

Review

Improving Access to Export Market for Fresh Vegetables through Reduction of Phytosanitary and Pesticide Residue Constraints

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Abstract: The horticultural sector is a key contributor to Kenya's gross domestic product through the export of fresh-cut flowers, fruits and vegetables to various niche markets. It employs over 350,000 people, while about six million depend on it. However, the sector is constrained by the strict technical and phytosanitary quality requirements set by the export markets. The phytosanitary concerns include the presence of pests and microbial contaminants, while the presence of chemical residues constitute the major technical challenge. These constraints cause the interception and rejection of produce at the export destinations. The fresh produce should be free of quarantine and regulated non-quarantine pests, pest damage, pesticides above the stipulated maximum residue levels (MRLs) and phytosanitary certification. This review discusses the following four-tiered approach to compliance with phytosanitary and pesticide residue requirements: (i) use of alternative pest management approaches, including biocontrol options, cultural and physical practices; (ii) collaboration among regulatory agencies, institutions, producers and regional countries in the enforcement of standards; (iii) investment in research and the adoption of innovative technologies; (iv) awareness creation and training of actors along the fresh vegetable value chain. It is envisaged that this approach will contribute to sustainable fresh vegetable value chains, leading to improved access to export markets, and increased export volumes and income to smallholder farmers and other actors in the fresh vegetable value chain.

Keywords: fresh produce; food quality; interceptions; market compliance; pesticides residues



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1. Introduction

Agriculture is the mainstay of Kenya's economy, and the horticultural sector significantly contributes to the gross domestic product of the country, mainly through the exportation of fresh produce to niche markets [1]. The horticultural sub-sector creates employment opportunities for farmers, traders, agro-processors and other players along the value chain [2]. The sub-sector is also a source of food for many in rural and urban areas and contributes to the alleviation of poverty [1]. The main horticultural fresh-produce exports include cut flowers, fruits, vegetables, medicinal and aromatic plants [3,4]. Cut flowers mainly include roses, statice, carnations, gypsophila, chrysanthemums, astroemeria, and mixed flowers, among others, and they are the bulk of horticultural exports [5]. Fruits include mangoes, avocados, pawpaw, pineapple, passion, citrus, melons, strawberries, grapes, apples, tangerines, and loquats for both domestic and international markets [2]. Vegetables are second in value for exports after cut flowers [6]. While most of the vegetables produced in the country are consumed in the domestic market, a good share are exported to Uganda, Tanzania, Rwanda, Egypt, United Kingdom, United States of America, United Arab Emirates, The Netherlands, Pakistan, Germany, and France [5]. The largest market share of fresh vegetable exports goes to the European Union. Vegetables such as tomatoes and potatoes are mainly consumed locally or traded in the regional markets [1]. In the year

2020, export earnings from horticulture were Ksh. 151 billion, with cut flowers, vegetables and fruits contributing 71.5%, 15.9% and 11.9%, respectively [7].

The leading exporters of fresh vegetables around the world continue to record an increase in the value and volume of exports. For instance, Morocco exports fresh tomatoes, green beans, zucchini, and pumpkins inter alia, with an upward trend in terms of volume and monetary value [8,9]. However, the major impediment to Kenya's fresh vegetable export potential is compliance with quality and technical requirements, especially due to the presence of pests and chemical residues from synthetic pesticides [7,10–12]. These constraints have led to limited access to the export market for Kenya's fresh vegetables, low export volumes and reduced monetary value during the last nine years [5]. The fresh vegetable export potential is valued at USD 98 million, while actual export is USD 50 million [13]. The deficit in export value of fresh vegetables can be met by all key players in the horticulture industry, including growers, adhering to the sanitary, phytosanitary and technical requirements.

The niche markets for Kenya's fresh vegetables dictate produce specifications that are stipulated in the phytosanitary and multiple private standards [14,15]. The International Sanitary and Phytosanitary (SPS) and private standards are overwhelming, especially to smallholder farmers, who produce most of the exported vegetables. The premium safety and quality export requirements include freedom from any contamination such as microbial and chemical residues [14]. Therefore, in order to meet the minimum standards required by importing countries and the retail markets, there is a need for synergy among all the value chain players in the fresh vegetable sub-sector. Uncoordinated fresh vegetable value chains may lead to non-compliance and, consequently, confiscation of consignments at the cost of the supplier, withdrawal of export license, and, eventually, loss of access to such markets [5,16–20].

Several organizations and bodies with different mandates contribute to the guaranteed production and trade of safe, healthy, and quality fresh vegetables, among other food crops exported to lucrative markets [4]. Such bodies and institutions include the Ministry of Agriculture, Livestock and Fisheries, Kenya Plant Health Inspectorate Service (KEPHIS), Horticultural Crops Directorate (HCD), Pest Control Products Board (PCPB) and various development bodies. Some of their activities include raising growers' awareness of good agricultural practices, the judicious usage of pesticides or organic farming, the importance of hygiene and sanitation and the technical requirements of the export markets, including the International Sanitary and Phytosanitary Standards (ISPMs) and private standards such as the Global GAP and Kenya GAP. Mitigation strategies that address issues related to chemical residues include the use of non-chemical methods to manage crop pests [21], the introduction of traceability systems [22], good agricultural practices, upgrading of inspection laboratories, ratification of regional and international sanitary and phytosanitary measures and standards, among other efforts. All these efforts are geared towards building confidence in the quality of fresh produce intended for niche domestic and foreign markets [23,24].

This study, therefore, hypothesizes that upscaling fresh vegetables for niche markets requires the development sustainable value chains from farm to fork by addressing phytosanitary and pesticide residue constraints. It is on this premise that this study aims to provide a four-tiered approach system targeting smallholder farmers, institutions, facilitators and value chain actors, and research how to reverse the declining fresh-vegetable export trends. The four tiers include (i) establishing structured grower systems, (ii) strict enforcement of standards, (iii) investment in research and adoption of innovative technologies and (iv) awareness creation and training.

