Hindawi
Journal of Food Quality
Volume 2022, Article ID 4141914, 24 pages
https://doi.org/10.1155/2022/4141914

Review Article

Microbial and Parasitic Contamination of Vegetables in Developing Countries and Their Food Safety Guidelines

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Received 30 January 2022; Revised 12 July 2022; Accepted 1 September 2022; Published 27 September 2022

Academic Editor: Efstathios Giaouris

The safety of humans is of paramount importance in the vegetable production chain. Evidence of microbial and parasitic contamination of these products poses a great threat to consumers. This is an emerging issue the world is battling, and it is still in the process of unravelling. However, one of the contributing factors responsible for the rapid spread of these pathogens to millions of people among other factors is the distribution of food in our food systems. The purpose of this study was to draw the attention of producers, retailers, consumers, and various stakeholders to the occurrence and potential hazard of these organisms, their contamination origin, and food safety protocols. Among the food system, vegetables play a major role, and their consumption has increased as they form a larger portion of daily diets. This urge for healthy diets coupled with changing dietary habits and human population explosion has therefore accelerated their production. This has resulted in parasitic and microbial contamination gaining grounds in salad vegetables, and as such, a wide range of microbes such as *Escherichia coli O157: H7*, *Listeria monocytogenes*, *Salmonella* spp., *Shigella*, and *Staphylococcus*, and parasites such as *Giardia lamblia*, *Entamoeba coli*, *Entamoeba histolytica*, *Cystoisospora belli*, *Toxoplasma gondii*, *Trichuris trichiura*, and *Ascaris lumbricoides* have been isolated from them. Therefore, major routes for salad vegetable contamination and prevention methods have been pointed out in this review article. The topic of protective countermeasures will also be covered here in this review. Notwithstanding, several control measures have been reported to be effective and efficient in removing or eliminating pathogens, including treatment of irrigation water and fertilizers, use of disinfectants like vinegar and saltwater, irradiation, ozone, and bacteriophages. Though consumption of vegetables and salads is encouraged due to their nutritional advantage, appropriate systems should be put in place to ensure their safety.

1. Introduction

In recent years, there has been an upsurge in vegetable production and consumption throughout the whole world; this is said to be twice its initial production weight of 30 million metric tons in 2018 [1]. In developing countries like Ghana, the initiation of programmes such as the current "Planting for Food and Jobs" by the Government of Ghana has expanded the mass production of fresh vegetables [2]. This was anticipated to increase vegetable consumption by roughly 25% by 2020 [3]. Hence, the consumption of vegetables globally has increased due to their relatively low cost, high nutritious value, and convenience in preparation. Vegetables are either eaten raw or cooked, and are essential in human nutrition as a result of their nutrient composition such as dietary fibre, minerals (like iron, calcium, zinc, magnesium, and phosphorus), and vitamins (like vitamins B, C, and K) [4]. Furthermore, some of these vegetables are processed into ready-to-eat salads prepared by combining two or more vegetables such as cucumber, tomatoes, pepper, cabbage, carrots, spring onions, and radishes. They are usually sold by street vendors and in canteens, restaurants, and grocery stores as they are served with foods like "waakye," fried rice, jollof rice, and plain rice. Despite the numerous advantages vegetable consumption contributes to our well-being, the practice can adversely affect our health given if food safety practices are not carefully followed. This is because vegetables present numerous avenues for adherence and invasion of dangerous microbes or parasites during cultivation, harvesting, processing, and marketing [5]. A consequence of vegetable contamination is the associated outbreaks (such as giardiasis, amebiasis, cyclosporiasis, and cryptosporidiosis) which have been responsible for the higher rate of morbidity and mortality in various parts of developing countries [6]. While the rate of vegetable and salad consumption is accelerating, there is a tendency for increased microbial and parasitic contamination leading to many other foodborne illnesses. However, few reviews such as this have been conducted to integrate studies on this subject for proper surveillance and measures to combat the incidence. Hence, the need to draw the attention of producers, retailers, consumers, and various stakeholders to the epidemiology of microbes and parasites found in salad vegetables and vegetable salads, their contamination origin, and food safety protocols in developing countries have necessitated the conduct of this review.

2. Production, Distribution, and Consumption Trend of Vegetables and Vegetable Salads

Globally, the agriculture sector from 1980 to 2004 experienced a surge in vegetable production by 94%, with population increase being a significant contributing factor [7]. Since that period, there has been a continuous surge in production within the last eighteen years (2000 to 2018) from 682.43 to 1088.9 million metric tons though there was a slight drop between 2017 and 2018 (Figure 1) [8]. Among developing countries, interestingly, the production of vegetables is widely distributed in various continents including countries like India, Iran, Vietnam, Nigeria, Egypt, and Mexico, which form part of the top ten producers of vegetables in the world (Figure 2) [8]. Due to this increase in the production, the consumption of vegetables in recent years has also accelerated in different regions with Asian countries being the highest consumer, and then Europe, Northern America, Oceania, and Africa [1]. Additionally, the consumption rate of vegetables specifically in developing countries increased by 69% from 1961 to 2013 (Figure 3) [8]. However, due to a multitude of factors, many people in South Asian developing countries such as India prefer to consume raw vegetables as compared to fast foods [9]. In other African developing countries, vegetables such as cabbages, onions, tomatoes, and lettuce are affordable, accessible, and readily available in the markets; hence, their consumption have increased as compared to fruits [10].

According to the World Health Organization, vegetables constitute the majority (86%) of the total market street-vended foods during its survey [9]. They are processed into vegetable salads and served in restaurants, in canteens, and as street-vended foods [11]. A survey conducted in Ghana revealed that of the 15,000 street food vendors in the capital region, about one-third of them sell foods that utilize ready-to-eat vegetable salads (mainly lettuce and/or cabbage) as accompaniments [12]. This result corroborates with other studies which investigated foods sold in canteens and restaurants [13]. Since vegetable salads and salad vegetables play a major role within the food system, their security has become a priority globally as they are faced with the risk of contamination [7]. The increased demand has exerted pressure on everyone from the producers to the consumers to actively improve the safety of vegetable consumption [14]. Farmers in developing countries especially in Africa who are usually into vegetable farming are also faced with threats ranging from poor water quality and infertile soil to pest infestation, and hence the need for more research into microbial and parasitic contamination [15].

3. The State of Foodborne Illness Outbreak

With a surge in the supply and consumption of vegetable salads and salad vegetables in developing countries, there has been an increasing threat of microbial contamination as a result of the conditions under which they are been produced and sold due to poverty [17]. Street-vended food remains the topmost source of foodborne sickness due to the high prevalence of different microorganisms pointed out in numerous research works [12]. In South African regions, for instance, purchased and examined vegetables from the streets of Gaborone and Botswana harboured a significant level of *Bacillus cereus*, and this suggests a threat of foodborne illnesses [18]. Interestingly, around 1990, about 12% of food-related diseases were specifically attributed to fruit and vegetable consumption [7]. This is not different in the recent era (2018) where foodborne outbreaks in Ghana were linked to the presence of *Vibrio* spp., *Salmonella* spp., and other microbes in vegetables and salads [19]. In the subsequent year (2019), diarrhoeal diseases (many of which are foodborne) were the second top cause of death in low-income countries (Figure 4) [8].

In Saudi Arabia, numerous outbreaks of foodborne diseases have consistently been revealed. 31 foodborne disease outbreaks representing 251 cases were accounted for in 2006. From that report, a larger part (68.9%) of the affected individuals became ill after eating vegetables and salads that were commercially made, and *Salmonella* species was the highest pathogenic agent followed by *Staphylococcus aureus* [20]. Likewise, foodborne disease outbreaks (typhoid fever, food poisoning, meningitis, pneumonia, and gastroenteritis) in India from 1980 to 2016 were linked to ready-to-eat foods harbouring *Staphylococcus aureus*, *Salmonella* species, *Escherichia coli O157: H7*, *Yersinia enterocolitica*, and *Listeria monocytogenes*, with *Salmonella* species again

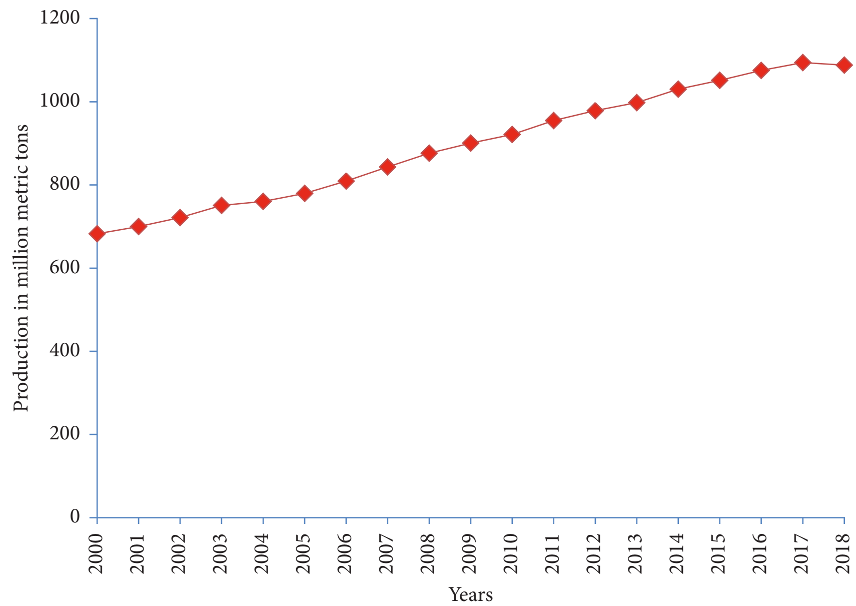

FIGURE 1: Volume (in million metric tonnes) of vegetables produced globally [8].

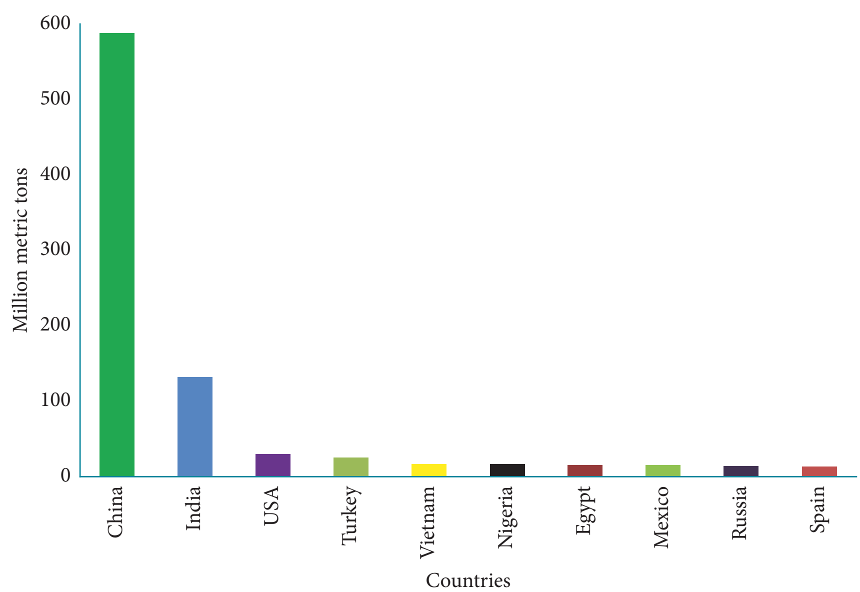

FIGURE 2: 2019 top ten leading producers of vegetables [8].

being the most common cause [21]. The epidemiological investigation also revealed the yearly prevalence of *Salmonella typhi* to be much higher in developing countries like Pakistan, India, and Vietnam, representing 451.7, 214.2, and 21.3 cases, respectively, per 10000 individuals as opposed to China (15.3 cases/100,000) [22]. A significant number of findings every year from Sri Lanka, Nepal, India, Maldives, Pakistan, Bhutan, and Bangladesh have indicated shigellosis as the most detrimental disease leading to high fatality and morbidity [22]. Concerning listeriosis, the disease initially occurred periodically in Asia [23]; however, it is presently spreading widely across developing regions [24]. This periodic disease is typically linked to consuming foods like milk and vegetables [25]. Though there are limited reports and surveillance on listeriosis in Nigeria, research has shown its effect on pregnant women and infants [26]. South Africa recently experienced severe outbreaks of listeriosis (820 cases) [27] and salmonellosis thought to be related to vegetable consumption [28].

Furthermore, parasites have been shown to play a major role in the occurrence of foodborne illnesses. Foodborne parasites are endoparasites comprising protozoans, trematodes (flatworms or flukes), nematodes (roundworms), and cestodes (tapeworms). Parasitic diseases have been prevalent in tropical countries, but factors like climate change, global warming, and globalization of food supply are extending them to other non-tropical regions. *Entamoeba histolytica*, which is responsible for amebiasis, was

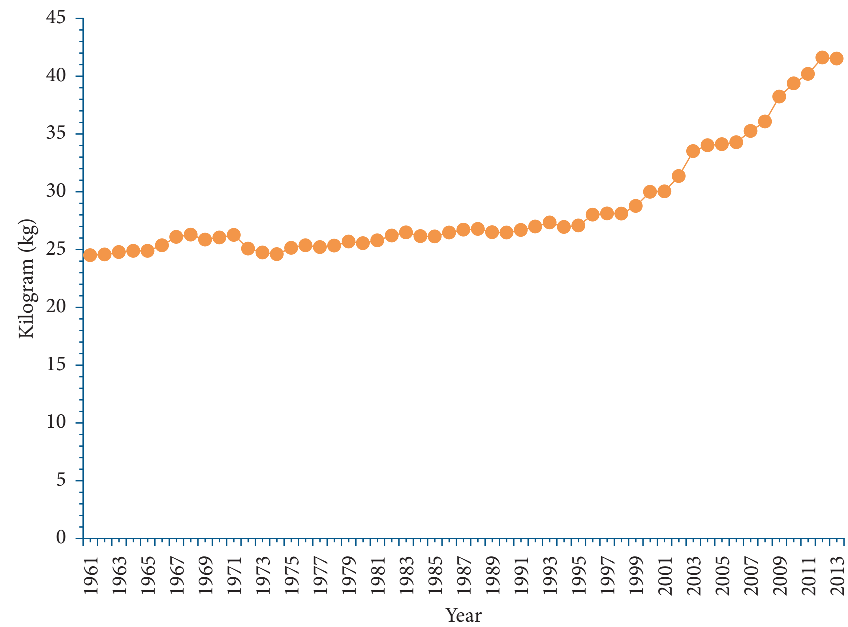

Figure 3: Trend in vegetable consumption per capita in the least developed countries, 1961 to 2013 [8].

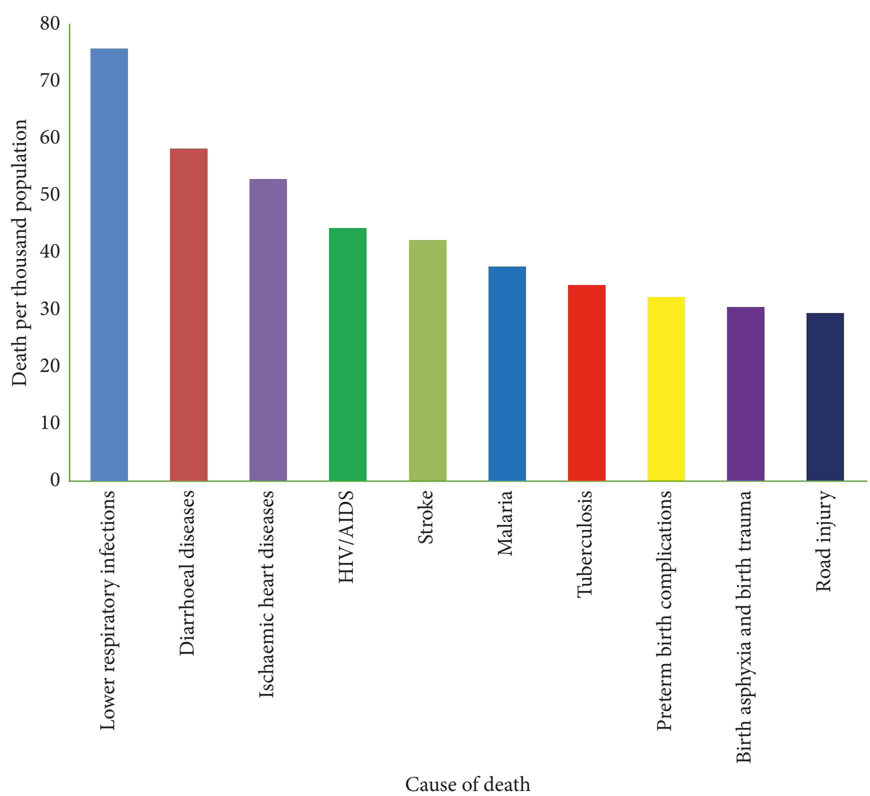

Figure 4: 2019 top ten leading causes of death in low-income countries [8].

reported to be the cause of illness among fifty million patients and also resulted in a hundred thousand deaths in developing countries across South America, Africa, and the Indian sub-continent [25]. Furthermore, toxoplasmosis (caused by *Toxoplasma gondii*), one of the most common foodborne diseases, sickens thousands globally each year [29]. It is thought that vegetables washed in contaminated water are a major contributing factor to foodborne parasite outbreaks [1]. Not only can these outbreaks be caused by familiar foes but there are also recent cases of emerging infections arising from contaminated vegetables. For instance, in 1977, the first human case of cyclosporiasis was reported [30]. Similarly, twenty states of the USA in 1990 and 2004 were affected by cyclosporiasis, and this was caused by a new member of the coccidian family, *Cyclospora cayetanensis* [30]. Interestingly, these outbreaks were linked to lettuce, basil, and raspberry consumption [25]. It is observed that the outbreak of foodborne illness has been overlooked or un-investigated, and will gain attention after a major health incidence. Under such circumstances, identifying the risk factors and controlling the outbreak will be impossible [31]. Therefore, instituting foodborne disease observations would be essential as it will help to generate data on the issue, determine the extent of contamination, and determine the kind of food to be contaminated in the future, and in other preventive measures [25].

