Organochlorine pesticides and cadmium residues in commercial feeds and edible tissues with implication to food safety and productivity

R S A Vega[1], C B Adiova[1], D Samsudewa[2], A Gargarino[1], D D Manalo[3] and D Anggraeni[4]

[1]Faculty and staff of the Institute of Animal Science, UPLB
[2]Faculty of the University of Diponegoro, Indonesia
[3]University Researcher, Agricultural Systems Institute, UPLB
[4]Faculty of University of Gadjah Mada, Indonesia

E-mail: rsvega@up.edu.ph

Abstract

Compelled to understand the continuous and 13% sharp decline in the population of Mallard ducks in the Philippines, we followed the evidence wherever it led. This paper is a summary of our published research results from the reported (1) evidence of organochlorine pesticides (OCPs) and heavy metals Cd in feeds and edible duck tissues; (2) the effect of combined Cd and OCPs at growing and (3) laying ducks. The important results showed that commercial feeds contain derivatives of Benzene Hexachloride (BHC; 0.10 ppm), Chlordane (0.00143 ppm), Endosulfan (0.0555 ppm), and Cd (0.3115 ppm). The edible part of Mallard ducks reveals that liver and ovary have levels above the Maximum Residue Limit (MRL) of 0.05 ppm, while lean and fat were below the MRL for Cd. At growing, Cd (0.050 and 0.10 ppm) alone downsizes the liver and hastens egg laying by 35 days. At laying, BHC stimulates WBC, while Cd suppresses packed cell volume, WBC, heterophil and monocyte. Overall implications of these results show that (1) conventional feedstuffs have Cd level lower than the commercial feeds, (2) and currently Cd and not OCPs is the residues of concern in terms of food and feed safety, (3) lastly it is recommended to consider mitigating the effects of Cd by using antioxidants.

Keywords: Pesticides, Cadmium, Tissues and Food Safety

Introduction

In the Philippines, duck production is one of the most profitable poultry industries mainly because of the increasing demand for duck eggs (fresh, balut, penoy, salted eggs, and century eggs). Despite the promising opportunities for the industry, there was a consistent decline in the duck industry performance. From 2006 to 2007 there was a 13.4% decline in the population of Mallard ducks, the egg supply dropped by 6.07%, and per capita consumption declined by 21.88% [1]. According to farmers, egg production requires 70% to make a breakeven feed cost, thus sustainability is threatened by the erratic egg production throughout the peak egg-laying period. To mitigate the high feed cost, farmers resort to duck-ranging and utilization of lake feed resources.

The decline in the Philippine duck production performance can be attributed to several problems and constraints, based on experts point of view, the main causes of the decline through the years were, (1) lack of selection and breeding programs for Mallard; (2) absence of nutritional feeding standard; (3) ducks are exposed to pesticides and heavy metal residues due to high cost of commercial feeds; (4) absence of standard housing; and (5) lack of value-added product technology [2].

The potential negative effects of the endocrine-disrupting chemicals (EDCs) in the physiology of duck's egg production are considered, which are thought to be present in the feed sources coming from Laguna Lake and from the expensive commercial feed. Therefore, in this manuscript includes, (1) organochlorine pesticide residues and heavy metal Cd in commercial feeds, golden snails and bivalves (shellfish) found in Laguna Lake were assayed using AAS-FLAME by a ISO accredited analytical laboratory, (2) effects of residues on growing and (3) laying.

Materials and Methods

A. Assessment of Feed Resources and Edible Tissues of Mallard

Sampling Sites

The main areas from where commercial feeds and the ducks were sampled in Candaba, Pampanga. The municipalities Candaba is known for duck production in the Philippines, and it is situated north of Metro Manila.

Animal Collection

The sampling matrix used for the assessment of the levels of organochlorine pesticide and heavy metal cadmium in feeds, liver, ovary, lean and fats of the female domestic mallard ducks is shown in Table 1. A total of 120 ducks at early (4-8 months), mid (10-14 months) and late (18 months and above) laying stages were needed in the assessment study. Sixty (60) ducks gathered from four farmers with five ducks each per stage were randomly sampled. All sampling activities were assisted by a GPS in the establishment of geographical coordinates of every site visited during the collection. This was done for future identification of sites with occurrences of physiological disturbances in the Mallard ducks grown in the different target locations. The profile of the different duck raisers and some necessary information like egg production and the feeds they are using were taken for record purposes and to keep track of any irregularities found during the conduct of series of analyses. The names and identities of the sources were not disclosed, were kept confidential and coded accordingly.

