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Assessment of trace element contents of chicken products from turkey

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ABSTRACT

Due to the consumption of chicken and chicken products in Turkey at high ratio, trace metal content of chicken and chicken products from Turkey were determined by atomic absorption spectrometry after microwave digestion. The accuracy of the method was confirmed by analysis of standard reference material (NIST SRM 1577b Bovine liver). Trace element content in various parts of chicken samples and chicken products were to be in the range of 0.10–114 μg/g for copper, 0.25–6.09 μg/kg for cadmium, 0.01–0.40 μg/g for lead, 0.10–0.91 μg/g for selenium, 0.05–3.91 μg/g for manganese, 0.06–0.10 μg/g for arsenic, 0.01–0.72 μg/g for chromium, 0.01–2.08 μg/g for nickel, 0.01–0.02 μg/g for cobalt, 0.10–1.90 μg/g for aluminium, 1.21–24.3 μg/g for zinc, 2.91–155 μg/g for iron. The levels of lead in some analyzed chicken products were higher than the recommended legal limits for human consumption.

1. Introduction

Trace elements have positive and negative effects on human health and the environment. Many researchers are interested in the analysis of the trace metal contents of the environmental samples and especially foods [1–5]. Accurate and adequate food composition data are invaluable for estimating the adequacy of intakes of essential nutrients and assessing exposure risks from intake of toxic non-essential heavy metals [6]. Heavy metals can be classified as potentially toxic (aluminium, arsenic, cadmium, lead, mercury, etc.), probably essential (nickel, vanadium and cobalt) and essential (iron, manganese, copper, zinc and selenium) [7–9]. Toxic elements can be very harmful even at low concentration when ingested over a long time period. The essential metals can also produce toxic effects when the metal intake is excessively elevated [10–12]. The ingestion of food is an obvious means of exposure to metals, not only because many metals are natural components of foodstuffs, but also because of environmental contamination and contamination during processing.

The levels of trace elements in chicken (*gallus gallus domesticus*) products and various parts of chicken samples have been widely reported in the literature [6,13–17]. However, the data on the trace element levels in chicken samples and chicken products produced in Turkey are very limited. Due to lower prizes of chicken products than meat products, chicken products are a popular food source in Turkey.

In the present study, the contents of copper, cadmium, lead, selenium, manganese, arsenic, chromium, nickel, cobalt, aluminium, zinc and iron in chicken samples were determined by flame and/or graphite furnace atomic absorption spectrometry after microwave digestion.

2. Experimental

2.1. Samples

The chicken samples were collected from popular markets (TAV-PA, YIMPAS and MERIDYEN) from Tokat City, Turkey in 2006. The chicken products including kidney, heart, liver, gizzard, meatball, meat, skin, burger, salami, sausage, egg white and egg yolk samples were analyzed after microwave digestion.

2.2. Reagents

All reagents were of analytical reagent grade unless otherwise stated. Double deionised water (Milli-Q Millipore 18.2 MΩ-cm resistivity) was used for all dilutions. HNO_3 and H_2O_2 were of suprapure quality (E. Merck, Darmstadt, Germany). All the plastic and glassware were cleaned by soaking in dilute HNO_3 (1 + 9) and were rinsed with distilled water prior to use. The element standard solu-

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Table 1
Instrumental analytical conditions of investigated elements

Conditions for FAAS				
Element	Acetylene (L/min)	Air(L/min)	Wavelength (nm)	Slit width (nm)
Fe	2.0	17.0	248.3	0.2
Cu	2.0	17.0	324.8	0.7
Zn	2.0	17.0	213.9	0.7
Mn	2.0	17.0	279.5	0.2

