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Carcinogenic and non-carcinogenic risk of organochlorine pesticide residues in processed cereal-based complementary foods for infants and young children in Ghana

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HIGHLIGHTS

- Health risk of OCPs to babies from cereal-based complementary foods assessed.
- Levels of *p,p′*-DDE, dieldrin, β-HCH, and γ-HCH were higher than their MRLs.
- Hazard ratio for carcinogenic by some of the pesticides were greater than 1.
- Result raises concerns of possible carcinogenicity for infants and young children.

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ABSTRACT

Fourteen organochlorine pesticides (OCPs) residues were analyzed in 10 brands of processed cereal-based complementary foods with the aim of assessing the health risk to infants and young children. The QuEChERS method was used for extraction and clean-up of pesticide residues. Subsequent detection and quantification were done using GC with ECD and PFPD. Levels of *p,p′*-DDE, dieldrin, β-endosulfan, β-HCH, and γ-HCH detected in the processed cereal-based complementary food were higher than their respective MRL. The mean estimated daily intakes of OCPs in infants were significantly higher than that of young children. Exposure levels of heptachlor and dieldrin were higher than their respective ADI's. Their HIs recorded were greater than 1 indicating the possibility of adverse health effect on consumers. Hazard ratio for carcinogenic risk posed by β-HCH, dieldrin, heptachlor, γ-HCH and γ-chlordane were greater than 1. This result raises concerns of possible carcinogenicity for infants and young children.

1. Introduction

Organochlorine pesticides (OCPs) are classified as persistent organic pollutants (POPs), due to their ability to persist in the environment for long periods even after application. Many OCPs have been identified as hormone disrupters, exerting their toxic effects on the hormonal and reproductive systems thus resulting in adverse health effects to human (Golden et al., 1998; Hosie et al., 2000; Tiemann, 2008).

Although enormous restrictions have been placed on the use of OCPs due to the entry into force of the Stockholm Convention on POPs (UNEP, 2004), there is still documented evidence of OCPs in food samples (Waliszewski et al., 2003; Da Silva et al., 2010; Dubois et al., 2010; Fernandes et al., 2011a; Akoto et al., 2013). OCPs have been detected in cereals and grains, such as wheat, maize and cowpea which are used as raw materials for processing cereal-based complementary foods (Toteja et al., 2003; Bakore et al., 2004; Mawussi et al., 2009; Akoto et al., 2013).

Dietary intake represents a major route of pesticides exposure to humans especially children (Fenske et al., 2002a; Clayton et al., 2003). Due to their higher basal metabolic rate and energy requirements, children use more oxygen and therefore have a higher food consumption rate per kilogram body weight than adults (IPCS, 2004; FSA, 2012). Hence children risk higher than adults when exposed to contaminated food (Faustman et al., 2000; Kroes et al., 2002; IPCS, 2004). Several adverse health outcomes have been linked with children's exposure to pesticides. Parkinson-like declines in dopaminergic neurons in adulthood (Cory-Slechta et al., 2005; Eskenazi et al., 2006), delayed puberty

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(Laws et al., 2000; Ashby et al., 2002; Eskenazi et al., 2006), childhood cancer, neurological and endocrine disruption effects have been associated with the consumption of pesticide-contaminated foods (Garry, 2003; Bhatia et al., 2005).

Despite the higher risk posed by environmental toxicants to children, studies on dietary exposure in children are limited in Africa (Flower et al., 2004; Renwick et al., 2005; Cohen et al., 2000), with most studies focusing on chemical exposure among adults (Huybrechts et al., 2011). The paucity of exposure data for infants (6–11 months) and young children (12–24 months) could present risk management challenges. Monitoring of foods for infants and young children is crucial in assessing the dietary exposure to potentially harmful chemicals during the early years of life (Piccinelli et al., 2010).

In Ghana studies on risk assessment of pesticide residues in food are limited, and have focused mainly on fruits and vegetables (Bempah et al., 2011) and maize and cowpea (Akoto et al., 2013) for the general population. There is the need for dietary exposure studies on pesticide residues in processed cereal-based complementary foods for infants and young children considering their unique vulnerabilities. The objective of this study is to assess the risk posed to infants and young children by OCP residues following the consumption of processed cereal-based complementary foods sold in Ghana.

