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Human Health Risk Assessment of Pesticide Residues in *Solanum lycopersicum* Fruit Sold in Lagos Metropolis, South-West Nigeria

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Abstract *Tomato is a vegetable that is eaten all over the world including Nigeria and in order to control infestation by pests, most tomato farmers use pesticides that may impart harmful effect on human. Consequently, this study was designed to assess pesticides residues and associated health risks in tomatoes sold in Lagos state. The result obtained indicated the presence of alpha and delta lindane, heptachlor, heptachlor epoxide, endrin, endosulfan, endosulfan sulphate and ether. Mean concentrations (mg/kg) and estimated daily intake (EDI) (mg/kg/day) of the pesticide residues were in the range of 0.0042 to 0.336 mk/kg and 7.5E- 6 to 2.3E-4 mg/kg/day respectively. The hazard quotient (HQ) ranged from 0.00024 to 17.77, while the hazard indices range from 1.00 to 18.92. The incremental lifetime cancer risk (ILCR) for the pesticide residues ranged from 5E- 5 to 2.1E- 3. The mean concentration of most of the pesticide residues in the tomato samples were above their maximum residue limit (MRL) while some had estimated daily intake (EDI) above their established acceptable daily intake (ADI) and hazard quotients (HQ) above their safe value. The hazard indices (HI) and Incremental lifetime cancer risk (ILCR) for the pesticide residues were above their safe values. The results and findings of the study indicate that there is need for continuous monitoring of pesticides residues in tomatoes and education of farmers on the uses of pesticides.*

Key Words: *Tomato, pesticide residue, health risk assessment, maximum residue limit*.

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1.0 Introduction

Tomato (*Lycopersicon esculentum Mill.)* is a well-known vegetable crop that is widely grown and consumed worldwide. According to FAO (2011), *Lycopersicon esculentum Mill*, is the second most important vegetable crop next to potato (FAO, 2011). Results reported for the chemical constituent of tomato indicated the presence of fatty acid derivatives (C_6 aldehydes and alcohols, terpenoids, sugars, organic acids), glutamate, lycopene, carotenoids, α-, β-, γ -, δ-carotene and lutein, polyphenol, dietary fibre, proteins, fats, minerals (potassium, phosphorus, sulphur, magnesium, calcium, iron, copper and sodium), vitamins (B_1, B_2, B_3, provitamins A, E and H) (Paolo *et al*, 2018 ; Mladenovic, 2014; Viskelis *et al*, 2015). Tomato is also rich in minerals, sugars, acids, antioxidants such as lycopene, β-, carotene, carotenoids content, this makes it contribute significantly to human nutrient (FAO, 2013).

One of the major challenges that limits the growth and yield of tomato in the farm is attack by pest including fungi, bacteria, viruses and nematodes. In order to curb the menace from pests, farmers have integrated several approaches including the use of chemical compounds called pesticide (Singh, 2013). Pesticides are chemical compounds(insecticides or herbicides) formulated to kill pest (insects, rodents and microorganisms) and unwanted plants (weeds) that damage and affect crop yield (Singh, 2013). They are applied on crops in varying manner either on the farm, after harvest during storage, for curative purposes where broad-spectrum pesticides are applied to quickly remove, or minimize pest population; or in a protectant mode where pesticides are applied before the predicted infestation or attack of the pest, or as prophylactics, to prevent the expansion of pest populations (Tijani and

Sofoluwe, 2016). Pesticides provide higher crop yield and quality to farmers thus increasing agricultural output and farm income and cheaper food price to consumers (Jozsef, 2013). The benefits of pesticides use are high relative to risks, when they are properly applied (Jozsef, 2013). Using pesticide correctly means application of pesticide on crops in the right quantity/dose that does not exceed maximum residue limit and avoidance of spray drift by effectively targeting the crops or pest of interest. Spray drift leads to movement of pesticides to non-target organisms and evaporation of the pesticides (Pimentel, 2005). Pesticides are potentially toxic to organisms in the environment and can impart short term (acute) and long term (chronic) health effects on humans, depending on the type (i.e, insecticide or herbicide. For example; insecticide tend to be more toxic to humans than herbicides), concentration, and route of exposure (the order of effect or toxicity is ingestion >inhalation>dermal) hence needs to be used safely (WHO, 2012). For these reasons, in view of the known and established toxicity risk that can be incurred from improper application of pesticide, the World Health Organisation (WHO) reviews evidence and develops internationally accepted maximum limits for pesticide residue (maximum residue limits) in food and water in order to protect public health. This regulation covers the production, distribution and use of pesticide and periodic monitoring of pesticide residues in food and the environment (WHO, 2012). Pesticide residue refers to any substance or mixture of substances in food resulting from the use of a pesticide including any specified derivatives, such as degradation and conversion products, metabolites, reaction products and impurities considered to be of toxicological significance (McNaught and Wilkinson, 2019). Pesticides that are legalized for use on food in international trade presently are non-genotoxic because within certain concentration, they do not have any effect on the DNA and will not cause mutation or cancer (WHO, 2012).