Organ Samples

The ducks sampled were sacrificed for the extraction and isolation of organ samples which include the liver, ovary, and oviduct as well as lean and fat samples. Each of the samples was wrapped in a labeled aluminum foil, placed in an ice bucket, and kept inside the refrigerator at - 40˚C so as to prevent natural chemical degradation of the sample components until analysis for the degree of pesticide and cadmium concentrations. Laboratory analyses were done at the University of the Philippines Diliman's – Natural Sciences Research Institute in, Quezon City (ISO-17025:2005).

Table 1. Duck sampling matrix for the assessment of OCPs and heavy metal Cd in feeds, selected organs, leans, and fats of the female domestic Mallard Ducks in two provinces

Parameters	**Candaba, Pampanga (n=60)**	
Commercial Feeds Assayed for Cd	A, B, C, D, E, and F	
Ages of Ducks Sampled	Early Laying	4 to 8 months
	Mid-Laying	10 to 14 months
	Late- Laying	18 months and above
Organs/Tissues Sampled	Blood, liver, ovary, oviduct, leans, and fats	
Organochlorine Pesticides Assayed	Organs and tissues pooled according to age group	

Conventional and commercial feed samples

Duck feeds of 200 grams for every duck raiser were randomly sampled. The feed samples, be it conventional such as kuhol and suso (mixed with small fishes), were then subjected to laboratory analysis to determine the organochlorine pesticide residues and Cadmium contaminants present in duck feeds. All the samples were taken to the Analytical Services Laboratory of the University of the Philippines Diliman - Natural Sciences Research Institute (NSRI) for residue analysis.

B. Experiment at Growing Stages

Sample Size and Treatments

Day-old ducklings (DODs, n=252) purchased from a hatchery farm in Victoria, Laguna were allotted in a 3 x 4 factorial experiment in CRD replicated three times with seven birds per replicate or cage. The study was accomplished with levels of Cadmium (0, 50 and 0.10 ppm) as the first factor, and pesticide residues which include control, 0.10 ppm Beta-BHC, 7.14 ppb Γ-BHC and 1.43 ppb Gama-Chlordane, as the second factor. The five coded available commercial duck feeds in Laguna and the feed utilized in the experiment has no detectable lindane residue. The heavy metal Cd was found present in Laguna Lake shellfish (bivalves) at 50 ppb as reported earlier [3,4] but not in the commercial feeds used in the experiment. The heavy metal Cd and OCP residue analysis was accomplished using Atomic Absorption Spectrophotometry (AAS) and Gas Chromatography (GC) / Mass Spectrophotometry (MS) by an internationally accredited institution, the University of the Philippines Natural Science Research Institute (UP-NSRI).

The treatments, i.e. different isoforms of pesticide residue in combination with levels of cadmium were dissolved in acetone that serves as the vehicle used to mix desired treatment levels with the commercial feeds.

Mixing was done in a closed drum and then the acetone was vaporized easily in an open room allowing the contaminants to remain in feeds.

Feeding Regime

The ducks were fed with commercial starter to growing feeds. Feed was given ad libitum with actual average feed intake of 50g /head/day. This was increased from week 5 onwards up to 18 weeks with approximately 100g/head/day until before sexual maturity. The feeds were composed of starter mash from 0-4 weeks and growing mash from 4 to 16 weeks. The feed intake of ducks at different ages of treated and untreated ducks were monitored daily and weekly within the experimental period or prior to animal sacrifice.

Growth Rate

After proper animal restraint, live weight was measured weekly using a triple beam balance or analytical balance. Then the average daily gain (ADG) and total weight gain were derived from the live weight measured.

C. Experiment at Laying

Treatments

This study utilized randomly selected laying ducks at 43 to 47 weeks of age (n=140). The ducks were procured from a single farm in Cavite at 16 weeks of age and then housed and reared for 43 weeks in the Quarantine Area of the Institute of Animal Science, UPLB. When the animal reached 44 weeks of age the experiment was conducted.

The contaminants used in this study were CdCl2 (Supelco), β-BHC (Supelco), and β estradiol (Sigma). This study was composed of six treatments using cadmium (Cd), and organochlorine pesticide (OCP). The concentrations and combinations of treatments are presented in Table 2. The experimental were replicated four times with 5 female and 1 drake for each replication. The experimental design was done using two factorials in Completely Randomized Design with Cd and BHC as the 1st and 2nd factors (3 x 3), respectively.

Results and Discussion

A. Cd and OCPs in Commercial Feeds, Liver, Ovary, Lean and Fats of Mallard

Cadmium Content in Feeds and Edible Tissues

Samples of different brands of commercial feeds and conventional feed samples such as snails taken from different sources in Pampanga were also subjected to cadmium content analysis. The commercial feed samples were coded in such a way that unwary disclosure is prevented. In a poultry farm in Beijing, China it was reported that OCPs were similarly detected in commercial feeds, and fresh weight basis of muscle, liver, stomach, skin and eggs, with skin as the highest [5].