Conditions for GFAAS								
Instrumental conditions	Pb	Cd	Ni	Cr	Se	As	Co	Al
Argon flow (mL/min)	250	250	250	250	250	250	250	250
Sample volume (μL)	20	20	20	20	20	20	20	20
Modifier (μL)	5	10	5	5	10	5	5	5
Heating program temperature °C (ramp time (s), hold time (s))								
Drying 1	100 (5, 20)	100 (5, 20)	100 (5, 20)	100 (5, 20)	100 (5,20)	100 (5,20)	100 (5,20)	100 (5,20)
Drying 2	140 (15, 15)	140 (15, 15)	140 (15, 15)	140 (15, 15)	140 (15,15)	140 (15,15)	140 (15,15)	140 (15,15)
Ashing	700 (10, 20)	850 (10, 20)	1300 (10, 20)	1600 (10, 20)	1100 (10,20)	1300 (10,20)	1400 (10,20)	1700 (10,20)
Atomization	1800 (0, 5)	1650 (0, 5)	2500 (0, 5)	2500 (0, 5)	2100 (0,5)	2300 (0,5)	2500 (0,5)	2500 (0,5)
Cleaning	2600 (1, 3)	2600 (1, 3)	2600 (1, 3)	2600 (1, 3)	2600 (1,3)	2600 (1,3)	2600 (1,3)	2600 (1,3)

tions used for calibration were prepared by diluting stock solutions of 1000 mg/L of each element supplied from Sigma.

2.3. Apparatus

A PerkinElmer AAnalyst 700 atomic absorption spectrometer (FAAS) equipped with HGA graphite furnace and with deuterium background corrector was used in the experiments. For flame atomic absorption spectrometric measurements, a 10 cm long slot-burner head, a lamp and an air-acetylene flame were used. Zn, Mn, Fe and Cu were determined by flame AAS. The other elements were determined by graphite furnace AAS (GFAAS) using argon as inert gas. The operating parameters for the working elements were set as recommended by the manufacturer (Table 1). Pyrolytic-coated graphite tubes (PerkinElmer part no. B3 001264) with a platform were used. Samples were injected into the graphite furnace using PerkinElmer AS-800 auto sampler.

Milestone Ethos D closed vessel microwave digestion system (maximum pressure 1450 psi, maximum temperature 300 °C) was used. Teflon reaction vessels were used for all the digestion procedures. The reaction vessels were cleaned using 5 mL of concentrated nitric acid before each digestion.

2.4. Microwave digestion

Microwave digestion procedure was applied for chicken samples. One gram of each sample was digested with 6 mL of HNO_3 (65%) and 2 mL of H_2O_2 (30%) in microwave digestion system and diluted to 10 mL with deionized water. A blank digest was carried out in the same way. All sample solutions were clear. Digestion conditions for microwave system were applied as 2 min for 250 W, 2 min for 0 W, 6 min for 250 W, 5 min for 400 W, 8 min for 550 W, ventilation: 8 min, respectively [1,2]. The accuracy of the microwave digestion method was checked by standard reference material (NIST SRM 1577b Bovine liver). Four replicate were done on NIST SRM 1577b Bovine liver to check the accuracy.

2.5. Statistical analysis

The whole data were subjected to a statistical analysis and correlation matrices were produced to examine the inter-relationships between the investigated trace element concentrations of the samples. Student's t-test was employed to estimate the significance of values.

3. Results and discussion

The detection limits for analyzed elements are defined as the concentration corresponding to three times the standard deviation of ten blanks. Detection limit values of elements as milligram per liter in flame AAS were found to be 0.018 for Cu, 0.010 for Zn, 0.013 for Fe, 0.009 for Mn. The other elements were below detection limit of flame AAS. Cadmium, lead, selenium, arsenic, chromium, nickel, cobalt, aluminium were determined using graphite furnace AAS. Detection limit values of these elements as microgram per liter in GFAAS were found to be 0.02 for Cd, 0.15 for Pb, 0.25 for Se, 0.12 for As, 0.30 for Cr, 0.42 for Ni, 0.35 for Co and 0.65 for Al.

