Pak. J. Agri. Sci., Vol. 60(3),307-313;2023
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI:10.21162/PAKJAS/23.51
http://www.pakjas.com.pk

Variation in element contents among free-range turkey egg yolks and albumens analyzed by inductively coupled plasma optical emission spectrometry

Serap Kılıç Altun[1*], Nilgün Paksoy[2] and Hatice Kara[3]

[1]Department of Food Hygiene and Technology, Faculty of Veterinary Medicine, The University of Harran, Şanlıurfa 63200, Türkiye; [2]Department of Biochemistry, Faculty of Veterinary Medicine, The University of Harran, Şanlıurfa 63200; [3]GAP Agricultural Research Institute, Şanlıurfa 63200
Both the authors contributed equally
*Corresponding author's e-mail: skilicaltun@harran.edu.tr

Poultry eggs are not only a source of nutrients for embryonic development, but also one of the main sources of food for humans. The demand for turkey eggs is increasing day by day due to their functional properties such as supporting muscle and cell formation and being beneficial to the immune and digestive systems. In addition, it contains essential elements such as iron at a reasonable level, which is among the reasons for the consumer's preference. The data on the element content of free-range turkey eggs, which is such an ancient food, is very scarce. This study focused on determining various element content of free-range turkey egg yolk and albumen by inductively coupled plasma optical emission spectrometry (ICP-OES). Within the scope of the research, sodium (Na), potassium (K), calcium (Ca), phosphorus (P), iron (Fe), manganese (Mn), magnesium (Mg), copper (Cu), zinc (Zn), chromium (Cr), boron (B), aluminum (Al), and lead (Pb) levels were determined in turkey egg yolk (n=52) and albumen (n=52) samples. Phosphorus was the most concentrated element in both egg yolk and albumen. Element contents in yolks were higher than those in albumen, except Na, K, B, Al, and Pb. The element with the lowest concentration was Al in turkey egg yolks, while Mg was the lowest analyzed element in albumens. This study separately exhibited the element content of turkey egg consumers in their preference for egg yolk or albumen.
Keywords: Element, free-range, turkey, egg yolk, egg albumen.

INTRODUCTION

Demand for poultry products is increasing rapidly all over the world. There are two main reasons for this increase. First; the increase in the consumer population, where fast-food and ready-to-eat food consumption habits are developed, and the other is the increase in the demand for low-energy, cheap but quality protein sources. Domestic poultry eggs, although designed as a cell containing all the nutrients for embryonic development, have for centuries become one of the main food sources for humans (Cotterill *et al.*, 1978; Sun *et al.*, 2019).

Egg yolk is a perfect origin of proteins, lipids, phospholipids, and elements. This is normally owing to its composition. Egg yolk contains water (50.1 %), 30.6 lipids (30.6 %), 17 proteins (17 %), minerals (1.7 %), and carbohydrates (0.6 %) (Board *et al.*, 1995). Egg yolk is an ingredient with different valuable properties that can be used for various uses both in food and in different fields. It is widely used in cosmetic cream formulations, the freeze preservation of packaged foods, and the production of pro-inflammatory mediators in the healthcare industry. It is also used as a preservative and emulsion stabilizer. It is also included in the formulation of infant formula for brain development in infants (Shapira, 2009).

According to Campbell *et al.* (2003), egg albumen, which makes up about 60 % of the egg, is primarily made up of water (88 %), proteins (11 %), minerals, and carbohydrates (1 %). Egg albumen has emulsifying, foaming, adhesive, stabilizing, and gelling properties thanks to a number of its components (Abeyrathne *et al.*, 2014). According to Xu *et al.* (2017), egg albumen is a quick and efficient medical adhesive for bone regeneration. In addition to its use as an egg albumen, it is a material used for packaging films, bioceramics, bioplastics, biomimetic films, hydrogels, biopatterning, biosensors (Dong and Zhang, 2021). However, research on egg yolk and albumen properties is mostly limited to chicken eggs. Attention should be paid to the composition and properties of turkey eggs, which will help in the technological and functional application of turkey eggs.

