Infection and Drug Resistance

REVIEW

Foodborne Pathogens and Antimicrobial Resistance in Ethiopia: An Urgent Call for Action on "One Health"

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Abstract: Foodborne pathogens are the most common cause of foodborne disease worldwide. They contaminate food at all stages of the food chain, at the agricultural production level (soil and irrigation), from animal sources or at the time of preparation by food handlers. Therefore, food security is a critical issue that affects everyone in the world. Current studies indicate that the problem is more severe in low-income countries like Ethiopia. The majority of studies in Ethiopia have been conducted partially on human, animal or environmental samples with conventional culture-based diagnostic methods. Therefore, this review was conducted to gather information on the main foodborne pathogens and identify gaps in their traceability. Clinically important foodborne pathogens in Ethiopia include (*A. lubmbricoids, Toxocara* spp., *H. nana. E. histolytica/dispar, G. intestinalis, H. diminuta and C. belli*), bacteria (*Salmonella* spp, *E. coli O157:H7, B. anthracis, Yersinia, C. perfringens, Klebsiella* spp. *M. paratuberculosis*, and *L. monocytogenes*), and viruses like (rotaviruses, enteroviruses and astroviruses, hepatitis E virus). In Ethiopia, all isolated foodborne bacterial pathogens showed high rates of antimicrobial resistance (AMR). In particular, the most studied foodborne pathogens, *Staphylococcus* spp., *Salmonella* spp., and *E. coli* from specific sources, showing high levels of resistance to most of the antibiotics prescribed in Ethiopia. The occurrence and persistence of AMR in food is one of the main factors causing the spread of antimicrobial resistance in different compartments, humans, animals and the environment. Therefore, strategies of coordination and struggle from a One Health perspective is an urgent strategy to control antibiotic resistance in order to achieve better outcomes for human and animal health.

Keywords: foodborne pathogens, antimicrobial resistance, food, Ethiopia, one health

Introduction

Food is essential for survival. To properly maintain human health, it must be pure, nutritious and free of any kind of impurities. Foodborne illness is defined as any infectious or noxious disease caused by eating contaminated food. A foodborne illness outbreak occurs when two or more cases of similar foodborne illness occur after consuming a common food.[1] Physical, chemical, and microbiological agents can all contaminate food. Bacteria, viruses, parasites and fungi are microbial agents that cause foodborne illness.[2] Food contamination can come from many different sources. Contaminants include contaminated water, flies, animals and pets, dirty cookware and utensils, dust, and additional impurities. Contaminated feces, pus, respiratory secretions, and other infectious waste from unsanitary food handlers can contaminate food.[3]

Foodborne pathogens are a major public health problem worldwide.[4] Foodborne pathogens are one of the leading causes of illness in low-income countries, killing approximately 1.9 million people worldwide each year.[5] Even in developed countries, foodborne illnesses affect about a third of the population each year.[6] The effects of these pathogens also vary from region to region, as public awareness of food hygiene varies from country to country. Most foodborne pathogens are introduced as exogenous contaminants during handling, processing and preparation rather than as endogenous contaminants.[7,8] The problem is serious in developing countries such as Ethiopia due to limitations in ensuring optimal hygienic food handling practices.[9,10]

Received: 29 June 2022
Accepted: 29 August 2022
Published: 6 September 2022

Pathogenic bacteria contaminate food at all stages of the food chain, from farm to table.[11] Humans can acquire pathogens or their infection through the consumption of a variety of contaminated food and water, or through contact with infected livestock and other animal feces. Infected people and the environment are also sources of infection.[12] Some important organisms circulating in different compartments include *Campylobacter* spp., *Salmonella* spp., *Staphylococcus* spp., *Enterococcus* spp. and Enterobacteriaceae produce ESBL. These bacterial pathogens are recognized as a global One Health concern due to the emergence and rapid transmission of antimicrobial resistance (AMR) in humans, animals and the environment. However, there are few studies evaluating foodborne pathogens and their AMR profiles in humans, animals, food and/or the environment in low-resource settings. According to a recent WHO review, high-quality data on the prevalence and abundance of AMR in humans, animals and food is lacking in low-income countries.[13]