Tomato is widely consumed in Nigeria but due to existing land mass and weather condition, it is widely cultivated in the Northern part of Nigeria than in the South (Abolusoro *et al*., 2014). The use of pesticides in Nigeria is regulated by the National Agency for Food and Drug Administration and Control (NAFDAC), National Environmental Standards and Regulation Enforcement Agency (NESREA) and Federal Ministry of Agriculture and Rural Development (NAFDAC, 2016a). NAFDAC approved the use of about 62 pesticides of which about 34 and 28 are insecticides and herbicides respectively (NAFDAC, 2016a; FMAWR, 2007), while banning 30 pesticides (NAFDAC, 2016b). Pesticide application for enhance yield or protection of tomato is receiving wider acceptability but existing challenges seems to be knowledge of proper method of application and utilization of banned and toxic pesticides. Therefore, the present study is aimed at determining the concentration of pesticide residues in some tomatoes sold in Nigeria in order to assess the risk associated with the consumption of this product.

2.0 Materials and methods

2.1 Chemicals and reagents

Mixed organochlorine pesticides (OCPs) reference standard containing fourteen (14) pesticides namely, alpha-lindane, delta-lindane, endosulfan ether, heptachlor, aldrin, heptachlor epoxide, trans- chlordane, p,p'-DDE, dieldrin, endrin, endosulfan, endosulfan sulfate, endrin ketone and methoxychlor of 99 % purity were imported from AccuStandard (New Haven, USA). Dichloromethane, n-hexane and methanol were purchased from Merck, Darmstadt (Germany). Anhydrous sodium sulphate and sodium chloride were purchased from Sigma – Aldrich (USA). All chemicals and reagents were stored according to manufacturer's recommendation until use.

2.2 Sample collection

Fresh tomatoes samples about 5 kg each from four different sources; Kano, Abeokuta, Sagamu and Ghana (all in Nigeria and Ghana) were purchased in September, 2019 from Mile 12 market located in Ketu, Lagos state, Nigeria. Most food crops eaten in Lagos state are grown in other states or regions and brought into Lagos state for sale. Information on the source of the tomato samples was obtained from the tomato wholesalers. Each tomato sample was a composite of subsamples of the same commodity (source) collected through random sampling. Mile 12 market is a major market that serves as entry route of most food stuffs intended for Lagos state consumers. It is there that retailers buy from wholesalers who bring foodstuffs from different part of Nigeria into Lagos state and retail them in different parts of Lagos state. The tomato sampling was done according to the

Guidance Document on Analytical Quality Control and Method Validation Procedures for Pesticides Residues Analysis in Food and Feed (SANTE/11813/2017) document of the European Commission. They were packaged in clean dark properly labelled polythene bags after purchase, taken to the laboratory immediately and stored in the refrigerator pre-set at 4^0 C. They were processed and analysed within three (3) days.

2.3 Sample preparation

The tomato samples were washed with water, blended and homogenised using a domestic blender. The blended samples were stored in conical flask, stoppered and labelled according to source before preservation in a refrigerator at -20^0 C**.** An aliquot of 2 g of homogenized tomato sample was put in a clean 50 ml conical flask and 10 ml of dichloromethane was added, stoppered and sonicated for two hours at 270 rpm. The mixture was vortexed for one minute, followed by the addition of 4 g anhydrous sodium sulfate and 1 g sodium chloride**.** The samples were re-sonicated for 20 minutes, after which it was allowed to stand for 5 minutes and centrifuged for 5 minutes at 2500 rpm before removing the supernatant for clean-up. The clean-up was produced by solid phase extraction using Agilent cartridges for the removal of impurities and other contaminants. The cartridges were initially conditioned with 10 ml methanol before connecting to solid phase extractor and the extract were poured through for elution with 5 ml dichloromethane. The eluted sample was concentrated using nitrogen concentrator at room temperature to 2 ml and transferred into GC vials for GC-MS analysis.

2.4 Standard preparation

Stock solution of pesticide standard mix containing fourteen (14) pesticides was prepared in n-hexane at a concentration of 100 µg mL^{-1} and stored in dark flasks at -20 °C until use. The working standard solutions were prepared daily at concentrations of 2.5 µg mL^{-1}, 5 µg mL^{-1} and 10 µg mL^{-1} by dilution of the standard stock solution with hexane for the calibration of the instrument.

2.5 GCMS analysis

Tomato sample extracts were analysed using GC 7890A Agilent coupled with an electron capture detector and interfaced with mass selective detector model 5975 C (MSD). The electron ionization was at 70 ev with an ion source temperature of 250^0 C. Helium gas (99.9 %) at constant flow rate 0.5 $ml\,min^{-1}$ was used as carrier gas while HP 5 column (30 *m* ×320 µm ×0.25 µm film thickness) was the stationary phase. 1 µL standard or sample was injected in splitless mode at 250 °C. The GC oven was operated with the following temperature program: initial temperature of 80 ^{0}C for 4 minutes and then heated at a rate of 5 °C min^{-1} to 240 °C and heated again at a rate of 11 ^{0} C to 280 °C and held for 5 minutes. The constituents of the mixed pesticide reference standards were identified by comparing the mass spectra with a known standard using 5975 MSD (mass detector) with Chemstation software library.