It is important to diversify different poultry egg applications

Altun, S.K., N. Paksoy and H. Kara. 2023. Variation in element contents among free-range turkey egg yolks and albumens analyzed by inductively coupled plasma optical emission spectrometry. Pakistan Journal of Agricultural Sciences 60:307-313.
[Received 22 Mar 2023; Accepted 30 Jul 2023; Published 29 Sep 2023]
Attribution 4.0 International (CC BY 4.0)

to increase overall egg production and consumption. Multiple products, each with use in food processing, nutritional supplements, pharmaceuticals, cosmetics and other fields, can be separated from chicken eggs and used as is or in a modified form (Trziszka *et al.*, 2007). Turkey eggs are a commonly consumed food source rich in protein, healthy fats, vitamins, and minerals. Turkey eggs' nutritional benefits and frequent use in a variety of meals, including baked products, pasta, and mayonnaise, have increased in recent years (Onwenyeaku, 2018). Turkey eggs can be an excellent starting material for producing new functional products that can be used as ingredients for both food products and health products. For a wider variety of uses, further studies on its components should focus specifically on its elements. It is a fact that layer rearing and housing systems have an impact on egg quality. It would seem fair to investigate eggs from free-range systems as opposed to the frequently generated and examined eggs from cages (Trziszka *et al.*, 2007). Therefore, this study focused on the determination of various elemental contents of free-range turkey egg yolk and albumen by ICP-OES.

MATERIALS AND METHODS

***Sample collection*: The eggs (n=52) of free-range turkey were purchased from two different poultry farms located in the rural areas of Diyarbakır (37° 54' 36.00" N: 40° 14' 24.00" E) and Şanlıurfa (37° 10' 1.49" N: 38° 47' 38.11" E) provinces of Türkiye. The breed of this poultry was American Bronze Turkey (48-52 weeks old). Eggs were transported at 4°C to the laboratory within 4 hours. Egg samples were kept for a short time at 20-21°C in a lightless place until analysis. The eggs are from American Bronze turkeys that leave from the coop to the pastures to the harvested fields at sunrise and return to the hens in the evening. Apart from this, they were not fed any other ration.

***Equipments*:** Elemental analysis was performed on an ICP-OES (Optima 7000 S10, Perkin Elmer, USA). For the digestion procedure, (sample pretreatment) a microwave oven (MARS Xpress CEM, USA) is large in diameter, doing sample addition and cleaning as easier was used.

***Solutions and reagents*:** A water purification system (MES MP Minipure, Turkey) that uses distilled water to produce ultrapure water was used to make all solutions. Except as otherwise noted, all of the reagents were of analytical grade. The elements' standard solution was obtained from Agilent Japan's 10-160YPY2 standard solution. Nitric acid (65 % volume concentration of HNO_3, Merck, Germany) and strong hydrogen peroxide (30 % volume concentration of H_2O_2, Merck, Germany) were used to digest all samples. Spike solutions were provided as a multi-element solution from stock solutions (Merck, Germany).

***Analysis process*:** The yolk and albumen of the turkey eggs were taken into separate falcon tubes. A total of 1.0±0.2 g of egg yolk and albumen were weighed and put in the proper microwave sample boats, and then put in teflon TFM flasks. Then, 6.00 mL of HNO_3 65 % and 2.0 mL of H_2O_2 30 % were added. Then, flasks were closed and placed into the microwave rotor and digested in 3 stages: 100 % power at 120 °C for 7 min, 100 % power at 160 °C for 5 min, and 100 % power at 210 °C for another 20 min. A cooling step to 22°C was then applied for about 40 minutes. Quantitatively, the finished solution was transferred to a polypropylene tube and filled up to 50.00 mL with ultrapure water. Since the microwave oven has a capacity of 40 vessels, 39 samples and 1 blank digested are simultaneously in each batch. The operating parameters of ICP-OES for the analysis were as follows: 1450 W RF Power, 17 L min^{-1} plasma argon flow rate, 0.2 L min^{-1} auxiliary argon flow rate, 0.60 L min^{-1} nebulizer argon flow rate, 1.5 mL min^{-1} sample uptake rate, with a concentric nebulizer and cyclonic spray chamber (Altun *et al*., 2018).

Table 1 shows detailed instrumental parameters for ICP-OES. This protocol was previously determined by performing preliminary batches with recoveries, and the particle-free structure of the target final solution was observed showing a clear and satisfactory matrix.