Table 2 gives the mean Cd contents (mg/kg) in the commercial and conventional duck feed samples in Candaba, Pampanga. Surprisingly, the majority of the commercial feed samples have cadmium ranging from 0.12 to as high as 0.84 mg/kg, the first time that the commercial feeds were subjected to cadmium assay. Conventional feed samples such as suso (mixture of different types of mollusks including bivalves and univalves) and golden apple snails from rice field (kuhol) were included in cadmium assay. Clearly, the results revealed that the commercial feeds in both locations had much higher cadmium residue levels than the conventional feed samples.

Table 2. Mean Cd (mg/kg) in commercial and conventional feeds and pooled samples of liver, ovary, lean and fats at various stages of laying domestic Mallard in Candaba, Pampanga with EMDL of 0.04 mg/kg (ppm). The MRL in meat and liver is 0.10, and 0.50 mg/kg [6].

Commercial Feeds	Cd (mg/kg)	Edible Tissues	Laying Stages	Cd (mg/kg)
A	0.16	Liver	Early	0.75^{ay}
			Mid Laying	0.35^{bz}
B	0.29		Late Laying	1.17^{ax}
C	0.16	Ovary	Early	0.09^{ay}
			Mid Laying	<EMDL
D	0.12		Late Laying	0.15^{ax}
E	0.84	Lean	Early	<EMDL
			Mid Laying	0.07
F	0.83		Late Laying	0.09
Conventional Feeds		Fats	Early	<EMDL
Bivalves	0.03		Mid Laying	<EMDL
"Suso"	0.07		Late Laying	<EMDL

[a,b] Mean values within rows having different superscripts significantly differ ($P<0.05$).
[x,y] Mean values within columns having different superscripts are significantly different ($P<0.05$).

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) as cited in the EFSA (European Food Safety Authority) website established a PTWI for cadmium of 7 µg/kg of body weight in 1988 and was reconfirmed by the JECFA in 2003. The term "provisional tolerable weekly intake" (PTWI) is being used by JECFA for contaminants that may accumulate in the body [7]. The European Food Safety Authority (2009) has set a lower tolerable weekly intake (TWI) for cadmium of 2.5 µg/kg of body weight by applying the results on their recently conducted analysis on the relationship between urinary cadmium levels and beta- 2 microglobulin, a protein excreted in the urine which is a biological indicator of kidney function.

The Maximum Residue Limit in meat, liver and kidney has been set to 0.1, 0.5 and 1.0 mg/kg respectively by Butterworth and Bugang [6] as approved by the US Embassy in China. On this basis, the mean liver Cd residue of commercial feed (Table 4) cannot pass the MRL limit imposed by the US Embassy, Chengdu, China. In the Joint FAO/WHO Food Standard Programme of the Codex Alimentarius Commission held in Utrecht, The

Netherlands in 2018, the amount of Cd in chocolates and quinoa is being debated upon, because as they bring down the MRL limit from 0.8 mg/kg to 0.6 mg/kg the consequence of this is the increased rejection of 4.3%. Clearly the MRL limit of Cadmium is influenced by trade and commerce, with minor consideration to the health of the consumer.

Organochlorine Pesticide in Feeds and Edible Tissues

The results of the organochlorine pesticide content analysis of the biological and duck feed samples are all presented in Figure 1 radar graph of OCPs of commercial feeds from Candaba. The E commercial feeds were detectably high in Methoxychlor and α-BHC and while other OCPs are below the EMDL values.

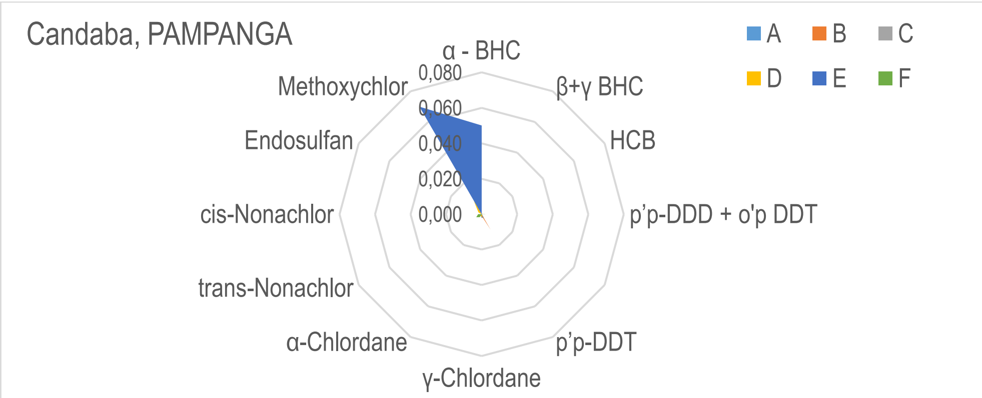

Figure 1. Radar graph of OCPs determined from varying commercial formulated rations for laying Mallard (mg/kg or ppm) in Candaba, Pampanga

