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REVIEW

Food safety of fresh fruits and vegetables in the Philippines: challenges and prospects

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Abstract

Fruits and vegetables are high-value nutritious crops and are integral parts of food security and nutrition policies and programs. They are consumed fresh or partially processed and are often implicated in food safety problems. As food supply becomes increasingly globalized, food safety concerns have become multifarious, and impacts on lives and society have magnified, affecting both developed and developing countries. Reducing the risks of unsafe food involves preventing contamination throughout the food chain. This review draws the food safety situation of fruits and vegetables in the Philippines, particularly the prevalence of food safety hazards and issues in selected supply chains, and synthesizes the food safety gaps to lead the way forward, towards mainstreaming food safety and a safe food culture harnessing existing enabling ecosystems.

1. Introduction

Food safety is an overarching public health and trade concern that has escalated in recent years due to the increased globalization of food production and trade. Food safety challenges have never been more compelling than they are today, especially in developing countries as they strive to engage in the global economy. Despite the growing international awareness of foodborne diseases as a significant risk to health and socioeconomic development, food safety remains marginalized.

Food safety is the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (Food and Agriculture Organization of the United Nations (FAO)/World Health Organization (WHO), 1999). Food safety problems are closely linked to poverty and food insecurity, which are targets of the United Nations' Sustainable Development Goals (SDG) 1 and 2. They could also exacerbate food loss and waste, a target of SDG 12. In addition, food safety is essential to good health and well-being (SDG 3). Achieving the SDG targets could help to safely feed the world of two billion more people in 2050. The World Health Organization (WHO) emphasized that access to sufficient amounts of safe and nutritious food is key to sustaining life and promoting good health (WHO, 2022).

Unsafe food containing harmful bacteria, viruses, parasites, or chemical substances causes more than 200 diseases, ranging from diarrhea to cancer (WHO, 2022). Billions of people are at risk, millions fall ill every year, and many die as a result of consuming unsafe food. Economic losses are large because of healthcare costs, productivity losses, and foregone markets. Approximately 600 million people (almost 1 in 10 people) in the world fall ill after eating contaminated food, and 420,000 die every year, resulting in the loss of 33 million healthy life years (DALYs). US$ 110 billion is lost each year in productivity and medical expenses resulting from unsafe food in low- and middle-income countries. Foodborne diseases impede socioeconomic development and harm national economies.

Fruits and vegetables support food security and prosperity goals being nutritious and high-income-generating crops. However, they are usually implicated in food safety issues and food poisoning cases. The main

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contributing factor is that fruits and vegetables are consumed fresh or partially processed (UN, 2007). Any breakdown in food safety in supply chains could lead to contamination by microbial, chemical and physical hazards (Fresh Produce Safety Centre Australia and New Zealand, 2022).

Reducing the risks of unsafe food involves preventing contamination throughout the supply chain. A supply chain approach (value chain or food chain approach) is crucial to preventing food safety problems and sharpening a safe food culture that supports the three cornerstones of sustainability – economy, society, and environment. Good collaboration between government, private sector, producers, and consumers is needed to help ensure food safety and inclusive and sustainable food systems.

This review draws on the food safety situation of fruits and vegetables in the Philippines, particularly the prevalence of food safety hazards and issues in selected supply chains. Desktop research was conducted to access publicly available literature regarding the incidence of food safety hazards (pesticide residues and microbial contamination) in fruits and vegetables. Supply chain research on fruits and vegetables of the Postharvest Horticulture Training and Research Center (PHTRC), University of the Philippines Los Banos (UPLB), was analyzed to identify supply chain practices and deficiencies that compromise food safety and substantiate the importance of supply chain approach to food safety management. Figure 1 shows the location of these supply chain studies. From these documentary studies, food safety gaps were synthesized to define the way forward toward mainstreaming food safety by harnessing existing enabling ecosystems which are also specified. The overall research design employed for this documentary review and analysis is shown in Figure 2.

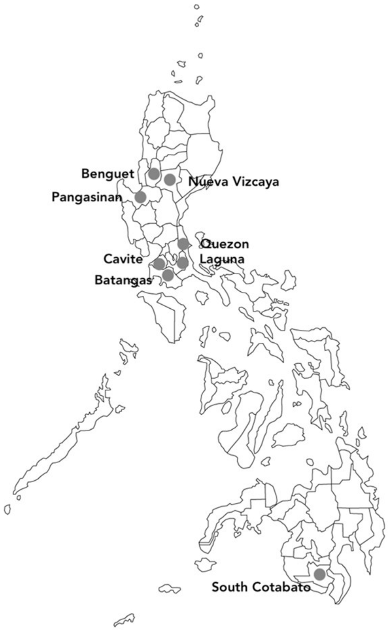

Figure 1. Philippine location of fruit and vegetable supply chains examined - bitter gourd (Laguna, Batangas, Pangasinan); chili (Benguet, Laguna, Batangas, Quezon, South Cotabato); pechay (Batangas); mungbean sprout (Cavite, Batangas, Laguna); organic fruit and vegetables (Laguna, Batangas, Nueva Vizcaya, Benguet); organic Romaine lettuce (Laguna)].

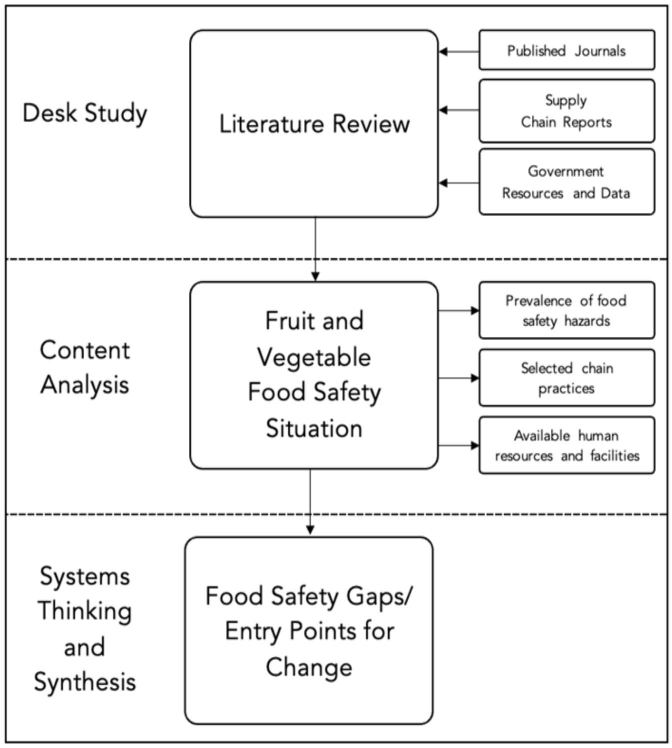

Figure 2. The overall research design employed in this documentary review and analysis.

2. Food safety hazards

2.1 Pesticide residues

2.1.1 Prevalence in crops

Chemical pesticides are widely used production inputs, particularly in vegetables (Table 1), which dominate reports on pesticide residues (Table 2). A study on organophosphate residue screening on cabbage, potato, and sweet peas in Benguet and Mountain Province in Luzon (Northern Philippines) showed a total of 18 pesticide residues - 16 in cabbage, 12 in potato, and 13 in sweet peas at varying concentrations (Reyes *et al.,* 2017). Some pesticide residues were beyond the maximum residue limits (MRLs), and some pesticides were already banned. On the other hand, low concentrations of pyrethroid pesticide residues (deltamethrin and lambda-cyhalothrin) were found in cabbage, soil, and water samples from a major vegetable-growing area in Cebu in the Visayas (Central Philippines) (Calinawan *et al.,* 2017). The presence of pesticide residues was linked to improper practices. Pesticide practices posing risks to humans, the environment, and biota include the application of

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Table 1. Pesticides used in fruit and vegetable production.

