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Assessment of the Pesticides Utilization and the Pesticide Residues Presence in Fresh and Tomato Products for the Tomato Supply Chain in Rwanda

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Abstract

Pesticide residues are either natural or synthetic and are found in most edible products such as fresh fruits, vegetables, meat and other processed products. Excess of these pesticides' residues is unsafe for consumption due to regulatory measures. Thus, it is beneficial to assess the level of residues of pesticides in the food diet in order to improve the standard of living of the population. This study intends to assess the pesticide usage and residue levels of selected pesticides in fresh tomatoes in the supply chain of Rwanda. The results of the study confirm that there are around 10 brands of pesticides used in Rwanda. 58.97% of the surveyed people around the country are males and 71.79% of farmers apply rockets as the main pesticide. More than 22% of surveyed farmers affirmed to consume the raw or/and unwashed tomatoes. This study revealed that the residues of the active ingredients contained in the pesticides are accumulated in unwashed tomatoes and the quantity of such residues is shown in this study. Deltamethrin was 0.64 ± 0. 009 $mg{\cdot}kg^{-1}$ in tomatoes collected in Rusizi district, cypermethrin 1.1435 ± 0. 0375 $mg{\cdot}kg^{-1}$ in tomatoes collected from Gisagara District, mancozeb residues was 0.620 ± 0.000 $mg{\cdot}kg^{-1}$ in tomatoes collected from Rusizi district. The results of the study also show that pesticide residues are not found in the washed tomatoes. Therefore, the detection of pesticide residues in unwashed tomatoes in some samples indicates the malpractice of residues among farmers in Rwanda. Also, consumers eating the unwashed fresh tomatoes are recommended to wash the tomatoes before use.

Keywords

Pesticide Residues, Tomatoes, Health Effect, Social Economic

1. Introduction

Pesticides are classified as any substance or mixture of substances used in agriculture for mitigating, restricting, demolishing or dispersing pests such as weeds, insects, rats, nematodes, mites, etc. [1]. As the world population increases day by day, the worldwide application of pesticides is increasing steadily as a response to the need for increased quantities of food. Around one third of the worldwide agricultural products are subject to pesticide application [2]. The study of Sitaramaraju *et al.* [3] revealed that the environmental pollution caused by pesticides results in severe problems in Asia, Africa, Eastern Europe, Latin America and the Middle East. Pesticides are among the leading causes of death by self-poisoning in low- and middle-income countries [4]. This study highlighted that the pesticides are intrinsically toxic and deliberately spread in the environment, the production, distribution, and use of pesticides require strict regulation and control. The most at-risk population is people who are directly exposed to pesticides. This includes agricultural workers who apply pesticides and other people in the immediate area during and right after pesticides are spread. The study revealed that people who grow their own food do not, when using pesticides, follow instructions for use and protect themselves by wearing gloves and face masks as it is very necessary [5].

Fruits and vegetables are important contributors to a healthy and diversified diet [6]. It is well highlighted that high fruit and vegetable consumption is associated with a decreased risk of noncommunicable disease (NCD) [7] and the contrary is estimated to cause approximately 14%, 11% and 9% of deaths for gastrointestinal cancer, ischemic heart disease and ischemic heart disease, respectively [8]. However, fruits and vegetables can also be a source of pesticide residue used during their production. There are more than 1000 pesticides used worldwide to protect crops against insects, fungi, weeds and other pests. In addition to its use in agriculture, pesticides are also used to protect public health by controlling the vectors of tropical diseases such as mosquitoes [9]. Therefore, humans can be exposed to pesticides in a variety of ways, from food consumption to dietary exposure, occupational exposure during production and application, and entrainment or contamination of water [10] [11]. Because they are naturally toxic and are deliberately dispersed into the environment, the manufacture, distribution and use of pesticides require strict regulation and control. Before use is allowed, pesticides must be tested for potential health effects and results must be analyzed by experts to assess risk to humans. WHO, in collaboration with FAO, is responsible for assessing the risks of pesticides to humans through both direct exposure and residues in food and recommending adequate protections (Codex

Alimentarius). Risk assessments for pesticide residues in food are carried out by the Joint FAO/WHO Meeting on Pesticide Residues (JMPR1), an independent, international expert scientific group. These assessments are based on all data available for national registries of pesticides worldwide and all scientific studies published in peer-reviewed journals. JMPR establishes Health-Based Guidelines to protect people against both acute (Acute Reference Dose-ARfD) and chronic (Acceptable Daily Intake-ADI) risk.

