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Occurrence of organochlorine and organophosphorus pesticide residues in poultry feeds, raw and cooked eggs from selected farms in Ilala and Kibaha Districts, Tanzania

***MAHUGIJA, JAM; CHIBURA, PE; LUGWISHA, EHJ**

Chemistry Department, University of Dar es Salaam, P.O. Box 35061 Dar es Salaam, Tanzania
*Corresponding author. *E-mail addresses: mahugija@udsm.ac.tz; johnmahugija@yahoo.com*

ABSTRACT: This study assessed the levels of seventeen pesticides and metabolites residues in chicken feeds and raw eggs as well as the effects of processing methods on the levels in eggs in samples obtained from six poultry farms in Ilala and Kibaha districts, Tanzania. Extraction was performed by solid dispersion method and the extracts were cleaned-up by adsorption column chromatography. The analytes were determined by Gas Chromatography–Mass Spectrometry (GC–MS). The highest mean concentrations of the contaminants in feeds and eggs were as follows, respectively: aldrin 0.62 and 2 mg/kg, dieldrin 0.71 and 1.3 mg/kg, total DDT 6.68 and 8.14 mg/kg, total endosulfan 3.53 and 3.74 mg/kg, total HCHs 0.91 and 1.21 mg/kg, chlorpyrifos 12.2 and 0.59 mg/kg, fenitrothion 4.9 and 0.64 mg/kg and pirimiphos methyl 22.11 and 1.6 mg/kg. Chicken feeds were found to be the most contaminated followed by raw eggs and finally cooked eggs. Most of the concentrations were above the maximum residue limits (MRLs) indicating risks and concerns. Proper selection and preparation of poultry feeds could reduce the levels in the feeds and eggs.

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Poultry feeds may contain chemical contaminants such as pesticides (Zhao *et al*., 2013) and can be sources of contamination of poultry products including eggs (Windal *et al*., 2009). Chicken eggs are important sources of nutrients to the human body. They are good sources of proteins, unsaturated fatty acids, vitamins and minerals (Bradley and King, 2004) and are consumed by many people worldwide. The presence of pesticides in such foods is of great concerns to the consumers (Tao *et al*., 2009; Wang *et al*., 2013).

Pesticides are known to cause many health effects to animals including human beings (WHO, 2010). Pesticides are widely used in agricultural and livestock production in Tanzania for control of pests during farming, transportation, processing and storage. Most of the poultry feeds are derived from agricultural sources. A study by Mahugija *et al*. (2017) found high levels of pesticide residues in maize grains, which are among the sources of poultry feeds in Tanzania. This suggested that the poultry feeds and poultry products could also contain high levels of pesticide residues. Therefore, this study was conducted to investigate the levels and status of residues of selected organochlorine and organophosphorus pesticides in poultry feeds and raw eggs. The study also assessed the effects of cooking on the pesticide residues in eggs.

MATERIALS AND METHODS

Study sites and sampling: Poultry feeds and eggs were collected from six poultry farms in Ilala and Kibaha Districts in Tanzania in December 2014 to March 2015. Four sampling sites were located in Kibaha district and two sites were located in Ilala district (Figure 1). The farms use feeds prepared from mixtures of products including maize bran, rice bran, sardines, fish, animal bones, cow blood, ground dried legume leaves and mineral premix. Composite poultry feed samples (500 g each) and eggs were collected from the farms. A total of 63 samples of poultry feeds and eggs were obtained from the farms. Each sample was wrapped in aluminium foil. In the laboratory, the feed samples were kept frozen at –18 °C, while the eggs were stored in a refrigerator at 4 °C until extraction.

Preparation of samples, extraction and clean-up: The shells of the raw eggs were removed prior to processing. The effects of cooking were assessed through boiling the eggs with distilled water for 15 minutes, and then cooled and their shells were removed. Each of the samples was homogenized by grinding using mortar and pestle. The homogenized sample (20 g) was extracted by shaking with cyclohexane: ethyl acetate mixture (1:1 v/v, 70 mL, then 50 mL and finally 40 mL) in a flask; dried with anhydrous sodium sulfate (10-20 g) and concentrated

*Corresponding author. *E-mail addresses: mahugija@udsm.ac.tz; johnmahugija@yahoo.com*

to 2 mL using a rotary evaporator. Clean-up of the concentrated extracts was performed using florisil (10 g) and sodium sulfate (5 g) packed in a glass column (10 mm i.d. x 32 cm) and eluted with cyclohexane: ethyl acetate (40 mL) then concentrated in a rotary evaporator and made up to 2 mL in cyclohexane: acetone (9:1 v/v) ready for analysis.

