

Determination of Pesticides Residues in Eggplant and Tomatoes from Central Market in Khartoum State Using Quechers Method and Gas Liquid Chromatography-Mass Spectrometry

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Abbreviations: MRL: Maximum Residue Limits; GC: Gas Chromatography; ECD: Electron Capture Detectors; MS: Mass Spectrometry; SIM: Selected Ion Monitoring; EC: European Commission; RSD: Relative Standard Deviation; LOD: Limit of Detection; LOQ: Limit of Quantification

ABSTRACT

Pesticides are widely used in food production to increase food security, but they can have negative health effects on consumers. Both raw and processed vegetables have been found to be contaminated with pesticide residues. Consumers can be exposed to pesticides via food consumption. In this paper, we present the investigation of 30 pesticides in total of 90 samples of tomatoes and 27 samples of eggplant from central markets in Khartoum state using the quick easy cheap effective rugged and safe (QuEChERS) multi-residue extraction, followed by gas chromatography-mass spectrometry (GC-MS). Pesticide residues were not detected in 9 samples (8%), while 108 samples (92%) contained detectable amount of pesticide residues. The percentage of contaminated vegetable samples was high for both tomatoes (91.2%) and eggplant (96.3%). Multiple pesticides residues were detected on 65 samples with percentage of (55.6%) from total analyzed samples. Multiple residues with four pesticides were present in two samples of tomatoes. Sixteen pesticides chlorpyrifos, diazinon, cypermethrin, deltamethrin, omethoate, lambda-cyhalothrin, dimethoate, fenvalerate, fenpropathrin, pendimethalin, endosulfan, imidacloprid, carbaryl, permethrin, malathion and profenofos were detected in the analyzed vegetable samples with concentration range between 0.008-1.882 mg/kg and mean range between 0.0225- 0.8631 mg/kg. Summer and autumn were the most seasons contaminated with pesticides residues. It is concluded that the continuous monitoring and strict regulation of pesticide use on food crops, especially vegetables, are necessary.

Keywords: Pesticide residues; Tomatoes; Eggplant; QuEChERS; GC MS; Seasons; Markets; Khartoum

Introduction

A pesticide defines as "any substance or mixture of substances intended for preventing, destroying, attracting, repelling, or controlling any pest including unwanted species of plants or animals during the production, storage, transport, distribution, and processing of food, agricultural commodities, or animal feeds or which may be administered to animals for the control

of ectoparasites, pesticides are part of a large group of organic compounds that present extremely diverse physico-chemical properties and are widely used in the control or prevention of diseases in various crops, such as fruits, vegetables and cereals [1,2]. The use of pesticides in agriculture has helped to increase productivity and rising food production, most pesticides are

applied directly to the soil or sprayed over crop fields and hence are release directly to the environment. However, the continued use of pesticides specially insecticides increases the possibility of residues to be found in some vegetables, threatening the alimentary security. Pesticide residue refers to the pesticides that may remain on or in food after they are applied to food crops [3]. Pesticide residues in agriculture have been a crucial worldwide problem that directly threatened the environment and people's health. Over 1000 compounds may be applied to agricultural crops in order to control undesirable moulds, insects or weeds to ensure the safety of food for consumers, numerous legislations such as codex directives and European Commission have established Maximum Residue Limits (MRLs) for pesticides in foodstuffs [4,5].

The determination of pesticide residues in agricultural products, plant and environmental samples has been a major subject for many years because of their toxic potential risk for human health, persistence and tendency to bioaccumulate. For many years, analysis of fruit and vegetable samples for organophosphorus, organochlorine, and pyrethroids pesticides at low levels were by gas chromatography (GC) using selective detectors: flame photometric, nitrogen phosphorus, and electron capture detectors (FPD, NPD, and ECD). Although these detectors are sufficiently sensitive for compliance with maximum residues limits (MRLs) in European Union regulations, they provide poor specificity for confirmation in these matrixes; therefore, GC coupled with mass spectrometry (MS) was required [6,7]. Many investigations studies form many areas were reported that different type of pesticides left residual amounts in fruit and vegetables with residues levels in rang of mg/kg [8-10], also many methods and studies have reported the use of GC/MS and LC/MS with either full scan or selected ion monitoring (SIM) to control pesticide residues in matrixes such as fruit, vegetables, milk, and soils [11,12]. During the last years, the Quick, Easy, Effective, Cheap, Rugged, and Safe (QuEChERS) approach, has become very popular for the determination of pesticides on diverse food matrices include fruits and vegetables, this method has been readily accepted by many pesticide residue analysts because of its low organic solvent consumption, low cost per sample, fast, the accurate procedures non time consuming, and have high analyte recoveries [13,14]. Vegetables are commonly used to fulfill the balance diet requirement as they are a vital source of vitamins and fiber, tomato (*Lycopersicon esculentum*) and eggplant (*Solanum melongena*) are from the most popular and widely grown vegetables in the world, tomato and eggplant crops are much susceptible to insect attack and disease infestation from seedling to fruiting stage. Eggplant helps to prevent colon cancer, reduces cholesterol level, helps in the type 2 diabetes management, is very rich in antioxidant, and helps to control weight [15,16].

