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LEVELS AND SAFETY ASSESSMENT OF PESTICIDE RESIDUES IN SELECTED VEGETABLES AND FRUITS SOLD IN IKORODU, LAGOS, NIGERIA

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ABSTRACT

Pesticides are widely used to boost agricultural output, thus making food consumption a major route of human pesticide exposure. This study was aimed at determining the safety of pesticide residues in vegetables and fruits sold in Ikorodu Markets, Lagos, Nigeria. The vegetables analyzed were lettuce (Lactuca sativa), spinach (Spinacia oleracea), cabbage (Brassica oleracea), cucumber (Cucumis sativus), and onion (Allium cepa), while the fruits were orange (Citrus aurantium), mango (Mangifera indica), and guava (Psidium guajava). Samples of the vegetables and fruits were subjected to mass spectrometry (GC-MS) analysis, and the values obtained were compared with the minimum risk levels (MRLs) recommended by the World Health Organization (WHO). Thereafter, the estimated daily intake (EDI) and health risk index (HRI) of the detected pesticide residues were calculated and compared with the acceptable daily intake. The GC-MS analysis of the vegetables detected chlorepyrifos-ethyl beyond the MRLs in lettuce, spinach, and cucumber; metalaxyl exceeded the MRLs in cabbage; while cyhalothrin, emamectin, acetaprid, carbendazime, and cypermethrin were detected within the MRLs. The analyses of the fruits revealed non-tolerable levels of chlorepyrifos-ethyl in orange; imidacloprid exceeded the MRLs in mango; and carbon disulfide was above the MRLs in guava. The EDI and HRI of the pesticides were within acceptable limits, but the HRI of cyhalothrin in lettuce and carbon disulfide in mango were not. The results suggest that the vegetables and fruits may predispose consumers to health hazards, with spinach and mango posing the greatest risk. Farmers need to comply with safety guidelines on pesticide use.

Keywords: Chlorepyrifos-ethyl, Estimated daily intakes (*EDI*), Mango (*Manglifera indica*), Pesticides, Spinach (*Spinacia oleracea*)

INTRODUCTION

Pesticides are chemical substances or mixtures of substances used to prevent, destroy, or repel plant and animal pests, or mitigate their effects (Sule *et al.*, 2020). Pesticides include: herbicides, insecticides, rodenticides, fungicides, molluscicides, nematicides, avicides, and acaricides, as well as repellents and attractants used in agriculture, public health, and food storage (Maton *et al.*, 2016). Unfortunately, due to their persistence in the environment, toxicity, bioaccumulation, and lipophilicity, pesticides may cause adverse effects on humans (Yao, 2020). The effects can be acute or chronic, depending on the duration of exposure and the toxicity of the pesticide being used (Damalas and Koutroubas, 2016). Pesticides can cause diarrhea, dizziness, rashes, and even blindness as short-term effects. Long-term effects include cancer, effects on reproduction, thyroid disorders, neurological disorders, and disruption of hormones, among other things (Yao, 2020).

Owing to its wide application in agriculture to prevent or reduce loss of quantity and quality of farm produce, food consumption is a major route of human pesticide exposure (Adekunle *et al.,* 2017; Kelle *et al.,* 2020). Exposure to pesticides through food consumption is five times higher than exposure through air or water (European Commission, 2020). Of all the food groups, fruits and vegetables are the most commonly consumed, accounting for about 30% of the total, thus constituting a major entry route for pesticides (WHO, 2017). Moreover, fruit and vegetables are often consumed raw, a habit that increases human exposure to contaminants compared to other food groups of plant origin (European Commission, 2020). Also, farmers and vegetable sellers use pesticides to keep fruits and vegetables fresh after they are picked, which increases the amount of contamination (Ssemugabo *et al*., 2022).