2. Review of Determinants of Quality in Exported Fresh Vegetables

2.1. The Status of Fresh Vegetable for Niche Markets in Kenya

Globally, the production of vegetables has risen significantly between 2010 and 2018, with China leading the pack [25]. Fresh vegetables form about one third of the total export

volume of fruits and vegetables [9]. In a recent report, fresh vegetables in the United States of America continue to gain a large portion of the market. There is a similar trend in Spain, the leading exporter of fresh vegetables in the European Union (EU), which posted 9752, 9868, and 10,110 ('000 tonnes) in 2017, 2018, and 2019, respectively [26]. Morocco is a critical exporter of tomatoes to the EU, and its market is growing in leaps and bounds [9,26,27]. According to Ashebre [28], Ethiopia, which borders Kenya to the North, is recording an increased market of vegetables after receiving support from foreign investors. Kenya's fresh vegetable export market is not comparable to that of Morocco and Ethiopia, as African countries compete for the niche markets.

Kenya produces a variety of vegetables, including but not limited to exotic, Asian, aromatic and indigenous vegetables. These vegetables are either sold locally in open markets, grocery stores or supermarkets, or exported to lucrative markets. Taking the available and recent data on total production volume, the production of exotic vegetables increased from 4,145,900 to 4,404,171 Metric tons (MT), from 2016 to 2017, respectively (The Horticultural Crops Directorate [3]). Taking the same years into account, the production of Asian vegetables increased from 19,043 MT to 32,292 MT, while the production of aromatic vegetables raised from 124,642 MT to 129,253 MT, also recording an increase. Indigenous vegetables, famously referred to as African leafy vegetables, recorded 229,492 MT in 2016 and 265,267 MT in 2017 in terms of production volume [3]. These production volume data clearly indicate Kenya's fresh vegetable potential. On the other hand, export volumes in 2016 and 2017 were 78,791 MT and 87,240 MT, respectively. From 2012 to 2020, the peak in exported fresh vegetable volume occurred in 2017 and the lowest volume occurred in 2020. This study found that the export volumes were not steady across the nine-year period, ranging between 60,342 MT and 87,240 MT. It can be argued that the export volume fluctuations (Figure 1) are a function of various factors along the fresh vegetable value chains. The monetary value, in Kenyan Shilling (KES.), of those vegetables indicates the economic significance of this segment as part of the total horticultural exports. For example, the percentage value of vegetables relative to total horticulture exports was 23% in 2015 (KES 20.9 billion) and 2016 (KES 23.36 billion), whereas, in 2017 (KES 24.06 billion), exported vegetables were valued at 20.9%. (Figure 1). The top five exported fresh vegetables, out of the 22 that are exported, are mixed vegetables, fine beans, processed beans, snow/mangetout, and herbs [3]. The latter ranks fifth according to current validated data on fresh vegetables [14].

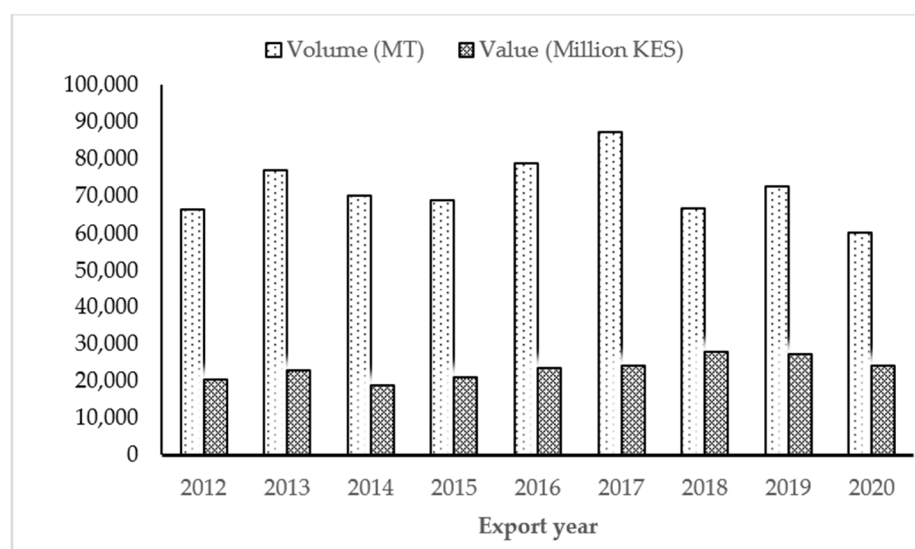


Figure 1. Volume and local value of vegetables exported from Kenya for nine consecutive years. Source: Kenya National Bureau of Statistics, 2021 [5].

2.2. Pests of Phytosanitary Concern in Fresh Vegetables

Insect pests such as whiteflies (*Bemisia* spp.), bollworms (*Helicoverpa* spp.), thrips (*Frankliniella*), spider mites (*Tetranychus* spp.), fruit flies (*Bactrocera* spp.) and leafminers (*Liriomyza* spp.), are some of the most important pests of fresh vegetables and of high phytosanitary concern [29]. These and other pests affect the quality of the harvestable portions of the fresh produce, which further affects their marketability [30]. Thrips (*Thrips tabaci*) attack a variety of vegetables, flowers and fruits. In onions (*Allium cepa*) thrips feed on the leaves, reducing their photosynthetic potential, which eventually reduces the size of the bulbs. Reduced bulb size is a quality defect that affects the marketability of the onions [31]. Moreover, thrips are agents of the transmission of bacterial, fungal and viral diseases such as Iris Yellow Spot Disease and purple blotch (*Alternaria porri*), which also affect crops and reduce their yield quality and quantity [31,32]. In snap beans (*Phaseolus vulgaris*), western flower thrips (*Frankliniella occidentalis*) reduce the quality of pods by affecting the plants at flowering stages. The resulting pods are usually deformed, a quality defect that is unacceptable for marketing [33]. Whiteflies (*Bemisia tabaci*) are also agents of disease transmission in various crops such as snap beans and tomatoes (*Solanum lycopersicum*), affecting the leaves and, eventually, the fruits due to the reduction in photosynthetic potential [34].