Materials and Methods

Study Area and Time

The tomatoes and eggplants samples were collected from central markets of Khartoum state including Khartoum central

market in Khartoum, Khartoum north central market in Khartoum north and Omdurman market (elshaabi) in Omdurman during summer, winter and autumn seasons during 2017.

Sample Collection and Treatment

A total of 117 vegetables samples were collected for pesticide residue analysis. The vegetable samples included 90 samples of tomatoes and 27 samples of eggplants. The sampling was performed in accordance with the general principles and methods of the European Commission (EC) directive 2002/63/EC [17]. Each representative vegetable sample was a composite of 6 to 10 subsamples of the same commodity collected through random sampling. All the samples (1-2 kg each) were placed in polythene bags, in box contain ice, to avoid contamination and deterioration, labeled, and transported to the laboratory and stored at -20°C until analysis.

Chemicals and Reagents

Pesticide reference standards including malathion, diazinon, profenofos, chlorpyrifos, chlorpyrifos-methyl, omethoate, dimethoate, cypermethrin, deltamethrin, fenpropathrin, permethrin, tetramethrin, cyfluthrin, fenvalerate, lamdacyhalothrin, lindane, heptachlor, aldrin, heptachlor epoxide, mixture endosulfan, dieldrin, endrin, o,p-DDT, carbaryl, carbofuran, bendiocarb, atrazine, imidacloprid, thiomethoxam and pendimethalin were purchased from Sigma Aldrich GmbH (Augsburg, Germany), Supelco and Bayer Crop Science, with certified purity ranging from 95% to 99%. Acetonitrile, acetone, sodium chloride, toluene, acetic acid and anhydrous magnesium sulfate were obtained from Scharlau (Barcelona, Spain). QuEChERS Finisterre micro centrifuge tube containing two or more of primary secondary amine (PSA), anhydrous magnesium sulfate (MgSO₄) and graphed carbon black (GCB) with details of TR-Q2035 (150mg MgSO₄, 25mg PSA, 2.5mg GCB) and TR-Q2015 (150mg MgSO₄, 25mg PSA) were obtained from Teknokroma (Barcelona, Spain). Piperonyl Butoxide (PPB) with certified purity 95% used as internal standard was obtained from Sigma Aldrich GmbH. All the organic solvents used were high performance liquid chromatography (HPLC) grade.

Preparation of Pesticide Standard Solution

Pesticide standard stock solutions (1000 mg/L) of malathion, diazinon, profenofos, chlorpyrifos, chlorpyrifos-methyl, omethoate, dimethoate, cypermethrin, deltamethrin, fenpropathrin, permethrin, tetramethrin, cyfluthrin, fenvalerate, lamdacyhalothrin, lindane, heptachlor, aldrin, heptachlor epoxide, mixture endosulfan, dieldrin, endrin, o,p-DDT, carbaryl, carbofuran, bendiocarb, atrazine, imidacloprid, thiomethoxam and pendimethalin were prepared separately with acetone and stored at -20 °C until use. A mixed pesticide standard solution of 50 mg/L was prepared by adding the proper volume of each individual stock solution and diluted to volume. Intermediate mixed pesticide standard solution of 10 mg/L was prepared from the mixed pesticide standard solution of 50 mg/L. Matrix-matched calibration standards were prepared by adding mixed pesticide standard working solutions in the blank

extract to reach the final concentrations of 0.005, 0.01, 0.05, 0.10, 0.20 and 0.50 mg/kg. Calibration standards in acetone were also prepared at the same concentration levels. All the standards were kept in a freezer at -20°C until use.

