THE CONCEPT OF VALUE CHAINS IN AGRICULTURE, CLIMATE ACTION AND ENVIRONMENTAL RESOURCES

GLOBAL ISSUES & LOCAL PERSPECTIVES

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous ***The Concept of Value Chains in Agriculture, Climate Action and Environmental Resources*** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which climate change, food security, national security and environmental resources issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue climate change, food security, national security and environmental resources necessary in policy making process that will stimulate increase in food production and environmental sustainability.

The Concept of Value Chains in Agriculture, Climate Action and Environmental Resources: Global issues and Local Perspectives is organized in three parts. Part One deals with The Concept of Value Chains in Agriculture, Part Two is concerned with The Concept of Climate Actions and Part Three deals with the Concept of Value Chains and Environmental Resources.

Eteyen Nyong/ Ignatius Onimawo

April 2025

Chapter Nine

Food safety challenges of antibiotic-resistant foodborne pathogens in street vended foods and report on evolving remedies

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THE CONCEPT OF VALUE CHAINS IN AGRICULTURE, CLIMATE ACTION AND ENVIRONMENTAL RESOURCES

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Table 3: Foodborne bacteria and their resistance genes against some antibiotics

1Introduction

Street foods are RTE foods, snacks, and beverages prepared at home or within the street to suppress food insecurity for low-income dwellers in many countries (Ma, Chen, Yan, Wu and Zhang, 2019). Street vended foods play important socio-economic roles in meeting the demand of consumers at affordable prices because the lower and middle-income groups appreciate the unique flavour and convenience of the food as their immediate wants (Rakha, Fatima, Bano, Khan, Chaudhary and Aadil, 2022). The busy activities and long-term schedules of individuals who cannot cook for themselves have contributed to an increasing number of street-hawk foods as optional fast foods. The street foods are often sold at different locations such as bus stops, building sites, busy marketplaces, campuses, industrial locations, pupil school gates, at highways, taxi stands, and stalls erected at the corner of the streets (Ogidi, Oyetayo and Akinyele, 2016). The sale of street foods at such locations attracts numerous consumers but do not meet the sanitary quality, specifications for food hygiene and safety

Street food vendors; a routine entrepreneur with low investment and a self-employed individual who does not depend on any institutional structures to earn incomes (Resnick, Sivasubramanian, Idiong, Ojo and Tanko, 2023). The enterprises of street-vended foods evolve individual strengths and receive support from their immediate social networks in the streets, their family, and other close associates (Adeosun, Oosterveer and Greene, 2023). The system of food vendor entrepreneurs has reduced the plight of food vendors to become an economic and social burden on their countries.

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Most of the food vendors sell in heavy containers, haul heavy loads of foods and plates, push on wheel borrow or stalls where people meet them as the point of sale, these physical environments lack proper infrastructures such as clean water, toilets, and solid waste removal, and thus contributed to the increase number of foodborne pathogens (Khairuzzaman, Chowdhury, Zaman, Al-Mamun and Bari 2014).

The frequent incidence of foodborne diseases has been attributed to the unhygienic status of street foods (Rane, 2011). Many factors are contributing to the contamination of street vended foods and thus, hinder their hygienic qualities This is directly or indirectly served as transmitting factors of foodborne pathogens and toxins. The direct or indirect sources of contaminants are from unwashed hands during food distribution, continuous use of utensil without cleaning, dirt materials used for wrapping foods especially old newspaper, re-use nylon or polyethylene bags, dirty leaves, undercooked methods have introduced different pathogenic microorganisms and toxins into street vended foods and thus, threaten human health with different foodborne diseases (Ogidi *et al*., 2016).

Street vended foods are considered harmful because vendors often lack basic food service infrastructures, food storage facilities, food reheating equipment, refrigerators, and waste disposal facilities (Rane, 2011). The lack of adequate food service equipment hinders the effective implementation of safe food practices on the streets during sales (Nkosi and Tabit, 2021). Most street-vended foods are often prepared under poor hygienic conditions with low-quality ingredients and displayed openly to high concentrations of air pollutants, which causes a high degree of contamination (Sharma and Mazumdar, 2014). Some of the food vendors have no formal education, no basic training on food safety and hygiene with no knowledge about the causes of food-borne diseases (Kharel, Palni,

and Tamang, 2016). Despite the inexperience qualities of the vendors coupled with the unsanitary conditions of preparing the foods, people often consume street foods in day-to-day life irrespective of the health challenges associated with street foods (Bereda, Emerie, Reta and Asfaw, 2016).

Most of the street food vending sites are not hygienic and not compliant with food safety regulations (Figure 1). The inadequate monitoring by health authorities has increased the number of food vendors in the street without any form of registration, which has hindered and prevented adequate measures to regulate food-borne diseases (Nkosi and Tabit, 2021). Epidemiological studies have revealed that the consumption of street-vended foods causes the world's population to suffer from foodborne diseases every year, while almost 56 million died in a year because of foodborne illnesses (Alemu, Mama and Siraj, 2018; and Teferi, 2020). Globally, it is widely known that unsafe foods and water pose serious health threats, endangering the lives of consumers such as infants, young children, pregnant women, the elderly, and those who are with underlying illnesses (Todd, 2014, and Bintsis, 2017). The popularity of street-vended foods is uncontrollable as it is increasing in the hamlets, villages, towns, and cities in many countries without adequate monitoring to ensure the safety and quality of street-vended foods. On these notes, the microbiological quality of street-vended foods is becoming of utmost importance globally, since street-vended foods act as a major transmission of antibiotic-resistant microorganisms, a source of food-borne illnesses and toxins (Beshiru *et al*., 2023; and Koumassa, Ouétchéhou, Hounsou, Zannou and Dabadé, 2025). These concerns raised by public health require the prompt attention of government authorities and continued research by scientists to mitigate multiple antibiotics resistant to microorganisms.