Considering their role as a major entry route for pesticides, there is a need to monitor pesticide levels and safety in fruits and vegetables consumed in every locality. In Nigeria, vegetables such as lettuce (*Lactuca sativa*), spinach (*Spinacia oleracea*), cabbage (*Brassica oleracea*), cucumber (*Cucumis sativus*), and onion (*Allium cepa*) are widely consumed as foods and spices. These vegetables and fruits are sources of dietary fiber linked to a reduced incidence of cardiovascular disease and obesity (Sandoval-Insausti *et al*., 2022; Salisu *et al*., 2022). They are also sources of vitamins and minerals, as well as phytochemicals that function as antioxidants, phytoestrogens, and anti-inflammatory agents, among others (Slavin and Lloyd, 2012; Roumelioti *et al*., 2021). Unfortunately, farmers in Nigeria do not adhere to recommended doses of pesticides used on vegetables and fruits and could be increasing human exposure to the contaminants (Ojo, 2016; Adesuyi *et al*., 2018). Moreover, literature searches show that there is a dearth of documented information on the safety of pesticides in fruits and vegetables often consumed in Nigeria. Such information is important for developing guidelines for pesticide use to prevent or reduce health hazards for consumers. This study is, therefore, aimed to determine the levels and safety of some pesticides in lettuce, spinach, cabbage, cucumber, and onion, as well as in oranges, guavas, and mangoes obtained from selected markets in Ikorodu, Lagos, Nigeria.

MATERIALS AND METHODS

Description of the study area

This study was carried out in Ikorodu, the headquarters of the Ikorodu Local Government Area (LGA) of Lagos State, Nigeria (Figure 1). The city is located between latitude 6° 35' 59.99'' N and longitude 3° 29' 59.99'' E in the north-east of Lagos, along the Lagos Lagoon, and shares a boundary with Ogun State (Latitude.to, 2022). The LGA is the second largest in Lagos State, with a population of over 500,000 people based on the 2006 census of the Federal Republic of Nigeria. However, the town has since then grown exponentially into a highly populated metropolis (NPC, 2020). The vegetation of the area is tropical, with an average daily temperature of about 26°C as well as long, wet and short dry seasons (Yahaya *et al*., 2020).

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Ikorodu is on the outskirts of Lagos, and so intense farming activities take place in the LGA. Among other things, farmers in the area cultivate vegetables and fruits for consumption and income. Some residents also cultivate vegetables within the metropolis. Moreover, vegetables and fruits are brought into the city's markets from other states in the country. These fruits and vegetables are grown and preserved with different varieties of pesticides, like anywhere else in the world. Unfortunately, pesticides are used indiscriminately in Nigeria without adhering to specified dosages by manufacturers, thus raising concerns that the vegetables and fruits would induce toxic effects on consumers. This necessitates the current study to determine the levels and health risks of pesticide residues in commonly consumed vegetables in the area in order to raise public awareness, particularly among policymakers.

