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Metal uptake in chicken giblets and human health implications

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ABSTRACT

Recognizing the global concerns about metal contamination in food chain coupled with the high rate of consumption of chicken products as a major component of daily diet to humans, the presence of 14 metals (Fe, Cu, Mg, Zn, Al, Hg, Cd, As, Pb, Se, Ni, Sr, Cr and Sb) due to their persistence in our environment and food chain were determined in poultry chicken giblets to assess the potential non-carcinogenic and carcinogenic risks to human health. In general, essential elements such as Mg, Fe show higher concentrations than the potentially toxic metals. Statistical analysis indicates the latter to have similar origin and/or similar feedstuffs, consistent with the wide spread use of Cu and Zn as feed supplements in intensive poultry farming. The daily intake of the studied metals by the Malaysian population showed to be below the permissible levels of dietary intake set by various international organizations. Estimated non-carcinogenic risk due to all of the metals in the giblets show a value of 0.51 indicating the giblets to be safe for consumption at the current intake level. However, the carcinogenic risk resulting from toxic metals show slightly higher values than the US-EPA reference limit of 10^{-4}. The results may not be thought to be of concern given the fact that chicken giblets form only a very minor part of dietary habit. However, considering the non-degradability of toxic metals and their potential accumulation in animal tissues, reduction in metal supplementation in animal feed should be introduced and periodic monitoring of chicken giblets may help to mitigate non-essential metal toxicity to public health.

1. Introduction

Some metals such as Cd, As, Hg, Pb, Sb, Sr are known as non-essential or toxic metals (Batista et al., 2012) due to their adverse effects in human body and other living organisms, and also recognized as serious environmental pollutants (Heidary et al., 2012). They have been readily available, especially in aquatic environments, being a result of natural processes and continuous human activities (Khan et al., 2008). The high rate of urbanization and rapid industrialization, especially in developing nations have been identified as potential route for mobilization of metals and potentially toxic pollutants into the human environment (Akan et al., 2010; Kolo et al., 2018; Swaileh and Sansur, 2006). Their accumulation in the environment poses a potential threat to food safety due to their abundant sources and non-biodegradable characteristics (Hu et al., 2017; Hussien and Nosir, 2017). Being persistent pollutants in the environment, they bio-accumulate and thus become magnified in the food chains, which may lead to increase several adverse health effects to human and animal (Swaileh and Sansur, 2006; Maleki et al., 2015; Okoye et al., 2015). The damaging effects of these metals on the metabolic, physiological and structural systems of organisms when present at concentrations above prescribed safety limits in the environment can be lethal (Heidary et al., 2012).

The rising demand for poultry meat and its products as a result of their nutritional values singles out the poultry industry as one of the largest and fastest growing agro based industries in the world (Okoye et al., 2015). New technologies including extensive poultry feed modifications are employed on a daily basis to help in meeting the demands (Mohammed et al., 2013). Poultry meat have proved to be an important source of animal protein with high biological amino acids, vitamins and minerals, all components of human nutrition vital for growth and body metabolism (Onyeka and David, 2015). Despite the nutritional advantages, chickens are constantly exposed to metal contaminants through poultry feed, drinking water and processing mechanisms (Mariam et al., 2004). Accumulation of these toxic metals in one or more organs, such as the liver, gizzard and heart have deleterious effects on the chickens ranging from feed refusal and direct inhibition of

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enzymatic systems to loss of weight, low hatchability, low digestibility, retarded growth, organ failure, increased susceptibility to diseases and stress and finally death (Swaileh and Sansur, 2006; Hassan et al., 1998).

The poultry industry has become a major part of agricultural practice in Malaysia. Apart from being one of the major sources of employment and revenue generation, Malaysia has become self-sufficient in poultry meat production in satisfying local needs. Chicken is the second most staple food item after rice, serving as a major source of protein in the Malaysian diet (Nur Syahirah et al., 2015). The industry is therefore vital in achieving food security in Malaysia.

Exposures to non-essential metals such as arsenic (As), cadmium (Cd), mercury (Hg), chromium (Cr), strontium (Sr), nickel (Ni) and lead (Pb) can cause carcinogenic and non-carcinogenic effects to humans, even at low concentrations, while essential metals including cobalt (Co), copper (Cu), manganese (Mn), antimony (Sb), zinc (Zn), iron (Fe) and magnesium (Mg) can also be toxic when present at concentrations above the thresholds for safety in food products (CODEX, 2016). Since there is a possibility of accumulation of metals in chicken meat products due to the use of formulated animal feeds and feed additives in intensive farming, their concentrations in chicken tissues and giblets have been studied extensively in different parts of the world (Abduljaleel et al., 2012; Batista et al., 2012; Baykov et al., 1996; Uluozlu et al., 2009) by the use of Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) etc. technique. Note that ICP-MS offers extremely lower detection limit compared to ICP-OES or AAS. However, data on metal concentrations in chicken and other poultry products in Malaysia are rather scarce. Thus, present study was aimed to determine the concentrations of a number of essential and potentially toxic metals in chicken giblets using ICP-MS technique. Additional aim was to estimate the non-carcinogenic and carcinogenic risks to the Malaysian population via the associated metals exposures.

2. Materials and method

2.1. Study area and sample collection

Selangor, the most economically developed state in Malaysia, ranks top nationally both in terms of chicken production as well as per capita chicken meat products consumption; this is followed by the Federal Territory of Kuala Lumpur. A total of 280 fresh chicken giblet samples comprising of liver, gizzard and heart were randomly collected from popular wet markets in Selangor and Kuala Lumpur on May 2016. Each sample type were packaged in different polyethylene bags and transported to the laboratory for subsequent preparation and analysis. The three principal chicken products, liver (100 samples), gizzard (100 samples) and heart (80 samples) were analysed in terms of their metal contents. Less number of heart samples were analysed following the low consumption demand by Malaysian population compared to the liver and gizzard. Upon receipt at the laboratory, all samples were thoroughly washed with distilled water to remove any surface contamination, including particles. The samples were cut into small pieces using a stainless steel knife for easy drying. They were then dried in a programmable closed system microwave oven (Memert GmbH + Co.KG, Germany) at food temperature of 75 °C, followed by subsequent 15 h of drying/day for three days until a constant dried weight was obtained. During the drying process, care was taken to prevent the samples from damages like heat burn or any other physical changes, after which the samples were blended into fine powder for easy digestion.