The recovery values for the investigated elements were nearly quantitative for microwave digestion method (>95%). The relative standard deviations were less than 10% for all investigated elements. T-test was used in this study ($p < 0.05$). The accuracy of the method was evaluated by means of trace element determination in standard reference material (SRM). The achieved results were in good agreement with certified values are given in Table 2.

Trace element levels in the chicken products from Turkey are listed in Table 3. All metal concentrations were determined on a wet weight basis. The concentrations of investigated trace element in chicken samples were found to be in the range of 0.10–114 μg/g for copper, 0.25–6.09 μg/kg for cadmium, 0.01–0.40 μg/g for

Table 2
Trace element concentrations in certified reference material (NIST SRM 1577b Bovine Liver), $N = 4$

Element	Certified value (μg/g)	Our value (μg/g)	Recovery(%)
Cu	160	157 ± 7	98
Cd	0.5	0.48 ± 0.03	96
Pb	0.129	0.125 ± 0.01	97
Se	0.73	0.71 ± 0.05	97
Mn	10.5	10.3 ± 0.6	98
As	(0.05)[a]	0.05 ± 0.004	100
Co	(0.25)	0.24 ± 0.02	96
Al	(3)	2.90 ± 0.02	97
Zn	127	130 ± 10	102
Fe	184	180 ± 12	98

[a]The values in the parenthesis are not certified.

Table 3
Trace element levels (as μg/g) in chicken products from Turkey, $N = 3$

Samples	Cu	Cd[a]	Pb	Se	Mn	As	Cr	Ni	Co	Al	Zn	Fe
Kidney	32.4 ± 2.8	0.25 ± 0.01	0.02 ± 0.001	0.60 ± 0.05	0.05 ± 0.003	0.09 ± 0.007	0.03 ± 0.002	0.02 ± 0.001	0.01 ± 0.001	0.28 ± 0.02	14.6 ± 1.2	98.2 ± 9.2
Heart	14.5 ± 1.2	0.25 ± 0.02	0.04 ± 0.003	0.39 ± 0.02	0.53 ± 0.004	0.06 ± 0.005	0.03 ± 0.002	0.02 ± 0.001	0.01 ± 0.001	0.10 ± 0.01	14.2 ± 1.1	25.6 ± 2.2
Liver	12.1 ± 1.1	2.24 ± 0.20	0.12 ± 0.010	0.91 ± 0.08	2.51 ± 0.178	0.06 ± 0.004	0.04 ± 0.003	0.01 ± 0.001	0.02 ± 0.001	0.14 ± 0.01	22.5 ± 2.1	155 ± 15
Gizzard	10.7 ± 1.0	0.90 ± 0.06	0.01 ± 0.001	0.17 ± 0.01	0.19 ± 0.012	0.10 ± 0.008	0.05 ± 0.004	0.02 ± 0.001	0.02 ± 0.002	0.23 ± 0.02	21.0 ± 1.9	17.8 ± 1.4
Meatball	87.3 ± 0.8	0.67 ± 0.04	0.12 ± 0.009	0.42 ± 0.04	1.87 ± 0.145	0.07 ± 0.004	0.27 ± 0.020	0.02 ± 0.001	0.02 ± 0.002	0.84 ± 0.07	7.5 ± 0.7	2.9 ± 0.2
Meat	1.2 ± 0.1	6.09 ± 0.49	0.40 ± 0.030	0.43 ± 0.03	0.23 ± 0.021	0.07 ± 0.005	0.07 ± 0.005	2.08 ± 0.026	0.01 ± 0.001	0.37 ± 0.03	19.9 ± 1.8	8.2 ± 0.7
Skin	114.0 ± 0.1	0.77 ± 0.06	0.31 ± 0.020	0.19 ± 0.01	0.14 ± 0.011	0.10 ± 0.007	0.06 ± 0.005	0.07 ± 0.005	0.02 ± 0.001	0.42 ± 0.04	7.1 ± 0.6	15.8 ± 1.5
Burger	3.9 ± 0.2	1.24 ± 0.12	0.06 ± 0.004	0.18 ± 0.01	1.28 ± 0.121	0.08 ± 0.003	0.03 ± 0.001	0.32 ± 0.020	0.02 ± 0.002	0.68 ± 0.05	8.8 ± 0.7	14.3 ± 1.3
Salami	31.0 ± 0.3	0.74 ± 0.06	0.04 ± 0.003	0.30 ± 0.02	0.82 ± 0.065	0.07 ± 0.005	0.72 ± 0.006	0.11 ± 0.010	0.01 ± 0.001	0.63 ± 0.05	10.1 ± 1.0	15.9 ± 1.2
Sausage	2.2 ± 0.2	2.62 ± 0.21	0.39 ± 0.003	0.24 ± 0.02	3.91 ± 0.321	0.10 ± 0.007	0.18 ± 0.010	0.80 ± 0.065	0.02 ± 0.001	1.90 ± 0.12	11.1 ± 1.0	38.2 ± 2.9
Egg white	0.1 ± 0.1	1.71 ± 0.14	0.01 ± 0.001	0.10 ± 0.01	0.11 ± 0.010	0.10 ± 0.009	0.06 ± 0.005	0.09 ± 0.007	0.01 ± 0.001	0.22 ± 0.02	1.2 ± 0.1	7.9 ± 0.6
Egg yolk	0.8 ± 0.16	2.97 ± 0.21	0.10 ± 0.010	0.29 ± 0.01	0.86 ± 0.078	0.08 ± 0.004	0.01 ± 0.001	0.09 ± 0.005	0.01 ± 0.001	0.37 ± 0.03	24.3 ± 2.1	40.9 ± 3.4

