frontiers | Frontiers in Sustainable Food Systems

TYPE Review
PUBLISHED 27 June 2023
DOI 10.3389/fsufs.2023.1173677

OPEN ACCESS

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RECEIVED 24 February 2023
ACCEPTED 02 June 2023
PUBLISHED 27 June 2023

CITATION
Essilfie GL, Lamptey S, Baddoo RNN, Amenorpe G, Hevi W, Owusu M and Atupra F (2023) Food safety in the horticultural sector in Ghana: challenges, risk factors and interventions.
Front. Sustain. Food Syst. 7:1173677.
doi: 10.3389/fsufs.2023.1173677

Food safety in the horticultural sector in Ghana: challenges, risk factors and interventions

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The fruit and vegetable industry remains one of Ghana's most promising agricultural sectors mainly because of heightened awareness of the health benefits associated with their consumption. However, food safety is of ultimate concern due to the association of foodborne hazards resulting in escalation of foodborne illness. This report is a review of key foodborne hazards in Ghana's horticultural value chain. The study identified the risk factors and hazards that contaminate fruits and vegetables in addition to existing methods for mitigating health risks and reducing pathogen levels in the produce. The study revealed that enteric pathogens such as *Escherichia coli* and *Salmonella* spp. mainly contaminate produce through fresh manure and contaminated irrigation water used during the production of vegetables. Chemical hazards identified included pesticides (organochlorine pesticides) and heavy metals such as cadmium, arsenic, chromium, and lead. Physical hazards identified included twigs, roots, sand, and stones. Washing fruits and vegetables thoroughly with potable water and sanitizing with vinegar and Chlorine solutions were among the common practices stakeholders adopted to reduce microbial levels. Soil remediation was also reported as a common approach for reducing chemical contaminants in agricultural fields. The study, therefore, recommends establishing a traceability system as well as appropriate measures and standards for hygienic practices for fresh fruits and vegetables produced and sold on the local market in Ghana. Value chain actors should be sensitized regularly on measures and interventions that can be employed to significantly reduce the levels of foodborne hazards and associated risks.

KEYWORDS

food hazards, food safety & quality, fruits and vegetables, foodborne illness, health risk, horticultural value chain

Introduction

The fruit and vegetable industry remains one of Ghana's most promising agricultural sectors, mainly owing to the heightened knowledge of the health benefits linked to their consumption. The sector is also supported by a vibrant export industry—a motivation for increased production due to the financial rewards. It also creates jobs for the youth as well as the vulnerable and marginalized members of society. There is a steady increase in consumption and utilization of fresh cut and packaged fruits and vegetables in Ghana and globally due to ease of accessibility and an awareness of the immense health and nutritional benefits (Nwachukwu and Osuocha, 2014; Balali et al., 2020). High consumption rates of sliced fruits, particularly, pawpaw, pineapple, watermelon, apple, and mango have been observed and this increase in consumption has boosted cultivating and trading of fruits and vegetables in many countries including Ghana.

Although the consumption of fruits and vegetables has many benefits, food safety is still of great concern owing to poor pre and postharvest handling. Such poor practices result in the contamination of produce with foodborne hazards, which when consumed result in an escalation of foodborne illness (Olu-Taiwo et al., 2021). According to an FAO/WHO report, out of the 1,400 microbial species responsible for contaminating food, 58% were identified as zoonotic which included *Listeria monocytogenes*, *Salmonella*, and *Escherichia coli* O157:H7. These three pathogens have been isolated from a wide variety of fresh produce and have thus been classified as among the most important pathogens of concern when it comes to the safety of fresh produce (FAO and WHO, 2008). In recent decades, several foodborne outbreaks associated with the consumption of fresh produce contaminated one of these pathogens have been reported in several countries around the world. In 2021, the United States alone reported outbreaks of *L. monocytogenes*, *S. typhimurium*, and *E. coli* O157:H7 associated with the consumption of pre-packaged salads (CDC, 2023; accessed 05/09/2023).