Pesticides	Active ingredient	Crop	Location	Reference
Anthranilic diamide	Chlorantraniliprole	Eggplant	Sta. Maria, Pangasinan	Prado-Lu and Leilanie (2015)
Carbamate	Dymethylamin	Vegetables	Cordillera Region (Ifugao, Mt. Province, Benguet)	Ngidlo (2013)
	Carbaryl, Methomyl	Mango	Negros Oriental	Cubelo and Cubelo (2021a)
	Methomyl	*'Pinakbet'* vegetables	Lal-lo, Cagayan	Sawadan, 2022
Dithiocarbamates	Propineb, Mancozeb	Mango	Negros Oriental	Cubelo and Cubelo (2021a)
Organophosphate	Methamidoph, Dimethoate, Chlorpyrifos	Vegetables	Cordillera Region (Ifugao, Mt. Province, Benguet)	Ngidlo (2013)
	Chlorpyrifos, Malathion	Vegetables	Lucban, Quezon; Pagsanjan Laguna	Varca (2012)
	Fenthion	Mango	Negros Oriental	Cubelo and Cubelo (2021a)
	Malathion	*'Pinakbet'* vegetables	Lal-lo, Cagayan	Sawadan (2022)
	Malathion, Chlorpyrifos, Methamidophos	Eggplant	Sta. Maria, Pangasinan	Prado-Lu and Leilanie (2015)
Organophosphates + Carbamates	Chlorpyrifos + BMPC	Mango	Negros Oriental	Cubelo and Cubelo (2021a)
Organochlorines	Endosulfan	Mango	Negros Oriental	Cubelo and Cubelo (2021a)
Pyrethroid	Fenvalerate, Cyhalothrin, Cypermethrin, Profenofos	Vegetables	Cordillera Region (Ifugao, Mt. Province, Benguet)	Ngidlo (2013)
	Lambda-cyhalothrin, Cypermethrin, Profenofos	Vegetables	Lucban, Quezon; Pagsanjan Laguna	Varca (2012)
	Beta-Cypermethrin, Beta-Cyfluthrin, Cypermethrin, Fenvalerate,	Mango	Negros Oriental	Cubelo and Cubelo (2021a)
	Cypermethrin	*'Pinakbet'* vegetables	Lal-lo, Cagayan	Sawadan (2022)
	Cypermethrin	Eggplant	Sta. Maria, Pangasinan	Prado-Lu and Leilanie (2015)
Pyrethroids + Neonicotinoids	Lambda- cyhalothrin + Thiamethoxam	Mango	Negros Oriental	Cubelo and Cubelo (2021a)
Strobilium	Azoxystrobin	Mango	Negros Oriental	
Thiadiazin	Bufrofezin	Mango	Negros Oriental	
Thiocarbamates	Cartap Hydrochloride	Mango	Negros Oriental	
	Rimsulfron	*'Pinakbet'* vegetables	Lal-lo, Cagayan	Sawadan (2022)

'Pinakbet' is a nutritious and delicious Filipino dish made of eggplant, okra, bitter gourd, yardlong beans, squash, and little meat served as a main entree or a side to fried fish or grilled meat.

pesticides as often as needed to prevent pest attacks; use of high pesticide concentration during big infestation; cocktailing of pesticides; application of pesticides too close to the crop; ignoring withholding period of pesticide application during bad weathers; and excessive pesticide use when there is high market demand or when an urgent need for income arose.

Pesticide residues on fresh commodities are influenced by the timing of application (Marquez and Bureros, 2022); in mango, this is a problem when applied during the fruiting stage (Cubelo and Cubelo, 2021a). Pesticide residues are also associated with conventional practices and the proximity of farms to the market where fresh produce is sold immediately (Manuben *et al.,* 2022; Marquez and Bureros, 2022; Sawadan, 2022). Alarmingly, pesticide residues were detected in vegetables sold as organically produced, indicating non-compliance to organic standards or mislabeling (Manuben *et al.,* 2022). The pesticide residue problem is mainly due to inadequate knowledge of farmers on proper pesticide management (Calinawan

Table 2. Pesticide residues detected in fruits and vegetables.

Commodity	Pesticide residue	Sampling point	References
Pechay	BPMC, Carbofuran, Methomyl	Retail (Public Market, Lal-lo, Cagayan)	Sawadan (2022)
	Organophosphate, Carbamate	Farm (Tanauan City, Batangas)	Nuevo *et al* (2019)
Pechay (Organically-labeled)	Residue detected Organophosphates (Profenofos) Organophosphates (Chlorpyrifos)	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
Bitter gourd	Carbufuran, BPMC		Sawadan (2022)
	Residue detected	On-farm	
	Pyrethroids (Lambdacyhalothrin)	On-farm (Negros Oriental)	Cubelo and Cubelo (2021b)
	Organophosphates (Endosulfans)	On-farm (Negros Oriental)	
	Residue detected	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
	Organophosphate, Carbamate	Farm (Tanauan City, Batangas)	Nuevo *et al* (2019)
Tomato	BPMC, Carbofuran, Methomyl, OP	Retail (Public Market, Lal-lo, Cagayan)	Sawadan (2022)
	Residue detected	On-farm	
	Residue detected	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
Eggplant	BPMC, Carbofuran, Methomyl, OP	Retail (Public Market, Lal-lo, Cagayan)	Sawadan (2022)
	Residue detected	On-farm	
	Organophosphates (Profenofos)	On-farm (Negros Oriental)	Cubelo and Cubelo (2021b)
	Chlorpyrifos, Cypermethrin	Farm samples and harvest samples	Prado-Lu and Leilanie (2015)
	Residue detected	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
Eggplant (with organic-label)	Pyrethroids (Lambdacyhalothrin) Pyrethroids (Cypermethrin)		
Okra	BPMC, Carbofuran, Methomyl, OP	Retail (Public Market, Lal-lo, Cagayan)	Sawadan (2022)
	Residue detected	On-farm	
Chili	BPMC, Methomyl, OP	Retail (Public Market, Lal-lo, Cagayan)	Sawadan (2022)
	Residue detected	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
Yardlong bean	Residue detected	On-farm	Sawadan (2022)
Yardlong bean (with organic-label)	Residue detected Pyrethroids (Cypermethrin)	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
Cabbage	Organophosphates (Chlorpyrifos) Organophosphates (Profenofos) Pyrethroids (Cypermethrin)	On-farm (Negros Oriental)	Cubelo and Cubelo (2021b)
	Residue detected	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
	Pyrethroids (Cypermethrin)	On-farm (Dalaguete, Cebu)	Marquez and Bureros (2022)
	Pyrethroids (deltamethrin) Pyrethroids (lambda-cyhalothrin)	On-farm Manlapay, Mantalongon, Dalaguete, Cebu	Calinawan *et al* (2015)
	Organophosphate (Dichlorvos, Mevinphos, Ethoprophos, Naled, Phorate, Disulfoton, Methyl parathion, Fenchlorphos, Chlorpyrifos, Trichloronate, Merphos, Fensulfoton, Bolstar (sulprofos, Azinphos methyl, Coumaphos, Demeton)	On-farm, Mt. Data, Bauko, Mt. Province and Loo, Buguias, Benguet	Reyes *et al* (2017)

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Table 2 (Cont.). Pesticide residues detected in fruits and vegetables.

