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# Multiresidue levels of pesticides in *Magnifera indica* (Mango) in Ghana; a preliminary study in the Yilo and lower Manya Krobo districts of the Eastern region

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**ABSTRACT**

Locally produced foreign varieties of *Magnifera indica* (Keith and Kent varieties) were sampled and purchased from farms and markets within the Yilo and Lower Manya Krobo districts and analyzed for pesticide residues by gas chromatography equipped with an Electron Capture Detector (GC-ECD). In all, 80 samples were extracted and analyzed for mainly organochlorine residues (γ-HCH, δ-HCH, aldrin, dieldrin, heptachlor, γ-chlordane, endosulfan s, *p, p'*-DDE etc.) and synthetic pyrethroid residues (allethrin, bifenthrin, fenpropathrin, permethrin, cyfluthrin etc.).

Analysis indicates that about 88% of the mangoes sampled from the farms and markets contained one or more of these pesticide residues. The data also revealed that about 6.2% of the samples analyzed contained organochlorine pesticide residues of γ-HCH (0.013mg/kg and 0.038mg/kg); δ-HCH [0.014mg/k]; methoxychlor [0.027mg/kg] above maximum residue limits. Synthetic pyrethroid residues of cyfluthrin [0.078mg/kg] and fenvalerate [0.025mg/kg] were also found above their respective maximum residue limits. However, 78.2% of detected pesticide residues were below the Maximum Residue Limits.

Nonetheless, the continuous consumption of these fruits with even the modest pesticide levels can result in accumulation that could result in deadly chronic effects.



## Introduction

Over the past 40-50 years, no single subject in the area of food quality and food safety has attracted more attention than the issue of pesticide residues in food. There is however the worldwide demand for adequate supplies for pest–free good quality commodities and foodstuffs and this necessitates the continued use of conventional pesticides for some time to come and hence the continued associated problems of pesticide residues. To minimize the economic losses caused by insects, fungi and weeds, various insecticides, fungicides, rodenticides and herbicides are used on food and cash crops on a massive scale (Delaplane, 1996).

Pesticides have a long history against insects and other pests. These pesticides were either inorganic chemicals or compounds extracted from plant and animal sources. Around World War II, the production of synthetic organic pesticides increased tremendously. Initially, the more persistent class of organochlorine pesticides were favoured, but it did not take long to realise the side effects of pesticides including losses of wildlife and beneficial insects, residues in crops and food chain, health hazards to humans and animals, etc. Moreover, many of the pests for whom these were designed to kill developed resistance and pest resurgence became a common phenomenon (Brown and Pol, 1971). All along this time, pesticide manufacture and consumption showed an exponential increase.

The business of pesticide companies flourished through the introduction of other classes of pesticides and targeting different pests. The pesticide import in Ghana started in 1954 through the Government of the then Gold Coast (now Ghana). In a policy change, the pesticide business was handed over to the private sector in the early 1980s. Since then, pesticide consumption has been on the rise. The pesticide consumption figures for 2010 stood at 615,000 metric tonnes for solid pesticides and 16,000 ('000 Litres) for the liquids (Ghana EPA, 2011). Insecticides comprise 85% of the total pesticides; and food crop is the major recipient of these chemicals.

A variety of pesticides are being imported into Ghana. It has been found that more than 80% of the total intake of pesticide residues in human beings is through the food chain (Martinez *et al.*, 1997; Trotter and Dickerson, 1993). There is a vital need for the continuous monitoring of pesticide residues in food especially fruits and other environmental media.

Pesticides constitute a vital group of compounds and their use has to be controlled due to their high toxicity and widespread use in agricultural practices. For field and post-harvest protection of crops, the use of pesticides could lead to extensive environmental pollution. To ensure the safety of food for consumers, numerous legislations such as Codex directives (CODEX Committee on Pesticide Residues, 2003) have established maximum residue limits (MRLs) for pesticides in foodstuffs.

