Research Article

Organochlorine Pesticide Residues in Feeds and Tissues of Female Mallard Ducks in Candaba, Pampanga, Philippines: An Exploratory Study

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Abstract | Organochlorine pesticides (OCPs) are synthetic pesticides with a wide range of applications in the agricultural and chemical industries. Organochlorine pesticides pose a threat to animals and humans due to their high toxicity, bioaccumulating and endocrine-disrupting abilities, though they are very useful in pest management. Duck production is one of the thriving industries in the Philippines, often involving the integration of ducks into rice fields where they feed on pests such as snails. Since pesticides are commonly used in rice farming, these birds may be exposed to OCPs through contaminated feed, soil, or water in their environment. In this paper, the presence of OCPs in the liver, ovary, muscle, and fat tissues of 60 female domestic mallard ducks at peripubertal, mid-laying, and late-laying stages in Candaba, Pampanga, Philippines was examined. This research also checked the occurrence of OCPs in various brands of commercial feeds, as well as conventional duck feeds such as *susô* and *kuhol* used by duck farmers in the area. Using gas chromatography/mass spectrometry, 13 types of OCPs were detected in the tissues of ducks across all stages of maturity. Ten types of OCPs were also found in both commercial and conventional duck feed samples. The co-occurrence of OCPs in duck feeds and tissues suggests a potential link, indicating that ducks may be exposed to these compounds through the oral route. Although certain OCP residues were detected, many of the targeted compounds were not found in the analyzed samples. While the detected residues were below the maximum residue limits set by the Codex Alimentarius and the European Commission, their presence may still pose potential risks due to cumulative exposure, mixture effects, and long-term exposure. Hence, proactive measures and continued monitoring of poultry feed ingredients may be considered to address this concern.

Keywords | Feeds, Mallard duck, Organochlorine pesticide, Tissues

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INTRODUCTION

Organochlorine pesticides (OCPs) are synthetic pesticides that belong to the group of chlorinated hydrocarbon derivatives with very wide applications in agricultural and chemical industries (Khan and Ahmad, 2019). Although very effective in pest control, these pesticides received global attention because of their high toxicity, carcinogenic, mutagenic, and teratogenic effects, slow degradation in the environment, and bioaccumulation in organisms (Keswani *et al.*, 2021; Tzanetou and Karasali, 2022). The persistence of OCPs in the environment and their ability to accumulate in tissues in humans and animals classify them as persistent organic pollutants (POPs). These and their negative effects on human health, such as cancers, reproductive issues, neurological disorders, and endocrine disruption, eventually led to their restriction and ban in several countries during the Stockholm Convention on POPs in 2001, as part of the initiative of the United Nations Environment Program, of which the Philippines is a signatory (Lallas, 2001). One alarming property of OCPs is that their application causes severe harm to the environment, often affecting non-target species. For instance, wildlife and even farm animals are likely exposed to these chemicals as they may be present in their environment or in the food chain. In fact, a comprehensive review on the presence of OCPs in chicken, eggs, and other livestock products was reported by Darwish *et al*. (2023). Considering the potential negative effects of OCPs on human health, these findings, if not properly addressed, may lead to further complications and pose a significant risk to consumers.

Duck production in the Philippines is a profitable and growing industry. In terms of economic value, the duck industry ranks second to chickens in the country, with eggs being its most important product. Mainly raised for its egg, the mallard (*Anas platyrhynchos*) constitutes much of the Philippine duck industry, while a small fraction is shared by the muscovy (*Cairina moschata*), which is raised mainly for meat production (Lambio, 2001). According to Chang et al. (2003), most of the duck eggs are utilized for "*balut*" or boiled embryonated egg production, while the rest are consumed as table eggs or processed into *penoy*, salted eggs, and century eggs. In terms of the volume of production of duck eggs by province, Pampanga ranks second in the Philippines, producing 2,595, 2,223, and 2,563 mt liveweight in 2021, 2022, and 2023, respectively, registering an annual growth rate of 15.3% in 2023 (PSA, 2023).

