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COMPARISON AND RISK ASSESSMENT OF TRACE METAL CONTENT IN FACTORY-FARMED BROILER AND FREE-RANGE CHICKEN MEAT SOLD IN LAGUNA, PHILIPPINES

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Abstract: *Chicken meat consumption remains high in the Philippines, and consequently, annual chicken production has risen steadily over the years. Although most of the chicken meat available in the market are sourced from factory farms, there has been growing popularity of free-range chicken production, largely driven by its perceived health benefits and sanitation concerns in factory farms, among others. In this work, we aimed at comparing the trace metal (copper, iron, lead, manganese, and zinc) content of free-range and factory-farmed broiler chicken meat that are being sold in Laguna, Philippines. The samples were subjected to acid digestion and analysis was done using atomic absorption spectrometry. Results showed an average concentration between 0.17 – 0.24 mg/kg, 2.22 – 2.34 mg/kg, 0.12 – 0.15 mg/kg, 0.95 – 1.32 mg/kg, and 1.81 – 1.96 mg/kg for copper, iron, lead, manganese, and zinc, respectively. Statistical analysis using one-way ANOVA and Tukey multiple comparison test ($p < 0.05$) showed no significant differences in the trace metal content of free-range and factory-farmed chicken meats, suggesting that in terms of the levels of these trace metals, not much differentiates the two varieties. Analysis of the health hazards, reported as target hazard quotient (THQ) and hazardous index (HI), associated with the consumption of the said chicken breast meat indicated no potential health risks.*

Keywords: *atomic absorption spectroscopy, free-range chicken, factory-farmed chicken, trace metal analysis*

1. Introduction

Livestock production accounts for about 40% of the gross value of agricultural products worldwide and is the fastest growing sector in agriculture, according to Food and Agriculture Organization (FAO) of the United Nations [*1*]. The FAO also notes that of the major source of animal protein, poultry ranks at the top, estimated to account approximately 39% of global meat production in 2019 which is projected to increase to 50% by 2025, and with global per capita consumption increasing fivefold since the 1960s [*2*, *3*]. In the Philippines, the situation is not much different, with volume of chicken production in 2018 recorded at 1.8 million metric tons, with around 80% being factory-farmed broilers, and a nationwide annual per capita consumption of around 13 kg, just behind pork meat [*4*, *5*]
Free-range practice in the Philippines, consisting mostly of native chickens raised in backyard farms, has increasingly gained popularity, which follows the global trend of more health-conscious consumers and their preference for organic chicken meat products [*6*]. Chickens reared through the free-range method have more freedom to forage for themselves rather than be dependent on feeds, with consequent health benefits of having more crude protein and lower fat content than their

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commercial broiler counterparts [*7*]. These traits, among others, justify the premium price of free-ranged chickens. Nevertheless, numerous reports over the years showed that free-range chickens are also exposed to various anthropogenic activities that ultimately result in undesirable contaminants in their meat such as antimicrobial-resistant bacteria, parasites, and other organic pollutants, e.g. dioxins [*8–10*].

Heavy metals and trace elements also accumulate in chicken tissues, especially under factory-farming conditions, arising from extensive use of formulated animal feed and feed additives [*11*]. In some cases, worse contamination, e.g. with lead, was even associated with free-range chickens [*12*, *13*]. These accumulated trace metals can then be passed on and in turn accumulate in animals on top of the food chain via biomagnification, and potentially cause chronic toxicity and serious health effects in humans. Therefore, as a an important health concern, trace metal content in chicken meat and meat products derived from them have been investigated extensively in various countries [*13*, *14*].

These imply that the quality, and therefore, health benefits associated with, and concerns raised against free-ranged and factory-farmed chickens, respectively, also greatly depend on the local environment where such practices are carried out. With these in mind, and the seemingly sparse studies available on the differences between free-range and factory-farmed chickens in the Philippines, in this study, we aimed to determine and compare the trace metal content of free-range and commercial factory-farmed chicken meat that are being sold in supermarkets in Laguna province, the Philippines. Results from this research could contribute to the human exposure assessment associated with the intake of these metals from chicken meat. The results could also serve as a focal point for further research on the factors - soil quality, environmental pollution, chicken feed, and breeding area location - that may have contributed to the levels of these metals in the chicken meat test samples. Finally, in conjunction with other data, the consumers might be provided with the necessary information to aid them in their decision-making process in the context of the financial and health considerations concerning free-ranged and factory-farmed chickens.

