Klerx, 2020). Specifically, the social consequences are linked to increased vulnerability and lower quality of life among people already facing socio-economic challenges. This suggests that, to protect public health and maintain socio-economic stability, it is very important to ensure food safety (Faour-Klingbeil & Todd, 2020). This review aims to evaluate the current state of food safety practices related to meat, fish, and poultry in developing countries. The main goals are to identify key challenges, assess how effective existing food safety measures are, and recommend strategies to reduce food safety risks and improve safety practices.

Challenges in primary production

Animal health and disease control

Food safety issues related to meat, fish, and poultry face serious challenges in many developing countries due to animal health and disease control problems. These countries mainly have limited access to veterinary services and diagnostics, inadequate vaccination and treatment programs, and concerns about zoonotic diseases and antimicrobial resistance (AMR) along the value chain.

The lack of veterinary services and diagnostics in developing countries reduces the safety of meat, fish, and poultry. Untrained veterinary workers in Western Kenya sold 40% of antimicrobials without prescriptions, often unaware of AMR (Kemp et al., 2021). Due to distribution, financial, and operational challenges, Cleaveland et al. (2017) found that poor vaccination programs hinder disease control in some regions. Antimicrobial resistance is common in animal products. Multidrug-resistant *E. coli*, *Salmonella*, and *Campylobacter* have been found in poultry, cattle, and fish in Tanzania, Nigeria, Kenya, and Ghana (Founou et al., 2016; Kimera et al., 2021, Mshana et al., 2021). A typical beef value chain is shown in **Figure 1**.

Limited access to veterinary services and diagnostics

Veterinary services and diagnostics are crucial for improving animal health (Thrusfield, 2018). Limited access to these services in developing countries makes it difficult to monitor and maintain animals' health, which in turn complicates ensuring the safety of food derived from them. The key challenges include a shortage of veterinary professionals and inadequate veterinary infrastructure, which hampers effective monitoring and management of animal health (Grace et al., 2012). This can lead to incorrect or delayed diagnoses of animal diseases, worsening health problems and lowering the quality of animals and their products.

Inadequate vaccination programs and treatment options

Vaccination is a vital part of preventing and controlling infectious diseases in livestock and poultry worldwide. Inadequate vaccination programs in many developing countries raise additional concerns about animal health and disease management (Cleaveland et al., 2017), and the efforts focused on animal vaccination are often insufficient and poorly implemented. These issues stem from factors such as financial limitations, poor infrastructure, and a lack of prioritization and support from the government (Knight-Jones & Rushton, 2013). Consequently, animals in these regions remain vulnerable to numerous diseases,

which can lead to significant socio-economic impacts and threaten food safety.

A survey conducted among Tanzanian livestock farmers showed that only 16% of herds were vaccinated against key diseases like Contagious Caprine Pleuropneumonia and Peste des Petits Ruminants during a specific year. Major challenges included a lack of vaccine knowledge, perceived low disease risk, vaccine shortages, long distances to veterinary services, and high vaccine costs (Msoffe et al., 2022). A systematic review in Uganda found that national vaccination coverage for its 14.5 million cattle herd was below 5%, with about 1.1% of eligible livestock vaccinated between 2015 and 2020. Main barriers included vaccine supply issues, strain mismatch, and limited funding for large-scale vaccination campaigns (Vudriko et al., 2024).

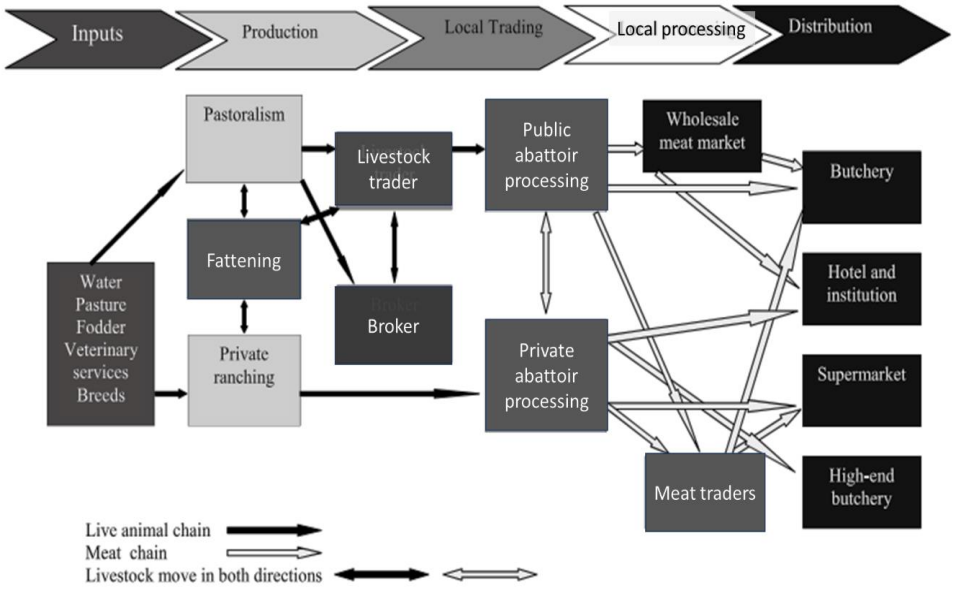

Figure 1. Beef value chain in developing countries (Ndiritu, 2020).