The concentrations of 13 elements (Na, K, Ca, P, Fe, Mn, Mg, Cu, Zn, Cr, B, Al, and Pb) were determined in turkey egg samples. The isotopes $^{23}Na^+$, $^{39}K^+$, $^{44}Ca^+$, $^{31}P^+$, $^{56}Fe^+$, $^{55}Mn^+$, $^{24}Mg^+$, $^{63}Cu^+$, $^{66}Zn^+$, $^{52}Cr^+$, $^{11}B^+$, $^{27}Al^+$, and $^{208}Pb^+$ were detected. Each sample was examined twice by ICP-OES, and each was measured three times.

Table 1. Instrumental parameters for ICP-OES

Analyte	Elements
Nebulizer type	Glass Concentric
Spray chamber type	Glass cyclonic spray chamber
RF power (W)	1450
Sample uptake rate (mL min^{-1})	1.5
Gas flow rates (L min^{-1})	0.60 L min^{-1}
Viewing mode	Radial
Read time	1-5 s
Measurement replicates	3
Plasma argon flow rate	17 L min^{-1}
Auxiliary argon flow rate	0.2 L min^{-1}
Nebulizer argon flow rate	0.6 L min^{-1}
Emission lines	Na= 589.592 nm K= 766.490 nm Ca= 317.933 nm P= 213.617 nm Mg=285.213 nm Fe=238.201 nm Cu=327.393 nm Zn=206.203 nm Mn=257.610 nm Pb=220.353 nm B=249.677 nm Al=396.153 nm Cr=267.716 nm

Quality control: In this study, certified reference material was used to evaluate the test procedure's quality (NIST SRM 1515-apple). The certified reference material's elemental analyses allowed for the evaluation of accuracy and precision over a variety of element concentrations. As indicated in Table 2, there was good agreement between the certified values and the analysis values of the certified reference material. Standard reference material was used to assess the accuracy of the microwave digestion process and the ICP-OES. The certified reference material was analysed in three replicates, and duplicate measurements were taken for each digested sample.

Table 2. Element concentrations in certified reference material (NIST SRM 1547-peach)

Element	Certified data ($\mu g\ g^{-1}$)	Our data ($\mu g\ g^{-1}$)	Recovery (%)
Na	312±7.2	310.00	99.3
K	24330±380	24305.00	99.9
Ca	15590±160	15600.00	100.1
P	1371±82	1362.00	99.3
Fe	219.8±6.8	218.40	99.4
Mn	97.8±1.8	97.30	99.5
Mg	4320±150	4355.00	100.8
Cu	3.75±0.37	3.78	100.8
Zn	17.97±0.53	18.00	100.2
Cr	11.46±0.53	11.75	100.2
B	28.73±0.81	28.50	99.2
Al	248.9±6.5	250.20	100.5
Pb	0.869±0.018	0.87	100.1

Statistic evaluation: SPSS 24.0 software was used to perform the statistical calculations (SPSS Inc., Chicago, USA). Levene's test for variance equality assumption and Shapiro Wilk test for normal distribution assumption were both used in the statistical analysis of the data. The differences between the groups were ascertained using Pearson correlation coefficient tests and two-way analysis of variance (ANOVA) in repeated measures. The element concentrations of yolks and albumens were calculated using an independent sample t-test. The correlations between measurements were examined using Pearson correlation analysis.

RESULTS

Table 3 indicates the concentration of 13 elements in 52 free-range egg of turkeys collected from the southeast region of Turkey. It is noticeable that the concentration of 13 elements summarizes wide diversity in egg yolk and albumen samples of turkey eggs. Within the analytes of the yolk samples, abundant elements are P, Ca, and Mg with average levels of 4361.56±846.35, 1372.17±267.16, and 120.08±17.49 $\mu g\ g^{-1}$, respectively. The first three most abundant elements in egg albumen analytes are P, Mg, and K with mean levels of 140.44±44.38, 115.91±21.13, and 113.23±154.09 $\mu g\ g^{-1}$, respectively.