The detection of insect pests, associated foreign material or defects caused by pests is a reason for the interception of produce intended for foreign markets. Fruit flies were found on karalla (*Momordica* spp.), which amounted to about 71% of the interceptions. There were also 10 reported notifications of thrips on karalla [35]. Chilli and capsicum peppers from Kenya were intercepted at the EU markets due to the presence of false codling moth (*Thaumatotibia leucotreta*), a pest that has been of importance to citrus plants [36]. In one year, Kenya had 46 interceptions relating to the presence of pests in their exported produce. These included leaf miners in great basil (*Ocimum basilicum*), fruit flies in luffa cucumbers (*Cucumis sativus*) and false codling moth in chillies [36,37]. Fruit flies are quarantine pests in several countries and have been found to be phytophagous on melons (*Citrullus lanatus*), cucumbers (*Cucumis sativus*), avocados (*Persea americana*), guavas (*Psidium guajava*) and wild fruits [38]. Wild fruits serve as alternative hosts of the various species of fruit flies [38,39]. The losses caused by fruit flies are immense, in addition to their costing trade relationships between countries due to phytosanitary concerns [40].

The export of fresh vegetables continues to be plagued by harmful organisms, with bulky arthropod pests significantly contributing to interceptions. In the recent past and at present, several harmful organisms have led to interceptions (Figure 2). The frequency with which various species of harmful organisms were found in the period from July 2018 to March 2021 is provided in Table 1. *Liriomyza* spp. are important insect pests of vegetables [41] and of phytosanitary significance, and their statistics show that they account for a third of total interceptions due to harmful organisms in this period. The latter and EUROPHYT [42] show that, over time, there has been no significant change to ameliorate *Liriomyza* spp. in vegetables destined for niche markets. *Scirtothrips aurantia* resulted in interceptions in fresh horticultural exports in the first quarter of 2021.

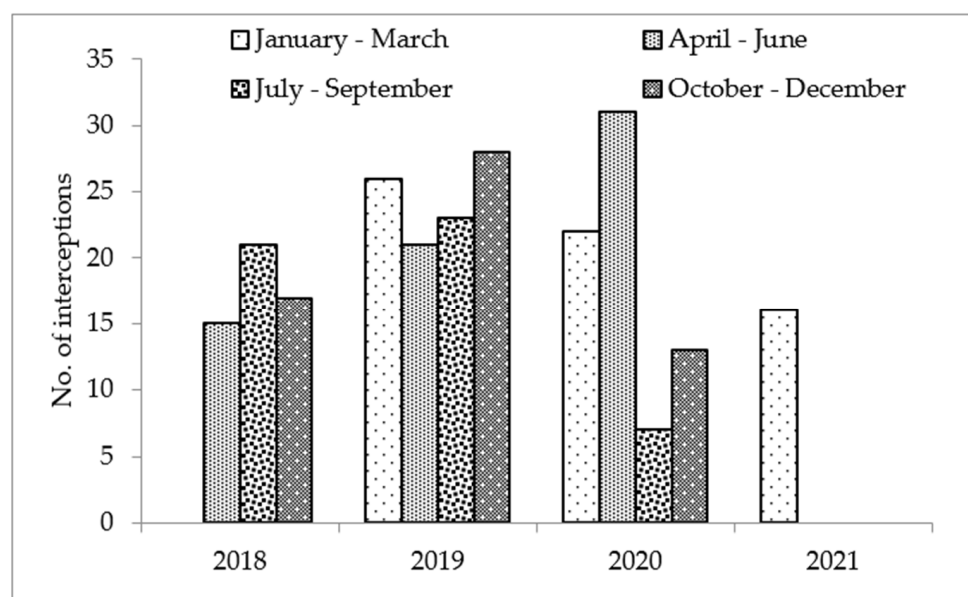


Figure 2. Latest quarterly interception statistics as a result of harmful organisms. Source: Fresh Produce Exporters Association of Kenya (FPEAK), 2021 [7].

Table 1. Frequency with which harmful organisms were intercepted in fresh horticultural exports from July 2018 to March 2021.

Harmful Organisms	Percentage
<i>Spodoptera frugiperda</i>	9.3
<i>Spodoptera littoralis</i>	9.3
<i>Thaumatotibia leucotreta</i>	14.7
<i>Bemisia tabaci</i>	13.3
<i>Liriomyza huidobrensis</i>	10.7
<i>Tephritidae</i>	10.7
<i>Liriomyza</i>	12.0
<i>Liriomyza sativae</i>	10.7
Thrips	8.0
<i>Scirtothrips aurantii</i>	1.3

Source: Fresh Produce Exporters Association of Kenya (FPEAK), 2021 [7].

2.3. Microbial Contaminants of Fresh Vegetables

Food safety is a global concern and hazardous microorganisms cause diseases either immediately or later, after the consumption of contaminated produce [43,44]. The sources of microbial contamination are varied and the hazards are reported at every stage of produce handling; from growth in the field, harvesting, post-harvest handling and packaging [45]. There is a high demand for vegetables all year round and in the rising urban population. The increase in urban population has also led to reductions in production areas, leaving land near wastewaters, and run-offs as the production sites [46]. Although the wastewater contains enough nutrients for the growth of crops, it also contains loads of microorganisms, which are a health hazard for consumers [45,47]. Producers of fresh vegetables, even for local markets, use fertilizers from any source as long as they provide nutrients to plants and provided that they are relatively cheap [48]. Manure from poultry units, animal sheds, organics and kitchen waste are usually utilized, as they are readily available and relatively cheap [49].

Worker health and hygiene is also a great contributor to the microbial contamination of fresh produce [47]. This is because workers are involved in all stages of vegetable production, from growing to harvesting to post-harvest handling. This is attributed to the availability and accessibility of sanitary facilities on the farms and production zones [45]. The water used to irrigate the vegetables and handle them after harvest also contributes

to microbial contamination if the sources are not treated. The usage of waste waters and sewers or run-offs is not good for irrigation, as reported by Seto et al. [46], as unclean water serves as a pathway for pathogen transmission. Using water from rivers for irrigation without treatment is also risky, since communities along rivers drain a lot of their wastes into the rivers. These wastes find their way downstream and carry collective microbial and faecal coliforms [50]. The water used to clean farm produce should also be clean or subjected to sterilization to get rid of the harmful microorganisms that have been reported on vegetables [44]. As provided in Table 2, different microbial species have been reported on fresh vegetables in Kenya. The major microorganisms reported are *Escherichia* and *Salmonella*, which are the most common and are major indicators of human waste contamination on fresh vegetables [43,51].