Due to limited infrastructure, veterinary services, and pharmaceutical quality, farmers often use broad-spectrum antibiotics and antiparasitic drugs without veterinary guidance, raising concerns about antimicrobial resistance (Grace, 2015). Traditional herbal remedies and indigenous knowledge are still widely used, especially in rural areas without modern healthcare (McCorkle et al., 1996). Community-based animal health workers can fill gaps in the veterinary profession by providing basic treatment and preventive care in distant locations (Catley et al., 2002). NGOs and governments also run mobile veterinary clinics for deworming and outbreak management.

Zoonotic diseases and AMR concerns

Another critical challenge in the primary production of meat, fish, and poultry in developing countries is zoonotic diseases and AMR. These zoonotic diseases and antimicrobial resistances pose significant public health threats. Inadequate disease control measures and poor agricultural practices in livestock and aquaculture systems can facilitate the spread of zoonotic diseases (Grace, 2015). Furthermore, the excessive and improper use of antibiotics in livestock and aquaculture significantly contributes to the emergence of antimicrobial resistance in animals, which subsequently becomes a public health threat due to the development of resistance to antibiotics after consuming food products derived from meat, fish, and poultry showing AMR characteristics (Van Boeckel et al., 2019). The rise of antimicrobial resistance weakens the effectiveness of medical treatments and poses a substantial risk to global health security. Bacterial antimicrobial resistance is estimated to have caused 4.95 million deaths worldwide in 2019, with 1.27 million deaths directly attributable to it (WHO, 2023). Additionally,

it was reported that roughly 10% of the global population falls ill after eating contaminated food, resulting in approximately 420000 deaths each year (WHO, 2022).

Pre-harvest practices

Uncontrolled use of antibiotics and growth promoters

Antibiotics and growth promoters are used in livestock and aquaculture systems before harvest to keep animals healthy and increase yield. However, their misuse and uncontrolled application pose significant challenges in developing countries. Weak enforcement of regulatory controls substantially contributes to this problem (Tiseo et al., 2020). In most cases, farmers often misuse antibiotics and growth promoters to treat sick animals or, in some instances, use them as preventive measures instead of vaccination (Albernaz-Gonçalves et al., 2021; Pokludová, 2020). Additionally, inappropriate use is worsened by limited knowledge and access to veterinary advice, leading to excessive and improper antibiotic use (Van Boeckel et al., 2019). These practices greatly contribute to the development of antimicrobial resistance (AMR), which poses serious health risks by reducing the effectiveness of antibiotics in both veterinary and human medicine (Tang et al., 2023). This resistance makes medical treatment more difficult by mainly decreasing the efficacy of existing antibiotics (Tang et al., 2023).

Effective management of AMR in livestock and aquaculture systems is vital, involving a mix of regulation, education, and public health strategies (WHO, 2015). Increasing surveillance of antimicrobial sales and usage and restricting non-therapeutic antibiotic use, especially as growth promoters, are key parts of regulatory frameworks (Tiseo et al., 2020). Preventing disease outbreaks through immunization and biosecurity can lower antibiotic use (Tang et al., 2023). Additionally, farmer education and stewardship programs are essential for proper antimicrobial use, particularly among smallholder producers who often lack veterinary support (Van Boeckel et al., 2019). Governments need to support veterinary extension services and enforce prescription-only policies for critical antimicrobials (Odetokun et al., 2021). The One Health approach, encompassing human, animal, and environmental health, should guide the implementation of national AMR action plans (WHO, 2015).

Deficient animal feed safety and hygiene

Feed safety and hygiene are vital for animal health and public food safety, greatly affecting livestock productivity and human health (Negash, 2018; Pandey et al., 2019). In many developing countries, regulations on animal feed are often inadequate, leading to contamination by pathogens and toxins, including mycotoxins like aflatoxins, which are associated with liver cancer and other serious health problems in humans and animals (Ababio & Lovatt, 2015). The risks worsen with the use of low-quality ingredients, unapproved additives, and agricultural waste, which reduce the nutritional value of the feed and introduce harmful substances into the food chain (Artavia et al., 2021; Mahato et al., 2019). Limited infrastructure for feed production, storage, and transport further increases the likelihood of contamination and spoilage (Bedane et al., 2022). To address these challenges, it is crucial to improve compliance with Codex Alimentarius feed standards (Codex Alimentarius Commission, 2020), implement Hazard Analysis and Critical Control Point (HACCP) systems in feed mills (FAO & WHO, 2009), and strengthen regulatory frameworks for overseeing feed additives and ingredients (FAO, 2016). Additionally, support from international organizations such as the FAO can improve capabilities in risk assessment, regulatory enforcement, and farmer education, especially in low- and middle-income countries (FAO, 2020).

Inadequate sanitation and biosecurity measures on farms

Good sanitation and biosecurity measures are essential for ensuring the safety of meat, fish, and poultry products (Kopper et al., 2023; Nyokabi, 2015). Inadequate sanitation and biosecurity practices on farms in developing countries harm the reputation of the meat, fish, and poultry industries. The main challenges in this area include poor waste management, limited access to clean water, and insufficient pest control. This, in turn, promotes the spread of infectious diseases among animals, resulting in economic losses due to increased morbidity and mortality among infected animals (Grace, 2015). Moreover, ineffective biosecurity measures such as isolating sick animals, pest control,

inadequate infrastructure, and poor hygiene practices during pre-harvest in developing countries increase the risk of contaminating meat, fish, and poultry products with pathogens that pose serious risks to consumers (Founou et al., 2016). These shortcomings affect animal health and raise the prevalence of zoonotic diseases like brucellosis and leptospirosis in humans (Havelaar et al., 2015).

