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Pesticide Residues on Tomatoes Grown and Consumed in Mwea Irrigation Scheme, Kirinyaga County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author MVN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. All authors managed the analyses of the study. Author MVN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The effects of pesticides on human health are of great concern worldwide despite their usefulness in agriculture. The aim of the study was to evaluate pesticide residues on tomatoes grown and consumed in Kirinyaga County in order to determine whether the levels fall within recommended MRLs. Reported increased use of unspecified pesticides and undocumented residue levels in tomatoes produced in the country justified the need to evaluate pesticide residues in tomatoes grown in the area and consumed locally. The study, which was conducted in Mwea Irrigation Scheme, Kirinyaga County, Kenya between July 2017 and July 2018 used analytical study design. Tomato samples of Rambo variety mainly grown in open fields and greenhouses in the Irrigation Scheme were purposively sampled from thirty-five sampling sites in open fields, greenhouses,

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markets and consumers. The samples were taken to Kenya Plant Health Inspectorate Services (KEPHIS) laboratory in Nairobi for analysis. Analysis was done using Quick Easy Cheap Effective Rugged and Safe (QuEChERS) multi-residue analytical method for Low-Fat products. Four pesticide residues detected on tomatoes above the recommended EU and Cordex MRLs were: malathion (0.0315±0.0032 mg/kg) in open fields, carbendazim (1.2341±0.1667 mg/kg) and thiamethoxam (0.3736±0.0358 mg/kg) from greenhouses and acephate (0.0321±0.0032 mg/kg) from the market. Pesticide residue levels of tomatoes from consumers were all significantly ($p<0.001$, $p<0.01$) below the EU and Cordex permitted MRLs. Occurrence of pesticide residues on tomatoes from production to consumption levels is of great concern to consumers because of the perceived long term negative health effects. Implementation, strengthening and enforcement of the food policy in the country will enhance frequent monitoring of pesticide residue levels in fresh produce consumed locally in Kenya.

Keywords: Tomatoes; pesticide residues; open field; greenhouse; market; consumer; health.

1. INTRODUCTION

Tomato (*Lycopersicumesculentum mill*), whose production has intensified over the years, is the second leading vegetable in Kenya in terms of value after potato [1;2;3]. Its production plays an important role in income generation for small-scale farmers, creation of employment, and foreign exchange earnings [4]. It is estimated that global production of tomatoes is about 177 million tonnes, production in Africa is 17.2 million tonnes and Kenya is ranked sixth with a total production of over 340,000 metric tonnesannually [5;6].

Tomatoes need the right type of soil to produce the best yield. The crop grows optimally in deep, medium textured loamy or sandy loam, fertile, well drained soils with a pH between 6.0 and 7.0 [7]. In order to produce best tomatoes, it needs 3 to 4 months warm, clear and fairly dry weather and temperatures between 20° to 27°C with a minimum 8 hours daily of continuous sunlight. Fruit setting is poor when temperatures get below 10°C or exceed 30°C [8]. Tomatoes prefer 25 - 50 mm of water per week or about 600 mm of well distributed rainfall over the growing period. Nursery, transplanting and during flowering are the most critical stages of growth to water requirements. However, too much water will drown the plants and too little will stop production of fruits [7].

In Kenya, tomato is widely grown and consumed as a vegetable [1]. However, major setbacks in its production include, high pest and disease infestation, and nutrient deficiency of which if not controlled can cause great losses [2]. Due to this, a variety of pesticides are used since no marketable produce can be harvested from untreated crops. Increased demand in Kenya has necessitated an increase in production forcing farmers in Mwea to rely heavily on pesticides to control pests and diseases, which has led to problems such as contamination of the produce and the environment [9;10;11].

2. MATERIAL AND METHODS

2.1 The Study Area

The study was conducted at Mwea irrigation scheme in Kirinyaga County, Kenya. The study area has eight wards within namely; Gathigiriri, Tebere, Kangai, Wamumu, Murinduko, Nyangati, Mutithi and Thiba (Fig. 1, Table 1). The Irrigation scheme has a total area of 516.7 km^2 with approximately 51,444 households with an average density of 341 persons per square kilometre.

