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ICP-OES Analysis of Some Nonessential Trace Elements in Hen's Eggs

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ABSTRACT

Eight trace elements (Al, V, Ni, As, Ba, Cd, Pb, and Hg) were quantitatively studied in three kinds of hen egg samples (home, street, and market hen eggs) collected from different regions in Aden city-Yemen including Al-Buraiqeh, Al-Hiswah, Khormaksar, and Shaikh Othman. Samples were wet digested and quantitatively analyzed by the Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) technique. Neglecting not detected values (ND), the range concentrations (in ppm units) of elements in hen's eggs were in the range 0.407-7.414 for Al, 0.116-0.645 for V, 0.320-3.130 for Ni, 14.35-21.21 for As, 0.180-4.700 for Cd, 1.372-4.054 for Ba, and 12.078-15.14 for Pb. Since Yemen country does not screen the explored elements in this foodstuff, the recent work was done by comparing the results with other available values reported in the literature and FAO/WHO standards. The mean concentrations of some studied elements such as arsenic, cadmium, and lead in some samples were exceeded the acceptable limits as detailed by presented international specifications and standards. The systematic national testing of hen's eggs production and the quality of environment and hen's feeds should be considered to protect public health.

استخدام ICP-OES لتحليل بعض العناصر النزرة غير الأساسية في بيض الدجاج

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الكلمات المفتاحية:
بلازما الحث المزدوج-مطياف الانبعاث الضوئي
بيض الدجاج اليمني
تراكم العناصر
العناصر غير الأساسية

الملخص

تم دراسة ثمانية عناصر نزرة (الألمنيوم، الفاناديوم، النيكل، الزرنيخ، الباريوم، الكادميوم، الرصاص، والزئبق) بشكل كمي في ثلاثة أنواع من عينات بيض الدجاج (المنزل، الشارع، والسوق) التي تم جمعها من مناطق مختلفة (البريقة، الحسوة، خورمكسر، والشيخ عثمان) في مدينة عدن – اليمن. بإهمال القيم تحت حدود الكشف(ND)، كانت التراكيز (بوحدات جزء لكل مليون ppm) من العناصر في بيض الدجاج في المدي 0.407-7.414 للألمنيوم، 0.116-0.645 للفاناديوم، 0.320-3.130 للنيكل،14.35-21.21 للزرنيخ، 0.180-4.700 للكادميوم،1.372-4.054 للباريوم، و12.078-15.14 للرصاص. نظرا لأن بلد اليمن لا يفحص العناصر التي تم استكشافها في هذه المواد الغذائية، فقد تم في هذا العمل مقارنة النتائج بالقيم الأخرى المبلغ عنها في بعض الأدبيات والمعايير الدولية المتاحة(FAO/WHO). تجاوزت تركيزات بعض العناصر المدروسة مثل الزرنيخ والكادميوم والرصاص في بعض العينات الحدود المقبولة كما هو مفصل في المواصفات والمعايير الدولية. ينبغي الأخذ في الاعتبار اجراء الاختبارات الوطنية المنهجية لإنتاج بيض الدجاج ونوعية البيئة ومراعاة حماية الصحة العامة.

Introduction

Eggs are one of nature's most nutritious and economical foods in the daily diet. Hen eggs are an important source of high-quality natural proteins, as well as lipids, fatty acids, amino acids, vitamins, and essential minerals [1-3]. The chemical composition of eggs is complicated due to the presence of many organic components that can be chelated to trace element ions, e.g. lipids of egg yolk can