[a] Cd (μg/kg).

lead, 0.10–0.91 μg/g for selenium, 0.05–3.91 μg/g for manganese, 0.06–0.10 μg/g for arsenic, 0.01–0.72 μg/g for chromium, 0.01–2.08 μg/g for nickel, 0.01–0.02 μg/g for cobalt, 0.10–1.90 μg/g for aluminium, 1.21–24.3 μg/g for zinc and 2.91–155 μg/g for iron. According to these data, iron has the highest concentration in the investigated samples and followed by copper, zinc and manganese.

Copper is known to both vital and toxic for many biological systems and may enter the food materials from soil through mineralization by crops, food processing or environmental contamination, as in the application of agricultural inputs, such as copper-based pesticides which are in common use in farms in some countries [6,18]. The highest and lowest copper levels were found 114 μg/g in skin and 0.10 μg/g in egg white. In the literature copper levels in chicken samples have been reported in the range of 0.3–3.5 μg/g in Brazil [16] and 1.00–1.13 μg/g in Nigeria [6]. Copper values in chicken samples investigated in the presented work were found to be higher than literature values. Meatball, kidney and salami samples are contained higher copper content (Fig. 1).

The minimum and maximum cadmium contents of the samples were found 0.25 μg/kg in kidney, heart samples and 6.09 μg/kg in meat samples, respectively. Cadmium levels in chicken samples have been reported in the range of 0.05–0.09 mg/kg in Nigerian [13], 1–2 μg/kg in Canada [19]. Cadmium may accumulate in the human body and may induce kidney dysfunction, skeletal damage and reproductive deficiencies. The maximum cadmium level permitted for chicken samples is 0.5–1.0 mg/kg according to Turkish Food Codex [20]. Cadmium levels in chicken products from Turkey were lower than permitted levels in this study.

The minimum and maximum lead content in analyzed samples were found 0.01 μg/g in egg yolk, gizzard and 0.40 μg/g in meat. The maximum lead level permitted for meat samples is 0.1 mg/kg according to Turkish Food Codex [20]. The levels of lead in some chicken products (meat, skin and sausage) were higher than the recommended legal limits for human consumption. The fact that toxic metals are present in high concentrations in chicken samples is of particular importance in relation to the FAO/WHO (1976) standards for Pb and Cd as toxic metals. The maximum permissible doses for an adult are 3 mg Pb and 0.5 mg Cd per week, but the recommended doses are only one-fifth of those quantities [21]. Lead is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults [22].