Ordinary people think they can choose either to smoke or drink alcohol. But they have little or no control over the water they drink, which makes any health risk within it that much scarier (Economist, 1986).

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Although the production and use of many types of organochlorine pesticides and some synthetic pyrethroids have been severely restricted (or completely banned in most cases) in many countries including Ghana, some such as hexachlorocyclohexane (mixed isomers) are nevertheless still being used in large quantities in many parts of Ghana (Ntow *et al*., 2005), and in other developing countries because of their effectiveness as pesticides and their relatively low cost (Racke *et al*., 1997) as well as inadequate regulation and management on the production, trade and use of these chemicals (Darko and Acquaah, 2007).

Mangoes, pineapples and to some extent bananas have, over the past years, become some of the major export commodities for the people of coastal areas of south-eastern Ghana in the absence of cocoa which does not do well in the coastal areas. The national best farmer for 2009 is the single major exporter of the mango produce and for which his award was largely based. A lot of small scale associations are into commercial cultivation and export of this commodity.

**Materials and Method**

**Sampling**

The Yilo and Lower Manya Krobo districts (0.0° N, 0.0°, 0.20°W and 6.20°N) are located in the south eastern part of Ghana, between the Akwapim range and the Volta Lake.

**Figure 1: Map showing farms and markets within the study districts**


Sixty (60) samples of mangoes (Keith and Kent varieties) were sampled from farms within the two districts of the study, using the *Codex* sampling plan (FAO/WHO, 2000).

The samples were sealed and labelled with unique sample identification numbers and transported to the Ghana Standards Board pesticide residue laboratory for analysis.

These samples were then extracted and analysed (within 48 hours from the time of sampling) for the presence of pesticide residues.

Twenty (20) more samples were bought from local markets and dealers dotted within the study area.

As much as possible, the sources of the fruits were verified to ensure that though being bought from different dealers, their origins are also different.

All samples were packaged in transparent plastic bags and refrigerated at 5°C. These samples were then extracted and analysed (within 48 hours from the time of sampling) for the presence of pesticide residues.

All the sampling was not done on the same day; time was allowed in between samples to ensure diversity and consistency with Codex sampling requirements (FAO/WHO, 2000).

**Materials and Methods**

**Reagents and Certified reference standards**

Pesticide grade ethyl acetate, analytical grade acetone, sodium hydrogen carbonate and sodium sulphate were supplied by BDH Laboratory Supplies, England. Solid-phase florisil cartridges column size (1000 mg/6mL) was packed and used.The individual certified reference standards, lindane, beta-HCH, delta-HCH, aldrin, heptachlor, gamma-chlordane, alpha-endosulfan, p,p'-DDE, dieldrin, endrin, beta-endosulfan, p,p'-DDT, p,p'-DDD, endosulfan sulfate, methoxychlor, allethrin, fenpropathrin, bifenthrin, lambda-cyhalothrin, permethrin, cyfluthrin, cypermethrin, fenvalerate and deltamethrin used for the identification and quantification were obtained from Dr. Ehrenstorfer GmbH (Augsburg, Germany). All standards were stored in the freezer at -20 °C to minimize degradation.

**Preparation of Florisil**

About 100g of 60 to 100 mesh florisil was transferred into a beaker, and placed in an oven at $130^0$C overnight. The florisil was then cooled in a desiccator and 3g of the activated florisil was weighed and poured into a column which has been plugged with glass wool followed by 1.5g layer of anhydrous sodium sulphate. Each day a new pack of florisil column was prepared.

**Instrumentation and Apparatus**

Information pertaining to the identity of instruments and apparatus typically used for pesticide analysis is listed below. Alternative, equivalent instrumentation and apparatus may be used, unless specifically stated otherwise.