The problem of foodborne disease is exacerbated in rural communities where awareness about the causes, transmission, and prevention of foodborne infections is generally lower. Furthermore, well-documented information on the extent of foodborne disease in Ethiopia is lacking as many cases are not properly diagnosed or reported, and foodborne illness patients do not seek medical attention. Therefore, it is difficult to get statistical data or even estimate the extent of the problem, except to say that it is very large. Today, everyday food safety has become a major global concern with the influence of international trade and public health. Therefore, this study aimed to review existing reports on major foodborne pathogens and AMR and point out gaps in the distribution of foodborne pathogens.

Methods

A systematic review was carried out in Ethiopia to assess the level of foodborne pathogen and antimicrobial resistance in food. Literature searches were performed using PubMed, Google Scholar, Scopus, Science Direct, and hard copies of locally published articles were obtained. The literature search was performed between February 1 and March 30, 2021. All available Ethiopian studies and data on foodborne pathogens and antimicrobial resistance from food reported in English have been compiled.

Literature Review, Discussion and Results

Foodborne Parasite

Parasites in food have long been an overlooked group of pathogens. However, they are a significant cause of disease and economic loss worldwide. Thus, the presence of these parasites in these foods warrants improved control efforts. To this end worldwide, significant progress has been made in the prevention and treatment of parasitic diseases in humans.[14] However, parasitic diseases remain one of the most serious public health problems in the world, causing significant morbidity and mortality, especially in tropical and subtropical countries.[15] In addition to causing morbidity and mortality, intestinal parasitic infections (IPIs) have been linked to iron-deficiency anemia, childhood stunting, and other mental and physical health problems.[16,17] It is estimated that 3.5 billion people are affected worldwide and 450 million people become sick from foodborne IPIs, with approximately 200,000 deaths each year.[18]

Parasite infections can contaminate fruits and vegetables from the moment they are planted to the moment they are consumed.[19] At the pre-harvest stage, the main contributing variables include the use of human and animal manure as natural fertilizers, as well as the irrigation of fruits and vegetables with untreated wastewater. The majority of local farmers in underdeveloped countries use untreated human or animal waste as fertilizer and contaminated water for irrigation, which contributes to the increased transmission of intestinal parasites (IP).[20] Storage, transport and marketing conditions, as well as hygienic standards during processing for food service or home consumption, are all factors in the postharvest stage.[21,22]

Ethiopia is a country with a large number of IPs. There is also a lack of clean water and sanitary practices. As a result, farmlands are predicted to be contaminated by infective IPs, owing to open defecation. Furthermore, natural fertilizer (human and animal excrement) is widely employed by farmers in the country, and irrigation water is frequently contaminated.[23] Raw fruits and vegetables, such as bananas, mangos, tomatoes, salads, and green peppers, are also consumed raw. All of these factors lead to parasite infection of fruits and vegetables, making these foods crucial vehicles for human transmission.[24] According to recent studies in Ethiopia, parasites were found in 25.1% to 57.8% of the fruit and vegetable samples collected during the marketing phase.[23–31] The incidence of contamination and parasite species, on the other hand, varies depending on weather conditions, sociocultural status, season of sample collection, fruit and vegetable products analyzed, and other factors.