The highest selenium concentrations were found 0.91 μg/g in liver and 0.60 μg/g in kidney samples. High protein food represents a rich source of selenium. Eggs and organ meats, such as liver and kidney have the highest capacity for accumulating selenium [23]. Low concentrations of selenium can cause anomalies in organisms and high concentrations are toxic. Selenium is recognized as an essential micronutrient in animal and humans, playing important biological roles as antioxidant, as a regulator of thyroid hormone metabolism or as anti-carcinogenic agent. In the literature selenium levels in chicken samples have been reported in the range of 97–154 ng/g in Slovenian [24], 76.3–82.4 ng/g in Greek [15]. Selenium values in chicken samples of presented work are higher than literature values. The adequate daily dietary selenium intake ranges from 50 to 200 μg, with an average value of 55 μg for adult humans [25].

The lowest and highest manganese concentrations were found 0.05 μg/g in kidney and 3.91 μg/g in sausage products. The Institute of Medicine recommends that intake of manganese from food; water and dietary supplements should not exceed the tolerable daily upper limit of 11 mg per day [26]. The intake of Mn in the investigated samples is well below the tolerable daily upper limit of 11 mg per day [26].

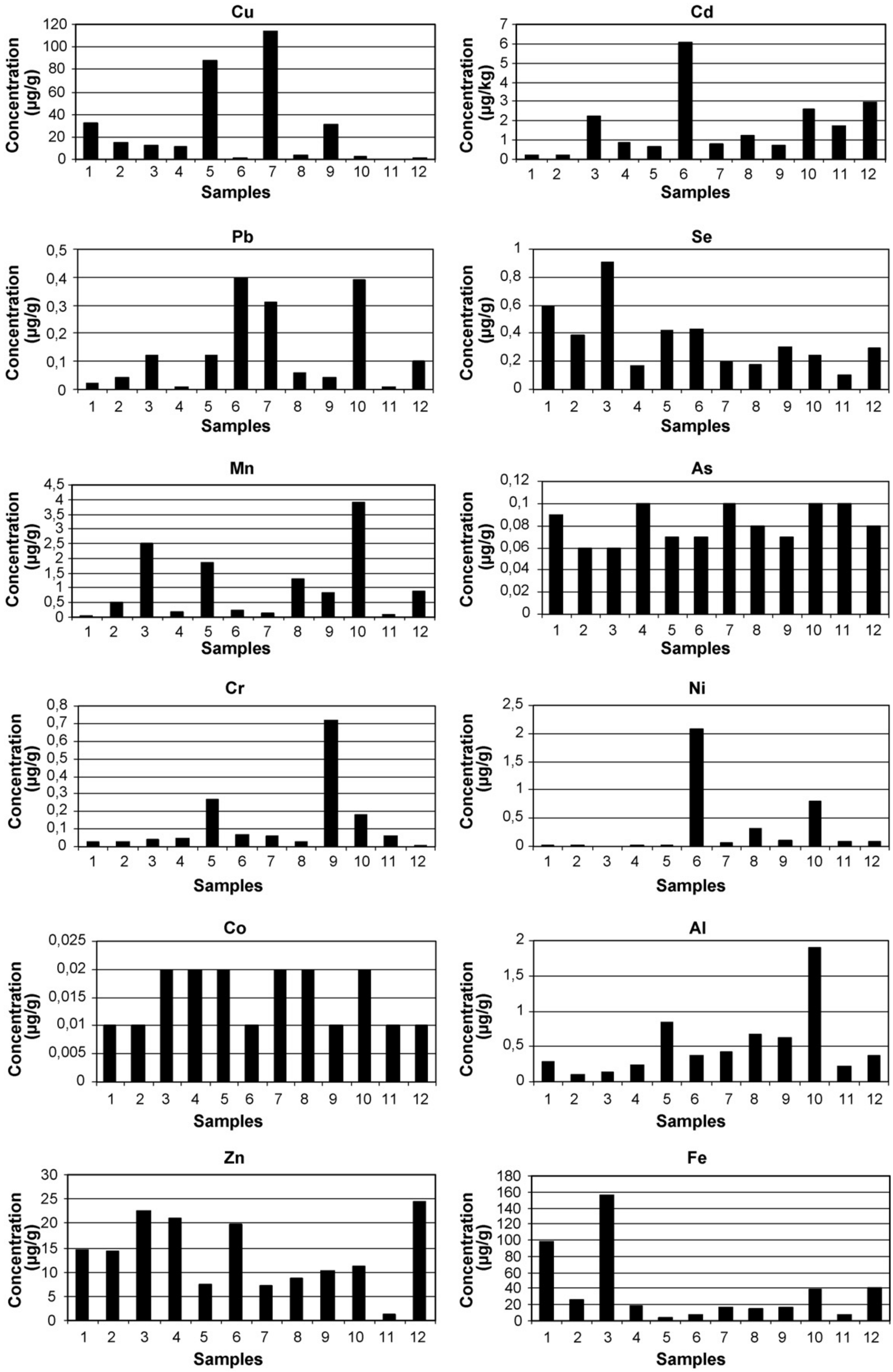

Fig. 1. Trace element levels in chicken products (1) Kidney, (2) Heart, (3) Liver, (4) Gizzard, (5) Meatball, (6) Meat, (7) Skin, (8) Burger, (9) Salami, (10) Sausage, (11) Egg white and (12) Egg yolk.

Table 4
