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Organochlorine Pesticide Residue Levels in Parts of Watermelon Grown in the Ada-West District of Greater Accra Region, Ghana and Its Related Human Health Risks

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Authors' contribution

This work was carried out in collaboration among all authors. Author SKA designed the study and performed the field work as well as laboratory analysis. Authors EAE and SA prepared the first draft of the manuscripts and data and statistical analysis. Author SS supervised the work wrote the final draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The study involved the use of soxhlet apparatus and CP-3800 Gas Chromatograph equipped with a ^{63}Ni electron capture detector to investigate the presence and levels of organochlorine pesticide (OCP) residues in sampled parts of watermelon. The study revealed the presence of fifteen OCPs residues in the peel, pulp and seeds of watermelon from the selected communities in the Ada-West District of the Greater Accra Region of Ghana. Most of the OCP residues investigated were below the limit of detection of 0.01 µg/kg. Detectable OCP residues whose concentrations were above detection limit were dieldrin and p, p'-dichlorodiphenyldichloroethene (p,p'–DDE). The seeds of

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watermelon from Koluedor recorded the highest level of 2.10 µg/kg of p'p-DDE while the lowest level of 0.20 µg/kg of dieldrin and p'p-DDE were recorded in the peel of watermelon from Sege. The mean levels of the detected pesticide residues in peel, pulp and seeds of watermelon were also below maximum residue limits (MRLs) set by European Union (EU). Estimated daily intake (EDI) of organochlorine pesticide residues as a result of consumption of the studied watermelon for children ranged from 0.001 µg/kg to 0.006 µg/kg and those for adults were from 0.0005 µg/kg to 0.003 µg/kg. EDIs values obtained were however, far below reference doses (RFDs) recommended by United State Environmental Protection Agency (USEPA).

Keywords: Gas chromatograph; soxhlet extraction; organochlorine pesticide; watermelon; estimated daily intake.

1. INTRODUCTION

In Ghana, different kinds of pesticides are registered and imported and these are widely used on cultivation of tomato, garden egg, pepper, watermelon, onion, mango, cabbage and other food crops. Vegetable and fruit farming on large scale attracts many pests and the plants are afflicted with pest diseases. Consequently, chemical pesticides are intensively applied to manage both pests and plant pathogens. Vegetables and fruits including watermelon cultivation has therefore, witnessed the use of pesticide products including organochlorine pesticides (OCPs) to improve crop yield [1].

Vegetables and fruits including watermelon form a good accompaniment to various meals, since the vitamins, minerals and fibre they contain constitute vital dietary components for the efficient functioning of the body. Consequently, the cultivation of vegetables and fruits including watermelon on a large scale to meet demands of the world population attracts the use of large amounts of pesticides in farming for the purposes of controlling and reducing the effect of insect-pests and diseases [2]. It is estimated that about 87% of farmers in Ghana use pesticides in vegetable cultivation [3]. There are various types of pesticides and these include insecticides, fungicides, herbicides and antibiotics [4]. Insecticides are mainly organochlorine pesticides (OCPs), organophosphates, carbamates and synthetic pyrethroids. While some pesticides have short residual action; others such as the organochlorine pesticide (OCPs) have long residual action [3]. OCPs in particular are widely used in the control of insect pests of vegetables and fruits due to their broad spectrum of activity and their cost effectiveness, a situation which may result in the accumulation of pesticide residues in fruit crop including watermelon mostly consumed raw in Ghana [5,2]. OCPs are resistant to environmental degradation through chemical, biological, and photolytic processes and as a result bioaccumulate in living tissues and biomagnified in food chains with the resultant negative impacts on human health and the environment [3]. These synthetic organic chemicals contribute to many acute and chronic illnesses. They are known or suspected hormone disruptors and have been implicated in a broad range of adverse human health effects including immune system dysfunction, cancers, reproductive failures and birth defects [3]. Recent studies suggest that extremely low levels of exposure to the womb can cause irreversible damage to the reproductive and immune systems of the developing foetus [6,7]. As a result of the persistency and toxicity associated with OCPs, the recent Stockholm convention on persistent organic pollutants (POPs) has banned and restricted the use of OCPs [8].

Although studies conducted so far in Ghana revealed levels of OCP residues in the environment which are emanating from current and past use of these chemicals, the changing trends of pesticide usage and the paucity of data regarding the pollution status of watermelon in Ghana call for regular and constant monitoring through residue level assessment to protect humans and the environment from the toxic effects of OCPs [9,10,11,12,13].