The town of Candaba in the province of Pampanga is recognized as a top producer of ducks and is also a major producing area of duck eggs in the Philippines. The industry is predominantly backyard level in scale, and many of the duck farmers and their families rely on sales from shipments to areas outside Luzon. Duck farmers in Candaba, Pampanga, ship 80% of their produce to Visayas and Mindanao, and only 20% of the eggs are distributed in the Luzon area (Mapiles, 2017). A common practice of duck farmers is the integration of duck production with rice farming, in which farmers allow their animals to feed on weeds and unwanted pests in the rice fields. Apart from using commercial feeds, it is also common for farmers to feed their animals with gastropods, specifically *susô* (shellfish) and *kuhol* (golden apple snail), to improve the performance of their ducks. These common duck-rearing practices make the animals vulnerable and exposed to pollutants that may be present in the environment where they are allowed to graze and from where the conventional feeds are obtained. A study by Navarrete *et al*. (2018) detected multiple OCPs in surface and groundwater along the Pampanga River, including dieldrin, endrin aldehyde, and BHC isomers, some of which exceeded regulatory limits. Candaba, Pampanga, lies within the Pampanga River floodplain, and its wetlands and water systems are hydrologically connected to the river, suggesting that ducks raised in the area may be exposed to OCPs through water, feed, or the surrounding environment.

We previously reported the presence of cadmium, a heavy metal pollutant and endocrine disruptor, in the tissues and feeds of ducks in Victoria, Laguna, and Candaba, Pampanga (Octura *et al*., 2017). The present study builds upon that research, focusing on OCPs. Hence, we conducted this exploratory study to examine the presence of OCP residues in the tissues of mallard ducks, as well as in the commercial and conventional feeds used by duck farmers in Candaba, Pampanga, to establish baseline information on OCP residues in both the tissues and feeds of ducks in the area.

MATERIALS AND METHODS

Sampling procedures

Female mallard ducks were selected for this study because they are mainly raised for egg production, one of their primary products. The ducks were sampled from Candaba, Pampanga, Philippines (15.09253° N, 120.82728° E). The area of Candaba, Pampanga, is popular for duck production, and a large portion of the duck eggs produced here is sent to processing centers for further processing before being sold to nearby areas. The study utilized 60 female mallard ducks at peripubertal (PP, 4-8 months), mid (ML, 10-14 months), and late (LL, 18 months and older) laying stages (Octura *et al*., 2017). The ducks were humanely euthanized by manual cervical dislocation in accordance with standard animal handling and welfare procedures (The Philippine Animal Welfare Act, 1998). Tissues, including liver, ovary, adipose tissue, and muscle, were aseptically collected. The samples were immediately wrapped in aluminum foil and stored under appropriate conditions until chemical analysis. Organochlorine pesticide residues were determined separately in each tissue to allow tissue-specific assessment of residue occurrence.

Commercial and conventional duck feed samples were also obtained from every duck farmer with their consent. The commercial feed samples were then assigned codes to maintain brand anonymity, with the samples labeled A through F. The commercial feed samples were placed in sterile plastic bags and stored at room temperature, while conventional feed samples (mollusks), namely *susô* and *kuhol*, were washed and immediately frozen until scheduled analysis. The collection of duck tissues, pre-chemical preparations, and preservation were done at the University of the Philippines Los Baños, Animal Physiology Laboratory, before the samples were subjected to chemical analysis.

The present study is exploratory in nature, aimed only at gathering baseline information. Due to financial constraints associated with multi-residue OCP analysis, samples were pooled by type and stage to allow comprehensive screening for multiple compounds. The samples similar in nature were pooled together and submitted as a single composite sample. Thus, all similar organ samples from the same stage of maturity, as well as similar conventional feeds obtained from various duck farmers, were pooled together. Moreover, feeds of the same brand were consolidated before being submitted for OCP analysis. The present study is primarily descriptive. Data from pooled samples were summarized to provide an initial assessment of OCP residues, and no formal statistical analyses were performed. While this approach precludes assessment of variability among individual ducks, farms, or feed batches, it enables detection of OCP presence and provides baseline data for future studies.