The United Nations Population Division estimates that, by the year 2050, there will be 9.7 billion people on Earth—around 30% more people than in 2017. Nearly all this population growth will occur in developing countries [12]. The Food and Agriculture Organization of the United Nations (FAO) estimates that, in developing countries, 80% of the necessary increases in food production to keep pace with population growth are projected to come from increases in yields and the number of times per year crops can be grown on the same land [13]. Only 20% of new food production is expected to come from expansion of farming land. Pesticides can prevent large crop losses and will therefore continue to play a role in agriculture. However, the effects on humans and the environment of exposure to pesticides are a continuing concern. The use of pesticides to produce food, both to feed local populations and for export is not complying with good agricultural practices regardless of the economic status of a country [14].

2. Materials and Methods

2.1. Tomato Sampling Sites

For this research, different tomato cultivation sites have been identified across the country and below are the selected sites for sampling. The main tomato samplings sites hubs are:

- EAST: Bugesera, Rwamagana
- NORTH: Musanze, Burera
- WEST: Rubavu-Nyabihu
- KIGALI CITY: Gasabo, Nyarugenge, Kicukiro
- SOUTH: Nyanza, Gisagara, Nyaruguru
- Cyanika Border
- Rusizi Border
- Kagitumba Border
- Gatuna Border

In each District 3 sites have been identified and in each site 3 samples have been collected.

2.2. Pesticides Residues Analysis in Tomato

2.2.1. Materials

The survey was conducted in all districts of the country. In every district, 3 sectors where mostly cultivated the tomatoes were selected with the help of district agronomist, then the farmers with good yield of tomatoes were selected. The

survey using the attached annex questionnaire (**Annex 1**) was applied on 278 tomato farmers to know the pesticide application and the health threat awareness. The control field of tomatoes was cultivated at INES-Ruhengeri and same pesticides were applied. After that, the tomato samples were collected from the above-mentioned sites and a representative portion of 5 kg fresh tomatoes and various brands of tomato paste, and ketchup samples (3 samples per brand and ketchup) were bought from the same area. Pesticide reference standards were obtained from Sigma-Aldrich. HPLC grade Reagents and chemicals such as methanol, acetone, glacial acetic acid, toluene, ethyl acetate and acetonitrile, sulfuric acid, etc., were supplied by Sigma–Aldrich and Ultrapure water was used.

2.2.2. Sample Collection

Samples of fresh tomatoes, and tomato products (tomato paste and ketchup) were selected and collected from the selected sites. After selection, the collected samples were put in a plastic bag and cooled in a cooler during transportation to INES laboratory facilities. Furthermore, samples were then stored in the refrigerator at 4˚C for further pesticides residues analysis.

2.2.3. Sample Preparation

Tomato samples, fresh tomatoes both washed and unwashed and tomato products (paste and ketchup) samples were prepared and analyzed based on QuEChERS (quick, easy, cheap, effective, rugged and safe) and HPLC method as described by Anastassiades and Lehotay, [15] and Golge and Kabak [16] with some modifications. Briefly, approximately 1kg of fresh tomato samples were homogenized with an electric blender for 1 min at room temperature. Then a portion of 15 g ground and homogenized fresh tomato sample or tomato products (paste or ketchup) is weighed into 50 ml Teflon centrifuge tube and covered by 15 ml of acetonitrile-acetic acid (99:1, v/v), 6 g $MgSO_4$ and 1.5 g sodium acetate. Next, the mixture is shaken by the vortex mixer for 1 min. Moreover, the sample extract is then centrifuged at 5000 rpm for 1 min. Next, 4 ml of upper layer extract is then transferred to a 15 ml centrifuge tube containing 0.6 g $MgSO_4$ and 0.2 g PSA. The mixture is vortexed for 1 min and centrifuged at 5000 rpm for 1 min. After centrifugation, an aliquot of the supernatant portion was transferred to a vial prior to injection to the HPLC (HPLC LC-100, China) system for analysis. The samples were further analyzed and compared to pesticide's standards.

2.3. Standard Solution Preparation

Stock standard solution of each pesticide (1000 ppb, µg/mL) was prepared in acetonitrile. Different concentrations of each pesticide standard were then prepared from the stock solution by dilution using mobile phase as diluent. The following diluted concentrations were prepared: 10, 20, 30 and 50 ppb (µg/mL). Each of these solutions was injected into HPLC and peak areas were recorded and plotted versus the concentration of the pesticide standard.