Chemical and physical hazards are also of concern when it comes to fresh produce safety in Ghana. It has been noted that chemical contaminants are introduced in fruits and vegetables *via* various routes such as from chemicals that are used during production, postharvest handling, sewage water, cattle manure, inorganic fertilizers, limes, pesticides, natural geological anomalies, mining activities, and industrial wastes (Norton et al., 2015). Chemicals such as pesticides, antibiotics, heavy metals, food additives, grease etc. have been found to be unsafe at high levels resulting in acute toxic responses and chronic illnesses. Physical hazards include glass and sharp objects, packaging, wood, metal, personal effects, residual soil and stones, foreign matter collected during harvesting, etc.

Over the years, studies, including epidemiological investigations, have been conducted in Ghana to understand the microbial pathogen situation as well as the physical and chemical contaminants associated with the fruit and vegetable value chain. To fully understand the magnitude and nature of the problem, a desk review was conducted to harmonize all the information gathered over the years. The aim was to provide an overview of the food safety situation in the country. The following objectives were adopted for the review: (i) identify key microbial pathogens, chemical and physical contaminants associated with horticultural produce in Ghana, (ii) determine the risk factors that influence microbial pathogens, chemical and physical contaminations of horticultural produce, (iii) identify available interventions used by actors to mitigate the risk factors and also reduce the levels of contaminants on horticultural produce, and (iv) to identify gaps, if any, in information obtained from the review.

Microbiological hazards

Pathogens that contaminate horticultural produce originate from various sources such as irrigation water, organic manure, poor postharvest handling, etc. In Ghana, it is observed that both contaminated irrigation water and organic manure that are not properly treated are applied on crops especially vegetables right before harvest. Studies conducted in Accra and Kumasi in Ghana (Cornish et al., 1999; Drechsel et al., 2000; Mensah et al., 2001; Keraita et al., 2002) have confirmed that most horticultural produce are contaminated using fresh poultry manure and also with contaminated irrigation water with fecal coliforms that exceed the WHO recommended level of 1×103, $100\,mL^{-1}$ for unrestricted irrigation. Handling, especially during harvesting, slicing and transportation where good sanitary standards (such as washing with potable water) are lacking also results in the contamination of produce (Olu-Taiwo et al., 2021).

In a 2008 report by FAO/WHO, *Salmonella* spp., *Shigella* spp., *E. coli*, *Campylobacter* spp., *Enterobacter sakazakii*, *E. cloacae*, *Entamoeba coli*, *Cryptosporidium* spp. were microbes that had been isolated from leafy green vegetables and green onions in Ghana. Enteric pathogens such as *E. coli* and *Salmonella* are of great concern in food safety and food-related outbreaks because several illnesses have been linked to the consumption of vegetables grown in soil fertilized with contaminated manure or sewage (Beuchat, 1998; Buck et al., 2003). Contaminated water used for irrigation and poor worker hygiene (handling of fruits and vegetables by infected fieldworkers) have also been identified as probable causes of contamination.

A study carried out in the Tamale in the Northern region of Ghana indicated contamination of 96.7% of lettuce samples with *E. coli* and *Bacillus cereus* was found in 93.3% of ready-to-eat vegetable salads (Abakari et al., 2018). *Salmonella* spp. and *Shigella* spp. were also present in 73.3% and 76.7% of salads, respectively.

In another study conducted in the Kumasi Metropolis in the Ashanti region, fresh-cut mixed vegetable samples collected from 270 sources were found to be contaminated with total coliforms and *E. coli* (Abubakari et al., 2015). Out of the samples tested, *E. coli* O157:H7 was detected in three (3) of the samples meaning there was a prevalence of 1.1%. Although, the prevalence is low, it still indicate that *E. coli* O157:H7 is still a major public health concern especially for ready-to-eat mixed vegetables.

Cabbage, carrots and scallions sold on the Abura and Kotokuraba markets in the Cape Coast Municipality (Central Region) analyzed for foodborne microorganisms tested positive for *E. coli*, *Enterobacter* spp., *Klebsiella* spp., *Salmonella* spp., *Serratia marcescens*, and *Staphylococcus*, as well as fungi of the genera *Aspergillus*, *Candida*, *Fusarium*, *Penicillium*, and *Rhodotorula* (Yafetto et al., 2019).