As these toxic chemicals have the potential to bioaccumulate, their presence is therefore, undesirable and of great concern. It is therefore, recommended that regulatory authorities should ensure compliance and enforcement of the laws on the use of banned and restricted pesticides. A constant and regular monitoring programmes through residue level assessment at the application sites is recommended due to the changing trends of pesticide usage. The study therefore, becomes relevant in updating data on OCPs residue levels in watermelon which is usually consumed raw.

2. MATERIALS AND METHODS

2.1 Chemicals and Standards

The instruments used for present study are: gas chromatograph-Varian CP-3800 (Varian Association Inc. USA) equipped with ^{63}Ni electron capture detector (ECD); OMNILAB Food AYTRS 60 Soxhlet extractor used for extraction of pesticide residues.

All chemicals and reagents used are: n-hexane (99% + purity, Sigma-Aldrich); acetone (99.9% +, BDH England); ethyl acetate (99.8% +, Sigma-Aldrich); florisil 60-100 mesh (Hopkin and William Ltd England); anhydrous sodium sulfate (Aldrich-Chemie, Germany). The pesticide standards used for the identification and quantification of OCP residues were obtained from Dr. Ehrenstorfer Gmbh (Augsburg, Germany. The chemicals were of analytical grade.

2.2 Study Area

The study was undertaken in four main areas in the Ada-West district in the Greater Accra region of Ghana as shown in Fig. 1. The criteria for sites selected were based on major crop cultivated, pesticide usage and ease of accessibility.

The district lies between latitude 5° 45'N and 6° 00'N and longitudes 0° 20'E and 0° 35'E. The total population of the district is 59,124 [14]. Of this figure 48.3% (28,579) are males and 51.7% (30,545) are females. There are sixteen health facilities including five CHPS compounds spread throughout the district. Currently there are forty five basic schools, (primary and Junior High Schools), few kindergartens and one Senior High Technical School [15].

The total land size of the district is about 323.721 square kilometers. The vegetation is Coastal Savannah, characterized by short grass and interspersed with shrubs and short trees [15]. A few strands of mangrove can also be found around the Songhor Lagoon and the tributaries of the Volta River where the soil is waterlogged and salt.

2.3 Climate

The district experiences bimodal rainfall pattern with the major rain season falling between March and June, and a minor rainy season around October. The mean annual rainfall ranges from 750 to 1000 millimeters and temperatures are moderate with maxima rarely exceeding 33°C while the minimum does not fall below 23°C. The relatively high temperatures help in the quick crystallization of salt for the salt industry.

2.4 Watermelon Cultivation

The climate of the district favours the cultivation of food crops such as watermelon, tomatoes, pepper, okro and cassava. Currently the district is becoming one of the large watermelon growing areas in Ghana. The crop is gaining ground in the district as the most widely cultivated crop due to the increasing demand and the presence of existing market. Watermelon is planted two times in a year, between January and March and also from September to November. The flat plains of the district couple with low precipitation seem to be an ideal condition for watermelon cultivation. Some suitable varieties include Sugar Baby, Florida Giant, Black Diamond and Charleston Gray. But Sugar Baby, Top Harvest, Sweet Dragon and Crimson Sweet are cultivated on a large scale in the district constitutes the main source of income for the people of Ada-West.

2.5 Sample Collection

A total of 96 samples of watermelon comprising 24 watermelons from each of the communities were randomly collected at harvest in September 2016. Sampling was done in September because of the fruit abundance in September. The collection of 96 watermelons was based on similar work conducted by Lozowicka et al. [16] where a total of 82 samples of cucumbers and tomatoes were collected from top agro-based market and greenhouses in the Almaty Region of Kazakhstan. The collected watermelon samples were wrapped in aluminum foil and sealed in polyethylene bags, well labelled with unique identity and transported to the Ghana Atomic Energy Commission (GAEC) laboratory for storage and analysis.