Commodity	Pesticide residue	Sampling point	References
Potato	Organophosphate (Dichlorvos, Ethoprophos, Naled, Phorate, Disulfoton, Fenchlorphos, Trichloronate, Merphos, Bolstar (sulprofos, Azinphos methyl, Demeton, Stirofos)	On-farm, Mt. Data, Bauko, Mt. Province and Loo, Buguias, Benguet	Reyes *et al* (2017)
Sweet pea	Organophosphate (Dichlorvos, Mevinphos, Ethoprophos, Naled, Phorate, Disulfoton, Methyl parathion, Fenchlorphos, Trichloronate, Bolstar (sulprofos, Azinphos methyl, Coumaphos, Demeton)	On-farm, Mt. Data, Bauko, Mt. Province and Loo, Buguias, Benguet	
Chinese pechay	Organophosphates (Profenofos)	On-farm (Negros Oriental)	Cubelo and Cubelo (2021b)
	Organophosphates (Chlorpyrifos)		
	Organophosphates and Pyrethroids (Profenofos and Cypermethrin) (Chlorpyrifos and Cypermethrin)		
	Residue detected	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
Cauliflower	Pyrethroids (Cypermethrin)	On-farm (Negros Oriental)	Cubelo and Cubelo (2021b)
Brocolli	Organophosphates (Profenofos)		
Lettuce	Organophosphates (Chlorpyrifos, Diazinon)	Supermarket (Laguna/ Metro Manila)	Nuevo *et al* (2015)
	Residue detected	Town markets, trading posts, supermarkets, and outlet stalls in Laguna, Quezon, and Metro Manila	Manuben *et al* (2022)
Cucumber	Residue detected		
Snap beans	Residue detected		
Celery	Residue detected		
	Organophosphates (Chlorpyrifos), T-Endosulfan	Benguet	Lu (2011)
	Organophosphates (Chlorpyrifos, Profenofos)	Supermarket (Laguna/Metro Manila)	Nuevo *et a*l (2019)
Commercial fresh green salad	Organophosphates (Chlorpyrifos, Profenofos)	Supermarket (Laguna/ Metro Manila)	
Mango	Organophosphates (Chlorpyrifos)	On-farm (Negros Oriental)	Cubelo and Cubelo (2021a)

et al., 2017; Lu, 2022).

The Philippine Bureau of Plant Industry's Plant Production Safety Services Division (BPI-PPSSD) conducts monitoring of pesticide residue on priority crops (tomato, bitter gourd, pechay, eggplant, yardlong beans, and sweet pepper) from all regions of the country through their 5 laboratories to enhance food safety awareness in different regions and check the compliance of the farmers and the commodities sold in public markets (BPI-PPSSD, 2023). Commodities greatly affected by pesticide residues are tomato, pechay, and sweet pepper (Table 3), indicating continuous and heavy use of pesticides.

2.1.2 Prevalence in soil and water

Soil and water in fruit and vegetable growing areas have been found to be contaminated with pesticide residues aside from fertilizers, heavy metals, and human pathogens (Table 4) (Gugino *et al.*, 2009). These pollutants have ways of entering the ecosystem, posing environmental and human health risks. Soil and water contaminations result from farming activities in the pursuit of greater yield with no pest damage, including excessive fertilizer and pesticide application, use of organic fertilizers (manure and sewage sludge), decaying vegetables left in the area or thrown in bodies of water, diverted human waste of those residing near water sources, use of wastewater for irrigation, plastic materials used in farm operations, and rural wastes (Ngidlo, 2013; Garcia *et al.,* 2015; FAO and UNEP, 2021).

The presence of pesticide residues in bodies of water is influenced by the timing of pesticide application and the proximity of the farm to a body of water (Varca, 2012). One example is the Pampanga River, where surface water and groundwater samples along the area showed the presence of phosphates (beyond regulatory levels), nitrates (below regulatory levels), and active ingredients and degradation products of organochlorines

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Table 3. Summary of pesticide residue incidence on priority vegetables from 2015 to 2019 Philippine (BPI-PPSSD, 2015-2019).

	Pesticide Analytes	Tomato	Bitter gourd	Pechay	Eggplant	Yardlong bean	Sweet pepper	Total Incidence
Organophosphates:								
1	Mevinphos	+	○	○	○	+	○	4
2	Isazophos	○	○	○	○	○	○	0
3	Dimethoate	+	+	+	+	+	+	68
4	Diazinon	+	+	+	+	+	+	22
5	Methyl parathion	○	○	○	○	○	○	0
6	Fenitrothion	+	○	○	○	○	+	4
7	Malathion	○	+	+	+	+	+	8
8	Chlorpyrifos	+	+	+	+	+	+	309
9	Phenthoate	+	+	+	+	+	+	58
10	Profenofos	+	+	+	+	+	+	510
11	Triazophos	○	○	+	○	○	+	2
12	Metamidophos	○	○	○	○	○	+	4
Pyrethroids								
1	lambda-Cyhalothrin	+	+	+	+	+	+	352
2	Permethrin	○	○	+	○	○	○	1
3	Cyfluthrin	+	+	+	+	+	+	123
4	Cypermethrin	+	+	+	+	+	+	786
5	Fenvalerate	+	+	+	○	+	+	29
6	Deltamethrin	+	+	+	+	+	+	40
7	Bifenthrin	+	+	+	○	+	○	4
Azole								
1	Difenoconazole	+	+	+	+	+	+	131
Organochlorines								
1	Lindane	○	○	○	○	+	+	3
2	Aldrin	○	○	○	○	○	○	0
3	Heptachlor	○	○	○	○	○	○	0
4	Heptachlor epoxide	○	○	○	○	○	○	0
5	alpha-Endosulfan	+	+	+	○	○	+	10
6	beta-Endosulfan	○	○	○	○	○	○	0
7	Endosulfan sulfate	○	○	○	○	○	○	0
8	4,4 DDE	○	○	○	○	○	○	0
Oxadiazine								
1	Indoxacarb	+	+	+	+	○	+	9
Phenylpyrazole								
1	Fipronil	○	○	+	○	○	+	2
Carbamate								
1	Methomyl	○		○	○	○	○	2
	Total incidence	476	316	587	161	180	761	2481
	Total sample analyzed	952	926	798	1084	961	752	5473
	Percent incidence (%)	50	34	74	15	19	101	45

○ – not detected; + - detected

(dieldrin, endrin aldehyde, α-BHC, β- BHC, δ-BHC, γ-chlordane, and endosulfan II) (Navarrete *et al.,* 2018). Organochlorine pesticide levels varied with location and water type, but endrin aldehyde, total BHCs, and heptachlor exceeded regulatory limits, indicating heavy and frequent use of phosphate and nitrogen fertilizers and banned organochlorine pesticides.

2.2 Microbial contamination

2.2.1 Prevalence at the farm level

Human pathogens and indicators have been detected in various fruits and vegetables in different parts of the Philippines (Table 5). These pathogenic microorganisms include *Escherichia coli (E. coli), Salmonella spp., somatic coliphage*s, coliforms, protozoa (*Isospora* sp.*; Balantidium coli*), helminths (*Ascaris* sp.*, Hymenolepsis diminuta, Trichuris* sp.*, Strongylid* sp.*,* hookworm,

Table 4. Detected food safety hazards in soil and water samples from various reports.