The values of elements in egg yolks were far higher than those in the egg albumen (Table 3) in all species, except for Na, K, B, and Pb. The element with the lowest concentration was Al in turkey egg yolks, while Mn was the lowest analyzed element in albumens.

The correlation between elements in free-range hen turkey egg samples was shown in Table 4. When we compared the egg yolk and albumen samples in terms of element content, statistical significance was observed between all analyzed elements except Mg and Al ($P<0.01$). The element with the highest correlation with the other elements analyzed in the

Table 3. Element content in yolk and albumen of turkey eggs

Element	Yolk		Albumen		P value
	Min-Max	Mean±SD	Min-Max	Mean±SD	
Na ($\mu g\ g^{-1}$)	0.235-79.78	12.97±17.74^{a}	21.39-262.3	74.63±67.6^{a}	***
K ($\mu g\ g^{-1}$)	24.72-85.00	50.80±12.84^{a}	20.56-787.1	113.23±154.09^{b}	**
Ca ($\mu g\ g^{-1}$)	160.7-1810	1372.17±267.16^{a}	32.28-133.7	50.91±14.74^{b}	***
P ($\mu g\ g^{-1}$)	723-6468	4361.56±846.35^{a}	79.34-243.1	140.44±44.38^{b}	***
Fe ($\mu g\ g^{-1}$)	7.11-88.59	59.68±15.53^{a}	0.178-2.374	0.78±0.41^{b}	***
Mn ($ng\ g^{1}$)	134.4-2459	1238.23±480.69^{a}	45.3-84.49	54.09±7.46^{b}	***
Mg($\mu g\ g^{-1}$)	92.95-182.8	120.08±17.49^{a}	77.99-143	115.91±21.13^{a}	N.S.
Cu ($ng\ g^{-1}$)	433-4002	2187.30±678.79^{a}	355.9-2145	1413.2±565.5^{b}	***
Zn ($ng\ g^{-1}$)	0.077-41.39	25.91±5.84^{a}	0.764-12.53	4.84±2.94^{b}	***
Cr ($ng\ g^{-1}$)	203.6-642.9	417.51±67.33^{a}	143.2-326.3	176.8±46.08^{b}	***
B ($\mu g\ g^{-1}$)	5.198-8.709	6.43±0.71^{a}	4.651-10.28	7.32±1.60^{b}	**
Al ($ng\ g^{-1}$)	15.88-423.9	150.37±142.14^{a}	15.65-668.8	220.40±144.65^{a}	N.S.
Pb ($ng\ g^{-1}$)	310.6-964.9	539.31±121.33^{a}	224.1-1171	671.07±252.14^{b}	**

[a-b] Different letters in the same row indicate significant differences (**: $P<0.01$, ***: $P< 0.001$). N.S.: Not Significant

Table 4. Pearson correlation coefficients of elements in turkey egg samples

		Egg Yolk												
		Al	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**B**	**Ca**	**K**	**Mg**	**Na**	**P**	**Zn**
Egg Albumen	Al	-0.026	-0.128	0.297*	0.106	0.083	0.322*	0.473**	0.012	-0.440**	-0.151	-0.049	-0.061	0.017
	Cr		0.281*	-0.396**	0.161	-0.200	-0.024	0.136	-0.151	0.152	-0.011	-0.209	0.469**	0.310*
	Cu			0.352**	-0.108	0.098	0.056	-0.118	0.098	-0.121	0.064	0.272*	-0.454**	-0.278*
	Fe				0.145	-0.111	0.057	0.598**	-0.107	0.029	-0.077	-0.134	0.291*	0.205
	Mn					0.051	0.049	0.437**	0.226	-0.037	0.153	-0.105	0.320*	0.403**
	Pb						0.051	-0.077	0.104	-0.142	0.059	0.244	-0.423**	-0.270
	B							0.307*	0.016	0.086	0.193	0.201	-0.184	-0.093
	Ca								-0.110	0.166	0.406**	0.386**	-0.174	-0.214
	K									0.140	-0.104	-0.220	0.374**	0.186
	Mg										-0.004	0.116	-0.224	-0.179
	Na											-0.155	0.033	-0.042
	P												0.281*	0.166
	Zn													-0.040

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed)

egg yolk and albumen samples was P. It was followed by B, Zn and Cu, respectively (Table 4).