Sample Extraction and Cleanup Procedure

Ten grams of properly homogenized vegetable sample was taken in a 50-mL screw-capped polypropylene centrifuge tube, and 10 ml acetonitrile (MeCN) contain 1% acetic acid was added into the centrifuge tube. The centrifuge tube was closed properly and shaken vigorously for 30 s by vortex mixer. Then, 4g anhydrous MgSO_4 , 1g sodium chloride, 1g trisodium citrated dehydrate and 0.5g disodium hydrogen citrated sesquihydrate were added into the centrifuge tube, and it was shaken by vortex mixer for 1 min. afterward, the extract was centrifuged for 5 min at 5,000 rpm. An aliquot of 1 mL of the MeCN layer was transferred into a micro centrifuge tube containing 150mg anhydrous MgSO_4 , 25mg PSA, 2.5mg GCB for tomatoes or containing 150mg anhydrous MgSO_4 and 25mg PSA for eggplants. The content of the centrifuge tube was thoroughly mixed by vortex for 30 s and centrifuged for 5 min at 4,000 rpm. A one mL supernatant was taken into a clean test tube, and one drop of toluene was added into the test tube. The test tube containing the extract was stored at -20°C until analysis.

Gas Chromatography-Mass Spectrometry Analyses

A Shimadzu (QP 2010 GC-MS) gas chromatography equipped with mass selective detector and a RTX-5MS column (30 m long, 0.25 mm internal diameter, and 0.25 nm film thickness) was used for analysis. Sample injection was performed in the split less mode, with an injector temperature of 250°C . The temperature of the was programmed from an initial value of 60°C for 2 min, ramped to 150°C at $10^{\circ}\text{C}/\text{min}$ for 10 min, and to 250°C at $20^{\circ}\text{C}/\text{min}$ for 10 min, and was raised to 270°C at $10^{\circ}\text{C}/\text{min}$ for 15 min. Helium (99.999% purity) was used as a carrier gas with a constant flow rate of 1 mL/min. For the mass detector MS, the ion source and interface temperatures were maintained at 220°C and 270°C , respectively. Electron ionization (EI) was used at 70 eV in selective ion monitoring (SIM) and full-scan modes between 50 m/z and 500 m/z for the detection of different analytes. The solvent cut and total run time were 5 and 53 min, respectively.

Quality Control

The performance of the QuEChERS method was evaluated by performing recovery studies. The recovery rate and precision of the method (expressed as relative standard deviation (RSD), %) were measured by analyzing replicate pesticide-free samples of each type of vegetable, which were fortified at a concentration of 0.01 or 0.05 mg/kg for each pesticide. Sensitivity was evaluated by determining the limit of detection (LOD) and limit of quantification (LOQ), using the signal-to-noise ratio (S/N) of 3:1 and 10:1, respectively [18].

Results and Discussion

Pesticide Residues and Multiple Residues in Analyzed Samples

The level of pesticide residues in 117 vegetable samples was determined. Pesticide residues were not detected in 9 samples (8%), while 108 samples (92%) contained detectable amount of pesticide residues. The percentage of contaminated vegetable samples was high for both tomatoes (91.2%) and eggplant (96.3%); eggplant has the highest percentage of contaminated samples. No pesticide residues were detected in only one sample of eggplant and 8 samples of tomatoes Figure 1. Multiple pesticides residues were detected on 65 samples with percentage of (55.6%) from total analyzed samples; in tomatoes from 90 samples analyzes only 51 (56.6%) samples contain multiple pesticides residues from them 31 (34.3%), 18 (20%) and 2 (2.2%) samples contain two, three and four kind of pesticides residues respectively. In eggplant from 27 samples analyzes only 14 (51.9%) samples contain multiple pesticides residues from them 12 (44.4%) and 2 (7.4%) samples contain two and three kind of pesticides residues respectively Figure 2.