Sample	Sampling Location	Hazards Detected	References
Soil			
Vegetable growing area	Negros Oriental	Difenoconazole	Cubelo and Cubelo (2021b)
Garden area (upper 15 cm)	Mt. Province, Benguet	Chlorpyrifos, Profenofos, Cyhalothrin, Cypermethrin and Fenvalerate	Ngidlo (2013)
Cabbage producing area	On-site, Manlapay, Mantalongon, Dalaguete, Cebu	Deltamethrin (0.007-0.008 ppm) Lambda-cyhalothrin (<0.001 ppm)	Calinawan *et al.* (2017)
Tomato farms (1 m depth)	On-site, 26 farms, Sta. Maria, Pangasinan	Profenofos and Triazophos (exceeded MRL), Chlorpyrifos, Cypermethrin, Malathion	Prado-Lu and Leilanie (2015)
Agricultural sites	Quezon City; Marikina City	Fecal indicator microorganisms (*E. coli*, Somatic coliphage)	Garcia *et al.* (2015)
Plot area	3 organic farms and 1 conventional farm (Laguna Province) plus one reference farm (certified organic farm	Stronglylid/hookworm larvae, *Trichostrongylus* sp. egg, *Toxocara* sp. Egg, *Trichuris* sp. egg, *Taenia pisiformis* egg, *Balantidium coli* cyst,	Paller *et al.* (2022)
Water			
Streams, rivers, or wells near vegetable growing sites	Negros Oriental	Malathion	Cubelo and Cubelo (2021b)
Creek water, natural spring water inside garden areas	Ifugao, Mt. Province, Benguet	Nitrates	Ngidlo (2013)
River water	Lucban River, Lucban, Quezon	Malathion	Varca (2012)
Creek water	Salasad creek, Pagsajan, Laguna	Profenofos	
Composite surface water and groundwater	Pampanga rive (Cabiao, Candaba A, Candaba B, and San Simon)	Phosphates organochlorines pesticides (active ingredient and degradation products)	Navarrete *et al.* (2018)
Water (water catchment)	On-site, located downhill, 20 m from the farm Manlapay, Mantalongon, Dalaguete, Cebu	Deltamethrin (<0.0005 ppm), Lambda-cyhalothrin (<0.0005 ppm)	Calinawan *et al.* (2017)
Creek water, natural spring water inside garden areas	Ifugao, Mt. Province, Benguet	Coliforms	Ngidlo (2013)
Surface irrigation water	Irrigation source near vegetable farming area (canal, seep, Marikina river)	Fecal indicator microorganisms (*E. coli*, Somatic coliphage, Salmonella spp.)	Garcia *et al.* (2015)
Water (spring water)	3 organic farms and 1 conventional farm (Laguna Province) plus one reference farm (certified organic farm	*Cryptosporidium* sp. *Giardia* sp.	Paller *et al.* (2022)
Water (pumped groundwater)		*Giardia* sp.	

Table 5. Pathogenic microorganisms in fresh fruits and vegetables.

Commodity	Pathogenic microorganisms	Sampling Location	References
Bacteria			
Malabar spinach, taro leaves, jute, water spinach, sweet potato leaves, spinach, yard long beans, lemon grass, bitter gourd leaves, pechay	*E. coli (31.5%), s*omatic coliphages (8.7%), *Salmonella* spp. (1.1%, in jute only)	Urban farms in Metro Manila (Quezon City and Marikina City)	Garcia *et al.* (2015)
Broccoli, cabbage	Coliforms, *E. coli*	La Trinidad Market, Benguet	Espigol *et al.* (2018)
Cabbage (organic)	*E. coli*	La Trinidad farm, Benguet	
Red cabbage	*E. coli*	Supermarket (Majayjay, Laguna)	
Celery	Coliforms, *E. coli, Salmonella* spp.	La Trinidad Market, Benguet	
Strawberry	Coliforms, *E. coli, Salmonella* spp.		
Strawberry (organic)	*Salmonella* spp.	Farm (La Trinidad, Benguet)	
Green Ice lettuce	Coliforms, *E. coli*	La Trinidad Market, Benguet	

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Table 5 (Cont.). Pathogenic microorganisms in fresh fruits and vegetables.

Commodity	Pathogenic microorganisms	Sampling Location	References
Bacteria			
Green Ice lettuce (organic)	*E. coli, Salmonella* spp.	Specialty store (Silang, Cavite); supermarket (Tanauan, Batangas)	Espigol *et al.* (2018)
	Salmonella spp.	Supermarket (Majayjay, Laguna)	
Iceberg lettuce	*Salmonella* spp.		
Red Sails Lettuce	*Salmonella* spp.		
Romaine lettuce	Coliforms, *E. coli*	La Trinidad Market, Benguet	
Romaine lettuce (organic)	*Salmonella* spp.	Retail market (La Trinidad, Benguet); super-markets (Tanauan, Batangas; Majayjay, Laguna)	
Bitter gourd	*Salmonella* spp.	Farm, Liliw, Laguna	Nuevo *et al.* (2019)
	E. coli	Retail market, Tanauan, Batangas	
Bell pepper, tomato, carrot	*E. coli* isolates, *Salmonella* spp., Coliphage	Wet markets and supermarkets in Metro Manila, North Luzon (Baguio City), South Luzon (Laguna), Central Luzon (Pampanga)	Vital *et al.* (2017)
Lettuce	*E. coli* isolates, *Salmonella* spp.,		
Mungbean sprouts	*E. coli* isolates, Coliphage		
Mungbean sprouts	*Salmonella* spp. *E. coli* *Coliforms*	Public markets of Metro Manila cities (Quezon, Taguig, Makati, Manila, Muntinlupa, Las Pinas, Valenzuela,	Gabriel *et al.* (2007)
	E. coli	Local supermarket, Laguna	Nuevo *et al.* (2019)
Strawberry, guava, and fresh-cut pineapple, melon, watermelon, papaya, mango,	Thermotolerant *E. coli*	Open-air and supermarkets in Metro Manila	Mathay *et al.* (2018)
Fresh-cut pineapple and watermelon	*Salmonella* spp.	Supermarket and wet market, Imus, Cavite	Piano and Castillo-Israel (2019)
Parasite			
Chinese cabbage, Cabbage, lettuce	protozoa (*Isospora* sp.) and helminths (*Ascaris* sp., *Hymenolepsis diminuta*, *Trichuris* sp., *Strongylid* sp. egg, *Taenia* sp., Hookworm/stronglids/free -living larvae)	selected wet market, San Jose City, Nueva Ecija	Vizon *et al.* (2019)
Pechay Lettuce	*Ascarid and Ascaris* (roundworm) egg; *T. trichiura* (whipworm) egg, G. *lamblia* cyst, *Trichostrongylus* sp. egg, *E. vermicularis* (pinworm) egg, *E. histolytica* trophozoite, unknown specimen, *E. coli* cyst	Selected public markets and supermarkets in Quezon City and Muntinlupa City, Metro Manila	Su *et al.* (2012)
Romaine, Iceberg and Red Ruby lettuce; cucumber	Strongylid/hookworm egg/larvae, *Ascarid* sp., *Toxocara* sp. eggs, protozoan *Balantidium coli* cysts	3 organic farms and 1 conventional farm (Laguna Province) plus one reference farm (certified organic farm outside the study area)	Paller *et al.* (2022)
Camote tops, lettuce, parsley, pechay, taro leaves, luffa, okra, strawberry, yardlong bean, carrot	*Ancylostoma ceylanicum*, *Toxocara* sp., *Trichuris trichiura*, *Ascaris suum*, *Hymenolepis* sp., unknown trematode, *Isospora*, *Balantidium*, *Giardia intestinalis* and *Cryptosporidium* (parasites)	Organic and conventional farms in two provinces in Northern and Southern Luzon	Ordoñez *et al.* (2018)

