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Mineral and Heavy Metals Content in Eggs of Local Hens at Different Geographic Areas in Egypt

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Abstract: The objective of this work was to estimate the heavy metals, major and trace elements contents in eggs produced from local hens in Egypt. One hundred and twelve eggs were collected from 4 sectors representing different geographic areas in Egypt. Whole eggs were dried, ashed and minerals and heavy metals were determined using atomic absorptions spectrophotometry. Results indicated that zinc, copper, manganese, calcium, magnesium, potassium, lead and arsenic were higher in the egg samples collected from Middle Delta sector. Iodine, iron and cadmium were found in the highest concentrations in the egg samples collected from North Delta sector. However, selenium concentration was higher in the egg samples collected from South Delta sector. On the other hand, the egg samples collected from upper Delta sector showed the lowest concentration in all tested elements. It could be concluded that egg produce in Egypt is deficient in trace elements due to the deficincy of these elements in diets and or other environmental factors.

Key words: Trace and major elements · Heavy metal · Egg · Hens · Egypt

INTRODUCTION

The pollution of food products with environmental contaminants becomes more and more documented. In general, data about contaminants in food are gathered to obtain information on background concentrations in view of intake and associated risk assessments. Although most metals are known to be toxic to many organisms at higher concentrations, several of them also participate in important metabolic and signalling pathways [1]. Moreover, trace elements iodine, selenium, zinc, iron, copper and manganese are essential for human and animal nutrition consequently they are supplemented in animal diets and there is a relationship between doses and sources of these elements for animals, accumulation in tissues and products, excretion from the organism and accumulation in soil and plants [2]. On the other hand, synthesis, metabolism and action of thyroid hormones require availability of selenium and iodine and adequate levels of these elements affect the homeostasis of thyroid hormone dependent metabolic pathways [3,4].

Egg is a highly nutritious food and can be an effective delivery system for health-regulating nutrients and especially for selenium in humans [5] and meat and eggs from hens fed commercial corn-soybean diet are a potential source of Se for humans [6].

According to Gochfeld [7], toxic metals such as Cr, Mn and Pb are passed to eggs by hens. Several reports indicated that food of animal origin can be a good source for iodine depending on the feed of the animal [8-10]. So, natural eggs can significantly contribute to overcoming dietary deficits [11]. According to the recent published reports, Iodine amount in eggs varies in relation to Iodine intake of the hen and that a larger portion of egg iodine is present in the yolk [12,13].

Copper, iron and manganese, beside zinc, belong to the most important, basic microelements that are standardized in poultry feeding. They are accumulated in tissues and organs of birds and also in the content and shells of egg in quite different concentrations, dependent on a dose and form of these elements as well as on many other factors, including physiological ones [14].

Eggs are well known functional foods for humans [5]; however, despite substantial interest in the trace element content of eggs by poultry breeders, nutritionists and environmental scientists, available data about different

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Fig. 1: A map for Egypt indicated the locations of samples collection.

elements levels in eggs are scarce. So the objective of this work was to assay different elements and heavy metals (i.e. iodine, selenium, zinc, iron, copper, manganese, calcium, sodium, potassium, magnesium, lead, arsenic and cadmium) concentrations in egg components of local hens in different geographic areas in Egypt.

MATERIALS AND METHODS

Sampling: One hundred and twelve eggs of local hens were collected from four sectors representing different geographic areas in Egypt during 2007. These sectors were: (1) North Delta; represented by Alexandria governorate, (2) Middle Delta; represented by Menoufia governorate, (3) South Delta; represented by Cairo governorate and (4) Upper Egypt; represented by Sohag governorate (Fig. 1). Twenty eight eggs were purchased from the local market in each governorate.

Egg Perpetration and Analysis: Within each sector, whole egg was dried and ashed at 105 and 450°C, respectively. The analysis of iodine content was carried according to the method described by Sandell and Kolthoff [15] as modified by Groppel *et al.* [16]. Selenium content was carried out according to Brown and Watkinson [17] using a semiautomated fluorometric. The analysis of the zinc, iron, copper, manganese, calcium, magnesium, sodium, potassium, lead, cadmium and arsenic were carried out using atomic absorptions spectrophotometry (AAS III, Carl Zeiss Jena, Germany). All elements were analyzed in Institute of Nutrition and Environment, Friedrisch-Schiller Uni. Jena, Germany.