4. Microbial Assessment of Salad Vegetables

4.1. Vegetables. Table 1 displays evidence of different species of microbes such as *Escherichia coli O157: H7*, *Listeria monocytogenes*, and *Salmonella* spp. isolated from salad vegetables including lettuce, cabbage, and cucumbers. In 2022, for instance, a study indicated the existence of multidrug-resistant *Listeria monocytogenes* in fruits and vegetables in South Africa [24].

4.2. Vegetable Salads. Due to the growing need for work and humans' busy schedules, most individuals in a bid to satisfy their nutritional requirements have resorted to the most convenient ways to access foods. They do not have enough time to cook, and that paves way for the consumption of already prepared foods which are usually served with ready-to-eat vegetable salads. These are sold in open markets, in grocery stores, as street-vended foods, and in restaurants. Notwithstanding, an increased level of consumption is worth noting because these foods have been indicated as a source of several pathogenic infections with contamination originating from each point in the supply chain including retailers, processors, and/or consumers.

4.2.1. Vegetable Salads from Street Vendors and Open Markets. The street food industry is known to satisfy the everyday food needs of a large number of inhabitants of developing countries by serving different kinds of dishes that are affordable and easily accessible [43]. The preparation of these ready-to-eat street foods takes place either at home or on the street, and is sold along the street; hence, their consumption requires no further processing [44]. These foods are now popular in developing countries due to economic changes, population growth, and urbanization [44]. Consumption of street foods raised concern about potential food poisoning outbreaks due to improper handling and unhygienic practices among street food vendors [45]. One of the most essential sources of pathogen contamination is vegetable salads which are commonly served along with other foods [46]. This is because several microorganisms of public health concern have been identified in vegetable salads prepared in the streets [46–50]. The presence of these microorganisms were also found when vegetables used for salad preparation and the salads itself were analysed concurrently [51, 52].

Contamination was reported in salads in some studies, and the total bacterial count was found to be above the national standard count of <5.0 log10 cfu/g [12, 53] as stipulated by the Ghana standard authority [16]. In those investigations, the bacterial count was 5.13 log10 cfu/g [53] and 6.3 ± 0.78 log cfu/g [12], but a standard count was recorded in another study in Johannesburg [54]. Similarly, these pathogenic bacteria were found in an investigation in Ghana [12]. One of the major contributing factors to several microbial contaminations is the source of the vegetables used for salad preparation. Moreover, most street food vendors purchase vegetables for salads from open-aired markets and subject them to poor handling due to preferential differences of buyers as well as improper washing methods, thereby leaving some microbes at the point of consumption [55]. Hence, *Penicillium* spp., *Staphylococcus aureus*, *Escherichia coli O157: H7*, coagulase-positive staphylococci, *Cladosporium*, and *Salmonella* spp. were observed in fresh-cut vegetables and ready-to-eat salads purchased from open-air markets [52, 56].

4.2.2. Vegetable Salads from Restaurants and Canteens. *Listeria* spp. is a pathogen that causes listeriosis in animals and humans. It is transmitted to susceptible individuals when foods contaminated with manure from ruminants are ingested [7]. *Listeria* has been isolated from vegetable salads, salad vegetables, and coleslaw restaurants, and this may present a threat to human health [57]. In this study, 95.8% of the total 355 vegetable samples were contaminated with *Listeria* spp. Out of the *Listeria* spp., 4.1% were *Listeria monocytogenes*. In classifying the samples following the infection rate, 4.7% of salad vegetables showed contamination preceded by coleslaw (4.4%), with traditional vegetable salads being the lowest (1.7). Concerning the salad vegetables, cabbage (8.5%), lettuce (6.2%), and tomatoes (4.3%) were highly contaminated, with carrot and cucumber being the least (2.2%) [57].

A comparable study in India indicated the presence of *Listeria* spp. in 73% of salads studied, while 20% of the samples harboured *Yersinia* spp. A higher range of bacterial (10^6–10^8 cfu/gm) and mould (10^4–10^7 cfu/gm) counts were also observed in ready-to-eat salads. On the other hand, fresh vegetables used to prepare the salads exhibited the presence of *Listeria*, *Yersinia*, total bacteria, yeast, and moulds. However, higher bacteria and mould counts in salads than in freshly washed vegetable ingredients denote that cross-contamination into salads probably occurred during/after the preparation of salads [58].

Other important bacteria isolated from ready-to-eat salads from restaurants are *Clostridium difficile* and *Helicobacter pylori* [59, 60]. The study reporting the presence of *Helicobacter pylori* in both traditional and commercial vegetable salads was the first research paper in a developing country to make such a finding [60]. The prevalence rate of *Helicobacter pylori* in salads from these two sources was

Table 1: Microbes isolated from notable vegetables.

Type of salad vegetable	Microbes isolated	Reference number
Lettuce	*Escherichia coli O157:H7*, *Proteus* spp., *Enterobacter* spp., *Staphylococcus aureus*, *Salmonella* spp., *Klebsiella* spp., *Listeria monocytogenes*, *Pseudomonas* spp., *Acinetobacter* spp., *Micrococcus* spp., *Bacillus*, yeast, and moulds	[32–35]
Cabbage	*Escherichia coli O157:H7*, *Pseudomonas* spp., *Erwinia* spp., *Salmonella* spp., *Listeria monocytogenes*, *Staphylococcus*, and *Enterococcus*	[33, 36, 37]
Carrot	*Escherichia coli O157:H7*, *Erwinia* spp., *Staphylococcus aureus*, *Enterobacter* spp., *Citrobacter* spp., *Klebsiella* spp., *Lactobacillus* spp., *Pseudomonas* spp., *Vibrio* spp., *Proteus* spp., *Aspergillus* spp., *Rhizopus* spp., and *Enterococcus*	[33, 34, 36, 38]
Cucumber	*Escherichia coli O157:H7*, *Staphylococcus aureus*, *Enterobacter* spp., *Klebsiella* spp., *Lactobacillus* spp., *Pseudomonas* spp., *Vibrio* spp., *Aspergillus* spp., and *Shigella* spp.	[34, 36, 38]
Onion	*E. coli*, *Pseudomonas* spp., *Enterobacter* spp., *Staphylococcus* spp., *Streptococcus* spp., and *Cryptosporidium* spp.	[36, 37, 39, 40]
Tomatoes	*Citrobacter* spp., *Enterobacter* spp., *Klebsiella* spp., *Lactobacillus* spp., *Pseudomonas* spp., *Staphylococcus* spp., *Vibrio* spp., *Aspergillus* spp., *Rhizopus* spp., *Penicillium* spp., *Shigella* spp., *Escherichia coli O157:H7*, *Salmonella* spp., *Listeria* spp., and *Enterococcus*	[33, 38, 41, 42]

Italicized words indicate scientific names of micrroganisms (Genus and Species).

significantly variable, wherein improperly cleaned leeks, lettuce, and traditional salads were the highly contaminated products. 9.56% of salad samples were found contaminated when the culture method was applied for isolation, while the polymerase chain reaction (PCR) technique also revealed 10.86% contamination.

Furthermore, a study conducted in Nigeria, which took three months, revealed that salads from restaurants harboured twelve nonhemolytic bacterial pathogens, including *Bacillus* spp., *Klebsiella oxytoca*, and *Escherichia coli O157: H7* [61]. The prevalence of microbial contamination in some vegetables from Tamale in Ghana [62] reflected in the salads sold in that same area such that 73.3% and 76.7% of salad samples were contaminated with *Salmonella* spp. and *Shigella* spp., respectively [63].

In and around several University campuses in developing countries, pathogens causing several foodborne illnesses have been reported. Concerning *E. coli* and *Salmonella*, the majority (80%) of vegetable salads (Kachumbari) served in canteens around Egerton University, Kenya, contained an average of 3.047 log10 cfu/g *Escherichia coli O157: H7*, while 70% of the samples tested positive for *Salmonella* [64]. This confirms the findings of a similar study wherein vegetable salads (Kachumbari) harboured *Escherichia coli O157: H7* but not *Salmonella*. Additionally, sampled vegetable salads were indicated as unsafe for consumption and hence detrimental to human health as a result of *Campylobacter* spp. and *staphylococci* contamination [65]. In another study, *Escherichia coli O157: H7* was found in over 80% of the product, but the topmost contamination was observed in street food salads (4.23 log10 cfu/g) [66]. Salads from a University campus in Bangladesh were also contaminated with *Escherichia coli O157: H7*, *Salmonella* spp., and *Staphylococcus* spp. Monte Carlo simulation calculation on risk assessment showed that the risks of *Staphylococcus* spp., *Salmonella* spp., and *E. coli* infection yearly are 100% on average due to frequent salad consumption in this region [67, 68]. Furthermore, different *E. coli* strains (enterotoxigenic, enteropathogenic, and Shiga toxin-producing *E. coli* pathotypes) have been identified in the vegetables [69]. In this study, vegetables were contaminated with *E. coli* strains, and less than half of the strains were classified as diarrhoea-causing *E. coli* pathotypes. 26.7% of salad samples were contaminated with *E. coli* pathotypes, 15% (two enterotoxigenic *E. coli* and one enteropathogenic *E. coli*) from spinach salads, and 25% (three enterotoxigenic *E. coli*, one enteropathogenic *E. coli*, and one Shiga toxin-producing *E. coli*) isolated from mixed salad [69]. These vegetables could be a route for the emergence of bloody diarrhoea and hemolytic uremic syndrome which have been of high prevalence in Africa, particularly in children and HIV patients, caused by these *E. coli* pathotypes [70]. Apart from the above-mentioned pathogens, *P. aeruginosa*, *K. pneumoniae*, *Streptococcus* spp., and *Bacillus cereus* were also isolated from ready-to-eat salads offered with waakye on and across the University of Ghana campus, and from eating places around the campus. The majority of the vegetable salads harboured *Bacillus cereus* (93.3%) and *Escherichia coli O157: H7* (96.7%), whereas *Staphylococcus aureus* was absent [71]. This prevalence on our campuses suggests the need for various departments in charge of food safety to strengthen safety guidelines in order to prevent foodborne illness among students.

4.2.3. Comparing Microbial Contamination of Vegetable Salads from Street Vendors and Restaurants/Cafeteria. There has been a notion that foods purchased from restaurants are much safer than those sold along the street. However, microbial contamination has been reported in salad prepared in restaurants and canteens though on a lower side than products from the street [72–75]. A study found street market salads to contain a higher bacteria load than those from fast food markets [72]. The vegetables used for the preparation of salad in the above study however harboured a lower number of bacteria, some of which include *Staphylococcus aureus*, *Citrobacter freundii*, and *Neurospora crassa*. However, *Corynebacterium* spp.

found in salad samples originated from street markets [72]. Similarly, all fresh vegetable and ready-to-eat vegetable salads purchased from restaurants in another study were satisfactory regarding *E. coli* contamination, but street-vended samples yielded unsatisfactory levels [73]. Then again, 32% of salad samples had *Salmonella* spp. and 17% had helminth eggs and thermotolerant coliforms in street-vended and cafeteria salads in similar research [74]. Conversely, isolated *Salmonella*, *Enterobacter aerogenes*, *Escherichia coli O157: H7*, and *Shigella* spp. in another study were higher in salads from restaurants than in those from homes. Bacterial contamination reported was not surprising because the same vegetable salads analysed in another experiment isolated 36 bacterial species [76]. The presence of *Shigella* spp. in the above study corroborates another finding which detected *Shigella* spp. in tested salads before and after the enrichment [77]. The results found in restaurants and home-made salads are consistent with a lower state of hygienic practices of service workers, quality of water, and processing of vegetables as well as observance of other precautionary measures in the restaurants than the homes where enhanced care is taken [75, 76]. Therefore, there is a need to improve food safety knowledge attitude and practices, and foods served in restaurants and cafeterias where food products are considered to be highly safe.

4.2.4. Relationship between Microbial Prevalence in Vegetable Salads and Time. In developing countries, most individuals usually consume foods such as "waakye" (rice and beans) and plain rice in the morning in order to increase their energy for work [78]. However, the prevalence of microbes has been reported to vary at different times in a day. In several investigations, the highest level of pathogen contamination in vegetable salads has been in the afternoon. Moreover, a high load of bacteria was recorded in raw-mixed vegetable salads obtained in Ghana for 15 days [11], and this was above the standard (Log10 3.0 cfu/g) given by the World Health Organization (WHO) [79]. The bacteria identified comprised *Streptococcus faecalis*, *Pseudomonas* spp., *Shigella* spp., and *Salmonella typhi.* The rate of contamination was higher in afternoon samples than samples taken in the morning [11], and this confirms the findings of a similar investigation [49].

Other researchers [50, 61, 80] have added their finding that vegetable salads sold in the afternoon have higher contamination rate than those sold in the morning. Amala and Agha [80] isolated *Staphylococcus aureus* (45%), *Escherichia coli O157: H7* (36%), and *Bacillus* spp. (18%). In the study by Uwamere et al. [61], a substantial difference existed between morning and afternoon dishes in terms of the rate of bacterial contamination, but another investigation [50] had no significant difference although the afternoon bacteria load was higher. The two principal contributing factors for bacterial growth associated with fresh produce are storage temperature and pH. Hence, the low pH values and the short shelf life of morning salads could have been responsible for the low bacterial load [81]. However, the underlying factors that warrant the reduction and multiplication of pathogens should be further investigated.

4.2.5. Evidence of Antibiotic and Multidrug-Resistant Bacteria from Vegetables Salads. Ingestion of vegetables and salads contaminated with bacterial strains is associated with several diseases and can even lead to death. It is therefore paramount to use antibiotics for proper treatment; however, there has been an evolution of resistance against these antibiotics by most pathogenic bacteria, resulting in the loss of drug effectiveness. In previous years, the resistance of pathogenic microorganisms to multiple drugs was limited to hospitals due to the frequent application of antimicrobial agents. In the recent era, antimicrobial resistance is found in other environments including food products like vegetables. This situation is highly alarming, given that antimicrobial resistance can often spread via horizontal gene transfer [82]. Research in Nigeria revealed the existence of several bacterial antibiotic resistances in different fast food industries, and this has led to a spike in illness due to the consumption of contaminated raw vegetables [83].

Salads made from these vegetables and sold in fast-food industries harboured bacteria (25) of different species (6) which were highly (>50%) resistant against eleven of the twelve antibiotics tested. Among the antibiotics, the highest resistance rates against *Pseudomonas* spp., *Bacillus* spp., *Escherichia coli*, *Proteus* spp., *Enterobacter* spp., and *Aeromonas hydrophila* were Augmentin (96%), Cotrimoxazole (92%), and nitrofurantoin (88%), with streptomycin (44%) being the least [83], and this agrees with another study [72]. Furthermore, *Escherichia coli O157: H7* found in vegetable salads and salads vegetables were resistant to more than five antibiotics, thus revealing the multidrug-resistant capacity of *Escherichia coli O157: H7* [59, 69].

Apart from *Escherichia coli O157: H7*, two bacteria species, *Salmonella spp.* and *Staphylococcus aureus*, found in ready-to-eat vegetable salads showed a varied resistance rate (25.71% to 81.82%) against Chloramphenicol, Ofloxacin, Dovid, Siprosan, gentamicin, Tarcvid, Ciproxin, and pefloxacin [84] with an overall multiple resistance rate of 35.29%. Comparably, potential human pathogens, *Staphylococcus aureus* and *Klebsiella aerogenes*, from vegetable salads exhibited antibiotic resistance profiles at a range of 25.71% to 81.82% [85]. Whereas another study [86] revealed the ability of *Staphylococcus aureus* to show 83% resistance against co-amoxiclav and 75% against penicillin. *Klebsiella aerogenes* was fully (100%) ampicillin-resistant and against other antibiotics such as imipenem and amoxicillin/clavulanic acid [86]. Other pathogens isolated from vegetable salads that showed multidrug resistance were *Listeria monocytogenes*, *Proteus vulgaris* strain, *Citrobacter freundii*, *Bacillus thuringiensis* strain, *Staphylococcus aureus*, and *Serratia marcescens* strain [57, 87]. Specifically, *Listeria monocytogenes* were highly resistant to ampicillin (92.9%), oxacillin (85.7%), gentamicin (21.4%), and ciprofloxacin (14.3%). This resistance outcome of microbes in this study indicated that microbes were resistant to more than one antibiotic and that most of them (64.3%) showed antimicrobial resistance against more than four antibiotics [57]. These results suggest that vegetables and salads may serve as a vehicle for bacteria that are resistant to multiple antibiotics.