Different organochlorine pesticides of varying amounts were detected in the submitted biological samples taken from Pampanga. Among contaminants, the organochlorine pesticide residues that were below the estimated method detection limits adopted by the UP-NSRI Analytical Laboratory in the organs of ducks include the γ-BHC, Heptachlor, Aldrin, Heptachlor Epoxide, o,p'-DDE, Dieldrin, Endrin and o,p'-DDT. The rest were detected in negligible amounts in the different organs of ducks at different stages of maturity. The mean α-BHC and Hexachlorobenzene residues (mg/kg) in the liver, ovary, lean and fat samples at different stages of female domestic mallard ducks in Pampanga are shown in Table 6a and 6b. The ovary of ducks at the mid laying stage was found to contain 0.068 mg/kg α-BHC while the lean of ducks at the Early Laying and late laying stage was detected with 0.030 and 0.033 mg/kg of α-BHC. The fat samples of ducks at the late laying stage were found to have a mean α-BHC residue level of 0.020 mg/kg. The levels of which were far below the EMDL of 0.0006 mg/kg. The lowest MRL of EU Regulation Guidelines (CE396/2005) is 0.02 in Chlordane and BHC. The OCPs of edible duck tissues that has lower than the MRL is not any more mentioned, except HCB, Endosulfan, Mirex, Chlordane and derivatives of DDT. The latter four OCPs were among the OCPs that appeared 3x or more in many edible duck tissues.

The acute lethality of ingested HCB in animal studies is relatively low. Oral LD50 values vary between 1,700 to 4,000 mg/kg body weight [8]. The Minimal Risk Level in monkey and rat were 0.0001 mg/kg/d and 0.008 mg/kg/d, respectively were set by Robert Williams [9] (Agency for Toxic Substances and Disease Registry, ESEPA, Atlanta, Georgia). The MRL for hexachlorobenzene in fat of livestock and poultry recommended by FAO/WHO as cited by IPCS (1972) is 1.0 mg/kg (ppm). The HCB residue levels detected in the biological samples of ducks were ≤0.0003 mg/kg very far below the MRL set by FAO/WHO for livestock and poultry.

The pooled fat tissues of the ducks at the late laying stage was the only biological sample detected with 0.001 ppm o,p'-DDD. The liver tissues in all stages were detected with p'p-DDD. The highest amount was found in the pooled liver samples at the mid laying stage (0.0012 mg/kg), late laying stage (0.0011 mg/kg) and at Early Laying stage with only (0.0006 mg/kg). The ovaries at the Early Laying and late laying stages were found to contain 0.0006 ppm and 0.0005 mg/kg p'p-DDD, respectively. There was also a detected p'p-DDD concentration of 0.0005 mg/kg in the lean tissues at mid laying stage, and the rest of the samples were below the EMDL. Apparently DDD and its derivative or isoforms are all below the MRL of the EU Regulations Guidelines.

Table 3a. Mean Organochlorine Pesticide Residues (OCPs) from the liver and ovary of Mallard of Candaba, Pampanga

Organochlorine Pesticide Residues (OCPs)	**Liver**			**Ovary**			**Estimated Method Detection Limit**	**MRL (mg/kg) (EU, 2005)****
	Early Laying	**Mid Laying**	**Late Laying**	**Early Laying**	**Mid Laying**	**Late Laying**		
α - BHC	<EMDL	<EMDL	<EMDL	<EMDL	**0.068**	<EMDL	0.0006	0.02
HCB	**0.0003**	**0.0003**	**0.0004**	**0.0003**	<EMDL	**0.0003**	0.0003	0.03
o'p-DDD	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	0.0007	-
p'p-DDD	**0.0006**	**0.0012**	**0.0011**	**0.0006**	<EMDL	**0.0005**	0.0003	0.05
p'p-DDE	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	0.0007	0.05
p'p-DDT	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	0.0009	0.05
γ-Chlordane	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	**0.0007**	0.0006	0.02
α-Chlordane	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	0.0008	0.02
trans-Nonachlor	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	0.0007	-
cis-Nonachlor	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	**0.0009**	0.0009	-
Endosulfan	**0.011**	<EMDL	<EMDL	**0.0150**	<EMDL	**0.0031**	0.0008	0.10
Mirex	<EMDL	<EMDL	**0.0007**	**0.0020**	<EMDL	**0.0020**	0.0007	-
Methoxychlor	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	0.009	0.50