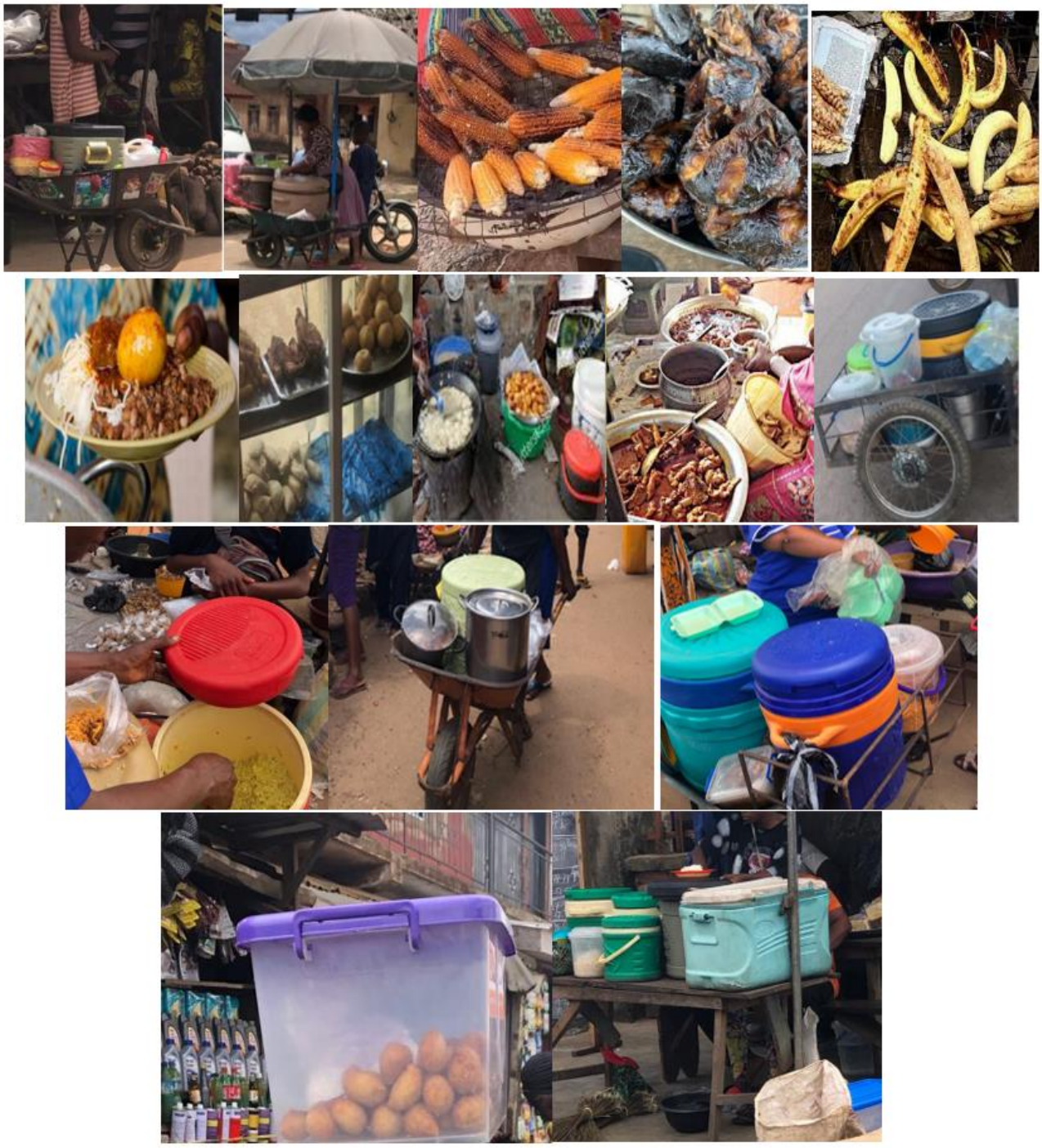

Figure 1: Vended foods under unhygienic conditions in the streets

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Source of Microorganisms in Street vended foods

Foodborne pathogens notably, bacteria, fungi, parasites, viruses, or their toxins are the commonest agents in street foods and water, which cause foodborne illnesses. Some street food vendors lack electricity supply to power their refrigerators and no quality potable water to prepare their foods, this has hindered safe food practices and exposes street foods to microbial colonization and spoilage. Street-vended foods contaminated with pathogenic microorganisms contributed to several foodborne disease outbreaks (Madilo, Islam, Letsyo, Roy, Klutse, Quansah, Darku and Amin, 2023). A defective water supply system has led to the use of contaminated water by vendors, use of low-quality ingredients for food preparation to make more profits, poor sanitation and lower hygienic status of street vendors, exposure of food to dust and flies increase the occurrence of microorganisms in foods (Salamandane, Silva, Brito and Malfeito-Ferreira, 2021). Many street food handlers have not received formal training in food preparation but rather acquire their culinary skills informally from home or relatives without any formal training in food hygiene practices (Tuglo, Agordoh, Tekpor, Pan, Agbanyo and Chu, 2021). The low education level of food vendors, lack of food safety knowledge, and low standard sanitary requirements have contributed to the occurrence of different pathogenic microorganisms in street foods as well as the continuous incidence of foodborne illnesses (Barnabas, Bavorova, Madaki and Kächele, 2024). Microorganisms found in street-vended foods are responsible for more than one million cases of food illnesses (Mengistu, Belami, Tefera and Asefa, 2022). Unhygienic and unsafe food handlers serve as a potential channel for the transmission of enteropathogenic bacteria into foods through their direct contact with contaminated hands and bodies.

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The foods become contaminated with microorganisms and transfer to consumers (Vicar, Alo, Koyiri, Opare-Asamoah, Obeng-Bempong and Mensah 2023). Food crops such as pepper, cereals, legumes, vegetables, nuts, spices, and tubers are rich in nutrients required by microorganisms and may become contaminated by microorganisms when exposed to water, air, dust, sewage, insects, and rodents (Kumar and Kalita, 2017). The use of such contaminated raw materials may increase the incidence of microorganisms in street-vended foods Cross-contamination of street-vended food by food items and food contact surfaces can lead to the transfer of harmful microorganisms to man.