Abass et al. (2016) conducted a study with urban and peri-urban vegetable farmers in the Kumasi Metropolis and documented that all eighteen (18) vegetables samples were highly contaminated with *E. coli* and total and fecal coliforms.

Table 1 shows the key microbial pathogens that have been associated with horticultural produce in Ghana.

Among the key pathogens isolated from fruits and vegetables, the most recurring pathogens were *E. coli* and *Salmonella* spp.

Risk factors that influence the contamination of horticultural produce with the microbial pathogens

Contamination of horticultural produce with microorganisms can occur at any stage along the supply chain. The two broad

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TABLE 1 Key microbial pathogens isolated from fruits and vegetables in Ghana.

Type of pathogen	Pathogen	Produce
Bacteria[a]	*Citrobacter koseri* *Citrobacter* sp. *Enterobacter* sp. *Klebsiella pneumoniae* *Klebsiella* sp. *Proteus vulgaris* *Pseudomonas* sp. *Staphylococcus aureus* *Staphylococcus epidermidis* *Listeria monocytogenes* *Salmonella enterica*	Cut watermelon, Cut pawpaw
	Salmonella sp. *Listeria monocytogenes* *Escherichia coli* O157:H7 *Erwinia carotovora*	Cut lettuce, cabbage Green Onions
	Pseudomonas fluorescens *Pseudomonas aeruginosa*	Cut watermelon, cut pawpaw

[a]Olu-Taiwo et al. (2021).

categories noted for contaminating fresh produce are from pre-harvest and postharvest sources (Gil et al., 2015). Some preharvest activities that result in the contamination of fresh produce relate to the soil in which fruits and vegetables are grown, water used for irrigation, water used to apply pesticides, feces, dust, and human contact with the produce at various points during the production process. Postharvest sources of contamination include human and animal feces, equipment used in harvesting and processing produce, poor postharvest handling of produce, insects, wild and domestic animals, por transportation methods, dust and water used in washing produce (Gil et al., 2015).

Organic fertilizers

Organic fertilizers, such as manures and slurries from animal sources (Beuchat, 1996; Natvig et al., 2002), wastes obtained from abattoirs (Avery et al., 2005) and sewage sludge (Al-Ghazali and Al-Azawi, 1990) which are applied directly to crops on the field contaminate the produce and the run-off may contaminate irrigation water which is later used to irrigate the produce. Organic manure which sometimes contain fecal matter harbor pathogens and crops that are very close to the ground, like lettuce and cabbage, easily get contaminated when it is applied to them. During watering, organic manure can splash unto vegetables close to the ground, contaminating them.

Irrigation water

Water sources used for irrigating fresh produce are usually contaminated with enteropathogens found in fecal matter, soil and run off from production fields as well as sewage overflow. Wastewater is used in many countries both developed and developing; however, the difference is that in developed countries they are treated before being applied to crops. In the United Kingdom, according to Tyrrel et al. (2006), surface waters that receive treated sewage effluent provide 71% of irrigation water. In developing countries such as Ghana, when wastewater is used to irrigate crops, the risk of pollution *via* irrigation water is higher since the water is usually untreated. Wachtel et al. (2002), reported that *E. coli* was isolated from cabbage roots irrigated with sewage-contaminated stream water but it was noteworthy that the edible parts of the cabbage were not contaminated. According to Islam et al. (2004), carrots and radishes at harvest tested positive for *S. typhimurium* when a single application of inoculated water was used to irrigate the produce. *Salmonella* was isolated from the soil 203 days after the inoculated water was applied to the produce and into the soil. In a similar study, lettuce plants irrigated with water inoculated with *E. coli* O157:H7 tested positive for *E. coli* O157:H7 during harvest which was 30 days after inoculation. Solomon et al. (2002) demonstrated that irrigation water polluted with *E. coli* O157:H7 is likely to penetrate and move to the edible sections of the plant through the vascular system.

