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Evaluation of Some Heavy Metals Concentration in Chicken Meat, Organs and Eggs in Faiyum, Egypt

Ayman I. N. Nasr [1*], Hend A. Mahmoud [2] and Wafai Z. A. Mikhail [3]

[1] *Director, Technical Dept., Pesticide Factory, Egypt.*
[2] *LAB Director of Central Laboratory of Pesticides Residue and Heavy Metals in Food, Egypt.*
[3] *Dept. Natural Resources Faculty of Postgraduate Studies Cairo University, Egypt.*

Abstract

THE aim of this study was to estimate the concentrations of heavy metals in chicken meat, organs and eggs in Egypt. Samples were collected from Faiyum governorate in Egypt. Copper, Lead, Cadmium, Iron and Zinc were determined using thermo atomic absorption spectrometer. Copper (Cu) concentrations were highest in the liver and lowest in muscle but still below the permissible limits established by the world health organization (WHO). Liver contains the highest concentration of the Lead (Pb) levels were found to be above the permissible limit while the levels in muscle and kidney remained within the WHO-recommended threshold of 0.2 ppm. Similarly the concentration of Cadmium (Cd) in muscles and kidneys fell within the permissible limit of 0.5 ppm. The highest concentration of Zinc (Zn) was found in the liver followed by the muscles and then the kidneys in decreasing order. However, these concentrations exceeded the Codex standard permissible limit of 50 ppm. Cu concentration levels were below the permissible limits 10 ppm**.** Heavy metals in eggs samples Cu concentration levels in the samples were found to be within the acceptable limit of 10 ppm. The mean Iron (Fe) concentration levels in the eggs were recorded at 72.67, 41.84 and 34.32 ppm. In comparison the average concentration of Fe level in eggs as reported by USDA is 17.6 ppm. The Pb concentrations measured in this study exceeded the WHO-recommended limit of 0.1 ppm. Regarding Cd, the study adhered to the Maximum Residue Limits (MRL) set by WHO at 0.1 ppm. Additionally the findings showed that all examined organic eggs complied with the WHO-established Maximum Permissible Levels (MPL) for Zn which is 20 ppm.

Keywords: Heavy Metals, Chicken, Eggs.

Introduction

Heavy metals readily infiltrate the food chain as noted by [1] and are known to have harmful effects on the human body. Consequently researchers have concentrated their efforts on studying their biohazardous potential. Once absorbed heavy metals tend to accumulate in the body and may persist for a lifetime [2]. Certain heavy metals are extremely toxic with even low concentrations capable of disrupting various metabolic processes in the body [3, 4]**.** A deficiency in essential metal nutrients may lead to various symptoms including immune system disorders, developmental abnormalities and other specific health issues. Metals like arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) are non-essential, serving no biological role and potentially toxic even at low concentrations. However all heavy metals can show toxic effects when consumed in large amounts. Chromium (Cr) despite being an essential element can behave as a mutagen, teratogen and carcinogen if taken in excessive quantities. The toxicity of metals like As, Cd, Hg and Pb depends on factors such as the dose duration of exposure and individual attributes such as age, gender, genetics and nutritional status. These metals are known to harm critical organs including the liver, kidneys, brain, cardiovascular and reproductive systems. Prolonged exposure to inorganic arsenic is strongly linked to an increased risk of cancer affecting multiple body parts, along with cardiovascular diseases and increased mortality rates. Cadmium is known for its potential to cause cancer and genetic damage, and it often accumulates in tissues such as the liver and kidneys [6]. Heavy metals like lead (Pb) and mercury (Hg) are especially notorious for their neurotoxic effects, posing significant risks to children's neurodevelopment. Children are particularly susceptible to lead exposure due to their higher rates of gastrointestinal absorption and a more permeable blood-brain barrier. Prolonged low-

*Corresponding authors: Ayman I.N. Nasr, E-mail: aymannasr91march@gmail.com Tel.: 01112722291
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dose exposure can lead to conditions such as anxiety, depression, restlessness, hypertension, anemia, damage to the fetal brain, tremors, kidney diseases and autoimmune disorders like rheumatoid arthritis [5]. Research indicates that low-dose exposures to mixtures of As, Cd, Pb and Hg interact synergistically resulting in higher toxicity levels compared to individual heavy metals [6].

