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Review Article

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Organochlorine Pesticides in Poultry Meat: A Review

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Abstract

Poultry meat including chicken ducks, geese, and quails are important sources of animal-derived protein, essential amino acids, and trace elements. However, poultry can be exposed to a wide array of environmental chemicals such as organochlorine pesticides (OCPs). Organochlorine insecticides, such as dichlorodiphenyltrichloroethane (DDT), have long been employed in agricultural and disease management. According to reports, DDT exposure may cause a multitude of negative impacts in humans. Such adverse health effects include teratogenic effects on fetus, carcinogenic effects, and reproductive disorders. Although being banned since 1970s, still OCPs are detected in foods of animal origin. Therefore, this review threw the light on the recent reports about the occurrence of OCPs residues in poultry meats and their potential adverse health effects on humans.

KEYWORDS
Organochlorine pesticides, Poultry meat, Health risk assessment

Introduction

Poultry meat, including chicken, duck, quails, geese, and pigeon, and their products, such as meat, liver, and meat products (such as burgers, luncheon meat, and frankfurters), are important sources of protein, energy, vitamins, and minerals around the world because they are nutritious, delicious, and affordable, and provide a significant portion of the recommended daily needs of trace minerals, proteins, and energy (Darwish *et al*., 2015, 2018a, b; Morshdy *et al*., 2021). However, birds might be exposed to a vast array of pollutants from the environment or their food chain, and therefore may pose a risk to the consumers. Such contaminants include heavy metals, antimicrobials, polycyclic aromatic hydrocarbons, heterocyclic amines, and pesticides (El Bayomi *et al*., 2018; Thompson and Darwish, 2019).

Organochlorine pesticides (OCPs) have been widely utilized for several decades because to their extended duration of action, low cost, and toxicity against a variety of pests (Darwish and Thompson, 2023). In the 1950s, several OCPs, notably aldrin, dieldrin, and dichlorodiphenyltrichloroethane (DDT), were widely employed in agriculture. DDT was formerly assumed to be dangerous primarily to insects, but toxicity and extensive biomagnification were soon discovered in other species, most notably wild birds, many of which saw catastrophic population losses as a result of its use. Lipophilic chlorine residues from OCPs accumulate within animals, and biomagnification is also observed in top-of-the-food-chain species. The Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted in May 2001 (UNEP, 2002), and it now has 179 signatories. The first 12 POP chemicals banned by this convention were aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), mirex, and toxaphene. Although several OCPs have been banned from use in agriculture, others are still utilized as agricultural pesticides in several countries. Many African countries continue to use DDT under an exemption for approved disease vector control. Chemicals are applied to bed nets (insecticide treated nets) or sprayed in homes (indoor residual spraying, IRS) in this case. Some places are likely to have stockpiled or obsolete chemicals, with unmonitored and potentially improper storage conditions. These can only be detected by testing environmental samples for contamination (Thompson *et al*., 2017a).

OCPs can enter the body through a variety of methods, including inhaling contaminated air, skin penetration, or ingestion of contaminated foods and drinking water (Mahmoud *et al*., 2013, 2016; Thompson *et al*., 2018). OCP-contaminated foods of animal origin include poultry meat and edible giblets are thought to be major contributors for pesticide exposure in humans (Hassal, 1990). Maternal transfer can occur across the placenta to the fetus or through breast milk to newborns. Such OCPs might lead to several adverse health effects on the human (Sallam and Morshdy, 2008; Morshdy *et al*., 2018). The levels of these chemicals in the living animals vary depending on their habitat and place in the food chain (Zhou *et al*., 2007).

In this review, we would like to report the recent literatures recording occurrence of OCPs on poultry meat and their potential health risks associated with the consumption of such meat sources.