2.4. HPLC Analysis

The residues analysis method, previously developed by Anastassiades and Lehotay [14] was used to determine the concentration of pesticides residues with slight modifications. Briefly, the residue extraction procedure was based on the QuEChERS method as described above. The analysis was performed using high performance liquid chromatography (HPLC), Exformma technologies LC100, coupled with UV detector and all used reagents were HPLC grade including acetonitrile, methanol, n-hexane, formic acid, ammonia solution, and glacial acetic acid. HPLC system with a pump (Spectra Series pump 4000), vacuum degasser for liquid chromatography (Solvent degasser SCM 1000), rheodyne and injection valve (Injection volume: 20 µl). System parameters were controlled with a system controller and chromatographic data were collected and recorded using the PC 1000 system software. The separation was carried out using a C18, 4 µm Luna column (4.6 × 150 mm ID, Hong Kong, China) fitted with guard column (4 mm·L × 3 mm I.D., Hong Kong, China) packed with the same material. The column eluate was monitored with a UV 6000 LP photo-diode array (PDA) detector.

3. Results

Pesticides Utilization and Awareness Information

The results of the present study revealed that around 11 pesticides are applied in tomato fields in Rwanda. The tomato farmers affirmed to starts the application of pesticides when they observe the first symptoms of the tomato disease. The results of the present study revealed that 58.97% of tomato farmers in Rwanda are male and 30.78% are female. With what, the most applied pesticide is rocket brand with profenofos 400 g/L + cypermethrin 40 g/L which are the active ingredients with 71.79% followed by Dithane with 66.67% of application (**Table 1**). 53.85 of the assessed farmers are between 36 - 55 years old. The majority of the farmers affirmed to apply pesticide two times a week in the rainy season and 1 time a week in the sunny season. 71.79% of the surveyed farmers affirmed to use small pumps while applying the pesticides. The study of Asante *et al.* [17] revealed the intensive use of pesticides in tomato farms seems to provide nice and best quality of produce at sight for the markets and makes good deals for both the farmers and vendors. But, this seems to have contributed to the increase of food hazards responsible for 200 diseases spanning from diarrhea to cancer and diabetes in humans [7]. The studies of Nyirenda *et al.* [18] and Tarla *et al.* [19] highlighted that, although it seems logical for the farmers to do so, this result may also be explained by the inability for some farmers to properly read the labels on the containers of pesticides or their incapacity to remember the names of the pesticides due to illiteracy.

This research also revealed that 38.46% of the farmers apply the pesticides mainly dithane and rocket of the fresh tomato harvests. 58.97% of the farmers affirm to not be aware of the pesticide health effects and 58.97% are aware of the

Table 1. Pesticides applied in tomato fields and the people are aware of their application.

Type	Details	Information		
Socio-demographic	Gender	M		58.97%
		F		30.78%
		Cooperatives		10.26%
	Age	18 - 35		20.51%
		36 - 55		53.85%
		Over 55		5.13%
		N/A		12.82%
Pesticide application practices	Brend of pesticides usage	Dimethoate		2.56%
		Dithane (Mancozeb)		66.67%
		Rocket (Cypermethrin)		71.79%
		DUDU (Aceramectine)		15.38%
		SAFAR ZEB		51.28%
		RIDOMIL		38.46%
		Victory		17.95%
		Indofil		12.82%
		Thioda		5.13%
	Use frequency (how many times per season)	1 Time/Week		64.10%
		2 Times/Week		71.79%
		1 Time/Week		17.95%
	Application methods	Tradition		7.69%
		Pomp		89.74%
	pesticides application after Harvesting	Applicable		38.46%
		N/A		61.54%
	Disposal of pesticides containers	Applicable	Burning	12.82%
			Burying	15.38%
		N/A		72.23%
Pesticide health effects	Awareness of pesticide effects on health	Aware		35.90%
		Not aware		58.97%
	Eating unwashed tomatoes on fields/at home	Applicable		22.76%
		N/A		77.24%
	Types of effects on health	N/A		71.79%
		Skin itching		5.13%
		Eyes irritation		7.69%
		Allergy		2.56%
		Vomiting		5.13%
		Respiration issues		17.95%
		Cancer		10.26%
		Nausea		2.56%
		Headache		2.56%
Farmers' knowledge and skills	Training on pesticides	Yes		24.51%
		Not		76.92%
	Assistance from extension officer and agronomist	Yes		25.64%
		Not		69.10%
		N/A		5.13%

concern such as skin itching, eyes irritation, allergy, vomiting, respiration issues, cancer, nausea and headache. 76.92% of the farmers affirmed to not have had the training on the usage of the pesticides and 25.64% are receiving the assistance from extension officer and agronomist. The previous study revealed that, the level of education plays a great role in tomato farming and the middlemen are the assessors determining the welfare of the tomato farmers in the farming areas [20]. Although the 2022 data for pesticide poisoning level has not yet published, every year this poisoning kills 200,000 to 300,000 people worldwide and mostly occurs in developing countries [21].