Parasites have also been detected in raw meat, posing a public health risk, especially in communities that consume raw. Zoonotic parasitic infection is a serious public health problem that requires a comprehensive control plan.[32–36] Ingestion of parasites in contaminated food, drink or soil, as well as direct contact with dogs, livestock, or other domestic animals, leads to transmission of the disease to humans. Backyard slaughter, large numbers of stray dogs, a shortage of slaughterhouses proportional to the population, and improper disposal of diseased organ waste can all contribute to the high level of parasitemia in Ethiopia.[35] According to research, dogs, cats and other wild predators have easy access to offal's.[35]

Zoonotic parasites can lead to significant financial losses[14] due to reduced productivity of infected animals and convict contaminated organs such as liver, kidney and meat. Milk production, animal fertility and skin quality can all be affected.[36] According to a 10-year retrospective study in Ethiopia, total economic losses of 1,219,399 Ethiopian Birr (ETB) ($61,946.9) were incurred, with an average annual cost of $6194.69 due to waste of food, organs and carcasses of slaughtered cattle. Parasitic diseases in cattle, particularly hydatidosis and fascioliasis, remain a major problem, accounting for more than half (43.7%) of all visceral diseases in calves slaughtered in Ethiopia.[34] In addition, statistics show that 38.3% of cattle slaughtered in Ethiopia have one or more abnormalities, resulting in a total loss of $61,946.9 (average annual loss of $6194.69) caused by a variety of parasites.[34] Farmers and anyone involved in the livestock chain in sub-Saharan African countries like Ethiopia, which are already struggling with food shortages, are particularly concerned about these losses.

In Ethiopia, the most commonly clinically relevant foodborne parasites are *A. lubmbricoids, H. nana, H. diminuta, E. histolytica /dispar, G. intestinalis, Toxocara spp*., and *C. belli*. The levels of parasitic contamination of foods from various sources are summarized in the table below (Table 1).

Foodborne Bacteria

To control infectious diseases, chemotherapy alone will not be enough; a concerted effort to limit and eliminate possible sources of infection is needed. To address this, the periodic detection of infectious pathogens in food and related processes is a priority goal.[37] Plants and animals, and things derived from them, make up the majority of human food sources. It is helpful to think of food security as a product or service that can be bought or sold. Food appears to be a common source of microbial contamination, as some foods naturally contain pathogens or may come from diseased animals.[38]

Bacteria in Fruits and Vegetables

Bacteria are found naturally in all food plants, from pre-harvest to post-consumption. Their presence or absence in food is considered as a sign of quality. The presence of bacteria in the soil can also affect the quality of food. This is most common in fruits and vegetables grown with contaminated irrigation water, as well as human and animal faces, grazing areas, and more.[39]

Pathogenic bacteria do not exist naturally in vegetables and raw foods. Some sources of pre-harvest bacteria that can cause foodborne illness are irrigation water or wastewater, compost, manure, etc. Salad vegetables, such as lettuce, cabbage, tomatoes, and spinach, are at risk for bacterial contamination from untreated irrigation water.[40] A report by Adjrah et al, 2013[41] found that manure used to support the growth of vegetables and crops contained significant amounts of harmful bacteria such as *Salmonella, E. coli O157:H7, B. anthracis, Yersinia, C. perfringens, Klebsiella* spp. *M. paratuberculosis*, and *L. monocytogenes*. Similarly, fields where wild animals or livestock have grazed are more likely to be contaminated with enteric infections like as *Salmonella* and *L. monocytogenes*, which can survive in agricultural soils for months.[42] Therefore, the place of cultivation is most likely the first factor affecting the safety of fruits and vegetables.[43] Pre-harvest parameters such as planting material selection and crop management should all aim to provide a high quality product.[44] Microbial contamination of fruits and vegetables can occur during transportation, washing, peeling, slicing, pruning, packaging, and post-harvest handling.[45] Similarly, food preparation areas are frequently contaminated with *Micrococcus*

https://doi.org/10.2147/IDR.S375043

Table 1 Researches Done in Ethiopia That Showed Level of Parasite Contamination in Different Food Items

