Chemical Analysis of some Essential Trace Elements in Hen's Eggs: A Comparative Study

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Abstract—Hen's egg is an inexpensive but very nutritious component within the human diet. It is one of the few foods that are used widely worldwide and are healthy and safe for consumers but if contaminated by toxic heavy metals due to industrial waste, geochemical structures and agricultural activities is a serious problem for environmental and human health. The aim of our study is focused on determining the levels of the concentrations of some essential elements in three kinds of the hen eggs (i.e. home, street and market hen eggs) were collected from four regions at Aden city including Al-Buraiqeh, Al-Hiswah, Khormaksar and Shaikh Othman at Yemen. The concentrations of Cr, Mn, Fe, Co, Cu, Zn, Se and Mo elements were measured using the Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) technique. Omitting not detected values (ND), the mean concentrations (ppm) of elements in hen's eggs were in the range 0.029±0.004–8.903±0.420 for Cr, 0.217±0.002–0.976±0.001 for Mn, 3.749±0.040–20.52±0.19 for Fe, 0.010±0.001–4.795±0.265 for Co, 0.251±0.002–2.528±0.029 for Cu, 10.26±0.05–48.07±0.06 for Zn, 12.15±0.25–55.00±0.01 for Se, and 2.208±0.008–5.923±0.059 for Mo. Because Yemen country does not monitor the investigated elements in this foodstuff, the recent work was compared with other values reported in literature and in international standards. The mean concentrations of some studied elements such as zinc and selenium in some samples were exceeded the permissible limits as stated by available international specifications and standards. The regular national checking of hen's eggs producing and the quality of environment and hen's feeds should be taken into account with the intention of protection public health.

Index Terms—Hen's eggs, Essential elements, Food safety, Aden/Yemen.

1 Introduction

NUTRITION, food safety and security of food are indissolubly linked that can reflect the kind of human life. Several factors can affect the quality of daily intake food such as nutrition value, bioactive components and minerals contents [1].

Trace elements and/or heavy metals are the substances which naturally present in everywhere of the environment, conversely, human activities have led to an increase in their levels [2]. They are found in all living organisms where they play a variety of roles, as structural, components of control mechanisms (e.g. in nerves and muscles) and enzyme activator. The most harmful and poisonous heavy metals, chromium (Cr), arsenic (As), selenium (Se), cadmium (Cd), mercury (Hg) and lead (Pb) are of matter great concern [3]. Whereas, mineral elements such as chromium (III), copper, cobalt, manganese, zinc, iron and molybdenum fit in essential and micronutrient category for humans and some other animals [4,5]. Those elements play a definitive role in the intrinsic mechanisms regulating vital biological processes. Furthermore, micronutrients are toxic when taken in above the threshold levels [6].

Hen's eggs are an excellent source of high-quality protein and they give a balanced distribution of minerals and vitamins, particularly vitamins E, A, B12, B2, and folate [7]. Hen's eggs are considered as one of nature's highly-nutritious for human health and economical food items in human daily diet, especially that of the children [8]. Moreover, it is one of the few foods that are used worldwide and are healthy and safe for consumers [9], but if contaminated by toxic heavy metals due to industrial waste, geochemical structures and agricultural activities is a serious problem for environmental and human health [10]. Hens are also exposed to heavy metals by feed intake and could take up heavy metal from different sources, especially via nutrition. Therefore, metal residues may concentrate in their meat, and eggs [11].

The present study was conducted to evaluate the levels of essential trace elements in three types of the hen eggs (home, street and market hen eggs). Therefore, the determination of heavy metals such as (Cr, Cu, Co, Mn, Zn, Fe, Se and Mo) in the hen eggs to safeguard the public health in Aden city. This study will be useful in determining the potential risks from the toxic effects of heavy metals and to make recommendations for future implementations by the local health regulatory

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2 Materials and Methods

2.1 Study Location

Aden, the temporary capital of Yemen country, is a port city located by the eastern approach to the Red Sea (the Gulf of Aden) at the coordination 12° 28' - 12° 57' N and 44° 27' - 45° 07' E. Its population is approximately 850,000 people.