2. Materials and methods

2.1. Sampling

Ten brands of processed cereal-based complementary foods comprising 5 locally produced and 5 imported produced were sampled from markets in Accra, (Ghana). For each brand of product, 5 samples of different batch were analyzed separately in triplicates. The mean concentration for each brand was then calculated. The various brands were designated as baby food A, B, C, D, E, F, G, H, I and J. Analyzed food products were to be consumed by children from six (6) months of age onward.

2.2. Extraction and clean-up of pesticide residues

All reagents and chemicals were of analytical grade. The QuEChERS method developed by Anastassiades et al. (2003) was used for extraction and clean-up, with slight modification. 5 g of each homogenous sample were weighed into 50 mL centrifuge tube and 10 mL of distilled water were added. The mixture was shaken for 1 min. on a vortex mixer to disperse solvent and pesticides evenly throughout the sample. 10 mL of acetonitrile were then added to the mixture and then shaken for 1 min.

Salt mixture containing 0.5 g disodium hydrogencitrate sesquihydrate, 1.0 g sodium chloride, 1.0 g trisodium citrate dihydrate and 4.0 g anhydrous magnesium sulphate was added to the acetonitrile-based mixture. The resultant mixture was vigorously shaken for 1 min and centrifuged for 5 min. at 3000 U min^{-1}. For samples containing fatty components, aliquot of 8 mL of the extract was taken and transferred into a centrifuge tube and frozen for 1.5 h. Freezing-out helped remove some additional co-extractives with limited solubility in acetonitrile, while the major part of fat and waxes solidify and precipitate.

For the solid phase extraction, 6 mL of the extract was transferred into a centrifuge tube containing 150 mg PSA and 900 mg magnesium sulphate. The mixture was shaken for 30 s and centrifuged for 5 min. at 3000 U min^{-1}. Four milliliters (4 mL) of the cleaned extract was transferred into a pear shaped flask and the pH adjusted to 5 by adding 40 μL of 5% formic acid solution in acetonitrile (v/v). The filtrate was then concentrated below 40 °C on rotary evaporator to dryness. The concentrate was re-dissolved in 1 mL ethylacetate and 20 μL of 1% glycol solution in ethyl acetate (v/v). The extract was transferred into a 2 mL vial for analysis by GC-ECD.

2.3. Analysis of pesticide residues

The limit of detection was checked for Gas chromatograph equipped with Electron Capture Detector (ECD). The limit of detection for OC pesticides was 0.0015 mg kg^{-1}. Separation and quantification of OC pesticides were carried out using Varian CP-3800 gas chromatograph with a CombiPAL Autosampler equipped with an Electron Capture Detector (ECD, 63Ni), on 30 m + 10 mEZ Guard × 0.25 mm internal diameter fused silica capillary column coated with VF-5 ms (0.25 μm film). The column oven temperature was set from 70 °C, held for 2 min and increased to 180 °C at a rate of 25 °C min^{-1}, and then from 180 °C to 300 °C at a rate of 5 °C min^{-1}. Purified nitrogen gas was used as carrier gas at the flow rate of 1.0 mL min^{-1} and make up gas of 29 mL min^{-1}. The injector and detector temperatures were maintained at 270 °C and 300 °C, respectively. The injector volume of the gas chromatograph was 1.0 μL.

Pesticide residues in the extracts were identified using the retention times of the reference standards. Quantification was achieved by comparing sample peak areas with those of the reference standards under the same conditions. Each sample was analyzed three times and the mean values calculated.

2.4. Quality control

All reagents used during the analysis were exposed to the same extraction procedures. Solvents used were run to verify any interfering substances within the runtime. In all batches reagent blanks and samples were fortified with mixed OCP standards for quality control checks. All the samples were analyzed in triplicates. Procedural recoveries were analyzed concurrently with each batch of analytical extracts. Fortification level of 0.05 mg kg^{-1} was chosen based on the limit of determination. Organochlorine pesticide residues were recovered in the range of 69–119%.