2.6. Method Validation

The method was validated by spiking each homogenised tomato sample from a specific source with different levels (2.5 µg ml^{-1}, 5 µg ml^{-1} and 10 µg ml^{-1}) of the mixed OCPs standard. The spiked tomato samples were extracted and cleaned as previously described. The extracts were analysed by GC – MS as described. The analytical parameters validated are the linearity, range, sensitivity, limits of detection and quantification, accuracy and precision.

Linearity, range, sensitivity, limits of detection and quantification were determined from the analytical curve plots for each pesticide. The limits of detection (LOD) were calculated by using equation 1(Escarlet *et al,* 2018).

$$\text{LOD} = {}^{3.3\,x\,S_y}/_{b} \quad (1)$$

where b is the slope of the analytical curve and s is the residual standard deviation of the analytical curve. LOQ was calculated as LOQ = 3 x LOD. The accuracy (recoveries) and precision of the extraction method were determined as the average of three replicates. The selectivity of the method was evaluated by the separation of the analytes.

2.7 Human health risk assessment

2.7.1 Estimation of daily pesticide residue intake

The health risk posed to consumers of the tomato samples was evaluated using dietary intake of pesticide residue and was compared with established acceptable daily intake (ADI, mg/kg bw)). The estimated daily intake (EDI, mg/kg/day)) of pesticides through tomato consumption was calculated according to equation 2 US-EPA, (2000)

$$\text{EDI} = \frac{C_R\ X\ IR}{BW} \quad (2)$$

where C_R is the average concentration of pesticide residue in the tomato samples (mg/kg), and IR is the daily tomato consumption rate. The daily ingestion of vegetables (tomato is a fruiting vegetable) for an adult Nigerian is 89.3 g/person/day i.e. 0.0893 kg/day (WHO, 2017), while the average body weight BW for an adult Nigerian used in this study is 63 kg (Kelle *et al*, 2020).

2.7.2 Non – carcinogenic risk

Non – carcinogenic risks for individual pesticide residue in tomato samples were evaluated by computing the hazard quotient using equation 3 (US EPA, 2014; Gerba, 2019).

$$HQ = \frac{EDI}{RfD} \qquad (3)$$

where RfD is the oral reference dose (mg/kg/day) which is an estimation of the maximum permissible risk on human population through daily exposure, taking into consideration a sensitive group that is likely to be without an appreciable risk of deleterious (non- cancer) effects during lifetime.

Non- cancer risks are expressed in terms of a hazard quotient (HQ) for a single substance, or hazard index (HI) for multiple substances (Gerba, 2019) that affect the same target organ or organ system (US EPA, 2005). HQ < 1 indicates no significant risk or systematic toxicity, HQ > 1 could represent a potential risk (Gerba, 2019).

To evaluate the potential risk to human health through more than one pesticide residue, the hazard index was calculated. Hazard index (HI) is the sum of all hazard quotients (HQ) calculated for individual pesticide residue for a particular exposure pathway (equation 4)

$$HI = \sum HQ \qquad (4)$$

It is assumed that the magnitude of the effect is proportional to the sum of the multiple pesticide residues and that the pesticide residues affect the same target organ or organ system.

The population is assumed to be safe when HI < 1, chronic risks may happen if H1 > 1 (USEPA, 2005; USEPA, 2014; Gerba, 2019).

2.7.3 Carcinogenic risk

The possibility of developing cancer through intake of carcinogenic pesticide residues in the tomato samples was estimated using the Incremental Lifetime Cancer Risk (ILCR) model expressed according to equation 5 equation (US EPA, 2014; Gerba, 2019)

$$ILCR = CDI \times CSF \qquad (5)$$

where CDI is chronic daily intake of chemical carcinogen, mg/kg bw/day which represents the lifetime average daily dose of exposure to the chemical carcinogen, CSF is the cancer slope factor (CSF), which is the risk produced by a lifetime average dose of 1 mg/kg bw/day and is contaminant specific

$$CDI = \frac{EDI.\ EF.\ ED}{AT} \qquad (6)$$

where EF is exposure frequency (days/ year), according to USEPA 365 days/year, ED is exposure duration (years), 70 years (American adult) for carcinogenic (USEPA, 2005; Gerba, 2019). According to World Bank the life expectancy of an adult Nigerian is 54 years (World Bank, 2018). AT is average time – the period over which exposure is averaged (days); for carcinogens the average time is 25,550 days (365 days/year x 70 years) based on a lifetime exposure of 70 years, for the Nigerian people is 365days/year x 54 years.