The external surface and the internal organs of animals can be contaminated during slaughtering, which in turn increases the chances of introducing more microorganisms into street-vended foods. Foods of animal origin such as eggs, fish, and other seafood are often used in the preparation of street vended foods. These serve as the main vehicles for the transmission of antibiotic-resistant food-borne pathogens (Shiningeni, Chimwamurombe, Shilangale and Misihairabgwi, 2019). Food products of animal origin have been noted as important vehicles for the dissemination of antibiotic-resistant pathogenic bacteria due to the use of antibiotics in the treatment of livestock (Akinware, Ogidi and Akinyele, 2023). The presence of antibiotic residues in muscle foods commonly used for preparation of street vended foods has caused pre-exposure of microorganisms to antibiotics and therefore, contributed to their multiple antibiotic-resistance and pathogenicity (Bodunde, Ogidi and Akinyele, 2019). Examples of commonly isolated microorganisms in street vended foods are species of *Bacillus*, *Clostridium botulinum*, *Escherichia coli, Listeria monocytogenes*, *Salmonella, Staphylococcus aureus*, *Shigella*, *Yersinia*, *Vibrio cholerae*, *V. vulnificus*, *V. parahaemolyticus* and others (Table 1).

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Table 1: Microorganisms in street vended foods from different countries and tested antibiotics

Street vended foods	Number of Examined foods	Microorganisms isolated	Antibiotics used	Country	References
Kachori, *Samosa*, *puchkka*, *alu chop*, vegetable *momo*, pork *momo*, *alu-cheura*, vegetable *chowmein*, *jhal-muri*, and *sya-faley and others*	*NS*	*Lactococcus lactis*, *Lactobacillus planta rum*, *L. brevis*, *Enterococcus faecium*, *Bacillus subtilis*, *B. pumilus*, *B. licheniform*, *B. cereus*, *Escherichia coli*, *Enterobacter aerogenes*, *E. cloacae*, *Salmonella enteritica*, *S. aureus*, *S. epidermidis*, and *Shigella flexneri*	ND		Kharel et al., 2016
Avocado, and cooked potato, local bread ('Ambasha' and 'Kita'), raw fish, chilli ('Awaze')	72	*E. coli*, *S. aureus*, *Salmonella* spp, *Proteus* spp, *Klebisella* spp, *Citrobacter* spp, *Entrobacter* spp, *Providenica* spp (*P. alkalifaciens* and *P. stuartii*), *Edwardisella*, *M. morgani*, and *Serratia*	ampicillin, erythromycin, ceftriaxone, cefotaxime, chloramphenicol, ciprofloxacin, nalidixic acid, cloxacillin, oxacillin, vancomycin, trimethoprimsulfamethoxazol, gentamicin, clindamycin, penicillin G, norfloxacin and kanamycin	Ethiopia	Eromo, Tassew, Daka, Kibru, 2016
Sanbusa, Donat, Bombolino and bread	72	*S. aureus*, *E. coli*, *Enterobacter species*, *Citrobacter* species	Ampicillin, Chloramphenicol, Ciprofloxacin, Ceftazidime, Tetracycline, Ceftriaxone, Penicillin, Norfloxacin, Gentamycin, Clindamycin,	Ethiopia	Amare, Worku, Ashagirie, Adugna, Getaneh, and Dagnew. 2019

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			Trimethoprim-sulfamethoxazole		
Traditional hot foods (Rice and cooked meat, Rice and peanut curry, Rice and beans, Xima and chatine, Rice, and matapa), Sandwiches, RTE fruit (Pear and apple, Strawberries, Sliced watermelon), RTE salads, Traditional cold foods (Molina/lifete, Badjia and Sanana)	83	Coliforms, *E. coli*¸ Coagulase-positive *Staphylococci, Salmonella, Listeria monocytogenes*	ND	Mozambique	Salamandane et al., 2021
Cooked beef	*NS*	*S. aureus, E. coli, Candida guilliermondii, Corynebacterium jeikeium, Psychrobacter phenylpyruvicus* and *Peptostreptococcus tetradius*	ND	South Africa	Moloi, Lenetha, Malebo, 2021
Street-Vended Chicken Products	15	*Salmonella, E. coli, Campylobacter jejuni, Staphylococcus aureus*	*ND*	Kenya	Birgen, Njue, Kaindi, Ogutu and Owade 2020
Doughnut, egg roll, meat pie, sausage roll, popcorn, hawk RTE foods, snacks from international food companies) and foods from fast food joints	76	*S. aureus, E. coli, Salmonella typhi, Shigella dysenteriae, Klebsiella pneumoniae, Proteus vulgaris, Enterobacter aerogenes, Streptococcus lactis, Pseudomonas aeruginosa, Bacillus* spp, *Vibrio parahaemolyticus, Saccharomyces cerevisiae, Aspergillus* spp, *Penicillium* spp, *Rhizopus stolonifer, Mucor mucedo* and *Candida albicans*	gentamicin (10 μg), tetracycline (25 μg), chloramphenicol, (30 μg), erythromycin (10 μg), amoxicillin (25 μg), cotrimoxazole (25μg), nitrofurantoin (20 μg), nalidixic acid (30 μg), ofloxacin (5 μg), augmentin (30 g), streptomycin (30 μg),	Nigeria	Ogidi et al., 2016

			ciprofloxacin, ketoconazole (15 µg), fluconazole (25 µg) and nystatin (1µg)		
Ampesi, Banku, Beans, Bofloat/Koose/Pinkaso, Bread, Fried egg, Fried fish/ meat, Fried rice, Gari, Grinded pepper, Hausa kooko (porridge), Indomie/ spaghetti, Jollof rice, Kenkey, Rice, Salad, Soup, Stew, Waakye	179	*Acinetobacter baumanii, Staphylococcus sciuri, Enterobacter asburiae, nterobacter cloacae, Citrobacter freundii, Enterococcus faecalis, Aeromonas caviae, Citrobacter braakii, Enterococcus faecalis, Aeromonas caviae, Citrobacter braakii, Acinetobacter baumannii, Citrobacter freundii* (ESBL-*bla*$_{TEM}$), *Enterococcus faecalis, Pseudomonas aeruginosa, Escherichia* spp., *Proteus mirabilis, Pseudomonas aeruginosa, Serratia ficaria, Pseudomonas mendoncina, Citrobacter braakii and others.*	Sulfamethoxazole-trimethoprim; Ticarcillin-clavulanate; Tetracycline; Nitrofurantoin; Gentamicin; Nalidixic acid; Piperacillin-tazobactam; Azithromycin; Amikacin; Chloramphenicol; Meropenem; Ciprofloxacin; Ceftriaxone; Ceftazidime; Amoxicillin-clavulanate.	Ghana	Dela, Egyir, Behene, Sulemana, Tagoe, Bentil, Bongo, Bonfoh, Zinsstag, Bimi, and Addo, 2023
Hamburgers, Chicken nuggets, Salad olivieh, Salami, Felafel, Grilled mushrooms, and Mexican corn	*415*	***S t a p h y l***	penicillin (10 µg), Gen: gentamicin (10 µg), amikacin (30 µg), azithromycin (15 µg), erythromycin (15 µg), tetracycline (30 µg), doxycycline (30 µg), ciprofloxacin (5 µg), levofloxacin (5 µg), clindamycin (2 µg), trimethoprim-sulfamethoxazole (25 µg), chloramphenicol (30 µg), rifampin	Iran	Mesbah, Mashak and Abdolmalek, 2021

