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Investigation of Some Elements Concentrations and Distribution in Body parts and Organs of Japanese Quail *Cotornix japonica*

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The presence, concentration and distribution of 42 trace and ultra-trace elements in addition to rare earth elements (REE), yttrium(Y) and Thorium (Th) were analyzed using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) in different body parts and organs of Japanese quail *Cotornix japonica* as a laboratory animal model. Twenty one of the investigated elements were below detection limit while the rest of the investigated elements varied in amount and distribution relative to organs and parts in which they were investigated. The existences, concentrations and distributions of thallium (Tl) and europium (Er) are recordedin a higher living species in the present work. The present work also documented the presence, concentration and distribution of Thulium (Tm) a living organism. The recorded concentrations and distributions of various elements may be related to their roles in structures and functions of organs in which they were distributed. From the present findings, a better classification of elements according to distribution and concentration levels in individual organs is recommended. It is also recommended to investigate the existence of Tm, Tl, and Er in other living species and a further investigation of the role of Tm, Tl, and Er in structure and metabolism of *Cotornix japonica* parts and organs in which they were detected.

Keywords: ICP-OES /element distribution/ element concentration/ trace elements/ ultra-trace elements

Introduction

The roles of many elements in biochemical processes in various biological systems have been studied for decades. It has been shown that the levels of elements are crucial for normal growth and functions of living organisms[1,2,3].Element requirements varies from living organism to another, [4]but in general they can be categorized according to their requirements and distributions into three major groups : Major elements (Oxygen(O), Hydrogen (H), Carbon(C), Nitrogen (N), Phosphorus (P),Sulfur(S),Sodium (Na),Potassium(K), Magnesium (Mg),Calcium(Ca), and chlorine (Cl)whose concentrations are higher than 0.01%, trace elements (Iron (Fe),Zinc(Zn), Fluorine (F), Strontium(Sr), Molybdenum (Mo),Cupper(Cu), Bromine (Br), Silicon (Si),Cesium(Cs),Iodine (I), Manganese (Mn),Aluminum (Al),Lead(Pb),Cadmium(Cd),Boron(B), and Rubidium(Rb)) having concentrations from 10^{-6}% to 10^{-2}%, and ultra-trace elements with concentrations less than 10^{-6}% including Selenium (Se), Cobalt (Co),Vanadium (V),Chromium(Cr),Arsenic(As),Nickel(Ni), Lithium (Li),Barium(Ba),Titanium(Ti),Silver(Ag),Tin(Sn), Beryllium(Be),Gallium(Ga), Germanium (Ge),

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Mercury (Hg),Scandium(Sc), Zirconium (Zr), Bismuth (Bi), Antimony (Sb),Uranium(U),Thorium(Th), and rhodium (Rh) [5]. The major elements O, H, C, N, P, and S are referred to as organogens because they contribute in the formation of organs and tissues [5]. Many trace elements such as Co, Cu, Fe, Mn, Mo, Se and Zn act as prosthetic groups for many enzymes. Some of the trace elements and ultra-trace elements are known to be essential but their functions are not yet revealed such as Silicon, vanadium, nickel, tin, others are not classified as essential but have effects on human and experimental animals which are fluorine and lithium [6]. Other trace and ultra-trace elements do not have known functions with toxic effect in excess [6]. Studies on the biochemical properties of lanthanides focused on their medicinal applications, toxicity, and their use as informative probes in biological and biochemical research[7].In complex multi-system living organisms, different organs contribute in the normal physiological process of the living organism through specialized activities of their tissue structures that require different levels of trace elements. The knowledge about the essentiality of chemical elements in different forms of life seems to be incomplete. The essential elements are not yet known all with certainty and the knowledge about the functions of apparently non-essential elements is even less than the essential elements[8].In addition to its economic importance as an alternative to commonly used chicken [9], Japanese quail (***Cotornix japonica, C. japonica* for short*)*** are used as Laboratory model animal in many laboratories all over the world[10]. Because of its short lifespan combined with its physiological similarity to humans, *C. japonica* has been considered as an ideal model for many studies in physiology, immunology, endocrinology, and reproductive biology[10].The contents of the elements were determined in male and female Japanese quail fed to captive raptors using atomic absorption of ashed whole quail samples (whole body samples of birds were burned in muffle furnace oven to evaporate all organic matter and leaving only organic elements for analysis). The average levels in mg/g of Cu, Fe, Mg, Mn, Zn, and Ca recorded for male samples were 2.66, 85.7, 578.6, 6.61, 55.01, and 32685, respectively and for female samples were 3.02, 112.4, 752.7, 8.45, 54.3 and 43615 respectively. The differences between male and female samples in the studied elements levels were not significant according to the author [11]. In another study [12], the authors, in order to estimate the nutritional requirements of ***C. japonica*** at different ages, studied the concentrations of Ca, Mg, P, K, Na, Cu, Fe, Mn, Ni, Se, Zn in ashes of whole birds (digestive contents removed) using atomic absorption. Sales et al. recorded the mean concentrations of Ca, Mg, P, K, and Na 223.3mg/g, 10.85mg/g, 174.9mg/g, 104 mg/g and 44.14 mg/g, respectively. The concentrations of Cu, Fe, Mn, Ni and Zn were 66.7, 1074, 49.03, 39.88, 1115 mg/kg respectively, while, Se recorded concentration was 8012 µg/g [12]. The concentrations of some heavy elements were determined in edible parts of migratory Japanese quail using ICP-MS. The samples of liver, kidney and muscles (chest & leg) were analyzed for the presence of Al, Cu, Fe, Mn, Zn, Cr, Mo, Ni, Pb and Sr. Their recorded ranges were Al (48.61 - 395.9), Cu (2.84 - 6.64), Fe (162.3 - 882.7), Mn (2.18 - 12.2) and Zn (8.11- 25.5), Cr (2.45-14.51), Sr (1.97-8.65), Pb (1.06-6.17), Ni (0.84-5.42) and Mo (0.23-1.48) mg/kg wet weight [13].