5. Parasitic Contamination of Vegetables and Salads

5.1. Vegetables. Multiple types of research have assessed the occurrences of parasites in vegetables worldwide and have recovered several parasites such as *Ascaris lumbricoides*, *Entamoeba histolytica*, and *Giardia intestinalis* [88–90]. This contamination is also evident in various parasitic isolates from vegetable salads, as shown in Table 2. Many studies in Ethiopia, Ghana, and Iran also have consistently compared parasite prevalence in vegetables found in open-aired markets and supermarkets where the former recorded a high occurrence of human parasites [6, 104, 105]. The potential cause is the unhygienic nature of the environment which serves as a medium for the growth, multiplication, and transfer of parasites [106]. However, in some developing countries like Ghana, there are only a few available reports highlighting parasitic contamination of fresh vegetables with many of the studies centred on bacterial and chemical contamination.

5.2. Salads. A recent investigation into top causes of morbidity at the outpatient department by the Ghana Health service revealed intestinal worm infestation to be the 7th leading cause and has gradually increased from 2.1% to 3.6% [107]. Based on these reports, it was suspected that consumption of street-vended salad may be contributing to the increasing prevalence of helminthiasis in Ghana. In Ashanti Mampong, Ghana, field studies have reported risk to human health as a result of parasitic contamination in salad vegetables and ready-to-eat vegetable salads. In that work, parasite prevalence in the salad was the highest (66.0%), but the individual vegetables had a greater number (16) of species diversity than the salads (10) [2]. In the vegetables and salads, *Ascaris lumbricoides* and *Giardia lamblia* recorded varying levels of prevalence. While *Ascaris lumbricoides was* the highest (26.94%) succeeded by *Giardia lamblia* (19.93%) and *Toxocara* spp. (1.48%); in the vegetables, *Giardia lamblia* was more prevalent (24.17%) in the salad followed by *Ascaris lumbricoides* (19.17%) and *Toxoplasma gondii* (0.8%). Additionally, other parasites, namely, *Fasciola* spp., *Moniezia*, *Toxocara* spp., *Trichuris trichiura*, and *Entamoeba histolytica*, were recovered from both vegetables and salads.

The above study agrees with a similar finding in Ghana wherein *Giardia lamblia* in the salad was the also most prevalent but the overall prevalence of parasites in the salad was low (32.0%) [108]. In that report, out of 313 ready-to-eat vegetable salad samples analysed, 99 (32%) harboured more than one parasite. Twelve parasite species, including protozoa (*Giardia lamblia*, *Entamoeba coli*, *Entamoeba histolytica*, *Cystoisospora belli*, and *Toxoplasma gondii*), nematodes (*Enterobius vermicularis*, *Trichuris trichiura*, *Ancylostoma duodenale*, and *Ascaris lumbricoides*), and cestodes (*Taenia* spp., *Moniezia* spp., and *Fasciola* spp.) were identified. About a third (32%) was contaminated with at least one parasite. Among the twelve genera of parasites recovered, *Giardia lamblia*, *Entamoeba histolytica*, and *Moniezia* spp. were 6.7%, 6.4% and 4.2%, respectively. Other parasites found were *Trichuris trichiura* (3.8%) and *Entamoeba coli* (3.5%), with the rest recording low prevalence (<2%) [108].

Another report by Tefera et al. [109] revealed that 208 out of 360 vegetable salads and salad vegetables were infected with several strains of parasites, resulting in an overall contamination rate of 57.8%. The prevalence rate of the salad (16.8%) was greater than that of the vegetables. Concerning the parasites, the prevalence is arranged in descending order: *Strongyloides* (21.9%), *Toxocara* spp. (14.7%), *Cryptosporidium* spp. (12.8%), *H. nana* (8.3%), *G. lamblia* (7.5%), *A. lumbricoides* (6.7%), *E. histolytica/dispar* (5.3%), *Cyclospora* spp. (5.0%), and *H. diminuta* (1.4%). It was worthy to note that samples obtained from open markets were more frequently contaminated (84.6%) than those purchased from grocery stores (15.4%) [109].

6. Major Sources of Contamination

6.1. On-farm Routes

6.1.1. Irrigation Water Sources. (1) Wastewater: since accessibility to potable water for vegetable production is a big challenge among farmers, one other way to irrigate their produce is the reuse of wastewater [94]. This practice is rampant among farmers in developing countries where about 10% of the population is engaged in urban agriculture [110]. The wastewater comprises liquid wastes released from homes, farmlands, institutions, and commercial and industrial companies which are usually combined with surface water, groundwater, and rainwater [111]. However, wastewater that can be applied either in the raw, or partially or fully treated state may harbour pathogens, pesticides, toxins, organic particles, or inorganic particles [111].

In South Africa, a high load of *Escherichia coli O157: H7* and *Vibrio* spp. were recovered from effluents of two wastewater treatment facilities [112]. However, due to the costly and time-consuming nature of the treatment procedure, only about 10% of wastewater is adequately treated in developing countries [113].

Unfortunately, insufficiently treated wastewater harbours a high burden of pathogenic microbes [114]. One litre of community sewage can harbour thousands of pathogens such as *Entamoeba histolytica* (4500), *Salmonella* spp. (7000), *Shigella* spp. (7000), and *Ascaris lumbricoides* (600) [115]. Therefore, the application of wastewater during vegetable production should be critically looked at by the necessary stakeholders as this raises public health concerns, especially where vegetables are eaten uncooked or improperly cooked.

(2) Surface water, groundwater, and rainwater: surface water bodies include rivers, streams, ponds, and dams.

Table 2: Parasites isolated from notable vegetables.

Type of salad vegetable	Parasites isolated	Reference number
Lettuce	*Cryptosporidium* spp., *Microsporidia* spp., *Cyclospora* spp., *Ascaris* spp., *Toxocara* spp., *Giardia* spp., *Hymenolepis nana*, *Ostertagia circumcincta*, *Cooperia* spp., *Fischoederius cobboldi*, *Fasciola hepatica*, *Entamoeba histolytica*, *Giardia intestinalis*, *Entamoeba coli*, *Trichuris trichiura*, *Balantidium coli*, *Hookworm*, and *Trichostrongylus* spp.	[32, 91–97]
Cabbage	*Balantidium coli*, *Fischoederius cobboldi*, *Fasciola hepatica*, *Entamoeba histolytica*, *Diphyllobothrium*, *Ascaris lumbricoides*, *cryptosporidium* spp., *Giardia intestinalis*, *Strongyloides stercoralis*, *Giardia lamblia*, *Entamoeba coli*, and *Trichuris trichiura*	[92–95, 98, 99]
Carrot	*Strongyloides stercoralis*, *Ascaris lumbricoides*, *Cryptosporidium* spp., *Entamoeba histolytica*, *Giardia lamblia*, *Entamoeba coli*, *Trichuris trichiura*, and *Cyclospora cayetanensis*	[6, 93, 95, 99]
Cucumber	*Fasciola hepatica*, *Entamoeba histolytica*, and *cryptosporidium* spp.	[92, 93]
Green Onion	*Cryptosporidium* spp., *Microsporidia* spp., *Ascaris* spp., *Toxocara* spp., *Trichuris trichiura*, *Hookworm* eggs, and *Taenia* spp.	[91, 97]
Onion	*Giardia lamblia*, *Entamoeba histolytica*, *Strongyloides stercoralis*, *Trichuris trichiura*, *Ascaris lumbricoides*, *Cyclospora cayetanensis*, *Cryptosporidium parvum*, and *Hookworm* ova	[6, 98, 100]
Tomatoes	*Cryptosporidium* spp., *Entamoeba histolytica*, *Giardia lamblia*, *Entamoeba coli*, *Trichuris trichiura*, *Isospora belli*, *Cyclospora cayetanensis*, *Cryptosporidium parvum*, *Fasciolopsis buski*, *Hookworm* ova, and *Taenia* spp.	[6, 33, 93, 95]
Radish	*Ascaris* spp., *Trichuris trichiura*, *Hookworm* eggs, *Taenia* spp., *Taenia/Echinococcus*, *H. nana*, *Trichostrongylus* spp., *Giardia lamblia*, *Fasciola hepatica*, *Entamoeba coli*, *Blastocystis hominis*, and *Dicrocoelium dendriticum*	[97, 101]
Spinach	*Ascaris lumbricoides*, *Giardia intestinalis*, *Entamoeba histolytica*, *Giardia lamblia*, *Entamoeba coli*, *Trichuris trichiura*, *Entamoeba coli*, *Trichostrongylus* spp., *Toxocara* spp., *H. nana*, *Taenia* spp., and *Isospora* spp.	[94, 95, 102]
Parsley	*Ascaris* spp., *Trichuris trichiura*, *Hookworm* eggs, *Taenia* spp., *Hymenolepsis nana*, *Trichostrongylus* spp., *Entamoeba* spp., *Giardia lamblia*, *Trichostrongylus* spp., *Fasciola hepatica*, *Blastocystis hominis*, and *Dicrocoelium dendriticum*	[97, 103]
Rocket	*Entamoeba histolytica*, *Entamoeba coli*, *Giardia lamblia*, *Cocci* spp., and *Balantidium coli*	[96]

Globally, surface water is the topmost and most extensively exploited water for irrigation but is highly open to pathogenic infestation as opposed to other water sources [116]. Contaminants such as heavy metals, and carcinogenic and organic substances from rural, urban, and industrial facilities can enter bodies of water. Furthermore, these water sources can harbour several pathogenic microorganisms such as *Salmonella* spp. and *Listeria* spp. [117]. These can be released into farmlands and produced during irrigation, which therefore can affect the safety of food and consumers [118].

At a time when surface water bodies have dried up, groundwater is another alternative and inexpensive source of water for domestic and agricultural production. This is because the aquifers help to protect the water reserves during drought [119]. Groundwater is usually suggested as water for irrigation of farm produce as compared to surface water, and this is due to the lower rate of contamination arising from the enclosed nature. Microbes like *Clostridium* spp., *Staphylococcus*, and *E. coli* were identified from borehole water in Kenya [120]. Since the occurrence of contamination in groundwater is usually minimal, they are relatively safe microbiologically for agricultural purposes [119].

Research has elaborated that in rural regions especially where there are few or no pipe-borne or boreholes, collected rainwater is an extremely useful and most convenient source of water for domestic use and irrigation [121]. However, the method of collection, that is, from rooftops or runoff on the ground which is then collected into containers or tanks, can affect the quality of the water. For example, faeces from animals (such as bird's faeces) and other debris as well as pathogens found in the soil such as *Salmonella* spp. may contaminate the harvested rainwater [121].

(3) Prevalence of pathogens in irrigation water: water on farmland coming from irrigation systems or rainfall can serve as a potential vehicle for pathogen transmission onto fresh produce [122, 123]. These water sources are usually contaminated with enteric microbes or parasites which come from faeces, sewage, soil, and other material introduced into them [124]. Rainwater from rooftops has been reported to harbour pathogenic bacteria like *Salmonella* spp., *Aeromonas* spp., *Listeria* spp., *Campylobacter* spp., *E.coli* (faecal indicator), and *Legionella* spp. [125]. This was confirmed by Sánchez et al. [126], who asserted that the presence of these microorganisms is detrimental to the security and quality of vegetables which is not intensively treated before consumption. Twenty-three parasite species including eggs of *Ascaris lumbricoides*, *Entamoeba histolytica*, and *Hymenolepis* species, among others, were isolated from different irrigation waters located in five African regions [127].

Several studies conducted in Morocco [128], Ghana [129], and Ethiopia [94, 130] have demonstrated that irrigation water could affect the safety of fresh vegetables due to the high level of microbial and parasitic contamination. Thus, the application of irrigation water contaminated with faecal coliforms (CF), total coliform bacteria, *Bacillus cereus*, etc. was also observed to be present in vegetable samples [131, 132].

Furthermore, lettuce is a significant vegetable and forms a major part of vegetable salads. However, the application of irrigation water containing helminth eggs and larvae on lettuce resulted in their contamination. The helminth eggs identified included *Ascaris lumbricoides*, *Trichuris trichiura*, Hookworm, *Enterobius vermicularis*, *Strongyloides* larvae, and *Taenia* spp. [133]. *Ascaris lumbricoides* and Hookworm were the most prevalent microbe in both irrigation water and lettuce samples [133]. Compared with the World Health Organization (WHO) standards, the faecal coliform and helminth egg levels in irrigation water and lettuce samples exceeded the recommended levels [133]. Levels of helminth eggs were substantially reduced after washing in that water containing vinegar as compared to water without vinegar [133]. Similarly, protozoan parasites (*E. histolytica* cysts, *microsporidia* spores, and *Cryptosporidium* oocysts) were identified in vegetable washing water and vegetable irrigation water in a similar investigation [134]. In line with the above study, species of helminth eggs, *Hymenolepis diminuta*, *Ascaris lumbricoides*, *Strongyloides* larvae, and *Fasciola hepatica*, were also isolated from water and lettuce samples [135].

Treatment of wastewater is one of the reported strategies to minimize the risk of microbial contamination. This is because research found microbes (like faecal coliform, coliform bacteria, and *E. coli*) and parasites (such as *Ascaris lumbricoides* and *Strongyloides stercoralis*) in wastewater which was higher than that recorded on the vegetables (lettuce, *Amaranthus*, and cabbages) [62]. Also, significantly higher bacteria counts were observed in surface water which subsequently contaminated salad vegetables (spinach, tomato, green chilli, radish, and cabbage) than partially treated wastewater from sewage treatment plants [136]. However, wastewater treatment could not eliminate pathogens as Javanmard et al. [137] reported parasitic contamination of treated wastewater (53.8%) and vegetable (41.7%) samples irrigated with this water. Also, intestinal helminth ova (*Trichuris trichiura*, *Ascaris lumbricoides*, and hookworms) were isolated from raw wastewater (83.3%) and treated wastewater (68.2%), soil (68.6%), and vegetables (44.2%) in the study area [137].

Agricultural soil is highly susceptible to pathogenic contaminations originating from irrigation water, animal faeces, sewage, and effluents [138]. Then apart from the naturally contained microbes in the soil, Klutse [139] reported that soils irrigated with wastewater have an increased level of pathogenic microbes such as *Staphylococcus* spp., Enterobacteriaceae, *Clostridium* spp., *Pseudomonas* spp., and *Bacillus* spp. However, it has also been pointed out that though irrigation water is more contaminated, the soil remained a major route for contamination. This is a result of the direct access farmers have to soil such that some (93%) worked barefooted, while others (86%) have direct hand contact with contaminated soil, which leads to oral contamination during hand-to-mouth events [66].

6.1.2. The Entry of the Pathogen into the Soil and Produce via Manure. The recent increase in population in developing countries has resulted in an upsurge in food production to ensure food security. However, vegetable production especially is facing many constraints like land pressure and low soil fertility [140]. Therefore, farmers have now intensified crop (vegetable) cultivation by introducing mineral and organic fertilizers to their crops in order to satisfy the increased demand by consumers. For centuries, the farmer has utilized animal manure of which the majority (60%) comes from poultry with the rest (40%) from cattle, and this is practiced even frequently in present days [141]. However, the intense application of manure from cattle, poultry, and other animal sources put the soil, water, crops, and humans at risk of pathogen infection [142]. This is because several disease outbreaks have been linked to the consumption of vegetables that had been directly or indirectly contaminated with infected animal manure [143]. The isolation of *E. coli* and faecal coliforms from sampled vegetables in three studies indicates faecal pollution [2, 142, 144]. Furthermore, several studies [136–138, 145] have also investigated how the type of manure applied determines the extent of contamination. Some of these studies [136–138] revealed that the ability of a pathogen to survive was greater in vegetables grown with manure from poultry as opposed to manure from cattle, whereas another study [145] found an opposite result. Contaminated manure has been reported to affect the quality of soil, and this subsequently contaminates the vegetables as pathogens found in soils reflected in the vegetables [146]. *Strongyloides stercoralis*, *Taenia*, and *Entamoeba* spp. were observed in raw manure of animal origin and vegetables [147]. Then also, fifteen different species of parasites, including nematode (9) species were concurrently identified from the soil, irrigation water, and vegetables produced, and these microbes emanated from animals and humans. From the soil samples were isolated Geo-helminth eggs, including *Trichuris trichiura*, *Strongyloides*, *Ascaris lumbricoides*, *Enterobius vermicularis*, and hookworms [2]. This suggests contamination from human faeces as a result of practices like open defecation among farmers and the use of improperly composted manure. Similarly, the recovery of *Toxocara* spp. and *Moniezia* spp. from vegetables, vegetable salads, and soils implicates the use of animal faeces as sources of fertilizer [148]. When bovine faeces was used as fertilizer, *E coli* was isolated from 17 samples (including 8 samples of soil and 9 samples of vegetables) [148].

Interestingly, several pathogenic microbes tend to thrive in the manure for a long-time, and this is due to specific elements including physiochemical properties (pH of soil and manure, moisture content, compost treatment techniques, air circulation, soil type, and the degree of fertilizer (manure) application) [149, 150]. *E. coli O157: H7* and *Salmonella* have been shown to live longer in farmyard manure under anaerobic conditions as well as in moist clay soil with a lower temperature [146, 151]. However, several methods such as composting, dry heating of pellets, and alkaline stabilization, among others, are accessible for the treatment of manure before they are being applied. At a temperature of 55°C for 3 days, composting is usually sufficient to destroy bacteria, whereas pelleting is more favourable for the treatment of poultry manure [138].