Soil

Pathogens such as *Listeria* spp. can naturally be found in soil or can be introduced into the soil through the use of organic fertilizers (Nicholson et al., 2005). When heavy rain or water gun irrigation causes splashing on leaves, pathogens in the soil can directly contaminate crops. Bhunia (2018) confirmed that lettuce can become contaminated with *E. coli* O157: H7 through exposure to contaminated soil and irrigation water. He indicated that the pathogen can remain on the plant throughout the life cycle of the plant and can be transmitted to humans who consume the crop after harvest.

Handling practices

Several studies have found that washing, handling and storage of fresh fruits and vegetables are major sources of microbial contamination with microbial hazards, however, it a real connection between contamination of fresh fruits from handling practices and outbreak of foodborne illnesses has not be fully established (Amoah, 2014; Acheampong, 2015; Amoah et al., 2018; Ankar-Brewoo, 2018). During processing, packaging and distribution, fruit handlers often use their bare hands in handling fruits such as mangoes. As a result, many mangoes in the country have been reported to be infected before marketing which can result in food-borne illnesses if not properly washed before being consumed (Boateng, 2016).

Methods used by value chain actors to mitigate risk factors and reduce levels of pathogens

Washing with water

A common conventional method for reducing microbial contamination of fruits and vegetables is by washing them with pipe borne/tap water. Although water is useful in reducing the contamination of fruits and vegetables, it can also transfer pathogenic microorganisms through cross-contamination of other clean produce when the same water is used in washing both clean and contaminated produce (Banach et al., 2015). In Ghana, washing of vegetables is mostly done using readily available water bodies such as streams and ponds near the production or retailing locations (Acheampong, 2015). Washing fresh produce using running water is usually not a common practice amongst farmers and retailers. Produce is usually washed in containers filled with water by farmers and fresh produce vendors. The obvious concern is that the water is reused for several cycles thereby fresh produce is contaminated because of the dirty water used (Acheampong, 2015).

Washing with sanitizers

Washing with disinfectants such as benzalkonium chloride, peracetic acid, hydrogen peroxide and calcium hypochlorite produces favorable outcomes in microbial risk reduction because it maintains water quality, especially when removing soil and debris during the processing of fresh-cut produce (Samadi et al., 2009). Compared to washing fresh produce with water, sanitizing solutions are very effective in reducing microbial levels in the produce after washing, however, when produce is stored, epiphytic microorganisms have been observed to grow rapidly and can reach similar levels in produce washed with plain water. In this regard, studies in some European countries have advocated for the use of potable water for washing fresh cut vegetables instead of using water containing chemical disinfectants (Gil et al., 2009). According to Ölmez and Kretzschmar (2009), the use of sodium hypochlorite in washing fresh produce is believed to adversely affect the environment and has been suggested to be associated with occupational and operational hazards and may have cumulative adverse effects on humans. Novel technologies which would be more effective and safer is therefore very necessary to explore microbial risk reduction.

Washing with organic acids

Organic acids such as citric, acetic, and sorbic acids are known to reduce microbial levels depending on concentration of the acid used and the exposure time. Karapinar and Gonul (1992) and Beuchat (1998) reported significant reductions in microbial populations on fruits and vegetables when varying concentrations of acetic, citric and sorbic acids in water was used to wash the fresh produce. It has been observed that a 2% increase (0.5%–2.5%) in the concentration of acetic acid solution used in washing fruits and vegetables resulted in a reduction in microbial load from 15% to 82%. Previous studies by Beuchat (1998) also revealed that parsley leaves dipped in varying concentrations of acetic acid resulted in a 3 to 6 log10 reduction in the number of aerobic bacteria.

Chemical hazards

The review determined the key chemical contaminants of fresh agricultural produce to be pesticide residue/pesticide poisoning and heavy metal accumulation.