Table 2. Selected harmful microorganisms reported on different vegetables.

Microorganism	Detected on	Place Sourced	Reference
<i>Enterobacteriaceae</i>	French beans	Harvested from commercial planting	[52]
	Tomatoes, kales, amaranth leaves	Markets and retail outlet in urban and peri-urban towns	[53]
<i>Escherichia coli</i>	Ready-to-eat kales, cabbage, and nightshades	Vending points	[54]
	Corriander, onions, tomatoes, and chili	Vending points	[55]
<i>Salmonella</i> spp.	Ready-to-eat kales, cabbage, and nightshades	Vending points	[54]
	Kales	Vegetable growing peri-urban areas around Nairobi	[56]
	Corriander, onions, tomatoes, and chili	Vending points	[55]
<i>Listeria monocytogenes</i>	French beans	Harvested from commercial planting	[52]
<i>Staphylococcus aureus</i>	Tomatoes, kales, amaranth leaves	Markets and retail outlet in urban and peri-urban towns	[53]
	French beans	Harvested from commercial planting	[52]

2.4. Strategies Used by Farmers in Managing Pests in Fresh Vegetables

The most relied-on method of pest and disease management is the use of synthetic pesticides [57,58]. Farmers try to manage pests throughout the growth of crops, from establishment to harvesting, and sometimes post-harvest [30]. They rely on chemical pesticides, since they equate quality with physical aesthetics as opposed to the safety of the produce [59]. Some farmers apply the chemicals indiscriminately, with the aim of eradicating the harmful pests from their fields, while remaining ignorant of the harmful effects such chemicals have on the environment or the residues left in their [60,61]. Calendar spray programmes are always altered in the event that pests are noticed in the fields, without considering the pre-harvest intervals. Consequently, people applying the chemicals are also exposed for a long time, which is a health hazard [59,62].

Farmers also combine cultural practices with chemical pesticides. When seeking varieties to plant, they settle for those with resistance against a certain disease, a common cultural practice [63]. Mulching is performed with the aim to smoothen the weeds and avoid soil splash during irrigation, which is a predisposing factor to soil-borne diseases [64]. Farmers also intercrop several crops that are either trap crops or repellents for certain pests and are not alternative hosts for pests or pathogens [65]. Weeding contributes to field sanitation since some weeds are alternative hosts of pests and pathogens. Farmers may weed manually or use herbicides to eliminate the weeds [66]. Farmers may also plant their crops early, before environmental conditions are favourable for pests and pathogens [67]. They may also plant late, after their neighbours have planted and, in this way, they reduce

their infestation and infection levels, since most of the pests are in the neighbouring plants. Depending on the type of crop, early harvesting can be used to avoid pests that mainly attack mature crops and could cause postharvest damage [68]. Farmers who have large tracts of land may rotate crops of different families or resistant varieties in order to avoid and starve pests and pathogens, thereby reducing their populations and inoculum, respectively [69]. These cultural practices are always coupled with pesticides to enhance crop protection. Table 3 is a summary of the strategies deployed by vegetable farmers in managing notorious pests, including those of phytosanitary significance.

Table 3. The current fresh vegetable pest management strategies deployed by Kenyan farmers.

Type of Control	Farmer's Strategy	Target Pest	Reference
Physical	Washing plants with strong jet of water	Arthropod pests	[70]
	handpicking	Pod borers	[71]
	Remove and destroy infested plant material.	Red spider mite	[66]
Cultural	Field sanitation		[66]
	Planting resistant varieties	Snap bean insect pests	[66]
	Weeding	Spider mites	[72]
	Crop rotation		[70]
	Planting early in the season	Bean fly	[70]
Biological	Intercropping	Thrips	[66]
	Organic production		[70]
	Use of predatory mite	Western flower thrips	[70]
	Use of botanicals	Pyrethrins-Aphids, whiteflies; Azadirachtin-thrips, leafminers, etc.	[73]
Chemical	Use of synthetic pesticides (cypermethrine, deltamethrin, fenvalerate, imidacloprid, triazophos, dimethoate)	Bean fly, aphids, whiteflies	[73,74]
Integrated	Use of multiple interventions	Targets all pests	[70]

2.5. Problems Associated with Use of Synthetic Pesticides

The usage of chemical pesticides in managing pests in vegetables causes direct and indirect damage to the environment, as well as the users and consumers of the produce on which they were used. The unguided use of pesticides has negative effects on trade relations and has serious negative implications for health and the environment, since some chemicals used to manage pests and diseases of crops are inherently toxic. The detection of residues above the maximum allowed levels in crop produce is unacceptable in lucrative markets. The usage of banned chemical pesticides is also a regulation that must be observed at all times by vegetable producers. Therefore, farmers who continuously use chemical pesticides to manage crop pests and diseases risk losing access to such markets as well as income. Sometimes the consignments are destroyed at the farmers' or suppliers' cost, thereby incurring uncountable losses. In 2013, Kenya's French beans were rejected at the EU due to the presence of dimethoate residue, a pesticide active ingredient regulated for use in vegetables in Kenya [75]. This led to reduced number of exports, increased inspection of Kenyan produce and huge monetary losses due to rejected consignments [16,37]. In 2015, the EU introduced stringent standards and requirements for beans and peas with pods, citing the safety of their consumers. The shelled peas and beans ought to be pest-free and pesticide-residue-free for them to be accepted in those lucrative markets [76]. Despite a high production rate in 2013, the sales of French beans declined by 33%, leading to a revenue loss, and this was due to the detection of a restricted pesticide [77].

Pesticides possess compounds capable of causing chronic diseases upon continued exposure or consumption [78]. According to Tsimbiri et al. [79], workers involved in the spraying of these pesticides or working in farms where such chemicals are used develop complications in the long run, including respiratory, cardiovascular and lymphatic malfunctions. The toxicity of pesticides can be determined through varied means, such as impact on the users and consumers of sprayed produce. Exposure to pesticides has both acute and chronic effects, such as neurological, carcinogenic and endocrine system impairment [80].