2.2. Sample preparation and chemical analysis

For each sample, 0.5 g aliquot of the dried chicken giblet powder was transferred into digestion flask and digested on a hot plate electronic device (Yellow-line MAG HS 7; IKA, Holland) with 9 ml of 65% HNO_3 (distilled in sub boiling stills) and 4 ml of 30% H_2O_2 at 120 °C for 8 h until a clear solution was obtained. The selected 120 °C used for the digestion process is far below the boiling and evaporation point of all analysed metals in this study. Again, it is also said to be suitable as it helped to prevent losses by volatilization of the concerned metals (Enamorado-Baez et al., 2013). Subsequently, the solution was allowed to evaporate slowly to near dryness and cooled at room temperature after which it was filtered through Whatman No. 41 filter paper. The filtered sample was then diluted with 25 ml of deionised water in a volumetric flask and stored at 4 °C for analysis. Each procedural blank and standards were prepared using the same volume and acid combinations, following the same procedure used to prepare the giblet samples (Khandaker et al., 2019).

An inductively coupled plasma mass spectrometry (ICP-MS) facility (Agilent Technologies 7500 Series, USA) was used for metal determination at the ICP-MS laboratory, University of Malaya. All glassware and equipment used for the analysis were thoroughly washed with 10% HNO_3 and distilled water. To ensure the instrumental accuracy, we followed the same procedure to our previous study (Asaduzzaman et al., 2017). More specifically, the instrument was calibrated using multi-element calibration standard solution 2A (10 mg/L stock solution of each element) (Agilent Technologies, USA, part no. 8500-6940) in 5% pure HNO_3 by subsequent dilution within the range 10 mg/L to 100 mg/L. In analysis of all samples, one blank solution and five standards were run with the same reagents used under the same conditions as a control to avoid any contamination from the digestion procedures.

The sample injection system for the ICP-MS comprises a nebulizer and a spray chamber coupled to an auto-sampler. The instruments adopted for metal analysis in this study is capable of covering an intensity range from a few ions/s to 10^{12} ions/s. To validate the ICP-MS results, NIST (National Institute of Standards and Technology) standard reference material SRM 1400 (bone ash) were analyzed in each ICP-MS run. The achieved results showed $> 96\%$ recovery values for all analysed metals than the certified value. The limit of detection (LoD) is the lowest analyte concentration likely to be reliably distinguished from the limit of blank (LoB) and at which detection is feasible. LoD is determined by utilising both the measured LoB and test replicates of a sample known to contain a low concentration of analyte (Jones, 2014; Armbruster and Pry, 2008). The detection limits (dry weight) for ^{27}Al, ^{52}Cr, ^{55}Mn, ^{63}Cu, ^{66}Zn, ^{75}As, ^{88}Sr, ^{118}Sn and ^{121}Sb was 0.002 mg/g, while for ^{208}Pb, ^{202}Hg, ^{137}Ba and ^{111}Cd it was 0.001 mg/g. The detection limit for Cd was 0.0055 mg/g. Each sample was analysed in duplicate for Cr, Pb, Ni, Cu, Zn, Hg, Al, Mg, Cd, Sr, Sb, Se, As and Fe concentrations.

2.3. Statistical analysis

The obtained values of metal concentrations were analysed using SPSS software for windows (IBM SPSS Statistics 24, USA). Analysis of variance (ANOVA) was performed to identify whether the mean concentration of each trace metal differing significantly within and between groups. Least significance difference at $p < 0.05$ was used to characterize the differences.

2.4. Assessment of health risk

The health risks associated with the consumption of metals contaminated chicken giblets were assessed based on the Daily Intake metals and other relevant parameters (e.g., Body weight). This provides an estimate of potential health effects from exposures to carcinogenic and non-carcinogenic chemicals.

2.5. Estimation of Daily Intake (DI) of heavy metals

The Daily Intake of analysed metals (in μg/kg-day) depends on metal concentration level in the sample and consumption characteristics of the sample among the population. The Daily Intake of metals for adults was estimated using the following formula:

$$DI = \frac{C_{metal} \times I_R}{B_w} \tag{1}$$

where C_{metal} is the average concentration of metals (mg/kg wet weight) in each sample, I_R is the ingestion rate and B_W is body weight (see details below). The average consumption of chicken meat by the Malaysian population for the year 2016 was found to be 41.32 kg (= 113 g/day), the data was obtained from relevant online source statista.com (Statista, 2019; Malaysia poultry consumption, 2019). If one considers the average proportion of chicken giblet in chicken meat to be < 10%, then a maximum of 11 g of giblets can be estimated to be consumed by the Malaysian population per day, thus the ingestion rate represents an approximate nominal value of 10 g/day chicken giblet consumed by the Malaysian population. The mean body weight of an exposed adult individual is taken to be 70 kg (Khandaker et al., 2015). The Accepted Daily Intake (ADI) or Tolerable Daily Intake (TDI) set by various international regulatory agencies and earlier studies (Antoine et al., 2012; Stern, 2010; Australia New Zealand Food Authority, 2001; U.S Panel on Micronutrients, 2001; Peter and Paul, 2010; European Food Safety Authority-EFSA, 2004; Institute of Medicine, 1997) provides daily acceptable levels of ingested metals via foodstuffs consumption. Consumed amounts above the recommended values may put individuals at risk of adverse effects.