- Gas Chromatograph- Varian CP-3800 Gas Chromatograph equipped with a CombiPAL Autosampler and Electron Capture Detector. Analytical column - 30m + 10m EZ Guard x 0.25mm internal diameter fused silica capillary coated with VF-5ms (0.25μm film) from Varian Inc.
- Centrifuge - Hermle Z 300, Jouan CR3i multifunction
- Macerator - IKA Ultra Turrax homogenizer
- General lab glassware - Round bottomed flasks, volumetric flasks, centrifuge tubes
- Water Bath - Bibby, RE 200B and Buchi, B-491
- Rotary film evaporator (RFE) - Bibby RE 200 and Buchi Rotavapor R-210
- Ultrasonic bath - Decon FS400b
- Vortex mixer - Thermolyne (Maxi Mix-Plus)

**Sample preparation**

Stalks, stones and peels (where applicable) were removed from each fruit sample and homogenized to maintain homogeneity using the laboratory blender. Appropriate representative sub-samples were taken for analysis, in accordance with *GSB-WI-T. Sampling of commodities for analysis, including labeling, preparing and storage (an SOP in the GSB Laboratory)*

**Extraction Procedure**

**Extraction**

A sub sample of prepared matrix (about 20g) from the homogenized fruit samples was weighed into a sample bottle. Pesticide grade ethyl acetate (about 40mL) was added and macerated for 30 seconds. Analar anhydrous sodium sulphate (about 20g) and sodium hydrogen carbonate (about 5g) were added and macerated for a further 90 seconds. The macerate was then centrifuged at 3000rpm for 5 minutes.

An aliquot (4mL≡ 2.0g) was pipetted into a round-bottomed flask (50mL) and evaporated to approximately 2ml (Rotary Film Evaporator temperature of $35^0$C), not to dryness for extract purification.

**Sample Cleanup**

The already packed 'Florisil' (1000mg/6mL) cartridge was conditioned with about 10 ml of ethyl acetate and the extract was loaded from a 2mL pipette onto the cartridge and the elute collected into 100 ml round bottom flask.

The cartridge was eluted again with 10mL of ethyl acetate and the filtrate concentrated below 40ºC to approximately 1mL on the rotary evaporator just to dryness. The extract was re-dissolved in ethyl acetate (2ml, standard opening vial) prior to quantization by GC-ECD.

**Chromatographic conditions for the determination of the pesticide standards**

A summary of the typical GC-ECD conditions used for the quantization of the pesticide standards are stated below:

ECD detector: Varian Factor four VF- 5ms, 30 m + 10 m column guard x 0.25 mm I.D. and 0.25 µm film thickness. Detector temperature of 300ºC, injector 270ºC, oven for organochlorines: 70ºC for 2 min, 70ºC –180ºC at 25ºCmin$^{-1}$ maintained for 1 min, 180ºC – 300ºC at 5ºCmin$^{-1}$; oven for synthetic pyrethroids: 90ºC for 1 min, 90ºC – 240ºC at 30ºCmin$^{-1}$, 240ºC – 300ºC at 5ºCmin$^{-1}$ maintained for 5 min, carrier gas ($N_2$) 1.0 ml min$^{-1}$, with an injection volume 1 uL.

**Quality Control**

All reagents used during the analysis were exposed to same extraction procedures and solvents used were run to verify for any interfering substances within the runtime. In all batches of pesticide residues analysis, reagent blanks, procedural matrix blanks and triplicate samples were included. For the reagent blanks in each extraction procedure, no pesticides were detected. All extracts were kept frozen until quantification was completed. Recalibration curves were run with each batch of samples to check that the correlation coefficient was kept above $r^2$=0.99

The method used was an international method, optimized and validated using various agricultural products (Chung *et al*, 2010. Fortified samples were determined with good recoveries.

$$\text{Recovery (\%)} = \frac{\text{Concentration of pesticide recovered from fortified sample}}{\text{Concentration of Pesticide added to sample}} \times 100$$

The recoveries of pesticide residues ranged between 90% and 110% for most of the pesticides analyzed in this study.