Synthetic compounds that are not easily biodegradable accumulate in and/or on the produce to which they are applied, as well as the environment. Upon consumption, these compounds become a health hazard [81]. The presence of heavy compounds in the environment accumulates in the atmosphere and leads to depletion of the ozone layer, which further contributes to global warming. Some of the pesticides associated with such effects include metham sodium and DDT, which have since been banned from agricultural use [82]. Upon application to crops, pesticides leach their way into soils and water systems, causing the death of aqua life. In the soils, chemical compounds act on untargeted soil microorganisms, killing them and rendering them unavailable for the work they do, such as biological nitrogen fixation, churning soils and improving soil aeration [83]. The absence of soil microorganisms contributes to soil degradation. In air, the pesticides affect other beneficial organisms, such as natural enemies of pests and pollinators [84]. All the consequent effects of using chemical pesticides contribute to the disruption of biodiversity. The continuous use of a certain pesticide to manage a targeted category of pests leads to the development of resistance by the pests. Farmers thus apply more pesticides in an attempt to eradicate the new strains of pests, which contributes to more residual accumulation and environmental pollution [85].

The constituents of synthetic chemicals have polluting effects, which further poison the lives existing in the environment, leading to imbalances in biodiversity [59]. Natural enemies and beneficial organisms die in both marine and terrestrial habitats. Plants in the aquatic systems die or become poisoned, which further kills the aquatic lives that depend on those plants. Oxygen levels decrease, leading to the death of more aquatic life forms. Bees and beetles also die in sprayings intended for harmful insects [86].

2.6. Fresh Produce Export Requirements and Their Implications

Fresh produce for export is expected to meet certain requirements for it to be accepted by the importing country and to be deemed safe for consumption [14]. In addition, fresh produce should be aesthetically presentable; hence, attributes such as tenderness, compactness, glossiness, and colour inter alia are desirable [71]. The produce should be free of pest damage, have a certain freshness and firmness, and be free from bruises, foreign smells and tastes, as well as stains [29]. Significantly, fresh produce for export should not be contaminated by pests, most importantly, quarantine and regulated non-quarantine pests, or parts of pests (I.S.P.M. 16). According to Codex Alimentarius Commission, for instance, tomatoes that are to be consumed fresh should be whole and free from pests, free from foreign smells and tastes, and free of any damage, with acceptable ripeness, firmness and moisture [87]. Aubergines should be firm, free of damage from pests or parts thereof and fresh, without a foreign smell or taste, among other standards [87]. Such quality standards have also been described for other fresh-food products, capturing minimum requirements for quality, maturity, size, tolerance, aesthetics, packaging, labeling and the country of origin of the produce [87].

The exported produce should not have traces of pesticides above the regulated levels. Importing regions have stringent regulations regarding the maximum residue levels (MRLs) allowed on fresh vegetables (Table 4). The use of non-recommended chemicals for pest management in vegetables is an impediment to the acceptance of exported produce. For permitted pesticides, postharvest intervals need to be observed keenly to allow for safety. However, organic production is highly recommended. To achieve safe food, good agricultural practices (GAPs) and good handling practices (GHPs) should be embraced.

Table 4. Maximum Residual Limits (MRLs) of selected active substances of pesticides on selected vegetables destined for the EU.

Active Ingredient	EU MRL (mg/Kg)	MRL mg/Kg	Year Adopted
Aldrin and Dieldrin	Leafy vegetables	0.05	1997
Abamectin	Tomatoes	0.09	2015
	Snow peas	0.01	
	French beans	0.03	
Azoxystrobin	Fruiting vegetables	3	2009
Acetamiprid	Cabbage	0.01	2017
	Coriander	0.01	
Bifenthrin	Peas with pods	0.9	2016
	Flowering brassicas	0.4	
Chlorpyrifos	Bulb vegetables	0.01	2003
	Root and tuber vegetables	0.05	
Cypermethrin	Leafy vegetables	0.7	2009
Deltamethrin	Leafy vegetables	2	2006
Dimethoate	Brussel sprouts	0.1	2009
	Legume vegetables	0.01	
	Carrots	0.03	
Imidacloprid	Peas with pods	5	2009
Paraquat	Leafy vegetables	0.07	2006
Metalaxyl	Chinese cabbage	0.02	2017
	Eggplants	0.01	
	Beans with pods	0.02	
	Peas with pods	0.02	
Cyantraniliprole	Peas with pods	2	2018
	Peas without pods	0.3	
	Beans with pods	1.5	
	Beans without pods	0.3	
Chlorothalonil	Bulb vegetables	0.01	2016
	Sweet pepper	0.01	
	Broccoli	0.01	
	Asparagus	0.01	

Source: European Commission, 2021 [88].

The export should be accompanied by documentation that are cleared by several bodies. A phytosanitary certificate should be given by the National Plant Protection Organization (NPPO) of the exporting country with declarations that are correct, concise and accurate. The certificate should include exporter details, date, name, quantities and type of consignment, and the package should include everything listed on the certificate. In addition, the package material should contain the name, date, quantity of the produce, country of origin and any other relevant information that is important to the importing country. Lost and adulterated documents are an indication of breaches of compliance and lead to damaged international trade relationships. Securing documents and passwords in an electronic system remains the responsibility of the exporter [29]. The documented cases that have resulted in the rejection of exported produce in Kenya for almost a decade include incomplete plant passports, missing additional declarations, unendorsed copies of plant passports, false information, and non-compliance with special requirements [86].

The fresh produce should be free of contaminants that have not been intentionally added [89]. Quality preference has been heightened and the buyers in these lucrative markets have offered to pay even higher prices for food grown using natural methods; this is meant to attract more organic farmers [89]. Farmers have had to deal with more

stringent measures and some have opted out of the markets due to cost reasons [90]. In addition, importers of fresh vegetables have opted for alternative suppliers from other, competing countries; this has led to loss of market access and reputation [91]. Alterations to the production processes, changes in the processes of pesticide assessment and a lack of pest management procedures are some of the reasons that the harmonization of MRLs by the EU has been carried out in efforts to enhance traceability [92]. In Kenya, pesticides containing compounds such as dimethoate, chlorpyrifos and beta cyfluthrin have been banned for use on fruits and vegetables [93].