Cancer risk of $1\,x\,10^{-4}$ to $1\,x\,10^{-6}$ is considered acceptable EPA (US EPA, 2014). Cancer risk of $1\,x\,10^{-4}$ and $1\,x\,10^{-6}$ indicates a probability of 1 in 10,000 individuals and 1 in 1,000000 individuals developing cancer during a lifetime. Estimation of cancer risk was computed for only those pesticide residues with evidence of probability or possibility of causing cancer.

3.0 Results and Discussion

The four sources of tomato samples used in the study are Kano, Abeokuta, Sagamu and Ghana abbreviated KT, AT, ST and GT for Kano tomato, Abeokuta tomato, Sagamu tomato and Ghana tomato respectively. The mean concentration (mg/kg) of alpha lindane is 0.0042 mk/kg in GT sample and 0.0053 mg/kg in KT sample, it was below detection limit in AT and ST samples. Delta lindane was detected only in KT at mean concentration of 0.0005 mg/kg. The mean concentration of heptachlor in GT, KT, AT and ST are 0.039 mg/kg, 0.337 mg/kg, 0.129 mg/kg and 0.009 mg/kg respectively, while heptachlor ranged from 0.008 mg/kg to 0.163 mg/kg in ST, GT, AT, and KT. 0. 003 mg/kg to 0.005 mg/kg is the range of mean concentration of endrin in ST, GT, AT and KT and 0.009 mg/kg to 0.336 mg/kg the range of mean concentration of endosulfan ether in GT, KT, AT and ST. Mean concentration of endosulfan is 0.001 mg/kg in GT and 0.004 mg/kg in KT, it was below detection limit in KT and ST. The mean concentration of endosulfan sulphate is 0.165 mg/kg in AT and 0.249 mg/kg in ST, it was below detection limit in GT and KT.

The analytical curve of pesticide residues in spiked tomato extracts had determination coefficient r^2 higher than 0.992 in the range of 2.5 µg ml^{-1} to 10 µg ml^{-1} which indicates linearity and acceptable fits of the data. The mean recoveries (accuracy) of the pesticide residues in the spiked tomato sample extracts ranged from 72 – 109 %, while the precision ranged from 9 to 13 %. These ranges are within the range 70 – 120 % for recoveries and RSD < 20 % recommended by SANTE/11813/2017 Guidance Document on Analytical Quality Control and Method Validation Procedures for Pesticides Residues Analysis in Food and Feed of the European Commission.

Figs.1 to 4 present the chromatograms of OCPs in tomato samples (from four different sources) obtained from Mile 12 market, Ketu, Lagos state, Nigeria. Six pesticide residues out of the 14 OCPs analysed were below detection limit hence were excluded from computation of the estimated daily intake (EDI) of the pesticide residues in the tomato samples. Also, out of eight pesticide residues used for the calculation of EDI some sources had pesticide residues below detection limit. The pesticide residues detected included alpha (α-HCH) and delta (δ-HCH) lindane, heptachlor, heptachlor epoxide, endrin, endosulfan, endosulfan sulphate and endosulfan ether. Alpha lindane residue was not detected in AT and ST but was detected in KT (0.0053 mg/kg) and GT (0.0042 mg/kg). The mean concentrations (mg/kg) of alpha lindane were below its maximum residue level (MRL) of 0.01 mg/kg in fruiting vegetables (tomato is a fruiting vegetable). With the exception of heptachlor in KT, heptachlor epoxide in GT, KT and AT, endosulfan sulphate in AT and ST, and endosulfan ether in KT and AT, all the pesticide residues had mean concentrations below their maximum residue level, MRL (Table 1 and 2). MRL refers to the highest concentration of a pesticide residue that is legally tolerated in or on food or feed when pesticides are correctly applied.