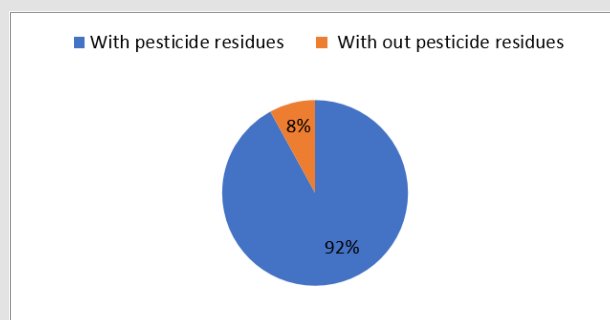


Figure 1: Percentages of samples without pesticides residue and with pesticides residue from the total number of samples analyzed.

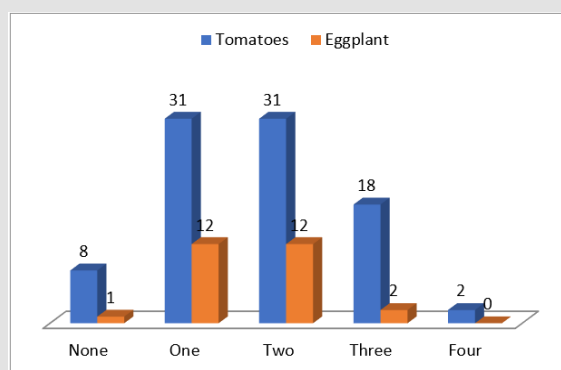


Figure 1: Number of different vegetable samples contains one or more pesticides residues.

Detection Frequencies of Pesticides in Analyzed Samples

From the 30 pesticides studied, only 16 pesticides were detected in the analyzed vegetable samples. Permethrin has been the most

common pesticides detected in the analyzed vegetable samples (21 samples) with concentration range between 0.032-1.025mg/kg followed by Endosulfan (20 samples) with concentration range between 0.015- 0.423mg/kg. Carbaryl has been detected in 17 samples with concentration range between 0.021- 1.052 mg/kg. Sixteen vegetable samples were contaminated by each of Cypermethrin, Deltamethrin and Malathion with concentration range of (0.008 - 0.051), (0.011 - 1.322) and (0.019 - 0.251) mg/kg respectively. Diazinon has been detected in fourteen samples with

concentration range of (0.114-0.543) mg/kg. Thirteen samples were contaminated by each of Profenofos and Fenprothrin with concentration range of (0.212 - 1.882) and (0.025 - 0.311) mg/kg respectively. Chlorpyrifos has been detected in eleven samples with concentration range of (0.035-0.123) mg/kg. Lamdacyhalothrin, Dimethoate, Pendamethalin, Fenlarate, Imidcloprid and Omethoate have been detected in 9, 8, 8, 7, 6 and 4 samples respectively Table1.

Table 1: Means and ranges of pesticides residues found in analyzed vegetable samples.

| Pesticides | Sample Information | | | Range mg/kg | Mean of (+) samples | Mean of total samples | Std D | Mean Std .Error |
|------------------|--------------------|-----------|----------|-------------|---------------------|-----------------------|--------|-----------------|
| | Total No | No of (+) | % of (+) | | | | | |
| Carbaryl | 117 | 17 | 14.5 | 0.022-1.052 | 0.4117 | 0.0637 | 0.2039 | 0.0189 |
| Chlorpyrifos | 117 | 11 | 9.4 | 0.035-0.123 | 0.0664 | 0.0062 | 0.0214 | 0.0019 |
| Cypermethrin | 117 | 16 | 13.7 | 0.008-0.051 | 0.0225 | 0.0035 | 0.0101 | 0.0009 |
| Deltamethrin | 117 | 16 | 13.7 | 0.011-1.322 | 0.5946 | 0.0813 | 0.2039 | 0.0225 |
| Diazinon | 117 | 14 | 12 | 0.114-0.543 | 0.2961 | 0.0354 | 0.1074 | 0.0099 |
| Dimethoate | 117 | 8 | 6.8 | 0.042-0.313 | 0.2188 | 0.0124 | 0.0515 | 0.0048 |
| Endosulfan | 117 | 20 | 17.1 | 0.015-0.423 | 0.1623 | 0.0286 | 0.0789 | 0.0073 |
| Fenprothrin | 117 | 13 | 11.1 | 0.025-0.311 | 0.1149 | 0.0128 | 0.0457 | 0.0042 |
| Fenlarate | 117 | 7 | 6 | 0.073-0.253 | 0.1496 | 0.0089 | 0.0388 | 0.0036 |
| Imidcloprid | 117 | 6 | 5.1 | 0.051-0.211 | 0.1312 | 0.0067 | 0.0322 | 0.0029 |
| Lamdacyhalothrin | 117 | 9 | 7.7 | 0.034-0.212 | 0.0952 | 0.0073 | 0.0298 | 0.0028 |
| Malathion | 117 | 16 | 13.7 | 0.019-0.251 | 0.1243 | 0.017 | 0.0521 | 0.0048 |
| Omethoate | 117 | 4 | 3.4 | 0.113-0.332 | 0.2045 | 0.0069 | 0.041 | 0.0038 |
| Pendamethalin | 117 | 8 | 6.8 | 0.123-0.424 | 0.2014 | 0.0139 | 0.0569 | 0.0053 |
| Permethrin | 117 | 21 | 17.9 | 0.032-1.025 | 0.3466 | 0.0671 | 0.02 | 0.0185 |
| Profenofos | 117 | 13 | 11.1 | 0.212-1.882 | 0.8631 | 0.0959 | 0.3235 | 0.0299 |