** MRLs of EU regulation guidelines (CE 396/2005)

The organochlorine pesticides γ-Chlordane and α-Chlordane were also found in the organs of ducks at different stages in Pampanga. The mean γ-Chlordane and α-Chlordane contents in the organs of ducks are presented in table 3a and 3b. The α-Chlordane was only found in the pooled fat samples of ducks at the late laying stage. The γ-Chlordane concentrations, on the other hand, were detected in several biological samples of ducks. The 0.0007 mg/kg γ-Chlordane was detected in the ovary at the late laying stage while 0.0006 mg/kg of the same compound was found in the lean at the mid laying stage. The fat samples of the female domestic mallard ducks at the Early Laying and late laying stages were found to contain 0.0008 and 0.005 mg/kg γ-Chlordane, respectively. The tolerable daily intake value for Chlordane as set by the U.S EPA is 0.0005 mg/kg of body weight. All the edible tissues were far below the MRL of 0.5 ppm of the EU Regulation Guidelines.

Table 3b. Mean Organochlorine Pesticide Residues (OCPs) from the lean and fats of Mallard of Candaba, Pampanga

Organochlorine Pesticide Residues (OCPs)	Lean			Fats			Estimated Method Detection Limit	MRL (mg/kg) (EU, 2002)**
	Early Laying	Mid Laying	Late Laying	Early Laying	Mid Laying	Late Laying		
α - BHC	**0.03**	<EMDL	**0.033**	<EMDL	<EMDL	**0.020**	0.0006	0.02
HCB	<EMDL	<EMDL	<EMDL	**0.0005**	<EMDL	<EMDL	0.0003	0.03
o'p-DDD	<EMDL	<EMDL	<EMDL	<EMDL	**0.001**	<EMDL	0.0007	-
p'p-DDD	<EMDL	**0.0005**	<EMDL	<EMDL	<EMDL	<EMDL	0.0003	0.05
p'p-DDE	<EMDL	<EMDL	<EMDL	**0.002**	<EMDL	<EMDL	0.0007	0.05
p'p-DDT	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	**0.002**	0.0009	0.05
γ-Chlordane	<EMDL	**0.0006**	<EMDL	**0.0008**	<EMDL	**0.005**	0.0006	0.02
α-Chlordane	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	**0.001**	0.0008	0.02
trans-Nonachlor	**0.001**	<EMDL	<EMDL	<EMDL	<EMDL	**0.001**	0.0007	-
cis-Nonachlor	<EMDL	**0.0009**	<EMDL	<EMDL	<EMDL	<EMDL	0.0009	-
Endosulfan	<EMDL	<EMDL	<EMDL	**0.0150**	<EMDL	<EMDL	0.0008	0.10
Mirex	<EMDL	**0.0008**	<EMDL	**0.0008**	<EMDL	<EMDL	0.0007	-
Methoxychlor	<EMDL	<EMDL	<EMDL	<EMDL	<EMDL	**0.030**	0.009	0.50

** MRLs of EU regulation guidelines (CE 396/2005)

Endosulfan is detectably low in liver, ovary, and fats at Early Laying stage and in ovary at late laying stage (≤ 0.015 mg/kg). In general, the doses of endosulfan involved in cases of poisoning have been poorly characterized. In a summary of case reports Lehr [10] as cited by IPCS [11], the lowest reported dose that resulted in death was 35 mg/kg bw. The clinical signs in these patients were consistent with those seen in laboratory animals, dominated by tonic-chronic spasms. The MRL set by EU Regulation Guidelines is 0.10 mg/kg endosulfan, which is less than 10x the level found in duck edible tissues.

Mirex is moderately toxic in single-dose experimental animal studies (oral LD50 values range from 365 - 3000 mg/kg bw; IPCS INCHEM [12]. The International Program on Chemical Safety concluded that no data on human health effects are available but findings in mice and rat's exposure implies potential carcinogenicity. The most sensitive effects of repeated exposure in experimental animals are associated with the liver observed with doses as low as 1.0 mg/kg diet (0.05 mg/kg bw/d), the lowest dose tested [12] Mirex was detectably low in the liver, ovary, learn and fats (≤ 0.002 mg/kg) at Early Laying mid-laying and late laying stages. The reported lowest tested in experimental animals were more than 10x higher values detected in Mallard (Table 3a and 3b).