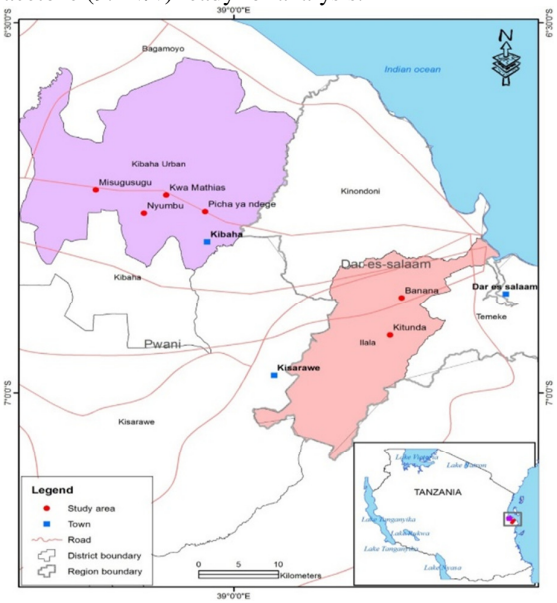

Fig 1: Map showing the sampling sites

Analytical quality assurance: Analytical quality assurance procedures included the use of analytical grade and high purity chemicals (Thermo Fisher Scientific, UK) and standards (Dr. Ehrenstorfer, Germany) and determination of blanks, recovery (accuracy), precision tests and detection limits. Procedural blank tests involved checking the solvents and reagents. The recovery tests were performed by spiking the matrix blanks at levels of 0.2, 0.5, 1.0, 2.0 and 5 µg/kg and the experiments were carried out with three replicates at each level. Detection limits were established based on signals that were three times higher than the noise level. The analytes were not detected in the procedural blanks. The recoveries of the analytes ranged from 82% to 115% and were acceptable with precision of relative standard deviation of < 10% (European Commission, 2015). The calibration curves were linear with correlation coefficients (r^2) > 0.9. The detection limits varied from 0.0003 to 0.001 mg/kg.

Gas chromatographic analysis and data analysis: The compounds in the purified extracts were quantified on a gas chromatograph coupled to a mass spectrometer (Agilent GC-MS), equipped with HP-5MS capillary column, XL mass selective detector and autosampler. Oven temperature programme was 90 °C held for 1 min, raised to 180 °C at a rate of 30 °C/min then to 260 °C, at a rate of 4 °C/min. A 1 µL sample was injected in splitless mode at 250 °C and purge flow of 3 mL/min. The carrier gas was helium at the flow rate of 2.2 mL/min and the internal pressure was 150 kPa. The interface was heated at 300 °C, the ion source temperature was 230 °C and the mass spectrometer was operated in electron ionization and full scan mode in the range of 45 to 500 *m/z*. Standards dissolved in cyclohexane:acetone (9:1 v/v) were analyzed in each batch. The concentrations of working standards ranged from 0.5 to 2 µg/mL. The retention times and mass spectra of the analytes in samples were compared with those of reference standards for identification of the compounds. The NIST mass spectral library and AMDIS programme were also used in the identification of the analytes. Peak heights were used for quantification of the analytes. Data analysis involved analysis of variance (ANOVA) and *t*-test to test for significance of variations using GraphPad Instat software (GraphPad Software, Inc. San Diego California, USA).