Material and Methods

Study design:

This study was carried out over the course of one year from January 2023 to December 2023. Chickens and eggs were collected from various batches sourced from local markets located across different areas of Faiyum governorate. A total of 10 samples were taken from each market representing diverse locations in Faiyum and each sample was individually analyzed for heavy metals including lead (Pb), copper (Cu), cadmium (Cd), iron (Fe) and zinc (Zn). Working solutions were prepared in isooctane at a concentration of 1000 mg/L. To measure the levels of Pb, Cd, Cu, Zn and Fe, 5 grams of the homogenized sample were placed in evaporating dishes and dried in an oven at 70°C for 24 hours. The dried samples were then ashed at a temperature of 500°C for 5 to 8 hours. The resulting ashes were transferred into 25 mL volumetric flasks using 4.2 mL of concentrated hydrochloric acid (HCl) and deionized water. The levels of heavy metals were subsequently measured using a Thermo atomic absorption spectrometer equipped with a hollow cathode lamp and deuterium background correction (Table 6).

The chicken (Gallus gallus domesticus):

Thirty-five samples were obtained from a commercial poultry market in Egypt, specifically within the Faiyum governorate. The study included chicken samples weighing 1 kg or more. The chickens were slaughtered and tissue samples were taken from the pectoral muscle, liver and kidney. These tissues were rinsed thoroughly with deionized water to remove any blood following a standard method described by [7] with minor modifications. The samples were dried in an oven at 70°C for 24 hours, finely ground with a mortar and pestle, and then passed through a 0.75 µm mesh sieve.

Eggs:

Egg samples were collected every four months over a one-year period from January 2023 to December 2023 a total of 35 random egg samples were obtained from local shops and super markets in different four locations in Faiyum Governorate. Representing from various regions. The albumin from the egg samples was gathered, combined, and homogenized using an electric mixer in clean polyethylene bottles. Subsequently, each sample was labeled and stored at −20°C until transported to the laboratory for chemical analysis. Prior to the analysis, all egg samples were uniformly weighed.

Statistical analysis

All calculations were performed using SPSS for Windows (vers. 18.0, SPSS Ltd., Woking, Surrey, UK). The descriptive statistics (mean values, standard deviation) for values of egg content were analysed by one-way analysis of variance followed by the Tukey honestly significant difference test. Differences were considered significant at the $p<0.05$ level.

Results and Discussion

Heavy Metals in chicken organs and Eggs
Copper (Cu) residues

The liver was observed to have the highest concentration of Cu at (7.81 ± 2.42 ppm), whereas the muscles exhibited the lowest level at (2.36 ± 0.93 ppm) this may be due the liver is the primary organ responsible for storing minerals such as copper and iron, as it is involved in numerous metabolic reactions associated with enzymes and proteins that depend on these elements. Similarly, [8] reported the highest Cu concentration in the liver at (8.38 ± 0.26 ppm) and the lowest in the muscles at (3.36 ± 0.48 ppm) On the other hand Cu not detected in kidney (Table 5). The mean concentration levels of copper white shell eggs were (1.02± 0.42 ppm). (Table 5). The copper concentration in the analysed samples was determined to be below the allowed limit of 10 ppm, as defined by [9]. The elevated copper residue levels observed in white shell eggs may result from the inclusion of Cu sulphate as an additive in the diet of laying Leghorn hens. These results, however, the copper residue in eggs surpassed the permissible limit of 0.72 ppm. Set by the United States Department of Agriculture [10]. The copper (Cu) concentrations in brown-shelled and Baladi (local) eggs were comparable to those found in studies conducted in other countries, such as Bangladesh (0.64 ppm) as reported by [11]. Belgium (0.60 ppm) [12] and in British eggs (0.62 ppm) [13]. (1.02 ppm) in Indonesia [14]. The gastrointestinal tract is particularly sensitive to the effects of copper toxicity. Human studies conducted with a single dose of copper after an overnight fast showed adverse gastrointestinal symptoms including nausea, vomiting, abdominal pain and/or diarrhea at doses ranging from 0.011 to 0.03 mg/kg [15].