o c o c c u s a u r e u s					
Cheeses, cooked meats, pre-processed fruits and vegetables (chopped fruit, fruit salads with strawberries, melon, and peaches, and leafy vegetable salads)	436	*Listeria monocytogenes*	ampicillin (10 µg), penicillin (10 µg), sulfamethoxazole-trimethoprim (25 µg), erythromycin (15 µg), vancomycin (30 µg), tetracycline (30 µg), ciprofloxacin (5 µg), and chloramphenicol (30 µg)	Chile	Parra-Flores, Holý, Bustamante, Lepuschitz,, Pietzka, Contreras-Fernández, Castillo, Ovalle,

Potato Chips, Koker, 330 Sambusa, Ambasha, and Bombolino	***Staphylococcus aureus, E. coli* O157:H7, *Salmonella* and *Shigella* Species**	Penicillin (10 µg), cefoxitin (30 µg), gentamicin (10 µg), erythromycin (15µg), tetracycline (30 µg), doxycycline (30 µg), chloramphenicol (30 µg), ciprofloxacin (5 µg), clindamycin (10 µg), cotrimoxazole (25 µg), ampicillin (10 µg), amoxicillin-clavulanic acid (30 µg), cefepime (30µg), ceftriaxone (5 µg), meropenem (10 µg), gentamicin (10 µg), azithromycin (15 µg), tetracycline (30 µg), doxycycline (30 µg), ciprofloxacin (5 µg), cotrimoxazole (1.25 µg), and chloramphenicol (30 µg)	Alarcón-Lavín,, Cruz-Córdova, Xicohtencatl-Cortes, Mancilla-Rojano, Troncoso, Figueroa and Ruppitsch, 2022 **Alelign, Yihune, Bekele, Oumer, Beyene and Atnafu, 2023**

Panipuri, Chole, Sandwich, Samosa, Momos	NS	***Escherichia coli, Pseudomonas aeruginosa, Klebsiella, Staphylococcus aureus***	Rifampicin, Vancomycin, Tetracycline and Streptomycin	Upadhyaya, Srivastava, Chandra and Arora, 2017
Street vended meat; chicken, chicken gizzard, beef head meat, beef intestines, and wors	115		ampicillin (10 µg), gentamicin (10 µg), tetracycline (30 µg), sulphonamides (300 mg), streptomycin (10 µg), ciprofloxacin (5 mg), chloramphenicol (30 mg), and erythromycin (5 mg)	Tshipamba, Luba

				nza and Adetunji, 2018
RTE foods, including polony, fruit salad, chips, fried fish, Russian sausage, red Vienna sausage, bread, fried chicken, vetkoek, meat pies, cupcakes, muffins, and assorted sandwiches	239	***L. monocytogenes***	penicillin G, ampicillin, ampicillin-sulbactam, amoxicillin, gentamicin, amikacin, streptomycin, doripenem, ertapenem imipenem, ceftriaxone, cefotetan, vancomycin, erythromycin, clarithromycin, ciprofloxacin, trimethoprim, sulfamethoxazole, trimethoprim-sulfamethoxazole, oxytetacycline, chloramphenicol, fosfomycin	Kayode and Okoh 2022

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NS: not stated, ND: Not detected

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Biotoxins in street vended foods

Microbial toxins from bacteria and fungi can be traced to street-vended foods and RTE-fermented foods (Ayoade and Adegbite, 2016). Mycotoxins are toxic secondary metabolites of fungal origin that can be contaminated with cereals (rice, maize, wheat, oat, barley, rye, millet, and sorghum) and legumes commonly used in the production of street vended foods. Mycotoxins such as aflatoxins, fumonisins, ochratoxins, trichothecenes (beauvericin, deoxynivalenol, moniliformin, nivalenol, enniatins, tenuazonic acid, and zearalenone) have been reported in RTE foods (Makinde, Sulyok, Adeleke, Krska and Ezekiel, 2023). The raw ingredients used for the preparation of street vended foods can be contaminated with one or more types of mycotoxins producing fungi. The presence of the toxin-producing microorganisms may not be totally eliminated by most of the processing methods like thermal treatment and refrigeration. The presence of aflatoxins in street-vended snacks, which are cereal and legumes-based snacks has been reported in Nigeria. About 70 and 35% of peanut from Kinshasa in the Democratic Republic of Congo and Pretoria in South Africa contain 5µg/kg of aflatoxin (Kamika, Mngqawa, Rheeder, Teffo and Katerere, 2014). The presence of aflatoxins, ochratoxins, and patulin-producing fungi; mainly *Aspergillus* and *Penicillium* spp. were found in raw ingredients, various street food items, cereal-based food products; bread, flour, pasta, fruit juice, coffee, cocoa, nuts, spices, licorice, processed meat, cheese (Ben Miri, Benabdallah, Chentir, Djenane, Luvisi and DeBellis, 2024). Incidence of biotoxin in food and feeds is associated with contaminations by fungal strains such as *Aspergillus flavus* and *Aspergillus parasiticus* that produce aflatoxin, ochratoxin A produced by species of *Aspergillus* and *Penicillium*, fumonisin produced by *Fusarium verticillioides*, *Fusarium proliferatum* (Alshannaq and Yu, 2017; and García-Díaz, Gil-Serna, Vázquez, Botia and

Patiño, 2020). There is a possible health risk for the populace when consuming street-vended foods contaminated with bacterial toxins (exotoxin and endotoxin) and mycotoxin**.** Consumption of contaminated foods with biotoxins could result in suppression of the immune system, acute or chronic organ toxicities in humans and animals (Fayyaz, Nawaz, Olaimat, Akram, Farooq, Fatima, Siddiqui, Rana, Mahnoor, and Shahbaz, 2022).