RESULTS AND DISCUSSION

Pesticide residues in poultry feeds: The organochlorine pesticide residues detected in the poultry feeds included aldrin, dieldrin, hexachlorocyclohexane (HCH) isomers (α-, β-, γ- and δ-HCH), endosulfan isomers (α- and β-endosulfan) and dichlorodiphenyltrichloroethane (DDT) residues (*p,p'*- and *o,p'*-DDT, DDD and DDE). Their concentrations are presented in Table 1. Aldrin was detected in all the poultry feed samples and the concentrations ranged from 0.1 to 0.62 mg/kg. Dieldrin was detected in samples from three sites with concentrations up to 0.71 mg/kg. The concentrations of aldrin and dieldrin suggested contamination as pesticides as well as transformation of aldrin to dieldrin. The concentrations of total DDT in feeds ranged from 3.7 to 6.68 mg/kg. The concentrations of DDT residues in feed samples were dominated by the metabolites (DDD and DDE) indicating contamination due to past use of DDT or significant degradation. The concentrations of total endosulfan detected in feed samples were up to 3.53 mg/kg. The concentrations of α-endosulfan were higher than β-endosulfan in samples collected from two sites, which indicated contamination with fresh technical endosulfan (ATSDR, 2013). In the feed samples collected from the other sites, only β-endosulfan was detected which can be due to contamination with old endosulfan and faster degradation of α-endosulfan than β-endosulfan (ATSDR, 2013). HCH isomers were detected in the feeds with concentrations of total HCHs ranging from 0.36 to 0.91 mg/kg (Table 1).

The concentrations of γ-HCH were the highest among the HCH isomers in most feed samples indicating technical lindane. The aldrin and dieldrin detected in feeds exceeded the maximum residue limit (MRL) of 0.02 mg/kg. The concentrations of total DDT, total endosulfan and most HCHs in feeds exceeded the MRLs of 0.1, 1.0 and 0.01 mg/kg, respectively (WHO/FAO, 2016). A study on feed samples in Italy reported aldrin at concentrations with mean ± SD of 0.00453 ± 0.00112 mg/kg (Panseri *et al*., 2013) that were lower than the concentrations found in the present study. The concentrations of DDT residues found in chicken feeds in the present study were greater than the levels found in feeds in Punjab (India), Italy and China where the mean concentrations of total DDT were up to 0.91, 0.00412 and 0.401 mg/kg, respectively (Aulakh *et al*., 2006; Panseri *et al*., 2013; Zhao *et al*., 2013). The concentrations of the HCHs found in this study were comparable to the levels found by Aulakh *et al.* (2006) in Punjab (mean total HCHs = 0.65 mg/kg) but were generally greater than the levels found in poultry feed in China by Zhao *et al.* (2013) that were up to 0.01929 mg/kg for total HCHs.

Table 1: Mean concentrations of pesticide residues in chicken feeds (mg/kg, n = 3)

Pesticides/ Metabolites	Misugusugu	Kwa Mathias	Nyumbu	Kitunda	Banana
α-HCH	0.10 ± 0.01	0.10 ± 0.10	ND	0.30 ± 0.02	ND
β-HCH	0.03 ± 0.02	0.003 ± 0.002	0.10 ± 0.01	ND	0.85 ± 0.10
γ- HCH	0.14 ± 0.04	0.15 ± 0.01	0.17 ± 0.01	0.13 ± 0.01	ND
δ-HCH	0.14 ± 0.01	0.11 ± 0.01	0.10 ± 0.01	0.10 ± 0.01	0.06 ± 0.03
Total HCH	0.41 ± 0.03	0.36 ± 0.03	0.37 ± 0.02	0.53 ± 0.04	0.91 ± 0.09
Aldrin	0.24 ± 0.10	0.10 ± 0.02	0.28 ± 0.20	0.62 ± 0.05	0.56 ± 0.04
Dieldrin	ND	ND	0.40 ± 0.30	0.71 ± 0.10	0.58 ± 0.05
α-endosulfan	1.30 ± 0.30	1.50 ± 0.42	ND	ND	ND
β-endosulfan	0.90 ± 0.21	0.41 ± 0.03	3.53 ± 1.90	ND	2.12 ± 1.52
Total endosulfan	2.20 ± 0.40	1.91 ± 0.50	3.53 ± 1.90	ND	2.12 ± 1.52
p,p'-DDT	0.22 ± 0.02	1.40 ± 0.10	ND	0.74 ± 0.06	ND
o,p'-DDT	ND	ND	ND	ND	ND
p,p'-DDD	1.25 ± 0.20	0.90 ± 0.10	2.28 ± 0.30	3.07 ± 0.52	3.00 ± 0.60
o,p'-DDD	0.50 ± 0.10	0.10 ± 0.01	1.42 ± 0.20	2.32 ± 0.40	2.11 ± 0.50
p,p'-DDE	1.83 ± 0.40	1.25 ± 0.42	ND	0.55 ± 0.10	ND
o,p'-DDE	0.63 ± 0.10	0.53 ± 0.10	ND	ND	ND
Total DDT	4.43 ± 1.50	4.18 ± 1.03	3.70 ± 0.50	6.68 ± 1.76	5.11 ± 1.23
Chlorpyrifos	2.52 ± 0.20	0.81 ± 0.06	11.00 ± 1.32	6.20 ± 5.34	12.20 ± 1.34
Fenitrothion	0.03 ± 0.01	2.20 ± 0.20	4.90 ± 0.30	ND	2.50 ± 0.20
Pirimiphos methyl	0.15 ± 0.01	11.00 ± 0.80	22.11 ± 2.23	ND	12.00 ± 1.10