Author	Food Items	Source of Sample	Isolated Parasite	Reference
Bekele F. et al, 2017	Tomato, lettuce, cabbage, carrots, green pepper and avocado	Local open-market	*A. lubmbricoids, Toxocara* spp., *H. nana., E. histolytica/ dispar, G. intestinalis, H. diminuta and C. belli*	[23]
Tefera T et al[18]	Tomato, lettuce, cabbage, carrots, green pepper, tomato, banana and mango	Local open markets	*Toxocara* spp., *H. nana, E. histolytica/dispar, G. intestinalis, H. diminuta and Hookworms, A. lubmbricoids, Strongyloides, Cyclospora* spp *and Cryptosporidium* spp	[24]
Endale A et al, 2018	Lettuce, cabbage, spinach, carrot, green pepper, mango, tomato. orange banana	Local open markets	*E. histolytica/dispar, G. lambila, Strongyloides, A. lubmbricoids Cyclospora* spp., *Cryptosporidium* spp., *I. Belli, Hymenolepis* spp., *and T. trichiura*	[25]
Alemu G. et al, 2019	Lettuce, cabbage, spinach, carrot, green pepper, mango, tomato	Local open markets	*E. histolytica/dispar, E. coli, G. intestinalis, Hookworms, A. lubmbricoids, Strongyloides, Cyclospora* spp., *Cryptosporidium* spp., *F. hepatica, E. vermicularis and T. trichiura*	[26]
Gebremariam Gk, Girmay TG. 2020	Lettuce, cabbage, spinach, green pepper, potato tomato	Open market	*E. histolytica/dispar, G. lamblia, Cryptosporidium* spp., *A. lubmbricoids, Taenia* spp., *Hook worm* spp., *E. Vermicularis, Fasciola* spp.	[27]
Delesa DA. 2017[22]	Lettuce, cabbage, carrots	Farm and market	*Giardia spp., Entamoeba* spp., Ascaris spp., and *Cryptosporidium* spp.	[28]
Kifleyohannes T et al, 2021	Cabbage, carrots, tomato, green pepper, lettuce, guava	Local open-market, Backyards of farmers, irrigated farm lands	Giardia spp., *Cryptosporidium* spp. and *Entamoeba* spp.	[29]
Alemu G. et al, 2018	Tomato, cabbage, carrots, green pepper and salad	Local open markets	*G. lamblia, Cryptosporidium* spp., Hookworms, *B. coli, E. histolytica, Cyclospora* spp., *Stronglode, A. lubmbricoids*	[30]
Bekele F et al, 2020	Tomato, lettuce, cabbage, carrots, green pepper and avocado	Local open markets	*Toxocara* spp., *H. nana., E. histolytica/dispar, G. intestinalis, H. diminuta and Hookworms, A. lubmbricoids*	[31]
Getahun et al, 2020	Meat	Abattoirs	*Echinococcosis, Fasciola and Cysticercus*	[32]
Muhammed S & Birhanu T. 2020	Organ (lung, liver, heart and kidneys)	Municipal Abattoirs	*Bovine hydatidosis, Bovine Fasciolosis and Cysticercus bovis*	[33]
Molla D. et al, 2018	Organ (lung, liver, heart, kidneys, head and tongue)	Abattoir condemnations	*Hydatidosis, Fasciolosis and Cysticercus*	[34]

spp. and *Staphylococcus* spp.[46] from the hands of the handlers. This means that dishwashing liquid, food preparation surfaces, serving equipment and main meals are all contaminated.[46] This suggests that the degree of microbiological contamination of fruits and vegetables is influenced by the individual handling of the suppliers. The microbiological safety of fruits and vegetables is also affected by the movement of consumers from one region to another.[47]

Eating fruits and vegetables is now generally considered a risk factor for infection with enteric pathogens.[48,49] Eating fruits and vegetables has been linked to foodborne illness outbreaks in many countries. During foodborne outbreaks, enteric pathogens such as *E. coli* and *Salmonella* spp. are among the most serious concerns.[42] *Salmonella* spp., *E. coli O157:H7, B. anthracis, Yersinia, C. perfringens, Klebsiella* spp., *M. paratuberculosis*, and *L. monocytogenes* are the most common clinically important foodborne bacteria in Ethiopia. The table below summarizes the level of bacterial contamination in various food items from various sources in Ethiopia (Table 2).