Statistical Analysis: All data were subjected for statistical analysis using the General Linear Model Procedure of the Statistical Analysis System [18]. The significance of the differences among treatment groups was determined by Waller-Duncan k-ratio [19]. All statements of significance were based on probability of $P \leq 0.05$.

RESULTS AND DISCUSSION

Results presented in Table 1 showed that eggs obtained from Upper Egypt sector were poor in their iodine content, being only almost half as low ($P \leq 0.001$)

as iodine content of eggs of North, Middle or South Delta sectors, which had similar iodine content. The same trend was observed when minimum and maximum egg iodine content was considered. In this concern, Kaufmann *et al*. [8] reported that iodine concentration in eggs significantly increased with increasing iodine intake of the hens. Moreover, FAO/WHO [20] reported that iodine content of fresh eggs is 93 µg/100g can significantly contribute to overcoming dietary deficits and suggested that iodine content of food varies with geographic location. The recorded values for iodine in whole were similar to that reported by Kaufmann [21] who reported that hen eggs contain 1135 ± 205 µg iodine per kg of yolk fresh matter and 49 ± 14 µg iodine per kg of albumen fresh matter.

Results of selenium concentration in whole eggs (Table 1) showed that eggs obtained from Upper Egypt sector were found to be poor in selenium content compared to selenium content of eggs collected from North, Middle or South Delta sectors. The same data showed that eggs collected from South Delta had the highest selenium content. These results reflex the selenium content in the feed consumed by the hen. Payne *et al*. [22] stated that selenium concentration in the whole egg from hens fed the basal diet was 0.249 ppm. Moreover, Surai [23] and Payne *et al.* [22] showed that selenium level in whole egg was linearly increased ($P \leq 0.01$) as dietary selenium level increased. In this regards, selenium level of the eggs collected from the Chamfrains Islands was lower than those of the Ebro Delta which was attributed to the differences in both the marine contamination and the diet in the two colonies [24].

The current results indicated that zinc contents in eggs of Egyptian local hens did not differ significantly among the four studied sectors (Table 1). Minimum values of zinc in eggs were also similar among the different sectors except for of Middle Delta which was showed an observed higher value. Moreover, the maximum values were similar except for the eggs collected from Upper Egypt which showed an observed lower value (Fig.2). Although the literature contains different values for zinc in eggs, Inal *et al.* [25] found that the zinc level of the egg yolk of Hisex brown laying hens was 136 mg/kg. However, depending on a system of hen's husbandry, the concentration of zinc in the egg was found 97.7, 131.1 and 135 mg/kg of fresh mass [26-28]. These results suggested that zinc levels of egg contents increased linearly as dietary Zn levels increased [29].

No significant differences were found in iron content of eggs collected from North, Middle and south Delta however, lower iron content was found in eggs obtained from Upper Egypt (Table 1). These data were lower than those reported by Fakayode and Olu-Owolabi [30] who found that the concentration of iron in eggs from hens was found to be 232 mg/kg however; Egg cyclopedia [31] reported a 144 mg/kg of fresh mass. On the other hand, Copper content in eggs obtained from South Delta sector tended to be lower compared to those in eggs obtained from the other sectors (Table, 1). These results were in the range reported earlier by Elmadfa and Muskat [28] who found that cupper level ranged from 5 to 23 mg/kg fresh mass while; Uzlęblo *et al*. [32] claimed that copper concentration ranged from 4.9-7.0 mg/kg fresh mass.

The results clearly indicated that Manganese content in eggs collected from Middle Delta was higher significantly ($P \leq 0.05$) compared to its content in egg obtained from other sectors which was almost similar (Table 1). The concentrations of Mn reported herein were lower than those reported previously by Zbigniew *et al.* [33] who found a concentration ranged from 3.92 to 4.82 mg/kg of fresh mass and Elmadfa and Muskat [28] who reported a Mn concentration of 3 mg/kg of fresh mass. However, Dobrzañski *et al.* [34] reported that Mn concentration in the eggs ranged from 2.74 to 2.35 mg/kg fresh mass. On the other hand, concentrations of Mn did not differ among the eggs samples of California cities of Riverside, Los Angeles and San Francisco [35].