Taenia sp.), and other parasites (e.g., *Trichuris trichiura* or whipworm, *G. lamblia, Trichostrongylus* sp*., E. vermicularis* or pinworm, *E. histolytica trophozoite, Toxocara* sp*., Ancylostoma ceylanicum, Giardia intestinalis,* and *Cryptosporidium*). In a more recent study, parasites were detected on fresh commodities (Romaine, Iceberg and Red Ruby lettuce, cucumber, and tomato), soil, and water samples from 4 selected farms in Laguna province (Paller *et al.,* 2022). Parasites found were *Ascaris*, strongylids, hookworms, *Toxocara*, *Trichuris* sp., *Balantidium*, *Cryptosporidium,* and *Giardia*. Higher parasite contamination in certain lettuce varieties was due to their broad and large surface area, proximity to the ground, and uneven surface, which increased contact with contaminated soil and water.

Parasites, such as *Ancylostoma ceylanicum*, *Toxocara* sp., *Trichuris trichiura*, *Ascaris suum*, *Hymenolepis* sp., unknown trematode egg, *Isospora*, *Balantidium*, *Giardia intestinalis, Cryptosporidium*, were found on fresh vegetable samples from organic and conventional farms in two provinces of Northern and Southern Luzon (Ordoñez *et al.*, 2018). A total of 252 vegetables (broccoli, cabbage, camote tops, kangkong, lettuce, singkang, onion leaves, parsley, pechay, spinach, taro leaves, eggplant, luffa, okra, squash, strawberries, yardlong beans, tomato, and carrot) were sampled, and 58 were detected with parasites. The highest contamination rate was in Deep Red lettuce attributed to its rough, highly textured surfaces with deep crevices and proximity to the soil during production. The presence of parasites was attributed to surrounding livestock farms, the use of manure, the presence of stray dogs and cats, watering crops with contaminated water, and the presence of rats.

Soil, water, and vegetable samples in urban farms (city agricultural sites) were contaminated with *E. coli* and coliphage at varying extents but very low prevalence of *Salmonella* spp. (Garcia *et al.,* 2015). Vegetables included Malabar spinach, taro leaves, jute, water spinach, sweet potato leaves, spinach, yardlong beans, lemon grass, bitter gourd leaves, and pechay. Field conditions contributed to the presence of fecal bacteria in water, soil, and vegetable samples and are not solely due to processing and packaging conditions. In addition, highly polluted surface water is contaminated with antibiotic-resistant and multi-drug-resistant *E. coli* that may cause gastrointestinal infections (Vital *et al.,* 2018).

2.2.2 Prevalence in markets

Green leafy vegetables (Chinese cabbage, cabbage, and lettuce) from selected wet markets of San Jose, City, Nueva Ecija (Luzon) were reported to be positive for foodborne parasites (Vizon *et al.,* 2019). These parasites include protozoa (*Isospora* sp.) and helminths (*Ascaris* sp., *Hymenolepsis diminuta*, *Trichuris* sp., *Strongylid* sp., Hookworm, *Taenia* sp.). Another study showed parasitic infestation in pechay and lettuce in public wet markets (open-air markets) and private markets (supermarkets) of Metro Manila (Munoz, Quezon City, and Alabang, Muntinlupa City) (Su *et al.,* 2012).

The microbiological assessment of vegetables (bell pepper, carrot, lettuce, mungbean sprout, and tomato) commonly eaten raw or minimally processed from open-air markets and supermarkets in Luzon showed the presence of *E. coli*, *Salmonella* spp., and coliphage (Vital *et al.,* 2017). The highest load of *E. coli* was in mungbean sprouts, *Salmonella* spp. in tomatoes, and coliphage in bell peppers. Contamination was highest in Baguio City for *E. coli* and Manila-Divisoria wholesale market for *Salmonella* spp. Contaminations were attributed to the use of contaminated water during the sprouting of mungbean, pathogen internalization in tomatoes, and the use of contaminated water for bell peppers. On the other hand, the higher contamination in open-air markets was attributed to unhygienic handling and poor storage and transportation. An earlier study on mungbean sprouts sold in public markets of Metro Manila showed that microbiological quality is poor due to the presence of *Salmonella* spp. in 94% of samples and high counts of coliform and *E. coli* in some samples (Gabriel *et al.*, 2007).

Bacteriological screening of fresh and fresh-cut fruits (whole apples, grapes, strawberries, cherry and guava, and fresh-cut pineapple, watermelon, melon, papaya, jackfruit, mango, and pomelo) sold in open-air markets and supermarkets, showed contamination with thermotolerant *E. coli* depending on the commodity (Mathay *et al.,* 2018). *Escherichia coli* contamination was highest in fresh-cut jackfruit and was absent in apples, grapes, and cherries. Fresh-cut fruits have higher contamination, implying contamination occurred during preparation in addition to the unhygienic practices and location in some open-air markets near the meat, poultry, and fish stalls. However, the difference in contamination levels in whole and fresh-cut fruits and their source, whether open-air markets or supermarkets, was not established, indicating that the higher price paid in supermarkets does not guarantee the safety of produce. *Salmonella* spp. was not detected but could not be ruled out due to limitations in the detection procedure.

The microbiological quality of fresh-cut pineapple and watermelon from supermarkets and wet markets in Imus, Cavite, was shown to be unsafe due to a high coliform count that exceeded the maximum tolerance level and for being positive for *Salmonella* spp. (Piano and Castillo-Israel, 2019). This result indicates the unsanitary preparation of fresh-cut produce and poor temperature control. In a study on fresh-cut vegetable mixes, *E. coli* was present in samples from 2 wet markets and 2 supermarkets in Los Banos, Laguna (Sotiangco *et al.,* 2016). Though most *E. coli* contaminants are harmless, it indicates poor sanitation of personnel, buildings, equipment, and produce and the absence of refrigeration facilities in wet markets.

2.3 Food safety hazards and market access

The price of food safety failures is high, including productivity losses, healthcare costs, and foregone markets. In export markets, the presence of foodborne hazards can mean rejection of consignments and loss of confidence among trading partners, which may lead to higher regulatory burdens and/or loss of market access under the terms of the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary (SPS) measures. Countries that strictly enforce standards and routine monitoring could disallow entry of Philippine products. A total of 257 fruit and vegetable and related products from the Philippines were recorded in the US FDA Import Refusal Data File of 2014-2022 (Table 6) (US FDA, 2014). As for Japan, the Philippines has reported violations and is subject to enhanced monitoring of specific agricultural commodities and chemicals (Table 7).