Mwea Irrigation Scheme lies between latitudes 0.540^o and 0.788^o South and longitudes 37.228^o and 37.497^o East (Fig. 1) with relatively uniform topography which extends over the flat land on the outskirts of Mt. Kenya [12]. The scheme is well supplied with irrigation water from Nyamindi and Thiba Rivers, which favours tomato production throughout the year. Mwea irrigation scheme was considered appropriate for the study to fill in the knowledge gaps in information in the pesticide residue levels in the tomatoes grown and consumed in the area

2.2 Tomato Sampling, Packaging and Submission to Laboratory

Triplicate tomato samples each weighing approximately 1 kg were randomly harvested from open fields and greenhouses, or purchased

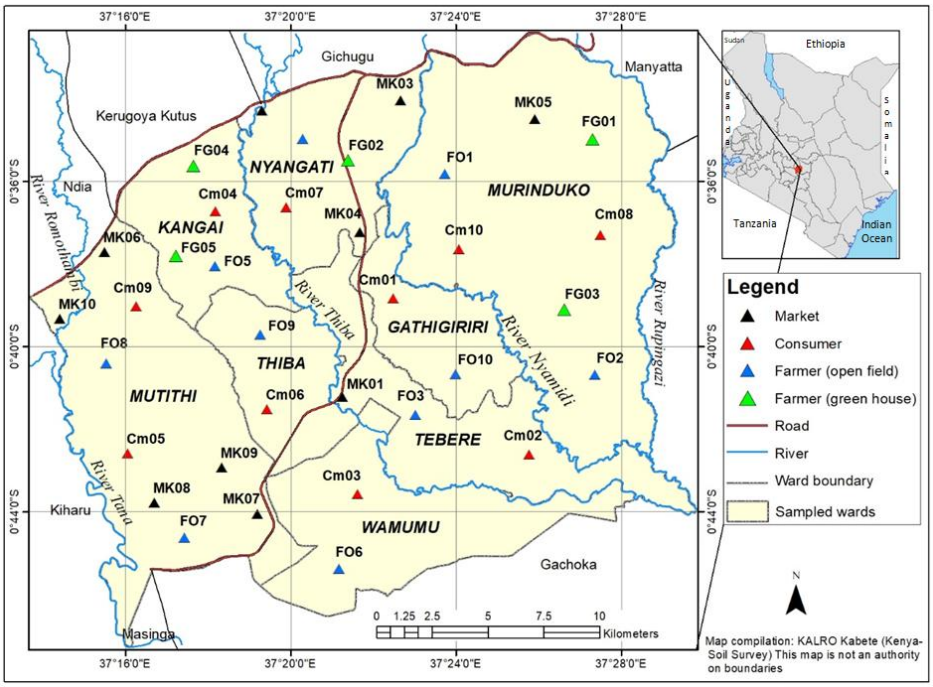

Fig. 1. Map of Mwea Irrigation Scheme showing sampling points (wards)
FO= Farmer open field; FG= Farmer greenhouse; MK= Market; Cm= Consumer

Table 1. Description and major crops sprayed with pesticides at sampling sites

Sampling site/ ward	Altitude (m)	Longitude	Latitude	Name of crop
Gathingiri	1151	37.391°E	0.658°S	Tomatoes, French beans, onions, maize, beans, rice
Tebere	1123	37.388°E	0.699°S	Tomatoes, French bean, onions, maize, beans, rice
Kangai	1227	37.301°E	0.616°S	Tomatoes, bananas, coffee, maize, beans, rice
Wamumu	1126	37.373°E	0.738°S	Tomatoes, bananas, French beans, onions, water melon, maize
Murinduko	1176	37.431°E	0.602°S	Tomatoes, French beans, onions, water melon, passion fruit, coffee, maize
Nyangati	1259	37.348°E	0.591°S	Tomatoes, pawpaw, coffee, maize, rice
Mutithi	1160	37.281°E	0.687°S	Tomatoes, maize, beans, rice
Thiba	1161	37.329°E	0.678°S	Tomatoes, maize, beans, rice

**Table extracted from [13]*

from the markets and consumers. The tomatoes were thoroughly mixed to form a composite sample of 3 kg. A sample of 1 kg tomatoes was picked randomly from each composite sample, wrapped in sterilized aluminium foil, placed in a self-sealing polythene bag, labelled, placed in a plastic container with a lid and stored temporarily in polyurethane cool-boxes containing dry ice before transportation to Kenya Plant Health Inspectorate Service (KEPHIS) laboratory on the same day. Ten (10) samples were collected from the open fields, 5 from greenhouses, 10 from markets and 10 from consumers.The samples were received in the laboratory through the filled sample submission form and their qualities were checked to ensure that they were fresh in terms

of water quantity and not rotten. The laboratory ensured that all the samples had been labelled from the field, indicating the origin and date of collection, for traceability. Theo samples were each given a laboratory traceability code that showed the source and date of submission and stored in a cold room at a temperature of -18ºC, prior to extraction, to stop the pesticides from degradation that leads to a reduction of pesticide residue levels.