**Chromatographic Calibration**

Mixed instrument calibration standards were prepared from the individual stock standards by serial dilution to obtain four concentration levels.

The mixed standards, using the pesticide mixtures with concentrations of 0.005, 0.01, 0.02, and 0.05, were plotted against the peak area to obtain a calibration curve. The area of the curve had $R^2$= 0.996. Recalibration curves were run with each batch of samples to check that the correlation coefficient was kept above 0.99.

**Limit of detection (LOD)**

The limit of detection of the pesticides determined was based on the extract of the fortified samples that were serially diluted by factor of two to give different concentrations.

One out of each concentration that gave a response three times the standard deviation of the least fortified sample was noted. And this was used to estimate the statistical significance of differences between low level analyte responses and the combined uncertainties in both the analyte and the background measurement (G. Wells *et al*, 2011).

**Results and discussions**

**Mean concentration levels of pesticide residues in Mango (*Magnifera indica)* from the farms**

**Table 1: Concentrations of organochlorine pesticide residues (mg/kg) detected in mangoes from the farms in the study area.**

| Pesticides | Yilo Farms (mg/kg) | | Manya Farms (mg/kg) | |
|---|---|---|---|---|
| | MF1 (Mean±SD) | MF2 (Mean±SD) | MF3 (Mean±SD) | MF4 (Mean ± SD) |
| β-HCH | <LOD | <LOD | <LOD | 0.005±1.00 |
| γ-HCH | 0.001±2.03 | 0.002±1.22 | 0.002±0.36 | 0.003±1.21 |
| Heptachlor | <LOD | 0.002±0.22 | <LOD | 0.002±0.22 |
| δ-HCH | 0.006±1.72 | <LOD | 0.002±1.00 | 0.006±0.30 |
| α-endosulfan | <LOD | 0.010±8.23 | 0.004±0.01 | 0.010±8.23 |
| p,p'-DDE | 0.005±3.02 | 0.012±2.44 | 0.008±2.60 | 0.012±4.10 |
| β-endosulfan | 0.003±1.23 | <LOD | 0.001±1.01 | <LOD |
| p,p'-DDT | 0.001±0.12 | <LOD | 0.001±1.10 | <LOD |
| Endosulfan sulf. | 0.009±1.43 | 0.003±1.12 | 0.001±1.00 | 0.004±2.10 |
| Methoxychlor | 0.002±1.17 | 0.003±1.00 | 0.002±1.54 | 0.001±1.20 |

Each value is a mean of ten farm samples with three determinations

LOD= Limit of Detection. MF1, MF2, MF3, MF4 = Mango Farms at sites within the study area

SD = Standard Deviation

Table 1 gives the residual concentrations of organochlorine pesticides in mangoes from farms within the study area. The results showed that endosulfan sulfate recorded the highest mean concentration (0.009mg/kg) followed by γ-HCH (0.006mg/kg), p,p'- DDE (0.005mg/kg), β-endosulfan (0.003mg/kg), methoxychlor and δ-HCH (0.002mg/kg each) and p,p'-DDT (0.001mg/kg) in farm MF1.

*p,p'*-DDE recorded the highest mean levels of 0.008mg/kg and 0.012mg/kg respectively in farms MF3 and MF4. α-endosulfan recorded a level of 0.010mg/kg in farm MF4.

Considering farm MF2, p,p'-DDE recorded the highest concentration level (0.012mg/kg), followed by α-endosulfan (0.010mg/kg), endosulfan sulfate and methoxychlor (0.003mg/kg each) and both γ-HCH and heptachlor recorded (0.002mg/kg each) in mango samples.

γ-HCH was detected in mango samples from all farms while δ-HCH was not detected in farm MF2 but at relatively higher concentrations in MF1 and MF4.