The concentration of the pesticides found in the tomato samples from different districts of Rwanda are presented in **Table 2**. Farmers are applying pesticides regularly but the level of application might be critical. And pesticides are the active ingredients that are sold under various trade names for vegetables including tomatoes. With the frequent use of these pesticides, it can lead to their accumulation in tomatoes and subsequently in the people who consume them. The main objective of the survey was to investigate whether pesticide residues in tomatoes are significant enough to address to the public the minimum requirements of diet consumption. The results confirmed that pesticide residues were present in the unwashed tomatoes with certain quantities. While in washed tomatoes, the pesticides were absent in all samples including the tomato products such as paste

Table 2. Active ingredients of the used pesticides residues used in tomato farming in Rwanda ($mg \cdot kg^{-1}$).

Sites	Cypermethrin	Profenofos	Cyhalothrin	Alpha Cyper.	Mancozeb
Rusizi	0.812 ± 0.006	0.421 ± 0.001	nd	Nd	0.620 ± 0.000
Rusizi border	nd	nd	nd	Nd	0.241 ± 0.000
Rubavu	0.423 ± 0.189	0.563 ± 0.00	nd	0.217 ± 0.097	0.260 ± 0.002
Nyabihu	1.245 ± 0.001	nd	nd	Nd	
Musanze	0.328 ± 0.004	nd	nd	Nd	0.280 ± 0.000
Burera	0.586 ± 0.031	0.423 ± 0.002	nd	Nd	Nd
Gasabo	nd	nd	nd	Nd	Nd
Kicukiro	0.8445 ± 0.3275	nd	nd	Nd	0.615 ± 0.045
Rwamagana	0.517 ± 0.235	nd	nd	Nd	Nd
Nyagatare	0.351 ± 0.214	0.408 ± 0.013	nd	Nd	0.220 ± 0.000
Gisagara	1.1435 ± 0.0375	nd	nd	Nd	Nd
Nyanza	0.517 ± 0.235	nd	nd	0.018+0.000	Nd
Nyaruguru	nd	nd	nd	Nd	Nd
Control field A	0.526 ± 0.004	nd	nd	Nd	0.640 ± 0.009
Control field B	0.288 ± 0.007	nd	nd	Nd	Nd
Ketchup	nd	nd	nd	Nd	Nd
Tomato sauces	nd	nd	nd	Nd	Nd

nd: Not detected.

and ketchup. The concentration level of Cypermethrin is much more significant in Kicukiro and Rusizi Districts tomatoes than other districts with 0.8445 ± 0.3275 $mg \cdot kg^{-1}$ and 0.812 ± 0.006 $mg \cdot kg^{-1}$ respectively (Table 2). For tomatoes, the allowed Maximum Residue Limits (MRL) for cypermethrin is 0.5 $mg \cdot kg^{-1}$. Also, the concentration of cypermethrin in tomatoes collected from Burera district was 0.586 ± 0.031 $mg \cdot kg^{-1}$, Rwamagana was 0.517 ± 0.235 $mg \cdot kg^{-1}$ and Nyanza was 0.517 ± 0.235 $mg \cdot kg^{-1}$. This implies that these concentrations are very high in comparison with the MRL. The presence and the absence of some pesticides depend up on the type and the quantities of the active ingredients present in the distinctive brand. The studies highlighted the misuses of pesticides in Africa, this results in environment pollution, health risk and also the social economic effects [22] [23] [24].

4. Conclusion

In Rwanda, pesticides such as insects, fungi, rod*ents, and herbicides are applied to the tomatoes for the mitigating the pests and increase the tomato productivity. The aim of this work was to evaluate the utilization of pesticides and the analysis of tomato residues in the tomatoes and tomato products. The results of the present study showed that there are no proper and general ways to use pesticides in Rwanda and the pesticides' active ingredients residues are present in unwashed tomatoes at a level beyond that of allowed Maximum Residue Limits (MRL). The farmers must not consume un*washed tomatoes and they may be advised to use the proper way while applying the pesticides to the tomatoes.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

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