2.6 Sample Preparation

Sample extraction, clean up, and GC analysis of the pesticides were carried out according to the procedure described by the Afful et al [17] and Bempah et al [18] with slight modifications. Thoroughly washed watermelon samples were separated into three representative parts (peel, pulp and seeds). Peels and pulps were shredded

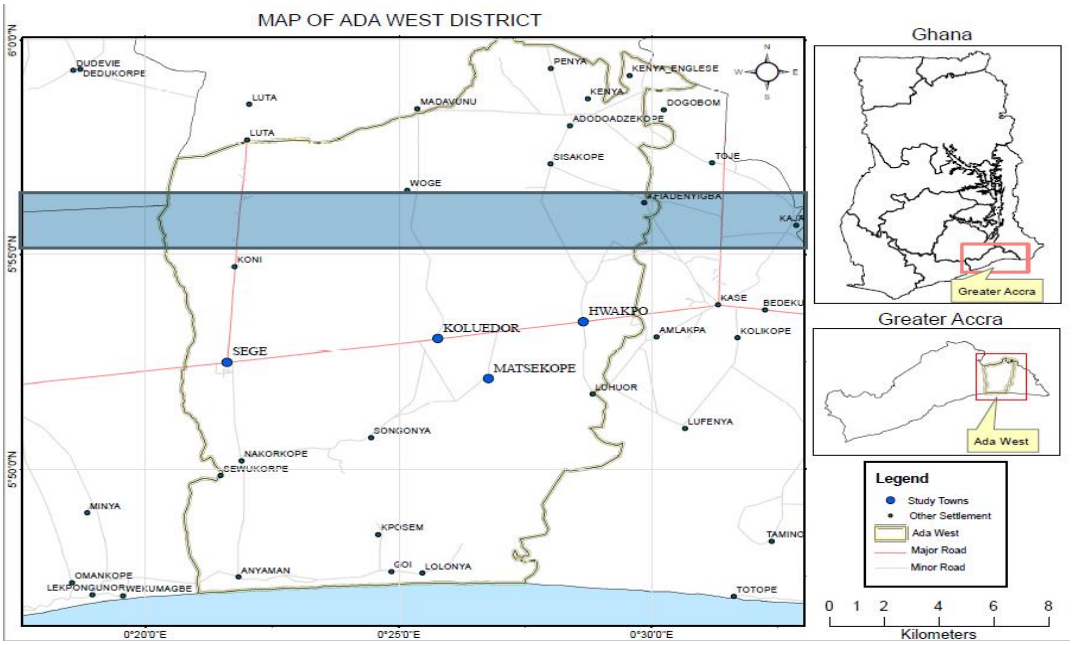

Fig. 1. Map showing the study area and sampling site

with Kenwood ice crusher stainless steel blender while seeds were crushed with mortar and pestle. Approximately 10 g of these parts were mixed together with anhydrous sodium sulphate and sodium hydrogen carbonate to remove moisture to almost dryness. The samples were soxhlet extracted with 3:1 hexane/ acetone mixture for 8 hours. The extracts were concentrated using a rotary evaporator fitted to a vacuum pump. A virgin cellulose extraction thimble was extracted in the same manner as the samples to obtain the blank. Each concentrated extract as well as the blank were later dissolved with a known volume of n-hexane on to the clean-up column.

2.7 Clean Up of Sample

The florisil packed column with 2.0 g of anhydrous sodium sulphate on top of the florisil was conditioned with 10 ml of n-hexane prior to cleanup. The extracts of samples and blanks were eluted three times each with 10 ml portions of n-hexane and eluate collected into a flask with a ground-glass stopper and concentrated to dryness on the rotary evaporator fitted to a vacuum pump and later recovered with a known volume of ethyl acetate. Two (2) ml of the extracts were transferred quantitatively into 2 ml glass vials using Pasteur pipette for Gas Chromatography (GC) analysis.

2.8 Gas Chromatographic Analysis

A Varian CP-3800 Gas Chromatograph (Varian Associates Inc. USA) equipped with 63Ni Electron Capture Detector was used for the analysis. One µl of the extracts as well as the blank were injected and the separation performed on a fused silica gel capillary column coated with VF- 5 ms, 40 m long with internal diameter and film thickness of 0.25 mm and 0.25 µm respectively. The carrier gas and make up gas were nitrogen at a flow rate of 1.0 ml/min and 29 ml/min respectively. The injector and detector temperatures were 270°C and 300°C respectively. The column oven temperature was programmed as follows: 80°C for 1 min to 180°C at 25°C/min and up to 300°C at 5°C/min held for 1 min. Sample peaks were identified by their retention times compared to the corresponding retention times of the pesticide standards.