2.6. *Estimation of average daily dose*

The average daily dose (ADD) provides an estimate of the level of human exposure due to residues in food. The ADD (mg/kg/day) for a particular residue in consumed chicken giblets can be calculated using the following formula:

$$ADD = \frac{DI \times E_f \times D_E}{T_p} \tag{2}$$

where DI refers to the estimated Daily Intake of metal via consumption of chicken giblets, E_f is the exposure frequency (250 days/year), based on the local knowledge of chicken giblet consumption rate of 5 days per week, D_E is the duration of exposure to ingested metals over a lifetime (75 years, commensurate with the average life span of the Malaysian population) (Malaysia population, 2019 https://en.wikipedia.org/wiki/List), T_P is the time period over which the dose is averaged (in days) and it is generally considered to be equal to D_E for non-carcinogenic effects (= 365 days × D_E).

2.7. *Non-carcinogenic risk*

The non-carcinogenic risk to an exposed cohort/population is typically characterized by a term called the hazard quotient (HQ), which is defined as the ratio of the average daily dose of a specific metal to the reference dose (R_fD), a non-carcinogenic threshold for that metal toxicant (US-EPA, 1993). HQ, a unit-less number, expresses the probability of an individual suffering an adverse effect. If the ratio is < 1, there will be no obvious risk. The non-carcinogenic health risk due to metal exposure (via the oral pathway) can be estimated as follows:

$$HQ = \frac{ADD}{R_f D} \tag{3}$$

where HQ is the hazard quotient, R_fD is the oral reference dose for a particular metal, representing the maximum permissible daily dose that an exposed individual can suffer at this level over a protracted period of time without experiencing harmful effects. R_fD values for various toxicants (most often in units of mg/kg-day) have been set out by a number of international bodies who advise on regulatory matters, including the US-EPA (1992; 2000; 2017), WHO (1989), OEHHA (2009) and Harmanescu et al. (2011). Published R_fD values for the various toxicants of interest studied herein and which were used for the estimation of HQs are listed in Table 1. The sum of HQs for all major metal species provides the potential health risk from exposures to multiple metals. It has been assumed that they have similar working mechanisms and linearly affect a given target organ (US-EPA, 1989; Stara et al., 1986). In general, the exposed population is considered to be at minimal risk when the hazard index (HI) is < 1, where:

$$HI = \sum HQs \tag{4}$$

2.8. *Carcinogenic risk*

The carcinogenic risk can be characterized by a linear relationship between the intake dose of carcinogenic metal and the concomitant effects (US-EPA, 2005). The cancer risk to the local population from potential carcinogens in consumed chicken giblets was calculated in accordance with the following equation:

$$LCR = ADD \times CSF \times LT \tag{5}$$

where LCR is the lifetime cancer risk from carcinogenic metal exposures, CSF (a carcinogen potency factor) is the cancer slope factor relating to the metal, for carcinogens representing the upper-bound estimate of the slope of the dose-response curve in the low-dose region (US-EPA, 1993; 1992). The slope factor is usually expressed as risk per mg/kg-day and LT is considered herein to be 75 years, the average lifetime of Malaysians. The slope factor for each particular metal is used

Table 1
Reference doses (R_fD) and slope factors (SF) of metals.

Metal name	Oral toxicity reference dose, R_fD		Cancer Slope Factor	
	(mg/kg-day)	References	$(\text{mg/kg/day})^{-1}$	References
Al	7.00	(WHO, 1989)		
Cr-IV	0.003	(US-EPA, 2017a)	0.50	(Fanfu et al., 2015;Caspah Manny and Morgan, 2016
As	0.0003	(US-EPA, 2017a)	1.5	(US-EPA, 1988)
Se	0.005	(US-EPA, 2017a)		
Zn	0.300	(US-EPA, 2017a)		
Cd	0.001	(US-EPA, 2017a)	0.38	(Nkpaa et al., 2016)
Hg	0.0003	(US-EPA, 2017a)		
Pb	0.004	(US-EPA, 2017a & OEHHA, 2009)	0.01	(OEHHA, 2009)
Cu	0.040	(US-EPA, 2017a)		
Sb	0.0004	(US-EPA, 2017a)		
Ni	0.020	(US-EPA, 2017a)	1.7	(Isa et al., 2015)
Sr	0.600	(US-EPA, 2017a)		
Fe	0.700	(2011)		
Mg	0.140	(US-EPA, 2017a)		

to directly convert the daily dosage of an individual, averaged over a lifetime of exposure, into the incremental risk developing cancer. The LCR was estimated for several of the metals (Cr, Cd, As, Ni and Pb) which through oral exposure have carcinogenic effects. Table 1 shows the oral R_fD (USEPA, 1992; 2000; 2017; WHO, 1989; OEHHA, 2009; Harmanescu et al., 2011) and CSF (Fanfu et al., 2015; Caspah Manny and Morgan, 2016; US-EPA, 1988; Nkpaa et al., 2016; Isa et al., 2015) values for non-essential metals in foodstuffs. The cumulative cancer risk from exposure to metal carcinogens in consumed foodstuffs has been assumed to be the linear sum of each of the individual metal risks:

$$\sum_{i=0}^{n} = LCR_1 + LCR_2 + \ldots\ldots\ldots\ldots\ldots + LCR_n \tag{6}$$

where n = 1, 2… n are the individual metal carcinogens in foodstuffs. According to the US-EPA, the level of acceptable cancer risk for regulatory/controlled purposes should be within the range 10^{-6} to 10^{-4}. Cancer risk is considered negligible when the LCR is below 1.0×10^{-6}, while it is serious when the value exceeds 10^{-4} (US-EPA, 2000).