Challenges in processing and distribution of fish, meat, and poultry products

Slaughterhouse and processing facility limitations

Lack of proper infrastructure and hygiene control measures

Proper infrastructure in slaughterhouses is crucial for maintaining good hygiene along the processing lines (Kopper et al., 2023). However, in developing countries, poor infrastructure significantly hampers the effective implementation of hygienic practices. Many facilities lack essential infrastructure, such as effective waste management, a reliable supply of potable water, and modern equipment for cleaning the processing areas. This often results in unsanitary conditions that increase the risk of contamination and the growth of foodborne pathogens (Grace, 2015).

Inadequate waste management

Many slaughterhouses in developing regions lack effective waste management systems. This often results in improper disposal of animal by-products, creating unsanitary conditions and increasing the risk of contamination. Poor waste management can exacerbate the spread of pathogens and provide breeding grounds for disease (Olaimat & Holley, 2012). Nigerian slaughter facilities frequently show inadequate hygiene infrastructure, with workers noting the lack of proper water supply, cold storage, and organized waste collection systems. Offal is washed with drainage water, and indiscriminate waste disposal is common, directly raising the risk of zoonotic diseases from bacteria such as *Salmonella, Campylobacter, Brucella, and E. coli* O157. Ineffective waste management significantly contributes to environmental pollution and threatens the safety of meat supply chains (Odetokun et al., 2021). Despite years of awareness, many slaughterhouses in developing countries still lack proper waste disposal facilities. Singh et al. (2023) analyzed numerous slaughterhouses in rural India, finding that over 70% lacked adequate wastewater treatment, leading to contamination of local water sources with untreated effluents. These findings align with previous reports, highlighting only gradual progress in sustainable waste management. A recent study by Mbatha and Dlamini (2023) in South Africa noted that improper disposal of solid waste, such as blood, offal, and bones, sustains unsanitary conditions around slaughterhouses, thereby increasing the risk of zoonotic disease transmission.

Limited potable water supply

Slaughterhouses, which depend heavily on water for cleaning and sanitation, are especially vulnerable to the effects of insufficient water supply (Ovuru et al. 2024). Access to reliable and safe water is often limited in developing countries. Slaughterhouses frequently face irregular or inadequate supplies of potable water, which jeopardizes the cleaning and sanitation processes. Insufficient water availability can also hinder the proper execution of hygiene protocols (Olaimat & Holley, 2012). An inconsistent or inadequate supply of potable water in slaughterhouses can compromise cleaning and sanitation measures, potentially leading to meat contamination and the spread of diseases (Ovuru et al., 2024).

Outdated equipment

Slaughterhouses in developing countries often rely on outdated or poorly maintained equipment. This lack of modern technology reduces the efficiency and effectiveness of cleaning and sanitation procedures. Inadequate equipment can also lead to higher contamination rates and lower meat quality (Founou et al., 2016). Recent research shows that slaughterhouses in Sub-Saharan Africa use old or insufficient technology, along with poor infrastructure and basic tools (Adesola et al., 2024). This situation jeopardizes meat quality and food safety because sanitation capabilities are severely limited, increasing the risk of pathogenic bacteria contamination. According to Adesola et al. (2024), outdated tools and poor infrastructure allow pathogenic bacteria to survive on surfaces and carcasses, posing a threat to human health.

Temperature control issues

Refrigeration and temperature control systems are vital for ensuring the safety and shelf life of meat products; however, many developing countries lack these facilities. Improper cooling and storage of perishable animal-derived foods expose them to temperatures within the danger zone (5 °C – 63 °C), which encourages the rapid growth of pathogenic bacteria, including *Salmonella* spp., *Listeria monocytogenes*, and *Escherichia coli* O157:H7. These organisms can cause serious foodborne illnesses and often contaminate meat due to poor handling, cross-contamination, or inadequate chilling after slaughter (Kopper et al., 2023). Besides pathogens, spoilage bacteria such as *Pseudomonas* spp. and *Brochothrix thermosphacta* flourish in insufficient cold chain conditions, resulting in off-odors, slime, and discoloration that make the meat unfit for consumption. This issue is especially acute during transportation and distribution, where inadequate refrigerated vehicles and poor temperature monitoring worsen microbial growth and product spoilage (Kopper et al., 2023). In many developing countries, including Tanzania, slaughter often occurs in unclean environments without refrigeration or cooling facilities. Studies show that poor and inadequate cold chain infrastructure in Sub-Saharan Africa leads to high post-harvest and post-slaughter losses. Poor temperature control and transportation refrigeration contribute to microbiological deterioration and food waste. Indonesian research indicates that ambient slaughtering and meat processing promote bacterial growth. The lack of refrigerated transportation and storage raises contamination risks during distribution, especially for beef (Darmawan et al., 2022).

Poor sanitation facilities

Sanitation facilities in developing countries often suffer from inadequacy or poor maintenance, including insufficient hand washing stations, unclean restrooms, and a lack of proper cleaning equipment. These deficiencies can lead to poor hygiene practices among workers, increasing the risk of contamination (Founou et al., 2016; Nonga et al., 2013). Workers demonstrated inadequate carcass decontamination, insufficient equipment sanitization, and infrequent medical check-ups, emphasizing how poor sanitation facilities affect hygiene practices (Kimindu et al., 2023). Studies in slaughterhouses and retail outlets revealed common issues such as limited access to hand washing, lack of hot water baths, absence of chilling facilities, and limited cleaning equipment. These factors were associated with improper handling of carcasses and retail meat (Woldu et al., 2021). Additionally, Ovuru et al. (2024) conducted a focused review highlighting widespread deficiencies in personal and environmental hygiene, particularly the lack of potable water, sanitation infrastructure, and cleaning tools, which collectively increase the risk of microbial contamination.