Pesticides

Pesticides are used in controlling insect pests and diseases in fruits and vegetables and human exposure to these pesticides above acceptable limits has been linked to the incidence of diseases such as immune dysfunctions, respiratory and neurobehavioral disorders (Bempah et al., 2011a). Fruits and vegetables grown and sold in Ghana are often exposed to chemical hazards, especially organochlorine pesticides (OCPs). It has been established that they can pose risks to consumers' health.

According to Dinham (2003), a high percentage of farmers in Ghana (87%) use pesticides during production to combat pests and diseases on horticultural produce. The types of pesticides used widely by farmers on their vegetables farms were as follows: herbicides (44%), fungicides (23%), and insecticides (33%) (Ntow, 2005).

A study by Asiedu (2013) detected pesticide residue at 52%, 40%, 45%, and 48% on lettuce, garden eggs, pineapples and mangoes, respectively. Less than half the number (39.2%) of fruits and vegetables sampled had no trace of the pesticides of interest; 51% showed trace levels of the pesticides and these were below the maximum residue level (MRL) and 9.8% of the samples had levels that were above the MRL.

The difference in the concentration of pesticide residue observed in the study could be attributed to the types of fruits or vegetables as well as the different agronomic practices carried out by farmers. The average residue concentrations for organophosphates, synthetic pyrethroids and organochlorine ranged from 0.01 to 0.45 mg/kg, 0.01 to 0.30 mg/kg and 0.01 to 1.27 mg/kg, respectively (Bempah et al., 2012; Asiedu, 2013). These residue levels exceeded the MRLs recommended by FAO/WHO. Analysis of four different produce for heptachlor showed that the level of this pesticide far exceeded the reference doses. This therefore indicates that heptachlor may be of public concern with great potential for systemic toxicity to consumers in Ghana. The most common and frequently used pesticides (organochlorine, organophosphate and synthetic pyrethroid) were Lindane, chlorpyrifos and cypermethrin, respectively (Bempah et al., 2012; Asiedu, 2013).

Pesticide poisoning has been reported in Ghana as a result of human ingestion of pesticide-contaminated food commodities. In a report by Gerken et al. (2001), three children died after consuming fruits containing high residues of carbamates in Ghana. Darko and Akoto (2008) detected pesticide residue in pepper, tomato and eggplants when samples were analyzed from farms in Kumasi. Bempah et al. (2011a,b) also detected similar pesticide residue in pawpaw, tomato, apple and other fruits and vegetables samples from the Accra and Kumasi Metropolis. The pesticide residues detected in both cases included Chlorpyrifosmethyl, Chlorpyrifos, Dichlorvos, Dimethhoate, Malathion, Monocrotophos, Omethioate, Parathion-methyl, Parathion, γ-HCH, δ-HCH, Heptachlor, α-endosulfan, β-endosulfan, p,p'-DDE, Endrin, o,p'-DDT, Endrin aldehyde, p,p'-DDT, and Endrin ketone.

Heavy metals

Soil contamination by heavy metals is often restricted to the surface of the soil and it also depends on the soil texture and the level of anthropogenic activities or land use. The key heavy metals encountered in the horticultural industry in Ghana include arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), manganese (Mn), nickel (Ni) and lead (Pb) (Lente et al., 2014; Fordjour, 2015). According to Bempah et al. (2011b), the most common heavy metals detected in fruits and vegetables in Ghana are lead (Pb), cadmium (Cd), and chromium (Cr). The highest levels of Pb and Cd were detected in lettuce, although these levels were below the permissible limits set by (WHO/FAO). However, it is important to take note of the adverse health risks that their cumulative effects are likely to cause. Soil amendments can be made to contaminated soils to reduce the toxicity of heavy metals in the soil before using them for farming.

Addae (2015) sampled 479 vegetables in the farm and market sites within the Accra Metropolis. From the study, it was observed that all the vegetables sampled were contaminated with at least two (2) or more heavy metals. He reported that with reference to the European Union guideline values, a higher percentage had heavy metal values above the limits while only 18.99% of the samples had metal detections below the limits. Vegetables sampled from Mallam Attah Market and the Ghana Broadcasting Corporation (GBC) sites (both sites in Accra) recorded the highest levels of heavy metals (100). Higher levels of heavy metals were also detected in vegetables at the point of sale compared to the production sites farms except for As, Cd, Co, and Fe. The highest concentrations of nickel and chromium (1.236 and 2.459 mg/kg respectively) were detected in lettuce sampled from the markets whilst at the farm sites the metals were undetected.