In general, Fakayode and Olu-Owolabi [30] found strong positive correlations between the levels of metals in the feeds and the corresponding levels of metals in the eggs. The overall average concentrations (mg/kg) of each metal in eggs were as follows: copper, 0.78, iron, 23.20 and zinc, 13.75. The concentrations of metals in eggs reported in the current study did not differ appreciably from levels determined in eggs from other countries. Mabe *et al.* [36] showed that addition of Zn, Mn and Cu to a basal corn-soybean meal diet increased these metal concentrations in egg yolk. Furthermore, Skrivan *et al.* [2] reported that the concentration of these metals in egg yolk from hen fed basal diet were 70.4, 116.5 and 3.32 mg/kg dry matter respectively. While the concentrations of these metals in white egg were 11.5, 3.15 and 133 mg/kg dry matter, respectively. These results also may explain the differences in bioaccumulation of the metal content in the eggs laid by hens from industrialized and agricultural regions [37].

The results of microelements contents presented in Table 2 revealed that the low calcium and magnesium content was found in the eggs collected from Upper Egypt and the higher content of these elements was found in the eggs collected from the Middle Delta (Fig. 3).

Table 1: Trace elements concentrations in eggs collected from different Egyptian sectors (means ± SE) Within the same row, means superscript with different letters (a, b, c) are significantly different ($P < 0.05$).

	Sector											
	North Delta			Middle Delta			South Delta			Upper Egypt		
Element	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE
Iodine (µg/kg DM)	298	841	$518 \pm 31.8^{a*}$	246	887	$504 \pm 46.8^{a*}$	227	817	$491 \pm 52.7^{a*}$	136	425	$261 \pm 22.9^{b*}$
Selenium (µg/kg DM)	0.02	0.85	0.31 ± 0.1†	0.03	0.63	0.25 ± 0.1†	0.3	1.22	0.41 ± 0.13†	0.01	0.41	0.19 ± 0.07†
Zinc (mg/kg DM)	38.6	74.9	58.6 ± 1.37	42.04	129.45	64.3 ± 4.9	42.0	68.5	57.6 ± 1.36	22.5	81.1	56.8 ± 2.89
Iron (mg/kg DM)	60.4	117.3	86.1 ± 2.9^{ab}	57.28	114.51	77.1 ± 3.4^{cb}	59.2	110.94	80.9 ± 3.1^{cb}	32.9	103.55	73.2 ± 3.7^{c}
Copper (mg/kg DM)	0.62	15.5	6.1 ± 0.5	3.2	13.4	6.7 ± 0.6	3.09	9.3	5.6 ± 0.3	1.98	11.1	6.1 ± 0.4
Manganese (mg/kg DM)	0.57	1.82	1.13 ± 0.1^{b}	0.73	4.41	1.59 ± 0.2^{a}	0.73	1.33	1.02 ± 0.04^{b}	0.5	1.5	0.93 ± 0.1^{b}

Table 2: Microelements and heavy metals concentrations in eggs collected from different Egyptian sectors (means ± SE)

	Sector			
	North Delta	Middle Delta	South Delta	Upper Egypt
Element	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Calcium (mg/kg DM)	2354 ± 51.35^{a}	2588 ± 191.2^{b}	2430 ± 63.61^{a}	2297 ± 104.1^{c}
Magnesium (mg/kg DM)	421.8 ± 7.27^{a}	442.6 ± 25.59^{b}	431.9 ± 11.24^{a}	388.1 ± 20.48^{c}
Sodium (mg/kg DM)	4.09 ± 0.09^{a}	4.09 ± 0.21^{a}	3.75 ± 0.14^{b}	3.57 ± 0.21^{b}
Potassium (mg/kg DM)	4.75 ± 0.14^{a}	4.80 ± 0.24^{a}	4.46 ± 0.12^{a}	4.07 ± 0.24^{b}
Lead (mg/kg DM)	0.228 ± 0.04^{a}	0.303 ± 0.07^{b}	0.178 ± 0.02^{c}	0.172 ± 0.02^{c}
Cadmium (mg/kg DM)	0.015 ± 0.005^{a}	0.012 ± 0.003^{a}	0.006 ± 0.001^{b}	0.007 ± 0.002^{b}
Arsenic (mg/kg DM)	0.025 ± 0.004^{a}	0.033 ± 0.004^{a}	0.023 ± 0.004^{a}	0.029 ± 0.006^{a}