Inefficient HACCP implementation

HACCP is a systematic approach to food safety measures. HACCP aids in reducing food safety risks by identifying and controlling potential hazards during food production, preventing contamination before it occurs (Motarjemi & Warren, 2023). Many meat, fish, and poultry processing facilities in developing countries lack proper and adequate HACCP implementation. This is due to several factors, including limited resources, inadequate regulatory support, and a shortage of technical expertise (Mensah & Julien, 2011). Consequently, critical control points in the meat, fish, and poultry production processes are not monitored or controlled effectively, increasing the risk of food contamination and foodborne illnesses (Hoffmann et al., 2012). Common foodborne bacterial diseases caused by consuming meat, fish, and poultry products are listed in **Table 1**. Additionally, there is a shortage of training and education on HACCP principles among stakeholders, which results in poor implementation of this crucial food safety measure (Havelaar et al., 2015).

Inadequate temperature control during processing and storage

The growth of pathogens largely depends on their surrounding temperature (**Fig. 2**). Controlling temperature outside the temperature danger zone (5 to 63 °C) during processing and storage is crucial to prevent the growth of pathogenic and spoilage microorganisms in meat, fish, and poultry products (Comi, 2017). The temperature danger zone is the range where most foodborne pathogens grow

quickly, posing serious food safety risks. Within this range, bacteria such as *Salmonella*, *E. coli*, and *Listeria monocytogenes* can multiply rapidly, especially in perishable products like meat, fish, and poultry. To limit microbial growth, foods must be kept below 5 °C during refrigeration or above 63 °C during hot holding or cooking. Maintaining temperatures outside this danger zone during processing, storage, and distribution is vital for controlling spoilage and preventing foodborne illnesses (Comi, 2017). Many processing facilities in developing countries lack reliable refrigeration and temperature monitoring systems. This often results in failure to maintain cold chains, which is essential for ensuring the quality and safety of perishable foods, including meat, fish, and poultry (Nkosi & Tabit, 2021). Holding foods within the temperature danger zone accelerates contamination and pathogen growth, increasing the risk of foodborne illness and greatly reducing the food's shelf life (Alum et al., 2016; Kussaga et al., 2014). Besides compromising food safety, poor temperature control also causes significant economic losses due to spoilage and decreased product quality (Diriba et al., 2021).

Table 1. Common foodborne bacterial diseases due to consumption of meat, fish and poultry products (Shaltout & Shaltout, 2024).

Disease	Bacteria	Major contamination point
Salmonellosis	*Salmonella* spp.	Contamination during slaughtering and processing, primarily through the fecal contamination
Campylobacteriosis	*Campylobacter* spp.	Cross-contamination during the processing
Escherichia coli infections	*E. coli* O157:H7	Contamination during the slaughtering process, primarily due to fecal contamination
Listeriosis	*Listeria monocytogenes*	Contamination during processing, and unlike many other bacteria, *Listeria* can grow at refrigerator temperatures

Challenges in the distribution chain of fish, meat, and poultry

Reliance on informal markets with poor hygiene practices

Market conditions also significantly influence food safety. The heavy dependence on informal markets for distributing fish, meat, and poultry in many developing countries challenges the hygienic quality of these foods (Bukachi et al., 2021; Hoffmann et al., 2019). Problems such as limited access to clean water, poor sanitation infrastructure, and inadequate pest and waste management are common in these markets, raising the risk of food contamination and foodborne illnesses (Kariuki, 2018). The lack of adherence to basic food safety practices—such as hand washing, waste management, proper storage, separation of raw and cooked foods, and pest control among market workers—poses serious safety risks. Furthermore, enforcing food safety rules in these markets is challenging, which increases the likelihood of foodborne illnesses among consumers (Hoffmann et al., 2019).

Inefficient cold chain infrastructure leading to temperature abuse

A cold chain is a temperature-controlled supply system crucial for maintaining the quality and safety of perishable food items. Meat, fish, and poultry are perishable foods that need an effective cold chain during distribution (Mercier et al., 2017; Nastasijević et al., 2017). In many developing countries, the situation differs due to poor cold chain infrastructure in processing and distribution. This lack of infrastructure raises the risk of food spoilage and contamination caused by temperature abuse throughout these chains (Weng et al., 2022). The absence of cooling facilities in processing plants and transportation lines leads to increased contamination and microbial growth (Grace, 2015). Consequently, consumers may struggle to find foods that meet safety and quality standards, resulting in public health issues and damaging the reputation of producers, processors, and distributors (Fox et al., 2018).

Lack of proper transportation and storage facilities

Proper transportation and storage infrastructure are vital for maintaining the quality and safety of meat, fish, and poultry throughout the distribution chain. However, developing countries often lack adequate transportation and storage facilities, which further worsen food safety challenges along the distribution process, leading to microbial and physical contamination during transit and storage (Fisher et al., 2012). This also causes significant food loss. Moreover, limited access to refrigerated storage facilities speeds up contamination and spoilage, thereby harming the quality and safety of meat, fish, and poultry (Grace, 2015). Additionally, poor packaging and handling practices during transit increase the risk of food contamination, further jeopardizing food safety (Liu et al., 2017).