Iron (Fe) residues

Liver contain (51.64 ± 7.94 ppm) followed by Muscle (41.02 ± 11.61 ppm) the results of our study align with those of [15] who reported that chicken liver contains higher levels of Fe (4.65 ± 0.30 ppm) compared to chicken muscle. (1.92 ppm). And kidney contains the lowest (16.41 ± 3.61 ppm), the present study agreement with [16]. The mean of iron concentration levels in eggs are (72.67 ± 14.60 ppm). According to the [10] the average iron (Fe) concentration level in eggs is 17.6 ppm. The Fe concentration was notably higher compared to copper (Cu), zinc (Zn), lead (Pb) and cadmium (Cd). The increased iron levels are linked to the substantial incorporation of iron into hens' diets. Iron is often supplemented to improve the shell colour of brown eggs, as observed by [17]. Enhancing their commercial attractiveness. This consideration also applies to eggs produced at home, such as those from backyard hens. The birds are primarily fed household food scraps. Additionally ducks are often fed fish which are naturally rich in iron contributing to the higher iron content in their eggs. Iron is a crucial dietary element for both humans and animals, as it plays a vital role in haemoglobin formation. It aids in the oxidation of carbohydrates, proteins, and fats, contributing to body weight regulation. Insufficient iron levels can increase susceptibility to gastrointestinal infections, nosebleeds, and myocardial infarctions [18]. Iron is naturally present in all plant- and animal-based foods and can also be found in drinking water. However, toxic doses of iron in animals have been linked to symptoms such as depression, coma, seizures, respiratory failure, and cardiac arrest. Post-mortem analyses of affected animals have shown significant damage to the gastrointestinal tract. Iron from animal sources, like eggs, usually contains heme iron, which the body tends to absorb more efficiently than the non-heme iron present in plant-based sources [10]. The findings of this study align with those of [11] who reported iron concentration levels of 29.23 ppm in commercially produced hen eggs 124.58 ppm in home-produced eggs and 44.10 ppm in duck eggs. In comparison, [19] documented a lower value of 9.3 ppm for boiled table eggs.

Lead (Pb) residues

The findings of this study indicate that the liver contains a higher concentration of lead (Pb) at 0.31 ± 0.13 ppm compared to muscle tissue, which has a concentration of 0.24 ± 0.12 ppm. This is consistent with earlier research indicating that the liver generally accumulates higher lead levels compared to other tissues [20]. Significant variations in Pb concentrations were detected among districts for kidney, liver and muscle tissues. Samples from Faiyum exhibited higher Pb levels with concentrations in muscle, liver and kidney recorded at 0.24 ± 0.12 ppm, 0.31 ± 0.13 ppm, and 0.15 ± 0.04 ppm respectively (Table 5).Excessive Pb exposure is associated with reduced cognitive development and intellectual performance in children as well as an increased risk of high blood pressure and cardiovascular diseases in adults [21]. The lead concentration in the liver exceeds the [22] permissible limit of 0.2 ppm whereas levels in muscle and kidney remain within acceptable ranges. The findings of our research study aligned with those reported by [16]. Pb concentrations observed in this study surpassed the [22] recommended limit of 0.1 ppm in 10% of the eggs examined Faiyum (7.82 ± 2.10 ppm) (Table 5). Excessive lead content in food can severely impact the brain, kidneys, nervous system, and red blood cells in humans, as noted by [23]. Cases of lead poisoning from food consumption have recently been reported among children in Nigeria, Zambia and China [24, 25]. When lead enters a chicken's body it tends to accumulate in various parts such as the bones, eggs (including the shell, yolk and albumen) as well as soft tissues like the liver and kidneys ultimately resulting in elevated blood lead levels. In this study the detected concentrations of lead in eggs were found to be nearly equivalent to the toxic threshold of 1 ppm which can cause lead poisoning in chickens. At such levels in their diet, chickens may exhibit symptoms such as depression, reduced growth rates and a decline in food conversion efficiency.