2.5. Risk assessment

2.5.1. Consumption rate

Consumption rate (CR) for each brand of processed food was calculated using recommended serving size on the label of the sampled products (Piccinelli et al., 2010). Meal frequency of 4 per day, depicting worst case scenario, was used to calculate consumption rate using WHO recommended meal frequency, as guide (WHO, 2002).

$$\mathrm{CR} = W \times F$$

where CR is the consumption rate in (kg d^{-1}), W is the weight of food per serving and F is the meal frequency per day.

2.5.2. Estimation of dietary exposure

The Estimated Daily Intake (EDI) for the OCP residues detected in the various food samples was calculated for each age category using the equation below.

$$\mathrm{EDI} = \frac{\mathrm{C} \times \mathrm{CR}}{B_W}$$

where EDI is the estimated daily intake (mg kg^{-1} d^{-1}), C is the mean concentration of pesticide residues (mg kg^{-1}), CR is the consumption rate (kg d^{-1}) and B_W is the average body weight (kg). The average body weight for infants and young children were estimated using the procedure outlined by the Multicentre Growth

Reference Study Group (WHO, 2006). In this study, 8.4 kg and 10.6 kg were used as the average body weight for infants and young children respectively.

2.5.3. Risk characterization

For non-carcinogenic risk, the ratio of EDI to Acceptable Daily Intake (ADI) was used to obtain the Hazard Index (HI). If the ratio is less than 1.0, it can be concluded with certainty that there is essentially no probability of adverse effect. However, if the ratio exceeds 1.0, then the potential for adverse effects is indicated but not demonstrated (US EPA, 2000).

For carcinogenic effects, the hazard ratios (HRs) were calculated using the equation below169 (Dougherty et al., 2000):

$$\mathrm{HR} = \frac{\mathrm{EDI}}{\mathrm{CBC}}$$

where CBC is the Cancer Benchmark Concentration which was calculated using the formula below (Dougherty et al., 2000):

$$\mathrm{CBC} = \frac{(\mathrm{RL}/\mathrm{OSF}) \times B_W}{\mathrm{CR}}$$

RL is the maximum acceptable risk level (1×10^{-6}), OSF is the Oral Slope Factor (mg kg^{-1} d^{-1}), B_W is the body weight (kg) and CR is the consumption rate (kg d^{-1}). The CBC for carcinogenic effect is derived by setting the risk to one in one million due to lifetime exposure. The OSFs for the pesticides were obtained from US EPA (2014).

3. Results and discussion

The processed cereal-based complementary baby food samples were analyzed for the residues of 14 different types of OCPs comprising (β-HCH, γ-HCH, δ-HCH, heptachlor, aldrin, γ-chlordane, *p,p′*-DDE, *p,p′*-DDT, dieldrin, endrin, α-endosulfan, β-endosulfan, endosulfan sulphate and methoxychlor). The results show that 90% of samples analyzed were contaminated. Residues of 8 out of the 14 OCPs considered in this study were detected in 9 brands of baby food samples (Table 1). The mean concentration ranged from 0.002 ± 0.001 mg kg^{-1} in baby food F to 0.022 ± 0.007 mg kg^{-1} in baby food E.

The most frequent encountered pesticide residue was γ–HCH; it was detected in 5 different types of the analyzed food brands. Food brands E, F and G recorded the highest number of different pesticide residues. Each recorded the presence of 4 different pesticides residues. Even though the use of OCPs is banned in Ghana, they were detected in all the locally produced food brands (A to E) used in this work. All the 5 selected locally based processed food recorded the presence of at least 3 different types of OCP residue. On the other hand dieldrin and *p,p′*-DDE which are metabolites of aldrin and *p,p′*-DDT were the most frequent residues detected in the foreign based processed foods (F to J) as presented in Table 1. This observation shows an aged used of these pesticides which breaks down to these metabolites that are more persistent and therefore still present in the environment.