Challenges in regulatory frameworks and enforcement

Limited capacity of regulatory bodies

Insufficient resources and manpower

Regulatory agencies are vital in ensuring food safety in any country. To use these agencies effectively, they need to be well empowered (Faour-Klingbeil & Todd, 2018). Many developing nations struggle because their regulatory agencies lack sufficient capacity, which slows down the enforcement and implementation of food safety laws and regulations (Jaffee et al., 2018; Ortega & Tschirley, 2017). These issues are often caused by a shortage of resources and staff needed to perform inspections, audits, sampling, and other enforcement tasks. Consequently, the risk of food contamination and foodborne illness outbreaks increases (Kotsanopoulos & Arvanitoyannis, 2017; Madilo et al., 2024).

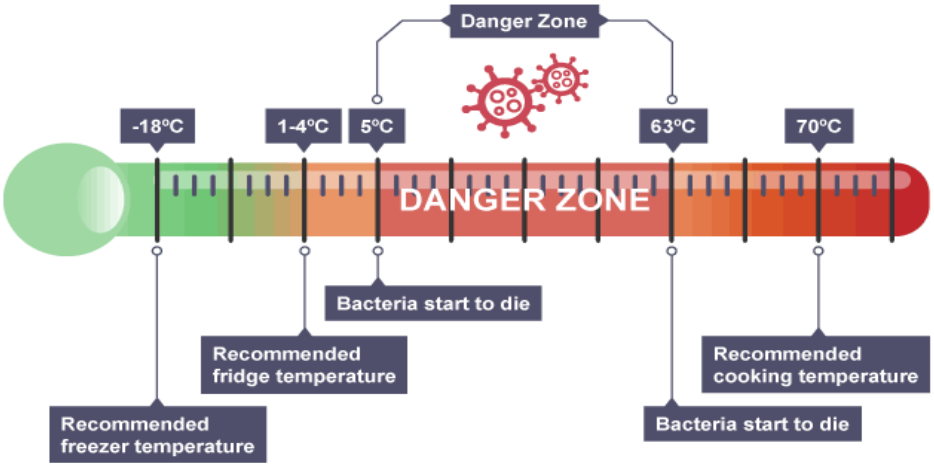

Figure 2. Temperature ranges and their effect on bacterial food pathogens (BBC Bitesize, 2025).

For example, in Kenya, the capacity of the regulatory body responsible for food safety, the Kenya Bureau of Standards (KEBS), is limited by inadequate funding and a shortage of inspectors, which results in gaps in enforcement and monitoring (Jaffee et al., 2018). Likewise, in Nigeria, the National Agency for Food and Drug Administration and Control faces challenges due to limited resources and personnel, hindering its ability to effectively oversee and enforce food safety regulations (Ortega & Tschirley, 2017).

Weak enforcement mechanisms

As regulatory bodies work to enforce and uphold standards, weak implementation mechanisms weaken the overall situation (Lambek et al., 2014; Marks, 2015). Additionally, Madilo et al. (2024) suggested implementing harsher penalties for non-compliance to boost enforcement effectiveness. This enforcement strategy fosters a culture of neglect for food safety procedures among industry stakeholders, from production to consumer, in managing hazards (McAllister, 2018; Si et al., 2018).

This issue is especially evident in many developing nations, including Tanzania, Kenya, and Bangladesh. These countries' regulatory agencies often lack enough tools, facilities, and expertise needed to enforce food safety regulations effectively (Lambek et al., 2014; Marks, 2015). A general disregard for food safety procedures stems from weak enforcement in these areas, which not only encourages non-compliance but also undermines the legitimacy and authority of regulatory agencies. According to McAllister (2018) and Si et al. (2018), in such situations, the lack of strict and consistent enforcement measures increases the risk of food hazards, potentially harming public health.

Difficulty in harmonizing regulations with international standards

Harmonizing national regulatory frameworks with international standards is a key challenge for developing countries (Chen et al., 2018). Fagotto (2014) and McAllister (2018) argue that inconsistent practices and efforts to promote food safety are main obstacles that hinder the development of trade partnerships in international business. Similarly, Adams (2023) and Eruaga (2024) highlight issues with barriers to adopting global trade standards, which fail to address systemic problems. Therefore, bridging this gap is crucial for establishing strong safety regulations that protect the public from foodborne illnesses and boost international trade (Keiichiro et al., 2015).

For example, countries such as Nigeria, Ghana, Kenya, and Zambia often face significant challenges when trying to align their national laws with global standards due to limited financial resources, lack of technical knowledge, and poor infrastructure (Chen et al., 2018). These challenges not only make it more difficult for them to comply with international trade rules but also increase the risk of food safety issues. According to Fagotto (2014) and McAllister (2018), inconsistent practices are a major obstacle to building trust in international trade partnerships. As noted by Adams (2023) and Eruaga (2024), unsuccessful efforts to fully adopt these standards highlight the need for a more systematic approach to addressing systemic issues. To improve food safety practices, access global markets more effectively, and protect their populations from foodborne illnesses, developing nations must work to close this gap (Keiichiro et al., 2015).

Consumer awareness and education

Limited knowledge about safe food handling practices among consumers

Insufficient consumer knowledge of safe food handling practices presents a major challenge to the safety of meat, fish, and poultry products in developing countries (Al Banna et al., 2021; Bukachi et al., 2021). Studies by Adebowale and Kassim (2017) and Roesel and Grace (2014) found that many foodborne illness cases are linked to a low awareness of proper food storage, preparation, and cooking methods. Likewise, Adzitey (2016) and Das et al. (2019) identified a lack of understanding of the essential cooking times and temperatures needed to eliminate parasitic and pathogenic microorganisms, leading to undercooked food that may contain harmful pathogens. In addition, limited education on preventing cross-contamination further raises food safety risks, as consumers might contaminate ready-to-eat meat or fish by using the same cutting boards and utensils for raw and cooked products without proper cleaning.