2.9 Impact of Pesticides Residues on Humans

The impact of pesticide residues on humans on consumption of the watermelon was studied by comparing measured residues to maximum residue limits and estimating daily intake or exposure to the pesticide residues on eating the watermelon. Mean residue concentrations were compared to MRLs of EU. Estimated daily

intakes (EDI) of residue through consumption of the watermelon were computed by multiplying the residue concentration in the samples by the rate of vegetable consumption which is estimated at 0.137µg/kg/day in Ghana [19]. EDI was calculated using the equation (1) below:

EDI = mean residue concentration x rate of fish consumption (1)

The following assumptions were adopted from US Environmental Protection Agency guidelines [20,21]

1. A hypothetical body weight of 30 kg for children (2- 11years) and 70 kg for adults
2. Maximum absorption rate of 100% and a bioavailability rate of 100%.

The estimated daily intake or exposures computed were then compared to the available USEPA reference doses. EDI was estimated for only p, p' DDE and dieldrin contamination as the concentrations of the other pesticides were below detection limit.

2.10 Analytical Quality Assurance

Quality of pesticide residues analysis was established through analysis of solvent blanks, spikes and triplicate sample measurements. Solvent blanks were used to eliminate any interference in the system, while the spike samples were used for recovery analysis. Triplicate samples were used to confirm precision or reproducibility of the method. The spiked samples and blank were subjected to the same extraction and clean up procedure. It was also ensured that there was enough cleaning solvent in the GC cleaning vials to rinse the injection needle between injections. Recovery was determined using the equation (2) below:

% Recovery = Pesticide recovered from fortified sample / amount of pesticide added (2)

3. RESULTS

3.1 Sample Chromatogram

Fig. 2 presents the sample chromatogram of the OCPs obtained by running a mixed standard of the organochlorine pesticide standard solution of concentration 1.00 ppm. The chromatogram shows the individual OCPs and their elution or retention times: β-HCH (12.347), δ-HCH (13.581), γ-HCH (12.620), heptachlor (14.047) aldrin (15.403), γ –chlordane (17.584), p,p^1 – DDE (18.348), endrin (19.681), p,p^1 DDT (19.973).