6.1.3. Intruding Animals on Farms. Domestic or wild animals moving into farmlands can result in vegetable contamination before harvest [152]. This is because several outbreak investigations have been associated with free-moving animals intruding into farms or cross-contamination originating from faeces of a neighbouring animal farm. Unfortunately, a lot of these wild and untamed animals harbour several parasites causing zoonotic diseases of human importance [153]. Similarly, houseflies have been found to transfer *E. coli O157: H7* in cattle [154] and spinach farms [155]. The contamination of tomatoes by *Salmonella* was attributed to the movement of some of these animals such as mice and opossums onto production sites. It has been indicated that some bacteria such as *Campylobacter* spp. and *E. coli O157: H7* originating from these animals can spread in the agricultural environment [156]. In Ghana, the identification of *Toxocara* spp., *Giardia lamblia*, and *Moniezia* spp. in farm soil and salad vegetables originating from droppings of dogs and ruminants is indicative of free-moving animals into production sites [2].

6.2. Off-Farming Routes

6.2.1. Impact of Washing Procedure and Hygienic Practices. Washing is one of the hygienic practices done to remove dirt, bacteria, and parasites on vegetable surfaces. Washing of vegetables is of utmost importance and therefore encouraged. The level of microbial and parasitic contamination usually depends on the quality of water used, together with the kind of washing procedure performed. However, some of the vegetable sellers in some study areas use the same water in washing all vegetables [157]. This will lead to the transfer of pathogens to uncontaminated ones if the water used is not safe and the same wash water is repeatedly used. Most vegetables washed before sales and displayed on tables had more geohelminths contamination than those that were not washed [158]. Conversely, another study reported more parasites in unwashed produce before selling than in washed produce [159]. However, contamination in unwashed vegetables in this study was facilitated by the environment in which they were displayed. Most of them were on the floor, and it is known that bacterial and viral contamination can take place on the floor together with flies that can act as a vector for several microorganisms like *Toxoplasma gondii* and *Cryptosporidium parvum* [159]. Additionally, the source of contamination in washed vegetables was linked to the medium (well and river water) in which the samples were washed, wherein they were contaminated with several parasites [160]. In the removal of pathogenic parasites, Alsubaie et al. [161] attributed running water from taps to perform a similar role to normal saline; therefore, the use of running taps and proper draining of the wash water should also be encouraged instead.

Normally, the water used for the washing procedure is also utilized for salad preparation, and if the water is not clean, there can be contamination in the prepared salad. Assessment of water quality and vegetable salads from a restaurant in a study revealed a high level of coliform, faecal coliform, *Vibrio* spp., and *Salmonella* spp. in both the water and salad samples. *Salmonella* spp. and *Vibrio* spp. were resistant to Cephalexin, Amoxicillin, and Cephradine [162]. The occurrence of coliforms in salads could be associated with cooks not engaging in enhanced sanitation, and the use of contaminated water to cleanse equipment like cutting or slicing machines resulting in cross-contamination. Most cooks also during salad preparation use their uncovered hands, potentially transferring harmful pathogens into the food. Similarly, the predominant population of coliforms, *Salmonella* spp., *Listeria monocytogenes*, *E. coli*, and *Bacillus cereus*, were found concurrently in prepared salads, worker's hands, and cooking equipment in a study [163]. This indicates the probable transfer of microbes between preparation surroundings and ready-to-eat foods. However, coliforms identified in vegetable salads are not surprising because vegetable irrigation water, as well as manure utilized as fertilizers, have been reported to harbour coliforms and other enterobacteria [164].

Furthermore, improperly washed vegetables can result in the contamination of vegetable salads, and this has been noticed in several studies [156, 157]. Among these studies, Orozco et al. [156] noticed contamination variation between vegetables that were cleaned with pure water, germicide, and vinegar as well as the uncleaned ones. Contamination of nematodes larvae was discovered in 82.5% of the uncleaned group. Additionally, 32.5%, 12.5%, and 0.5% of vegetables cleaned with pure water, vinegar, and germicide, respectively, were also infested with nematodes. This showed that the rate of parasite recurrence was significantly higher in vegetables cleaned with pure water than in the germicide and vinegar groups. Washing with soap has also been indicated to have a lesser effect on the reduction of microbial and parasitic contamination [165]. In that, the majority (43%) of parasites and bacteria were identified in vegetables used with soap plus water, whereas those washed with pure water were lesser (40.6%). Some isolated parasites and bacteria include *Giardia lamblia*, *Taenia* spp., *Enterobacter aerogenes*, *Trichocephalus* spp., and *Ascaris lumbricoides* [165].

In a one-year study, intestinal parasites (*Entamoeba histolytica/dispar*, *Ascaris lumbricoides*, *Toxocara* spp., *Hymenolepis nana*, *Dicrocoelium*, *Echinococcus*, *Fasciola*, *Giardia lamblia*, *Entamoeba coli*, and *Trichostrongylus*) were identified from unwashed (63.7%), traditionally washed (49.1%), and standard washed vegetables (36.9%) [166]. Comparing similar works in other developing countries, it

Table 3: Highlights on pathogens identified among various developing countries.

Country	Salad ingredients	Microbes/parasites identified	Reference number
Africa			
Ghana	Cabbage, tomato, onion, and lettuce	*Shigella*, *Escherichia coli O157:H7*, *Bacillus* spp., and *Salmonella* spp.	[63]
Ghana	Lettuce, cabbage, onion, cucumber, and tomato	*Escherichia coli O157:H7*, *Staphylococcus aureus*, *Klebsiella* spp., and *Bacillus* spp.	[48]
Ghana	Raw mixed vegetable salads	*Salmonella typhi*, *Shigella* spp., *S. faecalis*, and *Pseudomonas* spp.	[11]
Ghana	Salad (leaves and fresh vegetables)	*Bacillus* spp., *Klebsiella* spp., *Aeromonas* spp., *Escherichia coli O157:H7*, and *Citrobacter* spp.	[53]
Ghana	Salad (leaves and fresh vegetables)	*Salmonella* spp. and *Helminth* eggs	[74]
Ghana	Cucumber, carrot, onions, tomatoes, and cabbage	*Giardia lamblia*, *Entamoeba coli*, *Entamoeba histolytica*, *Cystoisospora belli, and Toxoplasma gondii*, *Trichuris trichiura*, *Ascaris lumbricoides*, *Enterobius vermicularis*, *Ancylostoma duodenale*, *Taenia* spp., *Moniezia* spp., *and Fasciola* spp.	[108]
Ghana	Cabbage, lettuce, carrot, and green pepper	*Giardia lamblia*, *Ascaris lumbricoides*, *Moniezia* spp., *Entamoeba coli*, *Toxocara* spp., *Taenia* spp., *Fasciola hepatica*, *Enterobius vermicularis*, *Trichuris trichiura*, and *Toxoplasma gondii*	[2]
Nigeria	Vegetable salad	*Listeria monocytogenes*	[57]
Nigeria	Carrot, lettuce, cabbage, and cucumber	*Mucor* spp., *A. fumigatus*, *Aspergillus niger*, *Neurospora crassa*, *Proteus vulgaris*, *Staphylococcus aureus*, and *Pseudomonas*	[72]
Nigeria	Vegetable salads	*Escherichia coli O157:H7, Staphylococcus aureus, Salmonella spp.*	[84]
Nigeria	Ready-to-eat vegetable salads	*Bacillus* spp., *Pseudomonas* spp., *E. coli*, *Proteus* spp., *Enterobacter* spp., and *Aeromonas hydrophila*	[83]
Nigeria	Fresh vegetable salads	*Aeromonas* spp., *Serratia* species, *Pseudomonas* spp., *Corynebacterium*, *Klebsiella* spp., *Escherichia coli*, *Lactobacillus*, *Staphylococcus*, *Aspergillus* spp., and *Rhizopus* spp.	[47]
Nigeria	Vegetable salads	*Enterobacter* spp. and *Streptococcus* spp.	[46]
Nigeria	Cabbage, lettuce, carrot, and cream	*Serratia* spp., *Citrobacter* spp., *Proteus* spp., *Staphylococcus* spp., and *Bacillus* spp.	[87]
Nigeria	Vegetable salads	*Acinetobacter* spp., *Bacillus* spp., *Pseudomonas aeruginosa*, *Proteus mirabilis*, *Staphylococcus epidermis*, *Micrococcus luteus*, *Enterobacter aerogenes*, *Serratia marcescens*, *Klebsiella pneumoniae*, *Klebsiella oxytoca*, and *Citrobacter freundii*	[61]
Ethiopia	Vegetable salads	*Salmonella* spp. and *Escherichia coli O157:H7*	[50]
Ivory Coast	Tomatoes, onion, cucumber, and lettuce	*E coli*, Enterobacteriaceae, and *Salmonella*	[75]
Kenya	Kachumbari (dhania, onions, tomatoes, and chilli)	*Salmonella* spp. and *Escherichia coli O157:H7*	[64]
Kenya	Onion, lettuce, carrot, tomatoes, cabbage, chilli, coriander, and green capsicum	*Escherichia coli O157:H7*, *Campylobacter* spp., and *Staphylococcus* spp.	[65]
Egypt	Cucumber, carrot, onions, tomatoes, cabbage, and parsley	*Shigella*, *Salmonella*, and *Staphylococcus aureus*	[167]
Egypt	Arugula, coriander, parsley, celery dill, lettuce, cucumber, tomato, green pepper, and mint	*Escherichia coli O157:H7* and *Salmonella*	[73]
Asia			
Pakistan	Lettuce, tomato, onion, cucumber, and carrot	*Escherichia coli O157:H7*	[69]
Pakistan	Vegetable salads	*Escherichia coli O157:H7*, *Shigella* spp., *Citrobacter* spp., *Pantoea* spp., *Bacillus* species, *Klebsiella* spp., *Enterobacter* spp., and *Pseudomonas aeruginosa*	[86]
Iran	Lettuce, coleslaw, cucumber, carrot, and tomato	*Cladosporium* spp., *Penicillium* spp., *Alternaria*, *Escherichia coli O157:H7*, *Salmonella* spp., *Geotrichum*, *Trityracium*, and *Aspergillus*	[56]
Iran	Vegetable salads	*Helicobacter pylori*	[60]

Table 3: Continued.

Country	Salad ingredients	Microbes/parasites identified	Reference number
Iran	Lettuce, cabbage, tomato, cucumber, and carrot	*Escherichia coli O157:H7*	[59]
Iran	Vegetable salads	Yeast, *Staphylococcus aureus*, *Escherichia coli O157:H7*, and parasitic eggs	[68]
Iran	Lettuce	*Shigella* spp.	[77]
Iran	Mixed fresh cut vegetable salads	Yeast, mould, *E coli O157:H7*, *Salmonella*, and *Staphylococcus aureus*	[52]
India	Ready-to-eat green vegetable salads	*Listeria* spp. and *Yersinia* spp.	[58]
Saudi Arabia	Tabbouleh, Fattoush, Hummus, Mutabbel, and Caesar	*Escherichia coli O157:H7*, *Shigella* spp., *Salmonella* spp., and *E. aerogenes*	[76]
Saudi Arabia	Tabbouleh, Fattoush, Hummus, Mutabbel, and Caesar	*Pseudomonas* spp., *Bacillus cereus*, *Acinetobacter*, *Serratia marcescens*. *Klebsiella* spp., *Enterobacter* spp., *Kluyvera cryocrescens*, *Enterobacter* spp., *Pantoea* spp., and *Escherichia coli O157:H7*	[168]
Bangladesh	Cucumber, tomato, and carrot	*E coli*, *Staphylococcus* spp., and *Salmonella* spp.	[67]
Latin America and the Caribbean			
Mexico	Vegetable salad samples	*Salmonella*	[169]
Mexico	Lettuce, tomato, onion, cucumber, carrot, spinach, mushrooms, watercress, wheat sprouts, and radish	*E coli*, faecal coliform, and diarrhoeagenic *E coli* pathotypes	[170]
Brazil	Lettuce, carrot, cabbage, spinach, collard green, and watercress	*Staphylococcus aureus* and *Salmonella*	[171]
Brazil	Kale, cabbage, lettuce, onion, parsley, chicory, spinach, arugula, watercress, carrot, collard green, and escarole	*Listeria monocytogenes* and *Salmonella*	[172, 173]
Brazil	Cabbage, kale, lettuce, spinach, parsley, and collard green	*Cronobacter* spp.	[174]
Brazil	Lettuce	*Balantidium coli*, *Giardia* spp., *Ascaris lumbricoides*, *Entamoeba* spp., and *Strongyloides stercoralis*	[175]
Chile	Vegetable salads	*Listeria monocytogenes*	[176]

Italicized words indicates scientific names of microrganisms (Genus and Species).

was found that the contamination rates in the above research are higher than the findings from other countries (Table 3), like Libya [88], Egypt [90], and Nigeria [177]. In Kenya, however, parasitic contamination of unwashed vegetables increased significantly (75.9%) as compared to the reduced level of contamination observed in washed vegetables [178]. In conformity with this research [166], soil-transmitted helminth infestation in standard washed vegetables (1.2%) and in traditionally washed vegetables (3.2%) was also indicated by Nawas et al. [162]. In contrast, Fallah et al. [179] isolated intestinal parasites in unwashed (32.6%), traditionally washed (1.3%), and standard washed (0%) vegetables in Shahrekord, Iran. Despite the findings of these investigations, Salavati et al. [166] explained that standard washing procedures cannot utterly eliminate the parasite from the vegetables. It should be noted that the identification of parasites in standard washed vegetables is probably because disinfectant solutions are capable of completely killing worm eggs, cysts, and larvae, but the remaining dead agents in the corresponding vegetables are still detectable via light microscopy [166, 180].

6.2.2. Processing. Manipulation of vegetables after harvest is a major concern in the farm-to-fork chain. During processing, there are several ways through which pathogenic contamination can enter humans. Pathogenic microorganisms could be transferred from contaminated soil or produced in workers' hands. In other instances, workers harbouring infectious microbes could transfer them to produce [181]. Then also, harvesting knives can serve as contamination vectors during cross-contamination of microbes from infected soil to vegetables. For example, trimming and coring of lettuces after harvest can lead to plant contamination [182]. Moreover, the environment where these vegetables are handled including machinery for processing could also be an important route of vegetable contamination [183].

In an observational study, vegetables were displayed on unhygienic sacks, and unsold ones were stored in uncontrolled states in the market or backyard of homes, resulting in bacterial and parasitic contamination of these vegetables [184]. Six bacteria species were isolated in the previous study, with *Staphylococcus aureus* being the highest, while *Serratia marcescens* was the least. Furthermore, ten parasitic protozoans and helminths were discovered, with *Balantidium coli* being frequently detected and found in all samples together with *Entamoeba* spp. Interestingly, lettuce (25.4%) recorded the greatest level of infestation, with the lowest being green pepper (8.5%) [184].

6.2.3. Storage and Distribution. Several risk factors are associated with the presence of enteric pathogens on vegetables during storage. Some of which include relative humidity, gaseous composition of the atmosphere, storage temperature, and the presence of nutrients, bacteria, or antimicrobial compounds [185, 186]. Hence, at the point of storage, an intervention to reduce the multiplication and activity of human pathogens on the products is by storing them at an appropriate refrigerated temperature. This is because depending on the temperature range, the shelf life and survival of microbes on the surface of vegetables can extend *Listeria monocytogenes*, for instance, multiply slowly at temperatures above 3.8°C [187].

At home, cross-contamination is expected to occur if domestic refrigerated vegetables are stored together with other foods that have been contaminated. In developing countries, consumers usually store vegetables in all-purpose refrigerators together with other foods that have varying temperature ranges due to financial constraints [188]. However, if they are not routinely cleaned, they may serve as a source of harmful organisms. Furthermore, the spread of bacteria and mould is also predicated on refrigeration units located in warehouses; therefore, routine disinfection of air filters and refrigeration systems is required [189]. If contamination takes place in the storage area, the whole facility should be cleaned and disinfected to reduce any potential pathogens [190].

6.2.4. Retail Food Services and Consumer Handling. The foodservice industry receives the majority (60%) of fresh-cut produce, while the remaining (40%) goes into the retail market. A significant cause of foodborne diseases has been attributed to contamination by food service workers during outbreak studies [191]. This is thought to be a result of the frequency with which workers have an unguarded hold on fresh produce during preparation and distribution in food service and retail facilities [163, 192]. Higher bacterial contamination was observed in takeout vegetable salads kept in packages than in those prepared and served at the restaurant, suggesting potential cross-contamination [163, 192]. Those studies recorded a high prevalence of Gram-negative and positive bacteria in salads, and this was in correlation with bacteria found on cooking utensils, cutting boards, and serving spoons [163, 192]. Furthermore, most vendors do not take precautions during vegetable salad preparation as consumers reported the occurrence of food poisoning after consumption [11]. Since these places do not utilize techniques designed to kill microorganisms, the occurrence of microbes in fresh produces is expected to be influenced by the hygienic conditions of food workers. Hence, retailers should have a defined procedure to examine and accept only fresh produce that attains the ideal standard.