A maximum residue level (MRL) of 0.01 mg kg^{-1} has been established for pesticides in processed cereal-based foods for infants and young children (EC, 2006). The highest concentration of OCP residue was recorded for lindane (γ–HCH) at 0.022 ± 0.007 mg kg^{-1} in locally produced food sample E. OCP in other locally produced food exceeding their MRL were: β-endosulfan (0.021 ± 0.001 mg kg^{-1}) in sample B, β-HCH (0.017 ± 0.001 mg kg^{-1}) in sample C and γ-HCH (0.014 ± 0.014) in sample D. The highest OCP residue recorded in the imported baby food was 0.014 ± 0.001 mg kg^{-1} for β-HCH in sample I. This was followed by *p,p′*-DDE (0.013 ± 0.001 mg kg^{-1}). Endrin and dieldrin were detected in three brands of the imported products, thus samples F, G, and H (Table 1). β-HCH was detected in samples from brands A, C, G, and I; β-endosulfan was present in baby food brands B, and G; γ-HCH was also detected in samples of brands A, B, D, E, and F while heptachlor was found in samples of brands A, E, and F.

Results from this study are consistent with outcome of studies conducted for OCP residues in major ingredients used for the formulation of cereal-based complementary foods such as wheat, rice and maize in different regions of the world. For example, in Taiwan, Dong et al. (1999) detected different OCPs in various food samples including cereals. Isomers of HCH, aldrin, DDT and its metabolites, and heptachlor have been detected in rice and wheat from India (Toteja et al., 2003; Bakore et al., 2004). Mawussi et al. (2009) detected γ-HCH, heptachlor, DDT and its metabolites, α and β-endosulfan in maize and cowpea in Togo. In a study conducted in Turkey, methoxychlor, DDT and its metabolites, aldrin, heptachlor β and γ-HCH were found to be the highest OCP residues in wheat (Guler et al., 2010).

All the OCPs detected in the locally processed food brands in this study have been detected at various concentrations in maize and cowpea grown in Ghana (Akoto et al., 2013). The studies conducted by Akoto et al., recorded OC pesticides concentration range of 0.002–0.019 mg kg^{-1} in maize samples. The concentration range for OC pesticide residues reported in this paper (0.003–0.022 mg kg^{-1}) was higher than the levels reported by

Table 1
Mean concentrations (mg kg^{-1}) of OCPs in processed cereal-based complementary food.

Pesticides	Locally processed food samples					Foreign processed food samples				
	A	B	C	D	E	F	G	H	I	J
β-HCH	0.005 ± 0.001	BDL	0.017 ± 0.001	BDL	BDL	BDL	0.005 ± 0.001	BDL	0.014 ± 0.001	BDL
γ-HCH	0.008 ± 0.001	0.006 ± 0.002	BDL	0.014 ± 0.014	0.022 ± 0.007	0.002 ± 0.001	BDL	BDL	BDL	BDL
Delta-HCH	BDL	BDL	0.007 ± 0.003	0.008 ± 0.002	0.007 ± 0.001	BDL	BDL	BDL		BDL
Heptachlor	0.003 ± 0.001	BDL	BDL	BDL	0.006 ± 0.001	0.006 ± 0.001	BDL	BDL	BDL	BDL
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
γ-Chlordane	BDL	BDL	BDL	BDL	0.013 ± 0.002	BDL	BDL	BDL	BDL	BDL
α-Endosulfan	BDL	0.008 ± 0.003	0.006 ± 0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL
β-Endosulfan	BDL	0.021 ± 0.001	BDL	BDL	BDL	BDL	0.006 ± 0.001	BDL	BDL	BDL
Endosulfan sulphate	BDL	BDL	BDL	BDL		BDL	BDL	BDL	BDL	BDL
p,p′-DDE	BDL	BDL	BDL	BDL	BDL	0.013 ± 0.001	0.013 ± 0.001	BDL	BDL	BDL
p,p′-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Methoxychlor	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	0.005 ± 0.003	0.012 ± 0.002	0.003 ± 0.009	BDL	BDL

* BDL means concentration was below detection limit (0.0015 mg kg^{-1}).

Akoto et al. (2013). The higher levels of OCP residues recorded in this study could have resulted from the processing of the raw produce since water and other components were removed during processing.