DISCUSSION

The specification of elements in eggs became significant data for veterinarians, nutritionists, and environmentalists. This study focused to provide the element composition of turkey eggs; such information had been formerly deficient. There has been some information on separate element composition. particularly for chicken eggs owing to their prevalence. In the lack of comparative results for eggs from turkey, there is constantly a trend to assume that data obtained from the chicken can be applied to avian eggs in common. While such generalizations may have some currency when regarding the macronutrients of the egg such as proteins, they can be misleading with regard to the micronutrient composition (Sparks, 2006). Our results regarding the various element levels for turkey eggs can be compared with other data in the literature and with the element levels of egg albumen and yolk in itself.

Sodium is necessary for healthy cell function, maintaining plasma volume, maintaining acid-base balance, and transmitting nerve impulses (Sarkingobir *et al*., 2020). In the case of Na, turkey egg yolk samples' Na content was lower (12.97±17.74 µg g^{-1}) than egg albumen samples (with a mean level of 74.63±67.6 µg g^{-1}). The close relationship of Na with water in biological fluids may explain the high Na content of egg albumens, which have a higher water content.

Potassium was classified first among the four major deficient nutrients in the Dietary Guidelines for the American 2010 Advisory Committee. Potential benefit of potassium, which is an organic anion, is related to its content in foods (Kılıç Altun *et al*., 2017). In our research, an average of 113.23±154.09 µg g^{-1} potassium in egg albumen and 50.80±12.84 µg g^{-1} potassium in egg yolk were analyzed. It was seen that egg albumen is richer than yolk in terms of potassium content.

Calcium is an essential element for physiological functions such as bone health. neuromuscular function. blood clotting, enzyme activation, and egg laying in poultry (Tuyen *et al.*, 2016). In this study, Ca concentrations were found to be the lowest 32.28 µg g^{-1} and the highest 133.7 µg g^{-1} in turkey egg albumen samples. The lowest Ca was 160.7 µg g^{-1} and the highest 1810.0 µg g^{-1} in egg yolk samples. Our measurements for Ca levels in turkey egg yolks and albumens were higher than those reported by Onyenweaku *et al*. (2018). Calcium is a structural material in the yolk that makes the granular structure of the egg yolk compact insufficiently hydrated and poorly accessible to enzymes and provides effective protection against heat gelation and thermal denaturation (Anton, 2013). Calcium and P are the most efficient elements in the metabolism. with 99 % of Ca and 80 % of P stocked in the skeleton as hydroxyapatite and act a significant role in bone structure and mineralization (Veum, 2010). Phosphorus plays a fundamental role in growth, cell and membrane function, energy metabolism, hormone regulation, and acid-base balance by participating in the structure of nucleic acids, nucleotides, phospholipids, and phosphorylated proteins (Berndt *et al*., 2007; Veum, 2010). It is known that in poultry eggs, the yolk contains more phosphorus than the albumen. In this study, P levels variate over a range within 723-6468 µg g^{-1} in turkey egg yolks and a range of 79.34-243.1 µg g^{-1} in turkey egg albumen. Phosvitin in the yolk is a significant component of the granular fragment of the yolk and is the main source of phosphorus in the yolk (Golab *et al*., 2001). It forms complex compounds with elements such as Ca, Mg, Mn, Fe, and lipovitellin found in egg yolk (Proszkowiec-Weglarz and Angel, 2013). Phosvitin is a carrier of the elements Ca and Fe and binds almost all the Fe in the egg yolk, which determines its antioxidant properties (Anton, 2007). The other three elements that were higher in the yolk than in the turkey egg albumen of the samples analyzed were Fe, Mn, and Mg. The average level of these three elements in egg yolk samples were respectively; 59.68±15.53 µg g^{-1} (Fe), 1238.23±480.69 µg g^{-1} (Mn), and 120.08±17.49 µg g^{-1} (Mg). The averages of these three elements in egg albumen were respectively; 0.78±0.41 µg g^{-1} (Fe), 54.09±7.49 ng g^{-1} (Mn), 115.91±21.13 µg g^{-1} (Mg). The previously detected Mn concentrations in turkey egg yolk samples from northern central Greece were 1883±185 ng g^{-1} and the mean level of Mn concentrations in our study's egg yolk is tolerable lower than in the previous study (Nisianakis *et al*., 2009). The Mn level in our egg albumen samples was also a little bit higher than the average of the Mn levels of research conducted in Greece (Nisianakis *et al*., 2009). We think that this is due to the flora of the free-range turkeys in that region.