These knowledge gaps have a particularly negative impact in regions like Southeast Asia and Sub-Saharan Africa, where limited access to resources and education worsens the issue (Al Banna et al., 2021; Bukachi et al., 2021). In these areas, efforts to improve public health are impeded by consumers' lack of awareness of food safety procedures, which also contributes to the high rate of foodborne illnesses. Adebowale and Kassim (2017) emphasize that the cycle of foodborne illness is likely to continue without targeted educational interventions, especially in low-income and rural communities. Therefore, to reduce these risks and promote safer food consumption in developing countries, it is crucial to implement comprehensive educational campaigns and training programs focused on proper food handling, cooking, and storage practices.

Difficulty in accessing reliable information on food safety risks

The major barriers for consumers in developing countries are the availability of reliable information

related to food safety risks (King et al., 2017). Grace et al. (2012) reported that poor infrastructure, lack of free internet access, and high illiteracy rates pose significant challenges because they restrict the dissemination of information to consumers about potential hazards associated with unsafe practices during the production and processing of meat, fish, and poultry products. Additionally, Sanlier and Konaklioglu (2012) found that the lack of governmental and institutional commitment to gathering accurate and timely food safety information is a key issue that hampers consumer awareness. As a result, consumers often rely on rumors, informal sources, or primitive techniques when it comes to safety practices.

This knowledge gap is especially evident in rural areas of African countries, including Tanzania, Malawi, Mozambique, Ethiopia, Uganda, and others, where reliable sources of information are scarce. This increases the risk of foodborne infections (King et al., 2017). Widespread misinformation and the absence of structured communication channels make it harder to promote safe food handling practices. According to Grace et al. (2012), overcoming these obstacles requires comprehensive approaches, such as creating easily accessible information platforms and improving educational initiatives tailored to the local context. Additionally, Sanlier and Konaklioglu (2012) suggest that increased involvement from institutions and governments in food safety education and information sharing could significantly improve consumer safety behaviors and awareness, ultimately reducing the incidence of foodborne illnesses.

Socioeconomic factors influencing food choices and safety prioritization

Food choices and the emphasis on food safety among consumers in developing nations are closely linked to socioeconomic status. This factor likely limits consumers' access to safer food options due to the costs involved and leads them to choose cheaper alternatives that may pose higher safety risks (Roesel & Grace, 2014). Additionally, limited access to cold temperature control equipment such as freezers and refrigeration, as well as safe water supplies, presents further challenges, as these are essential for maintaining food safety from farm to fork (Grace, 2015). Research by Mensah and Julien (2011) shows that cultural behaviors and traditional preferences significantly contribute to unsafe food handling and preparation practices that do not meet modern food safety standards. Improving food safety and protecting public health in developing countries require addressing these socioeconomic factors (Hoffmann et al., 2019). Countries like Tanzania, Zambia, Nigeria, Uganda, and Zimbabwe demonstrate the importance of tackling these societal and economic issues. Due to the high cost of quality food products and the lack of refrigeration and clean water in some regions, less safe food options are often preferred (Grace, 2015). Furthermore, food handling and preparation methods in these countries are frequently influenced by customs and cultural practices that do not align with modern food safety regulations (Mensah & Julien, 2011). These socioeconomic challenges directly impact food safety and public health, highlighting the need for targeted efforts to address these issues in developing nations (Hoffmann et al., 2019).

Strategies for mitigating food safety challenges

Strengthening the food chain

Investments in infrastructure improvements for primary production and processing

The meat, fish, and poultry industries can easily benefit from investments in infrastructure in developing countries that improve food safety (Morris, 2023). Enhancing sanitation at both the source and processing stages of food production significantly reduces the risk of contamination and ensures high-quality final products (Jaffee et al., 2018). Slaughterhouses and processing plants are expected to meet safety microbiological standards by utilizing advanced equipment, machinery, and technologies (Henson and Humphrey, 2009). Additionally, it is essential to preserve the quality of animal-derived products and prevent the growth of spoilage and pathogenic bacteria during transit and storage by effectively controlling temperature in cold chain storage (Faour-Klingbeil & Todd, 2020).

To tackle food safety challenges, modernizing infrastructure has become essential in countries like Colombia, Bangladesh, and Kenya. For instance, updating slaughtering facilities with advanced processing and hygiene technology can greatly reduce contamination risks (Jaffee et al., 2018). Similarly, improving cold chain logistics helps keep meat and poultry products fresher for longer, decreases spoilage, and ensures compliance with safety standards (Faour-Klingbeil & Todd, 2020). Henson and Humphrey (2009) note that these investments boost the overall efficiency of the food supply chain in developing nations while also enhancing the safety and quality of food products.

Promoting best practices in animal husbandry and hygiene

According to Kopper et al. (2023), to ensure that meat, fish, and poultry are free from parasites and microbes, it is essential to promote and maintain a clean environment when handling animals. To reduce the occurrence of parasitic and pathogenic diseases transmitted through contaminated meat, fish, and poultry, training programs on proper animal care, nutrition, and veterinary practices were recommended by Grace (2015) and Shurson et al. (2022) for farmers, livestock keepers, aquaculture specialists, and producers. It is vital to emphasize hygiene and proper handling during processing to prevent the spread of food-borne and spoilage-related infections (Roesel & Grace, 2014). If the processing and manufacturing sectors are committed to achieving and upholding high hygiene standards, they must continuously monitor and follow acceptable hygiene practices (Henson and Humphrey, 2009). Developing countries like India, Kenya, and Ghana have benefited from adopting these best practices. For instance, improvements in livestock and aquaculture systems, along with better sanitation, have resulted in fewer cases of food poisoning and improved food safety in India (Grace, 2015). Similarly, Kenya has reduced food poisoning cases through enhanced training programs for aquaculturists and livestock keepers (Shurson et al., 2022). Initiatives to upgrade sanitary methods in fish and poultry processing have raised food safety standards in Ghana (Roesel & Grace, 2014). According to Henson and Humphrey (2009), these examples demonstrate how developing countries can enhance the quality and safety of animal products by implementing strict hygiene regulations and providing training.