Table 2 Researches Done in Ethiopia That Showed Level of Bacterial Contamination in Fruits and Vegetables

Author	Food Items	Source of Sample	Result and Isolated Bacteria	Reference
Mengistu DA. et al, 2022	Locally prepared fresh fruit juice	Juice houses	*E. coli* and other indicator organisms (Total coliform, fecal coliform and total viable bacterial count)	[50]
Berhanu M. et al, 2020	Packed and fresh fruit juice (non-refrigerated)	Supermarkets and cafes	*E. coli, S. aureus, Shigella* spp., *Salmonella spp., Klebsiella* spp., *Pseudomonas* spp.	[51]
Derra FA. et al, 2020	Mushroom, carrot, potato, Lentil, moringa, onion, salads and others	Retrospective data food microbiology laboratory of EPHI	*E.coli, S. aureus*, and indicator organism (total coliform, fecal coliform, Mesophilic aerobic bacteria and yeast and mold cont.)	[52]
Dobo B. 2019	Orange, banana, tomato, cabbege	Local markets	*S. aureus, Salmonella* spp., and indicator organism (total coliform, fecal coliform, Mesophilic aerobic bacteria and yeast and mold count)	[53]
Alemu et al, 2018	Tomato, cabbage, green pepper, carrot, lettuce	Local vendor	*E. coli, S. aureus, Shigella* spp., *Salmonella* spp.	[30]
Shiferaw M. and Kibiret M. 2018	Avocado, guava	Juice houses	*Shigella* spp., *Salmonella* spp., and Indicator organisms (total coliform count, fecal coliform count, *S. aureus* count, Mesophilic aerobic bacteria and total yeast and mold counts)	[54]
Delesa DA. 2017	Lettuce, cabbage, carrots	Farm and market	Indicator organisms (total aerobic mesospheric count, total coliform count, fecal coliform count and total yeast and mold counts)	[28]
Weldezgna D. and Muleta D. 2016	Lettuce, cabbage, tomato, carrots, potato, green pepper, onion	From irrigation farm land with river	*S. aureus, Salmonella* spp., and indicator organism (total coliform and fecal coliform)	[55]
Leul A. and Kibret M. 2012	Mango and pineapple juice	Cafes and juice houses	*Citrobacter* spp., *Salmonella* spp., *E. coli, Enterobacter* spp., *Klebsiella* spp., *Pseudomonas* spp. and indicator organism	[56]
Ayele W. 2009	Some vegetable like lettuce	Locally produced and marketed vegetable	*E. coli* (indicator organism)	[57]
Solomon ET. et al, 2002	Lettuce	Irrigation (study purpose)	*E. coli O157:H7*	[58]

Zoonotic Foodborne Bacteria

Due to the limited scope of the study and the lack of a coordinated epidemiological surveillance system, it is difficult to assess the burden of zoonotic bacterial infections in Ethiopia. In addition, underreporting of cases and the prevalence of other diseases considered high priority may mask the problem of foodborne infections.[59] A study in Jimma, South West Ethiopia,[60] Gondar, Ethiopia[61] and Wolita Sodo, South Ethiopia[62] showed high carriage rates of *Salmonella* spp., isolated from raw beef. The same study, conducted in the same area, showed high rates of *E. coli* and multidrug resistant (MDR) *E. coli O157:H7* in meat from abattoirs and butchers.[63] In another study conducted at abattoirs and butchers in Addis Ababa, Ethiopia, a significant frequency of *S. aureus* was found.[64] A similar study conducted in Addis Ababa, Ethiopia, in a selected number of butcher shops also found inadequate meat quality and microbiological safety.[65] Additionally, another study found that cooked meat and fish posed a public health risk in Ethiopia.[66]