2.3 Sample Processing

One (1) kilogram of each tomato sample from the cold room was chopped into smaller sizes using Stephen chopper then homogenized by a wiring blender to get a representative uniform sample. The chopper and blender were thoroughly cleaned with distilled deionized water after chopping each sample to remove contamination from the previous sample and rinsed twice with high purity acetone (99%) to remove pesticides or any contaminants from the previous samples. The homogenized supernatant/ sample was divided into 3 equal samples/ portions and analyzed using QuEChERs analytical method stated in Sahoo et al. 2011 [14].

2.4 Sample Extraction and Separation

A 50ml single use extraction polyethylene tube was rinsed twice with high purity acetone (99%), to remove any contaminants, dried before use. Ten grams (10g) of each homogenized sample was weighed in duplicate in the tube using calibrated ADAM AFP 200100 LC analytical balance. Two internal standards for quality control check, 50µl (0.05µg/g) of Malathion D10 (10ppm) for the liquid chromatography-mass spectrometry mass spectrometry (LC-MS/MS) and 5µl (0.005µg/g) of Dichlovos D6 (10ppm)for the gas chromatography mass spectrometry (GC-MS) were each added. The acetonitrile, 10ml ± 0.2ml, solvent used for extraction was added into each tube, vortexed using Wiemix-VM-10 machine for 1 minute and 6.5g of pre-mixed extraction salts (4g ± 0.2g anhydrous magnesium sulphate anhydrous, 1g ± 0.05g sodium chloride, 1g ± 0.05g trisodium citrate dehydrate and 0.5g ± 0.03g disodium hydrogen citrate sesquihydrate) were added. The mixture was vortexed for 1 minute and centrifuged using a universal 320 R centrifuge for 5 minutes at 3700 revolutions per minute to separate liquid and solid portions of the sample extracts. The liquid portion was taken for a sample clean-up.

2.5 Sample Clean-up and Analysis

Four, 4 ml portions of the liquid sample extracts containing pesticides were each pipetted into 15ml centrifuge tubes. Two sample portions were taken for LC-MS/MS and the other two for GC-MS analysis. A standard mixture, 20µl (0.02 µg/g), of each targeted pesticides were added to obtain the calibration curves for the LC-MS/MS analysis. The targeted pesticide residue levels analysed used in Mwea irrigation scheme included Alpha-cypermethrin, carbendazim, thiamethoxam and malathion [13]. QuEChERs multi-residue method for analysis of pesticide residues in low-fat products was used for analysis. For sample analysis, 10 µl of formic acid (10 µl per ml of sample) and 60µl of D-sorbitol (30µl per sample) were added to each separated liquid sample extract portion in 15_ml centrifuges tube. After shaking vigorously for 1 minute, 500µl of mixture was pipetted into a 1ml auto sample vial and 5µl of the procedural injection internal standard dimethoate D6 (10ppm) added. It was diluted by adding 495µl of High Performance Liquid Chromatograph (HPLC) water, vortexed and taken for analysis using Liquid Chromatography technique with triple quadruple mass detectors (LC-MS/MS Agilent 6430) for 30 minutes at room temperature.

For the GC-MS analysis, 50µl (0.05 µg/g) of targeted pesticides, standard mixtures were prepared and used for the calibration of GC-MS machine. Triplicate 500µl of each liquid sample extract was pipetted from each sample mixture into a 1 ml auto sample vial, concentrated on nearing dryness under a gentle stream of white spot nitrogen gas, then 500µl of GC-MS pesticide solvent 2, 2, 4-Trimethylpentane (Iso-octane) was added and vortexed, then analysed in the GC-MS machine for 42.5 minutes at a temperature between 60-300ºC.

