Ecotoxicology and Environmental Safety 161 (2018) 691–698

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

Comparison of zinc, lead, cadmium, cobalt, manganese, iron, chromium and copper in duck eggs from three duck farm systems in Central and Western, Thailand

P. Aendo[a,c], R. Netvichian[b], S. Viriyarampa[a], T. Songserm[c,d], P. Tulayakul[a,c,*]

[a] *Department of Veterinary Public Health, Faculty of Veterinary Medicine, Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom 73140, Thailand*
[b] *Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand*
[c] *Center for Duck Health Science, Faculty of Veterinary Medicine, Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom 73140, Thailand*
[d] *Department of Pathology, Faculty of Veterinary Medicine, Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom 73140, Thailand*

ARTICLE INFO

Keywords:
Eggs
Duck
Heavy metal
Food safety
Thailand

ABSTRACT

This was a comparative study of the heavy metal levels (Zn, Pb, Cd, Co, Mn, Fe, Cr and Cu) in eggs from free grazing duck, small-scale, and large-scale farms in central and western regions of Thailand. A questionnaire was used to gather demographic data for the analysis of heavy metal contamination in feed, drinking water and wastewater. The correlation between the amounts of heavy metal contamination in eggs was studied against the heavy metals found in feed, drinking water and wastewater. The levels of Pb, Cd, Cr and Cu in eggs from large-scale farms were significantly higher than small farms and free grazing farms at $P < 0.001$. Zn in eggs from free grazing farms was higher than in the small farms and large-scale farms sampled. The contamination of Pb in eggs from all types of farms exceeded the standard limits of ACFS 6703–2005. The average levels of Pb in the eggs from small-scale farms correlated significantly with the level of Pb found in the feed at $P < 0.05$, while the average levels of Pb in eggs from free grazing duck farms correlated significantly with the levels of Pb found in the drinking water at $P < 0.05$. Additionally, the average level of Cu in duck egg from large-scale farms correlated significantly with the level of Cu found in the feeds at $P < 0.001$. Furthermore, from a calculation of the provisional tolerable daily intake (WHO-FAO) of heavy metals in this study, it was concluded that consumers face health risks from Cd contamination. Thus, heavy metal contamination, especially Pb and Cd in duck egg, must be of concern due to the health risks and the route of crucial heavy metals contamination should be elucidated and long - term monitoring of heavy metals posing health effects in farm systems should be carried out.

1. Introduction

Heavy metals are released into the environment from both anthropogenic and natural sources with highly reactive and often toxic effects at low concentrations. They may enter the soil and groundwater, accumulate in food webs and have adverse effects on biota. Heavy metals may remain in the environment for years, posing long-term risks to life after the sources of the pollution has been removed (Gall et al., 2015). Heavy metals have been categorized into essential and non-essential groups, essential heavy metals such as Zinc(Zn), Cobalt(Co), Manganese (Mn), Iron(Fe), Chromium(Cr) and Copper(Cu) are essential in small amounts for organisms to function properly (Epstein and Bloom, 2004; Marschner, 2012). All heavy metals are toxic if ingested in excessive concentrations (Chronopoulos et al., 1997; Lane and Morel, 2009). However, non-essential metals such as Lead (Pb) and Cadmium (Cd) are not essential for normal biological function and may quickly lead to toxicity even in low concentrations. Lead reduces the growth rate of birds, leads to growth retardation and increased mortality. It also causes reproductive effects such as reduced egg production, for example in Japanese quail, it can cause oxidative damage to DNA, proteins and lipids (Hoffman et al., 1985; Grue et al., 1986; Mateo et al., 2003). Cadmium, on the other hand, causes lower egg production in birds, kidney damage, testicular damage and modified behavioral reactions (Furness et al., 1996). All heavy metals may accumulate in tissues with the potential to transfer to higher trophic levels (Neilson and Rajakarura, 2014; Bourioug et al., 2015).

Eggs are one of nature's most important sources of nutrition for humans. Female birds release metals in their eggs and tissues (Burger

* Corresponding author at: Department of Veterinary Public Health, Faculty of Veterinary Medicine, Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom 73140, Thailand.
E-mail address: fvetpnt@ku.ac.th (P. Tulayakul).

https://doi.org/10.1016/j.ecoenv.2018.06.052
Received 6 February 2018; Received in revised form 13 June 2018; Accepted 15 June 2018
0147-6513/

and Gochfeld, 1991; Burger, 1994). Free-grazing ducks play a major role in the agricultural economy of East Asia (Saijuntha et al., 2013) as well as in Thailand where the number of egg-producing ducks was 13,548,366 in 2015 of which 51.86% were on free-grazing duck farms. The egg-producing ducks are mainly raised in the central and western regions of Thailand (Information and Statistics Department of Livestock Development, 2015). Free grazing duck farms are predominantly private farms which have a high potential to chemical exposure from the environment, in particular, from heavy metals and insecticides. The contamination on such farms was found to be higher than other systems since the free-grazing system entails direct contact with the outdoor environment. However, this hypothesis has not yet been demonstrated for other types of small holding and large-scale duck farm systems (Holt et al., 2011). Therefore, the aim of this study was to compare the contamination levels of heavy metals (Zn, Pb, Cd, Co, Mn, Fe, Cr and Cu) in duck egg from three types of farm: Free grazing farms, small and large-scale duck farms, which were categorized for evaluation of the risk of egg contamination.