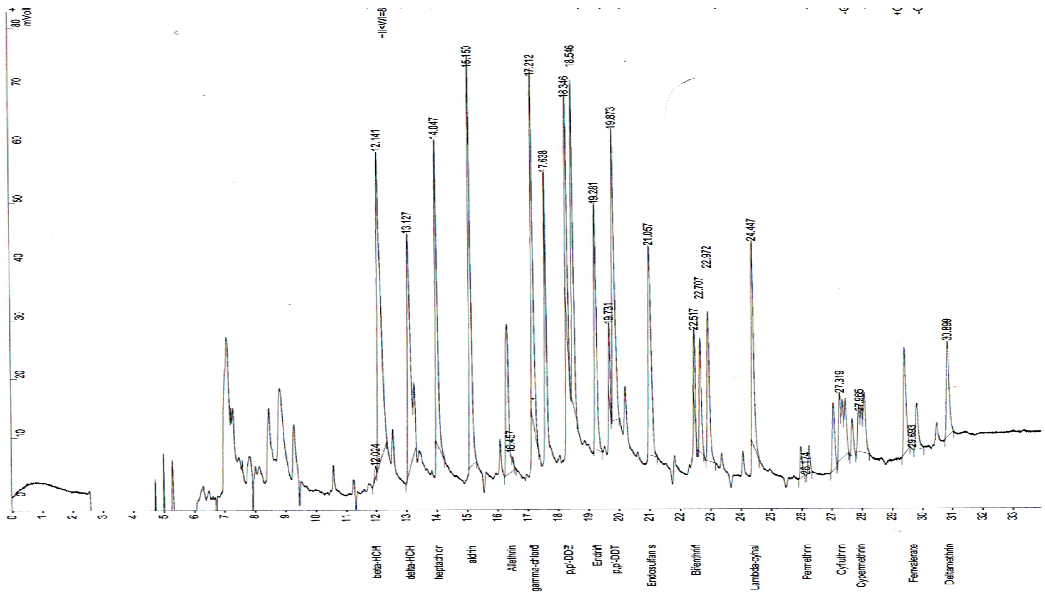

Fig. 2. Chromatogram of organochlorine pesticides mixed standard

3.2 Analysis of Samples

The chemical analysis revealed the presence of fifteen OCP residues in parts of watermelon. However, the concentrations of most of them were below detection limit. The limit of detection (LOD) is defined as the lowest practical concentration of the pollutant that can be identified and quantitatively measured in a specific matrix. LOD was estimated as concentration which peak was three times the peak of signal to noise ratio. Samples spiked with OCP standards were also determined for recovery investigation and recovery data presented in Table 1 ranges from 89.6 to 101.6%. Table 2 to Table 5 show individual OCP pesticides studied, their respective mean concentrations and margin of errors as standard deviation associated with the mean concentrations. The mean residue concentrations are compared with the standard guidelines for pesticide in food set forth by European Union (EU) as shown in the Tables.

3.3 Estimation of Daily Exposure

Tables 6 to 7 capture the estimated daily exposure of p,p'- DDE and dieldrin on eating the watermelon investigated and the estimated values are compared with United State reference dose. The Reference Dose (RfD) is the reference point from which potential health effects of a chemical pollutant at other doses may be estimated. Estimated daily intake was computed for p, p'-DDE and dieldrin contamination as the concentrations of the other investigated pesticides were below detection limit.

Table 1. Recoveries data for the pesticides

Pesticides	Recovery (%)
alpha - HCH	89.6
gamma- HCH	101.2
heptachlor	101.6
aldrin	101.5
alpha-endosulfan	99.0
beta-endosulfan	98.7
dieldrin	97.5
p,p'-DDT	101.1
p,p'-DDE	99.5
dieldrin	92.3

Table 2. Levels (μg/kg) of OCP residues in watermelon parts from Hwakpo

	Peel	Pulp	Seed	Eu/MRL
Pesticide	Mean±SD	Mean±SD	Mean±SD	(ng/g)
Gamma - HCH	<0.01	<0.01	<0.01	10
Beta - HCH	<0.01	<0.01	<0.01	10
Heptachlor	<0.01	<0.01	<0.01	10
Delta - HCH	<0.01	<0.01	<0.01	10
Endrin	<0.01	<0.01	<0.01	10
Gamma- chlordane	<0.01	<0.01	<0.01	10
Alpha - endosulfan	<0.01	<0.01	<0.01	50
p,p' - DDE	<0.01	<0.01	<0.01	50
Dieldrin	<0.01	<0.01	<0.01	10
Aldrin	<0.01	<0.01	<0.01	10
p,p' - DDT	<0.01	<0.01	<0.01	50
B - endosulfan	<0.01	<0.01	<0.01	50
p,p' - DDD	<0.01	<0.01	<0.01	50
Endosulfan-S	<0.01	<0.01	<0.01	50
Methoxychlor	<0.01	<0.01	<0.01	10

Limit of detection of pesticide residues = 0.01 ng/g, SD = Standard Deviation, NA = Not available, EU = European Union, MRL = Maximum Residue Limit

Table 3. Levels (µg/kg) of OCP residues in watermelon parts from Matsekope

	Peel	Pulp	Seed	Eu /MRL
Pesticide	**Mean±SD**	**Mean±SD**	**Mean±SD**	**(µg/kg)**
Gamma - HCH	<0.01	<0.01	<0.01	10
Beta - HCH	<0.01	<0.01	<0.01	10
Heptachlor	<0.01	<0.01	<0.01	10
Delta - HCH	<0.01	<0.01	<0.01	10
Endrin	<0.01	<0.01	<0.01	10
Gamma- chlordane	<0.01	<0.01	<0.01	10
A - endosulfan	<0.01	<0.01	<0.01	50
p,p' - DDE	<0.01	<0.01	<0.01	50
Dieldrin	<0.01	<0.01	<0.01	10
Aldrin	<0.01	<0.01	<0.01	10
p,p' - DDT	<0.01	<0.01	<0.01	50
B - endosulfan	<0.01	<0.01	<0.01	50
p,p' - DDD	<0.01	<0.01	<0.01	50
Endosulfan-S	<0.01	<0.01	<0.01	50
Methoxychlor	<0.01	<0.01	<0.01	10

Limit of detection of pesticide residues = 0.01 ng/g, SD = Standard Deviation, NA = Not available, EU = European Union, MRL = Maximum Residue Limit