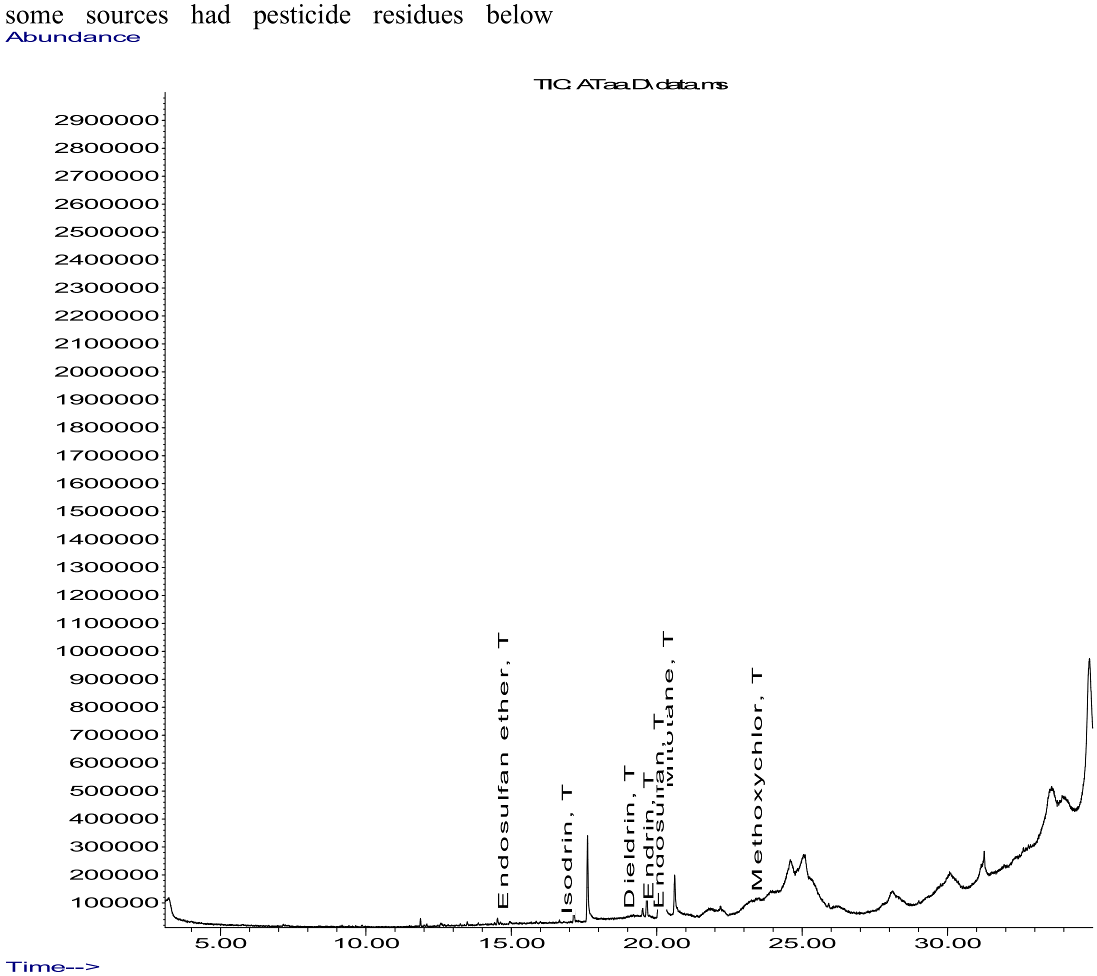

Fig. 1: Chromatogram of Abeokuta tomato (AT)

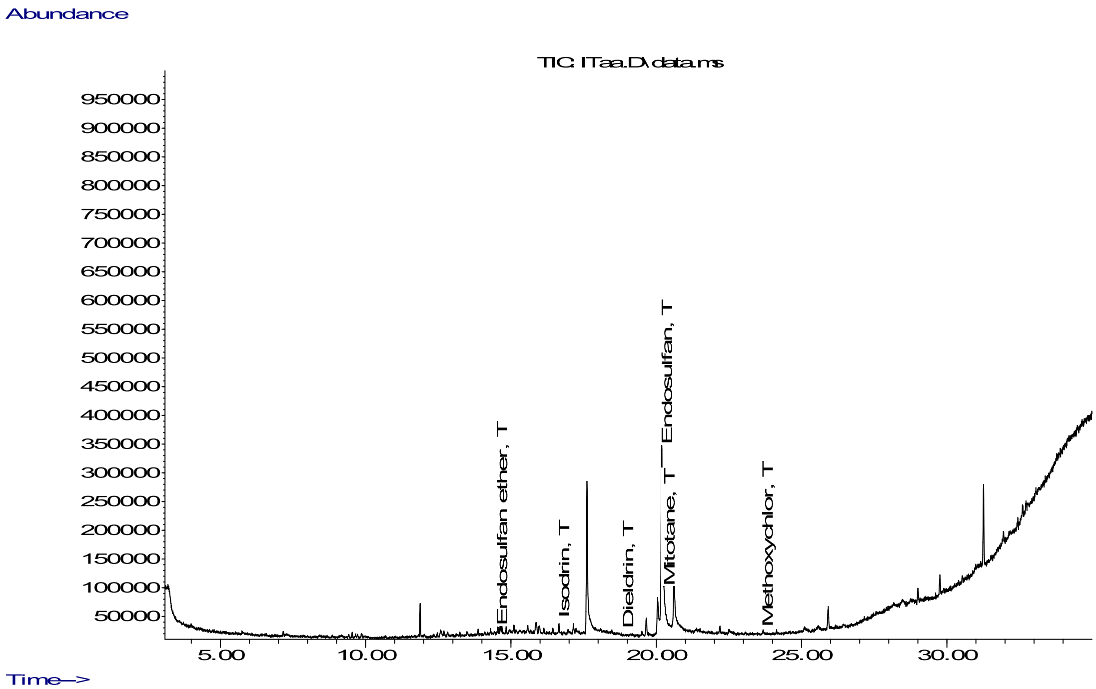

Fig. 2: Chromatogram of Sagamu tomato (ST)