Technical endosulfan consists of α- and β- isomers. It is one of the few cyclodiene pesticides that are still used extensively to control a number of insects on crops. In the environment, the cyclic sulphite group of endosulfan can be oxidized to the corresponding sulphate (endosulfan sulphate) (Chandler *et al*., 1991; Guerin *et al*., 1992; Kathpal *et al*., 1997), which is more persistent than its parent compound (Guerin, 2001).

Although many organochlorine pesticides such as DDT and heptachlor had been banned from use on food crops since 1985, they have remained in the environment where they continue to be incorporated into plant biomass. The mean residue levels of *p,p'*-DDE was 0.005mg/g and 0.008mg/kg in farms MF1 and MF3 respectively. Levels of 0.012mg/kg of *p,p'*-DDE were detected in samples from farms MF2 and MF4. *p,p'*-DDT was detected only in samples from farms MF1 and MF3 with mean concentrations of 0.001mg/kg.

The presence and high concentrations of *p,p'*-DDE may be due to metabolic conversion and dehydrochlorination of *p,p'*-DDT. DDT can be biodegraded into DDE under aerobic conditions and DDD under anaerobic conditions, and a value of DDT/(DDD+DDE) > 1 can be used as an indicator of possible new sources of DDT. From this study, all the DDT /

(DDD+DDE) values obtained were < 1 in 100% of mango samples. This suggests that DDT concentrations in mangoes from the farms in the study districts were mainly due to historic use, even though the existence of point and non-point sources cannot be totally ruled-out.

**Comparison of organochlorine pesticide residues from the different farms**

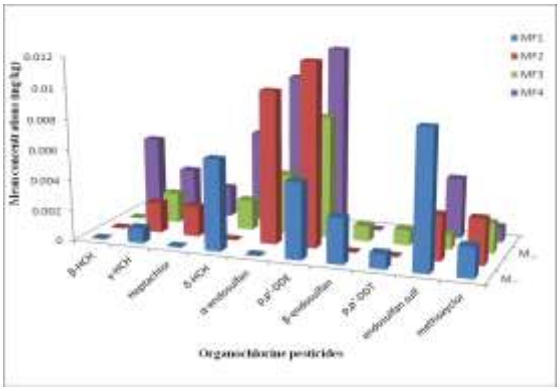


**Figure 1:** ***Comparative representations of the levels of organochlorie pesticide residues in mango samples from the different farms.***

From Figure 1, it is observed that p,p'-DDE presented the highest levels of organochloride residues throughout the farms. Though γ-HCH was detected is samples from all the farms, levels are not as high as compared to metabolites such as *p,p'*-DDE. Endosulfan sulphate was also detected in 100% of mango samples; perhaps as metabolites of used parent compounds. α- and β-isomers were not detected in all samples from the farms, even though a high levels of 0.010mg/kg each was detected in farms MF2 and MF4. Lower results in other samples confirm its restricted use in Ghana which does not include fruits (It is registered for use on cotton) (Ntow, 2001).

Methoxychlor was detected in 100% of mangoes sampled from the farms in the study districts (Figure 4.2). However, mean concentrations were low, perhaps in agreement with its characteristics of higher concentrations in fatty samples like fish than in fruits.

**Comparison of synthetic pyrethroid residues from the different farms**

**Table 2: Mean concentrations of synthetic pyrethroid residues (mg/kg) in mangoes from the farms.**

| Pesticides | Yilo Farms (mg/kg) | | Manya farms (mg/kg) | |
|---|---|---|---|---|
| | MF1 (Mean±SD) | MF2 (Mean±SD) | MF3(Mean±SD) | MF4 (Mean±SD) |
| Bifenthrin | 0.005±1.54 | 0.001±1.10 | 0.006±1.88 | 0.007±1.10 |
| Permethrin | 0.010±2.23 | 0.006±2.30 | 0.001±3.11 | 0.009±1.00 |
| Cyfluthrin | 0.012±5.11 | 0.015±1.91 | 0.010±2.72 | 0.015±4.20 |
| Cypermethrin | 0.001±1.00 | 0.002±1.10 | 0.003±2.00 | 0.005±2.15 |
| Fenvalerate | 0.005±1.11 | 0.001±0.86 | 0.010±1.90 | 0.004±0.86 |
| Deltamethrin | <LOD | 0.004±1.20 | 0.001±2.01 | 0.003±2.01 |