Within the same row, means superscript with different letters (a,b,c) are significantly different ($P < 0.05$).

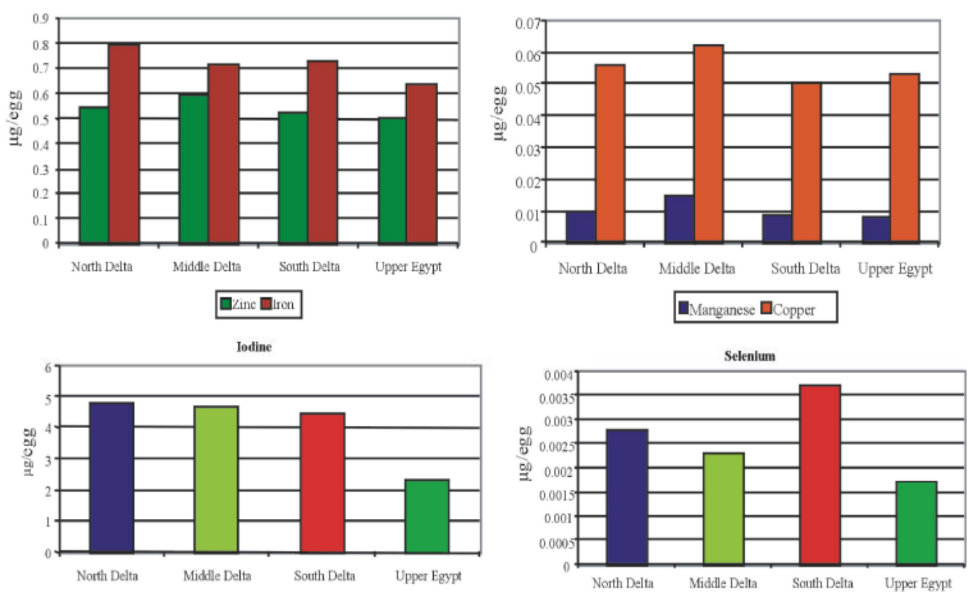

Fig. 2: Trace elements concentrations in egg based on dry matter content.

The higher calcium concentration in eggs collected from Middle Delta reported in the current study may be due to the its higher content in the feed since the higher calcium requirements for the female during egg production may be resulted in increased calcium absorption in the gut and consequently increased it content in eggs [38].

Table 2 shows that eggs collected from North and Middle Delta contain the same higher concentration of sodium and the same lower concentration was found in the eggs collected from South Delta and Upper Egypt. The same data (Table 2) indicated that eggs collected from Upper Egypt contain the lower concentration of