2.2 Sample Collection

Hen's eggs samples were randomly collected in 2017-2018 from the houses and the markets at four regions of Aden city including Al-Buraiqeh (Latitude 12° 81'66" N; Longitude 44° 71'94"E), Al-Hiswah (Latitude 12° 49'27" N; Longitude 44°55' 59"E), Khormaksar (Latitude 12° 01'05" N; Longitude 45° 03' 27"E), and Shaikh Othman (Latitude 12° 88'42" N; Longitude 45° 02'80"E) as shown in Fig. 1.

Egg samples were transferred into plastic bags and kept at refrigerated temperature until analyzed.

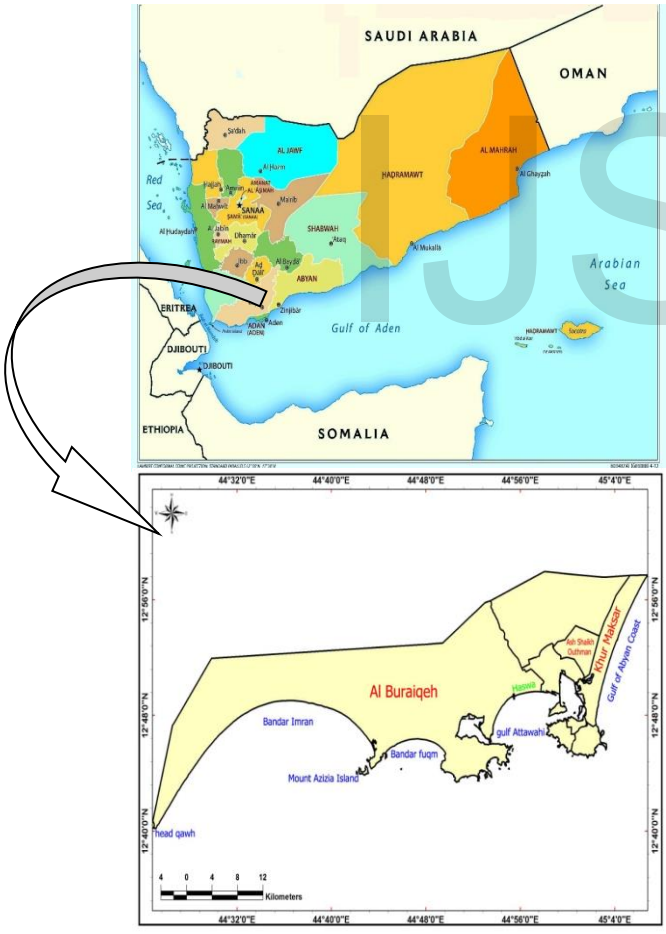

Fig.1. The location of Aden city with sampling sites: Al-Buraiqeh, Al Hiswah, Khormaksar and Shaikh Othman.

2.3 Chemicals

All chemicals used were of suprapur quality, analytical grade. Nitric acid (≥65%) (SIGMA-ALDRICH; Germany), Hydrogen peroxide (29 %) (PEKINGS; China) along with the stock standard solutions of Cr, Mn, Fe, Co, Cu, Zn Se and Mo in concentrations of 1,000 mg/l and dilution by de-ionized water (0.1 – 0.4 µS/cm)

2.4 Elemental Analysis

The egg samples were prepared for elemental analysis and the procedure was repeated three times on the different part of the samples. The concentrations of the 8 elements: Cr, Mn, Fe, Co, Cu, Zn Se and Mo in the studied egg samples were analyzed by using Inductively Coupled Plasma hyphenated to Optical Emission Spectrometry (ICP-OES) Model Thermo Scientific iCAP 6000 Series, USA at Central Processing Facility Laboratory of Masila Petroleum Exploration and Production Company, Hadramout – Yemen and the standard method was followed as mentioned in [12].