Foodborne diseases associated with street vended foods

Foodborne diseases also referred to as foodborne illnesses are any illnesses that occur in humans due to consumption of contaminated food with pathogenic bacteria, fungi, protozoans, and viruses. The occurrence of foodborne diseases from developing countries is not under adequate control and outbreaks still cause health challenges and economic losses (Lake and Barker, 2018). The economic costs of foodborne diseases are severe to people, companies, and countries. Foodborne diseases occurred due to unhygienic practices in food production, harvesting of spoiled crops with healthy ones, poor preparation of food, and poor knowledge of food safety, which have not been adequately tackled, and monitored by national authorities and international agencies (Amit, Uddin, Rahman, Islam and Khan, 2017).

Wide ranges of foodborne illnesses such as gastroenteritis, diarrhea, Typhoid fever, dysentery, and others have been associated with street-vended foods. Foodborne illnesses of microbial origin from street foods have caused major health challenges (Christiana, Balali, Titus, Osafo and Taufiq, 2022). The increasing multi-antibiotic resistant of foodborne microorganisms has made food safety circumstances more vulnerable in public health. The continuous burden of foodborne diseases is associated with occurrence of pathogenic bacteria, fungi, and parasites in street-vended food items

(Salamandane *et al*., 2021). Many clinically important foodborne pathogens such as enteropathogenic *Escherichia coli*, *Bacillus cereus*, *Clostridium perfringens*, *Staphylococcus aureus*, *Salmonella* species, *Shigella* species, *L. monocytogenes* in street vended foods cause different foodborne illnesses (Table 2). The incidence of foodborne diseases can be mild or severe but can result in death if not diagnosed and treated promptly. The symptoms of foodborne diseases vary and widely based on the type of foodborne disease, microorganisms involved, and nature of the immune system of affected host (Pontello and Gori, 2023).

The manifestation of foodborne diseases depends on the incubation period, the quantity of infected food consumed, and the singular incidence of foodborne disease, which can be widely spread to become an outbreak in a community or a country. Diarrheal diseases are the most common food poisoning that occurs due to toxins from the microbe or the human body's reactions to the microbe (Khairuzzaman et al., 2014). Street food vendors used their bare hands to count money and exchange money while handling or serving food on the street. This poor practice has contributed to the transmission of foodborne pathogens (Huynh-Van, Vuong-Thao, Huynh-Thi-Thanh, Dang-Xuan, Huynh-Van, Tran-To, Nguyen-Thi-Thao, Huynh-Bach and Nguyen-Viet, 2022). The outbreak burden of foodborne diseases affects the populations of low- and middle-income countries in Asia and Africa due to no access to quality food, malnutrition, and poor diagnostic and treatment options (Grace, 2023). Consumption of unsafe street-vended foods can cause illnesses and death.

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Table 2: Diseases and symptoms associated with food-borne pathogens

Foodborne pathogens	Diseases associated	Symptoms	References
Staphylococcus aureus and its enterotoxins	Staphylococcal food-borne disease	nausea, violent vomiting, abdominal cramping	Akinware et al., 2023
Bacillus cereus (emetic toxin)	emetic illness or Gastrointestinal (GI) syndromes	nausea, vomiting, and diarrhea	McDowell, Sands, Friedman, 2023
Salmonella spp.	Salmonella gastroenteritis	Nausea, vomiting, diarrhea, and abdominal pain Headache, Loss of appetite	Giannella, 1996
L. monocytogenes	Listeriosis	Fever, muscle aches, headache, stiff neck, confusion, loss of balance, and convulsions.	Parra-Flores et al., 2022
Shigella spp.	Shigellosis	Abdominal pain, tenesmus, watery diarrhea, and/or dysentery (multiple scanty, bloody, mucoid stools)	Tadesse, Mitiku, Teklemariam, and Marami, 2019
Yersinia enterocolitica	Yersiniosis	Gastroenteritis, with diarrhea and/or vomiting, fever, abdominal pains, and skin rashes	Sreedharan, Jones, Schneider, 2015
Campylobacter spp.	Campylobacteriosis	bloody diarrhea or dysentery syndrome, mostly including cramps, fever, and pain.	Zenebe, Zegeye, Eguale, 2020
Clostridium botulinum	botulinum neurotoxin	Nausea and vomit	Bacon and Sofos, 2003

Associated factors that contribute to multiple antibiotic resistance in microorganisms

The unceasing uses of antibiotics in human health, animal husbandry, and other agriculture sectors, coupled with unsanitary food conditions will continue upset the microbial balance in favour of resistant bacteria through selective pressure (Pokharel and Karna, 2022). The rise of antibiotic-resistant pathogens in foods of animal origin highlights that these street foods should be properly cooked before consumption. Multiple antibiotic resistance occurs by "selection", mainly through antibiotic use, and "transmission", through the antibiotic residues from the environment into microorganisms to humans and animals or *viz a viz* (Figure 2).