Pesticides residues in different Markets and Seasons in Analyzed Samples

In eggplant only five samples (18.5%) contain pesticides residues more than codex maximum residues limits, carbaryl has been detected in nine samples(33.3%) from each seasons and markets and only one sample from khartoum north market in autumn has been found above the codex maximum residues limits , cypermethrin has been detected in six samples(22.2%)and only one sample from omdurman market in summer has been found above

the codex maximum residues limits, endosulfan has been detected in five samples(18.8%)and only two sample from khartoum central and omdurman in summer and autumn respectively have been found above the codex maximum residues limits, imidacloprid has been detected in six samples(22.2%) and only one sample from omdurman market in summer has been found above the codex maximum residues limits. Each permethrin and fenprothrin has been detected in 7 (25.9%) and 8 (29.6%) samples respectively but no sample contains permethrin above the codex maximum residues limits Table 2.

Table 2: Comparison between markets and seasons in pesticides residues found in Eggplant. S (Summer), A (Autumn), W (Winter) and - (no MRLs established by Codex).

| Pesticides | Khartoum central market | | | Khartoum north | | | Omdurman | | | No above MRL | CODEX MRL [19] |
|---------------|-------------------------|------------|------------|----------------|------------|------------|------------|------------|------------|--------------|----------------|
| | S | A | W | S | A | W | S | A | W | | |
| Carbaryl | 1 0.953 | 1 0.882 | 1 0.521 | 1 0.072 | 1 1.052 | 1 0.062 | 1 0.822 | 1 0.759 | 1 0.052 | 1 | 1 |
| Cypermethrin | 1 0.029 | 1 0.015 | 0 | 1 0.019 | 0 | 1 0.008 | 1 0.045 | 0 | 1 0.008 | 1 | 0.03 |
| Endosulfan | 1 0.052 | 1 0.095 | 1 0.105 | 0 | 0 | 0 | 1 0.095 | 1 0.125 | 0 | 2 | 0.1 |
| Fenpropathrin | 1 0.112 | 1 0.209 | 0 | 1 0.172 | 1 0.311 | 1 0.025 | 1 0.185 | 1 0.089 | 1 0.052 | - | - |
| Permethrin | 1 0.832 | 0 | 1 0.968 | 1 0.059 | 1 0.561 | 0 | 1 0.985 | 1 1.025 | 1 0.052 | 0 | 1 |
| Imidacloprid | 1 0.162 | 1 0.092 | 1 0.051 | 0 | 1 0.211 | 1 0.076 | 1 0.195 | 0 | 0 | 1 | 0.2 |