3.1. Risk assessment

3.1.1. Non-carcinogenic risk

Risk assessment and EDIs were calculated for pesticides that were detected in baby food samples (Tables 2–4). γ-HCH in sample D and recorded the high EDI (5.53×10^{-4} mg kg^{-1} d^{-1}; 5.24×10^{-4} mg kg^{-1} d^{-1}) respectively for infants. (Table 3). The EDI recorded for both age categories were higher than the ADI for γ-HCH (5×10^{-3} mg kg^{-1} d^{-1}) (FAO/WHO, 2014), for infants consequently, the hazard index calculated for these dietary exposure scenarios for γ-HCH were greater than 1, for infants but less than 1 for young children in both food samples. The intake level for γ-HCH were also less the ADI in baby food F, for infants and young children respectively. Again the EDIs for heptachlor in baby food E for both infants and young children were greater than their corresponding ADI resulting in an HI of 1.43 for infants and 1.13 for young children (Table 3).

Table 4 also shows the EDI and health risk index of OCPs in baby food G, H and I. The EDI for young children exposed to dieldrin in baby food G was 1.13×10–4 mg kg^{-1} d^{-1}. The HI recorded was 1.13. Again the EDI of dieldrin in samples of processed food H were higher than their ADIs for both infants and young children. Health risks recorded for processed food H for infants and young children were 2.86 and 1.13 respectively. Dieldrin in processed food H recorded the highest HI of 2.26 for infants whiles heptachlor in food sample E recorded the highest HI for young children.

The ADI is a health-based regulatory value established to protect the health of consumers (FAO/WHO, 2009). The high EDI of heptachlor and dieldrin in some processed food samples detected in this paper demonstrates that there is the potential for adverse effect on infants and young children through dietary exposure of these pesticides. There is therefore the need for further evaluation of specific issues surrounding chemical exposure and toxic potency (US EPA, 2000). Statistical analysis of the mean exposure to OCPs in infants (252.12 mg kg^{-1} d^{-1}) using paired *t*-test, ($p < 0.05$) was significantly higher than mean exposure in young children (206.99 mg bkg^{-1} d^{-1}). The results from the exposure assessment indicates that estimated exposure levels are age-dependent and confirms the scientific opinion that infants and younger age groups have higher food consumption per kilogram body weight and as a result have higher estimated exposure levels, which in most cases, is higher than that estimated for all other age groups (NRC, 1993 and EFSA, 2009).

3.1.2. Carcinogenic risk

Carcinogenic risk was assessed for the OCPs residue detected in the processed food samples that are known to have the potential to cause cancer. Tables 5 and 6 summarize the cancer benchmark concentrations (CBC) derived using oral slope factors obtained from US EPA (US EPA, 2014) and their hazard ratios (HR) for infants and young children respectively.

Hazard ratio obtained for β-HCH in processed food samples A, C, D and I could pose potential carcinogenic risk to both infants and young children since the HRs were far greater than 1. The HR for γ-Chlordane in processed food E was 2.58 and 1.62 for infants and young children respectively. γ-HCH recorded hazard ratio of 4.42 for infants and 2.79 for young children in baby food B. The HR for γ-HCH in baby food F was however less than 1 for both infants and young children. Heptachlor also recorded hazard ratios of 15.3 for infant and 9.61 for young children in baby food E. Baby food F recorded HR of 38.3 and 4.7 for infants and young children

Table 2
Health risk assessment and EDI of OCPs residues in processed cereal-based complementary food.

Pesticides	ADI (mg kg^{-1} d^{-1})	Baby food A					Baby food B					Baby food C				
		Infants		Young children		Health risk	Infants		Young children		Health risk	Infants		Young children		Health risk
		EDI (ng kg^{-1} d^{-1})	Hazard index	EDI (ng kg^{-1} d^{-1})	Hazard index		EDI (ng kg^{-1} d^{-1})	Hazard index	EDI (ng kg^{-1} d^{-1})	Hazard index		EDI (ng kg^{-1} d^{-1})	Hazard index	EDI (ng kg^{-1} d^{-1})	Hazard index	
β-HCH	NA	142	NA	113	NA	NA, NA	-	-	-	-	NA, NA	405	NA	321	NA	NA, NA
γ-HCH	0.0005	222	0.440	181	0.360	No, No	143	0.286	113	0.226	No, No	-	-	-	-	No, No
δ-HCH	0.003	-	-	-	-	No, No	-	-	-	-	No, No	167	0.056	132	0.044	No, No
Heptachlor	0.0001	57.1	0.570	45.3	0.453	No, No	-	-	-	-	No, No	-	-	-	-	No, No
α-Endosulfan	0.006	-	-	-	-	No, No	190	0.032	151	0.025	No, No	143	0.024	113	0.018	No, No
β-Endosulfan	0.006	-	-	-	-	No, No	500	0.083	396	0.07	No, No	-	-	-	-	No, No