ND =Not detected; Concentration expressed as mean ± standard deviation

The organophosphorus pesticides detected in poultry feed samples were chlorpyrifos, fenitrothion and pirimiphos methyl (Table 1). Chlorpyrifos, fenitrothion and pirimiphos methyl were detected in 80 to 100% of the feed samples at concentrations ranging from 0.81 to 12.2, 0.03 to 4.9 and 0.15 to 22.11 mg/kg, respectively. Chlorpyrifos concentrations in feeds exceeded the MRL of 0.05 mg/kg. Fenitrothion levels in feed samples were below the MRL of 6 mg/kg. The concentrations of pirimiphos methyl residues in 60% of the feed samples exceeded the MRL of 7 mg/kg (WHO/FAO, 2016).

Pesticide residues in chicken eggs: The concentrations of organochlorine pesticide residues detected in eggs are presented in Table 2 and Table 3. The mean concentrations of total DDT in eggs ranged from 0.75 to 8.14 mg/kg. The concentrations of DDD and DDE exceeded those of DDT indicating contamination with old DDT or significant degradation. Aldrin and dieldrin were detected in most egg samples and their mean concentrations were up to 2.0 and 1.3 mg/kg, respectively. Endosulfan isomers (α and β) were detected in eggs with mean concentrations of total endosulfan of up to 3.74 mg/kg. The mean concentrations of β-endosulfan in all the raw eggs were relatively higher than of α-endosulfan. This indicated that the contamination was due to old technical endosulfan which had undergone degradation. Some samples had higher concentrations of α-endosulfan than β-endosulfan indicating contamination with fresh technical endosulfan (ATSDR, 2013). The mean concentrations of total HCHs in eggs ranged from 0.03 to 1.21 mg/kg. The concentrations of γ-HCH were greater than the concentrations of other HCH isomers in most egg samples indicating contamination by technical lindane. Generally, the mean concentrations of DDT and HCHs residues in cooked eggs were lower than the concentrations in raw eggs. The concentrations of aldrin and dieldrin were greater in raw eggs than in cooked eggs except for aldrin in samples from two sites and the concentrations of endosulfan in raw eggs from three sites were greater than those in cooked eggs. These findings indicated that cooking transformed the pesticides into metabolites..

Table 2: Concentrations and occurrence of DDT residues in chicken eggs (mg/kg)