Chemical analysis

Chemical analyses of OCPs listed in Table 1 were conducted at the Analytical Services Laboratory of the University of the Philippines–Natural Sciences Research Institute (UP-NSRI), an ISO 9001:2015–certified laboratory. The OCP analysis was performed using gas chromatography–mass spectrometry (GC–MS) with a Shimadzu GC/MS-QP 2010 system equipped with a DB-5 capillary column (30 m × 0.32 mm internal diameter, 0.25 µm film thickness), using helium as the carrier gas. Internal calibration was applied for quantification. The laboratory's standard OCP analytical workflow involves the use of Phenanthrene-d10, Pyrene-d10, and Chrysene-d12 as internal standards, with p,p′-DDT-$^{13}C_{12}$ as a surrogate standard. However, complete methodological details for the analyzed samples were not available. Accordingly, the results are interpreted at a screening level, with emphasis on the detection and identification of OCP residues rather than precise quantification. The method of analysis, estimated method detection limit (EMDL), estimated limit of quantitation (LOQ), and the maximum residue limits (MRL) of the OCPs based on the standards set by Codex Alimentarius and the European Commission are also shown in Table 1. Since complete method validation data were not available, the measured values should be considered exploratory and not definitive for regulatory compliance. Comparisons with MRLs are provided only for contextual reference.

Table 1: Estimated method detection limits and estimated limits of quantitation for OCP residues tested in mallard duck tissue and feed samples.

Organochlorine pesticide	EMDL (ng/g)	ELOQ (ng/g)	MRL* (mg/kg)	
			Poultry meat	Animal feed
α-Benzene hexachloride	0.6	----	0.01	0.02
γ-Benzene hexachloride	0.7	----	0.01	0.2
Hexachlorobenzene	0.3	1	0.01	0.01
Heptachlor	0.5	----	0.2	0.01
Aldrin	0.5	----	0.2	0.01
Heptachlor epoxide	0.4	----	0.2	0.01
γ-Chlordane	0.6	----	0.5	0.02
o,p′-DDE	0.5	----	0.3	0.01
Endosulfan I	0.8	----	0.03	0.1
α-Chlordane	0.8	----	0.02	0.02
trans-Nonachlor	0.7	----	0.01	0.01
Dieldrin	2	----	0.2	0.01
p,p′-DDE	0.7	----	0.3	0.05
o,p′-DDD	0.7	----	0.3	0.01
Endrin	2	----	0.1	0.01
p,p′-DDD	0.3	1	0.3	0.05
cis-Nonachlor	0.9	----	0.01	0.01
o,p′-DDT	0.5	----	0.3	0.01
p,p′-DDT	0.9	----	0.3	0.05
Methoxychlor	0.9	----	0.01	0.5
Mirex	0.7	3	0.01	0.01
Method of analysis	Gas chromatography/ Mass spectrometry: Selected ion monitoring determination after acetonitrile/ C18 silica extraction, partitioning in acetonitrile/water/ethyl acetate-hexane, cleanup in NH_2 silica and silica solid phase extraction column			

EMDL= Estimated Method Detection Limit; ELOQ= Estimated Limit of Quantitation; MRL= Maximum Residue Limit. *MRLs retrieved from either the Codex Alimentarius FAO-WHO (n.d.) or European Commission (n.d.) online databases, accessed in January 2025.

RESULTS AND DISCUSSION

The levels of OCP residues in the liver, ovary, muscle, and fat of ducks across different stages of maturity are shown in Table 2. Among the OCPs analyzed in the selected tissues of ducks, no residues of γ-BHC, heptachlor, aldrin, heptachlor epoxide, o'p-DDE, dieldrin, endrin, and o,p'-DDT were detected based on the EMDL used by the UP-NSRI. However, a total of 13 OCPs at different concentrations were detected in various organs of ducks at different

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stages of maturity. Organochlorine pesticide residues were

Table 2: Levels of OCP residues in the liver, ovary, muscle, and fat samples of female domestic mallard ducks at various stages of maturity.