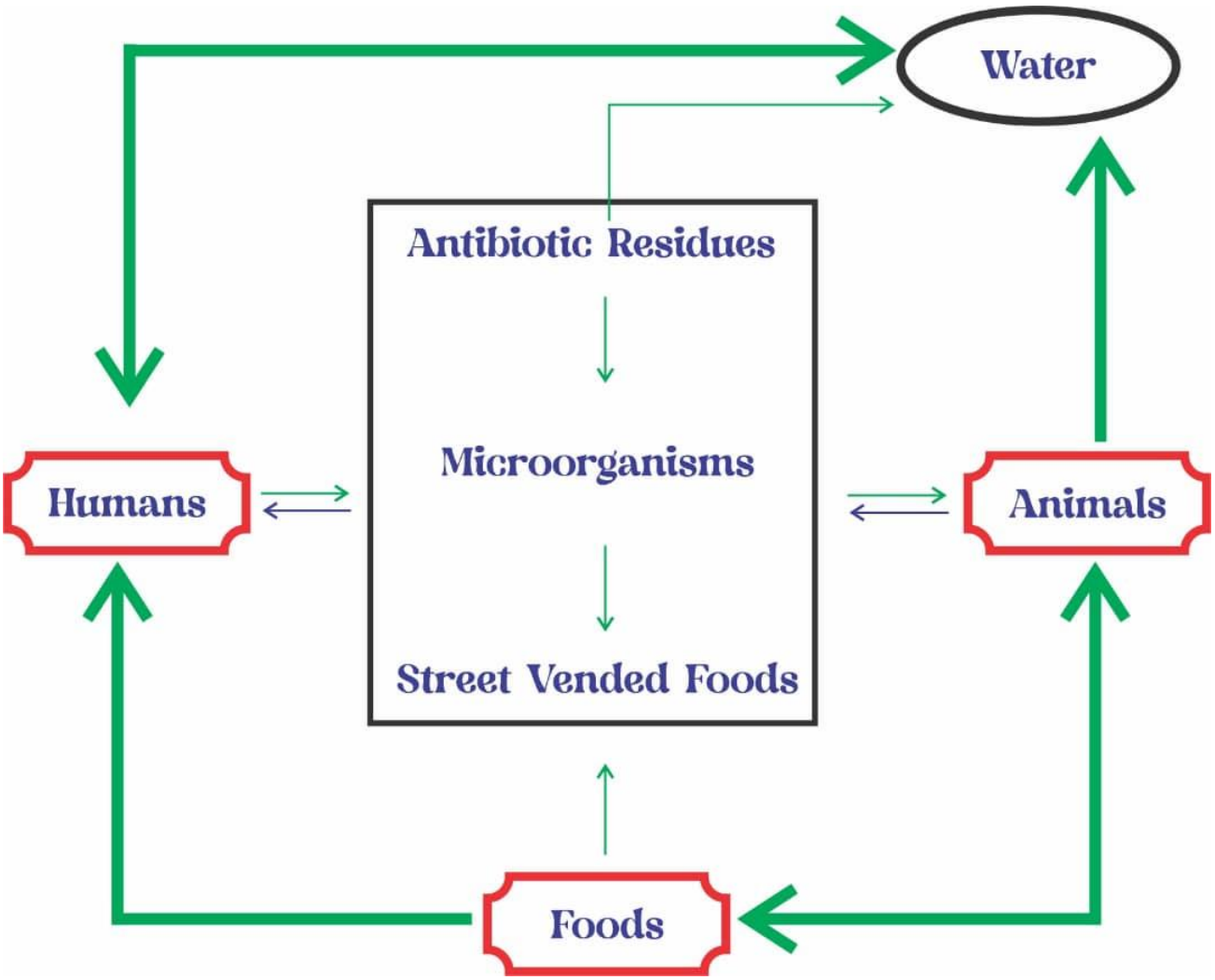

Figure 2: Inter-relations and transfer of antibiotic residues from environment to microorganism and street-vended foods

A huge amount of antibiotics is used in livestock production, fishery, and aquaculture technology. The use of antibiotics in animals raised for food is widely responsible for multiple antibiotic resistance (Kim and Ahn, 2022). Antibiotics-resistant bacteria and their resistant genes (Table 3) can be transferred to non-pathogenic microorganisms in foods from plants and animals' origin as well as in commonly sold street foods.

Table 3: Foodborne bacteria and their resistance genes against some antibiotics

Bacteria	Resistance genes	Antibiotics	References
S. aureus	*TetK* and *tetM* *ermA* and *msrA* *gyrA* and *grlA* *blaZ* *dfrA* *rpoB* *aacA-D*	Tetracycline Macrolide Fluoroquinolone Penicillin Ansamycin Aminoglycoside	Baghbaderani, Shakerian and Rahimi 2020; and Mesbah et al. 2021
S. aureus	*blaZ* *mecA*		Sivakumar, Dubal, Kumar, Bhilegaonkar, Vinodh Kumar, Kumar, Kadwalia, Shagufta, Grace, Ramees, and Dwivedi, 2019
Listeria monocytogenes	fosX, lin, norB, mprF, tetA, and tetC *sul*1, *sul*2, blaTEM, blaz, tetA-D, tet*G*, *tetK*, *tetM*, *cat*l arsBC, bcrBC, and clpL	Ampicillin Sulphonamides, β-lactams antibiotics, Tetracyclines, Phenicols, Aminoglycosides resistance to stress and disinfectants	Parra-Flores et al., 2022 Kayode and Okoh, 2022.
Salmonella spp.	*inv*A, *Sdf* I, *ViaB* and *Spy*		Anukampa, Sivakumar, Kumar, Agarwal,

			Bhilegaonkar, Kumar and Dubal, 2017
Campylobacter	gyrA cmeR, cmeABC	Fluoroquinolone	Kim and Ahn, 2022
	23S rRNA (rrn operon), erm(B), rplD, rplV cmeABC	Macrolide	
Shiga toxin-producing *Escherichia coli*	mph(A), mph(B), inu(F) cmeABC	Macrolide	

The use of antibiotic therapy is the commonly adopted treatment against foodborne infectious diseases, which has vastly improved the safety of individual health. However, the continuous use of such antibiotics for treatment will lead to the perpetual emergence and enhancement of antibiotics-resistant pathogens (Yao, Zou, Cui, Quan, Gao, Li, Gong and Yang, 2023). This is currently causing some challenges like treatment failure in foodborne diseases, increase mortality, expensive medical treatment, reduce infection control efficiency, and continuous spread of resistant pathogens from hospital to community (Hashempour-Baltork, Hosseini, Shojaee-Aliabadi, Torbati, Alizadeh and Alizadeh, 2019). There are different factors such as choice of antibiotics, sanitation, and hygienic status, which have been associated with the spread of infectious diseases as well as antibiotic-resistant bacteria. Several factors like increased consumption of antimicrobial drugs by humans and animals, wrong prescription of antibiotics therapy when not necessary, overuse of commonly available antimicrobial agents, and wrong combination of low-cost and low-toxicity antibiotics. The mechanisms of action by bacteria against antibiotics include inhibition of cell wall synthesis, depolarization of cell membrane, inhibition of protein synthesis, inhibition of nucleic acid synthesis, and inhibition of metabolic pathways (Munita and Arias, 2016). Bacteria have evolved many antibiotics-resistant mechanisms

by stopping antibiotics from reaching their target site even at a concentration high enough to kill them (Figure 3). The resistance to antibiotics is also achieved by modifications of the antimicrobial target site, decrease in the drug uptake, activation of efflux mechanisms to extrude antibiotic compounds, bacterial enzymes to inactivate antibiotics activity, and changes in antibiotic metabolic pathways through modulation of regulatory networks (Reygaert, 2018). The antibiotic-resistant genes in bacteria are acquired and transferred through mutational changes by external genetic material using transformation, transduction, and conjugation. The transfer of antibiotic-resistant genes, plasmid, transposons, interferon, bacteriophages, and insertion elements contributes to alarming multidrug resistance frequencies of food-borne bacterial contaminants in street food vending.