Sites	Pesticides/ Metabolites	Raw eggs (n = 6/site)	Cooked eggs (n = 2/site)	Detection frequency (%)
Misugusugu	*p,p'*-DDT	0.10 ± 0.11	0.20 ± 0.10	100
	o,p'-DDT	0.02 ± 0.01	0.004 ± 0.01	87.5
	p,p'-DDD	2.10 ± 2.51	2.90 ± 1.05	87.5
	o,p'-DDD	0.90 ± 0.24	0.50 ± 0.20	87.5
	p,p'-DDE	1.16 ± 1.58	0.10 ± 0.20	75.0
	o,p'-DDE	0.03 ± 0.03	0.10 ± 0.10	75.0
	Total DDT	4.31 ± 4.30	3.80 ± 1.10	100
Kwa Mathias	*p,p'*-DDT	2.36 ± 2.21	ND	75.0
	o,p'-DDT	0.02 ± 0.01	ND	50.0
	p,p'-DDD	2.89 ± 1.77	1.92 ± 1.40	100
	o,p'-DDD	0.46 ± 0.35	1.70 ± 1.10	100
	p,p'-DDE	1.35 ± 1.10	0.01 ± 0.01	100
	o,p'-DDE	0.04 ± 0.06	ND	50.0
	Total DDT	7.12 ± 5.43	3.63 ± 2.20	100
Picha ya Ndege	*p,p'*-DDT	0.70 ± 0.54	1.20 ± 1.40	100
	o,p'-DDT	0.06 ± 0.06	ND	62.5
	p,p'-DDD	2.30 ± 1.42	1.70 ± 1.3	100
	o,p'-DDD	0.89 ± 0.90	0.34 ± 0.40	100
	p,p'-DDE	1.55 ± 1.59	2.8 ± 1.26	100
	o,p'-DDE	0.20 ± 0.38	0.10 ± 0.01	75.0
	Total DDT	5.70 ± 3.88	6.14 ± 3.77	100
Nyumbu	*p,p'*-DDT	0.20 ± 0.32	ND	37.5
	o,p'-DDT	0.01 ± 0.04	0.04 ± 0.02	37.5
	p,p'-DDD	1.45 ± 1.29	0.60 ± 0.11	100
	o,p'-DDD	0.31 ± 0.463	0.11 ± 0.04	100
	p,p'-DDE	0.60 ± 0.53	ND	50.0
	o,p'-DDE	0.20 ± 0.17	ND	50.0
	Total DDT	2.77 ± 1.52	0.75 ± 0.20	100
Kitunda	*p,p'*-DDT	1.87 ± 1.96	0.77 ± 0.30	75.0
	o,p'-DDT	0.31 ± 0.75	ND	37.5
	p,p'-DDD	3.36 ± 2.15	1.65 ± 1.32	100
	o,p'-DDD	0.55 ± 0.74	0.20 ± 0.08	100
	p,p'-DDE	1.85 ± 2.13	2.25 ± 0.52	87.5
	o,p'-DDE	0.20 ± 0.17	0.02 ± 0.01	87.5
	Total DDT	8.14 ± 7.72	4.89 ± 2.22	100
Banana	*p,p'*-DDT	0.10 ± 0.17	0.12 ± 0.03	75.0
	o,p'-DDT	0.01 ± 0.01	ND	37.5
	p,p'-DDD	1.26 ± 1.17	2.50 ± 1.31	75.0
	o,p'-DDD	0.11 ± 0.15	0.41 ± 0.20	75.0
	p,p'-DDE	0.42 ± 0.53	1.12 ± 0.30	75.0
	o,p'-DDE	0.06 ± 0.07	ND	62.5
	Total DDT	1.96 ± 2.28	4.15 ± 1.43	100

The concentrations of total DDT in all of the eggs were above the MRL of 0.1 mg/kg. Aldrin and dieldrin had higher levels than the MRL of 0.1 mg/kg in 47.6% of the eggs. The concentrations of endosulfan in 92.7% of the egg samples were above the MRL of 0.03 mg/kg. All the concentrations of total HCHs detected in eggs were above the MRL of 0.001 mg/kg (WHO/FAO, 2016). The concentrations of the DDT residues found in eggs were greater than the levels reported by Ahmad *et al*. (2010) in Jordan (ranged from 0.005 to 0.600 mg/kg with a mean of 0.072 mg/kg) and by Salar-Amoli and Esfahani (2015) in Tehran (mean = 0.00005 mg/kg). A similar study by Polder *et al*. (2016) found relatively lower levels of DDT residues in free-range chicken eggs; total DDT ranged from 0.002 and 0.324 mg/kg lipid weight. The study by Aulakh *et al*. (2006) in Punjab, India reported concentrations ranging from 0.04 to 0.16 mg kg^{-1} for α-HCH, β-HCH and γ-HCH with total HCH mean concentration ± SD of 0.26 ± 0.012 mg kg^{-1} in poultry eggs that are similar to the findings in the present study.