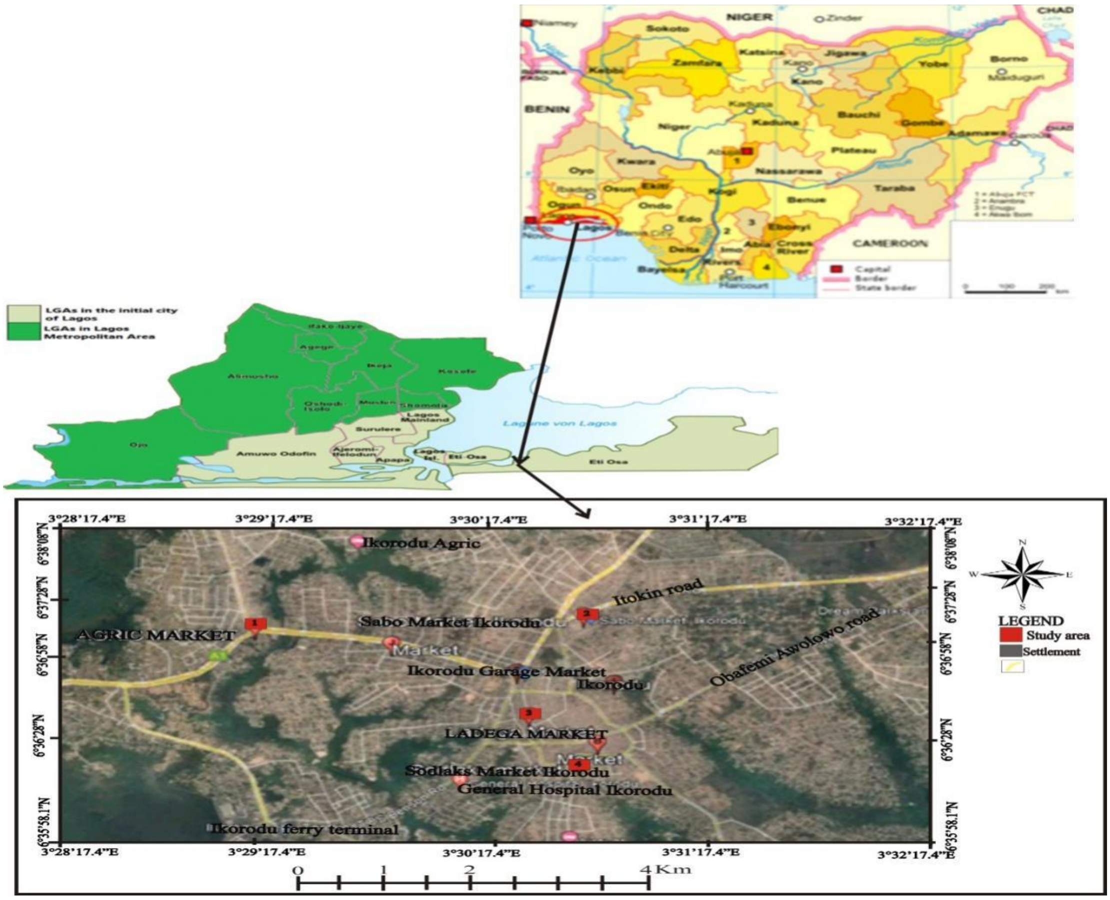

Figure 1: Locations of the Study Area

Vegetable sample collection and preparation

Fresh lettuce, spinach, cabbage, cucumber, and onion, as well as oranges, guavas, and mangoes, were purchased from markets in Ikorodu between April 2022 and July 2022. The samples were put in pre-washed polyethylene bags, labeled, and transported to the laboratory, where they were kept at room temperature (25°C). Then, the samples were properly washed with distilled water to remove impurities, after which the edible parts were cut with a knife and dried in an oven at 105°C for 24 hours. Using a mortar and pestle, each of the dried vegetable samples was ground into powder and stored in a desiccator for further use.

Extraction and determination of pesticide residues

Exactly 15 g of each vegetable and fruit powder was dissolved in a sealed flask containing 100 ml of ethyl acetate and 5 g of sodium chloride. The mixture was shaken well, allowed to stand for 24 hours, and then filtered with Whatman No. 1 filter paper. The filtrate was centrifuged for 10 minutes at 8,000 rpm to obtain the extract. 1 ml of the extract was then cleaned up in a mixture of 150 mg $MgSO_4$, 100 mg primary secondary amine (PSA), and 10 mg activated charcoal. The cleaned extract was shaken well, allowed to stand for 24 hours, and then centrifuged for 10 minutes at 8,000 rpm. The supernatant was collected in a GC vial, and 1µl of the clean extract was assayed for pesticides using the Torion T-9 GC-MS.

Health risk assessment of pesticides

The estimated daily intake (*EDI*) and health risk index (*HRI*) of pesticides in the vegetables were calculated from equations 1 and 2 (Nikhat *et al.*, 2020; Yahaya *et al*., 2022).

$$EDI \text{ (mg/kg/day)} = \frac{AC \ x \ RCP}{ABW} \quad (1)$$

$$HRI = \frac{EDI}{ADI} \quad (2)$$

In equation 1 above, *AC* signifies the average daily consumption of vegetables or fruits (kg), which is 0.065 kg; *RCP* stands for residual concentration of pesticide (mg/kg); and *ABW* represents the average body weight of Nigerians, which is 65 kg.

In equation 2 above, *ADI* stands for acceptable daily intake of pesticide residues in vegetables or fruits (given in Tables 3 and 4). Vegetables and fruits whose pesticide residue *HRI* was greater than 1 were considered toxic.

Data analysis

The levels of pesticide residue in the vegetable and fruit extracts were presented as mean ± standard deviation (SD) using the statistical package of Microsoft Excel software (version 2016). The *EDI* and *HRI* were also calculated using the software. MINITAB Statistical Software (version 20) was used to draw charts.