Each value is a mean of ten farm samples with three determinations

LOD= Limit of Detection. MF1, MF2, MF3, MF4 = Mango Farms at sites within the study area

SD = Standard Deviation

Table 2 summarizes the mean concentrations of detected synthetic pyrethroids in mangoes sampled from the farms within the study districts. Cyfluthrin recorded the highest mean concentrations with levels of 0.015mg/kg each in farms MF2 and MF4. The other two farms i.e. MF1 and MF3 also had relatively high levels of 0.012mg/kg and 0.010mg/kg respectively. Permethrin results in three farms were also significant, with values of 0.010mg/kg, 0.006mg/kg and 0.009mg/kg respectively in farms MF1, MF2 and MF4 respectively. Bifenthrin and fenvalerate recorded 0.005mg/kg and 0.001mg/kg each in farms MF1 and MF2 respectively. Levels were however variable (between 0.004mg/kg to 0.010mg/kg) in Manya farms. Mean concentrations of between 0.001mg/kg - 0.005mg/kg were detected for Cypermethrin and Deltamethrin in all farms.

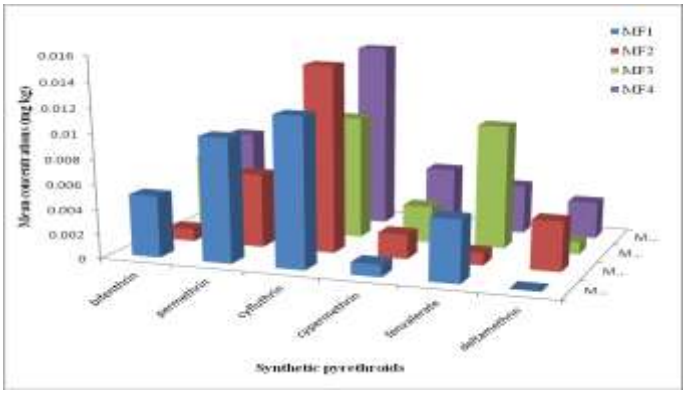


**Figure 2:** ***Comparison of synthetic pyrethroid residues in mangoes from the various farms***

Figure 2 presents a comparative plot of the various levels of synthetic pyrethroid residues in mangoes from the farms. Prominent bars of cyfluthrin from the various farm mangoes are an indication of its levels of detection. Apart from deltamethrin which was not detected in farm MF1 in Yilo farms, all other five were detected in all samples from the farms.

The present results are in accordance with the findings of Pang *et al.* (1995) and Pylypiw (1993) who also found synthetic pyrethriod residues in fruits and other farm commodities. Karol *et al*. (2000) found bifenthrin and permethrin in substantial quantities (0.128mg/kg) in fruits and vegetable in Pakistan but no such levels were recorded in the present study.

**Mean concentration of organochlorine and synthetic pyrethroid residues detected in fruits from the markets**

Table 3 below summarizes the organochlorine pesticide residual concentrations detected in mango samples from the markets within the study districts. The β-isomer of HCH was detected with a mean value of 0.002mg/kg in mangoes from Yilo markets. δ-HCH was not detected in any sample from any of the markets sampled while the γ-isomer was detected in all samples from the markets. Mean concentrations of 0.001mg/kg and 0.004mg/kg were recorded in mango respectively from Yilo and Manya farms.