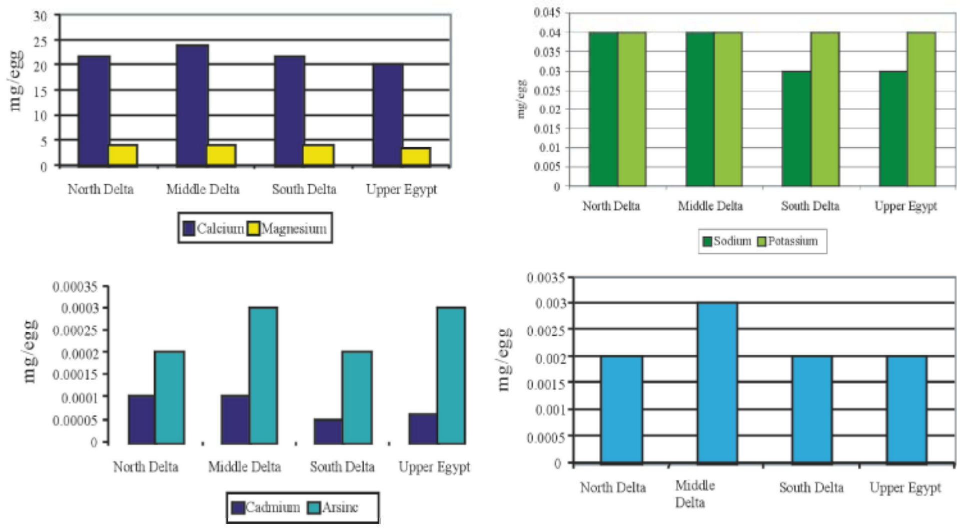

Fig. 3: Microelements and heavy metals content in eggs based on dry matter content.

potassium however; the higher concentration of potassium was found in the eggs collected from Middle Delta followed by those collected from North Delta.

Eggs collected from Middle Delta was found to contain the higher concentration of lead followed by the eggs collected from North Delta however; eggs collected from Upper Egypt contained the lower lead concentration. It was of interest to mention that eggs collected from South Delta and Upper Egypt were contained the lower cadmium content however; the samples collected from North and Middle Delta were found to contain the higher cadmium content. Furthermore, the higher arsenic concentration was found in the samples collected from Middle Delta followed by the samples collected from Upper Egypt. However, the samples collected from North and South Delta was found to contain the lowest arsenic concentration (Table 2). Similar results were reported by Hui [35] who reported a higher concentration of lead in eggs collected from California cities although this author did not establish a concentration of lead in egg that impairs avian health, the highest concentrations found was exceed the estimated safe concentrations. Regarding the cadmium concentration in egg reported in the current study, our data showed a lower concentration in this heavy metal compared to those reported in the literature [40]. On the other hand, arsenic content was found in a low concentration and the results were comparable with those reported in the previous reports [41-42].

Based on the dry and fresh weight of eggs, the estimated daily intake of each metal or trace elements revealed that the people at the four sectors are not under risk. Suppose that each person consumes 2 eggs per day, thus the estimated daily intake is within the safe limits suggested by the Egyptian and CODEX standards.

In Conclusion, local hens in Egypt produce eggs very deficient in their trace elements iodine, selenium, zinc, iron, copper and manganese content, particularly in Upper Egypt sector. On the other hand, calcium and magnesium were higher however; sodium, potassium, cadmium, lead and arsenic were found to be in the normal range reported in the literature. The deficiency in trace elements reported herein may be due to deficincy of these elements in diets and or other environmental factors.

REFERENCES

1. Valko, M., H. Morris and M.T.D. Cronin, 2005. Metals, toxicity and oxidative stress. Curr. Med. Chem., 12: 1161-1208.
2. Skrivan, M.V., M. Skrivanova and M. Marounek, 2005. Effects of dietary zinc, iron and copper in layer feed on distribution of these elements in eggs, liver, excreta, soil and herbage. Poul. Sci., 84: 1570-1575.
3. Arthur, J.R. and G.J. Beckett, 1999. Thyroid function. Br. Med. Bull., 55: 658-668.
4. Köhrle, J., F. Jakob, B.Contempré and J.E. Dumont, 2005. Selenium, the thyroid and the endocrine system. Endocr. Rev., 26: 944-984.
5. Surai, P.F. and N.H.C. Sparks, 2001. Designer eggs: from improvement of egg composition to functional food. Trends. Fd. Sci. Tech., 12: 7-16.