3. Food safety issues in supply chains

Fruits and vegetables are potentially exposed to food safety hazards from production to consumption. Reducing the risks of unsafe food should therefore involve preventing contamination throughout the food supply chain. The following supply chain studies of PHTRC illustrate the importance of the supply chain or value chain approach to food safety risk management. These studies were conducted in different parts of the country, as marked in Figure 1.

3.1 Bitter gourd supply chains

Three supply chains of bitter gourd were examined; (1) Laguna (Liliw town) farm to Batangas market (Tanauan City) 50 km or 2.5 hours apart; (2) Batangas (Tanauan City) farm to Manila markets 70 km or 3 hours apart; and (3) Pangasinan (Alcala town) farm to Metro Manila markets 200 km or 6 hours apart (Nuevo *et al.*, 2019). Supply chain practices are summarized in Table 8. Overall, poor sanitation and faulty handling practices are major food safety issues.

3.2 Chili supply chain

Six chili supply chains were examined: one from South Cotabato province in Mindanao (Southern Philippines) and 5 from Luzon (2 in Batangas province and one each in Laguna, Quezon, and Benguet provinces) (Esguerra and Absulio, 2016). Constraints and issues in chili production are non-compliance to Good Agricultural Practices (GAP), lack of knowledge on the specific chili variety planted, fluctuating market prices, and marketing. Chili growers can sell their produce both to local and exporting companies without any certifications and analysis for the presence of contaminants. Further dissection of each supply chain stage from production to transport and marketing revealed more issues that are often neglected:

Production stage – no mulching that may cause contamination from splattering soils during rainy days, in addition to weed problem that necessitates the use of herbicides that may leave harmful residues; improper use of farm manure; use of irrigation water of unknown quality due to lack of water testing; improper timing and overuse of pesticides due to lack of records

Harvesting - wide range of maturity from green to red; use of unsanitized plastic buckets and sacks as harvesting and collection containers; harvesters without proper outfit and hygiene

Packinghouse – sorting, cleaning, and washing not practiced; polyethylene bag for packaging has no adequate protection against damage; recycled carton box can be a source of contamination.

Storage – pallets not used, resulting in direct contact with the ground; overstacking

Transport – bulk transport with other commodities resulting in high incidence of product damage providing avenues for pathogen infection; unsanitary vehicle; lack of cold transport

Market handling – rough handling and lack of storage in trading/wholesale centers; buyers can freely select open-displayed chilies with bare hands; unsold chilies are stored unpacked, exposing them to market pests such as rats, flies, and cockroaches.

3.3 Pechay (Brassica rapa subsp. chinensis) supply chain

The pechay supply chain from farms in Batangas province (Tanauan City) to the market involves harvesting after 30 days from transplanting, carried out only once traders have placed orders (Nuevo *et al.,* 2019). Whole pechay crowns are cut at the base using a cutter, then the crowns are placed on the ground for packing in 10 kg-capacity PE bags left on the field until all harvested crowns are packed, providing opportunities

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Table 6. Fruits and vegetables and their related products with import refusals to the USA [US-FDA, 2014].

Commodity class	Product type
Bananas (Subtropical and tropical fruit)	Mixed vegetable soup, dried
Beans, corn, and pea, N.E.C. (vegetable)	Mixed vegetable, N.E.C.
Black beans	Moringa oleifera (herbal and botanical, not teas)
Breadfruit (Subtropical and tropical fruit)	Mung bean
Cassava (Root and tuber vegetables)	Mung bean, dried or paste
Chocolate and chocolate-covered candy, with nuts or nut products, N.E.C. (not coconut)	Other fruit and fruit products, jam, jelly, preserves, marmalades, butter or candied, N.E.C.
Coconut milk beverage base	Other fruit. Purees, N.E.C.
Coconut pudding (pie filling) mix (not custard)	Other fruits, mixed
Coconut, shelled	Palm nut (Palm fruit, sugar palm) (Subtropical and tropical fruit)
Coconut (Subtropical and tropical fruit)	Palm nut (Palm fruit, sugar palm), jam, jelly, preserves, marmalades, butter or candied
Coconut (Subtropical and tropical fruit) jams, jellies, preserves, marmalades, candied, butters, spreads	Palm nut (Palm fruit, sugar palm), topping or syrup
Coconut (Subtropical and tropical fruit), juices, milk, crème, drinks and nectars	Pea, dried or paste
Coconut (Subtropical and tropical fruit) toppings or syrups	Peanut, butter
Coffee, ground	Peanut, shelled
Cucumber (Fruit used as vegetable)	Peas, bean and pea sprout
Fruit cocktail, mixed fruits	Pepper, black, ground, cracked (spice)
Fruit juice	Pepper, black, whole (spice)
Fruits used as vegetables, breaded, N.E.C.	Pumpkin seed (edible seed)
Fruits used as vegetables, N.E.C.	Root and tuber vegetable, dried or paste, N.E.C.
Garbanzo beans	Soursop (Other fruit purees)
Halo halo (mix fruit and vegetable dessert, multiple food specialties, side dishes and desserts)	Soursop, dried or paste
Herbal coffer (Blend of herbs, grains, fruits and nuts)	Soursop, juice, other fruit juices or concentrates
Herbals and botanicals (not teas), N.E.C.	Squash, summer (Fruit used as vegetable)
Jackfruit (Subtropical and tropical fruit)	Subtropical and tropical fruit, jam, jelly, preserves, marmalades, butter or candied, N.E.C.
Jackfruit, dried or paste	Subtropical and tropical fruit, juice, milk, creme, drink or nectar, N.E.C.
Jackfruit, topping or syrup	Sweet potato (root and tuber vegetable)
Jute leaf (Leaf and stem vegetable)	Sweet potato, dried or paste
Leaf and stem vegetable, dried or past, N.E.C.	Tamarind (Subtropical and tropical puree)
Leaf and stem vegetable, N.E.C.	Tamarind (Subtropical and tropical fruit)
Macapuno (Coconut sport), shelled	Tamarind, dried or paste
Macapuno (Coconut sport), spread	Tamarind, juice, milk, creme, drink or nectar, sub/tropical fruit
Macapuno (Coconut sport), topping	Taro leaves (Leaf and stem vegetables)
Mango, juice, milk, creme, drink or nectar, sub/tropical fruit	Taro, dasheen (Root and tuber vegetable)
Mixed fruit, dried or paste, N.E.C.	Yams (Root and tuber vegetable)
Mixed spices and seasoning with salt, N.E.C.	Yams, dried or paste (Root and tuber vegetable)
Mixed spices and seasonings, liquid with salt, N.E.C.	

for contamination, especially from the soil, which is a rich source of spoilage and human pathogens. No cleaning or washing is practiced. Traders usually pick up the bags of produce from the farm, which are manually hauled and loaded to the trader's vehicle. Traders come from the local trading post (Tanauan), Sariaya Trading Post (Quezon Province), and Divisoria wholesale market (Metro Manila). Transport to local trading post is by tricycle and by jeepney or truck to Quezon and Metro Manila. At the markets, the bags of produce are manually handled and displayed without any cold system. Leaf crushing is common as the plastic bags do not provide adequate protection. Delays in transport and marketing result in water condensation inside the bag, which favors rotting and may promote the growth of pathogenic bacteria.

3.4 Mungbean sprout supply chain

Commercial mungbean sprouts are of two types - long and short sprouts classified visually without a standard basis (Nuevo *et al*., 2019). Short sprouts are popular in some provinces (Cavite and Batangas), while long sprouts are in other parts of the country. A short mungbean sprout producer in Cavite sprouted yellow

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Table 7. Fruits and vegetables for enhanced monitoring of specific agricultural chemicals in Japan (MHWL, 2015-2021).