2.6 Identification and Confirmatory Tests

Where, many compounds, including co-extracts interfered with retention times, their identities were confirmed by running the samples on two different (non-polar and polar) columns with different stationary phases. Non polar column CP-SIL 8CB-15 m, 0.25 mm internal diameter (id), 0.25µm film and polar column DB-1701-15 m, 0.53 mm internal diameter (id), 0.5µm film or GC-MS were used for confirmation. Whenever retention times of the substances and standards agreed on both columns and the GC-MS and the calculated concentrations would be about the same, the compound's identity was ascertained

by their peaks. The resolution and identification were also confirmed using relative retention times obtained by measuring the retention time of each test standard analyte.

2.7 Limits of Detection and Quantification

The limit of detection (LOD) is the lowest concentration of the analytes that the analytical process can reliably detect. The estimation of LOD was given by equation 1 based on the relationship between the lowest detectable analytes signal S_d, the field blank S_b, and the variability in the field blank (σ_b). LOD can be defined as the analyte concentration which gives a gross signal exceeding S_b by Kdunits of σ_b.

$$\text{At LOD, } S_d = S_b + Kd\sigma_b \quad (1)$$

Where a value of three is assumed forKd(Kd=3)

For the estimation of limits of quantification (LOQ) as given by equation 2, the quantification (Numerical estimations of the amount) of the concentration of the analyte is considered reliable if the corresponding gross signal (S_q) is:

$$S_q = S_b + Kt\sigma_b \quad (2)$$

Where avalue of 10 is assumed for Ktso that at least one figure of the results is significant

2.8 Statistical Analysis

Data for pesticide residue levels on tomatoes, the EU and Codex recommended MRLs were entered in Excel. A T-test was done to compare the EU and Codex MRLs with pesticide residue levels on tomato samples from various sites to show differences in their means. Analysis Of Variance (ANOVA) was then done at 95% Confidence level to compare means of pesticide residue levels detected on tomatoes from different sampling sites. Means that showed statistical differences were subjected to Tukey Kramer post hoc test at 95% Confidence level to determine where significant differences in means of pesticide residue levels on tomatoes were.

3. RESULTS

3.1 Pesticide Residues Detected in All Tomato Samples

Out of 35 tomato samples from the open fields, greenhouses, markets and consumers analysed in the laboratory, 46% of the samples had pesticide residue levels Below Detection Limit (BDL) while 54% were detected with pesticide residues. Twenty one percent (21%) of the samples detected with pesticide residues were from the open fields, 26% from greenhouses, 21% from the markets and 32% from consumers. The highest number of samples with pesticide residues was from consumers while samples from greenhouses had more pesticide and higher residue levels than the other sites.

Fig. 2 shows that about 46% of tomato samples had pesticide residues BDL of .001mg/kg, while 40% had one pesticide residue on a single sample. Samples that had a combination of two different pesticide residues were about 9% and were from the greenhouses. About 6% which had a combination of three different pesticide residues in each sample were from the open fields and greenhouses. Nevertheless, 11 pesticide active ingredients (ai) were detected on all the 35 tomato samples of which, 16% had pesticide residue levels above the EU and Codex Maximum Residue Limits (MRLs), while 84% had levels below the EU MRLs (Table 2, Table 3, Table 4, Table 5)