OCP	Organs at different stages of maturity (ng/g)											
	Liver			Ovary			Muscle			Fats		
	PP	ML	LL	PP	ML	LL	PP	ML	LL	PP	ML	LL
α-BHC	-	-	-	-	68	-	30	-	33	-	-	20
HCB	0.3	0.3	0.4	0.3	-	0.3	-	-	-	0.5	-	-
o'p-DDD	-	-	-	-	-	-	-	-	-	-	1	-
p'p-DDD	0.6	1.2	1.1	0.6	-	0.5	-	0.5	-	-	-	-
p'p-DDE	-	-	-	-	-	-	-	-	-	2	-	-
p'p-DDT	-	-	-	-	-	-	-	-	-	-	-	2
α-Chlordane	-	-	-	-	-	-	-	-	-	-	-	1
γ-Chlordane	-	-	-	-	-	0.7	-	0.6	-	0.8	-	5
Cis-Nonachlor	-	-	-	-	-	0.9	-	0.9	-	-	-	-
Trans-Nonachlor	-	-	-	-	-	-	1	-	-	-	-	1
Endosulfan-1	11	-	-	15	-	3.1	-	-	-	15	-	-
Methoxychlor	-	-	-	-	-	-	-	-	-	0.8	-	-
Mirex	-	-	0.70	2	-	2	-	0.8	-	-	-	30

Note: - in the table indicates <Estimated Method Detection Limit.

detected in the liver and ovary of ducks across production stages, with compound profiles varying by tissue and stage. In the liver, HCB and p,p′-DDD were consistently detected across all stages, while endosulfan I and mirex appeared in the liver at different stages of maturity. In the ovary, a broader range of OCPs was observed, including α-BHC, HCB, p'p-DDD, γ-chlordane, cis-Nonachlor, endosulfan I, and mirex, with some compounds detected at notably higher levels compared to the liver.

Residual OCPs were also detected in muscle and fat tissues of ducks across production stages. In muscle, OCP residues detected include α-BHC, p'p-DDD, γ-chlordane, cis-Nonachlor, trans-Nonachlor and mirex. Fat tissues, on the other hand, showed a wider range of OCPs, with almost all compounds detected across the different stages. Only p,p'-DDD and cis-Nonachlor were not detected. Across all tissues and production stages, the detected residue levels did not exceed the MRL established by the Codex Alimentarius and the European Commission.

The presence of OCPs in selected tissues of mallard ducks in the present study suggests that these contaminants indeed accumulate in the organs of the body. This accumulation can be partially explained by the chemical structure of these pesticides, particularly chlorine atoms attached to hydrocarbon rings, making them hydrophobic and lipophilic in nature (Jayaraj *et al*., 2016; Keswani *et al*., 2021; Tzanetou and Karasali, 2022). For these reasons, OCPs have a high tendency to accumulate in organs with high lipid content, such as the liver, ovary, and fats of ducks. It is noteworthy, however, that the muscles also contained OCPs despite having a lower lipid content than the other tissues (Tao *et al*., 2008). These findings are similar to the report of Rajaei *et al*. (2010) in which different levels of OCPs were detected in 3 duck species, including the mallard, in the wild. Similar results were observed by Dayan *et al*. (2025) in which OCPs, together with other contaminants such as mercury, polychlorinated biphenyls, and dibenzofurans, were detected in the bodies of mallard ducks and 4 other waterfowl species, which may pose potential risks to hunters and consumers of these wild ducks in the northeast Atlantic Flyway. The findings of the present study and other reports suggest that OCPs are still present in considerable amounts in the environment, leaving ducks exposed to these pollutants despite bans or restrictions. It is possible that some of the OCPs are still being used to date or that the OCPs detected in ducks are residues from the past, owing to the strong persistence of these pollutants in the environment.