6. Pan, C., K. Huang, Y. Zhao, S. Qin, F. Chen and Q. Hu, 2007. Effect of selenium source and level in hen's diet on tissue selenium deposition and egg selenium concentrations. J. Agric. Food Chem., 3: 1027-32.
7. Gochfeld, M., 1997. Spatial patterns in a bioindicator: heavy metal and selenium concentration in eggs of herring gulls (*Larus argentatus*) in the New York, Bight. Arch. Environ. Contamin. Toxicol., 33: 63-70.
8. Kaufmann, S., G. Wolfram, F. Delange and W.A. Rambeck, 1998. Iodine supplementation of laying hen feed: A supplementary measure to eliminate iodine deficiency in humans? Zeitschrift für Ernährungswissenschaft, 37(3): 288-293.
9. Cerovská, J., R. Bílek, H. Zamrazilová, P. Hoskovcová and M. Vosátková, 2006. Changes in iodine supply in adult Czech population after iodine deficit eradication and causes. Random study of adults in two regions in the Czech republic with in between period of 5 years. Vnitr. Lek., 52(10): 858-863.
10. Franke, K., F. Schöne, A. Berk, M. Leiterer and G. Flachowsky, 2008. Influence of dietary iodine on the iodine content of pork and the distribution of the trace element in the body. Eur. J. Nutr., 47(1): 40-46.
11. Bourre, J.M. and F. Galea, 2006. An Important Source of Omega-3 Fatty Acids, Vitamins D and E, Carotenoids, Iodine and Selenium: A New Natural Multi-enriched Egg. J. Nutr. Health. Aging, 10(5): 371-376.
12. Travnicek, J., V. Kroupova, I. Herzig and J. Kursa, 2006. Iodine content in consumer hen eggs. Vet. Med., 51(3): 93-100.
13. Wilder, O.H.M., R.M. Bethke and P.R. Record, 2008. The iodine content of hens' eggs as affected by the ration. J. Nut., 6(4): 407-12.
14. Smulikowska, S. and A. Rutkowski, 2005. Recommended allowances and nutritive value of feedstuffs. poultry feeding standards (in Polish). 4th Edition. The Kielanowski Institute of Animal Physiology and Nutrition, PAS, Jabonna (Poland) and Polish Branch of WPSA.
15. Sandell, E.B. and I.M. Kolthoff, 1937. Micro-determination of iodine by catalytic method. Mikrochim Acta, 1: 9-25.
16. Groppel, B., A. Hennig, M. Anke, E. Scholz and B. Koehler, 1988. Supply and status of iodine in ruminants. XI. Influence of iodine supply upon iodine content in milk. Proc. Macro-and Trace Element Seminar, University Leipzig-Jena, Germany. pp: 428.
17. Brown, M.W. and J.H. Watkinson, 1977. An automated fluorimetric method for determination of nanogram quantities of selenium. Anal. Chim. Acta, 89: 29-35.
18. SAS. 1982. SAS user's guide: Statistics, SAS Institute Inc, Cary, NC.
19. Waller, R.A. and D.B. Duncan, 1969. A Bayes rule for the symmetric multiple comparison problems. J. Am. Stat. Assoc., 64: 1484-1503.
20. FAO/WHO. 2002. Iodine. *In: Human vitamin and mineral requirements*. Report of a Joint FAO/WHO Expert Consultation. FAO, Rome. pp: 181-194.
21. Kaufmann, S., 1997. Ergänzende Strategien zur Bekämpfung von Jodmangel in Deutschland und Südostasien: Jodanreicherung in lebensmitteln tierischen Ursprungs. (Dissertation) Institut für Ernährungswissenschaft der Technischen Universität, München. pp: 95.
22. Payne, R.L., T.K. Lavergne and L.L. Southern, 2005. Effect of inorganic versus organic selenium on hen production and egg selenium concentration. Poult. Sci., 84(2): 232-237.
23. Surai, P.F., 2000. Effect of selenium and vitamin E content of the maternal diet on the antioxidant system of the yolk and the developing chick. Br. Poult. Sci., 41(2): 235-243.
24. Sanpera, C., M. Morera, X. Ruiz and L. Jover, 2000. Variability of mercury and selenium levels in clutches of Audouin's gulls (*Larus audouinii*) breeding at the Chafarinas Islands, Southwest Mediterranean. Arch. Environ. Contam. Toxicol., 39(1): 119-123.
25. Inal, F., B. Coşkun, N. Gülşen and V. Kurtoğlu, 2001. The effects of withdrawal of vitamin and trace mineral supplements from layer diets on egg yield and trace mineral composition. Br. Poult. Sci., 42(1): 77-80.
26. Dobrzański, Z., H. Gorecka, T. Trziszka and H. Gorecka, 1999. Concentration of macro-and microelements in the eggs of hens housed in three different systems. Proc. VIII Europ. Symp. Quality of Eggs and Egg Product. Bologna, Italy. pp: 283-287.
27. Żmudzki, J., T. Juszkiewicz, A. Niewiadomska, J. Szkoda, S. Semeniuk, A. Golęblowski and K. Szyposzynski, 1992. Chemiczne skaŻenia bydta, mlka Ijij wregionie zgorzelecko-bogatyñskim. Med. Wet., 48(5): 213-217.
28. Elmadfa, I. and E. Muskat, 2003. Wielkie tabele kalorii wartaści odŻywezych. Wyd. MUZA S.A. Warszawa.
29. Kim, W.K. and P.H. Patterson, 2005. Effects of dietary zinc supplementation on hen performance, ammonia volatilization and nitrogen retention in manure. J. Environ. Sci. Health B, 40: 675-686.