3. Four-Tiered Approach to Compliance with Phytosanitary and Pesticide Residue Requirements

3.1. Establishment of Structured Grower Systems for Exporters

The significance of establishing structured grower systems for vegetables is the basis on which the other three tiers are anchored. Large-scale exporters have embraced structured grower systems [94–96]. This study showcases the need to embrace integrated pest management, integrated crop management, good agricultural practices (GAPs) and good handling practices (GHPs) by smallholder farmers and retailers involved in the exportation of fresh vegetables. Such an undertaking would address the issue of food safety in regard to harmful organisms and pesticide residues [95]. The structured grower systems should encompass integrated pest and crop management approaches, coupled with good agricultural practices and good handling practices.

The essence of sanitary and phytosanitary standards is the aim to sustainably achieve safe produce for the increasing global population, with a preference for organically grown food without chemical residues. Achieving this objective cannot be met by using one management technique. Several strategies need to be combined to manage crop pests as well as the crops they affect; thus, the need for integrated pest management (IPM) and integrated crop management (ICM), respectively. The emphasis of IPM and ICM is the prevention of pest populations, the judicious and economic employment of pest management strategies, human health, environmental safety and the production of safe and healthy food [97]. The pests that affect crops belong to different families and genera, as well as species; therefore, managing them requires different but related approaches.

The use of biopesticides is a recent trend, for reasons such as their biodegradability, easy-to-access source materials, varied modes of action, little or no toxicity and their being economically affordable if sourced from local environments. Botanical pesticides are effective against several types of pests that affect different crops from establishment to post-harvest [98]. The resultant harmful effects resulting from the usage of synthetic pesticides have spurred interest in safe plant protection products. Botanical pesticides are derivatives of plant parts with bioactive compounds that are effective against important pests and crop diseases. Most of the commercialized botanical pesticides are insecticides, with most from neem, sabadilla, ryania tobacco, garlic, pyrethrum [99]. Plants belonging to families such as *Lamiaceae*, *Fabaceae*, *Asteraceae* have compounds that make them effective pest management [100,101]. Such compounds include tannins, ketones, terpenes, alkaloids, saponins, steroids and alcohols [102]. They do not leave residues in the crops due to rapid degradation, have several modes of action, are less toxic and are efficacious.

Biocontrol agents are effective on pests too and incorporated into soil. *Trichoderma*, *Bacillus*, *Pseudomonas*, *Xanthomonas*, *Beauveria*, *Paecilomyces*, *Metarrhizium* and *Verticillium* are some microorganisms whose species have been used as biocontrol agents [62]. In addition, biocontrol agents have been reported to be effective against insect pests. The relationship between predator and prey has also been exploited and used in the management of important crop pests. Biopesticides containing microorganisms are very effective against pests and crop diseases [103]. Species of bacteria, fungi, nematodes and protozoa have been isolated and used to manage insect pests, fungal, bacterial and nematode pests effectively. Pests are not likely to develop resistance since the interaction is a biochemical process.

Cultural and mechanical practices, used in combination with other pest management practices, are an effective contribution to integrated crop and pest management [104]. Early and late planting, early harvesting, crop rotation, use of mulches, manipulating different irrigation systems and crop spacing, use of barriers and traps, handpicking pests, pruning and field sanitation are some of the practices farmers have used in the past to manage crops in the field [105,106]. Lassiter et al. [107] reported an interaction between the variety of peanut (*Arachis hypogaea*) and planting dates, resulting in higher yield. This increase in yield, however, is subject to other crop growth factors. An intercrop of mustard (*Brassica napus*) with garlic (*Allium sativum*) led to a reduction in the population of aphids (*Lipaphis erysimi*) and had reportedly significant cost benefits [108]. Before handling pests and pathogens that attack crops, it is important to use varieties that are either resistant or tolerant to pests [109]. The use of standard or certified seeds is also encouraged, to start off with a clean planting material.

A combination of several of these strategies and the limited use of authorized chemical pesticides will contribute towards achieving the goal of producing healthy food while managing pests and diseases in a sustainable manner [110]. The use of traps is another safe strategy for pest management, especially for insects. Insect pests have been lured by the use of pheromones or coloured sticky traps [111,112]. These are compounds entrenched from host plants or from male or female species of subject pests. Once the pests are captured, the farmer could either starve them to death or the males could be sterilized and released back into the field and, upon mating with females, the resulting eggs will be infertile. This effectively reduces the population of pests in the subject field. Natural enemies such as predators and parasitoids are a sustainable way of controlling pests. Predators are raised in a laboratory and released into the field with pests. The effectiveness of this method is dependent on the predator–prey ratio, ability of the predators to establish themselves, and the availability and preference of host plants [113]. GAP practices are employed throughout the production of crops in order to achieve healthy, quality produce at the farm level, while GHP activities are conducted after harvesting the crops. GAPs mainly include proper sanitation at the farm level, the use of clean irrigation water, maintenance of field sanitation, and management of soil fertility, while GHPs may include the use of clean packing, packaging, storage and transportation facilities [114,115]. The adoption of GAPs is a strategic step towards providing safe, healthy and quality food to the continuously increasing global population. It allows for transparency in production systems and along the value chains. This transparency is crucial for domestic and export markets since it creates a sense of trust between producers and consumers [116]. The aim of using these activities in crop production systems is to attain food safety in a sustainable manner [115]. GAPs do not necessarily guarantee total food safety, since this is not a one-way approach, but they complement the efforts of the farmer or producer trying their best to ascertain the safety of their produce [117].

The water used for planting crops, washing the produce, drinking by the workers, cleaning packing facilities, warehouses, cooling produce and cleaning transportation facilities should be clean and inspected, depending on the source. Water from the municipal councils, rivers and boreholes should be treated and inspected differently [46,117]. The health and hygiene of workers is paramount to minimizing the contamination of farm produce. The owner of the farm should ensure proper sanitation by fully equipping the sanitation facilities. Designated places should have clean flowing water with detergents for washing after visitation. Sick workers should not be allowed to come into contact with food produce until after they have been medically treated. Designated areas eating and smoking should also be far from the produce to avoid foreign odours. In the event that body fluids come into contact with food produce, such produce should not be sold at all [118]. Using animal manure to enhance soil fertility should be carried out with caution, since most contaminants thrive in such places. Already decomposed manure should be applied to the soils weeks before planting and months before harvesting to allow for more breakdown and degradation. If the animals used to produce manure are raised within the farm, they

should be at a distance from the food-production areas. Water systems should not pass near the animal areas to avoid their carrying pathogens and other contaminants from the animal wastes to the fields with crops via irrigation [117,118]. The GAPs and GHPs aim for food safety, environmental conservation and worker's welfare, which all contribute to sustainable agricultural production and marketing.