RESULTS

Levels of pesticide residues in vegetable and fruit samples

Table 1 shows the levels of pesticide residues in lettuce, spinach, cucumber, cabbage, and onions obtained from markets in Ikorodu. Chlorepyrifos-ethyl was detected above the minimum risk levels (MRLs) in lettuce, spinach, and cucumber, while metalaxyl exceeded the MRLs in cabbage. Also found in the vegetables were cyhalothrin, emamectin, acetaprid, carbendazime, and cypermethrin, all of which were within MRLs.

The levels of pesticide residues in guava, orange, and mango collected from Ikorodu markets are revealed in Table 2. Chlorepyrifos-ethyl was above the MRLs in orange; imidacloprid was above the MRLs in mango; and carbon disulfide was above the MRLs in guava. Other pesticide residues were found within the MRLs.

Table 1: Levels of pesticide residues in vegetables obtained from markets in Ikorodu, Lagos

Vegetable	Pesticides detected	Detected levels (mg/kg)	MRLs (FAO/WHO, 2016)
Lettuce	Chlorepyrifos ethyl	0.533±0.252	0.05
	Cyhalothrin	0.080±0.010	0.50
Spinach	Cypermethrin	0.047±0.021	0.05

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	Chlorepyrifos ethyl	0.753±0.182	0.05
Cabbage	Metalaxyl	0.017±0.005	0.01
	Emamectin	0.007±0.002	0.20
	Acetaprid	0.017±0.003	0.02
Cucumber	Chlorepyrifos ethyl	0.367±0.026	0.05
	Cypermethrin	0.026±0.006	0.05
Onion	Carbendazime	0.009±0.002	0.01
	Cypermethrin	0.014±0.003	0.05

Values were expressed as mean ± SD; MRLs = Minimal Risk Levels; WHO = World Health Organization; and FAO = Food and Agricultural Organization

Table 2: Levels of pesticide residues in fruits obtained from markets in Ikorodu, Lagos

Fruit	Pesticides detected	Level detected (mg/kg)	MRLs (FAO/WHO, 2016)
Orange	Cypermethrin	0.487±0.015	0.50
	Chlorepyrifos ethyl	0.113±0.004	0.05
	Difenoconazole	0.075±0.011	0.10
Guava	Cypermethrin	0.256±0.034	0.50
	Emamectin	0.064±0.005	0.20
	Imidacloprid	1.074±0.064	0.50
Mango	Carbon disulphide	4.483±0.446	0.20
	Cypermethrin	0.050±0.000	0.50

Values were expressed as mean ± SD; MRLs = Minimal Risk Levels; WHO = World Health Organization; and FAO = Food and Agricultural Organization

Health risk assessment of pesticide residues in vegetable and fruit samples

The estimated daily intake (*EDI*) and health risk index (*HRI*) of pesticide residues in vegetables and fruits were revealed in Tables 3 and 4.

The *EDI* and *HRI* of pesticide residues in the vegetables were within the acceptable daily intake (*ADI*), except for the *HRI* of cyhalothrin in lettuce (Table 3 and Figure 2). Similarly, the *EDI* and *HRI* of the pesticide residues in the fruits were within the *ADI*, except for carbon disulfide in mango (Table 4 and Figure 2).

Table 3: Estimated daily intake (*EDI*) (mg kg^{-1} day^{-1}) of pesticide residues in vegetables obtained from markets in Ikorodu, Lagos

Vegetable	Pesticides detected	*EDI* (mg/kg)	*ADI* (FAO/WHO, 2004)
Lettuce	Chlorepyrifos ethyl	0.0004	0.0100
	Cyhalothrin	0.0250	0.0200
Spinach	Cypermethrin	0.0002	0.0200
	Chlorepyrifos ethyl	0.0040	0.0100
Cabbage	Metalaxyl	0.0001	0.0200
	Emamectin	0.0003	0.0005
	Acetaprid	0.0001	0.0700

Cucumber	Chlorepyrifos ethyl	0.0002	0.0100
	Cypermethrin	0.0001	0.0200
Onion	Carbendazime	0.0001	0.0100
	Cypermethrin	0.0001	0.0100

EDI = Estimated Daily Intake; *ADI* = Acceptable Daily Intake; WHO = World Health Organization; and FAO = Food and Agricultural Organization