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attract I, Zn, Ni, and Cr, protein ovalbumin binds Hg, Cu, Zn, Se, and Mn, but phosphoproteins and glycoprotein ovotransferrin can bind Fe ions [4]. Biochemical processes of avian organisms require such trace elements as Al, As, Co, Cr, Li, Mo, Ni, Si, Sb, and V that can accumulate in avian organs and tissues if taken up in overstated quantities by contaminated feed or from pollution. Poultry feed composition, which is different in various systems, may reflect egg yolk and albumen elemental content [4,5]. Food analysis is very important due to its association with consumer safety estimation and in the case of hens' products such as eggs, there are two major ways of contamination: by microorganisms and by chemical substances that can be transferred from the environment into the food chain [6,7].Global environmental pollution with trace elements is leading to increasing investigations concerning metal contamination of foodstuffs including eggs, which represent an important part of humans' diet, particularly kids [8]. Moreover, it is one of the few foods that are used widely worldwide and are healthy and safe for consumers, but potential contamination by toxic elements caused by geochemical structures, industrial drainage, and agricultural activities is a critical problem for human life and environmental health [8]. Hens are also exposed to nonessential elements by feed intake and could take up those elements from different environmental sources, especially via nutrition. Therefore, metal residues may concentrate in their meat, and eggs [9]. Inductively coupled plasma-optical emission spectroscopy (ICP-OES) is an analytical technique and a method of optical emission spectrometry that is used to identify/quantify the elemental compositions of a particular sample by means of the emission spectra of ionized/atomized sample molecules [10,11]. Heavy metals and trace elements are found in the environment as a result of geochemical changes in anthropogenic activities. Some of the trace elements are needed to a certain limit by living organisms to maintain normal body functions such as zinc and copper. Nonessential elements such as mercury, lead, cadmium, arsenic, and nickel have well-documented toxic effects [9]. Monitoring of such contaminants is a matter of importance for risk assessment of both animals and humans [12]. The current study was conducted to determine the levels of nonessential trace elements such as (Al, V, Ni, As, Ba, Cd, Pb, and Hg) in three types of hen eggs (home, street, and market 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 nonessential elements and to make recommendations for future implementations by the local health controlling systems.

Experimental Work

1. Sample collection

Hen's eggs were sampled in 2018-2019 from the houses and the markets at four regions of Aden city-Yemen including Al-Buraiqeh, Al-Hiswah, Khormaksar, and Shaikh Othman as shown in (Figs 1 and 2). Eggs samples were transferred into the laboratory and kept at 4 ºC until the contents were analyzed.

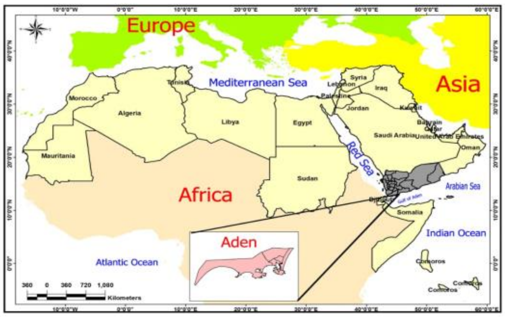


Fig. 1: A map for the Arab World indicates the location of Yemen and Aden city.

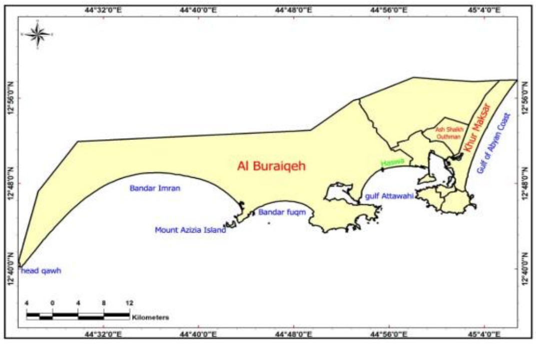


Fig. 2: A map for Aden indicates the locations of samples collection: Al-Buraiqeh, Al-Hiswah, Khormaksar, and Shaikh Othman.

2. Chemical reagents

Chemicals were in analytical grade and were used as usual without any further treatment. The stock standard solutions of Al, V, Ni, As, Cd, Ba, Pb, and Hg in concentrations 1000 mg per liter and dilution by deionized water.

3. Elemental analysis of the studied samples

The investigated nonessential elements in the eggs samples were simultaneously determined using a Thermo Scientific (iCAP 6000 series, USA) Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) instrument supported by Qtera intelligent scientific data solution (ISDS) software, and the standard method was followed as mentioned in [13]. The operating conditions of ICP-OES are given in Table 1 below.