Correlations between metal concentrations of chicken products

	Cu	Cd	Pb	Se	Mn	As	Cr	Ni	Co	Al	Zn	Fe
Cu	1.000											
Cd	−0.432	1.000										
Pb	0.161	0.650	1.000									
Se	−0.017	0.098	−0.010	1.000								
Mn	−0.182	−0.084	0.148	0.497	1.000							
As	0.096	−0.126	0.121	−0.625	0.036	1.000						
Cr	0.192	−0.183	−0.064	−0.085	0.099	−0.208	1.000					
Ni	−0.303	0.848	0.610	−0.144	0.000	0.054	−0.095	1.000				
Co	0.353	−0.188	0.238	0.015	0.664	0.220	−0.126	−0.277	1.000			
Al	0.017	0.110	0.531	−0.256	0.695	0.288	0.315	0.170	0.397	1.000		
Zn	−0.390	0.410	0.055	0.495	0.170	−0.340	−0.282	0.189	−0.077	−0.279	1.000	
Fe	−0.215	0.137	0.026	0.710	0.464	−0.387	−0.167	−0.163	0.289	−0.128	0.495	1.000

Arsenic is a problematic element for human. Arsenic concentrations in chicken products were found in the range of 0.06–0.10 μg/g. There is no information about maximum arsenic levels in chicken samples in Turkish standards [20]. The provisional tolerable weekly intake (PTWI) for inorganic arsenic indicated by the Joint FAO/WHO (1989) Expert Committee on Food Additives is 0.015 mg/kg body mass/week [27].

Chromium is considered as an essential trace element. The amount of chromium in the diet is of great importance as Cr is involved in insulin function and lipid metabolism [28,14]. The recommended daily intake of chromium is 50–200 μg [26]. Chromium levels in egg yolk, egg white and salami samples were found 0.01–0.06 μg/g and 0.72 μg/g, respectively. In the literature chromium contents have been reported in the range of 0.03–0.06 μg/g in egg white, 0.11–0.13 μg/g in egg yolk, 0.11–0.21 μg/g in chicken meat [14].