Cadmium (Cd) residues

The results of the current study indicate that cadmium (Cd) levels in the Faiyum region were notably higher in the liver (0.60 ± 0.16 ppm) compared to the muscle (0.41 ± 0.11 ppm) and kidney (0.41 ± 0.18 ppm) as shown in (Table 5). Statistically no significant difference was observed between the kidney and muscle samples. These results are consistent with the findings of [26]. Who also reported higher concentrations of Cd in the liver compared to the muscles. Likewise [27] observed elevated concentrations in the liver (0.0985 ppm), while lower levels were noted in the breast muscles (0.0187 ppm) and thigh muscles (0.0210 ppm).Our results also agree with the findings of [16] However, the Cd concentrations in the muscles and kidneys in Faiyum remain within the permissible limit of 0.5 ppm set by [22]. It is worth noting that this study's outcomes differ from those reported by [28] who found concentration of Cd level were higher in kidney than those of liver. Cadmium contamination in the environment and food chain generally results from its extensive use in industries like battery manufacturing, as well as in pigments and stabilizers. In this study, the average cadmium concentration found in the analysed egg samples from Faiyum was 1.14 ± 0.29 ppm. Similar to Pb, Cd concentrations were notably higher in Faiyum due the use of fertilizers and pesticides in rice, soybeans and corn can be the source of contamination through Cd-contained feed [29]. The concentrations recorded in this study align with the findings reported previously in Malaysia and Egypt [30, 31]. A higher concentration of cadmium (Cd) (0.3 ppm) was unexpectedly detected in Bangladesh, as reported by [32]. In comparison, [33] documented lower concentrations of Cd (1.44 ± 0.138 ppm) in chicken eggs sold in Greece. The detected levels in this study align with the findings of [34]. When compared to the Maximum Permissible Limits (MPL) for cadmium set by FAO/WHO (0.1 ppm), it was observed that 5% of the examined eggs in Faiyum exceeded this limit.

Zinc (Zn) residues

The zinc concentration was measured in the chicken muscle, liver, and kidney samples collected from the Faiyum governorate. it was found that the liver showed the highest concentration (107.36 ± 26.58 ppm) followed by muscles (101.84 ± 13.85 ppm) and kidney (10.98 ± 2.23 ppm) respectively . In general, liver had higher accumulation pattern for metals compared with other organs in the examined avian species, this is may be attributed to the fact that liver is the organ of metabolism and detoxification of xenobiotic in humans and animals [36] (Table 5). [35] Reported that the zinc (Zn) concentration in chicken liver was 158 ppm, whereas in muscle it measured 125 ppm. Conversely, the findings of this study differ from those of [15] who noted Zn concentrations of 3.11 ppm in the liver and 1.1 ppm in the muscle of chickens. The results of this research indicated that Zn concentrations in the liver, muscle and kidney across all districts were below the permissible limit of 150 ppm set by [37] but exceeded the Codex standard's permissible limit of 50 ppm. This lower concentration of Zn could potentially be attributed to Zn-deficient soils leading to water sources available to poultry lacking adequate Zn levels which may explain the lower Zn content in tissues [38] Noted that heavy metal accumulation was primarily more pronounced in metabolic organs. In (Table 5) showed that the residual concentrations of Zn (ppm) in the analysed samples were (12.05 ± 3.23 ppm) in the examined Faiyum. The zinc concentrations identified in this study align with levels documented in chicken eggs (15.75 ± 4.05 ppm) collected from the Campania region in Southern Italy, as reported by [39]. In contrast, notably higher zinc concentrations (56.8 ± 2.89 ppm) were reported in Upper Egypt by [30]. Lower zinc concentrations have also been observed in chicken eggs produced in Peshawar, Pakistan. [40]. The comparison of obtained zinc concentrations in chicken eggs from this study with the maximum permissible limits set by [22] showed that all the tested organic eggs fell within the acceptable zinc threshold of 20 ppm. The concentrations recorded align with findings by [34]. Zinc is a crucial trace element necessary for normal bodily functions, playing a significant role in many enzymes and receptors. Additionally, zinc is known for its antioxidant and anti-inflammatory properties and aids in boosting the immune system in both animals and humans as noted by [41]. The effect of dietary zinc supplementation on body weight gain or feed conversion efficiency remains unclear. For instance, chickens fed diets containing 600 ppm of zinc showed slightly lower body weights compared to those given 0 or 300 ppm of zinc. However, this decline in body weight did not influence meat yield, as reported by [23].