Table 3: Concentrations and occurrence of aldrin, dieldrin, endosulfan and HCH residues in eggs (mg/kg)

Sites	Pesticide residues	Raw eggs (n = 6/site)	Cooked eggs (n = 2/site)	Detection frequency (%)
Misugusugu	Aldrin	0.30 ± 0.43	1.10 ± 0.10	62.5
	Dieldrin	0.69 ± 1.53	ND	62.5
	α-endosulfan	0.60 ± 1.20	0.50 ± 0.05	100
	β-endosulfan	1.50 ± 1.27	0.30 ± 0.20	87.5
	Total endosulfan	2.10 ± 2.42	0.80 ± 0.60	100
	α-HCH	0.04 ± 0.04	0.01 ± 0.02	100
	β-HCH	0.01 ± 0.01	0.01 ± 0.01	87.5
	γ- HCH	0.03 ± 0.03	0.04 ± 0.01	100
	δ-HCH	0.02 ± 0.02	0.01 ± 0.01	100
	Total HCH	0.10 ± 0.10	0.07 ± 0.02	100
Kwa Mathias	Aldrin	2.00 ± 1.56	ND	75.0
	Dieldrin	1.30 ± 1.98	0.20 ± 0.01	87.5
	α-endosulfan	0.40 ± 0.48	0.14 ± 0.20	87.5
	β-endosulfan	1.49 ± 2.22	0.43 ± 0.30	87.5
	Total endosulfan	1.89 ± 2.69	0.57 ± 0.50	100
	α-HCH	0.02 ± 0.01	0.01 ± 0.004	100
	β-HCH	0.04 ± 0.09	0.002 ± 0.002	100
	γ- HCH	1.14 ± 2.19	0.01 ± 0.06	100
	δ-HCH	0.01 ± 0.01	0.004 ± 0.001	100
	Total HCH	1.21 ± 2.29	0.03 ± 0.001	100
Picha ya Ndege	Aldrin	0.10 ± 0.16	0.20 ± 0.02	62.5
	Dieldrin	1.20 ± 1.54	0.40 ± 0.30	100
	α-endosulfan	0.40 ± 0.28	0.60 ± 0.20	100
	β-endosulfan	0.85 ± 1.04	1.14 ± 1.50	62.5
	Total endosulfan	1.25 ± 1.73	1.74 ± 1.70	100
	α-HCH	0.02 ± 0.02	0.01 ± 0.01	100
	β-HCH	0.04 ± 0.08	0.01 ± 0.003	87.5
	γ- HCH	0.15 ± 0.2	0.02 ± 0.004	100
	δ-HCH	0.01 ± 0.01	0.01 ± 0.001	100
	Total HCH	0.22 ± 0.34	0.05 ± 0.003	100
Nyumbu	Aldrin	0.45 ± 0.76	0.10 ± 0.01	87.5
	Dieldrin	1.30 ± 1.16	0.30 ± 0.20	100
	α-endosulfan	0.60 ± 0.57	0.65 ± 0.10	87.5
	β-endosulfan	1.50 ± 2.08	ND	37.5
	Total endosulfan	2.10 ± 2.65	0.65 ± 1.00	87.5
	α-HCH	0.024 ± 0.02	0.01 ± 0.001	100
	β-HCH	0.033 ± 0.02	0.01 ± 0.002	100
	γ- HCH	0.114 ± 0.07	0.01 ± 0.003	100
	δ-HCH	0.006 ± 0.01	ND	62.5
	Total HCH	0.18 ± 0.12	0.03 ± 0.01	100
Kitunda	Aldrin	0.10 ± 0.10	0.10 ± 0.01	62.5
	Dieldrin	0.60 ± 1.37	0.20 ± 0.01	62.5
	α-endosulfan	1.00 ± 0.53	0.80 ± 0.10	100
	β-endosulfan	1.33 ± 1.33	2.94 ± 0.84	87.5
	Total endosulfan	2.33 ± 1.37	3.74 ± 1.20	100
	α-HCH	0.01 ± 0.01	0.01 ± 0.002	100
	β-HCH	0.01 ± 0.01	0.002 ± 0.001	87.5
	γ- HCH	0.02 ± 0.01	0.02 ± 0.001	100
	δ-HCH	0.01 ± 0.01	0.002 ± 0.002	100
	Total HCH	0.05 ± 0.04	0.034 ± 0.001	100
Banana	Aldrin	0.80 ± 0.95	0.07 ± 0.01	62.5
	Dieldrin	0.20 ± 0.28	0.12 ± 0.01	62.5
	α-endosulfan	0.80 ± 0.75	1.30 ± 0.02	87.5
	β-endosulfan	1.20 ± 2.05	2.07 ± 1.10	87.5

The concentrations of total HCHs in poultry eggs reported by Tao *et al*. (2009) in Beijing, China (0.00158 ± 0.000519 mg kg^{-1}) and the concentrations of endosulfan reported by Vanitha *et al*. (2014) in chicken eggs in Chennai, India (ranged from 0.025 ± 0 to 0.03125 ± 0.00377 mg kg^{-1}) were lower than the present findings.