2. Materials and methods

2.1. Sample collection

Duck egg, feed, drinking water and wastewater samples were collected from the three different farm systems and a questionnaire was used as a tool for descriptive data collection. From this, 8 free grazing duck farms, 6 small-scale duck farms (< 5000 ducks) and 6 large-scale farms (> 5000 ducks) were designated for sample collection. Between April to September in 2015 ten egg samples were randomly collected from each farm along with, 1 kg of duck feed, 1 l of drinking water and 1 l of wastewater. The farms were located in Nakhon Pathom, Suphanburi, Kanjanaburi, Nonthaburi and Ayutthaya provinces incorporating both the central and western regions of Thailand.

2.2. Heavy metal analysis

Two grams of duck feeds and 2 g of dried eggs sample (albumen and yolk dried) were digested with 10 ml of 65% nitric acid and 2 ml of 70% perchloric acid solution in a thermostatic bath at 120 ± 10 °C until the sample solution was completely digested (Pitot and Dragan, 1996), all the acid were AR grade. Drinking water and wastewater samples of 100 ml water were digested with 10 ml of 65% nitric acid and 2 ml of 36–38% solution of hydrochloric acid in a thermostatic bath at 250 ± 10 °C until the sample in solution was completely digested (Environmental Protection Agency, 1996). Then the sample solutions were filtrated and diluted with 20% nitric acid before analysis by using inductively coupled plasma optical emission spectrometry (ICP-OES) ULTIMA2, from Jobin yvon holiba, Italy.

2.3. Method performance

The spiked used was the ICP Multi-element standard solution TV 1000 μg/ml each in 1 mol/L HNO_3 (As, Al, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, In, K, Li, Mg, Mn, Na, Ni, Pb, Sr,Tl & Zn). The concentration of recovery of all metals was 0.2, 0.5, 1, 5, 20, 50 mg/kg in all the samples and 4 replications for each spike level was done as showed; Zn; percentage recovery = 98, Pb; percentage recovery = 81.76, Cd; percentage recovery = 93.2, Co; percentage recovery = 90.1, Mn; percentage recovery = 97.68, Fe; percentage recovery = 88.63, Cr; percentage recovery = 100.29, Cu; percentage recovery = 95.89. Relative standard deviations (RSD) were 5% lower. While the calibration level ranges were 0.5, 1, 5 and 10 ml/L. The analytical detection limits were Zn = 0.002409 ml/L, Pb = 0.005429 ml/L, Cd = 0.001348 ml/L,Co = 0.001229 ml/L, Mn = 0.006472 ml/L, Fe = 0.00583 ml/L, Cr = 0.00145 ml/L and Cu = 0.019483 ml/L.

Table 1
Descriptive data collected from questionnaires at the duck farms.

Items	Small scale	Free grazing	Large farm
Total number of ducks	500–2000	1000–15,000	6600–200,000
Age of ducks sampled (months)	11	8.5	8.3
Duck feed			
Commercial feeds	50%(3/6)	–	83.33%(5/6)
Commercial and Self-Mixed feeds	50%(3/6)	–	16.66%(1/6)
Grazing	–	62.5%(5/8)	–
Grazing naturally and self -mixed feeds	–	37.5%(3/8)	–
Drinking water			
Canal water	50%(3/6)	87.5%(7/8)	–
Groundwater	33.33%(2/6)	–	66.66%(4/6)
Tap water	16.66(1/6)	12.5%(1/8)	33.33%(2/6)
Sewage within the farm			
Yes	–	–	–
No	100%(6/6)	–	100%(6/6)
Total number of farms	6	8	6

2.4. Statistical analysis

All metal levels were tested and appeared as non-parametric data. A Kruskal–Wallis one-way analysis of variance test was used to compare the differences between the heavy metal means from the 3 different farm types. Pearson's correlation analysis was conducted to assess the correlation between metal levels in egg, feed, drinking water and wastewater by using Grapad Prism Statistical Software, version 5.0, 2012 (GraphPad Software, Institute. USA.)

3. Results

3.1. Small-scale farms

The survey revealed that the average number of ducks ranged from 500 to 2000 on small-scale farms as shown in Table 1. Duck age averaged 11 months on small-scale farms. Both commercial feed and self-mixed feed (3/6 =50% of farms) were used on small-scale farms. Canal water was the main source of drinking water for small-scale farms at 50% (3/6) as shown in Table 1.

The mean concentration and standard variation of Zn in whole egg from small-scale farms was 53.10 ± 13.93 mg/kg (dry weight) and the Zn concentration in whole egg from grazing duck farms was 54.21 ± 13.50 mg/kg (dry weight) which were significantly higher than Zn concentration in whole egg from large farms, 46.97 ± 8.37 mg/kg dry weight, at $P < 0.001$. Moreover, Pb concentrations in whole egg from small-scale farms were found to be significantly higher than from free grazing farms at $P < 0.05$. In addition, the Pb concentration in whole eggs from all types of farms exceeded the Thai agricultural standard for duck eggs (Thai Agricultural Standard in Duck Eggs No. 6703–2005) at 0.1 mg/kg as shown in Table 4. However, the Pb concentration in whole egg from small-scale farms correlated significantly with the Pb concentration in duck feed (r^2 =0.862) at $P < 0.005$ as shown in Table 5. Furthermore the levels of Fe in whole egg from both small-scale and free grazing farms was significantly higher than those on large-scale farms at $P < 0.05$ as shown in Table 4.

The concentration of Mn in drinking water from small-scale farms exceeded the water standard limits for animal consumption, 0.05 ml/L, by 33.2 times. Moreover, the concentration of Fe in drinking water on small farms exceeded the water the standards for animal consumption, 0.3 ml/L, by 26.26 times, as shown in Table 3.

3.2. Free grazing farms

The survey revealed that the average number of ducks ranged between 500 and 1000–15,000 on free grazing farms. Duck average age was 8.5 months for free grazing farms. Free grazing farms used both