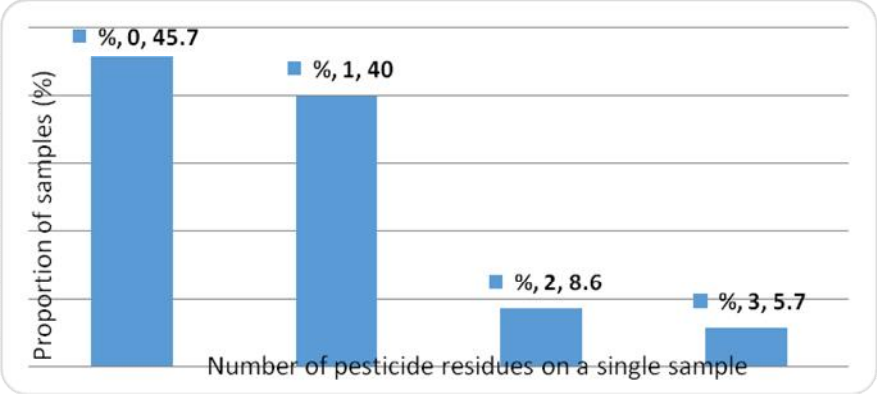

Fig. 2. Number of pesticide residue levels detected in all tomato samples

Table 2. Pesticide residue levels of open field tomatoes

Pesticide residues	Residue levels (mg/kg)	EU MRL (mg/kg)	df	Std. dev.	t	*P*	Codex MRL (mg/kg)	t	*P*
Acetamiprid	0.0256±0.0028	0.5	1	0.004	169.429	0.004	0.2	62.286	0.01
Azoxystrobin	0.0438±0.0039	3.0	1	0.006	758.000	0.001	3.0	758.000	0.001
Difenoconazole	0.0295±0.0014	2.0	1	0.002	1407.50	<0.001	0.6	407.500	0.002
Carbendazim	0.0596±0.0178	0.3	3	0.036	13.539	0.001	0.5	24.802	<0.001
Malathion	0.0315±0.0032	0.02	1	0.005	3.594	0.173	0.02	3.594	0.173

LOD = 0.001 mg/kg for all pesticide residue levels

Table 3. Pesticide residue levels of greenhouse tomatoes

Pesticide residue	Residue level (mg/kg)	EU MRL (mg/kg)	df	Std dev.	t	*P*	Codex MRL (mg/kg)	t	*P*
Difenoconazole	0.2597±0.0522	2.0	3	0.1045	33.310	<0.001	0.6	6.514	0.007
Imidacloprid	0.1446±0.0086	0.5	3	0.0171	41.456	<0.001	0.5	41.456	<0.001
Metalaxyl	0.0428±0.0039	0.2	1	0.0055	40.308	0.016	0.5	117.231	0.005
Dimethomorph	0.0231±0.0025	1.0	1	0.0035	390.76	0.002	1.5	590.760	0.001
Carbendazim	1.2341±0.1667	0.3	1	0.2357	5.606	0.112	0.5	4.405	0.142
Thiamethoxam	0.3736±0.0358	0.2	1	0.0506	4.849	0.129	0.7	9.117	0.069
Alpha-cypermethrin	0.087±0.0087	0.5	1	0.0123	47.459	0.013	0.2	12.977	0.049

LOD = 0.001 mg/kg for all pesticide residue levels

Table 4. Pesticide residues and levels of market tomatoes

Pesticide residue	Residue level (mg/kg)	EU MRL (mg/kg)	df	Std dev.	t	*P*	Codex MRL (mg/kg)	t	*P*
Acephate	0.0321±0.0032	0.01	1	0.005	6.906	0.092	0.01	6.906	0.092
Carbendazim	0.1160±0.0490	0.3	3	0.098	3.755	0.033	0.5	7.837	0.004
Imidacloprid	0.0236±0.0019	0.5	1	0.003	3.474	0.178	0.5	250.737	0.003

LOD = 0.001 mg/kg for all pesticide residue levels

Table 5. Pesticide residue levels of tomatoes from consumers

Pesticide residue	Residue level (mg/kg)	EU MRL (mg/kg)	df	Std dev.	t	*P*	Codex MRL (mg/kg)	t	*P*
Carbendazim	0.0494±0.0155	0.3	7	0.049	16.196	<0.001	0.5	29.123	<0.001
Alpha-cypermethrin	0.0218±0.0061	0.5	3	0.012	77.996	<0.001	0.2	29.065	<0.001
Imidacloprid	0.0170±0.0017	0.5	1	0.002	284.118	0.002	0.5	284.118	0.002

LOD = 0.001 mg/kg for all pesticide residue levels

3.2 Pesticide Residues on Open Field Tomatoes

Pesticide residues in 60% of the samples from open fields had levels Below the Detection Limit (BDL) of 0.001mg/kg, while 40% had combined detections of 3 fungicides azoxystrobin, difenoconazole and carbendazim, and 2 insecticides acetamiprid and malathion (Table 2).

From the results in Table 2 carbendazim, a fungicide, had a higher frequency of detection in more samples from the open fields than the other pesticide residues. Only the residue levels of malathion (0.0315±0.0032 mg/kg) from the open fields was above the EU and Codex MRLs of 0.03 and 0.5 mg/kg respectively. However, statistical analysis shows that the mean residue levels of acetamiprid (0.0256±0.0028 mg/kg), azoxystrobin (0.0438±0.0039 mg/kg), difenoconazole (0.0295±0.0014 mg/kg) and carbendazim (0.0596±0.0178 mg/kg) were significantly (P=0.004; P<0.001) below EU MRLs. Likewise, their residue levels were significantly (P=0.01; P=0.001; P=0.002; P<0.001 respectively) below Codex MRLs (Table 2).