The inductively coupled plasma optical emission spectrometer (ICP-OES) is widely used in elemental analysis, because of its ability to obtain low detection limits, highly sensitive technique, its precision and can perform multi element analysis when compared with other analytical techniques [13]. In this technique, emission signal response depends directly on the number of analyte atoms and ions present in plasma which depends mainly on the sample. In ICP-OES, the radiation generated is optically aligned then dispersed and finally measured using an appropriate detector [14, 15].In this study, the inductively coupled plasma optical emission spectrometer (ICP-OES) is used for multi-element analyses to determine the reference values of trace, ultra-trace elements and REE, in addition to Y and Th, in main organs of *C. japonica* which are fed basal feed meal.

Experimental and design

A total number of 50 ***C. japonica*** chicks, obtained from the farm of Biological Applications Department, Nuclear Research Center, Atomic Energy Authority, Egypt were used in the present study. The quail chicks were randomly selected. They were battery reared and provided with water and feed ad Libitum under the same conditions of temperature and light regimen during the experimental period which lasted for (6 weeks) of age. Quails basal diets contained 3000 Kcal ME/Kg and 24.25 crude protein in starting periods. Quails basal diets contained 3000 and 2862Kcal ME/Kg and 24.25 and 21.2% crude protein in Starting and Laying periods, respectively, as shown in Table (1). All chemicals were purchased from Honeywell Fluka.

At the age of six weeks, the birds were slaughtered for blood, part and organ samples collection. Blood samples were maintained in tubes to coagulate, then the serum sample were separated by centrifugation at 3000×g for 5 minutes. Blood coagulate samples and selected parts and organs were weighted, freeze-dried, and then dry weights were recorded. 0.5 ml of serum samples and Weights between 0.5 to 1 g of blood coagulate and dry organ samples were digested using a mixture of concentrated nitric acid and hydrogen peroxide then the sample digests were diluted with de-ionized water to a final volume of 10 ml. multi elements analysis of diluted samples were performed using Prodigy High Dispersion Inductively Coupled Plasma Optical Emission Spectrometer (Teledyne Leeman ICP-OES USA). The specific spectral lines of the measured elements are shown in Table (2). O, H, C, and N were not analyzed in this study because they are components of air which is found in the prism environment. Halogens were not analyzed also because, when exited by plasma, their atoms escape leading high uncertainty in measurements.

Results and Discussion

The presence and concentration of 42 elements were investigated in a total of 13 samples from each bird. The samples included brain, beak, crop, eyes, gizzard, heart, intestines, skeletal muscles, kidneys, lungs, liver, ovaries in addition to coagulated blood and serum. The elements investigated included trace elements which are Al, Cs, Cu, Fe, Pb, Mn, Mo, Si , and Sr. in addition to Ultra trace elements which are Ag, As, B, Ba, Cr, Co, Li, Ni, Sb, Se, Ti, Tl,Th,V , W, and Zr. The presence and concentration of the rare earth elements (REE) group in addition to Ytterbium and thorium were also investigated. Twenty one of the investigated elements which are Li, Be, As, V, Y, Ag, Cd, Cs, and all REE except Er and Tm were below the detection limit while the rest of the investigated elements varied in amount and distribution relative to organs and parts in which they were investigated, as summarized in Tables (3-18) and Figures(1-4). Not all detected elements were found in all organs nor they had the same amounts. Types of elements detected also varied from organ to another.