The levels of OCP residues in the commercial and conventional duck feed samples are shown in Table 3. The commercial and conventional duck feeds collected from the duck farmers in the present study revealed the presence of 10 types of OCPs at different levels in both feed types. Residual OCPs were detected in all commercial and conventional duck feed samples, with compound profiles varying among feed types. Across most feeds, residues consisted primarily of DDT-related compounds, chlordanes, and HCB at low levels. One commercial feed (Feed E) showed a broader residue profile, including α-BHC, nonachlors, and methoxychlor, and was the only feed in which α-BHC was detected. Conventional feed components (*susô* and *kuhol*) also contained detectable OCP residues, dominated by DDT-related compounds, chlordanes, and endosulfan I. Except for α-BHC in Feed E, all detected residues in both commercial and conventional feeds were below the MRLs established by the Codex Alimentarius and the European Commission.

Table 3: Levels of OCP residues in the commercial and conventional feed samples of mallard ducks.

OCP	Commercial feeds (ng/g)						Conventional feeds (ng/g)	
	A	B	C	D	E	F	Susô	Kuhol
α-BHC	-	-	-	-	50	-	-	-
Hexachlorobenzene	0.6	0.5	0.5	0.8	-	-	-	-
trans-Nonachlor	1	-	-	-	3.5	-	2	-
cis-Nonachlor	-	-	-	-	2	-	-	-
p'p-DDD+o'p-DDT	-	-	-	-	2	-	2	2
p'p-DDT	3.19	10.1	7.2	-	2	3	4	2
γ-Chlordane	2	1	2	2	-	-	2	-
α-Chlordane	1	1	-	1	-	2	-	1
Endosulfan 1	-	4	-	2	-	-	-	20
Methoxychlor	-	-	-	9	70	-	-	-

Note: - in the table indicates <Estimated Method Detection Limit

The OCP residues detected in both commercial and conventional duck feed samples in the present study suggest that the ducks were directly exposed to these pollutants. The oral route might have been the main point of entry for these OCPs into the body of the ducks. The OCP residues detected in the commercial feeds may have come from the feed ingredients or raw materials used in the production of the duck feeds. However, it is also possible that the contamination occurred during the processing of the feed, which needs to be further studied (Li *et al.*, 2014). Several studies have reported the presence of OCP in feed ingredients for livestock and poultry, which may be the primary source of OCP residues in commercial feeds (Botaro *et al.*, 2011; Panseri *et al.*, 2013; Nag and Raikwar, 2010; Miclean *et al.*, 2024). Since these pesticides strongly persist in the environment, OCPS may still be present in the area where the raw feed materials were harvested. Organochlorine pesticide contamination during the post-harvest processing of raw materials of feeds, however, may also be possible and should not be ruled out. In addition, the presence of OCP residues in *susô* and *kuhol* samples might have also contributed largely to the accumulation of OCPs into the duck tissues since incorporating these mollusks into the duck's diet is a common practice for duck farmers not just in Candaba, Pampanga, but in the entire country. It is also for this reason that raising ducks is often mixed with rice farming since ducks feed on pests in rice paddies, especially the snails (Perialde and Elicot, 2012). According to Baroudi *et al.* (2020), mollusks are good indicators of pollution levels in the environment because of their ability to accumulate pollutants like heavy metals and OCPs. Therefore, the presence of these contaminants in the conventional feeds in the present study reinforces the idea that the OCPs persist and are still present in the environment, leaving animals and other living organisms exposed to these POPs. Although feeds are likely a major source of OCP contamination in duck tissues in this study, given the presence of residues in both commercial and conventional feed samples, it cannot be ruled out that other environmental sources may also contribute to exposure. In addition to feed, ducks may be exposed to OCPs through ingestion of contaminated water or soil during grazing, as well as from OCP residues persisting in the surrounding environment, including sediments, vegetation, and other materials (Lu, 2010; Navarrete *et al.*, 2018). The combined influence of these multiple pathways likely determines the overall levels of OCPs detected in tissues, highlighting the complexity of environmental exposure and the need to consider both feed and non-feed sources when assessing contamination.