2.5 Preparation and Digestion of Eggs Samples

Each egg was washed with de-ionized water and then its white and yolk were mixed in a 200 ml beaker [13]. About 5 g (±0.001) of the mixed sample were weighed and digested with 6 ml of HNO_3 and 2 ml of H_2O_2 into 100 ml beaker and covered with a watch glass. After 30 min the beaker was placed on a hot plate up to 140°C until the complete decomposition of the sample was achieved and the total volume was reduced to nearly 3 ml. the digested sample was cooled and filtered into a 50 ml calibrated flask with double-distilled water using Whatman 42 filter paper [14,15]. The preparation and digestion of egg samples were done at the Chemistry laboratory for Master degree at the faculty of Education of Aden.

3 Statistical Analysis

The (Genstat 12) software was used in two-way statistical analysis (two-way ANOVA) to analyze results at a significant level ($P < 0.05$). The least significant difference (L.S.D) to test the significant differences was calculated between the averages and the statistical analysis was made using the complete random design.

4 Results and Discussion

The highest mean concentration of chromium (Cr) in the studied egg samples was found in home hen eggs of Al-Hiswah (8.903 ppm), while the lowest mean concentration of chromium was found in market hen eggs of Khormaksar (0.029 ppm) (Table 1 and Fig. 2.1).

The concentrations of chromium in street hen egg of Al-Buraiqeh, Al-Hiswah and Shaik Othman were not detected as well as the Home hen egg of Al-Buraiqeh. The recorded values for chromium in whole eggs were similar to that reported by Sobhanardakani [16] in Iran who reported that chromium concentration in commercial hen's eggs ranged 0.10-0.50 ppm except home hen egg of Shaik Othman which had the highest

TABLE 1

MEAN CONCENTRATION OF ESSENTIAL TRACE ELEMENTS IN EGG SAMPLES (PPM±SD)* DRY WEIGHT

Parameters	Al-Buraiqeh	Al-Hiswah	Khormaksar	Shaik Othman	Mean±SD
			Cr		
Home Hen Eggs	ND**	**8.903±0.420**	0.139±0.032	0.105±0.031	2.287±0.422
Street Hen Eggs	ND	ND	0.070±0.021	ND	0.017±0.021
Market Hen Eggs	0.069±0.002	0.308±0.008	**0.029±0.004**	0.106±0.043	0.128±0.044
L.S.D*** for types					0.023
			Mn		
Home Hen Eggs	0.430±0.002	0.638±0.001	0.751±0.002	0.543±0.002	0.590±0.004
Street Hen Eggs	0.508±0.010	**0.217±0.002**	0.657±0.010	0.313±0.004	0.424±0.014
Market Hen Eggs	0.904±0.008	0.949±0.001	0.513±0.004	**0.976±0.001**	0.835±0.009
L.S.D for types					0.004
			Fe		
Home Hen Eggs	17.58±0.06	12.66±0.02	**20.52±0.19**	13.02±0.02	15.95±0.201
Street Hen Eggs	8.074±0.104	**3.749±0.040**	15.33±0.29	5.858±0.159	8.254±0.349
Market Hen Eggs	15.50±0.03	8.069±0.060	12.61±0.03	13.41±0.01	12.395±0.074
L.S.D for types					0.102
			Co		
Home Hen Eggs	4.309±0.103	2.145±0.126	0.655±0.012	3.027±0.046	2.534±0.169
Street Hen Eggs	0.937±0.055	**4.795±0.265**	3.000±0.000	4.084±0.099	3.204±0.288
Market Hen Eggs	4.075±0.058	ND	2.821±0.139	**0.010±0.001**	1.726±0.151
L.S.D for types					0.092