In a similar study, Lente et al. (2014) discovered that concentration levels of heavy metals (mg/kg) in vegetables analyzed were not elevated except for Pb in cabbage (10.51), lettuce (10.19), green pepper (9.44), hot pepper (7.61) and ayoyo (9.05). These levels far exceeded the FAO/WHO maximum recommended limit of 0.30 mg/kg for Pb. Odai et al. (2008) in a study on vegetables grown on waste dumping sites in Kumasi detected high levels of cadmium from 0.68 to 1.78 $mg\,kg^{-1}$; values which is above the allowable limits.

Risk factors that influence chemical contamination of horticultural produce

According to various studies, it has been established that plants naturally pick up both the important metals for growth as well as some toxic ones (Hg, Cd, Ni, and Pb) (Singh et al., 2004; Anim-Gyampo et al., 2012; Chen et al., 2013). Heavy metals can be accumulated in vegetables *via* different routes. Some routes through which metals are deposited into the soil are (i) Human waste deposits, (ii) agricultural inputs such as untreated manure and lastly, and (iii) the effect of industrial and urban pollution (Wilson and Pyatt, 2007). It has been reported that activities that are conducted by farmers also contribute significantly to the accumulation of heavy metals in the soils and uptake by vegetables. The main routes that heavy metals are known to have access into vegetables and fruits are through the soil, irrigation water and atmospheric depositions. These routes of entry constitute the main risk factors of chemical contamination so far as heavy metal accumulation is concerned.

Soil factors

It is reported that heavy metal ions which are immobilized by soil are released into the soil through natural weathering and/or mining methods. Transport of these metals is determined by their physicochemical properties such as density, conductivity, and reactivity. The physicochemical properties of the soil such as pH, organic matter content, clay fraction content, and mineralogical composition also play a vital role in determining a soil's binding capacity (Dube et al., 2001).

Chemicals and metal ions can adsorb, exchange, oxidize, reduce, catalyze, and precipitate in soils (Weber, 1991). Due to their solubility and exchangeable forms, metals become readily mobile, or may be bound within a crystalline lattice framework of clay minerals. Metals are mobile at low pH but are immobilized at higher pH levels (Wright et al., 2006). Due to the high surface area of clay minerals and the poor pH dependency of cation exchange power, heavy metal levels typically decrease from clay to coarse silt and to rich organic matter soils (Schulten and Leinweber, 2000).

Furthermore, agricultural lands have been exposed to directly or indirectly by different types of residues from the atmosphere and industries, especially mining companies. Levels of heavy metals and other contaminants have increased in the soils because of depositions from the atmosphere and industries. Additionally, as these heavy metals accumulate in agricultural organic soils, it allows for easy transfer of the metals from soils to vegetables. To reduce the uptake of these metals from the soil to the plants, greenhouse vegetable production rooms and soilless greenhouse vegetable production systems have been used to grow safer and higher-quality vegetables devoid of the high levels of heavy metals.

Water factor

In Ghana, there is continuous water shortage for domestic use and to a larger extent for commercial purposes such as irrigation of agricultural produce. In this regard, many urban and peri-urban vegetable growers rely on wastewater for irrigation. The wastewater which is channeled uncontrolled into stagnant drains, is a mixture of hospital and other industrial effluent which contain chemicals and pathogens.

In a study conducted by Arora et al. (2008), it was discovered that heavy metals accumulated significantly in vegetables irrigated with wastewater. His findings revealed that both adults and children who eat vegetables grown in wastewater-irrigated soils consume large amounts of these metals, even though the levels of the metal values below tolerable levels. Although, the levels were low, he recommended that heavy metal levels in effluents and sewage, as well as in vegetables and other food materials, be monitored on a regular basis to avoid excessive build-up of the metals in food.