2. Matherials and methods

Sample preparation

Whole chicken from two commercial brands that sell both free-range (with explicit labeling) and factory-farmed varieties were used in this study, designated either as FR or FF, respectively. The samples were bought from supermarkets in Sta. Rosa City, Laguna, in the Philippines. For each variety, four samples of whole chicken were chosen in random order.

Only the breast part of the chicken was used for the analysis. The separated meat/muscle from each variety were combined separately, and 10 replicates were prepared for each sample by weighing approximately 60 grams of chicken meat into an evaporating dish. These samples were dried in the oven at 100°C for 24 hours. Immediately after drying, the samples were ashed in a furnace for 3 – 4 hours at 400°C.

Two grams of ash for each sample were accurately weighed, transferred to 250-mL Erlenmeyer flasks, and were treated with 20 mL of 12 M hydrochloric acid. The samples were then heated under the hood at medium heat for 30 minutes, or until the solution turned into a yellowish color and there was an appearance of white smoke. Afterwards, 30 mL of distilled water were added to each sample. The solution was then filtered into a 50 mL volumetric flasks and diluted accordingly [*15*].

Trace metal analysis

Standard solutions of varying concentrations were prepared from the 1000 ppm stock solutions of metal standards (Sigma-Aldrich). The concentration range of prepared standard solutions was from 0.1 ppm to 10 ppm. Analysis of the trace metals was performed using a Shimadzu Atomic Absorption Spectrophotometer (AA – 6300) using an air-acetylene gas mixture, and with the following settings: fuel gas flow rate of 1.8 – 2.2 L/min, support gas flow rate of 15 L/min, burner height between 7 – 9 mm, and slit width between 0.2 – 0.7 nm. The detection wavelengths used for copper, iron, lead, manganese, and zinc were 324.7 nm, 248.3 nm, 217.0 nm, 279.5 nm, and 213.9 nm, respectively.

Estimated Daily Intake (EDI) of trace metals

The *EDI* of the different trace metals (Cu, Fe, Pb, Mn, and Zn) was expressed as mg/kg body weight/day that depended both on the average concentration of the metals and chicken meat consumption. This parameter was calculated based on the following equation [*16*]:

$$EDI = \frac{MC \ x \ FDC}{BW}$$

where *MC* is the average concentration of the metal in the chicken meat (mg/kg), *FDC* is the average chicken meat consumption in the region (g/person/day), and *BW* is the average body weight of a child (30 kg) or adult (60 kg). Based on government statistics [*17*], the average per capita chicken meat consumption in Laguna, Philippines stands at 26 g/day.

Target Hazard Quotient (THQ)

The non-carcinogenic and carcinogenic health risks associated with chicken meat consumption was assessed based on the *THQ*. This parameter is expressed as a ratio of a determined dose of a pollutant to that of a reference dose level, where a value of less than 1 implies that the exposed population is unlikely to experience adverse health effects. THQ was determined using the following equation [*18*]:

$$THQ = \frac{EFr \ x \ ED \ x \ FDC \ x \ MC}{RfD \ x \ BW \ x \ AT} \ x \ 10^{-3}$$

where *EFr* is the frequency of exposure (365 days/year), *ED* is the duration of exposure (70 years average lifespan), *FDC* is the food ingestion rate (g/person/day), *MC* is the average metal concentration in chicken meat (mg/kg), *RfD* is the oral reference dose (mg/kg/day), *BW* is the child (30 kg) or adult (60 kg) average body weight, and *AT* is the average exposure time (365 days/year and

assuming 70 years as the average lifespan). The *RfD* consensus values are as follows [*18*]: 0.04, 0.7, 0.004, 0.14, and 0.3 mg/kg/day for Cu, Fe, Pb, Mn, and Zn, respectively.

Hazardous Index (HI)

To evaluate the cumulative health risk of consuming the trace metals analyzed in this study, the *HI* was calculated based on the summation of all the *THQ* values for the analyzed trace metals using the following equation [*18*]:

$$HI = \sum THQ_n$$

An *HI* value of less than 1 is interpreted as having no hazard, between 1 and 10 is considered moderate hazard, while a value greater than 10 suggests high risk or hazard.

Statistical analysis

Determination of significant difference in the mean concentration values were carried out by one-way ANOVA and Tukey multiple comparisons test ($p < 0.05$) using Origin Pro 8.