Parameters	Al-Buraiqeh	Al-Hiswah	Khormaksar	Shaik Othman	Mean±SD
			Cu		
Home Hen Eggs	0.621±0.011	0.504±0.006	1.115±0.017	0.731±0.001	0.743±0.021
Street Hen Eggs	0.455±0.014	0.363±0.004	0.388±0.012	**0.251±0.002**	0.364±0.019
Market Hen Eggs	0.927±0.008	**2.528±0.029**	0.474±0.007	1.476±0.023	1.351±0.038
L.S.D for types					0.011
			Zn		
Home Hen Eggs	14.85±0.25	11.78±0.38	**48.07±0.06**	28.92±0.14	25.91±0.479
Street Hen Eggs	16.26±0.21	18.22±0.29	15.18±0.17	**10.26±0.05**	14.98±0.399
Market Hen Eggs	22.92±0.25	19.73±0.25	21.71±0.50	22.54±0.05	21.73±0.614
L.S.D for types					0.21
			Se		
Home Hen Eggs	**55.00±0.01**	ND	21.01±0.02	**12.15±0.25**	22.04±0.063
Street Hen Eggs	24.21±0.26	21.96±0.15	21.91±0.16	32.12±0.11	25.05±0.357
Market Hen Eggs	26.00±0.01	17.12±0.11	36.15±0.79	47.22±0.47	31.62±0.926
L.S.D for types					0.25
			Mo		
Home Hen Eggs	ND	ND	**5.923±0.059**	**2.208±0.008**	2.033±0.059
Street Hen Eggs	3.323±0.293	4.033±0.057	ND	ND	1.839±0.298
Market Hen Eggs	ND	ND	ND	ND	ND
L.S.D for types					0.072

**ppm±SD: Concentration in part per million unit± standard deviation*

*** ND: Not detected (< 0.001 ppm)*

**** L.S.D: Least significant difference of mean values for whole eggs types at (P<0.05)*

concentration of chromium. All examined egg samples in this study were below the maximum level of chromium (1.0 ppm) in eggs according to the United States Department of Agriculture [17], except the home hen egg of Al-Hiswah that the maximum concentration of chromium. (Fig.2.1).

The results that represented in the Table 1 show the highest mean concentration of manganese (Mn) in the studied egg samples was found in market hen eggs of Shaik Othman (0.976 ppm), and the lowest mean concentration was found in street hen eggs of Al-Hiswah (0.217 ppm) (Fig. 2.2).

The concentrations of manganese reported in this study were less than those reported previously by Abdou and co-workers in Egypt who found a manganese concentration ranged from 2.178 to 2.63 ppm of fresh mass [18]. Howeve