3. Results and discussion

3.1. Concentrations of metals in chicken giblets

Table 2 presents the measured essential and non-essential metal concentrations in chicken giblets (in μg of metal per g of food, μg/g) and their Estimated Intake (μg/kg/day) together with the permissible limits recommended by various advisory organizations. The metal concentrations are on a wet weight basis. Table 2 shows the range of concentrations as: Al (0.5–1.7), Cr (0.01-0.25), As (0.01), Se (0.01-0.09), Zn (1.9–4.0), Cd (0.01-0.15), Hg (0.01-0.44), Pb (0.01-0.25), Cu (0.1-0.54), Sb (0.16-0.56), Ni (0.02-0.27), Sr (0.01-0.29), Fe (4.1–12.9) and Mg (41.8–62.2). The variability is reflective of the absorption and accumulation capabilities of metals by the respective tissues and differences in the feeds, farming environment etc. In general, concentrations of the essential metals Fe, Mg, Zn and Al are some several orders of magnitude higher than the other metals studied herein. Cu, another essential metal, is one exception to this, with essentiality expressed at lower levels, albeit clearly above that at which cupranaemia will occur. Nonetheless, such metals are widely used as supplementations to the commercial feeds of intensive poultry farming, while most of the studied non-essential metals (Cr, As, Pb, Cd, Hg are clear examples) are unlikely to be intentionally introduced into chicken feed due to their toxicity; thus these show relatively lower concentrations than the essential metals. The appearance of these at low concentrations can result from differences of industrial activities in the surrounding environment that profligate toxic metals etc. The observed highest value amongst all the metals analyzed in this study is Mg in the gizzard sample. Table 3 shows a comparison of present data with values from literature of a similar nature. This is followed by a discussion for each of the metals.

Chromium (Cr) in the form of Cr(VI) is a non-essential metal and could be harmful to the body. High exposure to it can cause several biotoxic effects, including renal, hepatic and hematological systems. Futhermore, Cr toxicity is attributed to its absorption within the gastrointestinal tract and lung, also to an extent in intact skin (US-EPA, 1999). Cr(III) assists the body in utilising sugar, protein and fat (Akan et al., 2010), also playing a vital role in insulin and lipid metabolism (Uluozlu et al., 2009). The greatest mean concentration of Cr was found to be 0.09 ± 0.01 μg/g in heart samples, while the lowest amount was 0.03 ± 0.02 μg/g, observed in the liver. Present results are consistent with the data reported by Uluozlu et al. (2009) and Aljaff et al. (2014), but lower than the data reported by Mousa et al. (2010) for chicken liver. Overall, Cr values found in present study are below the WHO/FAO (2017) recommended safe limit of 2.3 mg/kg for foodstuffs.

Lead (Pb) can adversely affect the organs and systems of the body (Zhang et al., 2014), having an ability at high exposure to cause disrupted haemoglobin biosynthesis and associated anaemia, increased blood pressure, kidney damage, reduced fertility as a result of sperm damage, diminished learning abilities and behavioural disruption among children (US-EPA, 1999). In the present work, Pb was below the detection limit in gizzard samples, the heart and liver samples showing the greatest and lowest mean concentrations at 0.254 μg/g and 0.010 μg/g, respectively. Table 3 shows the measured Pb data to be in line with other available data, an exception being values reported by Ismail and Abolghait (2013) from Egypt. Present results for Pb in chicken giblet are within the safe limit of 0.5 ppm (0.5 μg/g) reported in the *Codex Alimentarius* international food standards (FAO/WHO, 2001) and the Malaysian Food Act (1983) recommended legal limit of 2 μg/g.

Anthropogenic cadmium (Cd) is a priority environmental pollutant and health hazard (Revitt et al., 2013), high intakes being associated with lung damage, induction of lung tumours included, renal damage and skeletal changes (Bernard, 2008). Cd was not found in the gizzard samples, while the heart and liver showed the highest and lowest mean concentrations at 0.09 ± 0.08 μg/g and 0.01 μg/g respectively. Present results for heart shows higher value than the literature data reported by Uluozlu et al. (2009); Aljaff et al. (2014), and Ismail and Abolghait (2013). However, the measured data are far below the maximum allowable level of 0.5 ppm (0.5 μg/g) for Cd in chicken liver given by the *Codex Alimentarius* for international food standards (Nkpaa et al., 2016) and the permissible limit of 1 μg/g by Malaysian Food Act (1983).

Arsenic (As) exposure has been shown to cause acute sore throat, vomiting, diarrhoea, anorexia and arrhythmia (US-EPA, 1999). In the present investigation, As was not found in the heart samples while a low mean amount (0.01 μg/g) was found in liver and gizzard samples. Although organoarsenic (Roxarsone) is using in poultry production in

Table 2

Chicken giblets metal concentrations in current study, estimated daily intake in Malaysia and daily intake (DI) limit reported in the literature. ND = Not Detected.