3.2. Strict Enforcement of Standards

Several institutions work in harmony to ensure the safety of food that is mainly produced for exportation. The Kenya Plant Health Inspectorate Service (KEPHIS) is the National Plant Protection Organization (NPPO) of Kenya, mandated to, among other functions, regulate quality assurance for food security in Kenya. The NPPO's areas of focus are seed certification, quality control of agricultural inputs, and phytosanitary certification inter alia. In matters concerning export trade, KEPHIS ensures compliance with regulations regarding pesticide residues, harmful organisms in exported produce and proper documentation [29]. In this capacity, KEPHIS has regionally recognized laboratories with the capacity for diagnostic procedures and studies regarding crop pests such as nematodes, viruses, insects, bacteria, fungi, and molecular biology and tissue culture. KEPHIS has also held two international phytosanitary conferences with the aim of sharing phytosanitary concerns and challenges with other countries' NPPOs and exchanging ideas regarding how to solve some of the common problems regarding phytosanitary, in addition to learning from one another [119,120]. In collaboration with other stakeholders, KEPHIS launched a centre of phytosanitary excellence (COPE). The objective was building phytosanitary capacity in Kenya with the combined experience of other African NPPOs.

Other organizations also mandate to contribute to the ability to comply with phytosanitary requirements. The Fresh Produce Export Association of Kenya (FPEAK) is an association representing players in the horticultural sector including growers, exporters and service providers. The association provides marketing and technical information through training and promotes Kenya's horticultural industry in the global market. FPEAK has the goal of implementing Kenya's GAP, as well as continuing to create awareness in the industry regarding global market requirements and regulations [7]. The Horticultural Crops Directorate (HCD) is mandated to coordinate and regulate the horticulture sub-sector in Kenya. HCD has the responsibility of marketing horticultural produce in the local and international markets, promoting the development and adoption of local and international standards and advising the government regarding horticultural produce and marketing [3]. It is the mission of Kenya Bureau of Standards (KEBS) to provide standard solutions that promote trade and quality of life [121]. Under the Ministry of Agriculture, Livestock and Fisheries, the Department of Crop Development and Agricultural Research is responsible for developing standards related to the safety of agricultural products [122]). The Department of International Trade under the Ministry of Industry, Trade and Cooperatives, aims to, among other functions, promote and coordinate regional trade relations, such as EAC, COMESA, and internationally trade relations, such as the WTO and UNCTAD [123]).

Various legislations regulate the sanitary and phytosanitary bodies and measures. The Agricultural Produce (Export) Act (CAP 319) stipulates, for the purpose of this paper, the inspection of export produce and the necessary documentation regarding the same. It rules that if, at the time of exportation, exported produce intended for human consumption is found to be unsound for that purpose, it should not be exported. Such a consignment should either be seized, destroyed or disposed of. All documents, permits and certificates needed to export agricultural exports should be authentic, and the forgery of either the documents or signatures is punishable by law. The Kenya Plant Health Inspectorate Service Act (No 54 of 2012) establishes KEPHIS to, among other functions, administer and enforce sanitary and phytosanitary measures and food safety measures, establish service laboratories to monitor the quality and level of toxic residues in produce, and regulate the importation and exportation of plant materials. One of the objectives of KEPHIS is to ensure compliance with market requirements, and it achieves this through the inspection and

issuance of phytosanitary certificates. The Pest Control Products Act (CAP 346) regulates, among other things, the use of products used to control crop pests through assessments and evaluations, and in the registration of such products.

Regionally, Kenya signed up for the East African Community (EAC) SPS Protocol giving the country a legal basis for reforms regarding food safety measures. The ratification puts the country in the position to mitigate risks arising from phytosanitary concerns, food safety and the improved competitiveness of produce targeted for external markets. The protocol seeks to help the EAC region to effectively contain major pest threats and fully commit to the WTO regarding the application of sanitary and phytosanitary standards. As a member state of Common Market for East and Southern Africa (COMESA), Kenya also benefits from regulations regarding the application of SPS, whose objective is to protect human health and life from food-related contaminations, plant health and life from pests and pathogens, and the socio-economic structures of a Member State from the risks arising from the entry, establishment and spread of pests and diseases. The COMESA regulations also ensure that the application of SPS does not hinder the trade of agricultural products in the Common Market.

Internationally, Kenya subscribes to the international SPS measures by having an NPPO (KEPHIS), a contracting party to International Plant Protection Convention (IPPC). IPPC is a multilateral treaty, governed by the Commission on Phytosanitary Measures (CPM), whose functions, among others, are to protect the natural plant resources from pests while ensuring that protection activities do not interfere with the international trade of goods and people. The Convention's activities include, among others, setting and implementing international sanitary and phytosanitary measures (ISPMs), and supporting developing countries in participating in Regional Plant Protection Organizations (RPPOs in order for them to become aware of the benefits of safe trade and increase their efficiency in compliance with trade standards [124]).

3.3. Investment in Research and Adoption of Innovative Technologies

The leading countries in vegetable production and marketing have continued to appreciate the innovative technologies stemming from scientific and technical advancements. Razin et al. [125] maintains that developed economies invest in agricultural projects that result in innovative technologies, which are then adopted in vegetable production, resulting in an increase in export volume. It can be said that, for developing countries such as Kenya to continue increasing the volume of exported vegetables, private–public partnership engagements ought to be streamlined. The vegetable products from smallholder farmers can only become competitive by addressing pitfalls along the value chain, which calls for technological know-how. Well-researched technologies, coupled with policy formulation and enforcement, would obviously lead to the desired vegetable quality, a parameter that is fraught with challenge for smallholder farmers.