In the ***C. japonica*** beak, 15trace, ultra-trace elements and REE were detected and determined (Table 3). The highest element in concentration was found to be Fe in the range of 55.29-499.43µg/g of dry Weight and had average concentration of 208.91±18.24µg/g dry Wt. Fe represented 35.4% of total detected elements. Tl and Tm were detected in the ***C. japonica*** beak. Tl abundance was about 0.3% in bone tissue while Tm abundance was 0.2%. To the best of our knowledge, there are no records for the presence of Tm in living organisms.

The ***C. japonica*** crop contained 12 elements as shown in Table (5) and as in the brain, Fe was found to have the highest abundance among detected elements. The estimated range of Fe in the crop is 85.57-173.49µg/g of dry Weight. and its average concentration is119.18±3.37µg/g dry Wt. which represents44.13% of total detected elements. From the recorded trace and ultra-trace elements and lanthanides [1-7], 11 elements were detected [1-7]. Twelve trace, ultra-trace elements and REE were detected in the ***C. japonica*** eyes, Table (6). Fe recorded the highest concentration in the ***C. japonica*** eyes which was 147.21±46.97µg/g dry Wt. Fe estimated range was 34.04-448.7µg/g of dry Weight and represented 49.25% of total detected elements. Ba, Th, W, and the REE Er detected concentrations in the ***C. japonica*** eyes are $2.44 x 10^{-3}$ % w/w, $2.53 x 10^{-4}$% w/w, $1.45 x 10^{-4}$% w/w. and 5 $x 10^{-5}$% w/w respectively. Although they are classified as ultra-trace elements which have concentrations less than 10^{-6}% [5] The determined concentrations of these four elements in the ***C. japonica*** eyes were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5].

In the ***C. japonica*** gizzard, 15trace, ultra-trace elements and REE were detected and determined, Table (7). The highest element in concentration was found to be Fe that ranged 94.17-129.54 and had an average concentration of 112.47±1.45µg/g dry Wt. which represented 38.9 % of total detected elements. The ultra-trace elements Ba, Cr, Ni, Se, Th, Ti, and W and the REE Er were found to have concentrations of $1.02 x 10^{-4}$% w/w, $2.3 x 10^{-5}$% w/w, $2.3 x 10^{-5}$% w/w, $1.35 x 10^{-4}$% w/w, $4.5 x 10^{-5}$% w/w, 1.4 $x 10^{-5}$% w/w, $1.5 x 10^{-4}$% w/w, and $5.3 x 10^{-5}$% w/w respectively. The determined concentrations of these elements in the ***C. japonica*** gizzard were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5].

Table (1): components of basal Diet fed to quail chick during experiment

Contents	Starter diet
Ground yellow corn	53.00
Soybean meal (44%)	34.00
Corn gluten meal (60%)	7.000
Calcium carbonate	1.400
Dicalcium phosphate	1.600
Sodium chloride	0.400
Vegetable oil	1.500
L-Lysine-Hcl	0.200
DL-Methionine	0.280
Choline chloride	0.240
Premix*	0.380
Calculated analysis**	100.00
Crude protein	24.0
ME	3000
Ca	1.01
Av.P	0.45
Lys.	1.37
Met.	0.64
Met+Cys	1.11

*Each kilogram of diet contains, A, 12000 I.U; D_3, 2000 I.U; E, 10mg; K, 2mg; B_1, 1mg; B_6, 1.5mg;B_{12}, 10µg; B_2, 4mg; Pantothonic acid, 10mg; Niacin, 20mg; Folic acid, 1g; Biotin, 50µg; and Choline chloride, 500mg. Copper, 10mg; Iodine, 1mg; Iron, 30mg; Manganese, 55mg; Zing, 55mg and Selenium, 1mg.