B. Experiment on Combined Cd and OCPs of Growing Ducks

Organochlorine pesticide residues (OCPs) and cadmium (Cd) are present in commercial feed. Beta-Benzenehexachloride (β-BHC), γ-BHC, γ-Chlordane and cadmium levels were 150, 7.14, 1.43 and 50-0.10 ppm, respectively. To determine its effect on growth and reproductive organ development, 252 heads of 12 weeks old female mallard were assigned in a 3 x 4 factorial experiment in CRD replicated three times with two levels of Cadmium and three different OCPs as the first and second factor, respectively. Growth, hepatic, gonad, oviduct weights and eggs were determined at 12, 16 and 20 weeks of age.

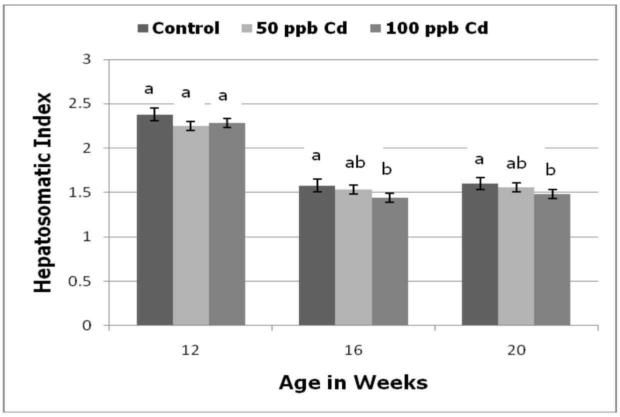

Figure 2. Mean hepatosomatic index (HSI) of growing domestic mallard ducks exposed to varying levels of cadmium in feed with vertical lines as SEM. Differences in letters a and b show statistical difference at 5% level

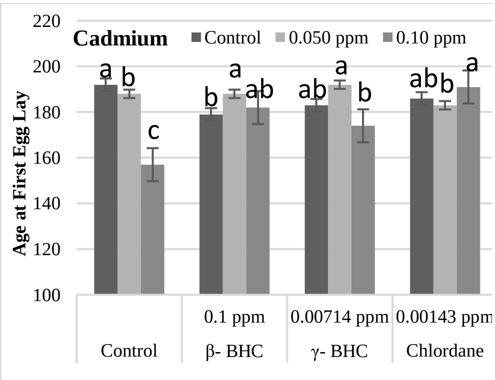

Figure 3. Age at first egg lay (days) of domestic mallard ducks at peri-pubertal stage exposed to different organochlorine residues in combination with varying levels of cadmium in feed

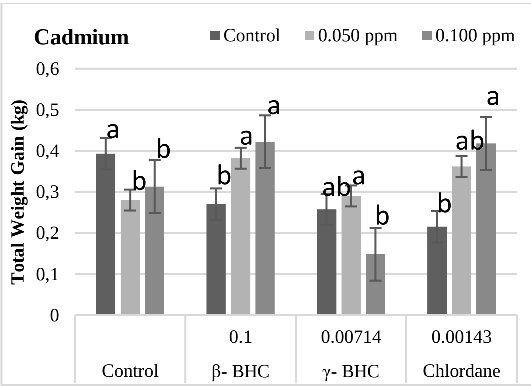

Figure 4. Total weight gain (kg) of growing domestic mallard ducks at peripubertal stage exposed to different organochlorine residues in combination with varying levels of cadmium in feed

Cadmium decreases the ratio of liver weight to liveweight (hepatosomatic index) at 0.10 ppm Cd of growing Mallard (Figure 2); and causes earlier age of first egg lay (AFEL) by 35 days (Figure 3). Significant interaction of Cd and OCPs on weight gain, and ADG, indicates the interplay of level of Cd and different OCPs (Figure 4). Weight gain and ADG were significantly increased by 0.10 ppm cadmium, in combination with γ-Chlordane but were significantly reduced with γ-BHC. Cadmium significantly downsizes the liver, weight gain and enhances the weight of oviducts, a manifestation of liver and oviduct activity, reflected by significantly earlier age of first egg lay.

C. Experiment on Combined Cd and β–BHC of Laying Ducks

This study assessed the effects of endocrine disruptors administered in feed on reproductive and physiologic performance of female Philippine Mallard after sexual maturity. Laying ducks at 33 to 47 weeks of age (n=140) were randomly allocated composed of combinations of cadmium (Cd) and organochlorine pesticide (OCP) in 3x2 factorial design and of estradiol in a single factor experiment in Complete Randomized Design (CRD), in different concentrations and stages of laying period. Hematological values, hepatosomatic index (HSI), gonadosomatic index (GSI) and oviductosomatic index (OVI) were measured.

The results of this study showed that the combination of Cd and OCP significantly increased heterophil (Figure 5) but this combination significantly decreased PCV (Figure 6) and monocyte (Figure 7). Cd significantly decreased WBC while OCP significantly increased WBC (Figure 8). Cd (0.05 and 0.1 ppm) significantly decreased WBC, on the other hand, OCP (0.10 ppm) significantly increased WBC (Figure 8).