Apart from the contamination originating from retailers in retail joints, consumers also play a major role in the contamination of vegetables. During sales, consumers deliberate on buying fresh vegetables by touching them, and this process could lead to cross-contamination if the buyer is contaminated as a result of poor hygienic practices [184]. Furthermore, the temperature of cars and the cooling period tend to proliferate pathogens when fresh vegetables are transported by consumers [193]. At home, undertaking food hygiene practices like hand-washing before handling fresh produce is important [188]. Kitchen sink, sponges, and dishrags are another substantial and familiar reserve for pathogenic microorganism [188]. Therefore, the number one point of call should be educating retailers on excellent food safety practices together with consumers on how to handle and process vegetable and vegetable salads in other to protect produce from contamination.

7. Food Safety Guidelines

7.1. Strategies of Minimizing Microbial and Parasitic Contamination. Whole vegetable and vegetable product contamination occurs at any point from planting to consumption. Unfortunately, there have been no potent antimicrobial treatments to efficiently eliminate pathogenic microbes and parasites [14]. However, the extent of contamination is usually linked to the environmental conditions under which the produce is grown and produced. Therefore, programs such as "Good Agricultural Practices (GAP) and an in-plant food safety program such as Hazard Analysis and Critical Control Point (HACCP)" at the preharvest level are major techniques to minimize threats to food safety [194].

Julien-Javaux et al. [181] and Gil et al. [190], from a food safety standpoint, suggested key factors that should influence the choice of cultivation sites at the preharvest level. Factors that should be considered include the closeness of the farm site to livestock farms or industrial facilities, prior land use, and landscape as a potential for water and soil runoff [195]. Another important factor is the establishment of sanitary facilities that are positioned away from the production environment coupled with producers' education on proper hygiene is essential to avoid cross-contamination of pathogens onto produce [190, 195]. Then again, the safety of irrigation water is necessary to prevent contamination of produce, soil, and working equipment and machinery that should be maintained in sanitized condition [190, 195]. However, plants cultivated close to the soil from which we get fresh vegetables consumed raw should not be irrigated with sewage or untreated water. This is because it could be a route through which *Escherichia coli O157: H7* enters the fruit via the leaves [196]. The use of either manual or mechanical harvest during processing together with containers for collecting produce should be done in a way to reduce the risk of potential contamination coming from soil, workers, water, or machine surfaces [190, 195].

During the postharvest period, good handling practices during processing are critical. Processing tends to facilitate the growth of pathogens when there is an alteration of vegetable colour, nutrients, and water loss as a result of mechanical injury, and hence the need for proper treatment [172]. This indicates the importance of a well-controlled layout across every production point. At this stage, one must consider several interventions consisting of physical, chemical, and biological treatments that minimize contamination, prolong life span, and enhance product quality

Table 4: Food safety legislation in some developing countries (Nigeria, South Africa, Ghana, Ethiopia, and Ivory Coast) [215].

Country	Legislation	Ministries, departments, and agencies involved in enforcement and monitoring (MDAs not in any particular order concerning the enforcement of food laws for each country. Mandates and functions overlap)
Nigeria	Counterfeit and Fake Drugs and Unwholesome Processed Food Decree (Act No. 25 of 1999)	Federal Ministry of Health
	National Agency for Food and Drug Administration and Control (Amendment) Decree 1999 (No. 19 of 1999)	Food and Drug Agency
	Food and Drugs (Amendment) Decree 1999 (No. 21 of 1999)	Food and Drug Administration and Control (NAFDAC)
	National Agency for Food and Drug Administration and Control Decree 1993 (No. 15 of 1993)	Standards Organization of Nigeria (SON)
	Public Health Ordinance Cap 164 of 1958	National Codex Committee
	The Standards Organisation of Nigeria Decree, No. 56 of 1971	Standards Organization of Nigeria (SON)
	The Animal Disease Control Decree, No. 10 of 1988 The Marketing of Breast Milk substitute Decree, No. 41 of 1990	Federal Ministry of Agriculture
South Africa	Regulations relating to the labelling of alcoholic beverages (No. 109 of 2005)	Ministry of Health
	Regulations governing general hygiene requirements for food premises and the transport of food of 12 July 2002	Ministry of Health
	Agreement between the European Community and the Republic of South Africa on trade in spirits - November 2002 Meat Safety Act, 2000	Dept. of Health and SABS
	Foodstuffs, cosmetics and Disinfectant, Act No. 54 of 1972	Dept. of Agriculture
	Health Act No. 63 of 1977	Ministry of Health
	Standards Act No. 29 of 1993	SABS
	Food, Drugs and Disinfectant, Act No. 13 of 1929	Dept. of Trade and Industry
	Trade Metrology Act No. 77 of 1973	Dept. of Trade and Industry
	Regulations on Food Establish & Export/Import	Customs and Excise Division
	The International Health Regulations Act, 1974 (Act 28 of 1974)	Ministry of Health
	The Medicines and Related Substances Act, 1965 (Act 101 of 1965) Wine and Spirits Control Act Regulations governing general hygiene requirements for food premises and the transport of food (G. N. No. R.918 of 1999)	Ministry of Health
Ghana	Food and Drugs Law (P.N.D.C.L. 305B, 1992)	Food and Drugs Board
	Standards Decree (N.R.C.D. 173, 1973)	Ghana Standards Board
	General Labelling Rules, 1992 (L.I. No. 1541, 1992)	Food and Drugs Board
	Ghana Standards Board Certification Mark Rule, LI 662,1970	Ghana Standards Board
	Pest and Plant Disease Act 307, 1965 (L.I. No. 1541, 1992)	Plant Protection and Regulatory Services
	Pesticides Act 528, 1997	Ministries of Health, Food and Agriculture and Trade
Ethiopia	Quality and Standards Authority of Ethiopia Establishment Proclamation (No. 102/1998) Emergency Food Security Reserve Administration Establishment Council of Ministers Regulations (No. 67/2000)	Emergency food security reserve administration
Ivory Coast	Decree No. 86–454 establishing the power of the government to the municipalities and to the city of Abidjan on veterinary public hygiene measures	Ministries of Finance, Rural Development

as well as its safety during processing vegetables into vegetable salads [197, 198]. Physical decontamination techniques involving irradiation, ultraviolet (UV), and high pressure have been used to deactivate microbes and parasites. Studies have revealed UV's efficacy to destroy and/or slow down the development of microorganisms, and increase shelf life, quality, and nutritional benefit of food products [199]. The application of biological treatments such as bacteriocins, bacteriophages, or protective cultures has also been reported [198]. The use of bacteriophages in recent years has gained ground to suppress microbes present in carrots and tomatoes [200, 201]. High doses of chlorine, chlorine-based compounds, ozone, electrolyzed water, organic acids, modified atmosphere packaging, refrigeration, and atmospheric cold plasma discharges or plasma-activated water have been employed in intervention in recent times [202, 203]. Washing is an important process that removes dirt and soil, reduces microbial load, and prevents cross-contamination to some extent; however, the addition of sanitizers such as chlorine has facilitated the action [204]. Chlorine is the most commonly used sanitizer in washing procedures due to its inexpensiveness and effectiveness against several pathogens. Notwithstanding, pathogen sensitivity varies; *Listeria monocytogenes* have higher resistance against chlorine than *E. coli O157: H7* and *Salmonella* spp. [205]. It has also been reported that it is detrimental to human health; hence, other alternatives such as chlorine dioxide, electrolyzed water, hydroxide peroxide, and ozone have been employed [70, 196]. The efficacy of ozone to eliminate microbes has been reported to be higher than treatments that make use of chlorine and organic acid [206]. Additionally, it helps to improve the sensory qualities of produce such as lettuce [206]. Increased ozone concentration in the atmosphere is harmful to human health; therefore, more research is needed regarding the efficient use of ozone treatment [207].

7.2. Biochemical and Molecular Methods for Isolating, Identifying, and Characterizing Pathogens. Applying robust techniques to identify, count, and characterize microorganisms is a major step toward understanding the risk associated with microbial and parasitic contamination as well as further mitigating measures to ensure food safety. Diagnostic techniques employed in molecular biology and microbiology such as ELISA, magnetic immunity isolation (IMS), polymerase chain reaction (PCR), microarrays, and biochip technologies have been extensively proven to be reliable in the said action [208]. PCR analysis including conventional, real-time, and more digital droplet PCR is used to detect microbial load and harmful pathogens in vegetables including *Listeria monocytogenes*, *Salmonella enterica*, and pathogenic *Escherichia coli* [209]. Other biochemical techniques like liquid chromatography-mass spectrometry (LC-MS), gas chromatography-mass spectrometry (GC-MS), and Raman spectroscopy have been utilized for bacterial, virus, pesticide, and pathogen detection, quality, and freshness assessment in vegetables and other food products to ensure their safety [210, 211].

Additionally, technological advancements in recent years have paved for the emergence of newer isolation detection techniques such as digital droplet PCR (ddPCR) [212], whole-genome sequencing (WGS) [213], and next-generation sequencing (NGS) [214]. These technologies make it possible to detect pathogens at a lower rate in vegetables, and they are more precise. Harnessing healthy vegetable consumption is a necessity and can only be attained when these technologies are integrated into the various production and inspection chain of vegetable production chain.

7.3. Food Safety Legislations. Developing countries are now working harder to develop working systems to achieve good food safety standards; these countries include South Africa, Nigeria, and Ghana. The table below shows the good safety guidelines adopted in these countries. Specifically, Table 4 presents food safety legislation in Nigeria, South Africa, and Ghana.

8. Conclusion

Several studies have pointed out the increased production and consumption of vegetables in today's world. This can be partially attributed to changes in increased dietary habits leading, to increased patronage of foods sold outside homes of which vegetable and vegetable products form a greater part. Microbes are found everywhere, but vegetables have demonstrated their higher susceptibility to being contaminated with these microbes. As such, almost any ready-to-eat vegetable and salads have been infested with microbes originating from the field of cultivation, produce processing, handling, or storage. This has accelerated the outbreak of several foodborne diseases. Since there is an increased need for healthy and quality products, it is essential and possible to minimize pathogens in vegetable and vegetable salads by utilizing various methods. At the preharvest level, the first step is to educate farmers on the threat posed by using contaminated water, fertilizers, human faeces, and untreated fertilizers. Therefore, treatment of sources of irrigation water and organic fertilizers should be done to reduce microbe contamination at the highest level. Then also individuals involved in the production continuum from cultivation to consumption comprising farmers, packers, and carriers should be trained on hygienic customs for contamination to reduce. During the processing and handling of vegetables and vegetable salads at the postharvest stage, issues regarding workers' hygiene and health, proper washing and disinfection procedures (making use of vinegar and salt but avoiding the utilization of one cycle of water to prevent cross-contamination), and equipment (use of smooth contact surfaces) should be addressed. This is because some retailers and consumers in developing countries like Ghana do not wash vegetables with disinfectants. Hence, these operations should be undertaken in a way that will guarantee the safety of products for consumption. Governmental stakeholders should have detectable limits always associated with pathogens' infectious doses, particularly in developing countries. To this end, various stakeholders should put in place various systems to survey when, where, how, and what preventive measures to take when there is contamination to address the issue of when and where it is essential to give attention to the "five major risks associated with vegetable production proposed by the European Commission. This comprises environmental and wildlife factors, irrigation water, usage of fertilizers and pesticides, hygiene of workers, equipment, and contact levels" [216].

Data Availability

All data used for the study have been included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors are grateful to Nick Poulton, a graduate fellow at the laboratory of Host-Pathogen Biology, University, the USA, for his input and comments.

References

[1] G. I. Balali, D. D. Yar, V. G. Afua Dela, and P. Adjei-Kusi, "Microbial contamination, an increasing threat to the consumption of fresh fruits and vegetables in today's world," *International Journal of Microbiology*, vol. 2020, Article ID 3029295, 13 pages, 2020.

[2] P. K. Amissah-Reynolds, D. D. Yar, I. Gyamerah, O. Y. Apenteng, and S. Sakyi, "Fresh vegetables and ready-to-eat salads: sources of parasitic zoonoses in mampong-ashanti, Ghana," *European Journal of Nutrition & Food Safety*, vol. 12, no. 2, pp. 47–55, 2020.

[3] J. Harrington, "Water for agriculture: global change and geographic perspectives on research challenges for the future," *Journal of Contemporary Water Research & Education*, vol. 142, no. 1, pp. 36–41, 2009.

[4] E. M. Yahia, P. García-Solís, and M. E. MaldonadoCelis, "Contribution of fruits and vegetables to human nutrition and health," in *Postharvest Physiology and Biochemistry of Fruits and Vegetables*, pp. 19–45, Elsevier, Amsterdam, Netherlands, 2018.

[5] K. Takeuchi, A. N. Hassan, and J. F. Frank, "Penetration of *Escherichia coli* O157:H7 into lettuce as influenced by modified atmosphere and temperature," *Journal of Food Protection*, vol. 64, no. 11, pp. 1820–1823, 2001.

[6] K. O. Duedu, E. A. Yarnie, P. B. Tetteh-Quarcoo, S. K. Attah, E. S. Donkor, and P. F. Ayeh-Kumi, "A comparative survey of the prevalence of human parasites found in fresh vegetables sold in supermarkets and open-aired markets in Accra, Ghana," *BMC Research Notes*, vol. 7, no. 1, 2014.

[7] V. Kumar and S. K. Mritunjay, "Fresh farm produce as a source of pathogens: a review," *Research Journal of Environmental Toxicology*, vol. 9, no. 2, pp. 59–70, 2015.

[8] Food and Agriculture Organization of the United Nations, *Food and Agriculture Organization of the UN: Global Production of Vegetables in 2017*, FAO, Rome, Italy, 2017.

[9] S. K. Mritunjay and V. Kumar, "A study on prevalence of microbial contamination on the surface of raw salad vegetables," *3 Biotech*, vol. 7, no. 1, pp. 13–19, 2017.

[10] B. E. Acheampong, *Assessment of Food Hygiene Practices by Street Food Vendors and Microbial Quality of Selected Foods Sold, A Study at Dunkwa-On-On, Upper Denkyira East Municipality of the Central Region*, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, 2015.

[11] E. Ameko, S. Achio, and S. Alhassan, "Microbial safety of raw mixed-vegetable salad sold as an accompaniment to street vended cooked rice in Accra, Ghana," *African Journal of Biotechnology*, vol. 11, no. 50, pp. 11078–11085, 2012.

[12] P. Mensah, D. Yeboah-manu, K. Owusu-Darko, and A. Ablordey, "Street foods in Accra, Ghana: how safe are they," *Bulletin of WHO*, vol. 80, pp. 546–554, 2002.

[13] P. Amoah, P. Drechsel, M. Henseler, and R. C. Abaidoo, "Irrigated urban vegetable production in Ghana: microbiological contamination in farms and markets and associated consumer risk groups," *Journal of Water and Health*, vol. 5, no. 3, pp. 455–466, 2007.

[14] J. W. Buck, R. R. Walcott, and L. R. Beuchat, "Recent trends in microbiological safety of fruits and vegetables," *Plant Health Progress*, vol. 4, no. 1, p. 25, 2003.

[15] I. D. Amoah, *Helminth Infection Risk Associated with the Use of Wastewater in Urban Agriculture in Kumasi, Ghana*, Master's thesis, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, 2014.

[16] Ghana Standard Authority (GSA), *Local Reference Standards*, vol. 7006, pp. 1–4, 2003.

[17] B. Keraita, R. Abaidoo, I. Beernaerts et al., "Safe Re-use practices in wastewater-irrigated urban vegetable farming in Ghana," *Journal of Agriculture, Food Systems, and Community Development*, vol. 2, no. 4, pp. 147–158, 2012.

[18] G. Y. Murindamombe, E. K. Collison, S. F. Mpuchane, and B. A. Gashe, "Presence of Bacillus cereus in street foods in Gaborone, Botswana," *Journal of Food Protection*, vol. 68, no. 2, pp. 342–346, 2005.

[19] A. Septembre-Malaterre, F. Remize, and P. Poucheret, "Fruits and vegetables, as a source of nutritional compounds and phytochemicals: changes in bioactive compounds during lactic fermentation," *Food Research International*, vol. 104, pp. 86–99, 2018.

[20] A. S. Al-Goblan and S. Jahan, "Surveillance for foodborne illness outbreaks in qassim, Saudi Arabia, 2006," *Foodborne Pathogens and Disease*, vol. 7, no. 12, pp. 1559–1562, 2010.

[21] J. Manitz, T. Kneib, M. Schlather, D. Helbing, and D. Brockmann, "Origin detection during food-borne disease outbreaks - a case study of the 2011 EHEC/HUS outbreak in Germany," *PLoS Currents*, vol. 6, 2014.

[22] R. L. Ochiai, C. J. Acosta, M. C. Danovaro-Holliday et al., "A study of typhoid fever in five Asian countries: disease burden and implications for controls," *Bulletin of the World Health Organization*, vol. 86, no. 4, pp. 260–268, 2008.

[23] L. Yi, P. Zeng, K. Y. Wong, K. F. Chan, S. Chen, and S. Chen, "Controlling Listeria monocytogenes in ready-to-eat leafy greens by amphipathic α-helix peptide zp80 and its antimicrobial mechanisms," *Lebensmittel-Wissenschaft und -Technologie*, vol. 152, Article ID 112412, 2021.