30. Fakayode, S.O. and I.B. Olu-Owolabi, 2003. Trace metal content and estimated daily human intake from chicken eggs in Ibadan, Nigeria. Arch. Environ. Health, 58(4): 245-251.
31. Egg cyclopedia. 1994. Am Egg Board. Park Ridge, Illinois, USA.
32. Uzlęblo, L., M. Ligocki, B. Hapanowicz and K. Romaniszyn, 1993. Zawartość niektórych metali ciężkich i fluoru w iajach o różnym pochodzeniu. Bromat. Chem. Toksykol., 20: 91-96.
33. Zbigniew, D., K. Mariusz, C. Katarzyna, G. Henryk and O. Sebastian, 2008. Influence of organic forms of copper, manganese and iron on bioaccumulation of these metals and zinc in laying hens. J. Elementol., 13(3): 309-319.
34. Dobrzañski, Z., H. Gorecka, G. Strzelbicka, J. Szczypel and T. Trziszka, 2001. Study on enrichment of hen eggs with selenium and iodine, EJPAU, Ser. Anim. Husb., 4(2): 2-6.
35. Hui, C.A., 2002. Concentrations of chromium, manganese and lead in air and in avian eggs. Environ. Pollut., 120(2): 201-126.
36. Mabe, I., C. Rapp, M. Bain and Y. Mys, 2003. Supplementation of a corn-soybean meal diet with manganese, copper and zinc from organic or inorganic source improves eggshll quality in aged laying hens. Poult. Sci., 82(12): 1903-1913.
37. Dobrzañski, Z., H. Gürecki, R. Kołacz, H. Gürecka and T. Trziszka, 2004. Zawartość metali cię¿kich wtreści jaj kurzych z chowu przyzagrodowego. Acta. Sci. Pol. Ser. Zoot., 3: 249-253.
38. Kottferova, J., B. Korenekova, P. Siklenka, A. Jackova, E. Hurna and J. Saly, 2001. The effect of Cd and vitamin D3 on the solidity of the eggshell. Eur. Food Res. Technol., 212: 153-155.
39. Gómara, B.G. Gómez, C. Dýáz-Paniagua, A. Marco and M.J.González, 2007. PCB, DDT, arsenic and heavy metal (Cd, Cu, Pb and Zn) concentrations in chameleon (*Chamaeleo chamaeleon*) eggs from Southwest Spain. Chemosphere, 68: 25-31.
40. Whitworth, M.R., G.W. Pendleton, D.J. Hoffman and M.B. Camardese, 1991. Effects of dietary boron and arsenic on the behavior of mallard ducklings. Environ. Toxicol. Chem., 10: 911-916.
41. Trumbo, P., A.A. Yates, S. Schlicker and M. Poos, 2001. Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium and zinc. J. Am. Diet. Assoc., 101: 294-301.
42. Marco, A., M. Lopez-Vicente and V. Perez-Mellado, 2004. Arsenic uptake by reptile flexible-shelled eggs from contaminated nest substrates and toxic effect on embryos. Bull. Environ. Contam. Toxicol., 72: 983-990.