Table 4: Estimated daily intake (*EDI*) (mg kg^{-1} day^{-1}) of pesticide residues in fruits obtained from markets in Ikorodu, Lagos

Fruit	Pesticides detected	*EDI* (Mg/Kg)	*ADI* (FAO/WHO, 2004)
Orange	Cypermethrin	0.0300	0.0200
	Chlorepyrifos ethyl	0.0010	0.0100
	Difenoconazole	0.0004	0.0100
Guava	Cypermethrin	0.0010	0.0200
	Emamectin	0.0003	0.0005
	Imidacloprid	0.0060	0.0600
Mango	Carbon disulphide	0.0240	0.0100
	Cypermethrin	0.0003	0.0200

EDI = Estimated Daily Intake; *ADI* = Acceptable Daily Intake; WHO = World Health Organization; and FAO = Food and Agricultural Organization

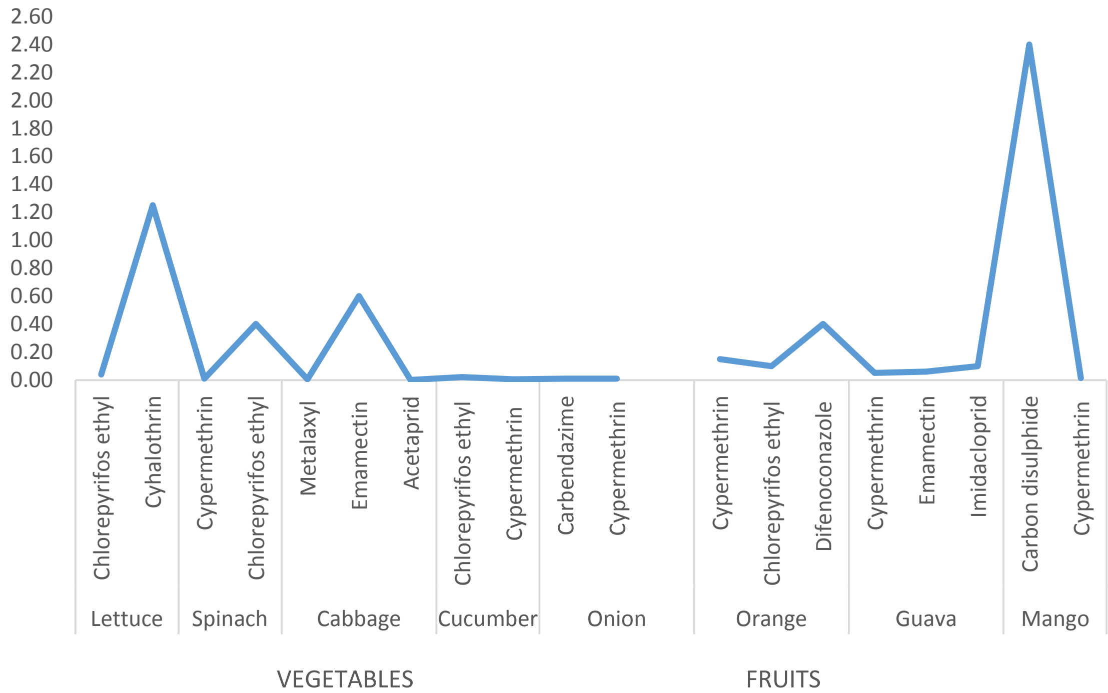

Figure 2: Health risk index (mg kg^{-1} day^{-1}) of pesticide residues in fruits and vegetables obtained from markets in Ikorodu, Lagos

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DISCUSSION

This study determined the concentrations and health risks of pesticide residues in selected vegetables and fruits purchased in markets in Ikorodu, Lagos, Nigeria. The study was conceptualized to determine the safety of commonly consumed vegetables and fruits in the town with regard to pesticide residues. Lettuce, spinach, and cucumber contained chlorepyrifos-ethyl beyond the MRLs, while cabbage had non-tolerable levels of metalaxyl. Regarding the fruits, chlorepyrifos-ethyl was above the MRLs in orange, imidacloprid was above the MRLs in mango, and carbon disulfide was above the MRLs in guava. The findings of the current study are consistent with those of Njoku *et al*. (2017), who detected non-tolerable levels of some pesticide residues in fruits and vegetables across three local governments in Lagos, Nigeria. Similarly, Omoyajowo *et al*. (2018) detected non-permissible levels of pesticide residues in fruits and vegetables across markets in Lagos, Nigeria. Dada *et al*. (2020) also reported non-tolerable concentrations of pesticide residues in fruits and vegetables purchased in Lagos, Nigeria.