Reports about the occurrence of OCPs in poultry products

In Hungary, Yamamoto *et al*. (2002) evaluated the amount

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of OCPs in Hungarian canned foods as part of an inquiry into endocrine disrupting chemicals (EDCs). Seven kinds of canned foods were purchased at a market in Budapest, Hungary, and the concentrations of eighteen organochlorine compounds (α-BHC; β-BHC; γ-BHC; δ-BHC; p,p′-DDT; p,p′-DDE; p,p′-DDD; o,p′-DDT; heptachlor; heptachlor-epoxide; aldrin; dieldrin; endrin; oxychlordane; trans-chlordane; cischlordane; trans-nonachlor; and cis-nonachlor) were measured.Aside from DDT and its metabolites, no EDCs were discovered (levels 0.4 ppb). DDT and its metabolites, on the other hand, were found in fish, pork, and chicken liver pate. p,p′-DDE was discovered at a level of 1.8 ppb in fish soup concentrate, 2.3 ppb in Hungarian luncheon meat, and 0.5 ppb in fish soup concentrate. Special luncheon meat had 0.5 ppb, while chicken liver pate containd 0.6 ppb. Only DDT and its metabolites were found in fish, animal flesh, and animal liver out of the eighteen organochlorine chemicals tested. DDT contamination in fish and meat is thought to be widespread, long after its usage has been banned.

In Jordan, Ahmad *et al*. (2010) measured OCPs residues in 519 Jordanian samples of eggs, chicken, and meat (lamb and beef). The residual amounts of aldrin, dichlorodiphenyltrichloroethane and metabolites (DDTs), dieldrin, endosulfan isomers, endrin, hexachlorocyclohexane isomers (HCHs), heptachlor, heptachlor epoxide, and hexachlorobenzene (HCB) were determined in all samples. The materials were Soxhlet extracted in 250 mL petroleum ether for 8 hours. Florisil column chromatography was used to clean the samples, and gas chromatography with an electron capture detector (GC-ECD) was used for analysis. The results showed that 28% (38/134), 20% (23/115), and 49% (131/270) of the eggs, chicken, and beef samples tested positive for OCP residues. HCHs and DDTs are the most prominently observed chemicals, having been discovered at high levels. Heptachlor, heptachlor epoxide, HCB, aldrin, and endrin chemicals, on the other hand, were found in fewer than 7% of the samples tested. These residues exist notwithstanding Jordan's complete ban on the use of OCPs for agricultural reasons. There were no traces of op′-DDD, op′-DDT, dieldrin, α-endosulfan, or β-endosulfan residues.

In Russia, during 1998-2002, the residues of persistent organic pollutants (POPs) were examined in 70 different food items from Northwest Russia. PCB levels in dairy products and lipids ranged from 0.2 to 16ng/g wet weight (ww), from 0.2 to 23 ng/g ww in meat products, from 0.5 to 16 ng/g ww in eggs, and from 0.3 to 30 ng/g ww in fish. DDT levels were found to be high (16 ng/g ww) in Kola Peninsula butter, hog fat from Arkhangels region (10 to 130 ng/g ww), and some fish samples from White Sea and Kargopol region (17 and 30 ng/g ww). The presence of low DDE/DDT ratios in many of the tested foods indicated recent DDT exposure.

In India, a total of 75 animals aged 1.5 to 8 years were chosen at random for the investigation, there were 57.8% cross-bred animals, and the rest were unremarkable. Furthermore, 61.8% of the animals in the survey were brought for slaughter from local sources, with the remainder coming from farmhouses. Organochlorine pesticides (0.01-0.22 μg/g) and organophosphorus pesticides (0.111-0.098 μg/g were detected in samples taken from five districts. In general, all raw meat samples included high levels of dichlorodiphenyltrichloroethane. Cow meat samples had the most contamination, whereas chicken meat samples had the lowest. For the pesticides chosen for investigation, no district-specific trend was found. Following a decontamination investigation it was discovered that boiling is the greatest approach for lowering pesticide load in raw meat samples (Sengupta *et al*., 2010).