3.3 Pesticide Residues on Greenhouse Tomatoes

All the tomato samples from the greenhouses were detected with pesticide residues. Seven pesticide residues detected on greenhouse tomatoes were four fungicides difenoconazole, metalaxyl, dimethomorph and carbendazim, and three insecticides imidacloprid, thiamethoxam and cypermethrin (Table 3).

Difenoconazole and Imidacloprid were on greenhouse tomatoes from more than one sample. Tomatoes from two samples had one pesticide residue while tomatoes from 4 samples had a combination of 2 pesticide residues. The mean residue levels of carbendazim (1.2341±0.1667 mg/kg) and thiamethoxam (0.3736±0.0358 mg/kg) on greenhouse tomatoes were above the EU MRLs (Table 3). However, the mean residue levels of metalaxyl (0.0428±0.0039 mg/kg), alpha-cypermethrin (0.0871±0.0087 mg/kg) and dimethomorph (0.0231±0.0025 mg/kg) were significantly (P=0.016; P=0.013; P=0.002 respectively) below EU MRLs. The three pesticide residue levels were also significantly (P=0.005 P=0.049 P=0.001 respectively) below Codex MRLs. In addition, the mean residue levels of difenoconazole (0.2597±0.0522 mg/kg) and imidacloprid (0.1446± 0.0082 mg/kg) were significantly (P= <0.001) below the EU and Codex (P=0.007; P<0.001) MRLs (Table 3).

3.4 Pesticide Residue Levels on Market Tomatoes

Pesticide residue levels in 60% of tomato samples from the markets were BDL of 0.001 mg/kg. Three pesticide residues, acephate, imidacloprid and carbendazim were detected in 40% of the tomato samples, but only the mean residue level of acephate (0.0321±0.0032 mg/kg) was above the EU and Codex MRLs.

However, statistical analysis in Table 4 shows that the mean residue level of carbendazim (0.1160±0.0490 mg/kg) was significantly below the EU and Codex MRLs (P=0.033; P=0.004respectively).

3.5 Pesticide Residue Levels of Tomatoes from Consumers

Pesticide residues levels on tomatoes from 40% of the samples from consumers were BDL of 0.001 mg/kg. However, 3 pesticide residues were detected in 60% of the samples. One sample had a combination of two pesticide residues, a fungicide carbendazim and an insecticide alpha-cypermethrin while the other samples had one pesticide residue each.

The mean residue levels of all pesticides on tomatoes from consumers were below the EU and Codex MRLs (Table 5). However, statistical analysis showed that the mean residue level of carbendazim (0.0494±0.0155 mg/kg) frequently detected on the tomatoes, and alpha-cypermethrin (0.0218±0.0061 mg/kg) were significantly below the EU and Codex MRLs (P<0.001). Likewise, the mean residue level of imidacloprid (0.0170±0.0017mg/kg) was significantly (P=0.002) below the EU and Codex permitted MRLs (Table 5).

4. DISCUSSION

Exposure to pesticide residues through food is a major food safety issue and health concern globally due to possible related acute (such as diarrhoea and allergy) and chronic (such as cancer, teratogenesis, reproductive toxicity and damage of the nervous system) negative effects on human health [15;16]. Over 50% of the analysed tomato samples had pesticide residues,

of which 16% had residue levels above the EU and Codex accepted MRLs. This is of great concern to the consumers, considering that some tomatoes had multiple pesticide residues which may increase health risks due to a possibility of synergism in their effects [17].

Very high pesticide residue levels detected in tomatoes from greenhouses could be attributed to slow degradation process in shaded environment unlike in open fields where sunlight and rain hasten the process [18]. Similar results indicating occurrence of high pesticide residue levels in tomatoes have been reported in other countries such as South Africa, Tanzania and Uganda [19,17,20].

Pesticide residues on 60% of tomato samples from consumers, although not above the EU and Codex standards is of concern to the consumer. Consumption of tomatoes contaminated with pesticides could have serious health implications for children, the sick, pregnant women and the elderly who are more vulnerable [19]. The children's immature liver and kidneys cannot quickly remove pesticides from the body and the brain, the nervous system and other organs that are still developing, whereas organs of the elderly are aging and not functioning effectively [21;22]. Although all the pesticide residue levels in tomatoes from the consumers were significantly below the EU and Codex MRLs, this cannot be overlooked because of their related perceived long term effects on human health [23;24].