In our results, Cu, Zn, and Cr levels of egg yolk samples were higher than egg albumen. Copper is an essential element for the appropriate physiological functioning of the metabolism (Świątkiewicz *et al.*, 2014). Due to the redox potential, Cu forms active centers of varied enzymes that play a significant role in the healthy functioning of the body (Festa and Thiele, 2011). Our measurements for Cu level in turkey egg yolks were lower than those reported by Nisianakis *et al*. (2009). On the contrary, our results were higher for Cu in egg albumens than Nisianakis *et al*.'s (2009) averages. Previous experimental studies have reported that Cu nanoparticles added to feed increase the amount of Cu in egg yolk. This data explains the higher Cu level in egg yolk of both studies (Jegede *et al*., 2015). Zinc is one of the trace elements that functions in various physiological processes as a cofactor of more than 200 enzymes (Ao and Pierce, 2013). The mode of action of Zn in poultry includes: (i) maintenance of normal growth; (ii) maintaining a strong immune system (iii) regulating the metabolism of carbohydrates, proteins, and lipids; (iv) enhancing the abilities of certain antioxidant enzymes; and (v) gene expression (Huang *et al*.. 2019). Most of the Zn in the egg is stored in the yolk, and about 86 % of the Zn originally found in the fertilized egg is transferred to the chicks (Richard, 1997). In our study, Zn levels were higher in egg albumen samples, while Zn levels were similar to the values reported by the previous study in egg yolk samples (Nisianakis *et al*.. 2009). Chromium plays a vital role in the mechanisms of automatic amplification of insulin signaling in glucose metabolism. Chromium has also been shown to support the immune system. It has been reported that supplementation of the poultry diet with chromium has a positive effect on performance and egg production in layers (Amata, 2013). Our Cr content in both egg yolk and egg albumen was higher than the contents of the previous study for turkey eggs. However, the results of this and previous study analyzing the elemental content of turkey eggs showed that the ratio of egg yolks to albumen of Cr content is 2.3. Different concentrations of Cr in both studies are attributed to different environment.

Boron is an integrative element in mineral metabolism and an effective factor in the development and maintenance of bone (Bozkurt and Küçükyılmaz, 2015). In this study, B was distributed almost equally in the yolk and albumen of turkey eggs. Studies have reported that supplementing the B with diet increases cholesterol levels in egg yolk (Eren and Uyanık, 2007). The average B level determined in this study was well below the daily tolerable limit (0.4 mg B kg^{-1} body weight day) for humans (Meacham *et al*., 2010). Aluminum is an element that makes up about 1.59 % by mass of the earth's crust. The probable cause of exposure of turkeys to Al is their free-range feeding. Our notion of what constitutes "exposure" is biased by the focus on Al in the diet (Exley, 2013). The highest Al concentration levels were measured as 668.8 ng g^{-1} in turkey egg albumen. The lowest was 15.65 ng g^{-1} in egg albumen. It was measured as 150.37±142.14 ng g^{-1} in average in egg yolk samples.

In environmental pollution-induced immunotoxicity studies, it has been reported that exposure to Pb, with a special interest among heavy metals. increases disease susceptibility, especially it has been shown to affect almost all components of the immune system (Dietert and Piepenbrink, 2006). In our study, the average Pb level was 539.31±121.3 ng g^{-1} in turkey egg yolks and 671.07±252.14 ng g^{-1} in turkey egg albumen. When the tolerable daily Pb intake limit for adults is considered as 200 µg day^{-1} (Zheng *et al*., 2007), it has been observed that it does not exceed the tolerable limit in terms of Pb exposure.