Thompson *et al*. (2017b) mentioned that DDT is sprayed in homes in South Africa's KwaZulu-Natal Province on a yearly basis (IRS) to suppress the mosquito vector of malaria. Samples of free-range chicken meat (n = 48) and eggs (n = 13), as well as commercially produced chicken meat (n = 6) and eggs (n = 11), were gathered and examined in the northern portion of the province. DDTs were found in 94% (45/48) of the free-range chicken meat samples (median 6.1 ng/g wet weight (ww), maximum 79.1 ng/g ww). The contents of chicken eggs were also polluted (DDTs in free-range eggs median 9544 ng/g ww). The most common DDT congener found in free-range meat (>63%) and eggs (>66%) was p,p-DDE, followed by p,p-DDT and then p,p-DDD. Based on anticipated daily intake values, the calculated human risk ratio (carcinogenic) values for DDTs found in both free-range chicken products were greater than one. Consumption of free-range eggs offers a very serious health risk.

In China, in November 2015, the most consumed 23 types of foods from eleven different categories (vegetable, fruit, fish, pig, cattle meat, chicken, egg, milk, oil, rice, and flour) were sampled in a market-based survey in Nanjing, a typical southeast metropolis in China. DDT and HCH amounts in foods were determined using gas chromatography with a mass spectrometer detector. DDT and HCH residual levels in foods were 0.95-3.53 ng g^{-1} and 0.32-1.96 ng g^{-1}, respectively. The greatest residual of 10OCPs in cattle meat was 4.75 ng g^{-1}, whereas the lowest was 1.31 ng g-1 in flour. Children had larger estimated daily intakes of both DDTs and HCHs than other age groups, regardless of gender (Zhang *et al*., 2017).

In Nigeria, Adeyi *et al*. (2021) assessed the levels of residual OCPs (α,β,δ-HCH, heptachlor, heptachlor epoxide, chlordane, methoxychlor, aldrin, dieldrin, endrin, endrin aldehyde, endrin ketone, endosulfan, endosulfan sulphate, 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane (DDD), 1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene (DDE), and 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (DDT)) in food commonly consumed in Lagos and Ibadan, Southwest, Nigeria. A statistical predictive model was used to assess the health risk associated with human exposure through food consumption. In Lagos and Ibadan, 248 composite food samples from eight categories were analysed. The QueChERS method was used for sample extraction and cleaning, and the extracts were injected into the GC-ECD. The largest concentrations of DDT were found in meat products, aquatic foods, dairy products, edible oils, fruits, and cereals, while the highest concentrations of HCHs were found in chicken eggs and vegetables. OCP concentrations (ng/g) in food categories were 6.091.6-6.850.9 (meat), 5.292.0-12.314 (aquatic foods), 4.861.7-5.890.8 (dairy products), and 4.530.8-6.321.1 (fruit and vegetables).

Potential adverse health effects of OCPs on human

OCPs are thought to be endocrine disrupting chemicals (McKinlay *et al*., 2008), causing a wide range of negative health outcomes in humans, including decreased fertility and fecundity, spontaneous abortion, skewed sex ratios in exposed communities' offspring (Windham *et al*., 2005), and male and female reproductive tract abnormalities (Bretveld *et al*., 2008).

Aneck-Hahn *et al*. (2007) conducted a cross-sectional investigation on healthy male volunteers (n=311) between the ages of 18 and 40 in Limpopo Province, South Africa, an endemic malaria area where DDT is sprayed regularly. The findings revealed a substantial positive relationship between the percentage of sperm with cytoplasmic droplets, poor ejaculate volume, and p,p′-DDT concentration. Furthermore, 28% of the study group had oligozoospermia and 32% had asthenozoospermia.