[24] A. J. Kayode and A. I. Okoh, "Incidence and genetic diversity of multi-drug resistant Listeria monocytogenes isolates recovered from fruits and vegetables in the Eastern Cape Province, South Africa," *International Journal of Food Microbiology*, vol. 363, Article ID 109513, 2022.

[25] S. Khare, A. Tonk, and A. Rawat, "Foodborne diseases outbreak in India: a review," *International Journal of Food Sciences & Nutrition*, vol. 3, no. 3, pp. 9-10, 2018.

[26] M. A. C. Ikeh, S. K. C. Obi, D. N. Ezeasor, I. M. Ezeonu, and A. N. Moneke, "Incidence and pathogenicity profile of Listeria spp . isolated from food and environmental samples in Nsukka, Nigeria," *African Journal of Biotechnology*, vol. 9, no. 30, pp. 4776–4782, 2010.

[27] C. D. Kaptchouang Tchatchouang, J. Fri, M. De Santi et al., "Listeriosis outbreak in South Africa: a comparative analysis with previously reported cases worldwide," *Microorganisms*, vol. 363, Article ID 109513, 2020.

[28] A. J. Niehaus, T. Apalata, Y. M. Coovadia, A. M. Smith, and P. Moodley, "An outbreak of foodborne Salmonellosis in rural KwaZulu-Natal, South Africa," *Foodborne pathogens and disease*, vol. 8, no. 6, pp. 693–697, 2011.

[29] R. A. M. de Barros, A. C. Torrecilhas, M. A. M. Marciano et al., "Toxoplasmosis in human and animals around the world. Diagnosis and perspectives in the one health approach," *Acta Tropica*, vol. 231, Article ID 106432, 2022.

[30] A. Hadjilouka and D. Tsaltas, "Cyclospora cayetanensis—major outbreaks from ready to eat fresh fruits and vegetables," *Foods*, vol. 9, no. 11, p. 1703, 2020.

[31] A. K. Bhunia, "Foodborne diseases and food safety in India," *Foodborne Microbial Pathogens, Food Science Text Series*, Springer, Berlin, Germany, 2018.

[32] A. I. Al-Hindi, A. A. Elmanama, and S. Khalaf, "Prevalence of intestinal parasites and microbial contamination in

common edible vegetables used in Gaza Governorate, Palestine," *Journal of Food Safety and Hygiene*, vol. 2, no. 1–2, pp. 21–25, 2016.

[33] M. Avazpour, M. R. Nejad, F. Seifipour, and J. Abdi, "Assessment of the microbiological safety of salad vegetables from different Restaurants in Ilam," *Journal of Paramedical Sciences*, vol. 4, no. 2, pp. 111–115, 2013.

[34] A. M. Itohan, O. Peters, and I. Kolo, "Short communication: bacterial contaminants of salad vegetables in abuja municipal area council, Nigeria," *Malaysian Journal of Microbiology*, vol. 7, no. 2, pp. 111–114, 2011.

[35] B. Guchi and M. Ashenafi, "Microbial load, prevalence and antibiograms of Salmonella and Shigella in lettuce and green peppers," *Ethiopian Journal of Health Sciences*, vol. 20, no. 1, pp. 41–48, 2010.

[36] B. C. Adebayo-Tayo, N. N. Odu, C. U. Esen, and I. O. A. Okonko, "Microorganisms associated with spoilage of stored vegetables in uyo metropolis, akwa ibom state, Nigeria," *Nature and Science*, vol. 10, no. 3, pp. 1036-1037, 2012.

[37] M. O. Ekong, T. J. Ebob, and I. C. Ukwuoma, "Bacteriological quality of fresh salad vegetables sold in calabar road and marian markets, calabar, cross river state, Nigeria," *South Asian Journal of Research in Microbiology*, vol. 4, no. 3, pp. 1–9, 2019.

[38] M. Nipa, R. Mazumdar, S. Islam, H. R. Bhuiyan, and A. Iqbal, "Prevalence of multi drug resistant bacteria on raw salad vegetables sold in major markets of chittagong city, Bangladesh," *Middle-East Journal of Scientific Research*, vol. 10, no. 1, pp. 70–77, 2011.

[39] A. O. Eni, I. A. Oluwawemitan, and O. S. Solomon, "Microbial quality of fruits and vegetables sold in Sango," *African Journal of Food Science*, vol. 4, pp. 291–296, 2010.

[40] S. Ranjbar-Bahadori, A. Mostoophi, and B. Shemshadi, "Study on Cryptosporidium contamination in vegetable farms around Tehran," *Tropical Biomedicine*, vol. 30, no. 2, pp. 193–198, 2013.

[41] A. H. Hosseinvand, S. Sohrabvand, and A. mortazavian, "Assessment of the microbiological safety of some spices and raw vegetables in Tehran caterings," *Arvand Journal of Health and Medical Sciences*, vol. 1, no. 2, 2016.

[42] F. Rahman and R. Noor, "Prevalence of pathogenic bacteria in common salad vegetables of Dhaka metropolis," *Bangladesh Journal of Botany*, vol. 41, no. 2, pp. 159–162, 2013.

[43] J. B. Rosales Chavez, M. Bruening, P. Ohri-Vachaspati, R. E. Lee, M. Jehn, and M. John, "Street food stand availability, density, and distribution across income levels in Mexico City," *International Journal of Environmental Research and Public Health*, vol. 18, no. 8, p. 3953, 2021.

[44] B. A. Alimi, "Risk factors in street food practices in developing countries: a review," *Food Science and Human Wellness*, vol. 5, no. 3, pp. 141–148, 2016.

[45] A. Rakha, M. Fatima, Y. Bano et al., "Safety and quality perspective of street vended foods in developing countries," *Food Control*, vol. 138, Article ID 109001, 2022.

[46] H. Mepba, S. Achinewhu, S. Aso, and C. Wachukwu, "Microbiological quality of selected street foods in Port Harcourt, Nigeria," *Journal of Food Safety*, vol. 27, no. 2, pp. 208–218, 2007.

[47] O. A. Adeyemi, B. M. Fejukui, and O. O. Adeyemi, "Microbial contamination of fresh vegetable salads from food vendors in oyo metropolis," *Nigerian Journal of Pure and Applied Sciences*, vol. 32, no. 1, 2019.

[48] G. A. Pesewu, J. N. Y. K. Agyei, K. I. Gyimah et al., "Bacteriological assessment of the quality of raw-mixed vegetable salads prepared and sold by street food vendors in korlegonno, accra metropolis, Ghana," *Journal of Health Science*, vol. 2, pp. 560–566, 2014.

[49] A. Adu-Gyamfi and J. Nketsia-Tabiri, "Microbiological studies of macaroni and vegetable salads in waakye, a local street food," *Ghana Journal of Science*, vol. 47, pp. 3–9, 2007.

[50] F. K. Kechero, K. Baye, A. T. Tefera, and T. S. Tessema, "Bacteriological quality of commonly consumed fruit juices and vegetable salads sold in some fruit juice houses in Addis Ababa, Ethiopia," *Journal of Food Safety*, vol. 39, no. 1, pp. 1–9, 2018.

[51] P. Viswanathan and R. Kaur, "Prevalence and growth of pathogens on salad vegetables, fruits and sprouts," *International Journal of Hygiene and Environmental Health*, vol. 203, no. 3, pp. 205–213, 2001.

[52] M. B. H. Najafi and M. Bahreini, "Microbiological quality of mixed fresh-cut vegetable salads and mixed ready-to-eat fresh herbs in mashhad, Iran," *International Conference on Nutrition and Food Sciences IPCBEE*, vol. 39, 2012.

[53] P. Feglo and K. Sakyi, "Bacterial contamination of street vending food in Kumasi, Ghana," *Journal of Medicine and Biomedical Sciences*, vol. 1, no. 1, pp. 1–8, 2012.

[54] D. K. Olukoya, S. B. Bakare, and O. Abayomi, "Letters to the editor," *Journal of Tropical Pediatrics*, vol. 37, no. 5, pp. 266–268, 1991.

[55] M. A. Halablab, I. H. Sheet, and H. M. Holail, "Microbiological quality of raw vegetables grown in Bekaa Valley, Lebanon," *American Journal of Food Technology*, vol. 6, no. 2, pp. 129–139, 2011.

[56] M. Z. Jeddi, M. Yunesian, M. E. haghi Gorji, N. Noori, M. R. Pourmand, and G. R. J. Khaniki, "Microbial evaluation of fresh, minimally-processed vegetables and bagged sprouts from chain supermarkets," *Journal of Health, Population and Nutrition*, vol. 32, no. 3, pp. 391–399, 2014.

[57] I. I. Ieren, M. Bello, and J. K. P. Kwaga, "Occurrence and antibiotic resistance profile of Listeria monocytogenes in salad vegetables and vegetable salads sold in Zaria, Nigeria," *African Journal of Food Science*, vol. 7, no. 9, pp. 334–338, 2013.

[58] K. Pingulkar Anu Kamat Dilip Bongirw, A. Kamat, and D. Bongirwar, "Microbiological quality of fresh leafy vegetables, salad components and ready-to-eat salads: an evidence of inhibition of Listeria monocytogenes in tomatoes," *International Journal of Food Sciences & Nutrition*, vol. 52, no. 1, pp. 15–23, 2001.

[59] H. Kouchakkhani, P. Dehghan, M. h. Moosavy, and B. Sarmadi, "Occurrence, molecular detection and antibiotic resistance profile of *Escherichia coli* O157: h7 isolated from ready-To-eat vegetable salads in Iran," *Pharmaceutical Sciences*, vol. 22, no. 3, pp. 195–202, 2016.

[60] S. Atapoor, F. Safarpoor Dehkordi, and E. Rahimi, "Detection of *Helicobacter pylori* in various types of vegetables and salads," *Jundishapur Journal of Microbiology*, vol. 7, no. 5, pp. e10013–e10014, 2014.

[61] O. O. Uwamere, O. O. Nosa, A. T. Wakil, U. Frances, O. N. Eseosa, and I. O. Nicholas, "Bacteriological quality of vegetable salads sold at restaurants within okada town, edo state, Nigeria," *IOSR Journal of Pharmacy and Biological Sciences*, vol. 5, no. 2, pp. 87–90, 2013.

[62] S. J. Cobbina, M. C. Kotochi, J. K. Korese, and M. O. Akrong, "Microbial contamination in vegetables at the farm gate due to irrigation with wastewater in the Tamale metropolis of

northern Ghana," *Journal of Environmental Protection*, vol. 4, no. 7, pp. 676–682, 2013.

[63] G. Abakari, S. J. Cobbina, and E. Yeleliere, "Microbial quality of ready-to-eat vegetable salads vended in the central business district of Tamale, Ghana," *International Journal of Flow Control*, vol. 5, no. 1, pp. 3–9, 2018.

[64] S. K. Kibitok and J. M. Ndoku, "Journal of food safety and hygiene evaluation of microbial contamination of consumed fruits and vegetable salad (kachumbari) around Egerton university, Kenya," *Journal of Food Safety and Hygiene*, vol. 2, no. 1, pp. 3–6, 2016.

[65] K. M. Mbae, M. K. Ndwiga, and F. G. Kiruki, "Microbiological quality of kachumbari, a raw vegetable salad popularly served alongside roast meat in Kenya," *Journal of Food Quality*, vol. 2018, Article ID 8539029, 7 pages, 2018.

[66] P. A. Agyei and J. Ensink, "Wastewater use in urban agriculture: an exposure and risk assessment in Accra, Ghana," *Journal of Science and Technology*, vol. 36, no. 1, pp. 7–14, 2016.

[67] M. I. Younus, A. Sabuj, Z. Haque et al., "Microbial risk assessment of ready-to-eat mixed vegetable salads from different restaurants of Bangladesh agricultural university campus," *Journal of Advanced Veterinary and Animal Research*, vol. 7, no. 1, pp. 34–41, 2020.

[68] T. Shahryari, A. A. Ramazan, A. Gholami, and A. Zolfaghari, "Bacterial contamination of salads and vegetables offered in restaurants and fast food in Birjand city in 2015," *Journal of Birgand University of Medical Sciences*, vol. 25, no. 2, pp. 167–171, 2015.

[69] M. S. Shah, M. Eppinger, S. Ahmed, A. A. Shah, A. Hameed, and F. Hasan, "Multidrug-resistant diarrheagenic *E. coli* pathotypes are associated with ready-to-eat salad and vegetables in Pakistan," *J Korean Soc Appl Biol Chem*, vol. 58, no. 2, pp. 267–273, 2015.

[70] U. De Corato, "Improving the shelf-life and quality of fresh and minimally-processed fruits and vegetables for a modern food industry: a comprehensive critical review from the traditional technologies into the most promising advancements," *Critical Reviews in Food Science and Nutrition*, vol. 60, no. 6, pp. 940–975, 2019.

[71] D. Yeboah-Man, G. Kpeli, M. Akyeh, and L. Bimi, "Bacteriological quality of ready-to-eat foods sold on and around university of Ghana campus," *Research Journal of Microbiology*, vol. 5, no. 2, pp. 130–136, 2010.

[72] R. E. Uzeh, F. A. Alade, and M. Bankole, "The microbial quality of pre-packed mixed vegetable salad in some retail outlets in Lagos, Nigeria," *African Journal of Food Science*, vol. 3, no. 9, pp. 270–272, 2009.

[73] A. F. Abaza, "Bacteriological assessment of some vegetables and ready-to-eat salads in Alexandria, Egypt," *Journal of the Egyptian Public Health Association*, vol. 92, no. 3, pp. 177–187, 2017.

[74] J. Fung, B. Keraita, F. Konradsen, C. Moe, and M. Akple, "Microbiological quality of urban-vended salad and its association with gastrointestinal diseases in Kumasi, Ghana," *International Journal of Food Safety, Nutrition and Public Health*, vol. 4, no. 2/3/4, p. 152, 2011.

[75] E. Toe, A. Dadié, E. Dako, and G. Loukou, "Bacteriological quality and risk factors for contamination of raw mixed vegetable salads served in collective catering in abidjan (ivory Coast)," *Advances in Microbiology*, vol. 7, no. 06, pp. 405–419, 2017.

[76] M. Khiyami, N. Al-Faris, B. Busaeed, and H. Sher, "Food-borne pathogen contamination in minimally processed vegetable salads in Riyadh, Saudi Arabia," *Journal of Medicinal Plants Research*, vol. 5, no. 3, pp. 444–451, 2011.

[77] S. Tahmasebi Tehrani, N. Harzandi, and L. Jabalameli, "Molecular detection of Shigella spp. contamination in ready-to-eat salad samples in west of tehran," *International Journal of Enteric Pathogens*, vol. 6, no. 2, pp. 41–44, 2018.

[78] R. Annan, N. Agyapong, C. Apprey, and R. Aryeetey, "Review of Ghana's food environment: drivers of availability, barriers to healthy food access, and impact of interventions and policies," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 22, no. 2, pp. 19658–19701, 2022.

[79] World Health Organization (WHO), *WHO's First-Ever Global Estimates of Foodborne Diseases Find Children under 5 Account for Almost One-Third of Deaths*, WHO, Geneva, Switzerland, 2019.

[80] A. S. Enoch and A. I. Christiana, "Bacterial burden of vegetables salad sold in some fast food centers in port harcourt, rivers state, Nigeria," *Journal of Advances in Microbiology*, vol. 13, no. 2, pp. 1–10, 2018.

[81] J. B. James and T. Ngarmsak, *Processing of Fresh-Cut Tropical Fruits and Vegetables: A Technical Guide*, FAO, Rome, Italy, 2011.

[82] R. J. Olson, A. Shalapyonok, and H. M. Sosik, "An automated submersible flow cytometer for analyzing pico- and nanophytoplankton: FlowCytobot," *Deep-Sea Research Part I Oceanographic Research Papers*, vol. 50, no. 2, pp. 301–315, 2003.

[83] E. A. Adebayo, O. N. Majolagbe, I. O. Ola, and M. A. Ogundiran, "Antibiotic resistance pattern of isolated bacterial from salads," *Journal of Research in Biology*, vol. 2, no. 2, pp. 136–142, 2012.

[84] M. D. Wogu and I. Iwezeua, "Microbial quality of ready-to-eat salad sold in," *International Journal of Science and Technology*, vol. 2, no. 2, pp. 26–38, 2013.

[85] S. Udo, I. Andy, A. Umo, and M. Ekpo, "Potential human pathogens (bacteria) and their antibiogram in ready–to–eat salads sold in calabar," *The Internet Journal of Tropical Medicine*, vol. 5, no. 2, 2009.

[86] S. Ilyas, M. U. Qamar, M. H. Rasool, N. Abdulhaq, and Z. Nawaz, "Multidrug-resistant pathogens isolated from ready-to-eat salads available at a local market in Pakistan," *British Food Journal*, vol. 118, no. 8, pp. 2068–2075, 2016.

[87] E. J. Okafor-Elenwo and O. S. Imade, "Ready-to-eat vegetable salads served in Nigerian restaurants: a potential source of multidrug-resistant bacteria," *Journal of Applied Microbiology*, vol. 129, no. 5, pp. 1402–1409, 2020.