Table 1: ICP–OES parameters.

Radio Force (RF) power	1200 W
Plasma gas (Ar) flow rate	12 L min−1
Carrier gas flow rate	0.24 L min−1
Sweeping rate	0.7 L min−1
Pumping rate	1.50 mL min−1
Plasma position	Axial
Correlation factor	0.98
Signal background correction	Fixed
Analytical wavelength (nm)	Selective

4. Preparation and digestion of eggs samples

Egg samples were washed with deionized water and then digested by hot 3:1 (HNO_3/H_2O_2) [9,14-16]. Then, the cleaned and filtrated liquid samples were kept in the refrigerator ready for analysis. The preparation and digestion of egg samples were done at the Chemistry Department Laboratories-Faculty of Education of Aden.

5. 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.

Results and discussion

Nonessential trace elements (Al, V, Ni, As, Cd, Ba, Pb, and Hg) were quantitatively determined in three kinds of hen egg samples (home, street, and market hen eggs) it can be shown in Tables 2 and 3. The highest mean concentration of aluminum in the studied egg samples was found in market hen eggs of Al-Hiswah (7.414 ppm), and the lowest mean concentration of aluminum was found in street hen eggs of Shaik Othman (0.407 ppm) (Table 2 and Fig. 3.1).

Table 2: Mean concentrations of nonessential trace elements in egg samples (ppm±SD)* dry weight.

Parameters	Al-Buraiqeh	Al-Hiswah	Khormaksar	Shaik Othman	Mean±SD
Al					
Home Hen Eggs	4.024±1.283	3.090±2.851	5.872±2.206	4.037±1.393	4.256±4.072
Street Hen Eggs	3.387±0.648	0.886±1.429	6.674±1.261	0.407±2.839	2.838±3.480
Market Hen Eggs	6.618±0.953	7.414±1.552	3.989±2.085	4.902±0.422	5.731±2.800
L.S.D for types					0.023
V					
Home Hen Eggs	0.406±0.006	0.299±0.001	0.244±0.005	0.282±0.005	0.308±0.009
Street Hen Eggs	0.309±0.010	0.645±0.020	0.281±0.007	0.528±0.528	0.441±0.528
Market Hen Eggs	0.148±0.004	0.174±0.002	0.206±0.012	0.116±0.005	0.161±0.014
L.S.D for types					0.008
Ni					
Home Hen Eggs	2.455±0.068	1.003±0.006			1.729±0.068
Street Hen Eggs	0.320±0.035	--		3.130±0.133	1.725±0.138
Market Hen Eggs	0.696±0.006	--	1.004±0.006	--	0.850±0.008
L.S.D for types					0.037
As					
Home Hen Eggs	--	19.27±0.57	--	--	--
Street Hen Eggs	--	18.47±0.44	19.18±0.31	21.21±1.4	19.617±1.499
Market Hen Eggs	17.98±0.22	--	14.35±0.43	--	16.165±0.483
L.S.D for types					0.350
Ba					
Home Hen Eggs	3.459±0.022	3.262±0.007	4.054±0.025	3.042±0.005	3.454±0.034
Street Hen Eggs	2.498±0.047	1.666±0.020	3.758±0.040	1.372±0.024	2.324±0.069
Market Hen Eggs	3.975±0.028	3.768±0.038	2.758±0.021	3.680±0.016	3.545±0.054
L.S.D for types					0.024
Cd					
Home Hen Eggs		0.180±0.002	3.806±0.182	0.431±0.019	1.472±0.183
Street Hen Eggs		4.103±0.016	--	--	--
Market Hen Eggs	4.700±0.047	3.107±0.106	4.032±0.029	3.265±0.128	3.776±0.175
L.S.D for types					0.250
Pb					
Home Hen Eggs	--	--	12.29±0.51	--	--
Street Hen Eggs	15.14±0.25	12.44±0.43	--	12.078±0.072	13.219±0.503
Market Hen Eggs					
L.S.D for types					0.160
Hg					
Home Hen Eggs	ND	ND	ND	ND	ND
Street Hen Eggs	ND	ND	ND	ND	ND
Market Hen Eggs	ND	ND	ND	ND	ND
L.S.D for types					ND