Previous studies, similar in nature to the present study, have consistently shown the persistence of OCPs despite many years of global restrictions and bans. In crops, a study revealed that some non-edible parts, such as stems and leaves, have high residual levels of OCPs such as heptachlor epoxide, dieldrin, and lindane (Chandra *et al.*, 2021). This poses an indirect risk of exposure to humans since these parts of the crops could serve as feed components for livestock and poultry. In aquatic systems, OCPs can make their way to the water reservoirs and accumulate in fish organs and tissues. For instance, elevated levels of OCPs such as dieldrin, aldrin, BHC isomers, and endosulfan were detected in the coastal waters of Mexico and fish samples from Nigeria, confirming the potential exposure of humans to OCPs via this route (Abubakar *et al.*, 2025; Ruiz-Ciau *et al.*, 2025).

Similar concerns extend to livestock and poultry production, where animal-derived food products such as meat, milk, liver, kidney, and even cheese were found to contain residual OCPs with contamination rates ranging from 25% to 80%. Of particular concern are the types of OCPs detected in these food products, such as aldrin, DDT, lindane, and carbofuran, which are extremely toxic and banned a long time ago and are still detectable in food products at various levels (Mohamed *et al.*, 2024). In fact, several of these food products contained OCPs exceeding MRLs, raising serious concerns for food safety regulation in developing areas. In India and Mali, poultry meat and eggs, as well as chicken feed samples, have been reported to contain OCP residues exceeding the MRLs such as HCH, DDT, heptachlor, and endosulfan (Aulakh *et al*., 2006; Coulibaly *et al*., 2022).

In the present study, OCP residues were generally detected at levels below established MRLs, suggesting that the immediate risk to animal and human health is likely low. However, the presence of banned and persistent substances, even at low concentrations, highlights the ongoing potential for bioaccumulation and chronic exposure (Jayaraj *et al*., 2016; Rokni *et al*., 2023; Shekhar *et al*., 2024; Zhang *et al*., 2025). Routine monitoring of feeds and animal tissues, along with the implementation of good agricultural practices, remains critical to ensure food safety and minimize long-term exposure risks.

CONCLUSION

Overall, the findings of the present study suggest that OCP residues in duck tissues and feeds were mostly within permissible limits according to standards set by Codex Alimentarius and European Commission, with many targeted OCPs not detected, indicating a likely low risk to health. Nevertheless, the detection of persistent and banned substances in the samples underscores the importance of continued monitoring. While ingestion of contaminated feeds is likely the primary route of exposure, ducks may also acquire OCPs from other sources such as soil, water, and the surrounding environment. The pooling of samples in this study, while appropriate for initial screening, limited the ability to perform detailed statistical analyses. Therefore, future studies using individual samples, larger sample sizes, and more robust statistical approaches would provide a more comprehensive assessment of exposure and help refine risk evaluations, particularly for chronic exposure scenarios.

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NOVELTY STATEMENT

This study provides the first documented assessment of OCP residues in commercial and conventional duck feeds and duck tissues in Candaba, Pampanga, Philippines. Using pooled samples, the investigation offers an initial concentration profile of selected OCPs present in duck feeds and tissues. This study establishes baseline residue levels that can inform future monitoring programs, risk assessments, and more comprehensive studies with expanded sampling frameworks. These findings provide foundational data to support feed quality control, residue monitoring, and food safety assurance within the local duck industry.

AUTHOR'S CONTRIBUTION

RSV and JEO contributed equally to this work. RSV conceptualized the study, developed the methodology, supervised the investigation, and contributed to writing the manuscript. JEO conducted the experiments and wrote and revised the manuscript. Both authors approved the final version.

Generative AI and AI-assisted technology statement

We used AI-assisted tools solely for grammar correction and improving clarity in the manuscript during the revision stage. All scientific content, data analysis, and conclusions are entirely our own.

Conflict of interest

The authors have declared no conflict of interest.

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