3. Results and discussion

The bird population is especially susceptible to the effects of anthropogenic activities on the environment. In line with this, it was identified that factors such as eating habits, growth, age, and breeding may influence metal concentration in the species [*19*]. Although some heavy metals are identified to be biologically important trace elements, the toxic effects brought upon by consumption beyond the recommended limits continue to be a concern globally [*20*]. In this regard, consumers have turned to patronize free-range meat products since these are deemed to be a safer and healthier option. Nevertheless, there is still a lack of data to back these claims in the Philippine setting, since comparative analysis on the trace metal content of poultry products, specifically between commercial factory-farmed broilers and free-range chickens, remain very limited.

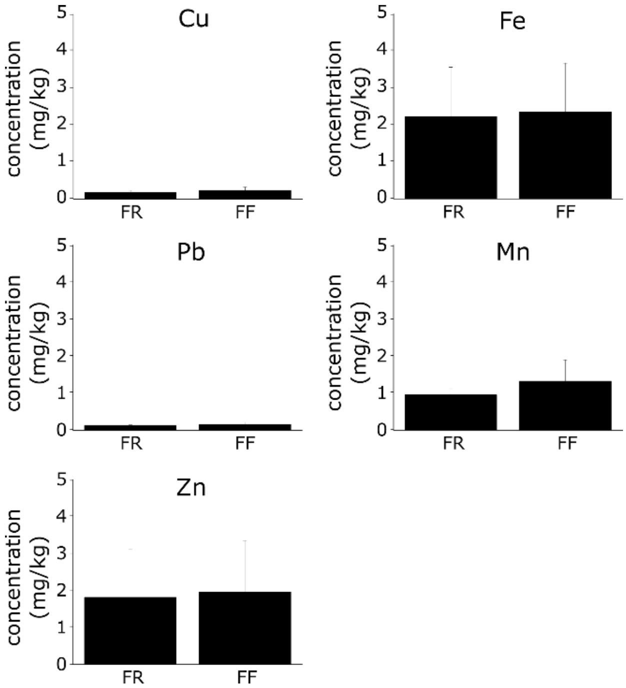

Fig. 1. Average concentration of various trace metals from the breast part of free-ranged (FR) and factory-farmed (FF) chickens.

Using atomic absorption spectroscopy, we quantified the trace metal content of chicken breast meat samples from two brands of free-range (FR) and factory-farmed (FF) chickens. The average metal concentration generally followed the following trend: Fe > Zn > Mn > Cu > Pb (Figure 1). As the first four elements are known to have essential biological role in various organisms, while Pb is a toxic contaminant, these results agree with previous findings showing the higher content of these essential metals in the analyzed chicken tissues [*21*].

Iron and zinc, with the former being one of the most abundant transition metal elements, are known to have extensive physiological roles such as in aerobic respiration, DNA synthesis and repair, and cell death. As such their higher concentration in an organism, relative to other essential metals, are expected. Overexposure to these two metals may lead to tissue damage, inflamed pancreas, anemia, and acute renal failure, to name a few. In our work, we found an average Fe concentration of 2.22 and 2.34 mg/kg in FR and FF samples, respectively. Similarly, a comparable concentration of Zn was found in the FR and FF samples, with mean value of 1.81 and 1.96 mg/kg, respectively. The higher content of these two metals in chicken meat relative to the others analyzed in this study was consistent with previous reports showing a similar trend [*14, 18, 21*].

Manganese is an essential element in various organisms, and its deficiency in vertebrates is known to cause skeletal and reproductive abnormalities while overexposure to this metal has been linked to neuropsychiatric disorders [*16*]. The average concentration of manganese found in this study was 0.95 and 1.32 mg/kg in the FR and FF samples, respectively (Fig. 1).

Copper is an essential element that has important role as co-factor in various enzymes that are part of many physiological processes such as cellular respiration and energy production and utilization [*22*]. In this study, the average concentration of Cu was determined to be 0.17 and 0.24 mg/kg in FR and FF samples, respectively. These values were lower than those detected from chicken muscles in other studies, which reported mean Cu content of more than 0.44 mg/kg [*14*, *18*, *21*].

Table 1.

Estimated daily intake of trace metals. Free-ranged (FR) and factory-farmed (FF) chickens.

	***Estimated Daily Intake, EDI* (mg/kg BW/day)**			
	FR	**FF**	**FR**	**FF**
	adult		**child**	
Cu	0.075	0.10	0.15	0.21
Fe	0.96	0.97	1.93	1.94
Mn	0.41	0.57	0.83	1.15
Pb	0.052	0.066	0.10	0.13
Zn	0.79	0.85	1.58	1.70

Lead is one of the most toxic heavy metals, and prolonged exposure to this contaminant is often ascribed to varying physiological and pathological effects. This element affects almost all organs in the body, although it has its most profound deleterious consequence in the nervous system [*23*].