Conclusion

The liver was found to have the highest copper concentration (7.81 ± 2.42 ppm), while the muscle contained the lowest (2.36 ± 0.93 ppm). The findings of the present study indicate that copper levels are below the permissible limits established by the World Health Organization (WHO).The Pb level in the liver exceeds the FAO/WHO permissible limit of 0.2 ppm, while the levels in the muscle and kidney remain within the acceptable range. The concentration levels of Cu in the analysed samples were found to be below the allowable limit of 10 ppm. In District Faiyum it was evident that 5% of the eggs tested exceeded the specified limit. The study, referencing the Maximum Permissible Levels (MPLs) established by FAO/WHO, revealed that all tested organic eggs fell within the acceptable zinc MPL of 20 ppm.

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TABLE 1. Number, mean, Standard error, and coefficient of variation of heavy metals detected in Chicken Muscle's sampled from Faiyum.

	Cu	Fe	Pb	Cd	Zn
N	7	7	7	7	9
Mean	2.36	41.02	0.24	0.41	101.84
SE	0.35	4.38	0.04	0.04	4.61
Variance	0.86	134.83	0.01	0.01	191.83
SD	0.93	11.61	0.12	0.11	13.85
CV	39.50	28.30	51.17	27.70	13.59

N= Number, $\overline{X}$ = Mean, SE= Standard Error, SD= Standard Deviation, C.V. = Coefficient of variation

TABLE 2. Number, mean, Standard error , and coefficient of variation of heavy metals detected in Chicken Liver's sampled from Faiyum.

	Cu	Fe	Pb	Cd	Zn
N	6	6	10	8	11
$\bar{X}$	7.81	51.64	0.31	0.60	107.36
SE	0.99	3.24	0.04	0.05	8.01
Variance	5.88	63.09	0.01	0.02	706.58
SD	2.42	7.94	0.13	0.16	26.58
CV	31.02	15.37	42.72	27.61	24.75

N= Number, $\bar{X}$ = Mean, SE= Standard Error, SD= Standard Deviation, C.V. = Coefficient of variation

TABLE 3. Number, mean, Standard error, and coefficient of variation of heavy metals detected in Chicken Kidney's sampled from Faiyum.

	Cu	Fe	Pb	Cd	Zn
N	ND	9	9	7	7
$\bar{X}$	ND	16.41	0.15	0.41	10.98
SE	ND	1.20	0.01	0.06	0.84
Variance	ND	13.08	0.002	0.03	5.00
SD	ND	3.61	0.04	0.18	2.23
CV	ND	22.03	28.76	44.19	20.36

N= Number, $\bar{X}$ = Mean, SE= Standard Error, SD= Standard Deviation, C.V. = Coefficient of variation, ND = Not Detected

TABLE 4. Number, mean, Standard error, and coefficient of variation of heavy metals detected in Chicken Eggs sampled from Faiyum.