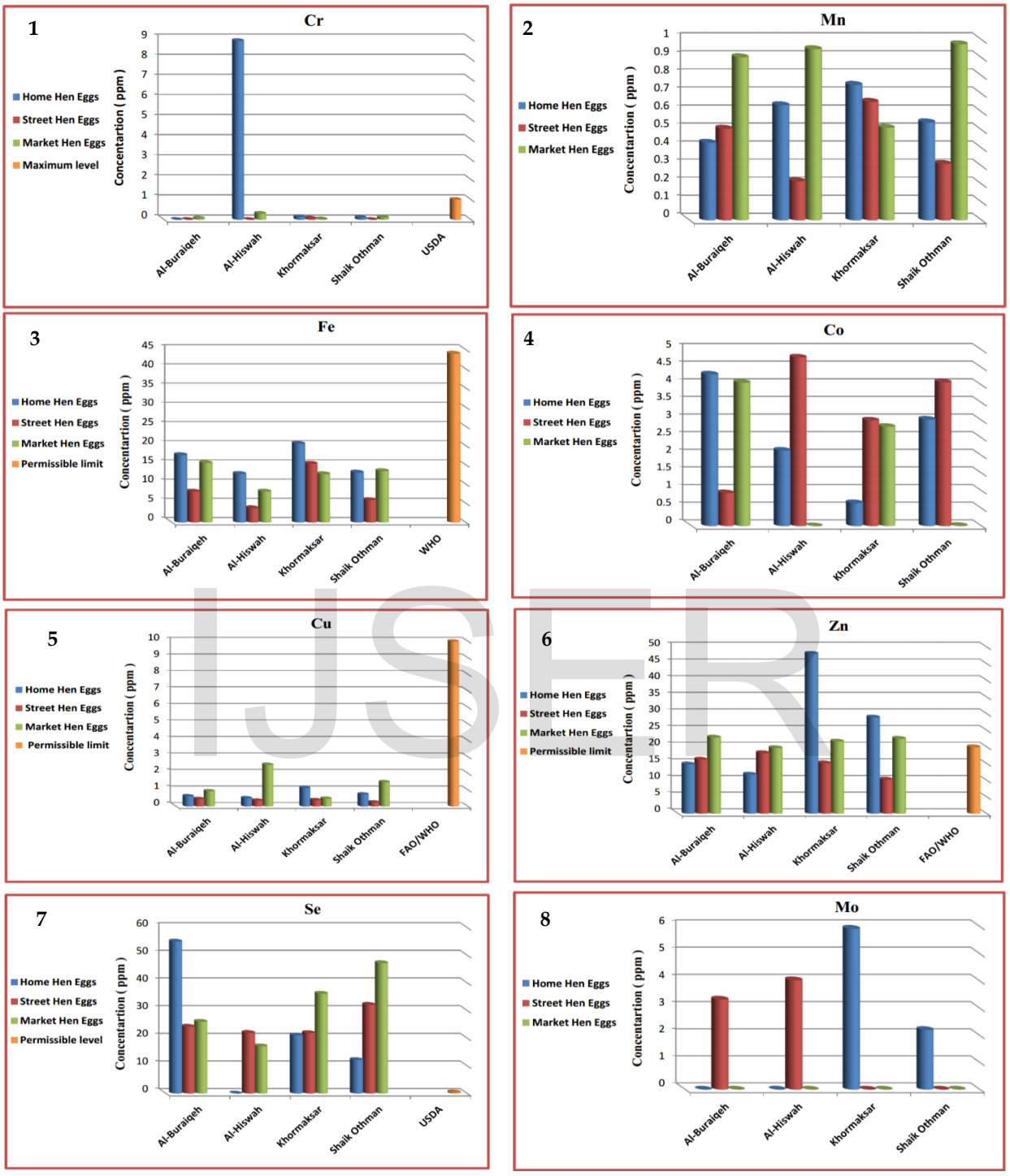

Fig. 2. Concentrations of essential trace elements (in ppm) (Figures 2.1-2.8) in egg samples collected from different areas.

the mean concentrations of manganese in our study were higher than those reported by [19] in Sudan who found the manganese content in hen's eggs (0.070 ppm). The Permissible limit for manganese in eggs range from 0.10-3.99 ppm [20] and the mean concentrations of manganese in all analyzed egg samples here were within that range above.

Table 1 declares that the highest mean concentration of iron (Fe) in the studied egg samples was found in home hen eggs of Khormaksar (20.52 ppm), and the lowest mean concentration of iron was found in street hen eggs of Al-Hiswah (3.749

ppm) (Fig. 2.3). The permissible limit of World Health Organization for iron is (44 ppm) in chicken eggs [19] and the iron contents in all examined egg samples in this study were below that limit.

In the present study, the recorded values for iron in whole eggs were lower than reported by [21] in Egypt who found that iron level ranged from 73.2 to 86.1 ppm, while the iron concentrations in this study were higher than that reported in Sudan (0.070 ppm) [19].

The highest mean concentration of cobalt (Co) in the studied egg samples was followed for street hen eggs of Al-Hiswah (4.795 ppm), but on the other hand, the lowest mean concentration of cobalt was reported in market hen eggs of Shaik Othman (0.010 ppm) (Fig. 2.4).