Implementation of HACCP-based food safety management approach

The use of the HACCP based food safety and quality management approach is a recognized strategy designed to address food safety challenges (Dlamini & Adetunji, 2023). Implementing the HACCP approach for identifying and controlling potential hazards throughout the food value chain ensures that critical points are monitored and managed, with corrective actions taken effectively (Mensah & Julien, 2011). It offers guidance for developing countries on successfully implementing the HACCP approach and establishing robust food safety procedures that align with international standards, thereby improving the quality and safety of meat, fish, and poultry products. Regular training programs are crucial for stakeholders, including farmers, livestock keepers, and manufacturers, to enhance their expertise, experience, and skills necessary for the successful operation of HACCP systems (Roesel & Grace, 2014).

Many developing regions have demonstrated the effectiveness of HACCP systems in enhancing food safety outcomes through their implementation. According to Dlamini and Adetunji's (2023) research, adopting HACCP-based techniques can lead to significant improvements in the safety and quality of products derived from animals, thereby reinforcing compliance with international food safety standards. Supporting the importance of these techniques in achieving progress in global food safety is the link between implementing HACCP systems and better risk management of contamination, as well as more reliable food supply chains (Mensah & Julien, 2011; Roesel & Grace, 2014).

Capacity building and collaboration

Training programs for farmers, processors, and regulators

It is crucial to strengthen and enhance food safety in developing countries, especially within the meat, fish, and poultry industries, through the implementation of comprehensive training programs for farmers, food processors, and regulators (Shrestha & Khanal, 2019). These

programs should emphasize best practices in animal husbandry, hygiene, and safe processing techniques to minimize contamination risks (Roesel & Grace, 2014). Food safety training provides stakeholders with the essential knowledge to identify potential hazards and the effective control measures needed, thereby elevating overall food safety standards (Mensah & Julien, 2011). Furthermore, periodic training for regulators on modern inspection methods and the enforcement of food safety regulations is vital to ensure compliance and safeguard the public against any food safety hazards (Henson & Humphrey, 2009).

Inadequate training of stakeholders often worsens food safety issues in developing countries. For example, poor understanding of good animal husbandry and sanitation techniques can increase contamination risks and lower food safety standards (Roesel & Grace, 2014). Lack of training might prevent farmers and processors from implementing essential control measures, raising the risk of foodborne illnesses and degrading product quality (Mensah & Julien, 2011). Additionally, insufficient training for regulators can limit their ability to conduct effective inspections and enforce food safety laws, allowing hazardous practices to persist. Conversely, comprehensive training programs have been shown to address these gaps by improving practices and knowledge across the food supply chain, which enhances risk management and strengthens public health protections. This highlights the importance of launching targeted training initiatives to tackle food safety challenges and improve standards in the meat, fish, and poultry sectors (Henson & Humphrey, 2009).

Public-private partnerships for improved food safety initiatives

Enhancing public-private partnerships is crucial for advancing food safety initiatives in developing nations (Leigland, 2018). These partnerships can improve and strengthen the resources of both parties to implement inclusive food safety programs (Jespersen et al., 2017). Henson and Humphrey (2009) suggested that private corporations can offer technical staff with expertise and funding for infrastructure improvements, along with government support in regulatory provisions and supervision. In contrast, the collaborative facilitation and integration of best practices and innovations in food safety are vital for enhancing and sustaining solutions (Grace, 2015). The involvement of multiple stakeholders ensures a coordinated strategy to address various food safety challenges (Nayak & Jespersen, 2022).

The effectiveness of public-private partnerships in tackling food safety issues varies. Progress in food safety often faces barriers like poor infrastructure, weak regulatory frameworks, and limited resources (Nayak & Jespersen, 2022). Weak or poorly maintained partnerships result in gaps in infrastructure and safety practices, continuing the cycle of foodborne illnesses and undermining food quality. Without strong public-private collaborations, developing countries may continue to encounter persistent challenges and risks stemming from inadequate food safety systems. To improve food safety outcomes and solve ongoing problems in these regions, it is crucial to strengthen partnerships to ensure effective implementation and ongoing support of food safety programs (Leigland, 2018; Jespersen et al., 2017).

Knowledge transfer and technology advancements for developing countries

Knowledge transfer and technological advancements are essential for enhancing food safety in developing countries (Hassoun et al., 2024). Adopting experience and knowledge from developed nations can help bridge the gap in food safety issues and standards (Henson & Humphrey, 2009). Jespersen et al. (2017) suggested that implementing modern technologies, such as rapid diagnostic methods for food spoilage and foodborne pathogens, as well as emerging refrigeration systems, can significantly improve food safety. Similarly, food safety training initiatives that focus on knowledge transfer demonstrate the potential to empower local food handlers and stakeholders to implement and sustain these improvements (Roesel & Grace, 2014). Cooperative efforts among national and international organizations, governments, non-governmental organizations, and the private sector are also essential for streamlining knowledge and technology exchange programs (Grace, 2015).