***Conclusion*:** This is the first study to analyze a large number of elements in egg yolks and albumens of free-range turkeys, and this study provided valuable evaluation data for consumers who prefer turkey eggs in their diet. The results of this study indicated that the analyzed elements were not homogeneously distributed in turkey egg yolk and albumen. It was not surprising that this heterogeneous distribution was due to the structural difference. Calcium, P, Fe, Mn, Cu, Zn, Cr elements were higher in turkey egg yolks than in turkey egg albumens. Opposite to this, Na, K, and B elements were higher in turkey egg albumens than in egg yolks. Lead, which is a toxic element and detected in both yolk samples and albumens of turkey eggs, was found to be higher in turkey eggs albumens. The Pb content of free-range turkey eggs, which we can consider as an environmental bioindicator, did not exceed the tolerable daily limit. However, it should not be forgotten that the detection of Pb element, which is an indicator of environmental contamination, in turkey eggs may pose a threat to food safety.

***Conflict of Interest*:** The authors declare that they do not have any conflict of interests.

***Authors' Contribution Statements*:** SKA and NP conceptualization, prepare the research plan, analysis, writing, and proofreading. HK helped with data analysis and research methodology.

***Acknowledgement*:** The study received no external funding.

REFERENCES

Abeyrathne, E.D.N.S., H.Y. Lee, C. Jo, K.C. Nam and D.U. Ahn. 2014. Enzymatic hydrolysis of ovalbumin and the functional properties of the hydrolysates. Poultry Science 93:2678-2686.

Altun, S.K., N. Paksoy, H. Kara and A. Şakak. 2018. Macro-Elements in Raw Sheep Milk Samples from Şanlıurfa, Turkey. Manas Journal of Agriculture Veterinary and Life Sciences 8:31-36.

Amata, I.A. 2013. Chromium in livestock nutrition: A review. Global Advanced Research Journal of Agricultural Science 2:289-306.

Anton, M. 2007. Composition and structure of egg components. Bioactive egg compounds. R. Huopalahti, R. Lopez-Fandiño, M. Anton and R. Schade (eds). Springer-Verlag, Berlin. pp. 1-24.

Anton, M. 2013. Egg yolk: structures, functionalities and processes. Journal of the Science of Food and Agriculture 93:2871-2880.

Ao, T., and J. Pierce. 2013. The replacement of inorganic mineral salts with mineral proteinates in poultry diets. World's Poultry Science Journal. 69:5-16.

Berndt, T., L.F. Thomas, T.A. Craig, S. Sommer, X. Li, E.J. Bergstralh and R. Kumar. 2007. Evidence for a signaling axis by which intestinal phosphate rapidly modulates renal phosphate reabsorption. Proceedings of the National Academy of Sciences 104:11085-11090.

Board, R.G., H.S. Tranter, W.J. Stadelman and O.J. Cotterill. 1995. Egg science and technology. W. J. Stadelman and O.J. Cotterill (eds), Haworth Press Inc, New York.

Bozkurt, M. and K. Küçükyilmaz. 2015. The role of boron in poultry nutrition Part II: Compositional and mechanical properties of bone and egg quality. World's Poultry Science Journal 71:483-492.

Campbell, L., V. Raikos and S.R. Euston. 2003. Modification of functional properties of egg-white proteins. Food/Nahrung 47:369-376.

Cotterill, O.J., J. Glauert and G.W. Froning. 1978. Nutrient composition of commercially spray-dried egg products. Poultry Science 57:439-442.

Dietert, R.R. and M.S. Piepenbrink. 2006. Lead and immune function. Critical Reviews in Toxicology 36:359-385.

Dong, X. and Y.Q. Zhang. 2021. An insight on egg albumen: From most common functional food to biomaterial application. Journal of Biomedical Materials Research Part B: Applied Biomaterials 109:1045-1058.

Eren, M. and F. Uyanik. 2007. Influence of dietary boron supplementation on some serum metabolites and egg-yolk cholesterol in laying hens. Acta Veterinaria Hungarica. 55(1):29-39.

Exley, C. 2013. Human exposure to aluminium. Environmental Science: Processes & Impacts 15:1807-1816.

Festa, R.A. and D.J. Thiele. 2011. Copper: an essential metal in biology. Current Biology 21: R877-R883.

Golab, K., J. Gburek, A. Gawel and M. Warwas. 2001. Changes in chicken egg white cystatin concentration and isoforms during embryogenesis. British Poultry Science 42:394-398.