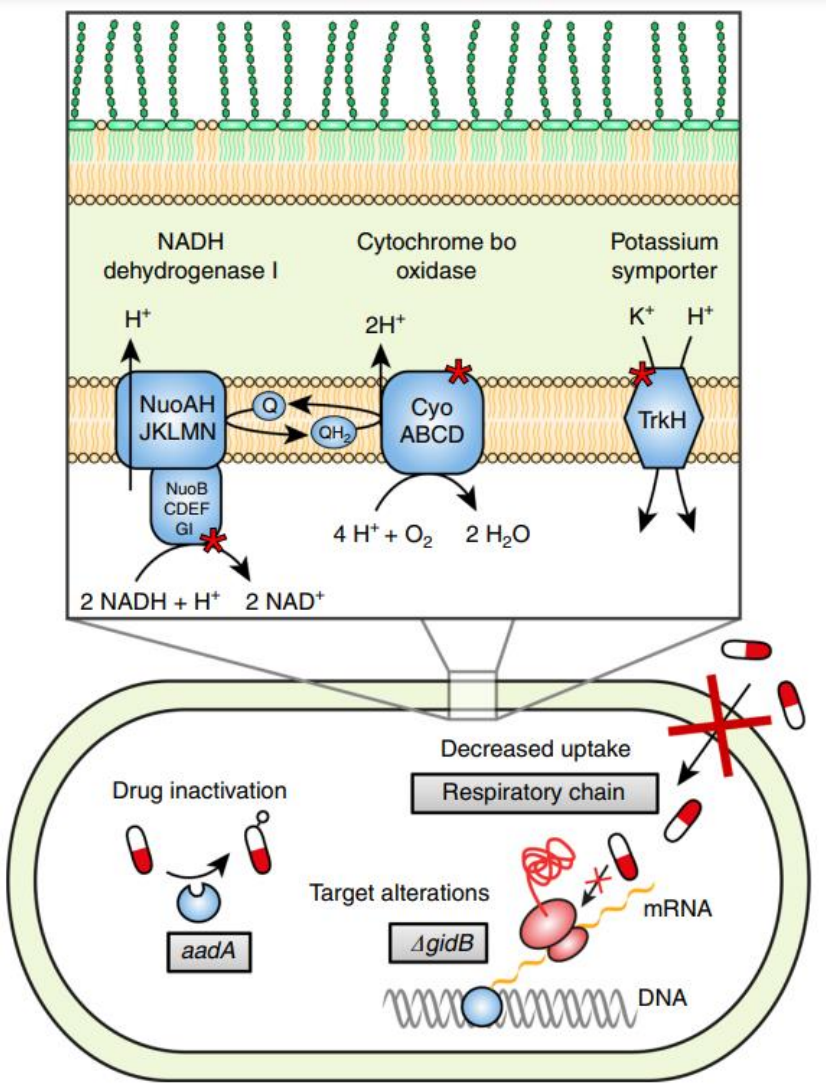

Figure 3: Mechanisms of multiple antibiotic resistance by microorganisms

Source: Wistrand-Yuen, Knopp, Hjort, Koskiniemi, Berg and Andersson, 2018

Environmental stresses on microorganisms during food preparation such as the application of heat during cooking, use of detergent, and addition of chemical preservatives and food components may lead to changes in nature by inducing multiple drug resistance and decreasing the

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susceptibility of organisms to antibiotics (Ogidi and Oyetayo, 2013; and Fusaro, Miranda-Madera, Serrano-Silva, Bernal, Ríos-Montes, González-Jiménez, Ojeda-Juárez and Sarria-Guzmán, 2024)). The co-existence of resistant microorganisms in the food chain and environment lead to the rapid spread of antibiotic-resistance gene among other microorganisms. The use of antimicrobial agents in clinical medicine has been an important foundation and contributor to the re-occurrence of multiple antibiotic resistance by microorganisms. The multiple antibiotic-resistant bacteria are causing a great number of life-threatening bacterial infections (Karnwal, Jassim, Mohammed, Al-Tawaha, Selvaraj and Malik, 2025).

Strategies and regulatory roles to achieve healthy street vended foods

The emergence and spread of antibiotic resistance in pathogenic bacteria around the globe have led to hundreds of thousands of deaths (Samtiya, Matthews, Dhewa and Puniya, 2022). Safe street foods can be achieved through preventive measures and behavioral changes. Therefore, arrays of approaches with modern facilities are needed at both the national and international levels to control the spread of foodborne pathogens, and multiple antibiotic resistance by pathogenic microorganisms and to promote food safety and security are essential (Farrukh, Munawar, Nawaz, Hussain, Hafeez and Szweda, 2025). These will proffer solutions to health challenges associated with consumption street vended foods. The vendors carry a lot of pathogenic microorganisms that can be eventually transferred from street-vended foods to the consumers. The hands of the food handlers are the most important vehicle for the transfer of organisms from faeces, nose, and skin to food. The physical hygiene and cleanliness of the food handlers must be encouraged. They must ensure that their clothes are not dirty, they must cover their body with an apron, cover the hair on

their head and their nails must not be overgrown. The food vendors must not engage in conversation, smoke, chew gum, change a baby's nappy, spit (saliva), cough, or sneeze when cooking and dishing out food to the customers (Adeosun *et al*., 2023).