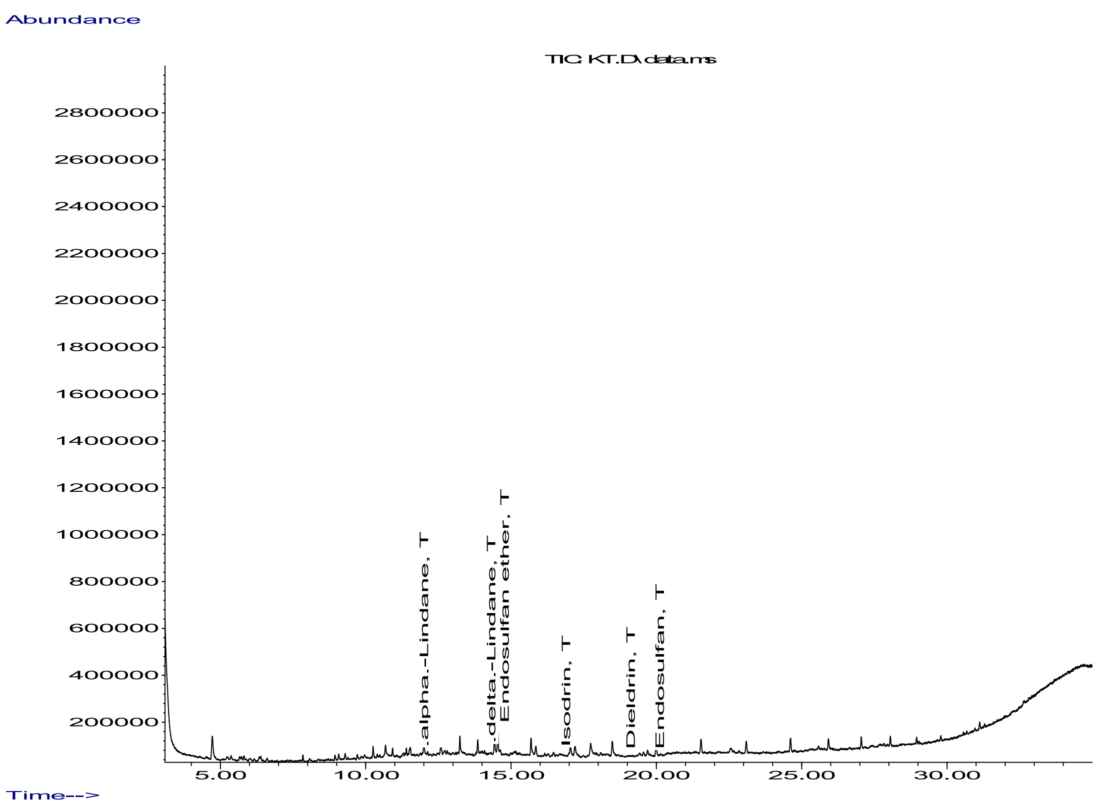

Fig. 3: Chromatogram of Kano tomato (KT)