**Table 3: Concentrations of organochlorine pesticide residues (mg/kg) in mango fruits from the markets in the districts**

| Pesticides | Yilo markets (mg/kg) (Mean±SD) | | | Manya markets (mg/kg) (Mean±SD) | | |
|---|---|---|---|---|---|---|
| β-HCH | 0.002±1.23 | | | <LOD | | |
| γ-HCH | 0.001±0.06 | | | 0.004±1.43 | | |
| Heptachlor | 0.002±0.91 | | | <LOD | | |
| δ-HCH | <LOD | | | <LOD | | |
| α-endosulfan | 0.004±2.44 | | | 0.002±1.59 | | |
| p,p'-DDE | 0.005±1.01 | | | 0.001±0.0 | | |
| β-endosulfan | <LOD | | | 0.002±1.15 | | |
| p,p'-DDT | 0.002±2.00 | | | <LOD | | |
| endosulfan s | 0.004±1.24 | | | 0.003±0.89 | | |
| Methoxychlor | 0.015±3.12 | | | 0.004±1.00 | | |

LOD= Limit of Detection. SD = Standard Deviation

Endosulfan was detected in all fruit samples from the markets with mean values of between 0.002mg/kg to 0.010mg/kg; and

there was a 100% occurrence of the α-isomer in all fruits sampled.

**Table 4**: **Concentrations of synthetic pyrethroid residues (mg/kg) in mango fruits in markets of the study districts**

| Pesticide | Yilo markets (mg/kg) (Mean±SD) | | | Manya markets (mg/kg) (Mean±SD) | | |
|---|---|---|---|---|---|---|
| Bifenthrin | 0.001±1.00 | | | <LOD | | |
| Permethrin | 0.006±0.71 | | | 0.004±1.02 | | |
| Cyfluthrin | 0.015±0.91 | | | 0.011±1.58 | | |
| Cypermethrin | 0.002±1.23 | | | 0.004±2.51 | | |
| Fenvalerate | 0.001±2.44 | | | 0.004±1.59 | | |
| Deltamethrin | 0.004±1.01 | | | 0.007±1.10 | | |

LOD= Limit of Detection. SD = Standard Deviation

Table 4 summarizes synthetic pyrethroids detected in mango samples in the study areas. Allethrin, Fenpropathrin and Lambda-cyhalothrin were all omitted from the table because levels in all samples were below the LOD, perhaps confirming pyrethroids break down quickly after application and are extremely less persistent compared to the organochlorines.

Bifenthrin, though registered in Ghana as an insecticide and permitted to be used on fruits, was only detected in mango in Yilo Krobo markets with mean concentration of 0.001mg/kg.

Permethrin, Cyfluthrin and Cypermethrin were detected in all samples from the markets in the area. With concentrations ranging from 0.001mg/kg to 0.015mg/kg, the synthetic pyrethroids are perhaps the most widely distributed residues (among ones detected) in fruits from the markets within the study area. The widespread detection and distribution of synthetic pyrethroids in fruits is a positive indication compliance of farmers moving away from the more persistent organochlorines to the less persistent synthetic pyrethroids.

**Tolerance Limits**

The concentration of organochlorine pesticides in mango samples from farms and markets within the study districts were compared with maximum residue limits (MRLs) set forth by the FAO/WHO Codex Alimentarius Commission (Table 5).

**Table 5**: **Highest concentration of pesticide residues (mg/kg) found in mango fruits from farms and markets within the study area compared with FAO/WHOs MRLs.**