Metal	Range (Mean) Concentrations in (μg/g)			Estimated Daily Intake (μg/kg/day)				Limit of DI intake (μg/kg/day)
	Liver (n = 100)	Gizzard (n = 100)	Heart (n = 80)	Liver	Gizzard	Heart	Total	
Al	0.5-1.7(1.2)	0.4-2.5 (1.5)	0.4-1.7 (1.0)	0.171	0.214	0.143	0.529	143 (Antoine et al., 2012)
Cr	0.01-0.04 (0.03)	0.01-0.05 (0.03)	0.01-0.25(0.09)	0.004	0.004	0.013	0.021	143 (Stern, 2010)
As	0.01	0.01	**ND**	0.001	0.001	0.000	0.003	10 (Australia New Zealand Food Authority, 2001)
Se	0.01-0.04 (0.03)	0.02-0.09(0.06)	0.01-0.03 (0.02)	0.004	0.009	0.003	0.016	20 (Australia New Zealand Food Authority, 2001)
Zn	2.2-3.0(2.5)	1.9-2.1(2.4)	2.7-4.0 (3.3)	0.357	0.357	0.471	1.186	10 (Australia New Zealand Food Authority, 2001)
Cd	0.01	**ND**	0.02-0.15(0.09)	0.001	0.000	0.013	0.014	5.0 (Australia New Zealand Food Authority, 2001)
Hg	0.01-0.44 (0.18)	0.08-0.34 (0.22)	0.02-0.18 (0.08)	0.026	0.0314	0.011	0.069	10 (Australia New Zealand Food Authority, 2001)
Pb	0.01	**ND**	0.25	0.001	0.000	0.036	0.037	10 (Australia New Zealand Food Authority, 2001)
Cu	0.1-0.4(0.3)	0.43-0.50 (0.47)	0.18-0.54(0.35)	0.043	0.067	0.050	0.160	10 (Australia New Zealand Food Authority, 2001)
Sb	0.2-0.34 (0.28)	0.16-0.22 (0.19)	0.2-0.56(0.37)	0.040	0.027	0.053	0.120	10 (Australia New Zealand Food Authority, 2001)
Ni	0.03	0.02	0.002-0.027(0.016)	0.004	0.003	0.002	0.009	17 (US Panel, 2001)
Sr	0.01-0.06 (0.04)	0.02	0.01-0.29(0.11)	0.006	0.003	0.016	0.024	30 (Peter and Paul, 2010)
Fe	4.2-11.6 (6.5)	6.2-11.5 (9.2)	4.1-12.9 (7.6)	0.929	1.314	1.086	3.329	800 (European Food Safety Authority-EFSA, 2004)
Mg	41.8-45.4(43.6)	56.9-62.2(59.4)	49.8-54.0(51.9)	6.229	8.486	7.414	22.14	5000 (Institute of Medicine, 1997)

Table 3
Comparison of present data with other similar studies conducted elsewhere around the world. Literature data (Okoye et al., 2015; Onyeka and David, 2015; Abduljaleel et al., 2012), apparently with a number of very high values, are assumed to be on a dry weight basis (albeit not declared except Abduljaleel et al., 2012). ND = Not Detected.

Metal name	Mean concentrations ± Std. Dev. in (µg g^{-1})			References	Study Origin
	Liver	Gizzard	Heart		
Al	1.2 ± 0.5	1.50 ± 1.03	1.02 ± 0.57	This work	Malaysia
	31.65 ± 13.66	21.426 ± 7.493	–	Abduljaleel et al., 2012	Malaysia
	0.14 ± 0.01	0.23 ± 0.02	0.10 ± 0.01	(Uluozlu et al., 2009)	Turkey
Cr	0.03 ± 0.02	0.034 ± 0.03	0.09 ± 0.01	This work	Malaysia
	5.13 ± 0.69	2.726 ± 0.842	–	Abduljaleel et al., 2012	Malaysia
	0.04 ± 0.003	0.05 ± 0.004	0.03 ± 0.002	(Uluozlu et al., 2009)	Turkey
	0.08693			(Aljaff et al., 2014)	Iraq
	0.38 ± 0.08	0.22 ± 0.06		(Mousa et al., 2010)	Egypt
	45 ± 16	104 ± 12		(Okoye et al., 2015)	Nigeria
	131 ± 32	91 ± 18		(Onyeka and David, 2015)	Nigeria
As	0.01	0.01	ND	This work	Malaysia
	0.515 ± 0.19	0.238 ± 0.160		Abduljaleel et al., 2012	Malaysia
	0.06 ± 0.004	0.10 ± 0.008	0.06 ± 0.005	(Uluozlu et al., 2009)	Turkey
	132 ± 80	118 ± 18		(Okoye et al., 2015)	Nigeria
	189 ± 58	99 ± 14		(Onyeka and David, 2015)	Nigeria
Se	0.03 ± 0.01	0.06 ± 0.03	0.02 ± 0.01	This work	Malaysia
	2.014 ± 0.60	1.179 ± 0.087		Abduljaleel et al., 2012	Malaysia
	0.91 ± 0.08	0.17 ± 0.01	0.39 ± 0.02	(Uluozlu et al., 2009)	Turkey
	0.01742			(Aljaff et al., 2014)	Iraq
Zn	2.5 ± 0.4	2.5 ± 0.4	3.3 ± 0.6	This work	Malaysia
	78.86 ± 21.45	85.934 ± 7.89		Abduljaleel et al., 2012	Malaysia
	22.5 ± 2.1	21.0 ± 1.9	14.2 ± 1.1	(Uluozlu et al., 2009)	Turkey
	5.27 ± 0.59	3.15 ± 0.39	2.23 ± 0.26	(Mousa et al., 2010)	Egypt
	1.342			(Aljaff et al., 2014)	Iraq
	1.20 ± 0.79	1.00 ± 0.51		(Okoye et al., 2015)	Nigeria
	23.22	19.54	18.61	(Jokanović et al., 2014)	Serbia
Cd	0.01	ND	0.09 ± 0.08	This work	Malaysia
	0.159 ± 0.114	0.157 ± 0.067		Abduljaleel et al., 2012	Malaysia
	0.00224 ± 0.00020	0.00090 ± 0.00006	0.00025 ± 0.00002	(Uluozlu et al., 2009)	Turkey
	0.040714 ± 0.0290	0.0041 ± 0.0028	0.0036 ± 0.008	(Ismail and Abolghait, 2013)	Egypt
	0.00509			(Aljaff et al., 2014)	Iraq
	424 ± 59	82 ± 8		(Onyeka and David, 2015)	Nigeria
	8.80 ± 7.43	5.53 ± 3.04		(Okoye et al., 2015)	Nigeria
Hg	0.18 ± 0.11	0.22 ± 0.13	0.08 ± 0.05	This work	Malaysia
	508 ± 54	136 ± 12		(Okoye et al., 2015)	Nigeria
	394 ± 47	112 ± 38		(Onyeka and David, 2015)	Nigeria
Pb	0.010	ND	0.254	This work	Malaysia
	0.354 ± 0.18	0.300 ± 0.188		Abduljaleel et al., 2012	Malaysia
	0.12 ± 0.010	0.01 ± 0.001	0.04 ± 0.003	(Uluozlu et al., 2009)	Turkey
	0.8762 ± 0.2089	0.3186 ± 0.1462	0.1733 ± 0.06777	(Ismail and Abolghait, 2013)	Egypt
	0.47 ± 0.08	0.24 ± 0.06	0.09 ± 0.024	(Mousa et al., 2010)	Egypt
	59.03 ± 52.28	61.29 ± 35.39		(Okoye et al., 2015)	Nigeria
	421 ± 46	148 ± 33		(Onyeka and David, 2015)	Nigeria
Cu	0.253 ± 0.16	0.471 ± 0.029	0.348 ± 0.16	This work	Malaysia
	9.67 ± 1.60	4.399 ± 1.327	–	Abduljaleel et al., 2012	Malaysia
	12.1 ± 1.1	10.7 ± 1.0	14.5 ± 1.2	(Uluozlu et al., 2009)	Turkey
	5.13 ± 0.59	3.57 ± 0.45	1.77 ± 0.26	(Mousa et al., 2010)	Egypt
	0.1583			(Aljaff et al., 2014)	Iraq
	193 ± 28	125 ± 11		(Onyeka and David, 2015)	Nigeria
	5.82 ± 3.05	23.74 ± 4.89		(Okoye et al., 2015)	Nigeria
	5.56	2.18	4.06	(Jokanović et al., 2014)	Serbia
Sb	0.279 ± 0.067	0.189 ± 0.0247	0.371 ± 0.150	This work	Malaysia
Ni	0.026	0.022	0.016 ± 0.014	This work	Malaysia
	1.909 ± 0.96	1.839 ± 0.43		Abduljaleel et al., 2012	Malaysia
	0.01 ± 0.001	0.02 ± 0.001	0.02 ± 0.001	(Uluozlu et al., 2009)	Turkey
	0.0904			(Aljaff et al., 2014)	Iraq
	117 ± 24	92 ± 22		(Onyeka and David, 2015)	Nigeria
Sr	0.035 ± 0.02	0.0171	0.112 ± 0.012	This work	Malaysia
Fe	6.5 ± 3.4	9.2 ± 2.7	7.6 ± 2.7	This work	Malaysia
	401.74 ± 47.4	143.170 ± 19.19		Abduljaleel et al., 2012	Malaysia
	155 ± 15	17.8 ± 1.4	25.6 ± 2.2	(Uluozlu et al., 2009)	Turkey
	6.482			(Aljaff et al., 2014)	Iraq
	82.42	19.61	31.54	(Jokanović et al., 2014)	Serbia
Mg	43.6 ± 1.7	59.43 ± 2.45	51.88 ± 1.73	This work	Malaysia
	263	254	258	(Jokanović et al., 2014)	Serbia