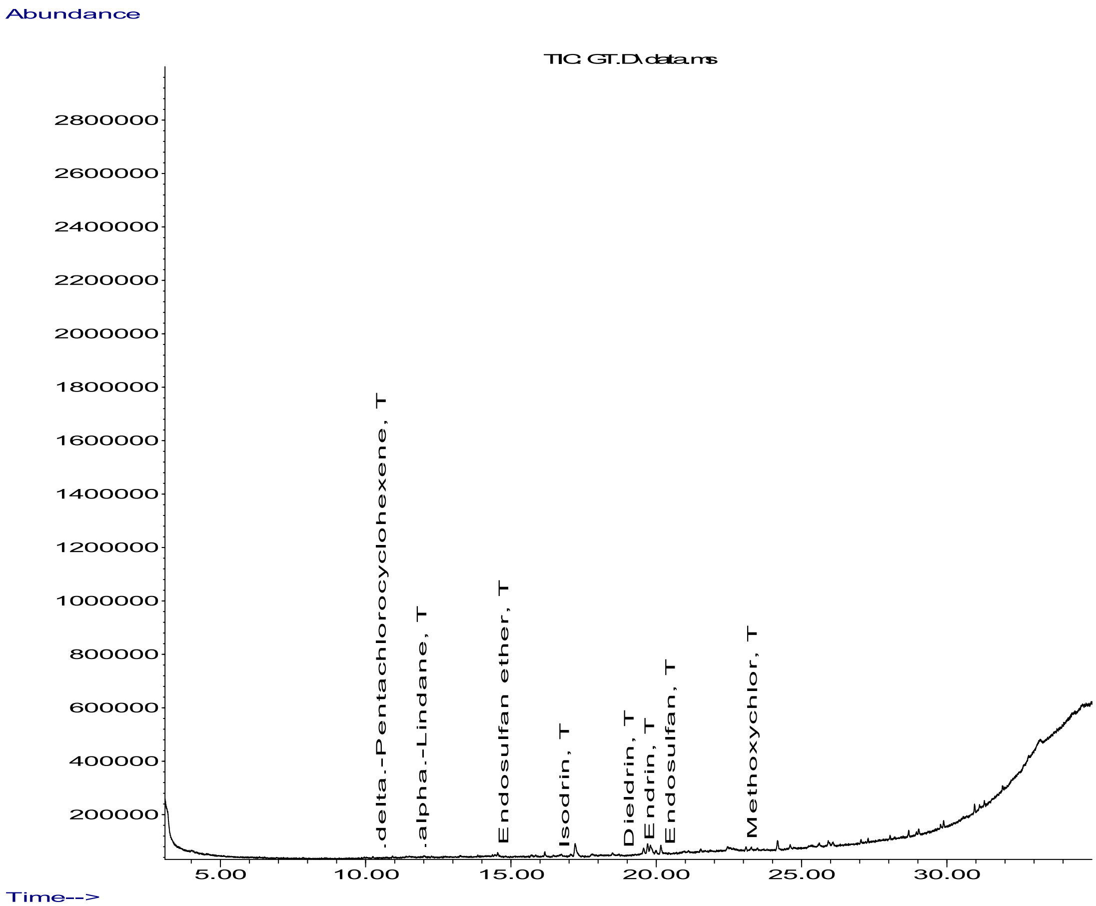

Fig. 4: Chromatogram of Ghana tomato (GT)

Table 1: Mean concentration of pesticide residues in tomato samples

S/N	Pesticide	Average residue level mg/kg			
		GT	KT	AT	ST
1	Alpha.-Lindane	0.0042	0.0053	*BDL*	*BDL*
2	Delta.-Lindane	*BDL*	0.0005	BDL	BDL
3	Heptachlor	0.039	0.337	0.129	0.009
4	Aldrin	*BDL*	*BDL*	*BDL*	*BDL*
5	Heptachlor epoxide	0.019	0.163	0.019	0.008
6	Trans-Chlordane	*BDL*	*BDL*	*BDL*	*BDL*
7	p,p'-DDE	*BDL*	*BDL*	*BDL*	*BDL*
8	Dieldrin	*BDL*	*BDL*	*BDL*	*BDL*
9	Endrin	0.003	0.005	0.003	0.005
10	Endosulfan	0.001	BDL	0.004	BDL
11	Endosulfan sulfate	*BDL*	*BDL*	0.165	0.249
12	Endrin ketone	*BDL*	*BDL*	BDL	BDL
13	Methoxychlor	*BDL*	*BDL*	BDL	BDL
14	Endosulfan ether	0.039	0.336	0.1298	0.009
	Total pesticide mg/kg	0.069	0.48	4.394	0.277

****GT-Ghana Tomato; KT-Kano Tomato; AT-Abeokuta tomato; ST-Sagamu Tomato**

Table 2: Estimated daily intake (EDI), with established maximum residue limit (MRL), acceptable daily intake (ADI), oral reference dose (RfD) and oral cancer slope factor (CSF) of pesticide residues in sampled tomatoes.

Pesticide					EDI mg/kg/day			
	MRL mg/kg	ADI mg/Kg bw	**Oral slope factor per mg/kg/day USEPA**	**RfDis mg/kg/day**	**GT**	**KT**	**AT**	**ST**
Alpha.-Lindane	0.01	0.005	6.3	3E-4	6E-6	7.51E-6	-	-
Delta.-Lindane	0.01	0.005		3E-4	-	7.1E-6	-	-
Heptachlor	0.01	0.0001	4.5	5E-4	5.52E-5	5E-4	1.83E-4	1E-5
Heptachlor epoxide	0.01	0.0001	9.1	5E-4	3E-5	2.31E-4	3E-5	1.13E-5
Endrin	0.01	0.0002		3E-4	4.25E-6	7E-6	4.25E-6	7E-6
Endosulfan	0.05	0.006		6E-3	1.42E-6	-	5.67E-6	-
Endosulfan sulfate	0.05	0.006		6E-3	-	-	2.3E-4	3.53E-4
Endosulfan ether	0.05	0.006		6E-3	5.53E-5	4.76E-4	1.84E-4	1.28E-5

However farmers often respond to pest infestation in crops by heavy applications of pesticides which may threaten food safety, environmental quality and enhanced risks to human and livestock. Tomato samples with mean concentration of pesticide residues above the MRL may not be safe for consumption. Consumption of large dosage of alpha lindane (α-HCH) and delta lindane (δ-HCH) could lead to seizures, liver and kidney diseases and even death (ATSDR, 2005). The department of Health and Human Services (DHHS) of the United States of America and the International Agency for Research on Cancer (IARC) has classified alpha lindane (α-HCH) and delta lindane (δ-HCH) as possibly human carcinogens (ATSDR, 2005). Endosulfan is toxic to the nervous system, exposure to high amounts of endosulfan induces hyperactivity and convulsions and severe poisoning may result in death (ATSDR, 2015). Toxicity of endosulfan sulphate is similar to endosulfan, both exert neurotoxicity through the same mechanism (US EPA, 2013) while endosulfan ether is less or non- toxic (Fang-Bo, 2012). Endrin is highly toxic in man affecting the nervous system causing neurological problems such as nausea, vomiting, dizziness, stomach ache, headache, sudden unconsciousness, convulsions and CNS depression. Acute and Chronic toxicity result in liver and kidney damage (ATSDR, 2011). Adverse effects of heptachlor and heptachlor epoxide includes liver effects, neurological effects, reproductive system dysfunction and developmental effects (ATSDR, 2007). Both are classified as probable and possibly human carcinogens by the International Agency for Research on Cancer (IARC) (ATSDR, 2007). The National Agency for Food and Drug Administration and Control (NAFDAC) had prohibited the use of most of the organochlorine pesticides (OCPs) determined in this study on crop and livestock protection in Nigeria, except endosulfan, heptachlor and lindane (restricted to use on cocoa only) when applied below their MRL (NAFDAC, 2016a).