Pesticides residues have been detected in all tomatoes sample analyzed in summer and autumn from Khartoum central market but in winter only three samples were free of pesticides residues. The most pesticides detected in Khartoum market during the three seasons were Carbaryl, Chloropyrifos, Dimethoate, Deltamethrin, Profenofos, Lamdacyhalothrin, Malathion, Pendamethalin, Permethrin, Diazinon and Endosulfan in addition to Cypermethrin, Fenlarate, Omethoate in summer and autumn and Fenpropathrin in autumn only. In khartoum central market only one sample in each summer and winter contain fenlarate and deltamethrin respectively had been found more than MRLs established by codex; but in autumn three samples were been found more than MRLs established by codex contain deltamethrin in two samples and diazinon in one sample. The most pesticides detected in Khartoum north during the three seasons were Carbaryl, Dimethoate, Deltamethrin, Malathion, Pendamethalin, Permethrin, Diazinon and Endosulfan in addition to Cypermethrin, Fenlarate, Lamdacyhalothrin, Fenpropathrin and chloropyrifos in summer and autumn and Profenofos in autumn and winter. In Khartoum north market two samples contain deltamethrin been found more than MRLs established by Codex in each summer and winter; but in autumn one sample had been found more than MRLs established by Codex contain deltamethrin. One sample from each summer and autumn contain Fenlarate more than MRLs established by Codex [19].

The most pesticides detected in Omdurman market during the three seasons were Deltamethrin, Cypermethrin, Fenlarate, Profenofos, Malathion, Pendamethalin, Permethrin and Endosulfan in addition to Chloropyrifos and Diazinon in summer and autumn; Carbaryl and Lamdacyhalothrin have been detected in autumn and Fenpropathrin detect in summer only. Regarding Omdurman

samples deltamethrin had been found more than MRLs established by Codex in 1, 3 and 2 samples from summer, autumn and winter respectively and one sample contain fenlarate from summer exceeded the MRLs established by Codex Table 3. This study shows the evidence of contamination of vegetables specially tomatoes and eggplant with pesticides residues in Khartoum state markets. Slightly more than 92% of the samples analyzed contained pesticides residues and from present samples more than 18.8% above MRLs established by Codex. According to results there were a little different in pesticides found in tomatoes and eggplant in the different seasons and no sample from the tow kind of vegetables contain organochlorine pesticides except Endosulfan in 15 different samples and no tomatoes samples show Endosulfan residues above MRLs set by Codex, in previous studies some vegetables from Ghana [20], Saudi Arabia [21] and China [22] contain organochlorine pesticides which were banned or restricted in majority of countries. Most of pesticides residues found in tomatoes in winter are similar to that found by Magdoleen especially for Malathion, Chloropyrifos and Dimethoate [23]. In study by Safiqul and other there were detected different organophosphorus like diazinon, malathion and chloropyrifos in eggplant from retail markets of some town in Bangladesh and there result show little different from our study specially in pesticides residues exceeded the MRLs which was dimethoate [24]. In the analysis of pesticides on fresh vegetables using GC, interference and contamination resulting from plant pigments and the matrix are often encountered. Although silica gel and florisol are commonly used to reduce the matrix effects, in this study activated carbon were another material used to remove the pigments from fresh vegetables. Activated carbon is often used because it is cheap and strongly adsorbs many organic compounds in some fresh vegetables [25].

Table 3: Comparison between markets and seasons in pesticides residues found in Tomatoes.