Table 4. Levels (µg/kg) of OCP residues in watermelon parts from Koluedor

	Peel	Pulp	Seed	Eu MRL
Pesticide	**Mean±SD**	**Mean±SD**	**Mean±SD**	**(ng/g)**
Gamma - HCH	<0.01	<0.01	<0.01	10
Beta - HCH	<0.01	<0.01	<0.01	10
Heptachlor	<0.01	<0.01	<0.01	10
Delta - HCH	<0.01	<0.01	<0.01	10
Endrin	<0.01	<0.01	<0.01	10
Gamma- chlordane	<0.01	<0.01	<0.01	10
α - endosulfan	<0.01	<0.01	<0.01	50
p,p' - DDE	0.70 ± 0.14	0.40 ± 0.02	2.10 ± 0.16	50
Dieldrin	0.50 ± 0.14	0.35 ± 0.07	1.10 ± 0.12	10
Aldrin	<0.01	<0.01	<0.01	10
p,p' - DDT	<0.01	<0.01	<0.01	50
B - endosulfan	<0.01	<0.01	<0.01	50
p,p' - DDD	<0.01	<0.01	<0.01	50
Endosulfan-S	<0.01	<0.01	<0.01	50
Methoxychlor	<0.01	<0.01	<0.01	10

Limit of detection of pesticide residues = 0.01 ng/g, SD = Standard Deviation, NA = Not available, EU = European Union, MRL = Maximum Residue Limit

4. DISCUSSION

4.1 Occurrence and Distribution of OCP Residues in the Peel, Pulp and Seed of Watermelon

Detectable OCPs whose concentrations were above detection limit were dieldrin and p,p'-DDE (para-dichlorodiphenyldichloroethene) from watermelon sampled from Koluedor and Sege. Concentrations of OCP residues detected in the samples from Hwakpo and Matsekope were below detection limit. The mean levels of dieldrin detected in the peel, pulp and seeds of the samples from Sege were 0.55 µg/kg, 0.35 µg/kg and 1.15 µg/kg while p,p' DDE recorded mean levels of 0.47 µg/kg, 0.40 µg/kg and 1.10 µg/kg in the peel, pulp and seeds respectively. In Koluedor, dieldrin recorded a detectable mean concentration of 0.50 µg/kg, 0.35 µg/kg and 1.10 µg/kg in the peels, pulp and seeds. p'p DDE on the other hand, recorded mean levels 0.70 µg/kg, 0.40 µg/kg and 2.10 µg/kg in the peel, pulp and seeds respectively. Thus, the highest mean residue concentration recorded was 2.10 µg/kg while the lowest mean concentration recorded

was 0.02 µg/kg. The high detectability of p,p'-DDE (para-dichlorodiphenyltrichloroethane) may be due to metabolic conversion and dehydrochlorination of p,p' DDT and possible isomerization of p,p' DDT by solar radiation to p,p'-DDE [22].

The ratio of DDE to DDT levels are often used as a criterion for the identification of new DDT sources. The high DDE/DDT ratio suggests that the current levels may originate from previous contamination and environmental persistency. DDE is generally more persistent in the environment than DDT as a result when the input levels of DDT in the environment ceases, DDE it metabolite, may still be in the environment [10].

Comparing this study with the similar one conducted by Bempah and Donkor [23], where the mean concentration of 50 µg/kg was detected for p,p' DDE in pawpaw sampled from markets in Accra metropolis to mean concentration of 2.10 µg/kg of p,p' DDE then the concentrations being reported in the current study is quite low. Additionally, the detectable of dieldrin may suggest metabolism of the parent aldrin into dieldrin. Thus, sunlight and bacteria may have converted aldrin into dieldrin [24]. In Ghana aldrin was used extensively used to control pests on cocoa as well as termites under the trade name Aldrex [24]. Fokuo [25] detected a higher dieldrin concentration of 8.59 µg/kg in watermelon sampled from Mampong Municipality.