[88] A. K. Abougrain, M. H. Nahaisi, N. S. Madi, M. M. Saied, and K. S. Ghenghesh, "Parasitological contamination in salad vegetables in Tripoli-Libya," *Food Control*, vol. 21, no. 5, pp. 760–762, 2010.

[89] A. Daryani, G. H. Ettehad, M. Sharif, L. Ghorbani, and H. Ziaei, "Prevalence of intestinal parasites in vegetables consumed in Ardabil, Iran," *Food Control*, vol. 19, no. 8, pp. 790–794, 2008.

[90] A. Hassan, H. Farouk, and R. Abdul-Ghani, "Parasitological contamination of freshly eaten vegetables collected from local markets in Alexandria, Egypt: a preliminary study," *Food Control*, vol. 26, no. 2, pp. 500–503, 2012.

[91] D. El-Said Said, "Detection of parasites in commonly consumed raw vegetables," *Alexandria Journal of Medicine*, vol. 48, no. 4, pp. 345–352, 2012.

[92] Z. Khurseed and T. Majeed, "Prevalence of parasitic contamination in leafy raw vegetable consumed in lahore,

Pakistan," *Journal of Natural and Applied Sciences Pakistan*, vol. 1, no. 2, pp. 167–173, 2019.

[93] J. Rahman, A. Islam Talukder, F. Hossain, S. Mahomud, M. Atikul Islam, and S. Shamsuzzoha, "Detection of *Cryptosporidium oocyts* in commonly consumed fresh salad vegetables," *American Journal of Microbiological Research*, vol. 2, no. 6, pp. 224–226, 2014.

[94] G. Benti and F. Gemechu, "Parasitic contamination on vegetables irrigated with Awash River in selected farms, Eastern Showa, Ethiopia," *Journal of Parasitology and Vector Biology*, vol. 5, no. 7, pp. 103–109, 2014.

[95] A. E. Adeleke, T. T. Sodiya, and A. A. Hassan, "Parasitic contamination of some vegetables sold at two major markets in jos," *The University of Sindh*, vol. 2, no. 3, pp. 1–9, 2018.

[96] L. O. Elmajdoub, M. A. Omar, S. Mohammed, F. Al-Aboudy AboSheba, and S. Elzwawi, "Prevalence of parasitic contamination of leafy green vegetables in Misurata, Libya," *Russian Journal of Parasitology*, vol. 40, no. 2, pp. 197–204, 2017.

[97] A. Rostami, M. Ebrahimi, S. Mehravar, V. Fallah Omrani, S. Fallahi, and H. Behniafar, "Contamination of commonly consumed raw vegetables with soil-transmitted helminth eggs in Mazandaran province, northern Iran," *International Journal of Food Microbiology*, vol. 225, pp. 54–58, 2016.

[98] B. Sunil, D. R. Thomas, C. Latha, and H. Shameem, "Assessment of parasitic contamination of raw vegetables in Mannuthy, Kerala state, India," *Veterinary World*, vol. 7, no. 4, pp. 253–256, 2014.

[99] P. U. Umeanaeto and O. F. Nwofor, "Parasite contamination of edible vegetables sold in onitsha markets," *The Bioscientist*, vol. 4, pp. 21–31, 2016.

[100] O. S. Omowaye and P. A. Audu, "Incidence and detection of parasitic infections by cyst and ova on fruits and vegetables from different major markets in Kogi, Nigeria," *Journal of Applied and Natural Science*, vol. 4, no. 1, pp. 42–46, 2012.

[101] S. Nazemi, M. Raei, M. Amiri, and R. Chaman, "Parasitic contamination of raw vegetables in shahroud, semnan," *Zahedan Journal of Research in Medical Sciences*, vol. 14, no. 8, pp. 84–86, 2012.

[102] A. Endale, B. Tafa, D. Bekele, and F. Tesfaye, "Detection of medically important parasites in fruits and vegetables collected from local markets in Dire Dawa, Eastern Ethiopia," *Global Journal of Medical Research*, vol. 18, no. 1, 2018.

[103] S. A. Alshareef, A. M. Abdulsalam, R. A. Alghanaei, E. S. Salim, and M. Chibani, "Parasitic contamination of raw vegetables sampled from different farm locations in Brack Al-Shati, Libya," *Journal of Pure and Applied Sciences*, vol. 18, no. 4, pp. 210–214, 2019.

[104] G. Alemu, M. Mama, D. Misker, and D. Haftu, "Parasitic contamination of vegetables marketed in Arba Minch town, southern Ethiopia," *BMC Infectious Diseases*, vol. 19, no. 1, pp. 410–417, 2019.

[105] A. C. Rodrigues, M. D. C. Silva, R. Â. S. Pereira, and L. C. Pinto, "Prevalence of contamination by intestinal parasites in vegetables (*Lactuca sativa*L. and*Coriandrum sativum*L.) sold in markets in Belém, northern Brazil," *Journal of the Science of Food and Agriculture*, vol. 100, no. 7, pp. 2859–2865, 2020.

[106] A. Taghipour, E. Javanmard, A. Haghighi, H. Mirjalali, and M. R. Zali, "The occurrence of *Cryptosporidium* sp., and eggs of soil-transmitted helminths in market vegetables in the north of Iran," *Gastroenterology and Hepatology from Bed to Bench*, vol. 12, no. 4, pp. 364–369, 2019.

[107] GHS, "The health sector in ghana facts and figures 2017 foreword," *The Health Sector in Ghana Facts and Figures*, vol. 2, 2017.

[108] P. K. Amissah-Reynolds, D. D. Yar, V. Aboagye, I. Monney, F. Nuamah, and E. A. Ndego, "Parasitic contamination in ready-to-eat salads in the accra metropolis, Ghana," *South Asian Journal of Parasitology*, vol. 3, no. 4, pp. 1–11, 2020.

[109] T. Tefera, K. R. Tysnes, K. S. Utaaker, and L. J. Robertson, "Parasite contamination of berries: risk, occurrence, and approaches for mitigation," *Food and Waterborne Parasitology*, vol. 10, pp. 23–38, 2018.

[110] I. D. Amoah, A. Abubakari, T. A. Stenström, R. C. Abaidoo, and R. Seidu, "Contribution of wastewater irrigation to soil-transmitted helminths infection among vegetable farmers in kumasi, Ghana," *PLoS Neglected Tropical Diseases*, vol. 10, no. 12, 2016.

[111] FAO, *On-farm Practices for the Safe Use of Wastewater in an Urban and Peri-Urban Horticulture-A Training Handbook for Farmers Field Schools*, FAO, Rome, Italy, 2012.

[112] M. A. Adefisoye and A. I. Okoh, "Ecological and public health implications of the discharge of multidrug-resistant bacteria and physicochemical contaminants from treated wastewater effluents in the Eastern Cape, South Africa," *Water (Switzerland)*, vol. 9, no. 8, p. 562, 2017.

[113] M. Uyttendaele, L. A. Jaykus, P. Amoah et al., "Microbial hazards in irrigation water: standards, Norms, and testing to manage use of water in fresh produce primary production," *Comprehensive Reviews in Food Science and Food Safety*, vol. 14, no. 4, pp. 336–356, 2015.

[114] M. Steele and J. Odumeru, "Irrigation water as source of foodborne pathogens on fruit and vegetables," *Journal of Food Protection*, vol. 67, no. 12, pp. 2839–2849, 2004.

[115] R. G. Feachem, D. J. Bradley, H. Garelick, and D. D. Mara, *Sanitation and Disease: Health Aspects of Excreta and Wastewater Management*, pp. 23–43, John Wiley & Sons, Hoboken, NJ, USA, 1983.

[116] A. Allende and J. Monaghan, "Irrigation water quality for leafy crops: a perspective of risks and potential solutions," *International Journal of Environmental Research and Public Health*, vol. 12, no. 7, pp. 7457–7477, 2015.

[117] E. Páll, M. Niculae, T. Kiss, C. D. Şandru, and M. Spînu, "Human impact on the microbiological water quality of the rivers," *Journal of Medical Microbiology*, vol. 62, no. 11, pp. 1635–1640, 2013.

[118] M. P. Combarro, M. Gonzalez, M. Araujo, A. C. Amezaga, R. A. Sueiro, and M. J. Garrido, "Listeria species incidence and characterisation in A river receiving town sewage from A sewage treatment plant," *Water Science and Technology*, vol. 35, no. 11–12, pp. 201–204, 1997.

[119] S. Siebert, J. Burke, J. M. Faures et al., "Groundwater use for irrigation - a global inventory," *Hydrology and Earth System Sciences*, vol. 14, no. 10, pp. 1863–1880, 2010.

[120] A. E. Onyango, M. W. Okoth, C. N. Kunyanga, and B. O. Aliwa, "Microbiological quality and contamination level of water sources in isiolo county in Kenya," *Journal of Environmental and Public Health*, vol. 2018, Article ID 2139867, 10 pages, 2018.

[121] M. Jongman and L. Korsten, "Irrigation water quality and microbial safety of leafy greens in different vegetable production systems: a review," *Food Reviews International*, vol. 34, no. 4, pp. 308–328, 2018.

[122] D. Faour-Klingbeil, E. C. D. Todd, and V. Kuri, "Microbiological quality of ready-to-eat fresh vegetables and their link to food safety environment and handling practices in

restaurants," *LWT—Food Science and Technology*, vol. 74, pp. 224–233, 2016.

[123] D. Faour-Klingbeil, M. Murtada, V. Kuri, and E. C. D. Todd, "Understanding the routes of contamination of ready-to-eat vegetables in the Middle East," *Food Control*, vol. 62, pp. 125–133, 2016.

[124] A. Rajwar, P. Srivastava, and M. Sahgal, "Microbiology of fresh produce: route of contamination, detection methods, and remedy," *Critical Reviews in Food Science and Nutrition*, vol. 56, no. 14, pp. 2383–2390, 2016.

[125] W. Ahmed, T. Gardner, and S. Toze, "Microbiological quality of roof-harvested rainwater and health risks: a review," *Journal of Environmental Quality*, vol. 40, pp. 13–21, 2011.

[126] A. S. Sánchez, E. Cohim, and R. A. Kalid, "A review on physicochemical and microbiological contamination of roof-harvested rainwater in urban areas," *Sustainability of Water Quality and Ecology*, vol. 6, pp. 119–137, 2015.

[127] A. Zacharia, A. H. Outwater, B. Ngasala, and R. Van Deun, "Pathogenic parasites in raw and treated wastewater in Africa: a Review," *Resources and Environment*, vol. 8, no. 5, pp. 232–240, 2018.

[128] S. Idrissa, D. Belghyti, K. Kharrim, and C. Yoro, "Parasitic contamination of the mint and turnip irrigated by untreated wastewater in sidi yahia gharb (Morocco)," *Balwois, Ohrid, Republic of Macedonia*, 2010.

[129] K. Abass, J. K. Ganle, and E. Adaborna, "Coliform contamination of peri-urban grown vegetables and potential public health risks: evidence from kumasi, Ghana," *Journal of Community Health*, vol. 41, no. 2, pp. 392–397, 2016.

[130] G. Alamnie, A. Kebede, and S. Menkir, "Microbiological quality of leafy vegetables irrigated with wastewater in harar town vegetable farm, eastern Ethiopia," *Food Science and Quality Management*, vol. 79, pp. 1–8, 2018.

[131] L. Adetunde, I. Sackey, D. DombirI, and Z. Mariama, "Potential links between irrigation water microbiological quality and fresh vegetables quality in upper east region of Ghana subsistence farming," *Annual Research & Review in Biology*, vol. 6, no. 6, pp. 347–354, 2015.

[132] M. C Kayombo and A. W Mayo, "Assessment of microbial quality of vegetables irrigated with polluted waters in dar es salaam city, Tanzania," *Environment and Ecology Research*, vol. 6, no. 4, pp. 229–239, 2018.

[133] D. Woldetsadik, P. Drechsel, B. Keraita, F. Itanna, B. Erko, and H. Gebrekidan, "Microbiological quality of lettuce (Lactuca sativa) irrigated with wastewater in Addis Ababa, Ethiopia and effect of green salads washing methods," *International Journal of Flow Control*, vol. 4, no. 1, p. 3, 2017.

[134] M. A. Gad, A. A. Ashour, M. I. Soliman, F. E. R. Saleh, A. Z. Al-Herrawy, and A. H. Nigm, "Article info," *Egyptian Journal of Aquatic Biology & Fisheries*, vol. 24, no. 2, pp. 451–468, 2020.

[135] P. Amoah, P. Drechsel, and R. C. Abaidoo, "Irrigated urban vegetable production in Ghana: sources of pathogen contamination and health risk elimination," *Irrigation and Drainage*, vol. 54, no. S1, pp. 49–61, 2005.

[136] P. K. Rai and B. D. Tripathi, "Microbial contamination in vegetables due to irrigation with partially treated municipal wastewater in a tropical city," *International Journal of Environmental Health Research*, vol. 17, no. 5, pp. 389–395, 2007.

[137] E. Javanmard, H. Mirjalali, M. Niyyati et al., "Small-scale risk assessment of transmission of parasites from the wastewater treatment plant to downstream vegetable farms," *Gastroenterology and Hepatology from Bed to Bench*, vol. 11, no. 4, pp. 352–358, 2018.

[138] O. O. Alegbeleye, I. Singleton, and A. S. Sant'Ana, "Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: a review," *Food Microbiology*, vol. 73, pp. 177–208, 2018.

[139] C. K. Klutse, *M. Sc. Thesis Submitted to the Department Of Theoretical And Applied*, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, 2009.

[140] P. Drechsel and S. Dongus, "Dynamics and sustainability of urban agriculture: examples from sub-Saharan Africa," *Sustainability Science*, vol. 5, no. 1, pp. 69–78, 2010.

[141] M. Delgado, C. Rodríguez, J. V. Martín, R. Miralles de Imperial, and F. Alonso, "Environmental assay on the effect of poultry manure application on soil organisms in agroecosystems," *Science of the Total Environment*, vol. 416, pp. 532–535, 2012.

[142] S. C. Atidégla, J. Huat, E. K. Agbossou, H. Saint-Macary, and R. Glèlè Kakai, "Vegetable contamination by the fecal bacteria of poultry manure: case study of gardening sites in southern Benin," *International Journal of Food Science*, vol. 2016, Article ID 4767453, 8 pages, 2016.

[143] O. A. Ijabadeniyi, L. K. Debusho, M. Vanderlinde, and E. M. Buys, "Irrigation water as a potential preharvest source of bacterial contamination of vegetables," *Journal of Food Safety*, vol. 31, no. 4, pp. 452–461, 2011.

[144] T. Garcia-Armisen and P. Servais, "Respective contributions of point and non-point sources of *E. coli* and enterococci in a large urbanized watershed (the Seine river, France)," *Journal of Environmental Management*, vol. 82, no. 4, pp. 512–518, 2007.

[145] M. Islam, M. P. Doyle, S. C. Phatak, P. Millner, and X. Jiang, "Survival of *Escherichia coli* O157: H7 in soil and on carrots and onions grown in fields treated with contaminated manure composts or irrigation water," *Food Microbiology*, vol. 22, no. 1, pp. 63–70, 2005.

[146] J. P. Brooks, A. Adeli, M. R. Mclaughlin, and D. M. Miles, "The effect of poultry manure application rate and AlCl3 treatment on bacterial fecal indicators in runoff," *Journal of Water and Health*, vol. 10, no. 4, pp. 619–628, 2012.

[147] Z. Tomass and D. Kidane, "Parasitological contamination of wastewater irrigated and raw manure fertilized vegetables in mekelle city and its suburb, tigray, Ethiopia," *Momona Ethiopian Journal of Science*, vol. 4, no. 1, p. 77, 2012.

[148] J. Khandaghi, V. Razavilar, and A. Barzgari, "Isolation of *Escherichia coli* O157:H7 from manure fertilized farms and raw vegetables grown on it, in Tabriz city in Iran," *African Journal of Microbiology Research*, vol. 4, no. 9, pp. 891–895, 2010.

[149] S. C. Ingham, J. A. Losinski, M. P. Andrews et al., "*Escherichia coli* contamination of vegetables grown in soils fertilized with noncomposted bovine manure: garden-scale studies," *Applied and Environmental Microbiology*, vol. 70, no. 11, pp. 6420–6427, 2004.

[150] J. L. Wood, *Examination of Microbiological Quality of In-Field Leafy Vegetables and Identification of On-Farm Generic Escherichia coli Transmission Dynamics*, University of British Columbia, Endowment Lands, Canada, 2013.

[151] A. V. Semenov, L. Van Overbeek, A. J. Termorshuizen, and A. H. C. Van Bruggen, "Influence of aerobic and anaerobic conditions on survival of *Escherichia coli* O157:H7 and *Salmonella enterica* serovar Typhimurium in Luria-Bertani broth, farm-yard manure and slurry," *Journal of Environmental Management*, vol. 92, no. 3, pp. 780–787, 2011.

[152] E. A. Alum, S. M. O. C. Urom, and C. M. A. Ben, "Microbiological contamination of food: the mechanisms, impacts and prevention," *International Journal of Scientific & Technology Research*, vol. 5, no. 3, pp. 65–78, 2016.

[153] S. Altizer, R. Bartel, and B. A. Han, "Animal migration and infectious disease risk," *Science*, vol. 331, no. 6015, pp. 296–302, 2011.