Food vendors should sweep their surroundings and dispose of their waste regularly without piling up any waste around their food vending outlets, these will keep their environment clean and provide safe food management to consumers (Nkosi and Tabit, 2021). For the fact that street food vendors contribute to food security and employment, the government should formally recognize the importance of the sector in economic development and establish regulatory agencies to monitor the vendors as well as their foods to protect the consumers.

Most of the food handlers have not attended any food safety training because their schedule involved cooking at intervals and continuous meetings with customers at the selling point every day. This has contributed to poor food safety knowledge (Aduah, Adzitey, Amoako, Abia, Ekli, Teye, Shariff and Huda, 2021). To prevent food contamination that has led to several food-borne diseases, street-vended food handlers should be routinely trained regularly on food safety knowledge by qualified facilitators, engage in courses that can translate into the improvement of attitudes towards achieving quality hygiene, and proper food handling practices to control the occurrence of pathogens responsible for foodborne diseases (Putri and Susanna, 2021). The issue of food safety knowledge needs to be promoted and taken seriously like national security in the country. The safety of street vended food has become a matter of safety concern to individuals and the general public (Onyeaka, Ekwebelem, Eze, Onwuka, Aleke, Nwaiwu and Chionuma, 2021). Most of the street food vendors are relatively uneducated, often uninformed, and have little effectiveness in achieving hygiene practice as they are involved in an unregistered skill (Islam,

Tanjia, Mitra, Hossain, Jasika, Suhi and Hossain, 2024). Food vendors need to be registered with the government before being allowed to sell food. Certificates of food hygiene practice, licenses, and identity cards subjected to annual renewal should be issued to street food vendors to efficiently monitor the number of registered vendors' activities. This will ensure safe street food vending in rural and urban.

Most of the street food vendors have no access to clean water for food preparation, which cannot allow the vendors to perform necessary personal hygiene activities, such as washing hands, washing raw materials before food preparation, and cleaning and washing cooking equipment (Rosales, , Linnemann and Luning, 2023). To avoid microbial multiplications in street-vended foods, knowledge of food preparation at holding temperatures must be imparted to food vendors. Provision of health education to the vendors, regular monitoring, and enforcing implementation of appropriate hygienic practices would improve the bacteriological quality of street-vended foods (Desye, Tesfaye, Daba and Berihun, 2023). Relevant agencies must be established to oversee the food vendors activities, enforce strict compliance with hazard analysis with critical control points, and establish consumer protection rights. The government and private establishments should address the problem of infrastructure and other challenges affecting the street food vending economy. The implementation of a food stall system with adequate space, and a power supply, that is well-resourced to ensure proper control and compliance with relevant food safety regulations. This will be required to maintain hygiene in the sale and distribution of street-vended foods.

Safety of street foods is very important to achieve the Sustainable Development Goals; eradication of poverty, and hunger, and promoting the health and well-being of individuals. This will improve nutritional security, improve nations' economy, and public health delivery systems, and boost the national economy. Foodborne illnesses and diseases are major threats to human health (Jaffee, Henson, Unnevehr, Grace and Cassou, 2019). The incidence of foodborne diseases in low- and middle-income countries has increased over the years, which has resulted in major public health challenges (Devleesschauwer, Haagsma, Mangen, Lake and Havelaar, 2018). Foodborne pathogens have been isolated from various vended foods. The presence, isolation, and identification of these multiple antibiotic pathogens have created awareness about health challenges associated with the detection of foodborne pathogens. The use of conventional methods to detect foodborne pathogens in foods is time-consuming, labour-intensive and cannot meet up with the rapid food test techniques. Hence, rapid detection methods like nucleic acid-based, biosensor-based, and immunological-based methods need to be developed for immediate detection of foodborne pathogens (Ndraha, Lin, Wang, Hsiao and Lin, 2023). This will provide a safe food and to prevent foodborne diseases. The use of nucleic acid-based Polymerase Chain Reaction (PCR) and next-generation sequencing-based methods for bacterial, fungal, and viral pathogens' detection and their toxins in foods will lead to early detection and control of foodborne diseases, enhancing public health and reducing the frequency of disease outbreaks (Aladhadh, 2023). The rapid detection of pathogenic microorganisms in street-vended foods will ensure safety and ensure compliance with regulatory agencies on food safety.

Conclusion

Most of the microorganisms isolated from street-vended foods displayed a wide range of multiple antibiotic resistance, causing several foodborne disease outbreaks such as cholera, diarrhea, shigellosis, Typhoid fever, acute aflatoxicosis, hepatitis, giardiasis, and others. The incidence, emerging, and re-emerging of foodborne pathogens in street foods remain unresolved threats to the food chain, which continue due to inadequate government authorities or policies to properly monitor the street vendors and their foods. The occurrence of multi-antibiotic-resistant strains as causative agents of foodborne diseases in street foods is due to the misuse of commercially available antibiotics in health care and animal husbandry. The incidence and wide spread of pathogenic microorganisms from street-vended foods to consumers occur through different routes. Therefore, national and international policies are urgently required to control the spread of foodborne pathogens and to promote food safety. Multi-antibiotic resistance in foodborne pathogens is a worldwide health challenge and therefore, requires pressing attention for new policies, alternatives, and effective antibiotics to the existing antibiotics.

Food safety issues on street vended foods currently need the attention of government authorities to control the incidence of foodborne illnesses. The primary causes of food-borne diseases when street-vended foods are consumed are as a result of cross-contamination of raw ingredients, poor handling during cooking, insufficient heating, keeping the foods at a temperature that support the growth of pathogenic microorganism, contamination by infected food handlers, inadequately cleaned equipment, and environment. The possession of adequate food safety knowledge by food vendors, training on hygiene skills, availability of adequate infrastructures, portable and clean water, and cleaned equipment are essential to maintain food safety. Regular inspections and effective supervision of food handlers who engage in the cooking of street-vended foods is

necessary to avoid the transfer of pathogenic microorganisms. The use of antibiotics in foods of animal origin needs to be regulated to avoid the prevalence of antibiotic-resistant microorganisms. Finally, more effective health education and training for vendors is required to maintain the safety of street-vended foods, regular inspections of vending sites, and sensitizing the vendors about dangers associated with antibiotic resistance patterns of food-borne pathogens are essential to overcome challenges of food safety.

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