many countries including United States, Canada, Australia, etc. as a feed additive to increase weight and improve feed efficiency, however in a recent study conducted by Aghajani and Amiri (2013) observed that roxarsone does not accumulate in poultry tissue but excreted. Present results of As confirmed their findings on the non-accumulation of As in poultry tissue. The As data reported by Uluozlu et al. (2009) in chicken giblets are somewhat greater. However, both the results of Uluozlu et al. (2009) and present work are below the permissible limits of 2.0 ppm (2 µg/g) (Australia New Zealand Food Authority, 2001).

Mercury (Hg), a toxic metal, is found in the environment via natural and anthropogenic sources (Pirrone et al., 2010). High rates of Hg ingestion can be fatal to humans and even at relatively low rates compounds containing Hg can have serious adverse effects on the developing nervous system, also being linked with possible harmful effects on the cardiovascular, immune and reproductive systems (Holmes et al., 2009). In this work, Hg has been found in practically all liver, gizzard and heart samples. The concentrations in gizzard are somewhat greater than in the other samples types. The probable reason is that relatively more Hg was accumulated in gizzard than the liver or heart since this organ is located in the digestive tract. No information on the maximum allowable limits of Hg is available in the Malaysian food Act (1983).

While in some respects the health effects of aluminium (Al) remain matters of conjecture, increasing evidence is being found of its toxicity, as in gradual accumulation in the brain and subsequent effects on the nervous system, as well as the skeletal and haematopoietic system (Mir-Marqués et al., 2012; Domingo, 1995). Herein, the maximum and minimum mean levels of Al have been found to be in the gizzard and heart, at 1.50 ± 1.03 and 1.02 ± 0.57 µg/g respectively; these levels apparently exceed those reported in the study by Uluozlu et al. (2009). There is no information about the allowable limits of Al level in Malaysian food Act (1983). It is important to mention that FAO/WHO (2001) has revised its previous Provisional Tolerable Weekly Intake from 7 mg/kg body weight (7 µg/g-bw) to just 1 mg/kg body weight (1 µg/g-bw). Comparing this WHO value, the measured concentration of Al in chicken giblet just exceeds the safe level.

Although not typically listed as an essential metal, nickel (Ni) has been found to play a significant role in some enzymes and in the biology of microorganisms (Zhang et al., 2014). Ni content in consumer products and possibly in food and water is critical in respect of dermatological effects. The analysed chicken liver samples show the greatest mean value of Ni, at 0.026 µg/g while the lowest mean value of 0.022 µg/g was found in the gizzard tissues. These values were found to be within the range reported by Uluozlu et al. (2009) for chickens of Turkish origin but below the reported data by Aljaff et al. (2014). Although no upper limit has been recommended by the Malaysian food Act (1983) or WHO report, however an amount of less than 0.5 mg/kg (0.5 µg/g) (fresh weight) is found in most of the food products (World Health Organization, 1991).