Atmospheric depositions

Urbanization has resulted in an increase in manufacturing activities, raising concerns about air pollution. Many toxic metals, such as mercury, arsenic, and selenium, are released into the atmosphere as unwanted gases by factories. Demirezen and Aksoy (2006) found higher Pb, Cd, and Cu concentrations in okra collected from urban areas in Turkey compared to those collected from rural areas. Several farms are located near highways and are, therefore, regularly exposed to metal-aerosol depositions in the atmosphere.

Accra experiences heavy vehicular traffic on a regular basis, which has increased the rate of toxic gas emissions into the atmosphere and, agricultural produce. In urban India, Sharma et al. (2008) reported high levels of Cd, and Pb in a variety of vegetables caused by atmospheric deposition with Cd and Pb presenting a significant health risk to the local population when consumed. Finally, they concluded that during the sale, atmospheric depositions increased the levels of heavy metals in vegetables. According to Agrawal (2003), air pollution can pose a threat to post-harvest vegetables during transportation and marketing, due to higher levels of heavy metals in the vegetables.

Available interventions used by actors to mitigate the risk factors posed by chemical contaminants

Soil remediation is a popular approach for reducing pollutants in the environment. One easy approach is to eliminate polluted topsoil from agricultural fields, which usually contain higher levels of pollutants than subsoil (Lai et al., 2010). Alternatively, soil turnover and *in-situ* mixing may be necessary to reduce contaminant concentrations, such as heavy metals, to an appropriate level.

Phytoremediation may be used to eliminate pollution from soils or reduce contamination in plants in a variety of ways. Reduced absorption is advantageous if the plants are intended for human consumption. The selection of plants to explicitly extract pollutants from agricultural land is an example of phytoremediation, such as the use of black nightshade (*Solanum nigrum* L.) to remove thallium from soil (Wu et al., 2015). Yu et al. (2014) found that two oilseed rape cultivars accumulate cadmium differently in cadmium-contaminated agricultural land. In a recent study, Opoku et al. (2020) showed that four indigenous plant species; *Chromolaena ordorata*, *Paspalum viginatum*, *Chrysopogon zizanioides* and *Cynodon dactylon* can be used to reduce Cadmium levels in the soils that have a history of illegal mining.

The latest studies have also used microalgae in irrigation waters to extract free metal ions from the water as a solution to heavy metal contamination because of their high affinity to sequester (biosorbents) heavy metals (Kumar et al., 2015). Some farmers are aware of the dangers of using wastewater for crop production and the use of this microalgae technology, which is cost-effective, may help to encourage safer vegetable production.

Physical hazards

Physical hazards that can be found in produce include oils that may leak from farm tools and equipment, glass fragments, metal chippings that break off from farm equipment, nails, plastic, roots, sticks, insects, sand and stones. These contaminants can be introduced from farm equipment, while workers may drop rubbish into the harvested produce. In most instances, weeds also contaminate the produce, especially leafy vegetables. Such contamination may arise because of cultivation near bushes, landfill sites and poor attention to farm hygiene. Sometimes, parts of the packaging materials such as boxes, baskets and wooden boxes may also chip off into the produce.

Gaps identified between existing interventions in Ghana and documented technologies

Although regulators have outlined standards that are used to monitor horticultural produce, these standards are not harmonized and thoroughly documented. It, therefore, makes it difficult to strictly enforce regulations for produce designated for local consumption in Ghana. There are no clear locally adopted standards for reducing pathogen levels in the various horticultural produce and therefore consumers have the perception that there is no "safe source" of fruits and vegetables, and they bear the risk if they do not take any action to reduce the levels of contamination. Although some of the traders are aware of the indicators to look out for, they are unable to insist on what they want because there is a limited supply of the produce.

In literature, physical hazard consists of foreign materials such as stones, hairs, sand, metallic objects, broken glasses, insects, etc. However, no literature was cited in the Ghanaian context with regards to the present study. All the literature reviewed focused on already prepared meals and not on horticultural produce.