	Cu	Fe	Pb	Cd	Zn
N	8	7	9	10	8
Mean	1.02	72.67	7.82	1.14	12.05
SE	0.14	5.52	0.70	0.09	1.14
Variance	0.17	213.38	4.41	0.08	10.47
SD	0.42	14.60	2.10	0.29	3.23
CV	41.15	20.10	26.85	26.09	26.84

N= Number, $\bar{X}$ = Mean, SE= Standard Error, SD= Standard Deviation, C.V. = Coefficient of variation

TABLE 5. Mean ± SD Concentration of Heavy Metals in Chicken Organs and Eggs in Faiyum (ppm)

Metal / Sample	Cu	Fe	Pb	Cd	Zn
Muscle	2.36 ± 0.93	41.02 ± 11.61	0.24 ± 0.12	0.41 ± 0.11	101.84 ± 13.85
Liver	7.81 ± 2.42	51.64 ± 7.94	0.31 ± 0.13	0.60 ± 0.16	107.36 ± 26.58
Kidney	ND	16.41 ± 3.61	0.15 ± 0.04	0.41 ± 0.18	10.98 ± 2.23
Eggs	1.02 ± 0.42	72.67 ± 14.60	7.82 ± 2.10	1.14 ± 0.29	12.05 ± 3.23

TABLE 6. Wavelength and Detection Limit for Each Element.

Metal / Measure	Cu	Fe	Pb	Cd	Zn
Wavelength	324.8nm	248.3nm	217.0nm	228.8nm	213.9nm
Detection limit	0.0400	0.1859	0.1145	0.0214	0.0169

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تقييم تركيز بعض العناصر الثقيلة في بعض أنواع الدجاج و البيض

أيمن إسلام نعمان نصر[1] ، هند عبد اللاة محمود[2] ، وفائي ذكي عازر ميخائيل[3]

[1] مدير قسم الفني و مدير مسئول مصنع مبيدات، مصر.

[2] مدير المعمل المركزي لمتبقيات المبيدات والعناصر الثقيلة في الأغذية، مصر.

[3] أستاذ بيئة الحيوان، قسم الموارد الحيوانية، كلية الدراسات الأفريقية العليا، جامعة القاهرة، مصر.

الملخص

الهدف من هذه الدراسة هو تقدير تركيزات المعادن الثقيلة في لحوم الدجاج والأعضاء والبيض من محافظة الفيوم في مصر. أظهر الكبد أعلى تركيز من النحاس، في حين أن العضلات كان لها أقل تركيز. تشير النتائج الحالية إلى أن مستويات النحاس أقل من الحدود المسموح بها التي وضعتها منظمة الصحة العالمية. يحتوي الكبد على أعلى تركيز من الرصاص وقد وجد أن مستويات الرصاص أعلى من الحد المسموح به بينما ظلت المستويات في العضلات والكلى ضمن الحد الموصى به من قبل منظمة الصحة العالمية وهو 0.2 جزء في المليون. وبالمثل انخفض تركيز الكادميوم في العضلات والكلى ضمن الحد المسموح به وهو 0.5 جزء في المليون. تم العثور على أعلى تركيز للزنك في الكبد يليه العضلات ثم الكلى بترتيب تنازلي. ومع ذلك، تجاوزت هذه التركيزات الحد المسموح به وفقًا لمعيار الدستور الغذائي وهو 50 جزء في المليون. كانت مستويات تركيز النحاس أقل من الحدود المسموح بها وهي 10 جزء في المليون. في عينات البيض وجد أن مستويات تركيز النحاس ضمن الحد المقبول وهو 10 جزء في المليون. سُجِّل متوسط تركيز الحديد في البيض عند 72.67 و41.84 و34.32 جزء في المليون. وبالمقارنة، يبلغ متوسط تركيز الحديد في البيض، كما أفادت به وزارة الزراعة الأمريكية، 17.6 جزء في المليون. وتجاوزت تركيزات الرصاص المُقاسة في هذه الدراسة الحد الأقصى الذي أوصت به منظمة الصحة العالمية والبالغ 0.1 جزء في المليون. وفيما يتعلق بالكادميوم، التزمت الدراسة بالحد الأقصى المسموح به للمخلفات (MRL) الذي حددته منظمة الصحة العالمية عند 0.1 جزء في المليون. كما أظهرت النتائج أن جميع البيض المفحوص يتوافق مع الحد الأقصى المسموح به للزنك (MPL) الذي حددته منظمة الصحة العالمية، وهو 20 جزءًا في المليون.

الكلمات الدالة: العناصر الثقلية، الدجاج، البيض.