Food safety issues are worsened in poor nations by inadequate knowledge transfer and limited access to advanced technologies. According to Jespersen et al. (2017), many locations face challenges related to limited refrigeration facilities and outdated diagnostic procedures, which increase the risk of foodborne infections and spoilage. Ineffective training programs further hinder regional stakeholders from implementing and maintaining new food safety standards, aggravating ongoing problems with contamination and poor food handling (Roesel & Grace, 2014). These issues are compounded by the lack of international collaboration and technology sharing, highlighting the need for strong knowledge transfer and technological advancements to bridge these gaps and improve food safety standards in underdeveloped countries (Grace, 2015; Hassoun et al., 2024).

Empowering consumers

Educational campaigns on safe food handling practices

Providing food safety education to consumers is a very important strategy for raising community awareness about safe food handling practices (Birke & Zawide, 2019). Proper use of social media, television, and radio campaigns to promote hygienic food handling, processing, and storage is crucial for mobilizing the community (Charlesworth et al., 2021). According to Bass et al. (2022), the use of media campaigns to educate consumers about food safety hazards significantly reduces the incidence of foodborne illnesses. The engagement and joint efforts of local community leaders, religious leaders, community health volunteers, and non-government organizations enhance the effectiveness of these campaigns by rapidly spreading information to specific groups (Insfran-Rivarola et al., 2020).

The issues with food safety in underdeveloped countries are often worsened by limited consumer knowledge and inadequate training on proper food handling techniques. Many communities in these regions lack sufficient food safety education and awareness, increasing the risk of foodborne illnesses caused by improper handling, preparation, and storage of food (Birke & Zawide, 2019). These problems are compounded by the absence of comprehensive and easily accessible food safety campaigns, which may leave people unaware of or unable to follow safe eating practices (Charlesworth et al., 2021). Improving public knowledge and reducing food safety risks can be achieved through media campaigns and targeted education programs. Addressing the gaps in food safety practices and understanding common in developing nations helps improve food safety outcomes and decrease the incidence of foodborne illnesses (Bass et al., 2022; Insfran-Rivarola et al., 2020).

Improved food labeling and traceability systems

Traceability systems and consumer awareness of reading food labels are essential for ensuring food safety (Bacarella et al., 2015). Proper food labeling provides critical information to consumers about the origin, ingredients, and shelf life of food products, enabling them to make appropriate choices (Aung & Chang, 2014). Tracking food items throughout the value chain is crucial for detecting points of contamination (Bosona & Gebresenbet, 2013). These schemes can protect public health by simplifying quick recalls and the withdrawal of unsafe products from the market (Karippacheril et al. 2017).

By utilizing digital traceability technologies, the food supply chain can become more transparent and accountable, aiding in the identification of contamination sources and ensuring product integrity (Bosona & Gebresenbet, 2013). Infrastructure and legal frameworks need improvement in underdeveloped nations to support efficient food labeling and traceability programs. Additionally, public health campaigns and educational programs can help consumers understand and use food labeling information, empowering them to make safer and more informed choices (Bacarella et al., 2015; Aung & Chang, 2014). Addressing these elements can help develop a strong system that significantly reduces foodborne illnesses and enhances overall food safety (Karippacheril et al., 2017).

Fostering consumer advocacy for food safety

The powerful strategy for driving improvements in the meat, fish, and poultry industries is to foster consumer advocacy for food safety (Abbasi et al., 2024; Rahman et al., 2014). Consumers can advocate for advanced safety standards and hold

manufacturers and regulators accountable for conforming to these standards (De Boeck et al., 2015). Similarly, Kher et al. (2013) found that creating a consumer advocacy group provides a platform for sharing knowledge and information, which can help in identifying common issues and developing collective solutions. Full participation of consumers in food safety discussions can lead to more transparent and responsive food safety policies, ultimately promoting the mobilization of the entire community (Fontes et al., 2015).

Effective food safety measures can face challenges in developing nations, such as limited resources, poor infrastructure, and weak regulatory frameworks (Abbasi et al., 2024). These areas can serve as platforms for sharing knowledge and information, which are crucial for identifying common problems and developing collective solutions by establishing and supporting consumer advocacy groups (Kher et al., 2013). Public health campaigns and educational programs can also enhance consumers' understanding of food safety risks and best practices, empowering them to demand higher safety standards and make informed decisions (Rahman et al., 2014). According to De Boeck et al. (2015) and Fontes et al. (2015), active consumer participation can lead to legislative reforms, close gaps in the current food safety system, and foster a culture of accountability and ongoing improvement— all of which can improve public health outcomes and lead to safer food products.

Conclusion

Ensuring global public health requires strong food safety management, especially for perishable items like meat, fish, and poultry, which are more vulnerable to contamination and foodborne illnesses. In developing countries, where food safety systems are often fragmented and weak, it is crucial to strengthen veterinary services, increase immunization coverage, and reduce zoonotic diseases and antimicrobial resistance. Strategic actions include proper antibiotic use, improved regulatory frameworks, and the systematic application of HACCP principles in processing facilities. Additionally, raising consumer awareness and education is vital for improving food safety practices. Through collaborative efforts with consumer advocacy groups, better traceability systems, and comprehensive food labeling programs, developing nations can tackle local challenges and make significant progress in food safety. These combined efforts, along with strict regulation and industry compliance, will improve global public health and ensure access to safer animal-based foods.

Conflicts of interest

The authors declare no conflicts of interest.

Disclaimer

Authors hereby declare that NO generative AI technologies, such as large language models (ChatGPT, COPILOT, etc.) and text-to-image generators, have been used during the writing or editing of this manuscript.

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