Table 3
Health risk assessment and EDI of OCPs residues in processed cereal-based complementary food.

Pesticides	ADI ($mg\ kg^{-1}\ d^{-1}$)	Baby food D					Baby food E					Baby food F				
		Infants		Young children		Health risk	Infants		Young children		Health risk	Infants		Young children		Health risk
		EDI ($ng\ kg^{-1}\ d^{-1}$)	Hazard index	EDI ($ng\ kg^{-1}\ d^{-1}$)	Hazard index		EDI ($ng\ kg^{-1}\ d^{-1}$)	Hazard index	EDI ($ng\ kg^{-1}\ d^{-1}$)	Hazard index		EDI ($ng\ kg^{-1}\ d^{-1}$)	Hazard index	EDI ($ng\ kg^{-1}\ d^{-1}$)	Hazard index	
γ-HCH	0.0005	553	**1.11**	425	**0.850**	**Yes No**	524	**1.05**	415	**0.830**	**Yes, No**	23.8	0.079	26.4	0.088	No, No
δ-HCH	0.003	316	0.105	251	0.083	No, No	167	0.056	132	0.044	No, No	–	–	–	–	No, No
Heptachlor	0.0001	–	–	–	–	No, No	143	**1.430**	113	**1.130**	**Yes, Yes**	71.4	0.714	79.2	0.792	No, No
γ-Chlordane	0.0005	–	–	–	–	No, No	310	0.62	245	0.49	No,No	–	–	–	–	No, No
p,p′-DDE	0.01	–	–	–	–	No, No	–	–	–	–	No, No	155	0.016	172	0.018	No, No
Dieldrin	0.0001	–	–	–	–	No, No	–	–	–	–	No, No	595	0.595	660	0.660	No, No

Bold means values are greater than 1.

Table 4
Health risk assessment and EDI of OCPs residues in processed cereal-based complementary food.

Pesticides	ADI ($mg\ kg^{-1}\ d^{-1}$)	Baby food G					Baby food H					Baby food I				
		Infants		Young children		Health risk	Infants		Young children		Health risk	Infants		Young children		Health risk
		EDI ($mg\ kg^{-1}\ d^{-1}$)	Hazard index	EDI ($mg\ kg^{-1}\ d^{-1}$)	Hazard index		EDI ($mg\ kg^{-1}\ d^{-1}$)	Hazard index	EDI ($mg\ kg^{-1}\ d^{-1}$)	Hazard index		EDI ($mg\ kg^{-1}\ d^{-1}$)	Hazard index	EDI ($mg\ kg^{-1}\ d^{-1}$)	Hazard index	
β-HCH	NA	NA	NA	4.72×10^{-4}	NA	NA, NA	–	–	–	–	–	3.33×10^{-4}	NA	2.64×10^{-4}	NA	NA, NA
β-Endosulfan	0.006	–	NA	5.66×10^{-5}	0.094	No, No	–	–	–	–	No, No	–	–	–	–	No, No
Endosulfan sulphate	NA	–	NA	–	–	No, No	–	–	–	–	No, No	–	–	–	–	No, No
p,p′-DDE	0.01	–	NA	1.22×10^{-4}	0.016	No, No	–	–	–	–	No, No	–	–	–	–	No, No
Dieldrin	0.0001	–	NA	1.13×10^{-4}	**1.13**	**NA, Yes**	2.86×10^{-4}	**2.86**	1.13×10^{-4}	**1.13**	**Yes, Yes**	–	–	–	–	No, No
Endrin	0.0002	–	NA	–	–	No, No	1.43×10^{-4}	0.714	1.13×10^{-4}	0.566	No, No	–	–	–	–	No, No

Bold means values are greater than 1

Table 5
Cancer bench mark concentrations and Hazards ratio for OCPs residues in cereal-based complementary food for young children.