Prolonged exposure to Cd and OCP significantly increased PCV, RBC and heterophil. Histological structures of the liver showed swelling of hepatocytes, focal mononuclear infiltration, necrosis, hemorrhage, and vacuolar degeneration.

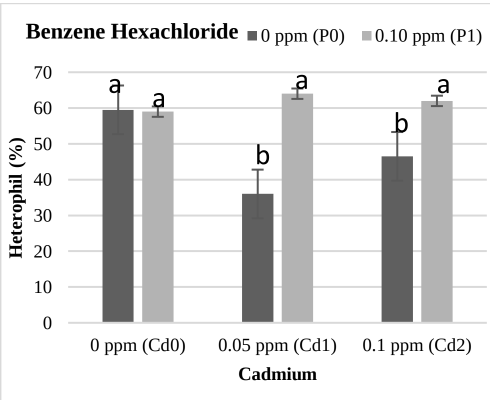

Figure 5. Mean of heterophil (%) of laying mallard after treatment with cadmium (CdCl2) and organochlorine pesticide (β-BHC) in feed

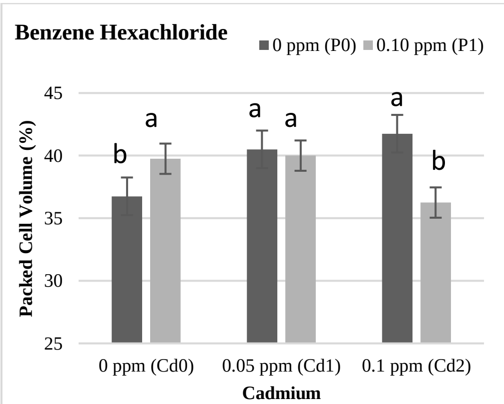

Figure 6. Mean of packed cell volume (%) laying mallard after treatment with cadmium (CdCl2) and organochlorine pesticide (β-BHC) in feed

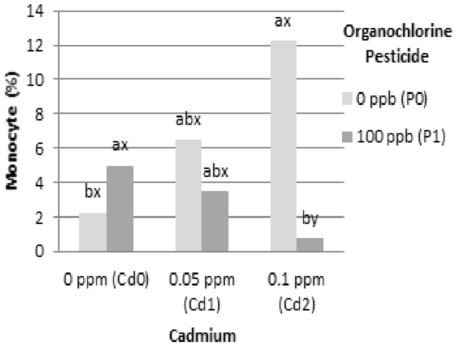

Figure 7. Mean of monocyte (%) laying mallard, treated with cadmium (CdCl2) and organochlorine pesticide (β-BHC) in feed

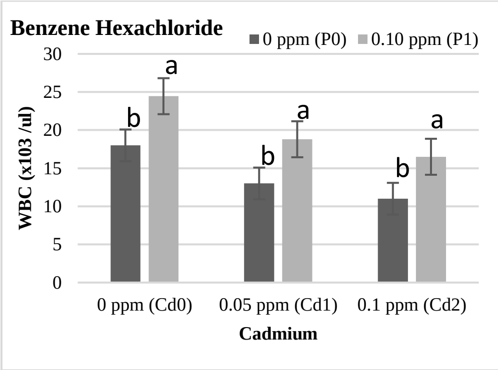

Figure 8. Mean of WBC (x103/µl) laying mallard after treatment with cadmium (CdCl2) and organochlorine pesticide (β-BHC) in feed

Based on the overall results, Cd and OCP acted as endocrine disruptors as shown by hematologic and pathological changes in the liver, ovary and oviduct of ducks resulting in the reduction in egg production.

Implications and Conclusions

At growing, 0.1 mg/kg Cd in feed decreases the liver (HIS) and causes 35 days earlier age of first egg lay. At laying 0.10 ppm Cd significantly reduces % monocyte (2.25 vs 0.75), % heterophil (60 vs 45), and WBC (x103/µl) (18 vs 11). Relative to β-BHC, Cd has concentration above the Maximum Residue Limits (MRL) in commercial feed ration, liver and ovary of ducks, while meat and fats are below the EMDL

The OCPs and Cd are considered endocrine disruptors because it alters the liver condition and ovary affecting egg laying productivity of Mallards. Considering food safety and amount present in edible tissues of Mallard, Cd poses more threat compared to OCPs because the residue registered above the Maximum Residue Limits and Cd persists in the environment.