*±SD: Concentration in part per million unit ±standard deviations, ** ND: Not detected (< 0.001 ppm)*
****L.S.D: Least significant difference of mean values for whole eggs types at (P<0.05)*

The overall mean concentration of aluminum (4.275 ppm) was lower than 17.1 ppm reported in Malaysia [17]. However, the concentration of aluminum reported here was higher than those reported previously by Uluozlu [14], and Dobrza´nski et al. [18] who found the concentration of aluminum was 0.59, and 2.215 ppm, respectively. Dust is a great factor in exposure to high-level Al. Other factors can be feeding hens using gray water, contaminated food, food cooked in aluminum cook, etc. [19].

The current results indicated that the highest mean concentration of vanadium in the studied egg samples was found in street hen eggs of Al-Hiswah (0.645 ppm), and the lowest mean concentration of vanadium was found in market hen eggs of Shaik Othman (0.116 ppm) (Fig. 3.2). The overall mean concentration of vanadium was higher than those reported by Freitas de et. al. [20] in Brazil (0.053, 0.046 ppm in conventional and home-produced eggs, respectively) and in Poland [18] (0.1245±0.0597 ppm). The major source of high vanadium levels may be a hen food supply. Another source is the inhalation of the air resulting from boiler-cleaning operation [21, 22].

Table 3: Overall mean concentrations of elements in egg samples compared with values cited in the literature and maximum permissible limits (MPL) established by the FAO/WHO.

Element	Overall mean concentration for types (ppm±SD) (This study)	Overall mean concentration for sites (ppm±SD) (This study)	Literature values (in ppm)	FAO/WHO [27]
Al	4.275±1.446	4.275±1.043	17.1 (Malyasia) [17] 0.59 (Turkey) [14] 2.215±1.591 (Poland) [18]	--*
V	0.3033±0.1400	0.3032±0.0537	0.046-0.053 (Brazil) [20] 0.1245±0.0597 (Poland) [18]	--

Ni	1.4347±0.506	--	4.26-15.6 (Bangladesh) [23] 0.01-0.08 (India) [24] 0.018 ± 0.035 (Kosovo) [25]	--
As	17.89±2.441	17.82±1.492	0.12- 0.14 (Egypt) [12] 0.841±0.263 (Turkey) [26]	0.1
Ba	3.108±0.6802	3.108±0.3765	4.2-15.7 (Brazil) [20] 0.012-2.166 (Poland) [18]	--
Cd	2.624±1.629	2.743±1.063	2.34 (Turkey) [14] 0.3 (Bangladesh) [32] 0.18 (Iran) [33]	0.1
Pb	13.219±0.503	--	0.29 (Iran) [33] 0.0251± 0.0168 (Serbia) [35] 0.013-0.071 (Kosovo) [25]	0.1
Hg	ND	ND	0.00084± 0.00022 (Serbia) [35] 0.0005-0.0049 (Poland) [18]	0.1

** No report.*

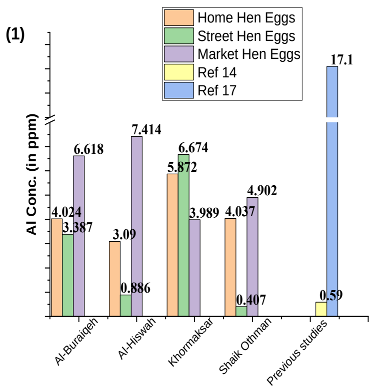
The results represented in Tables 2 and 3 show that the overall mean concentration of nickel in the studied egg samples was 1.435 ppm and the highest mean concentration was found in street hen eggs of Shaik Othman (3.130 ppm), while the lowest mean concentration of nickel was found in street hen eggs of Al-Buraiqeh (0.320 ppm) (Fig. 3.3). The obtained results in this study were lower than those reported by Zahurul et al. [23] in Bangladesh who found the nickel concentrations were (4.26, 15.6 ppm) in local and commercial hen eggs, respectively. However, the nickel concentrations in our study were higher than reported by Jagadeesh et al. in India [24] and Aliu et al. in Kosovo [25]. The high concentration levels of Ni may be related to contamination of the food composition used as hen feed and the activities of repairing and manufacturing industrial workshops near hens' places.