| **Pesticides** | **Highest amounts found (mg/kg)** | | | **Maximum residue limits (mg/kg)** | | |
|---|---|---|---|---|---|---|
| ***Organochlorines*** | | | | | | |
| β-HCH | 0.007 | | | 0.01 | | |
| γ-HCH | 0.013 | | | 0.01 | | |
| δ-HCH | 0.014 | | | 0.01 | | |
| Heptachlor | 0.006 | | | 0.01 | | |
| α-endosulfan | 0.030 | | | 0.05 | | |
| *p,p'*-DDE | 0.043 | | | 0.05 | | |
| β-endosulfan | 0.006 | | | 0.05 | | |
| *p,p'*-DDT | 0.004 | | | 0.05 | | |
| Endosulfan sulfa. | 0.024 | | | 0.05 | | |
| Methoxychlor | 0.027 | | | 0.01 | | |
| ***Pyrethroids*** | | | | | | |
| Bifenthrin | 0.020 | | | 0.03 | | |
| Permethrin | 0.036 | | | 0.05 | | |
| Cyfluthrin | 0.078 | | | 0.02 | | |
| Cypermethrin | 0.018 | | | 0.7 | | |
| Fenvalerate | 0.025 | | | 0.02 | | |
| Deltamethrin | 0.018 | | | 0.05 | | |

(-) Not detected

From table 5, the lindane value in mango was above MRL, 0.013mg/kg as compared to 0.010 mg/kg.

δ-HCH was also found to be above the MRL values of 0.01mg/kg in fruits sampled. A level of 0.014mg/kg was found in mangoes from the study area. Concentrations of α- and β-endosulfan were quite high (0.030mg/kg and 0.006mg/kg) but are not above MRL values of 0.05mg/kg set for mangoes (Table 5). Methoxychlor recorded the highest amount of organochlorine residues of 0.027mg/kg in mangoes. This value is almost thrice the MRL value of 0.01mg/kg (Table 5).

All other organochlorine pesticides detected had values lower than their corresponding MRL values in all samples and therefore do not present any significant health risks to consumers.

For the pyrethroids, cyfluthrin recorded the highest value of 0.078mg/kg in mango fruits. This level is about four times above the MRL value set for this pesticide in the sampled fruit (0.02mg/kg). Fenvalerate is the only other pyrethroid which presented mean values above the MRLs set forth for these pesticides by the European Union (EU) (Table 5). High value of 0.025 mg/kg was detected in mangoes as against the MRL value of 0.02mg/kg.

Generally, Table 5 reveals that most of the samples analyzed contain synthetic pyrethroid residues of the monitored pesticides below the MRLs adopted by the FAO/WHO Codex Alimentarius Commission, except for methoxychlor, cyfluthrin and fenvalerate.

In conclusion, the results from the present study revealed that the majority of fruit samples analyzed are contaminated with pesticides but their frequency and concentrations are significantly variable, especially the synthetic pyrethroids. One thing is encouraging, except for a few fruit samples, most residues were below or within the maximum residue limits (MRLs) (Table 5).

**Conclusions**

Pesticides are intensively used to protect fruits and other crops, and this result in pesticide residues in or on agricultural commodities and also contaminate the environment. The following conclusions are drawn from this research investigation:

The data revealed that most mango samples analyzed contain residues of the monitored organochlorine residues (γ-HCH, δ-HCH, aldrin, dieldrin, heptachlor, γ-chlordane, endosulfan s, *p, p'*-DDE etc.) and synthetic pyrethroid residues (allethrin, bifenthrin, fenpropathrin, permethrin, cyfluthrin etc.) below the European Union maximum residue limits (MRLs). Some pesticide residues (heptachlor, γ-chlordane, endrin, dieldrin, allethrin, labda-cyhalothrin and fenpropathrin) were largely undetected in the samples.

The analyzed mango sample matrices however showed the presence of a few pesticide residues (δ-HCH, γ-HCH, methoxychlor, cyfluthrin and fenvalerate) at concentrations above EU MRLs.

The widespread detection and distribution of synthetic pyrethroids in samples is a positive indication of compliance of farmers moving away from the more persistent organochlorines to the less persistent synthetic pyrethroids.

The results also show that 15.6% of the fruit samples analyzed contained no detectable levels of monitored pesticides, 78.2% of the samples gave results with trace levels of pesticide residues below the MRLs, whilst only 6.2% of the samples were above the MRL values.

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