Similar to previous reports [*14, 18, 21*], the concentration of Pb in chicken breast found in this study was the lowest among the metals tested, with average value of 0.12 and 0.15 mg/kg in FR and FF samples, respectively.

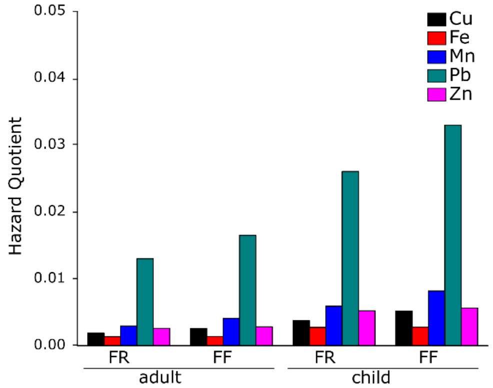

Fig. 2. Hazard quotient (*THQ*) of trace metals in adults and children via consumption of breast meat of free-ranged (FR) and factory-farmed (FF) chickens.

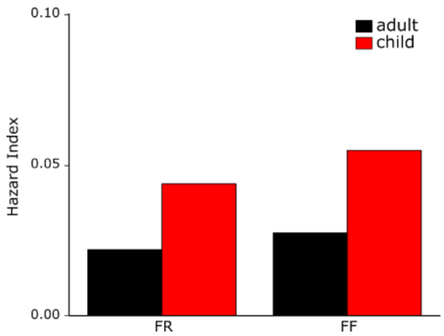

Fig.3. Hazard index (*HI*) for adults and children via consumption of breast meat of free-ranged (FR) and factory-farmed (FF) chickens.

Statistical analysis of the results ($p < 0.05$) indicated no significant differences between the two types of chicken samples in all the metals tested. This indicates that as far as this aspect is concerned, consuming a free-range chicken is not much different from the more common factory-farmed variety.

To assess the health risks associated with prolonged consumption of chicken muscle, the Estimated Daily Intake (*EDI*), Target Hazard Quotient (*THQ*), and Hazard Index (*HI*) were calculated. Meat consumption is a known way by which humans are exposed to different pollutants/ contaminants, and toxicity ultimately depends on the daily intake by individuals of contaminated foodstuffs. The *EDI* values are summarized in Table 1 and comparing these with the *RfD* for each of this metal, all except Pb exceeded the oral reference dose. It is important to point out, however, that consumption more than the designated *RfD* for a specific metal does not automatically translate to deleterious health effects, as this only taken to mean that a conservative reference oral dose has been exceeded [*18*]. Indeed, the computed *THQ* values for all metals are extremely small (less than 0.04), indicating that consumption of chicken breast meat from both free-ranged and factory-farmed animals will unlikely result in adverse health effects to the exposed population (Figure 2). Furthermore, the *HI*, which takes into account the cumulative risks associated with the five metals tested, had values less than 0.10 (Figure 3) indicating no potential hazard with consumption of chicken breast meat. It is worth mentioning that although *THQ* and *HI* values were very low, the risk is higher in children primarily due to a lower body weight and prolonged exposure since childhood increases the chances of developing acute and chronic toxic effects. Furthermore, it is also important to note that the study only considered chicken breast meat samples, but consumption of other organs like gizzard and liver, where these and other toxic metals bioaccumulate [*16*, *18*], as well as meat products from other animals could increase the risk of biomagnification and thus could potentially introduce health risks in the consuming population.

4. Conclusion

In this study, chicken breast meat samples from free-ranged and factory-farmed chickens were compared for their trace metal content. The determined average concentration ranged from 0.17 – 0.24 mg/kg, 2.22 – 2.34 mg/kg, 0.12 – 0.15 mg/kg, 0.95 – 1.32 mg/kg, and 1.81 – 1.96 mg/kg for copper, iron, lead, manganese, and zinc, respectively. Statistical analysis using one-way ANOVA and Tukey multiple comparison test showed no significant difference between any of the metals from the two types of chicken ($p < 0.05$), indicating no added benefit of eating the free-range variety, at least in the context of this study. Analysis of the potential health hazards from consuming chicken muscle, quantified using parameters such as *THQ* and *HI*, showed that consuming this meat product is unlikely to result in deleterious health effects for the exposed population.

5. Acknowledgments

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