Copper (Cu) is known to be of significance in the formation of bone, skeletal mineralization and effective functionality of connective tissues (Akan et al., 2010). Although limited information is available on chronic copper toxicity, copper overload is a pathological problem in Wilson's disease and Menke's syndrome (Amer et al., 2006), and it is not being properly eliminated from the body. These gives a clear indication of some of the associated health effects. The Cu contents in the investigated giblets were found to be lower than those reported for chickens giblets in Turkey (Uluozlu et al., 2009), Iraq (Aljaff et al., 2014), Egypt (Mousa et al., 2010), Serbia (Jokanović et al., 2014) and also below the allowable limits of 30 µg/g (Malaysian food Act, 1983) and the WHO recommended permissible limit of 40 mg/kg (40 µg/g) for foodstuffs (CODEX Alimentarius Commission, 2016).

Selenium (Se), an essential micronutrient in animals and humans, has important biological roles as an antioxidant, a regulator of thyroid hormone metabolism or as an anti-carcinogenic agent. While Se is an essential micro-nutrient, needed in small quantities for normal biological function. It is toxic to vertebrates at concentrations slightly greater than essential levels of 2 µg/g (Australia New Zealand Food Authority, 2001) in foodstuffs, and can lead to selenosis. Signs of selenosis include a garlic odour on the breath, gastrointestinal disorders, loss of hair, sloughing of nails, fatigue, irritability and neurological damage (Sakurai and Tsuchya, 1974). Present Se results are similar in value to the data reported by Aljaff et al. (2014) but much lower than the Uluozlu et al. (2009) measured data in Turkish chicken giblets. However, the Se concentration determined in this work (0.01-0.09 µg/g) lies well below the allowed maximum of 0.5 mg/kg in the diet (European Commission, 2014).

Antimony (Sb), regarded as a metalloid with metallic and non-metallic properties, shares similarity with arsenic in the sense that it exists in the environment in particular oxidation states and in the form of Sb (III) and Sb(V) (Shan and Ma, 2014). The trivalent compounds have toxicity of about 10 times that of the pentavalent compounds. Conversely, the solubility and mobility of the Sb(V) states are greater than those of Sb(III) (Mitsunobu et al., 2010). Sb and the compounds of Sb combine easily with the endogenous sulfhydryl in animal or human tissue, a matter which can potentially destroy the cellular ion balance via interference with the enzymatic activity of the body, leading to hypoxia (Ning and Xiao, 2007). This in turn, can produce disorder within the metabolic system, damaging organs, not least the nervous system. In the present study, the Sb concentration in heart tissue (0.371 ± 0.150 µg/g) was found to be the greatest amongst the other metals such as Zn, Fe and Mg aside (Table 2). No literature data is available on the presence of Sb in meat, hence the absence of comparison. According to US-EPA (1999), food contains small amounts of Sb, in the range 0.2–1.1 ppb (0.2–1.1 ng/g). To-date, the EPA has not established a reference concentration for Sb, however FAO/WHO Food Standards Programme, Codex Alimentarius Commission, (2001) and European Commission (2014) have established a tolerable daily intake (TDI) of 6 µg/kg-bw/day for antimony (bw indicating body weight).

While strontium (Sr) is not considered to be an essential metal, having no known biological role, it is ubiquitous in the environment, appearing in air, water, soil and food. The potential toxicological concern arises out of its chemical similarity to calcium, with an ability in bone to substitute sparingly for calcium, possibly a matter of benefit, not least for those suffering from osteoporosis (bone-thinning) but also deleterious effects depending on the amount taken up (Marie et al., 1985). The analysed heart samples showed the greatest mean value at 0.112 ± 0.012 µg/g while the lowest mean value of 0.017 µg/g was found in the gizzard. Present data show consistency with the typical range of Sr in biological samples, varying from 0.002 to 12.6 mg/kg (Ines et al., 2017). The US-EPA (2017a, 2017b) have recommended a reference level of 1.5 mg/L concentration of Sr for water, while the US Public Health Service have reported 2 mg/(kg-bw.day) to be the minimal risk level for intermediate duration oral exposure to stable strontium (U.S. Department of Health and Human Services, 2004).

The chicken giblets are a major source of the Fe, Mg and Zn metals that essential for proper growth, oxygen transport in organisms and building of nutrients when ingested or accumulated in the body up to the recommended limits set by the several international organizations. Present results are within such limits as well as available literature data (Table 3). The importance of these metals and deficiency symptoms are well documented by FAO/WHO Food Standards Programme, Codex Alimentarius Commission (2001), forming only a small aspect of this work.

Table 2 shows the estimated daily intake for all studied metals to be much below the permissible limits of daily intake of metals via foodstuffs. This is expected due to the fact that chicken giblets form only a minor portion of foodstuffs consumed by humans on a daily basis. Present results show there to be minimal likelihood of metal overload from daily consumption of chicken giblets by the Malaysian population and thus the population are not under any associated health risk.

3.2. Public health risk of metal exposures via the consumption of giblets

Table 4 presents the required factors/values for calculation of non-carcinogenic and carcinogenic health risks via the consumption of chicken giblets. Table 4 depicts the estimated HQs and LCRs for exposure to individual metals via the consumption of chicken giblets by

Table 4
Hazard quotient (HQ) from metals exposures in chicken giblets consumed by the Malaysian population.