[154] M. J. Alam and L. Zurek, "Association of Escherichia coliO157:H7 with houseflies on a cattle farm," *Applied and Environmental Microbiology*, vol. 70, no. 12, pp. 7578–7580, 2004.

[155] J. L. Talley, A. C. Wayadande, L. P. Wasala et al., "Association of *Escherichia coli* O157:H7 with filth flies (Muscidae and Calliphoridae) captured in leafy greens fields and experimental transmission of *E. coli* O157:H7 to spinach leaves by house flies (diptera: muscidae)," *Journal of Food Protection*, vol. 72, no. 7, pp. 1547–1552, 2009.

[156] L. Orozco R, M. H. Iturriaga, M. L. Tamplin et al., "Animal and environmental impact on the presence and distribution of Salmonella and *Escherichia coli* in hydroponic tomato greenhouses," *Journal of Food Protection*, vol. 71, no. 4, pp. 676–683, 2008.

[157] I. A. Simon-Oke, O. J. Afolabi, and O. P. Obasola, "Parasitic contamination of fruits and vegetables sold at Akure metropolis, Ondo State, Nigeria," *Researcher*, vol. 6, no. 12, 2014.

[158] H. G. Bishop and A. Z. Yohanna, "of vegetables with geohelminths: prevalence, intensity and roles of hygiene practices in samaru-zaria, Nigeria (geohelminthic contamination of vegetables)," *International Jjournal of Academic and Applied Research (IJAAR)*, vol. 2, no. 7, pp. 8–13, 2018.

[159] B. G. Meerburg, H. M. Vermeer, and A. Kijlstra, "Controlling risks of pathogen transmission by flies on organic pig farms A review," *Outlook on Agriculture*, vol. 36, no. 3, pp. 193–197, 2007.

[160] T. Tefera, A. Biruksew, Z. Mekonnen, and T. Eshetu, "Parasitic contamination of fruits and vegetables collected from selected local markets of jimma town, southwest Ethiopia," *International Scholarly Research Notices*, vol. 2014, Article ID 382715, 7 pages, 2014.

[161] A. S. R. Alsubaie, A. Al-Mekhlafi, L. A. Al-Shibani, S. M. Al-Eryani, and A. A. Azazy, "Hygienic assessment of pathogenic contamination in raw vegetables in local markets: an implication for public health," *International Research Journal of Microbiology*, vol. 5, no. 2, pp. 16–21, 2014.

[162] T. Nawas, R. Mazumdar, S. Das et al., "Microbiological quality and antibiogram of *E. coli*, Salmonella and Vibrio of salad and water from restaurants of chittagong," *Journal of Environmental Science and Natural Resources*, vol. 5, no. 1, pp. 159–166, 2012.

[163] C. A. Christison, D. Lindsay, and A. von Holy, "Microbiological survey of ready-to-eat foods and associated preparation surfaces in retail delicatessens, Johannesburg, South Africa," *Food Control*, vol. 19, no. 7, pp. 727–733, 2008.

[164] J. V. Gagliardi and J. S. Karns, "Leaching of *Escherichia coli* O157: H7 in diverse soils under various agricultural management practices," *Applied and Environmental Microbiology*, vol. 66, no. 3, pp. 877–883, 2000.

[165] A. Ashrafi Hafez, A. A. Hafez, E. Asadolahi et al., "Study on the parasitic and microbial contamination of vegetables, and the effect of washing procedures on their elimination in ilam city," *Journal of Paramedical Sciences*, vol. 4, no. 4, 2008.

[166] Z. Salavati, A. A. Chalehchaleh, and F. Rezaei, "Parasitic infections in raw vegetables of Kermanshah, Western Iran and their relation with season and washing procedures," *Journal of Food Quality and Hazards Control*, vol. 4, no. 2, pp. 37–41, 2017.

[167] M. F. Saddik, M. R. El-Sherbeeny, and F. L. Bryan, "Microbiological profiles of Egyptian raw vegetables and salads," *Journal of Food Protection*, vol. 48, no. 10, pp. 883–886, 1985.

[168] M. A. Khiyami, M. M. Shehata, and N. A. Al-Faris, "Isolation and identification of bacterial pathogens in minimally processed vegetable salads in some Saudi restaurants using DNA sequencing," *Journal of Food Agriculture and Environment*, vol. 9, no. 3–4, pp. 94–100, 2011.

[169] H. Bautista-De León, C. A. Gómez-Aldapa, E. Rangel-Vargas, E. Vázquez-Barrios, and J. Castro-Rosas, "Frequency of indicator bacteria, Salmonella and diarrhoeagenic *Escherichia coli* pathotypes on ready-to-eat cooked vegetable salads from Mexican restaurants," *Letters in Applied Microbiology*, vol. 56, no. 6, pp. 414–420, 2013.

[170] J. Castro-Rosas, J. F. Cerna-Cortés, E. Méndez-Reyes, D. Lopez-Hernandez, C. A. Gómez-Aldapa, and T. Estrada-Garcia, "Presence of faecal coliforms, *Escherichia coli* and diarrheagenic *E. coli* pathotypes in ready-to-eat salads, from an area where crops are irrigated with untreated sewage water," *International Journal of Food Microbiology*, vol. 156, no. 2, pp. 176–180, 2012.

[171] M. R. G. d. Cruz, Y. J. BdS. Leite, JdL. Marques et al., "Microbiological quality of minimally processed vegetables commercialized in brasilia, df, Brazil," *Food Science and Technology*, vol. 39, no. 2, pp. 498–503, 2019.

[172] M. A. d. Oliveira, V. Maciel de Souza, A. M. Morato Bergamini, and E. C. P. De Martinis, "Microbiological quality of ready-to-eat minimally processed vegetables consumed in Brazil," *Food Control*, vol. 22, no. 8, pp. 1400–1403, 2011.

[173] A. S. Sant' Ana, M. Landgraf, M. T. Destro, and B. D. G. M. Franco, "Prevalence and counts of Salmonella spp. in minimally processed vegetables in São Paulo, Brazil," *Food Microbiology*, vol. 28, no. 6, pp. 1235–1237, 2011.

[174] L. Vasconcellos, C. T. Carvalho, R. O. Tavares et al., "Isolation, molecular and phenotypic characterization of Cronobacter spp . in ready-to-eat salads and foods from Japanese cuisine commercialized in Brazil," *Food Research International*, vol. 107, pp. 353–359, 2018.

[175] T. M. A. Vidigal and E. E. C. Landivar, "Presence of parasitic structures in lettuces served in self-service restaurants of São Miguel do Oeste, Santa Catarina State, Brazil," *Acta Scientiarum. Biological Sciences*, vol. 40, pp. 35027–35035, 2018.

[176] A. M. Cordano, C. Jacquet, and C. Jacquet, "Listeria monocytogenes isolated from vegetable salads sold at supermarkets in Santiago, Chile: prevalence and strain characterization," *International Journal of Food Microbiology*, vol. 132, no. 2–3, pp. 176–179, 2009.

[177] N. B. Adamu, J. Y. Adamu, and D. Mohammed, "Prevalence of helminth parasites found on vegetables sold in Maiduguri, Northeastern Nigeria," *Food Control*, vol. 25, no. 1, pp. 23–26, 2012.

[178] R. M. Nyarango, P. A. Aloo, E. W. Kabiru, and B. O. Nyanchongi, "The risk of pathogenic intestinal parasite infections in Kisii Municipality, Kenya," *BMC Public Health*, vol. 8, no. 1, pp. 237–246, 2008.

[179] A. A. Fallah, K. Pirali-Kheirabadi, F. Shirvani, and S. S. Saei-Dehkordi, "Prevalence of parasitic contamination in vegetables used for raw consumption in Shahrekord, Iran: influence of season and washing procedure," *Food Control*, vol. 25, no. 2, pp. 617–620, 2012.

[180] M. A. Eraky, S. M. Rashed, M. E. S. Nasr, A. M. S. El-Hamshary, and A. Salah El-Ghannam, "Parasitic contamination of commonly consumed fresh leafy vegetables in Benha, Egypt," *Journal of Parasitology Research*, vol. 2014, Article ID 613960, 7 pages, 2014.

[181] F. Julien-Javaux, C. Gerard, M. Campagnoli, and S. Zuber, "Strategies for the safety management of fresh produce from farm to fork," *Current Opinion in Food Science*, vol. 27, pp. 145–152, 2019.

[182] Y. Yang, Y. Luo, P. Millner, E. Turner, and H. Feng, "Assessment of *Escherichia coli* O157:H7 transference from soil to iceberg lettuce via a contaminated field coring harvesting knife," *International Journal of Food Microbiology*, vol. 153, no. 3, pp. 345–350, 2012.

[183] B. Machado-Moreira, K. Richards, F. Brennan, F. Abram, and C. M. Burgess, "Microbial contamination of fresh produce: what, where, and how?" *Comprehensive Reviews in Food Science and Food Safety*, vol. 18, no. 6, pp. 1727–1750, 2019.

[184] J. F. T. K. Akoachere, B. F. Tatsinkou, and J. M. Nkengfack, "Bacterial and parasitic contaminants of salad vegetables sold in markets in Fako Division, Cameroon and evaluation of hygiene and handling practices of vendors," *BMC Research Notes*, vol. 11, no. 1, pp. 100–107, 2018.

[185] N. Garg, J. J. Churey, and D. F. Splittstoesser, "Microflora of fresh cut vegetables stored at refrigerated and abuse temperatures," *Journal of Food Science & Technology*, vol. 30, no. 5, pp. 385-386, 1993.

[186] D. Zagory, "Effects of post-processing handling and packaging on microbial populations," *Postharvest Biology and Technology*, vol. 15, no. 3, pp. 313–321, 1999.

[187] L. A. Rodriguez-Romo and A. E. Yousef, "Microbial stress adaptation and safety of produce," in *Microbiology of Fruits and Vegetables*, Taylor Francis Group, Abingdon-on-Thames, Oxfordshire United Kingdom, 2005.

[188] WHO, "Food and agricultural organization of the united Nations/world health organization," *Microbiological Hazards in Fresh Leafy Vegetables and Herbs*, WHO, Geneva, Switzerland, 2008.

[189] J. James, "Overview of microbial hazards in fresh fruit and vegetables operations," in *Microbial Hazard Identification in Fresh Fruit and Vegetables*, Wiley, Hoboken, NJ, USA, 2005.

[190] M. I. Gil, M. V. Selma, T. Suslow, L. Jacxsens, M. Uyttendaele, and A. Allende, "Pre- and postharvest preventive measures and intervention strategies to control microbial food safety hazards of fresh leafy vegetables," *Critical Reviews in Food Science and Nutrition*, vol. 55, no. 4, pp. 453–468, 2015.

[191] (National Advisory Committee on Microbiological Criteria for Foods) NACMCF, "Microbiological safety evaluations and recommendations on fresh produce," *Food Control*, vol. 10, no. 2, pp. 117–143, 1999.

[192] N. Achiwa, M. Katayose, K. Yoshida, S. Kusakari, and K. Abe, "Viable bacterial counts on fresh-cut salads and bactericidal effect of electrolyzed acidic water," *Food Preservation Science*, vol. 30, no. 4, pp. 185–190, 2004.

[193] T. Hofer, B. Gardner, and T. Ford, "Fresh produce safety in retail operations," in *Microbial Hazard Identification in Fresh Fruits and Vegetables*, pp. 245–259, Wiley, Hoboken, NJ, USA, 2006.

[194] P. V. Mahajan, O. J. Caleb, M. I. Gil et al., "Quality and safety of fresh horticultural commodities: recent advances and future perspectives," *Food Packaging and Shelf Life*, vol. 14, pp. 2–11, 2017.

[195] CAC, *General Principles of Food Hygiene*, Codex Alimentarius Comission, Rome, Italy, 2003.

[196] A. Meireles, E. Giaouris, and M. Simões, "Alternative disinfection methods to chlorine for use in the fresh-cut industry," *Food Research International*, vol. 82, pp. 71–85, 2016.

[197] I. Castro-Ibáñez, M. I. Gil, and A. Allende, "Ready-to-eat vegetables: current problems and potential solutions to reduce microbial risk in the production chain," *LWT - Food Science and Technology*, vol. 85, pp. 284–292, 2017.

[198] A. M. Sikin, C. Zoellner, and S. S. H. Rizvi, "Current intervention strategies for the microbial safety of sprouts," *Journal of Food Protection*, vol. 76, no. 12, pp. 2099–2123, 2013.

[199] E. O. Gogo, A. M. Opiyo, K. Hassenberg, C. Ulrichs, and S. Huyskens-Keil, "Postharvest UV-C treatment for extending shelf life and improving nutritional quality of African indigenous leafy vegetables," *Postharvest Biology and Technology*, vol. 129, pp. 107–117, 2017.

[200] T. Abuladze, M. Li, M. Y. Menetrez, T. Dean, A. Senecal, and A. Sulakvelidze, "Bacteriophages reduce experimental contamination of hard surfaces, tomato, spinach, broccoli, and ground beef by *Escherichia coli* O157:H7," *Applied and Environmental Microbiology*, vol. 74, no. 20, pp. 6230–6238, 2008.

[201] A. Vaidya, S. Ravindranath, and U. S. Annapure, "Bacteriophages for pre- and post-contamination biocontrol of artificial *Escherichia coli* contamination in carrots," *Lebensmittel-Wissenschaft und -Technologie*, vol. 97, pp. 193–197, 2018.

[202] F. Judée, S. Simon, C. Bailly, and T. Dufour, "Plasma-activation of tap water using DBD for agronomy applications: identification and quantification of long lifetime chemical species and production/consumption mechanisms," *Water Research*, vol. 133, pp. 47–59, 2018.

[203] P. Puligundla, J. W. Kim, and C. Mok, "Effects of Non-thermal plasma treatment on decontamination and sprouting of radish (raphanus sativus L.) seeds," *Food and Bioprocess Technology*, vol. 10, no. 6, pp. 1093–1102, 2017.

[204] M. I. Gil, M. V. Selma, F. López-Gálvez, and A. Allende, "Fresh-cut product sanitation and wash water disinfection: problems and solutions," *International Journal of Food Microbiology*, vol. 134, no. 1–2, pp. 37–45, 2009.

[205] L. R. Beuchat and J. H. Ryu, "Produce handling and processing practices," *Emerging Infectious Diseases*, vol. 3, no. 4, pp. 459–465, 1997.

[206] H. Ölmez and M. Y. Akbas, "Optimization of ozone treatment of fresh-cut green leaf lettuce," *Journal of Food Engineering*, vol. 90, no. 4, pp. 487–494, 2009.

[207] L. Carletti et al., "Use of ozone in sanitation and storage of fresh fruits and vegetables," *Journal of Food Agriculture and Environment*, vol. 11, no. 3–4, pp. 585–589, 2013.

[208] M. Nemati, A. Hamidi, S. Maleki Dizaj, V. Javaherzadeh, and F. Lotfipour, "An overview on novel microbial determination methods in pharmaceutical and food quality control," *Advanced Pharmaceutical Bulletin*, vol. 6, no. 3, pp. 301–308, 2016.

[209] E. Badosa, N. Chico, M. Pla, D. Parés, and E. Montesinos, "Evaluation of ISO enrichment real-time PCR methods with internal amplification control for detection of Listeria monocytogenes and *Salmonella enterica* in fresh fruit and vegetables," *Letters in Applied Microbiology*, vol. 49, no. 1, pp. 105–111, 2009.

[210] G. Holmes, D. Fletcher, and P. Reutemann, "An application of data mining to fruit and vegetable sample identification

using gas Chromatography-Mass Spectrometry," in *Proceedings of the 6th Biennial Meeting of the International Environmental Modelling and Software Society*, pp. 1577–1584, Brussels, Belgium, 2012.

[211] J. Qin, M. S. Kim, K. Chao et al., "Advances in Raman spectroscopy and imaging techniques for quality and safety inspection of horticultural products," *Postharvest Biology and Technology*, vol. 149, pp. 101–117, 2019.

[212] D. Cristiano, M. Peruzy, M. Aponte et al., "Comparison of droplet digital PCR vs. real-time PCR for Yersinia enterocolitica detection in vegetables," *International Journal of Food Microbiology*, vol. 354, Article ID 109321, 2021.

[213] S. Araújo, M. Tacão, R. Baraúna et al., "Genome analysis of two multidrug-resistant *Escherichia coli* O8: H9-ST48 strains isolated from lettuce," *Gene*, vol. 785, Article ID 145603, 2021.

[214] E. Manthou, G. Coeuret, S. Chaillou, G. J. E. Nychas, and G.-J. E. Nychas, "Metagenetic characterization of bacterial communities associated with ready-to-eat leafy vegetables and study of temperature effect on their composition during storage," *Food Research International*, vol. 158, 2022.

[215] WHO, "National food safety systems in Africa—a situation analysis," in *FAO/WHO Regional Conference of Food Safety for Africa*, Geneva, Switzerland, October 2005.

[216] A. Allende, P. Truchado, R. Lindqvist, and L. Jacxsens, "Quantitative microbial exposure modelling as a tool to evaluate the impact of contamination level of surface irrigation water and seasonality on fecal hygiene indicator *E. coli* in leafy green production," *Food Microbiology*, vol. 75, pp. 82–89, 2018.