The study by Salar-Amoli and Esfahani (2015) in Tehran, Iran detected lower levels of aldrin (up to 0.120 µg/kg) and dieldrin (mean = 0.015 µg/kg) in eggs than those found in this study. The levels of dieldrin and HCHs were comparable to the levels

found in the study by Polder *et al*. (2016) that ranged from 0.002 to 98.791 mg/kg lipid weight, but the levels of endosulfan found in that study were lower than the levels found in the present study.

The organophosphorus pesticides detected in most eggs were chlorpyrifos, fenitrothion and pirimiphos methyl. Their concentrations and detection frequencies are presented in Table 4. The mean concentrations of chlorpyrifos, pirimiphos methyl and fenitrothion in eggs were up to 0.59, 1.6 and 0.64 mg/kg, respectively. All the concentrations of chlorpyrifos and pirimiphos methyl detected in eggs were above the MRL of 0.01 mg/kg and the detected concentrations of fenitrothion were above the MRL of 0.05 mg/kg (WHO/FAO, 2016).

Variation of the pesticide residues among samples: There were significant differences in the concentrations of most of the pesticide residues among the samples ($p < 0.05$). Generally, the highest mean concentrations of most of the pesticide residues were found in chicken feeds and raw eggs. Most of the concentrations of the residues in cooked eggs were lower than those in raw eggs, indicating that cooking reduced the pesticide residues, probably due to transformations. On average, the concentrations of the residues in cooked eggs were less by 5.4% to 94.6% than the concentrations in raw eggs.

Conclusion: High levels of the pesticide residues were detected in chicken feeds and eggs and most of them exceeded the maximum residue limits indicating risks and concerns for public health. The findings indicated contamination due to past use as well as fresh applications of the pesticides.

Table 4: Concentrations of organophosphorus pesticide residues in eggs (mg/kg)

Sites	Pesticides	Raw eggs (n = 6/site)	Cooked eggs (n = 2/site)	Detection frequency (%)
Misugusugu	Chlorpyrifos	0.40 ± 0.59	0.13 ± 0.04	75.0
	Fenitrothion	0.33 ± 0.68	0.04 ± 0.05	100
	Pirimiphos methyl	1.60 ± 3.20	0.21 ± 0.20	100
Kwa Mathias	Chlorpyrifos	0.59 ± 0.77	ND	50.0
	Fenitrothion	0.64 ± 0.92	0.004 ± 0.001	100
	Pirimiphos methyl	0.31 ± 0.44	0.02 ± 0.01	100
Picha ya	Chlorpyrifos	0.20 ± 0.40	ND	25.0
Ndege	Fenitrothion	0.13 ± 0.10	0.18 ± 0.05	100
	Pirimiphos methyl	0.61 ± 0.45	0.86 ± 0.10	100
Nyumbu	Chlorpyrifos	0.20 ± 0.15	ND	62.5
	Fenitrothion	0.13 ± 0.09	0.01 ± 0.01	100
	Pirimiphos methyl	0.64 ± 0.44	0.03 ± 0.02	100
Kitunda	Chlorpyrifos	0.10 ± 0.20	ND	12.5
	Fenitrothion	0.15 ± 0.07	0.17 ± 0.20	100
	Pirimiphos methyl	0.61 ± 0.45	0.79 ± 0.10	100
Banana	Chlorpyrifos	0.26 ± 0.29	ND	37.5
	Fenitrothion	0.12 ± 0.11	0.16 ± 0.04	75.0
	Pirimiphos methyl	0.60 ± 0.53	0.80 ± 0.11	87.5

The highest concentrations were found in feed samples. The results indicated that cooking reduced the pesticide residues. The regulatory agencies should regularly monitor the practices in poultry farming and check the sources of poultry feeds.

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