Table 2 shows the estimated daily intake (EDI) mg/kg/day of the pesticide residues in tomato samples, the estimated daily intake (EDI) of the pesticide residues in the tomato samples are lower than their respective acceptable daily intake (ADI) mg/kg bw, except for the pesticide residues heptachlor in KT (5E- 4 mg/kg/day) and AT (1.83 E – 4 mg/kg/day) and heptachlor epoxide in KT (2.31 E- 4 mg/kg/day). With reference to the measured mean concentration and calculated EDI of the pesticide residues all the tomato samples had one or more pesticides residues above their MRL and ADI (Tables 1 and 2).

Tables 3 and 4 present the hazard quotient (HQ), hazard index (HI) and incremental lifetime cancer risk (ILCR) of the pesticide residues in the studied tomato samples. The Hazard Quotient (HQ) for alpha lindane (0.02), heptachlor (0.11), endrin (0.014), endosulfan (0.00024) endosulfan ether (0.0092) are less than one (1) in GT, implying that there is no significant risk or systematic toxicity, while that of heptachlor epoxide (1.11) is greater than one (1) which points toward potential risk (Gerba, 2019). Except heptachlor in KT which is 1.00 and heptachlor epoxide in KT and AT which are 17.77 and 2.31 respectively, the hazard quotients for alpha and delta lindane, heptachlor, endrin, endosulfan, endosulfan sulphate and endosulfan ether in KT (alpha lindane 0.024, delta lindane 0.024, endrin 0.023 and endosulfan ether 0.079), AT (heptachlor 0.37, endrin 0.014, endosulfan 0.001, endosulfan sulphate 0.04 and endosulfan ether 0.031) and ST (heptachlor epoxide 0.77, endrin 0.14, endosulfan sulphate 0.06 and endosulfan ether 0.0021) are less than one (1). The hazard index (HI) is greater than one (1) for the sum of the HQs of the pesticide residues in each source of tomato samples (GT 1.3, KT 18.92 and AT 3.0), excluding tomato from Sagamu (ST) which is 1.00. This suggests that chronic risks symptoms may be observed through their consumption (USEPA, 2005; USEPA, 2014; Gerba, 2019). The incremental lifetime cancer risk (ILCR) was calculated for alpha lindane, heptachlor and heptachlor epoxide which are the pesticide residues with likely probability of causing cancer. The calculated incremental lifetime cancer risk (ILCR) for these pesticide residues (Table 4) are higher than the US EPA acceptable value of $1\,x\,10^{-4}$ to $1\,x\,10^{-6}$.

Table 3: Hazard quotient (HQ) and hazard index (HI) of pesticide residue in tomato samples.

Sources	Alpha lindane	Delta lindane	Heptachlor	Heptachlor epoxide	Endrin	Endosulfan	Endosulfan sulphate	Endosulfan ether	HI
GT	0.02		0.11	1.11	0.014	0.00024		0.0092	1.3
KT	0.024	0.024	1.00	17.77	0.023			0.079	18.92
AT			0.37	2.31	0.014	0.001	0.04	0.031	3.0
ST				0.77	0.14		0.06	0.0021	1.00

Table 4: Incremental lifetime cancer risk (ILCR) for pesticide residues in tomato samples.

Source of tomato	Alpha lindane	Heptachlor	Heptachlor epoxide
GT	4E-5	2.4E4	2.73E-4
KT	4.73E-5	2.3E-4	2.1E-3
AT		8.24E-4	2.73E-4
SG		5E-5	1.03E-4

4.0 Conclusion

The mean concentration of most of the pesticide residues in the tomato samples were above their maximum residue limit (MRL) , while some had estimated daily intake (EDI) above their established acceptable daily intake (ADI) and hazard quotients (HQ) above their safe value. The hazard indices (HI) and Incremental lifetime cancer risk (ILCR) for the pesticide residues were above their safe values. There is need for regular monitoring of pesticide residues in tomato samples and food crops in general to ensure compliance to non-usage of banned organochlorine pesticides (OCPs) and safe usage of allowed OCPs on food crops so as to ensure food safety.

5.0 References

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Conflict of interest

Authors declared no conflict of interest