Conclusion and recommendations

Food-borne pathogens

From the information gathered, the major microbial pathogens in fresh fruits and vegetables in Ghana are *Staphylococcus aureus*, *Listeria*, *Salmonella*, *Bacillus*, *Escherichia coli*, *Enterobacter* spp., *Citrobacter* spp., and *Klebsiella* spp. Among these, *E. coli* and *Salmonella* are the most common foodborne pathogens in the country. The risk factors for microbial contamination include water used for irrigation, organic manure, soil, and handling practices. The use of contaminated water, especially wastewater from gutters has gained notoriety as the chief culprit for spreading food-borne pathogens in fruits and vegetables. It was also discovered that vegetables or fruits that are closest to the ground are highly susceptible to food-borne pathogens as compared to their other counterparts which are high above the ground.

Heavy metals and pesticide residue

The key heavy metals in the Ghanaian horticultural space include arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), cupper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn). Among these, As, Cr, Cd, and Pb are the most common heavy metals encountered in the Ghanaian horticultural industry. The risk factors for contamination are dependent on the soil, water used for irrigation and atmospheric deposition. Per this review, heavy metal accumulation in fruits and vegetables in Ghana still remains a problem. Although the only solution has been to avoid cultivation in affected soils, recent research has shown that soil remediation and phytoremediation can be used to reduce the accumulation of heavy metals in fruits and vegetables.

Fruits and vegetables grown and sold in Ghana are often exposed to chemical hazards, especially organophospates, synthetic pyrethroids and organochlorine pesticides (OCPs) that pose potential risks to consumers' health because residual levels exceed the maximum residue limits (MRLs) adopted by the FAO/WHO Codex Alimentarius Commission. Residues of pesticides such as Chlorpyrifosmethyl, Chlorpyrifos, Dichlorvos, Dimethhoate, Malathion, Monocrotophos, Omethioate, Parathion-methyl, Parathion, γ-HCH, δ-HCH, Heptachlor, α-endosulfan, β-endosulfan, p,p'-DDE, Endrin, o,p'-DDT, Endrin aldehyde, p,p'-DDT, and Endrin ketone have been reported in different concentrations.

Recommendations to improve the safety of fruits and vegetables

1. A food safety monitoring program for fresh fruit and vegetables should be designed and implemented.
2. A Traceability System for fresh fruits and vegetables should be developed in consultation with the regulators to facilitate the identification of sources of contamination along the value chain during food safety incidences.
3. Periodic soil testing should be done by regulatory institutions to ascertain heavy metal concentrations in areas where fruits and vegetables (especially lettuce and carrots) are produced. The introduction of appropriate soil amendments to help remove heavy metals from highly concentrated soils.
4. Extension officers assigned to urban vegetable producers to be trained in food safety issues and well-equipped with the appropriate logistics.
5. Farmers are to be trained on rainwater harvesting techniques and be resourced with irrigation equipment to have access to potable water for production.
6. Buyers, marketers and transporters who buy produce at the farm gate must be sensitized to demand and insist on quality and safe produce from producers.
7. Sensitization and training of farmers on the safe use of pesticides as well as strict adherence to Pre-Harvest Intervals.
8. Market women and other intermediaries should be trained on basic postharvest handling practices and consumer health.
9. Further research should be done to find out more practical ways of reducing heavy metals in soils used for fruit and vegetable cultivation.

Author contributions

GE, GA, WH, MO, and FA contributed to the conception and design, critically reviewed the first draft, and approved the final version of the manuscript. RB and SL wrote the first draft. All authors contributed to the article and approved the submitted version.

Funding

The study was funded through the HortiFresh programme which was financed by the Embassy of the Kingdom of Netherlands in Ghana (grant number 4000001025). This publication was supported by the Economic and Social Research Council (grant number ES/T003871/1) under the ARUA-GCRF UKRI Partnership Program as part of the Capacity Building in Food Security (CaBFoodS-Africa) project.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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