| Market | Season | Pesticide found and amount (mg/kg) | No(+) | No above MRL | Codex MRL [19] |
|---------------------------|------------------------------|--|-------|--------------|----------------|
| Khartoum central | Summer | Carbaryl (0.022,0.252) | 2 | 0 | 5 |
| | | Chloropyrifos (0.055, 0.064) | 2 | 0 | 0.5 |
| | | Dimethoate (0.225. 0.313) | 2 | - | - |
| | | Deltamethrin (0.011, 0.052) | 2 | 0 | 0.3 |
| | | Cypermethrin (0.014, 0.015) | 2 | 0 | 0.2 |
| | | Profenofos (0.452) | 1 | 0 | 10 |
| | | Fenylarate (0.154) | 1 | 1 | 0.1 |
| | | Lamdacyhalothrin (0.053, 0.064, 0.085) | 3 | - | - |
| | | Malathion (0.023, 0.059) | 2 | 0 | 0.5 |
| | | Pendamethalin (0.153) | 1 | - | - |
| | | Permethrin (0.184, 0.238) | 2 | 0 | 1 |
| | | Diazinon (0.114, 0.125, 0.354) | 3 | 0 | 0.5 |
| | | Omethoate (0.122, 0.332) | 2 | - | - |
| | | Endosulfan (0.113, 0.192) | 2 | 0 | 0.5 |
| | Autumn | Carbaryl (0.451) | 1 | 0 | 5 |
| | | Chloropyrifos (0.121) | 1 | 0 | 0.5 |
| | | Dimethoate (0.042) | 1 | - | - |
| | | Deltamethrin (0.453, 0.524) | 2 | 2 | 0.3 |
| | | Cypermethrin (0.024, 0.042) | 2 | 0 | 0.2 |
| | | Profenofos (0.452) | 1 | 0 | 10 |
| | | Fenylarate (0.092) | 1 | 0 | 0.1 |
| | | Lamdacyhalothrin (0.171, 0.212) | 2 | - | - |
| | | Malathion (0.095, 0.158) | 2 | 0 | 0.5 |
| | | Pendamethalin (0.184) | 1 | - | - |
| | | Permethrin (0.091) | 1 | 0 | 1 |
| | | Diazinon (0.154, 0.543) | 2 | 1 | 0.5 |
| | | Omethoate (0.113, 0.251) | 2 | - | - |
| | | Endosulfan (0.231, 0.326) | 2 | 0 | 0.5 |
| | Fenpropathrin (0.054, 0.064) | 2 | 0 | 1 | |
| | Winter | Carbaryl (0.451) | 1 | 0 | 5 |
| | | Chloropyrifos (0.082) | 1 | 0 | 0.5 |
| | | Dimethoate (0.212) | 1 | - | - |
| | | Deltamethrin (0.519) | 1 | 1 | 0.3 |
| | | Profenofos (0.412, 0.364) | 2 | 0 | 10 |
| | | Lamdacyhalothrin (0.093) | 1 | - | - |
| | | Malathion (0.064) | 1 | 0 | 0.5 |
| Pendamethalin (0.123) | | 1 | - | - | |
| Permethrin (0.032, 0.051) | | 2 | 0 | 1 | |
| Diazinon (0.253) | | 1 | 0 | 0.5 | |
| Endosulfan (0.032, 0.296) | | 2 | 0 | 0.5 | |

| | | | | | |
|---------------------------------|------------------------|------------------------------|---|-----|-----|
| Khartoum north | Summer | Carbaryl (0.511) | 1 | 0 | 5 |
| | | Chloropyrifos(0.046, 0.065) | 2 | 0 | 0.5 |
| | | Dimethoate (0.094) | 1 | - | - |
| | | Deltamethrin (0.344, 0.715) | 2 | 2 | 0.3 |
| | | Cypermethrin (0.012) | 1 | 0 | 0.2 |
| | | Fenvarlate (0.215) | 1 | 1 | 0.1 |
| | | Lamdacyhalothrin (0.054) | 1 | - | - |
| | | Malathion (0.207, 0.254) | 2 | 0 | 0.5 |
| | | Pendamethalin (0.254) | 1 | - | - |
| | | Permethrin (0.219, 0.521) | 2 | 0 | 1 |
| | | Diazinon (0.132, 0.353,) | 2 | 0 | 0.5 |
| | | Endosulfan (0.015, 0.423) | 2 | 0 | 0.5 |
| | | Fenpropathrin (0.025) | 1 | 0 | 1 |
| | Autumn | Carbaryl (0.485) | 1 | 0 | 5 |
| | | Chloropyrifos (0.035, 0.048) | 2 | 0 | 0.5 |
| | | Dimethoate (0.223, 0.254) | 2 | - | - |
| | | Deltamethrin (1.223) | 1 | 1 | 0.3 |
| | | Cypermethrin (0.035, 0.051) | 2 | 0 | 0.2 |
| | | Profenofos(0.212) | 1 | 0 | 10 |
| | | Fenvarlate (0.165) | 1 | 1 | 0.1 |
| | | Lamdacyhalothrin (0.091) | 1 | - | - |
| | | Malathion (0.183, 0.211) | 2 | 0 | 0.5 |
| | | Pendamethalin (0.424) | 1 | - | - |
| | | Permethrin (0.482) | 1 | 0 | 1 |
| | | Diazinon (0.254, 0.452) | 2 | 0 | 0.5 |
| | | Endosulfan (0.247) | 1 | 0 | 0.5 |
| | Fenpropathrin (0.1544) | 1 | 0 | 1 | |
| | Winter | Carbaryl (0.061) | 1 | 0 | 5 |
| | | Dimethoate (0.087) | 1 | - | - |
| | | Deltamethrin (1.322, 0.636) | 2 | 2 | 0.3 |
| Profenofos(0.676, 1.245, 1.882) | | 3 | 0 | 10 | |
| Malathion (0.025, 0.052) | | 2 | 0 | 0.5 | |
| Pendamethalin (0.195) | | 1 | - | - | |
| Permethrin (0.327) | | 1 | 0 | 1 | |
| Diazinon (0.394) | | 1 | 0 | 0.5 | |
| Endosulfan (0.211) | | 1 | 0 | 0.5 | |