Tables 2, 3 declare that the highest mean concentration of arsenic in this studied egg samples was found in street hen eggs of Shaik Othman (21.21 ppm), and the lowest mean concentration of arsenic was found in market hen eggs of Khormaksar (14.35 ppm) (Fig. 3.4). The obtained results in this study were higher than those reported by Saad and Raslan [12] in Egypt who reported that chicken eggs contain (0.12 ppm) in commercial eggs and (0.14 ppm) in Balady eggs. The overall concentration of As in this work was higher than that reported in Turkey [26] by Kılıç et al and exceeded the maximum permissible limits (MPL) (0.10 ppm) established by Food and Agricultural Organization (FAO)/World Health Organization (WHO) [27] revealed that the egg samples can be related to high contamination. Arsenic in foodstuff can cause serious health impacts as arsenic can enter the food supply through the surrounding environment. The major possible factors to contaminate eggs by As are mining, fracking, spread weapons, and pesticides [28,29]. It is not possible to swap As from environment and foodstuff and so it is important to limit consumer from environment and foodstuff and so it is important to limit consumer exposure to arsenic to the greatest extent feasible.

The data in Table 2 indicate that the highest mean concentration of barium in the considered egg samples was linked to home hen eggs of Khormaksar (4.054 ppm), while the lowest mean concentration of barium appeared in the street hen eggs of Al-Hiswah and Shaik Othman (1.666, 1.372ppm), respectively (Fig. 3.5). The overall concentrations of barium (Table 3) in the present study were lower than those reported in Brazil by Freitas de et. al. [20] who were found its concentrations (4.2, 15.7 ppm) in conventional and home-produced eggs, respectively. On the other hand, the recent study represents that Ba is higher than the concentration stated in Poland [18]. Barium (as inorganic salts) can be dissolved in body fluids, have a greater potential for absorption and accumulate in foods which can then enter the hen's body and finally eggs [30,31].

The highest mean concentration of cadmium in this work was followed for market hen eggs of Al-Buraiqeh (4.700 ppm), while the lowest mean concentration of cadmium was found in home hen eggs of Al-Hiswah (0.180 ppm) (Fig. 3.6). The overall mean concentration of Cd (Table 3) was greater than those informed in the literature [14,32,33]. To compare the results in this study with the allowed maximum permissible limits (MPL) of cadmium in eggs categorized by FAO/WHO (0.1 ppm) [27] all the examined eggs exceeded that limit, except the egg samples which the cadmium concentrations were not detected in the (Table 2 and Fig. 3.6). Cadmium found in food is likely to have originated from mining or other industrial activities. Edible food organisms can concentrate Cd and then accumulate in the hen's body and at the end in eggs [30,34]. The highest mean concentration of lead in the studied egg samples was found in street hen eggs of Al-Buraiqeh (15.14 ppm) and the lowest mean concentration of lead which is detectable was found in street hen eggs of Shaik Othman (12.078 ppm) (Fig. 3.7). The obtained results in egg samples in which lead contents can be detected were higher than those reported in previous studies (Table 3) [25,33,35]. Lead concentrations recorded in this study have surpassed FAO/WHO [27] recommended concentration (0.1 ppm) where FAO/WHO value was approximately 0.66%-0.83% in comparison with recent values. Eggs exposure is mainly to inorganic lead and occurs primarily through air, diet, and drinking water [30].

In contrary with other works [18,35] and MPL value [27], the concentration of mercury was not detected in any of the studied egg samples (Tables 2 and 3). The mercury concentration levels were below the detection limits of the apparatus.