In this study, the residue levels of acephate, carbendazim, malathion and thiamethoxam were above the EU and Codex MRLs. Acephate is converted to a more toxic compound methamidophos which damages the liver, kidneys and the heart [25]. Carbendazim frequently detected on tomatoes from production to consumption points and at very high levels of greenhouse tomatoes is known to cause genetic and fertility defects, and cancer [25,26]. Carbendazim has been frequently detected in a wide range of vegetables in countries such as Romania (1.241mg/kg) and Saudi Arabia (0.158mg/kg) [27;28]. Although carbendazim residue levels on tomatoes from consumers were below the EU and Codex MRLs, its presence on tomatoes being cooked or eaten raw should not be overlooked at because it may accumulate and biomagnify in the body over a period of time and affect consumers' health [29]. Malathion affects the Central Nervous System (CNS) by inhibiting acetylcholinesterase (AChE) in people leading to cholinergic syndrome-related symptoms [30]. The toxicity of malathion is caused by a reactive metabolite malaoxon, which is several times more toxic than malathion, resulting from its oxidation in the human body [31;32]. Thiamethoxam is a neonicotinoid insecticide known to affect the CNS by mimicking acetylcholine [33].

Occurrence of pesticide residues on tomatoes is often attributed to applying pesticides at higher rates than specified by the manufactures, and harvesting tomatoes sprayed with these pesticides before the specified Pre-Harvest Interval (PHI). The presence of several pesticide residues in a single sample was due to application of combinations of different pesticides (such as 3 fungicides and 2 insecticides) to control different or the same pest or disease. In addition, spraying high rates of pesticides and harvesting tomatoes before the specified withholding period was another reason. PHI allows degradation of pesticides in the crop. Inappropriate use of pesticides on crops and consumption of their residues has been frequently reported in many developing countries such as Tanzania [34;35] and Ghana [36]. Studies have associated inappropriate use of pesticides to lack of training in proper handling of pesticides [37].

5. CONCLUSION

The results of this study revealed that pesticide residue levels were detected in tomatoes from production to consumption points. This could be attributed to non-compliance with pesticide use standards specified by the manufacturers. There is a high health risk of consuming such vegetables with pesticide residues. Lack of training for some farmers and negligence by others who despite being trained and were knowledgeable about the associated pesticide risks chose to do the wrong thing. Farmers applied pesticides at higher rates than recommended and harvested tomatoes earlier than the specified PHI time which contributed to the retention of pesticide residue levels that were lower or higher than the EU and Cordex MRLs on tomatoes. Some residue levels such as carbendazim and thiamethoxam from the greenhouse tomatoes, malathion from the open fields and acephate from the markets were at higher levels than permitted by EU and Codex MRLs. From the food safety perspective, detection of pesticide residues on tomato samples even those from the consumers are a serious health risk and a great concern to those

who eat tomatoes (raw as salads or cooked in food) grown in Mwea Irrigation Scheme because of the known health risks of cancer, reproductive toxicity, among others. Such problems are difficult to manage and their treatment cost is very high [14].There is need for implementation, strengthening and enforcement of the food policy in the country through team approach from relevant bodies and frequent monitoring of pesticide residue levels in fresh produce consumed locally in Kenya.

CONSENT

"All authors declare that 'written informed consent was obtained from the farmer (or other approved parties) for the publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal."

ETHICAL ISSUES

Permission to carry out this research was obtained from Kenyatta University (KU) graduate school, KU Ethics Review Committee and the National Commission for Science, Technology and Innovation (NACOSTI). Permission to carry out research in Mwea irrigation scheme was sought from the Kirinyaga County Director of Agriculture.Informed consent was sought from individual participants after explaining the objectives of the study. They were assured of confidentiality throughout the study. Only those who were willing to participate by signing the informed consent form were recruited to participate in the study. Verbal permission was sought from participants to take photographs used in this thesis. Protection of participants' confidentiality was observed and guaranteed by not indicating their names on tomato samples taken to the laboratory for analysis. Participants were also assured that results obtained would be kept confidential and only used by the researcher for the intended purpose. Farmers who were not willing to participate in the study were assured of no victimisation from any office.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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