Metal name	Average daily dose (ADD) (mg/kg/day)			Non-carcinogenic risk				Carcinogenic risk (LCR)			
				Hazard Quotient (HQ)			Hazard index	Individual samples			Total
	liver	gizzard	heart	liver	gizzard	heart	HI = ΣHQs	liver	gizzard	heart	ΣLCR
Al	1.17E-04	1.47E-04	9.78E-05	0.00002	0.00002	0.00001	0.0001	–	–	–	–
Cr-(VI)	2.94E-06	2.94E-06	8.81E-06	0.0010	0.0010	0.0030	0.0049	1.1E-04	1.1E-04	3.3E-04	5.5E-04
As	9.78E-07	9.78E-07	–	0.0030	0.0030	–	0.0065	1.1E-04	1.1E-04	–	2.2E-04
Se	2.94E-06	5.87E-06	1.96E-06	0.0010	0.0010	0.0004	0.0022	–	–	–	–
Zn	2.45E-04	2.45E-04	3.23E-04	0.0010	0.0010	0.0010	0.0027	–	–	–	–
Cd	9.78E-07	–	8.81E-06	0.0010	–	0.0090	0.0098	2.8E-05	–	2.5E-04	2.8E-04
Hg	1.76E-05	2.15E-05	7.83E-06	0.0590	0.0720	0.0260	0.1566	–	–	–	–
Pb	9.78E-07	–	2.45E-05	0.0003	–	0.0070	0.0073	6.2E-07	–	1.6E-05	1.6E-05
Cu	2.94E-05	4.60E-05	3.42E-05	0.0010	0.0010	0.0010	0.0027	–	–	–	–
Sb	2.74E-05	1.86E-05	3.62E-05	0.0680	0.0460	0.0910	0.2055	–	–	–	–
Ni	2.94E-06	1.96E-06	1.57E-06	0.0001	0.0001	0.0001	0.0003	3.7E-04	2.5E-04	2.0E-04	8.2E-04
Sr	3.91E-06	1.96E-06	1.08E-05	0.00001	0.000003	0.00002	0.00003	–	–	–	–
Fe	6.36E-04	9.00E-04	7.44E-04	0.0010	0.0010	0.0010	0.0033	–	–	–	–
Mg	4.27E-03	5.81E-03	5.08E-03	0.0300	0.0420	0.0360	0.1083	–	–	–	–
Hazard index (HI) for individual giblet tissue = ΣHQs				*0.1664*	*0.1685*	*0.1756*					
Hazard index (HI) due to all metals in giblets = ΣHQs							*0.5100*				

the Malaysian population. Although measurable quantities of most metals in the giblets were found, the potential health risk from the giblet consumption was negligible due in part to the low ingestion rates (an estimated 10 g/day). The HQ values for all metals present in each type of giblet sample were found to be in the range from 3×10^{-6} to 0.091, very much lower than the respective reference dose (R_fD) values, indicating insignificant risk to health. The non-carcinogenic (chemical) risk from exposure to multiple metals is represented by the HI. Among all the essential metals in chicken giblets, Sr poses the least potential health risk while Sb represents the greatest. The total HI due to all metals via giblets consumption was found to be 0.51, much lower than 1 above which represents a risk. Hence dietary exposures to metals from consumption of chicken giblets are not found to pose a significant non-carcinogenic risk.

As, Hg, Cd and Pb are well known potential carcinogens (Abduljaleel et al., 2012; Holmes et al., 2009). Table 4 summarizes the estimated LCR due to exposure to Cr, As, Cd, Pb and Ni from lifetime consumption of chicken giblets for Malaysian population. Due to its rather low CSF, the carcinogenic risk from Pb is insignificant compared to the other metals. On the other hand, Ni exposures represent the dominant contributor to the total risk of cancer from lifetime consumption of chicken giblets. Overall, the cancer risk from dietary exposure to Cr, As, Cd, Pb and Ni resulting from lifetime consumption of chicken giblets is in the range from 1.6×10^{-5} to 8.2×10^{-4}. In general, values of LCR lower than 10^{-6} are considered negligible, above 10^{-4} are considered to constitute a risk and between 10^{-6} and 10^{-4} are considered as acceptable risks (USEPA, 2000). In the present study, the estimated LCR for all of the studied trace metals other than Pb (i.e. As, Hg, Cd and Ni) are within the range indicating a risk of cancer due to the life-long consumption of chicken giblets. Although, the general observation is that these higher values are a reflection of elevated CSF for the respective metals, the contribution from industrial activities and also the use of various feed additives cannot be neglected. These findings indicate a significant need for control of the use of feed additives in chicken production to protect the health of consumers.

4. Conclusion

Present study has detected the presence of 14 essential and non-essential metals (Al, Cr, As, Se, Zn, Cd, Hg, Pb, Cu and Sb) in chicken liver, with only a trace level of As in heart, and Cd and Pb in gizzard samples. The determined metal concentrations show levels that are typical of literature data, although no comparison can be made for Sb and Sr due to the lack of literature values. Considering the above results for the sampled Malaysian locations, it can be assumed that those factors which give rise to potentially toxic metals are of minimal effect. The estimated daily intake of the metals was generally below the respective recommended daily dietary allowance for those metals. The non-carcinogenic risk estimated by the hazard quotient, showed a value less than unity which indicates an absence of adverse health hazards to members of the public via consumption of chicken giblets. The carcinogenic risk of As, Hg, Cd and Ni due to the consumption of chicken giblets is marginally above the acceptable risk level of 10^{-4}. It is worth mentioning that the chicken giblets form only a very minor part of the total dietary intake of protein (most likely at only a few grams/week). Thus, the ingestion of studied metals via the consumption of chicken giblets does not equate with adverse effects to the inhabitants of Kuala Lumpur and Selangor. However, due to the non-degradability of potentially toxic metals and their potential accumulation in animal tissues, this provides reason for efforts to reduce the over-supplementation of metals in animal feed.

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Declaration of Competing Interest

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