This review is cognizant of the fact that Kenyan vegetables are so varied, and this can be an impediment to research programmes, such as those focusing on major industrial crops such as coffee and tea. It is on this premise that it can be argued that technologies to protect the environment should be within the reach of producers. Most smallholder farmers in Kenya cannot afford the use of greenhouses due to their shrunk pockets [126]; therefore, both national and county governments and development partners could provide financial support for the adoption of such technology. In the archived literature, greenhouse technology befits most highly valued vegetable production, as it is a mitigation tool for the challenges associated with climate change, which reduce the quantity and quality of vegetables within the tropics [127].

Due to vegetables' perishability, it is profound that, during transit, cold conditions should be maintained to overcome bottlenecks such as water stress and ethylene, which jeopardise quality. Exporters of vegetables continue to invest in cold chain as an assurance that the commodities will reach their destination fresh, within a limited timeframe. In addition, traceability has been lauded for instilling confidence in consumers and helps

in dealing with exportation rejections [128]. Recently, farmers in Western Kenya were introduced to blockchain, a digital technology that is versatile in connecting players within the supply chain. If this traceability practice is inculcated into vegetable supply chains, coupled with traceability protocols, then smallholder farmers would not only retain their current loyal markets, but also position themselves for new market opportunities.

Fresh vegetables from smallholders have been reported to be subjected to single decontamination treatment, an approach that is less efficacious in removing both chemical residues and bacterial pathogens such as *Escherichia coli*, *Listeria monocytogenes* and *Salmonella*. This study reaffirms the suggestion by Bhilwadikar et al. [44] of combining decontamination methods based on their criteria of mode of action and applicability to particular vegetables. The practicability of this proposition largely depends on huge investments in terms of research to determine the efficacy of combining modern techniques with chemical treatments or customized washing without compromising vegetable quality. Further, such an undertaking dictates huge investment in treatment facility systems; hence, it calls for financial support as the costs cannot ostensibly be realized by smallholder farmers.

Looking at the KEPHIS mandate of enforcing food safety measures, it can be said that the testing of pesticide residues has been enhanced by equipping the Analytical Chemistry and Food Safety Laboratory. Such an undertaking is plausible since the MRL audit is one parameter that any fresh-vegetable exporter must meet. However, MRLs continue to plague fresh-vegetable exports. This stalemate MRL causes in some vegetables for export can be reversed to ensure vegetables comply with market and food safety requirements by having a structured programme of testing pesticide residues in vegetables without laxity. The cost of analyzing samples for MRLs is overwhelming, especially when each sample of fresh vegetables is taken from every smallholder farmer. The authors of the article observe that the pesticide residue problem starts at the production site; hence, exporters who source fresh produce from smallholder farmers ought to treat each sample independently during private and public analyses of pesticide residues. However, the accreditation of KEPHIS Analytical Chemistry and Food Safety Laboratory with state-of-the-art equipment for the testing of over 300 pesticides in a single run, which translates to a remarkable output, would boost Kenya's fresh vegetable export trade.

3.4. Awareness Creation and Training

In order to have a sustainable vegetable production and marketing system, training is essential for the producers, exporters and facilitators involved. It is feasible to have smallholder farmers organized in groups based on contract farming or geographical orientation, and trained in IPM, GAP and export requirements. Kenya's NPPO, KEPHIS continually tasks itself to raise awareness in all farmers, and they have recently trained more smallholder bean farmers with pods relative to other vegetables. The expansiveness of smallholder farmers within Kenyan territory is overwhelming; hence, KEPHIS alone cannot meet the need to train farmers and exporters. Other stakeholders should take on their fair share of awareness creation to maintain the sector, considering the dynamic nature of vegetable export requirements. KEPHIS has conducted immense training sessions around the country on important issues such as pesticide application, pest management and the establishment of plant clinics [129]. This is in addition to hosting two phytosanitary conferences, which are a forum for the exchange of experiences, ideas, challenges, emerging issues and solutions to phytosanitary issues, as reviewed by the attending NPPOs.

The Centre of Phytosanitary Excellence (COPE) is a training unit that was established in Nairobi to, among other functions, provide training opportunities regarding phytosanitary standards, measures, policies and practices [130]. The target groups for this training include key players in the ministries of health, agriculture, trade, finance, foreign affairs, and port authorities among others. The training conducted by COPE is carried out in collaboration with other institutions, including KEPHIS, University of Nairobi and CAB. KEPHIS has successfully hosted two International Phytosanitary Conferences in 2016 and 2018, and was able to bring together NPPOs from different countries to share their expe-

riences in phytosanitary matters, as well as learn the challenges other countries face and exchange ideas depending on their accomplishments. The conferences also serve as an arena to discuss emerging issues regarding plant health. The idea of the International Phytosanitary Conference was presented to IPPC as a proposition to hold conferences on a regular basis, and for the proceedings to serve as a “Review of the Status of Plant Health in the World” [126].

4. Conclusions

The horticultural industry remains an important sector in Kenya due to the many benefits it has to the country and the people involved in the value chain. Horticultural produce, such as cut flowers, fruits and vegetables, targeted for lucrative market destinations such as the EU, need to meet certain quality, safety, health and aesthetic requirements. Recently, there have been bans on Kenyan produce due to sanitary and phytosanitary regulations. The country has made noticeable steps towards redeeming its name in the international market arena. There are still challenges in attaining full compliance with the sanitary and phytosanitary requirements due to the costs involved in a safer means of production and a lack of sufficient awareness.

It is worth noting that continued compliance with the SPS requires a multifaceted approach, with all the involved parties sharing a common goal. This includes the involvement of training institutions, the NPPO, the government and bodies charged with horticultural industry responsibilities, such as HCD and FPEAK. Countries such as Kenya should reconsider their agricultural policies by strengthening research that brings together research both private and public institutions and fresh vegetable growers in order to transfer knowledge and build on existing capacities. The current work proposes a holistic look at vegetable exports in terms of addressing the pertinent issue of rejection due to pests of phytosanitary significance, microbial contamination and MRLs. Together, market relations at the international arena will be accessed and maintained. However, this task must be undertaken by all parties, from growers to exporters and everyone in between, ensuring an upward trajectory in the value and quantity of exported vegetables.

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