OCPs have been found to be associated with a wide range of human malignancies (Hyer *et al*., 2000). For example, Ahmed *et al*. (2002) discovered higher residual levels of DDE in the sera of aggressive adenocarcinoma patients compared to controls in Port Said region, Egypt. Arrebola *et al*. (2015) discovered a link between breast cancer risk and -HCH, HCB, heptachlor, and p,p'-DDE in Tunisia.

Mean DDT levels in breast milk from malaria-endemic villages in South Africa that used DDT on a regular basis were 9.5-18 mg/kg milk fat (25-50 μM), which was high enough to exceed the provisional tolerable daily intake (PTDI) for infants and the maximum residue limit (MRL) set by FAO and the WHO (Bouwman *et al*., 2012). The postnatal period is regarded as a vital period of development, and exposure during this time period may have a major impact on newborns (Desaulniers *et al*., 2005). Concurrently, elevated DDT levels in lipid-rich breast milk may have harmful effects on breast tissue. DDT exposure has been related to an increased risk of breast cancer in humans (Cohn *et al*., 2015). DDT is classed by the International Agency for Research on Cancer (IARC) as a group 2A carcinogen, a "probable cause of cancer in humans" (IARC, 2018).

In Canary Islands, Spain, thirty-four (47.2%) of the 72 human milk samples were positive for DDT (mean: 0.92 ng/g), with levels ranging from 0.08 to 16.96 ng/g. The socio-demographic characteristics did not differ significantly between those with detectable DDT and those with non-detectable DDT. We discovered a link between DDT levels and vegetable (OR (95%CI): 1.23 (1.01-1.50)) and poultry meat intake (OR (95%CI): 2.05 (1.16-3.60)), as well as the presence of DDT in breast milk and gestational age (OR (95%CI): 0.59 (0.40-0.90)). The authors concluded that DDT is found in women's breast milk at the moment of delivery. DDT detection from plants and animal origin food is explained by residual levels and the spread from nations that still use DDT. The presence of this chemical in breast milk poses a prenatal and postnatal exposure risk to fetuses and babies due to chronic bioaccumulation and poor removal, with potentially negative health consequences. This information should be utilized to promote awareness of the dangers of OC exposure and to assist in the development of health regulations to avoid its usage worldwide and so prevent its spread (Vall *et al*., 2014).

In a study conducted in China, all demographic groups' daily intakes of γ-HCH and DDTs were significantly below the permissible levels recommended by the Food and Agriculture Organization of the United Nations/World Health Organization. There was no evident non-cancer danger for local residents, but the cancer risk was assessed to be between 10-6-10-4, which was greater than the tolerable risk threshold but lower than the priority risk level. Females had a higher risk than males in all age categories, and children were the most sensitive age group to health risk (Zhang *et al*., 2017).

Thompson *et al*. (2019) mentioned that DDT, an organochlorine insecticide, is persistent in the environment and has been linked to harmful human health effects. High concentrations in breast milk endanger both breast tissue and nursing newborns. The study's goals were to investigate DDT-induced transcriptome changes in enzymes and transporters involved in xenobiotic metabolism, immunological responses, oxidative stress markers, and cell growth in a human breast cancer cell line. In a short-term experiment, MCF-7 cells were exposed to both environmentally relevant and previously evaluated doses of p,p'-DDT. Metabolizing enzymes and transporters (ACHE, GSTO1, NQO1, and ABCC2), as well as oxidative stress indicators (CXCL8, HMOX-1, NFE2L2, and TNF), were clearly upregulated. In contrast, UGT1A6, AHR, and cell growth genes (FGF2 and VEGFA) were significantly downregulated.

Conclusion

Meat and poultry consumption were significant sources of OCPs (DDTs and HCHs), respectively. The contamination of animal feed and agricultural practices were thought to be the most important sources of the contamination of poultry meat with OCPs. Increased control over maximum residue levels in food and feed, on the other hand, may have resulted in significant changes in POPs levels and patterns in food in the examined areas.

Conflict of interest

The authors declare that they have no conflict of interest.

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