According to a review report, pathogenic bacteria such as *E. coli, Salmonella* spp., *Campylobacter* spp., *L. monocytogenes, Brucella* spp., and *C. burnetii* were the most common isolates from milk and dairy products in Ethiopia.[10] Another research report[67] revealed that dairy products in Ethiopia have poor microbiological characteristics. Research in the East Wollega Zone of Sibu Sire districts[68] and Lume and Siraro districts of Oromia state[69] showed poor hygienic practices and microbiological quality of milk obtained from farmers and markets. Collectively, a number of review articles[70–73] and primary research[74] have identified zoonotic bacterial pathogens such as Anthrax, *E. coli, Brucella* spp., *C. burnetii, Leptospirosis, Salmonella* spp., *M. bovis, F. tularensis, L. monocytogenes, Campylobacter* spp, *Streptococcus* spp., *Bartonella* spp., *S. aureus, Ehrlichia, O. tsutsugamushi, Y. pestis*, and *R. rickettsii* are still a public health problem in Ethiopia.

Antimicrobial Resistance

The discovery of bacteria as the source of disease and the discovery of antibiotics as effective therapeutic agents has contributed to the protection of humans and animals over the past century.[75] Despite the advancement of many antibiotic discoveries, the development of antimicrobial resistant strains of bacteria has risen to the top of the list of global public health priorities. The World Health Organization can make the fight against the spread and emergence of antimicrobial resistance a top priority (WHO). Antimicrobial resistance may represent a global threat to the effectiveness of antibiotics, raising questions about their usefulness for both preventing and treating infections.[76] Antimicrobial resistance is driven by complex interacting factors that can be described as a resistance network or interface of a multifaceted One Health System;[77] which links clinical factors (human and animal health) and environmental factors (persistence of antimicrobial agents and AMR microorganisms in soil and food).[78,79] Besides the indiscriminate use of antibiotics in human health, animal husbandry and agriculture, unsanitary food conditions can upset the microbial balance in favor of resistant bacteria through selective pressure. According to several studies conducted around the world, food is one of the potential sources of antibiotic resistance.[79,80] The rise of antibiotic-resistant pathogens in food highlights the common requirement that these foods be cooked before consumption.

In the case of AMR, these diverse causes can be divided into two components: "selection", mainly through antibiotic use, and "transmission", the human-animal-environment axis. In livestock, the majority of global antibiotic use is in animals raised for food,[81,82] and it is widely accepted that antibiotic use in animals is responsible for AMR,[70] although the magnitude of these effects is not well characterized and potentially specific to the AMR mechanism and organism. However, antibiotic use in humans is also a major cause of AMR.[83] In terms of transmission, resistant bacteria can be shared between humans, animals, and the environment through human-to-human contact (open community, patient contact, family transmission, workplace contact, traveler's), human-sanitary contact (occupational contact with animals, consumption or preparation of food), animal-animal contact (involving agriculture or the movement of wild or domestic animals) and human-environment or animal-environment interactions.[79] It is important to note that we do not know the aforementioned selection and transmission factors that contribute to the increasing prevalence of AMR and the increasing incidence of AMR diseases. AMR selection and transfer is not a completely independent process. Although the use of antibiotics in humans and animals is believed to be present, environmental pollution from these sources and the use of antibiotics in non-animal agriculture increase the overall prevalence of antibiotic resistance. The relationship between antibiotic use and resistance is complex and dependent on pre-existing microbial population structures.[82] Previous research has found that there is no single "quick fix" method for solving this problem. Instead, the prevention and reduction of the burden of AMR in the One Health system should take a coordinated, multifaceted approach that focuses on the specifics of antibiotic use, as well as type and prevalence of AMR in each system, while taking into account potential interactions within and between compartments.[84] It must also be multidisciplinary, multi-sector and collaborative.