Pesticides	OSF	Processed food samples															
		A		B		C		D		E		F		H		I	
		CBC	HR	CBC	HR	CBC	HR	CBC	HR	CBC	HR	CBC	HR	CBC	HR	CBCS	HR
β-HCH	1.80	19.4	7.35	–	–	23.3	17.4	19.5	48.4	–	–	–	–	–	–	23.3	14.4
γ-HCH	1.30	–	–	32.3	4.42	–	–	–	–	–	–	64.6	0.37	–	–	–	–
Heptachlor	4.50	–	–	–	–	–	–	–	–	9.33	15.3	18.7	38.3	–	–	–	–
γ-Chlordane	0.35	–	–	–	–	–	–	–	–	12.0	2.58	–	–	–	–	–	–
p,p′-DDE	0.34	–	–	–	–	–	–	–	–	–	–	247	0.63	–	–	–	–
Dieldrin	16.0	–	–	–	–	–	–	–	–	–	–	5.25	11.3	2.63	109	–	–

Table 6
Cancer bench mark concentrations and Hazards ratio for OCPs residues in cereal-based complementary food for young children.

Pesticides	OSF	Processed food samples															
		A		B		C		D		E		F		H		I	
		CBC	HR	CBC	HR	CBC	HR	CBC	HR	CBC	HR	CBC	HR	CBC	HR	CBCS	HR
β-HCH	1.80	24.5	5.28	–	–	29.4	10.9	24.6	17.3	–	–	–	–	–	–	29.4	8.97
γ-HCH	1.30	–	–	40.5	2.79	–	–	–	–	–	–	58.2	0.47	–	–	–	–
Heptachlor	4.50	–	–	–	–	–	–	–	–	11.8	9.61	16.8	4.70	–	–	–	–
γ-Chlordane	0.35	–	–	–	–	–	–	–	–	151.4	1.62	–	–	–	–	–	–
p,p′-DDE	0.34	–	–	–	–	–	–	–	–	–	–	233	0.77	–	–	–	–
Dieldrin	16.0	–	–	–	–	–	–	–	–	–	–	4.73	13.9	3.31	34.2	–	–

respectively. Dieldrin recorded the highest HR of 109 in the baby food H for infant (Table 5). The HR values obtained for dieldrin in baby food F, G and H were all greater than 1. These HR values indicate that the cancer benchmark concentrations exceeded the EDI for the respective OCP in the processed food samples, thus raising serious concerns of possible carcinogenicity. *p,p′-DDE* detected in process food F recorded hazard ratio of less than 1, indicating that it was unlikely for infants and young children to experience carcinogenic effect from dietary exposure to *p,p′*-DDE.

4. Conclusion

This study has shown the level of contamination of ten different brands of processed cereal-based complementary food obtained from the Ghanaian marker with OCP residues. γ-HCH which recorded the highest concentration was the most frequently encountered pesticide residue. Concentrations of γ-HCH β-HCH, β-endosulfan, γ-chlordane, dieldrin, and *p,p′*-DDE, were above their MRL where detected. Health risk assessment for the detected pesticide residues indicated that the EDI of heptachlor; and dieldrin were higher than their respective ADI's. Non-carcinogenic hazard indices for these pesticides were greater than 1, signifying that processed cereal-based complementary food containing these pesticides could pose adverse health risk to infants and young children.

Carcinogenic risk assessed for γ-HCH, β-HCH, heptachlor, γ-chlordane and dieldrin indicated that their CBCs exceeded their respective EDIs. Subsequently, the cancer hazard risks calculated for these pesticides were greater than 1 in all the food brand samples in which they were detected with dieldrin recording the highest HR of 109. Hence there is the possibility for carcinogenicity among consumers. The locally processed foods samples recorded more pesticides residues than the imported products.

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