Acknowledgement

This manuscript has been made possible by the Philippine government funds of the Department of Agriculture, UP Systems Enhance Creative Work and Research Grant for equipment and the Philippine Commission on Higher Education (CHED) DARE – K12 fund for the personnel services and operating expenses of the project entitled, "Backyard Livestock Island-based Sustainable System: Part 1. Development of Healthy Feeds for Backyard Production.

References

[1] BAS. Bureau of Agricultural Statistics – Department of Agriculture. 2009. Duck Industry Performance Report. Retrieved on April 12, 2011 from http://www.bas.gov.ph/?ids=ducksituation.

[2] Vega RSA, Lambio AL, Capitan SS, Yebron MGN. Unpublished. Accomplishment report of U.P. S&T Grant, entitled “Applied Animal Biotechnology for the Improvement of Philippine Mallard Duck.” University of the Philippines Los Baños. College, Laguna.

[3] Vega RSA, Lambio AL, Capitan SS, Purugganan DLS, HI Rivero. 2009. “Some aspects of the environmental physiology of mallard ducks pertaining to farming system and management”. Presented in the 46th National PSAS and 27th PSAS Visayas Chapter Scientific Seminar and Convention. Cebu City, Philippines. October 21-23, 2009.

[4] Rivero H. I., Vega R. S. A, Lambio A. L. and S. S. Capitan. 2009. “Ovarian hepatic condition of duck layers under two farming systems in Laguna, Philippines”. Presented in the 9th Annual Philippine Society for Study of Nature National Convention. MSU-Iligan Institute of Technology, Iligan City. Philippines. November 12-15, 2009.

[5] Tao, S. Liu, W.X. Li, X.Q. Zhou, D.X. Li, X. Yang, Y.F. Yue,D.P., Coveney, R.M. 2009. Organochlorine Pesticide Residuals In Chickens And Eggs At A Poultry Farm In Beijing, China; Environ. Pollut. 2009; 157 497

[6] Butterworth, J and W. Bugang. 2006. China, Peoples Republic of FAIRS Product Specific Maximum Levels of Contaminants in Foods 2006. GAIN Report Number: CH6064. USDA Foraeing Agricultural Service Global Agriculture Information Network. 14 August 2006.

[7] Nasreddine, L. and Parent-Massin, D. (2002) Food Contamination by Metals and Pesticides in the European Union. Should We Worry? Toxicology Letters, 127, 29-41.

[8] Health Council of the Netherlands. 2011. Hexachlorobenzene: Health-based Recommended Occupational exposure limit. Accessed 12 June 2021, file:///E:/Downloads/advisory-report-hexachlorobenzene-health-based-recommended-occupational-exposure-limit.pdf

[9] Robert Williams of Agency for Toxic Substances and Disease Registry (ATSDR). 2015. Hexachlorobenzene: ATSDR Minimal Risks Level and Worksheets. U.S. EPA, Atlanta, Georgia. Accessed 12 June 2021, https://www.atsdr.cdc.gov/ToxProfiles/tp90-a.pdf

[10] Lehr, W (1996) Summary of intoxications with endosulfan. Clinical cases and poisoning incidents. Unpublished Hoechst report No. psr 96/006, 12 March 1996; document A56361. Submitted to WHO by Hoechst Schering AgrEvo GmbH, Frankfurt-am-Main, Germany.

[12] International Programme on Chemical Safety (IPCS). 2021b. Mirex Health and Safety Guide. IPCS Intrenational Program on Chemical Safety Health and Safety Guide No. 39. WHO, Geneva 1990. http://www.inchem.org/documents/hsg/hsg/hsg039.htm

[11] International Programme on Chemical Safety (IPCS). 2021c. Endosulfan (JMPR 1998), International Agency for Research Center, Lyons, France. http://www.inchem.org/documents/jmpr/jmpmono/v098pr08.htm

[13] Food and Agriculture Organization of the United Nations World Health Organization. 1969. !968 Evaluations of Some Pesticide Residues in Food. The Monograph. Accessed 11 June 2021, http://www.inchem.org/documents/jmpr/jmpmono/v068pr03.htm

[14] FAO Panel of Expert on Pesticide Residues in Food and Environment and the WHO Care Assessment Group on Pesticide Residues. 2016. Pesticide Residues in Food - 2016: Toxicological Evaluation - 2016. Geneva, Switzerland 9 -`13 May 2016. Accessed 12 June 2021, http://www.fao.org/3/i8267en/I8267EN.pdf

[15] International Programme on Chemical Safety (IPCS). 2021a. International Peer Reviewed Chemical Safety Information. Copyright by the WHO. Website is provided by the Canadian Center for Occupational Health and Safety (CCOHS). http://www.inchem.org/#/search

[16] WHO. World Health Organization – International Program on Chemical Safety. 2002. Global Assessment of the State-of-the-Science of Endocrine Disruptors. 133 pp.