| | | | | | |
|---------------------------|---------------------------|------------------------------------|---|-----|-----|
| Omdurman | Summer | Chloropyrifos(0.039, 0.123) | 2 | 0 | 0.5 |
| | | Profenofos (0.981) | 1 | 0 | 10 |
| | | Deltamethrin (0.834) | 1 | 1 | 0.3 |
| | | Cypermethrin (0.023) | 1 | 0 | 0.2 |
| | | Fenvarlate (0.253) | 1 | 1 | 0.1 |
| | | Malathion (0.214, 0.251) | 2 | 0 | 0.5 |
| | | Permethrin (0.052, 0.253) | 2 | 0 | 1 |
| | | Diazinon (0.231, 0.294) | 2 | 0 | 0.5 |
| | | Endosulfan (0.045, 0.351) | 2 | 0 | 0.5 |
| | Fenpropathrin (0.042) | 1 | 0 | 1 | |
| | Autumn | Carbaryl (0.041) | 1 | 0 | 5 |
| | | Chloropyrifos(0.052) | 1 | 0 | 0.5 |
| | | Profenofos (0.525, 1.673) | 2 | 0 | 10 |
| | | Deltamethrin (0.474, 0.576, 0.952) | 3 | 3 | 0.3 |
| | | Cypermethrin (0.043) | 1 | 0 | 0.2 |
| | | Fenvarlate (0.095) | 1 | 0 | 0.1 |
| | | Lamdacyhalothrin (0.034) | 1 | - | - |
| | | Malathion (0.082, 0.115) | 2 | 0 | 0.5 |
| | | Pendamethalin (0.154) | 1 | - | - |
| | | Permethrin (0.326) | 1 | 0 | 1 |
| | | Diazinon (0.492) | 1 | 0 | 0.5 |
| | Endosulfan (0.114, 0.215) | 2 | 0 | 0.5 | |
| | Winter | Deltamethrin (0.921, 1.425) | 2 | 2 | 0.3 |
| | | Cypermethrin (0.024) | 1 | 0 | 0.2 |
| | | Fenvarlate (0.073) | 1 | 0 | 0.1 |
| | | Malathion (0.019) | 1 | 0 | 0.5 |
| | | Pendamethalin (0.141) | 1 | - | - |
| Permethrin (0.072, 0.521) | | 2 | 0 | 1 | |
| Endosulfan (0.057) | | 1 | 0 | 0.5 | |
| Profenofos (0.921, 1.425) | | 2 | 0 | 10 | |

The diversity of classes of pesticide residues such as organophosphorus (Chloropyrifos, Omethoate, Dimethoate, Malathion, Profenofos and Diazinon), pyrethroids (Deltamethrin, Cypermethrin, Permethrin, Fenvarlate, Pendamethalin, Fenpropathrin and Lamdacyhalothrin) and organochlorines (Endosulfan) detected in this study show that the proposed method to determine residues of pesticides in various tomatoes and eggplant is rapid, simple, sensitive and uses smaller amount of organic solvents, reducing the risk for workers and the environment.

Conclusion

This study investigated the levels of pesticide residues in vegetable samples (tomatoes and eggplant) and compared this level between seasons and markets in Khartoum state in Sudan. The results indicated that most of the tomatoes samples were contaminated with pesticide residues, some pesticides residues

concentrations in few samples of tomatoes and eggplant have been found above the MRLs established by Codex. The observed levels of pesticide residues may pose a potential health risk to consumers. Therefore, to reduce this risk, farmers should be sensitized to better pesticide safety practices and the need for continuous pesticide residue monitoring is highly recommended.

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