Huang, L., X. Li, W. Wang, L. Yang and Y. Zhu. 2019. The role of zinc in poultry breeder and hen nutrition: an update. Biological Trace Element Research 192:308-318.

Jegede, A.V., A.O. Oso, A.O. Fafiolu, R.A. Sobayo, O.M.O. Idowu and O. Oduguva. 2015. Effects of dietary copper on performance, serum and egg yolk cholesterol and copper residues in yolk of laying chickens. Slovak Journal of Animal Science 48:29-36.

Kılıç Altun, S., H. Dinç, N. Paksoy, F.K. Temamoğulları and M. Savrunlu. 2017. Analyses of mineral content and heavy metal of honey samples from south and east region of Turkey by using ICP-MS. International Journal of Analytical Chemistry.

Meacham, S., S. Karakas, A.Wallace and F. Altun. 2010. Boron in human health: evidence for dietary recommendations and public policies. The Open Mineral Processing Journal 3:36-53.

Nisianakis, P., I. Giannenas, A. Gavriil, G. Kontopidis and I. Kyriazakis. 2009. Variation in trace element contents among chicken, turkey, duck, goose, and pigeon eggs analyzed by inductively coupled plasma mass spectrometry (ICP-MS). Biological Trace Element Research 128:62-71.

Onyenweaku, E.O., H.N. Ene-Obong, I.O. Williams and C.O. Nwaehujor. 2018. Comparison of nutritional composition of bird egg varieties found in Southern Nigeria: A preliminary study. Food and Nutrition Sciences 9:868-879.

Proszkowiec-Weglarz, M. and R. Angel. 2013. Calcium and phosphorus metabolism in broilers: Effect of homeostatic mechanism on calcium and phosphorus digestibility. Journal of Applied Poultry Research 22:609-627.

Richards, M.P. 1997. Trace mineral metabolism in the avian embryo. Poultry Science 76:152-164.

Sarkingobir, Y., M. Dikko, U. Tukur and A.U. Imam. 2020. Determination of some Macroelements (Sodium, Potassium, Calcium, Magnesium and Phosphorus) in some Selected Eggs (Chicken, Duck, Quail, Pigeon, Guinea Fowl and Turkey) in Sokoto Metropolis. Journal of Science and Technology Research 2:155-159.

Shapira, N. 2009. Modified egg as a nutritional supplement during peak brain development: a new target for fortification. Nutrition and Health 20:107-118.

Sparks, N.H.C. 2006. The hen's egg–is its role in human nutrition changing? World's Poultry Science Journal 62:308-315.

Sun, C., J. Liu, N. Yang and G. Xu. 2019. Egg quality and egg albumen property of domestic chicken, duck, goose, turkey, quail, and pigeon. Poultry Science 98:4516-4521.

Świątkiewicz, S., A. Arczewska-Włosek and D. Jozefiak. 2014. The efficacy of organic minerals in poultry nutrition: review and implications of recent studies. World's Poultry Science Journal 70:475-486.

Trziszka, T., Z. Dobrzanski, T. Skiba and W. Kopec. 2007. Effect of breeding and housing systems of layers on egg quality and the activity of cystain and lysozyme. Polish Journal of Food and Nutrition Sciences 57:583-586.

Tuyen, L.D., V.T.T. Hien, P.T. Binh and S. Yamamoto. 2016. Calcium and vitamin D deficiency in Vietnamese: recommendations for an intervention strategy. Journal of Nutritional Science and Vitaminology 62:1-5.

Veum, T.L. 2010. Phosphorus and calcium nutrition and metabolism. In: Phosphorus and calcium utilization and requirements in farm animals. Wallingford UK: CABI. pp. 94-111.

Xu, K., Y. Liu, S. Bu, T. Wu, Q. Chang, G. Singh, X. Cao, C. Deng, B. Li, G. Luo and M. Xing. 2017. Egg albumen as a fast and strong medical adhesive glue. Advanced Healthcare Materials 6:1700132.

Zheng, N., Q. Wang, X. Zhang, D. Zheng, Z. Zhang and S. Zhang. 2007. Population health risk due to dietary intake of heavy metals in the industrial area of Huludao city, China. Science of the Total Environment 387:96-104.