The detection of pesticide residues in the current study suggests that fruits and vegetables can predispose consumers to health hazards. Chlorpyrifos-ethyl is a class II pesticide (moderately toxic) and one of the most widely used organophosphorus insecticides for industrial, agricultural, and public health purposes (Kumar *et al*., 2010; Abderrahim *et al*., 2022). However, chronic exposure to chlorepyrifos-ethyl can cause intra-uterine growth retardation, disruption of gut bacteria, nervous disorders, hormonal disorders, and disruption of glucose and lipid metabolism, leading to weight gain (Abderrahim *et al*., 2022; Djekkoun *et al*., 2022). Metalaxyl is a widely used fungicide against many diseases caused by *Plasmopara viticola* and *Phytophthora* in fruits, vegetables, and cereals (OuYang *et al*., 2021). Metalaxyl is a class II pesticide, but its chronic exposure can disrupt amino acid metabolism, energy metabolism, lipid metabolism, and antioxidant defense as well as cause cancer, allergic skin reactions, and eye and skin irritation (Zhang *et al*., 2017). In the majority of cases, imidacloprid pesticides cause only mild symptoms such as vomiting, abdominal pain, headache, and diarrhea (Mohamed *et al*., 2009). However, a high dose of the pesticide can cause sedation, respiratory arrest, cardiovascular effects, central nervous system effects, dyspnea, neurological disorders, serum abnormalities, and moderate eye irritation on contact (Mundhe *et al*., 2017; Sriapha *et al*., 2020). Carbon disulfide, also called carbon bisulfide, is a colorless, toxic, highly volatile, and flammable liquid chemical compound that is used in manufacturing, fumigation, insecticides, and as a solvent (Abdollahi and Hosseini, 2014). Long-term exposure to carbon disulfide in humans may cause reproductive anomalies, neurotoxicity, cardiotoxicity, and vascular atherosclerotic changes (Printemps *et al*., 2022; Sharma *et al*., 2022).

The level of risk posed by the detected pesticide residues was further assessed and established. The *EDI* and *HRI* of pesticide residues in both vegetables and fruits were within the *ADI*, but the *HRI* of cyhalothrin in lettuce and carbon disulfide in mango exceeded recommended limits. These findings indicate that daily consumption of lettuce and mango poses a significant health risk to consumers compared to other fruits and vegetables. This finding is consistent with those of Adefemi *et al*. (2018), Adeleye *et al*. (2019), and Dada *et al*. (2020), all of whom reported a health risk of some pesticide residues in vegetables and fruits in Lagos and other states across southwestern Nigeria. However, the results contradict those of Oyeyiola *et al*. (2017) and Adewole *et al*. (2021), as both did not find any risk of pesticide residues in vegetables and fruits in Lagos and elsewhere in southwestern Nigeria. The types of pesticides and their knowledge of application varied widely, which could have contributed to the inconsistencies in the findings of the various studies mentioned above.

CONCLUSION

The results established that lettuce, spinach, cucumber, and cabbage, as well as oranges, mangoes, and guavas sold in Ikorodu markets, contained some pesticide residues beyond the minimum risk levels recommended by the WHO. These pesticides are chlorepyrifos-ethyl, metalaxyl, imidacloprid, and carbon disulfide. The estimated daily intake (*EDI*) and health risk index (*HRI*) of the mentioned pesticides were within the acceptable daily intake (*ADI*) and less than 1, respectively, except for the *HRI* of cyhalothrin in lettuce and carbon disulfide in mango. This showed that the daily consumption of spinach and mango by consumers in the area could pose a greater risk compared to other fruits and vegetables.

There is a need to enlighten vegetable and fruit farmers and sellers on the choice, dosage, and best ways to apply pesticides to reduce or prevent toxicity. Consumers should also be enlightened on the dangers posed by pesticides in fruits and vegetables so that they may take precautionary measures. Agencies in charge of public health and the environment need to enforce strict compliance with guidelines on pesticide use.

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