Product/Commodity	Remarks	Fruit and Vegetable Safety Issue	Year [Reference]
Okra	Subject to enhanced monitoring inspections	Profenofos	FY 2021 (MHWL, 2021a) FY 2020 (MHWL, 2021b)
Banana		Deltamethrin and tralomethrin	FY 2021 (MHWL, 2021a)
		Fipronil	Apr-Sep 2018 (MHLW, 2018a)
		Imidacloprid	FY 2017 (MHLW, 2018b)
		Imidacloprid, Cypermethrin	FY 2016 (MHWL, 2017)
		Bifenthrin	FY 2015 (MHWL, 2016)
Papaya		Deltamethrin and tralomethrin	FY 2021 (MHWL, 2021a) FY 2020 (MHWL, 2021b)
		Cypermethrin	FY 2016 (MHWL, 2017) FY 2015 (MHWL, 2016)
Mango		Azoxystrobin	FY 2016 (MHWL, 2017) FY 2015 (MHWL, 2016)
Okra, Banana, Mango	Subject to Ordered Inspections and Inspection Results	Chlorpyrifos, Cypermethrin, Tebufenozide, Fipronil, Phenthoate, Fluazifop-butyl, Methamidophos	FY 2021 (MHWL, 2021a) 336 inspections 0 violations
			FY 2020 (MHWL, 2021b) 1288 inspections 1 violation
			Apr-Sep 2019 (MHWL, 2019a) 3606 inspections 3 violations
			FY 2019 (MHWL, 2020) 5685 inspections 4 violations
		Chlorpyrifos, Cypermethrin, Tebufenozide, Fipronil, Phenthoate etc.,	FY 2018 (MHWL, 2019b) 2502 inspections 4 violations

Table 8. Practices and potential food safety problems (italics) of three supply chains of bitter gourd (Nuevo *et al*., 2019).

Supply chain stage	(1) Laguna farm to Batangas market	(2) Batangas farm to Manila market	(3) Pangasinan farm to Manila market
Harvesting and field handling	• Early morning harvest • *Used unclean scissors/clippers* • *Fruits placed on the ground* • *Collected in sacks to shade area* • Sorting out unmarketable fruits on tarpaulin-covered ground • *Placed in unclean metal baskets with rubberized liner* • *Hauled on horseback (2 baskets each) to packhouse 2 km away along the road*	• Early morning harvest • *Used unclean scissors* • Placed in woven basket • Hauled to the makeshift packing shed	• Start at 45 days after planting, lasting 2-3 months? at 3-4days interval • *Used unclean scissors* • *Placed in unclean plastic crates without liner* • Hauled to farmers' house
Packing for market (packing shed or packhouse)	• Unloaded on lined flooring • Quality sorting (good-no or minimal damage; semi-good-minimal damage, smaller size; reject-deformed with damage) • Packing in 10 kg-cap PE bags • *Stacking before transport*	• *Sorting on the bamboo table (bluish fruit surface indicates pesticide residues)* • Packing in 10 kg- cap PE bags • *Bags stacked on bare ground to wait for transport*	• *Sorting based on size and quality on top of bamboo table* • Packing in 10-kg cap PE bags
Transport to market	• Market destinations (trading posts in Batangas-most produce; Quezon province-Sariaya) • *Bags picked up by traders; loaded to jeepneys stacked in layers inside and roof with tarp cover mixed with other vegetables*	• Loaded on jeepney • Transport to the trading post • Transfer to cart for loading to truck for Manila market	• Loading bags on a tricycle for Urdaneta (Pangasinan) trading post 20 km away • Bags of bitter gourd mixed with other vegetables in truck for Manila (Pasig market) • Unloading in market

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Table 8 (Cont.). Practices and potential food safety problems (italics) of three supply chains of bitter gourd (Nuevo *et al*., 2019).

Supply chain stage	(1) Laguna farm to Batangas market	(2) Batangas farm to Manila market	(3) Pangasinan farm to Manila market
Market handling	• Selling to wholesalers from Manila and local retailers	• Selling to retailers	• Manual handling within the market • *Drop on the market floor for stacking for selling to retailers* • *Market unsanitary; rats and cats roaming around*

mungbean seeds in large specialized drums with alternate soaking in clean water and draining at 12 hour-interval for 3 days. After 3 days, the sprouts are washed to remove the seed coats, then set aside for another 14 hours to drain excess water. Afterwards, sprouts are packed in 500 g-plastic bags and delivered to the market at dawn either in a tricycle or jeepney. The sprouts are usually distributed to retail markets within the town and adjacent province of Laguna (Calamba City). Retailers repacked the sprouts in smaller plastic packs. For long mungbean sprouts, growers in Batangas and Laguna provinces used the same sprout production technique and trading, except that the seeds are continuously irrigated for 24 hours after initial soaking, followed by removing excess water for 5 hours on clean jute sacks. Possible sources of microbial contamination include handling sprouts with bare hands; roaming animals around the preparation area; use of unsanitized materials though drums and jute bags are regularly cleaned after every operation; putting sprouts on unsanitized surfaces prior to packing; and exposure to high temperatures during transport and retail. Practical solutions are available to address microbial contamination on sprouts (FAO/WHO, 2023).

3.5 Organic fruit and vegetable supply chains

Supply chains of organic fruits and vegetables are generally simple and short, with minimal participation of middlemen (Del Carmen *et al*., 2016). This is the case for small-scale systems where growers, individually or as a group, are directly engaged in marketing through speciality organic or weekend markets. Although large-scale growers also practice direct marketing, where consumers or visitors buy vegetables directly from their farms, they market the bulk of their produce to institutional buyer-retailers like supermarkets, groceries, and speciality stores like Healthy Options shops. Some remaining produce is sold to organic markets within the area of production or in weekend markets in Metro Manila through the farmers' group representatives. Food safety hazards may arise during production due to improper preparation and application of organic fertilizers, use of contaminated irrigation water, and poor farm sanitation. During the postharvest stage, proper harvesting, packhouse operations, and packaging are observed, but there are opportunities for contamination due to inadequate sanitation and unhygienic practices, open display during marketing, and lack of cold chain.

In the organic lettuce supply chain, a handling trial was conducted to ascertain the specific points in the chain where contamination occurred (Del Carmen *et al*., 2016; Espigol *et al.,* 2018). Tests for the detection of coliforms and *E. coli* were performed on samples taken throughout the chain from surfaces of equipment and materials that come in contact with the organic produce from a farm in Laguna province. Four critical control points where contamination occurred were identified – sorting/trimming; washing; air-drying; and market display. Recommendations to address the contamination problem include: (1) water to be used in postharvest must be regularly tested to ensure the safety of washed vegetables, (2) all the tools, equipment, crates, and facilities used at different points in the handling chain must be cleaned/washed using sanitizers, and (3) handlers in the farm, market, and packinghouse must wash their hands to avoid contamination of the fresh produce. Microbial contamination can be prevented by following applicable guidelines in the Code of Practice for Organic Produce (PNS/BAFPS, 2013), the Sanitation and Standard Operating Procedures (SSOP), and Good Manufacturing Practices (GMP).