Table 5. Levels (µg/kg) of OCP residues in watermelon parts from Sege

	Peel	Pulp	Seed	EU MRL
Pesticide	**Mean±SD**	**Mean±SD**	**Mean±SD**	**(ng/g)**
Gamma - HCH	<0.01	<0.01	<0.01	10
Beta - HCH	<0.01	<0.01	<0.01	10
Heptachlor	<0.01	<0.01	<0.01	10
Delta - HCH	<0.01	<0.01	<0.01	10
Endrin	<0.01	<0.01	<0.01	10
Gamma- chlordane	<0.01	<0.01	<0.01	10
α- endosulfan	<0.01	<0.01	<0.01	50
p,p' - DDE	0.47 ± 0.14	0.40 ± 0.05	1.10 ± 0.14	50
Dieldrin	0.55 ± 0.14	0.35 ± 0.07	1.15 ± 0.07	10
Aldrin	<0.01	<0.01	<0.01	10
p,p' - DDT	<0.01	<0.01	<0.01	50
B - endosulfan	<0.01	<0.01	<0.01	50
p,p' - DDD	<0.01	<0.01	<0.01	50
Endosulfan-S	<0.01	<0.01	<0.01	50
Methoxychlor	<0.01	<0.01	<0.01	10

Limit of detection of pesticide residues = 0.01 ng/g, SD = Standard Deviation, NA = Not available, EU = European Union, MRL = Maximum Residue Limit

Table 6. Estimated daily intake of p,p' DDE and dieldrin residues for children (µg/kg body wt) through dietary intake of the studied watermelon

	Koluedor			sege			
Pesticides	**Pulp**	**Peel**	**Seed**	**Pulp**	**Peel**	**Seed**	**Reference dose**
p,p DDE	0.002	0.002	0.006	0.002	0.002	0.003	0.50
Dieldrin	0.001	0.002	0.003	0.001	0.002	0.004	0.10

Table 7. Estimated daily intake of p,p' DDE and dieldrin residues for adult (µg/kg body wt) through dietary intake of studied watermelon

	Koluedor			sege			
Pesticides	**Pulp**	**Peel**	**Seed**	**Pulp**	**Peel**	**Seed**	**Reference dose**
p,p DDE	0.001	0.001	0.004	0.001	0.001	0.002	0.50
Dieldrin	0.0006	0.001	0.0012	0.0005	0.001	0.003	0.10

4.2 Comparison of Pesticide Residue Levels to International Standard

The level of OCP residues measured were compared with maximum residue limits (MRLs) set forth by European Union (EU) [26]. The results indicated that all the OCP residue levels were below MRL of EU as shown in Table 2 to Table 5. The low levels of OCP residues in the samples may be attributed to low lipid contents of the fruits [23]. The results of present study also give an indication of the banned and restricted use of OCP pesticides in Ghana.

4.3 Estimation of Daily Exposure to p,p' DDE and Dieldrin through Dietary Eating of the Studied Watermelon

Exposure to the residues of p.p'-DDE and dieldrin through dietary consumption of watermelon from Koluedor and Sege are presented in Tables 6 and 7. The estimated daily intakes were then compared to USEPA reference doses (RfD). An aggregate daily exposure pesticide residue at or below the RfD is generally considered acceptable by the USEPA [27]. Estimated daily exposure ranges from 0.001µg/kg to 0.006 µg/kg for children and 0.0005 µg/kg to 0.003 µg/kg adults. The highest value of 0.006 µg/kg was obtained for children on consumption of seeds from watermelon sampled from Kuluedor as a result of p,p'DDE exposure. Clearly, the estimated daily exposure to residues of p,p'DDE and diedrin for both children and adults through consumption of the investigated watermelon fell below the USEPA reference doses. The effect is that eating of the investigated watermelon might not pose health risks to humans.

5. CONCLUSION

The study revealed the presence of fifteen OCPs residues in the peel, pulp and seeds of watermelon from the selected communities in the Ada-West district. Detectable OCP residues were dieldrin and p,p' DDE. The seeds of watermelon from Koluedor recorded the highest level of 2.10 µg/kg of p'p-DDE while the lowest level of 0.20 µg/kg of dieldrin and p,p'DDE were recorded in the peel of watermelon from Sege. The detectable OCP residues are also among the banned pesticides of the EPA of Ghana. Most of the OCP residues investigated were below the limit of detection of 0.01 µg/kg. The detectable OCP residues were also below maximum residue level (MRL) of European Union guidelines. Estimated daily intake or exposures to the pesticides through consumption of the studied watermelon were far below reference doses stipulated by USEPA. Consumption of seeds from the watermelon provided the highest risk of OCP exposure. In terms of exposure children were more exposed to OCP pollution compared to adults. It must be stressed that these chemicals have the potential to bioaccumulate, therefore, their presence in the watermelon is of great concern and undesirable since increased accumulation in living tissues could pose serious health hazards to the general population.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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