In Ethiopia, several studies have shown an increase in antibiotic resistance in most bacterial species of human, animal, food and environmental origin.[85] Various studies in patients, animals, food and the environment have shown the risk of loss of valuable antimicrobials. For example, several studies in Ethiopia have found high rates of AMR isolates in foods (both plant and animal sources).[70–73] However, the studies are not comprehensive and are difficult to compare. Evidence is often based on fragmented data from individual studies. Almost all studies have focused on specific pathogens, mainly *Staphylococci* spp., *Salmonella* spp., and *E. coli* from certain specific sources. Nevertheless, according to a review study,[85] the pooled prevalence of AMR bacteria from live food-producing animals was 20%. High estimates of pooled AMR prevalence were found to be 29% for bacteria identified in milk and environmental samples and 28% for meat.[85] In foods of non-animal origin, the prevalence was lower with 13%.[85] Microorganisms reported to have higher MDR patterns are: *Staphylococcus* spp., (96%), *Salmonella* spp., (81%) and *E. coli* (77%).[78] Another review studies have also identified foodborne pathogens (*Salmonella* spp., pathogenic *E. coli, Shigella* spp., and *Campylobacter* spp) (11%) were extracted from samples (meat and meat products, dairy and dairy products, poultry products, and food contact surfaces).[86] The consumption of animal products such as meat, dairy and eggs, as well as vegetable products (fruits and vegetables), is increasing due to rapid population expansion, urbanization, increasing income per capita income, globalization and changes in consumption habits.[70–73] Thus, the risk of the spread of emerging and re-emerging antibiotic resistance is increased by human-animal-ecosystem interactions and causes deaths and economic losses each year.[87]

Foodborne Viral Infection

In recent years, viruses have been widely recognized as the main source of foodborne illness. Many known outbreaks of foodborne viruses have been traced to an infected food handler who contaminated prepared and ready-to-eat foods. Although viruses are now considered an extremely common cause of foodborne illnesses in many countries, they are rarely recognized because tools for the analysis and diagnosis of these viruses are generally unavailable. However, in recent years, there have been significant methodological advances available for the detection and identification of viruses in food.[47] These advances can help improve the assessment of the true burden of viral foodborne illness, as well as measures to prevent and control viral contamination of food. Viruses can infect humans in a variety of ways, but the most common foodborne viruses are those that infect the digestive system and are excreted in the feces and, in some cases, vomit. Norovirus is the most common cause of viral gastroenteritis worldwide, and hepatitis A virus, which can also be spread through the gastrointestinal tract, remains a global health concern. Rotavirus, Enterovirus and Astrovirus, Hepatitis E virus, emerging viruses (eg, Nipah virus, Highly Pathogenic Avian Influenza virus (HPAI), and Coronavirus that causes SARS) are also significantly associated with infection via food route.[47] In Ethiopia, data on foodborne viral infections are inadequate. However, one study of young people participating in a drinking water intervention trial found elevated levels of virome in the gut.[88]

Conclusion and Recommendation

In Ethiopia, the presence of foodborne pathogens (parasites and bacteria) is significant and is considered as One Health concern. As a result, different sectors (public health, veterinary medicine, food safety, and the Water, Sanitation, and Hygiene (WASH) program) work together to deliver valuable interventions. It is necessary to develop food safety risk communication as well as a country-specific action plan to accelerate the response. It is essential to implement and identify practical, feasible and cost-effective interventions, as well as political commitment through high-level advocacy. It is essential to strengthen surveillance and diagnostic capacity at all levels, both in the veterinary and human sectors, to detect cases early and identify active reservoirs to protect benefits of humans and animals.

There is also a high prevalence of antibiotic resistance (AMR) in most bacterial species from food sources (animals and plants). Sources of contamination must be identified to control the spread of AMR through food. The prudent strategy of using antibiotics under expert supervision must be promoted and reinforced. Instead of acting as a "AMR amplifier", we propose that the food chain could act as a "resistance modulator" to reduce the prevalence of resistant microorganisms by controlling careful parameters of the food process. However, further research is needed to establish both the processes involved in the spread of AMR and the food processing and storage parameters that are important for their reduction. Then, on this basis, robust control methods to prevent the spread of AMR among bacteria along the food chain can be created and implemented.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study did not receive any funding in any form.

Disclosure

The authors report that they have no conflicts of interest.

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