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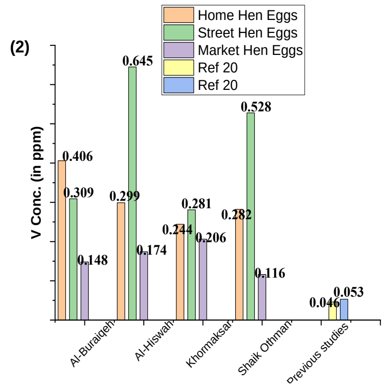

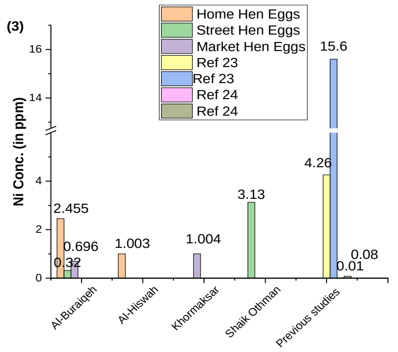

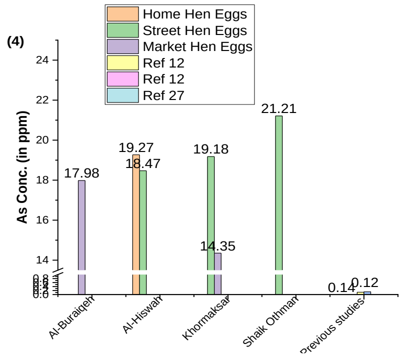

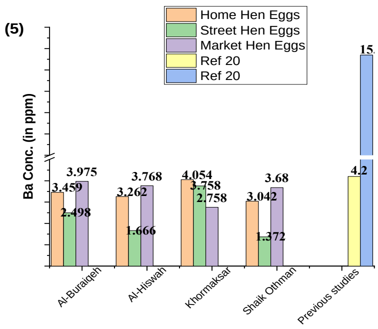

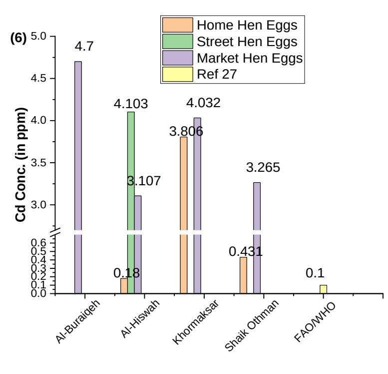

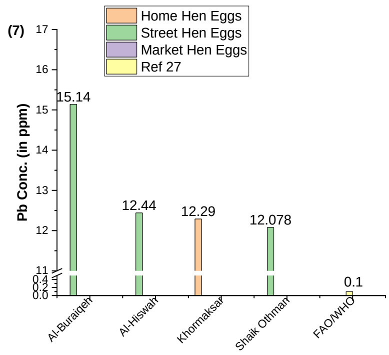

Fig. 3: Nonessential trace elements concentrations in egg samples collected from different areas.

Conclusions and recommendations

The present study revealed obvious differences between the trace elements content of hen egg samples derived from different kinds of hen egg samples, 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 arsenic, cadmium, and lead 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. The presence of illegal, detectable levels of toxic elements in eggs in Aden-Yemen directs the need for promoting good veterinary practices by all stakeholders in the hen egg chain. The levels of nonessential trace elements in a hen's egg can be measured by the ICP-OES technique and the concentration range vary significantly among the locations and species. The importance of food analysis is strongly connected with consumer safety evaluation and in the case of the research of poultry products such as eggs can be linked to the contamination by elements that can be transferred from the environment into the food chain. The probable toxicity of the studied elements varies depending on the period of exposure and the concentration level. To learn whether toxic elements will concentrate in eggs is to determine how the hen's body absorbs, uses, and releases those elements. The limitation of this study is the lack of full and new standard FAO/WHO. As a final point, the study recommends Yemen Standardization, Metrology and Quality Control Organization (YSMO) be more active by analyzing and developing standards for toxic elements in eggs.

Conflict of interest

The authors declare no conflicts of interest regarding the publication of this work.

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