To compare, the mean concentrations of cobalt were higher than reported by [19] in Egypt who found that cobalt level was found 0.090 ppm.

It can be said that the highest mean concentration of copper (Cu) in the studied egg samples was found in egg samples of market hen eggs of Al-Hiswah (2.528 ppm), and the lowest mean concentration of copper was found in egg samples of street hen eggs of Shaik Othman (0.251 ppm) (Fig. 2.5).

Comparing the obtained concentrations of copper in this study with the allowed Maximum Permissible Limits (MPL) of copper in eggs decided by FAO/WHO (10 ppm) [22], the copper concentrations in all examined eggs were below than that limit, however in this study its contents in egg samples were in agreement with that reported in Malaysia [23].

The data in Table 1 show that the highest mean concentration of zinc (Zn) in the studied egg samples was found in home hen eggs of Khormaksar (48.07 ppm), and the lowest mean concentration of zinc was found in street hen eggs of Shaik Othman (10.26 ppm).

Regarding the zinc concentration in whole eggs reported in the current study, our data showed a lower concentration in this heavy metal compared to those reported by Abdou et al. in Egypt who found a zinc concentration ranged from 55.24 to 57.74 ppm of fresh mass [18]. However, the recorded values for zinc in whole eggs were similar to that reported by Saad and co-workers in Egypt [24] who stated that chicken eggs contain 15.42 ppm as commercial eggs and 23.17 ppm as local eggs except home hen eggs of Khormaksar which had higher concentration of zinc than those informed in [24]. While the concentrations of zinc were higher than those testified previously in Pakistan were ranged from 0.046 to 0.166 ppm [25].

Matching the obtained Zn concentrations in hen's eggs from this study with MPLs established by FAO/WHO [22], revealed that almost all the examined egg samples were within the allowed Zn MPL (20 ppm), however home hen eggs and market hen eggs of Khormaksar and Shaik Othman as well as market hen eggs of Al-Buraiqeh exceeded that limit (Fig. 2.6).

The highest mean concentration of selenium (Se) in the studied egg samples was found in home hen eggs of Al-Buraiqeh (55.00 ppm), and the lowest mean concentration of selenium was found in home hen eggs of Shaik Othman (12.15 ppm) (Fig. 2.7).

In the recent work, the obtained results in egg samples were higher than those reported in Brazil by Freitas's team who found the contents of selenium were (0.9, 0.6) ppm in conventional and home-produced eggs, respectively [26]. The maximum level of selenium in eggs is 0.5 ppm according to US Department of Agriculture [17] and its content in all the examined egg samples in this study were exceed that level above.

The highest mean concentration of molybdenum (Mo) in the studied egg samples was found in home hen eggs of Khormaksar (5.923 ppm), and the lowest mean concentration of molybdenum was found in home hen eggs of Shaik Othman (2.208 ppm) (Fig. 2.8).

The obtained molybdenum levels in egg samples were higher than 1.2 and 0.2 ppm in conventional and home-produced eggs, respectively [26].

4 Conclusion

From the results of the current study, we conclude that the mean concentrations of some elements in the studied hen egg samples were lower than other hen egg samples in other countries, whereas the mean concentrations of the studied elements such as zinc, selenium in some hen egg samples were exceeded the permissible limits according to Food and Agriculture Organization of the United Nations, World Health Organization and United States Department of Agriculture. While the mean concentrations of copper and iron in all the studied hen egg samples were within the permissible limits according to Food and Agriculture Organization of the United Nations and World Health Organization.

Recent study presents that the level of several essential elements in hen's eggs can be measured by ICP-OES technique and the concentrations range vary significantly among the locations and types. The bioaccumulation of metals in hen's eggs can be influenced by different factors such as metal concentration, hen's feed, exposure time, and environmental conditions. However, hen's eggs consumption can be used as a biomarker for monitoring the human health and the environment pollutants.

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