The lowest and highest nickel contents in samples were found 0.01 μg/g in liver and 2.08 μg/g in meat (Fig. 1). Sausage and burger samples have contained high nickel levels. Nickel contents in the literature have been reported as 1.67 μg/g in chicken, 1.87 μg/g in egg [13], and 0.027 μg/g in chicken 0.007 μg/g in egg [19]. Egg white and yolk have contained 0.09 μg/g nickel in this study. There is no information about maximum nickel levels in chicken samples in Turkish standards. It is reported that maximum nickel levels in some food samples as 0.2 mg/kg [20]. Cobalt concentrations in chicken products were found 0.01–0.02 μg/g. There is no information about maximum cobalt levels in chicken samples in Turkish standards.

Aluminium is not considered to be an essential element in humans. Exposure of aluminium has been implicated in a number of human pathologies including encephalopathy/dialysis dementia, Parkinson disease and Alzheimer's disease [29,30]. The permissible aluminium dose for an adult is quite high (60 mg per day) [31]. There is no information about maximum aluminium levels in chicken samples in Turkish standards. The minimum and maximum aluminium contents in samples were found 0.10 μg/g in heart and 1.90 μg/g in sausage. Aluminium concentrations have been reported 1.5 μg/g in egg yolk and egg white [32]. Aluminium levels of egg white and egg yolk were found as 0.22 μg/g and 0.37 μg/g, respectively.

Zinc is known to be involved in most metabolic pathways in humans and zinc deficiency can lead to loss of appetite, growth retardation, skin changes and immunological abnormalities. Zinc is widespread among living organisms due to its biological significance. The recommended daily intakes of zinc and copper are 15 mg Zn for adult males and 12 mg Zn for adult females and 1.5–3.0 mg Cu [33]. The lowest and highest zinc values were found 1.21 μg/g in egg white and 24.3 μg/g in egg yolk. Liver and gizzard samples have contained high zinc levels. In the literature zinc values have been reported 2.87 μg/g in chicken and 6.87 μg/g in egg [6]. The level of zinc in egg samples was found higher than other chicken products.

The lowest and highest iron concentrations were found 2.91 μg/g in meatball and 155 μg/g in liver samples. Kidney, liver and egg yolk have contained higher iron than other chicken organs. Iron is a mineral essential for life and for our diets. It is known that adequate iron in a diet is very important for decreasing the incidence of anemia [34–36]. Iron deficiency occurs when the demand for iron is high, e.g., in growth, high menstrual loss, and pregnancy, and the intake is quantitatively inadequate or contains elements that render the iron unavailable for absorption [37]. Poor bioavailability is considered to be an important factor leading to iron deficiency in many countries. There is no information about maximum iron levels in chicken samples in Turkish standards [20]. In the literature iron levels in eggs have been reported in the range of 20.99–26.78 μg/g [38]. Iron values were found 7.86 μg/g in egg white and 40.9 μg/g in white yolk in this study.

A linear regression correlation test was performed to investigate correlations between metal concentrations. The values of correlation coefficients between metal concentrations are given in Table 4. There is a good correlation between Ni-Cd (r = 0.848). There were positive correlations of Pb–Cd, Ni–Pb, Co–Mn, Al–Pb, Al–Mn, Fe–Se with corresponding r values of 0.650, 0.610, 0.664, 0.531, 0.695, and 0.710, respectively. The negative correlations between As–Se and Cd–Cu were found as −0.625, and −0.432, respectively.

4. Conclusion

Traces heavy metals play important roles in human body. The main source of these metals for human is food [39–46]. The results obtained in the presented work for trace elements in chicken and chicken products were acceptable to human consumption at nutritional and toxic levels. The levels of lead in some chicken products investigated were higher than the recommended legal limits for human consumption. The levels of elements may be reduced by more careful handling practices and processing of raw materials. Chicken products should be analyzed more often in Turkish supermarkets with respect to toxic elements.

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