4. Synthesis of food safety gaps and the way forward

4.1 Baseline data

Substantial but sporadic evidence points to the prevalence of pesticide residues and microbial contamination in fresh fruits and vegetables. More efforts are needed to establish a comprehensive baseline of the extent and magnitude of the problem. These analytical data should be brought out to increase food safety awareness and to inform and influence policy and investment actions.

4.2 Risk management

Pesticide residues require risk management steps throughout production to ensure prescribed Maximum Residue Limits (MRLs) are not exceeded while microbial contamination requires risk management in the length of supply chains to eliminate contamination and prevent re-contamination. These are components of risk-based approaches, such as Hazard Analysis and Critical Control Points (HACCP), and related process-focused approaches like GAP, GMP, and Good Hygienic Practices (GHP).

GAP, GMP, GHP, and HACCP certification systems are already available but rarely adopted in fruit and vegetable ventures. Similarly, an organic system, which is supposed to deliver safer produce than a conventional system, at least in terms of freedom from pesticide residues, is also adopted by very few enterprising farmers. Mechanisms for their widespread adoption should be developed and strongly pursued, including a government-supported rapid certification system and incentive mechanisms such as affordable premium prices for food safety-assured produce that should be a national policy. On the other hand, those adopting the above food safety management systems are not diligently following recommendations, such as the report on organic produce with pesticide residues. Stricter enforcement and monitoring are essential, and adherence of producers to standards could be incentivized.

Smallholders, who dominate the fruit and vegetable industry, lack the capacity to employ risk-based approaches due to the cost involved, limited scale economy, and limited access to certification bodies. Adoption of improved risk-based approaches can upgrade food safety systems and increase market access. Effective implementation increases transparency and accountability of food safety measures, which in turn can increase trust between customers, suppliers, and regulators. Thus, the capacity of all supply chain stakeholders in food safety risk management must be strengthened and supported.

4.3 Traceability

Food safety management systems require a reliable tracking and tracing system, particularly to address food safety breakdowns. For this purpose, a national traceability system could be developed through the Department of Information and Communications Technology, which could also lead to the development of appropriate digital technologies in food safety management. This can be patterned after the national traceability system developed in Vietnam and Thailand. These initiatives could contribute to increased adoption and appropriate implementation of food safety management systems.

4.3.1 Capacity development

The supply chain cases presented earlier illustrate the needy state of farmers, handlers, and marketers for knowledge of even simple procedures in order to prevent food safety problems, such as avoiding direct contact with soil, ensuring maintenance of water quality and simple washing with safe sanitizers (e.g., baking soda or calcinated calcium from scallop shells). They also lack storage infrastructure that could be used to hold harvested produce before transport to markets. There are simple cold storage technologies that can be integrated into fresh fruit and vegetable chains, such as the Coolbot cold storage system. Thus, the lack of knowledge of food safety-enhancing technologies and best practices in supply chains should be addressed with cohesive and robust actions.

Safe food culture has yet to emerge in the country. One of the best ways to prepare people to embrace the culture is education. This could start with a very strong and sustained food safety awareness campaign, together with thorough utilization of the underutilized food safety infrastructure that includes strong policies, capacities, and testing laboratories.

4.4 Enabling ecosystem

Food safety has a strong mandate through the Food Safety Act of 2013 or Republic Act (RA) 10611 - *'An Act to Strengthen the Food Safety Regulatory System in the Country to Protect Consumer Health and Facilitate Market Access of Local Foods and Food Products and for Other Purposes'* (Food Safety Act of 2013, PH). More recently, food safety has been identified as one of the Department of Agriculture's (DA) key strategies to ensure food security in the One DA approach. DA Memorandum Order No. 11 Series of 2021 directs *'all food safety regulatory agencies (FSRAs) and other agencies involved in food safety should establish their respective food safety units with the corresponding food safety budget items beginning fiscal year 2022'*. FSRAs will oversee, plan, and implement food safety programs and activities as mandated under the Food Safety Act. Food safety initiatives of the current government include restructuring the country's food safety policies and regulations; developing world-class food safety standards with the help of institutions such as FAO and WHO; and encouraging closer coordination between local government units, national government agencies, and the scientific community to boost food safety research, education, and surveillance efforts. Furthermore, it is crucial to have a stronger focus on the role of local government units (LGUs) in supporting the enabling food safety environment.

Government line departments actively involved in food safety are the DA and the Department of Science and Technology (DOST). Food safety testing laboratories need to be widespread. DA through its component unit, BPI-PPSSD, undertakes responsibilities relevant to the food safety of fresh and minimally processed plant foods. It has an Accreditation and Inspection Section (AIS), a Contaminants Laboratory Section (CLS), and Pesticide Analytical Laboratory Section (PALS), and four Satellite Pesticide Analytical Laboratories (SPALs). AIS has a Food Safety Unit, Risk Analysis Unit, and GAP Unit tasked to ensure compliance with food safety standards and regulations. CLS has a Microbiological Contaminants Unit and a Chemical Contaminants Unit tasked to monitor and provide analytical services for microbiological and chemical contaminants. PALS has a Pesticide Residue Unit and Formulation Analysis Unit, which monitor and provide analytical services concerning pesticide residue for Metro Manila (National Capital Region) and nearby regions (Regions III, IV-A, IV-B, and V). SPALs provide the same services but cover regions not covered by PALS, located in Baguio (North Luzon), Cebu (Visayas), Cagayan de Oro (Mindanao), and Davao (Mindanao). On the other hand, DOST's OneLab is an online platform accessible to the public for all testing services provided by DOST laboratories and other OneLab member laboratories, including DOST's Regional Standards and Testing Laboratories, DOST Research and Development Institutes, and other OneLab members including the Food and Drug Administration, Fertilizer and Pesticide Authority, Department of Health's National Reference Laboratory, and University of the Philippines-Manila's National Institutes of Health. Private and international laboratories are also part of OneLab, such as SGS Philippines, GCH Center for Food Safety and Quality Inc., F.A.S.T. Laboratories, among others. However, testing and surveillance are nothing if results are not used to inform risk assessments, risk management and risk communication. A strong capacity for risk analysis is essential.

Human resources in food safety need to be further developed, mainly from state universities and colleges (SUCs). UPLB could provide leadership in research and human capacity development in food safety. The country has 112 SUCs; 121 local universities and colleges (LUCs), 13 other government schools (OGSs), and 1,729 Private Higher Education Institutions, spread over the 82 provinces, some of which have food safety capacity. In UPLB, the College of Agriculture and Food Science has leading involvement in food safety, including the National Crop Protection Center which developed the Rapid Test Kit (RTK) for pesticide residues; the Institute of Food Science and Technology which provides services on phytochemical and microbiological analyses; and PHTRC which conducts technical assistance, contract research, and training, and has developed several technologies that reduce food losses and ensure food safety of fresh fruit and vegetable value chains.

5. Conclusion

Pesticide residues and pathogenic microorganisms are prevalent food safety hazards on fresh fruits and vegetables. Substantial but sporadic evidence illustrated pesticide residues as a major production challenge while pathogenic microorganisms are problems arising from poor practices along supply chains. Containing these problems requires risk-based food safety management systems which are available but adoption is very limited. Food safety has a strong mandate through the Food Safety Law but this has not been translated into actions that fully mainstream food safety in the food industry. It is crucial to expand and strengthen existing food safety infrastructure, manpower, and collaboration.

Conflict of interest

The authors declare no conflict of interest.

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REVIEW

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