** Values were calculated according to the nutrient composition to the NRC [16].

Table (2): The specific spectral lines of the measured elements

Element	Line (nm)	Line type	S/B ratio
Al	396.152	A	1050
Ba	455.403	I	23000
Co	228.615	I	4300
Cr	267.716	I	4200
Cu	224.700	I	3900
Er	337.271	I	2900
Fe	240.489	I	2700
Mn	257.610	I	22000
Mo	277.540	I	1200
Ni	232.003	A	2000
Pb	217.000	A	330
Sb	206.833	A	910
Se	196.090	A	400
Si	288.158	A	1100
Sr	407.77	I	72000
Th	283.730	I	460
Ti	334.941	I	7900
Tl	190.864	I	740
Tm	313.126	I	5800
W	207.911	I	1000
Zn	202.548	I	7500
Zr	339.198	I	3900

A= A= Atomic line, I= Ionic line

Table (3): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* beak

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	36.6±4.17	3.07-96.79	6.2	$3.66x10^{-3}$
Ba (µg/g dry Wt.)	48.6±9.04	6.055-210.195	8.2	$4.86x10^{-3}$
Co (µg/g dry Wt.)	< D.L.	-------	-------	-------
Cr (µg/g dry Wt.)	0.63±0.04	0.24-1.18	0.1	$6.3x10^{-5}$
Cu (µg/g dry Wt.)	4.74±0.27	2.31-9.25	0.8	$4.74x10^{-4}$
Er (µg/g dry Wt.)	10.48±1.65	0.67-39.61	1.8	$1.05x10^{-3}$
Fe (µg/g dry Wt.)	208.91±18.24	55.29-499.43	35.4	$2.09x10^{-2}$
Mn (µg/g dry Wt.)	14.9±0.59	8.18-20.22	2.5	$1.49x10^{-5}$
Mo (µg/g dry Wt.)	< D.L.	-------	-------	-------
Ni (µg/g dry Wt.)	< D.L.	-------	-------	-------
Pb (µg/g dry Wt.)	< D.L.	-------	-------	-------
Sb (µg/g dry Wt.)	< D.L.	-------	-------	-------
Se (µg/g dry Wt.)	< D.L.	-------	-------	-------
Si (µg/g dry Wt.)	90.43±5.20	33.99-169.51	15.3	$9.4x10^{-3}$
Sr (µg/g dry Wt.)	23.46±0.61	17.59-25.5	4.0	$2.35x10^{-3}$
Th (µg/g dry Wt.)	3.44±0.16	2.1-5.55	0.6	$3.44x10^{-4}$
Ti (µg/g dry Wt.)	5.81±1	0-23.59	1.0	$5.81x10^{-4}$
Tl (µg/g dry Wt.)	1.71±0.17	0-4.67	0.3	$1.71x10^{-4}$
Tm (µg/g dry Wt.)	4.16±0.47	0-1.33	0.2	$9.5x10^{-4}$
W (µg/g dry Wt.)	2.87±0.2	1.69-6.42	0.5	$2.87x10^{-4}$
Zn (µg/g dry Wt.)	136.42±8.71	78.42-289.53	23.1	$1.36x10^{-2}$
Zr (µg/g dry Wt.)	< D.L.	-------	-------	-------

Table (4): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* brain

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	16.32±2.29	0-55.09	5.7	$1.63x10^{-3}$
Ba (µg/g dry Wt.)	< D.L.	------	------	------
Co (µg/g dry Wt.)	< D.L.	------	------	------
Cr (µg/g dry Wt.)	0.93±0.12	0.18-3.15	0.3	$9.3x10^{-5}$
Cu (µg/g dry Wt.)	12±0.36	7.91-16.88	4.2	$1.2x10^{-3}$
Er (µg/g dry Wt.)	1.46±0.17	0-4.46	0.5	$1.46x10^{-4}$
Fe (µg/g dry Wt.)	164.12±13.84	55.95-401.36	57.2	$1.64x10^{-2}$
Mn (µg/g dry Wt.)	1.77±0.08	1.06-3.14	0.6	$1.77x10^{-4}$
Mo (µg/g dry Wt.)	< D.L.	------	------	------
Ni (µg/g dry Wt.)	< D.L.	------	------	------
Pb (µg/g dry Wt.)	< D.L.	------	------	------
Sb (µg/g dry Wt.)	< D.L.	------	------	------
Se (µg/g dry Wt.)	< D.L.	------	------	------
Si (µg/g dry Wt.)	46.2±7.55	0-178.35	16.1	$4.62x10^{-3}$
Sr (µg/g dry Wt.)	< D.L.	------	------	------
Th (µg/g dry Wt.)	< D.L.	------	------	------
Ti (µg/g dry Wt.)	< D.L.	------	------	------
Tl (µg/g dry Wt.)	< D.L.	------	------	------
Tm (µg/g dry Wt.)	< D.L.	------	------	------
W (µg/g dry Wt.)	0.94±0.02	0.65-1.3	0.3	$9.4x10^{-5}$
Zn (µg/g dry Wt.)	42.93±0.97	32.64-54.02	15	$4.29x10^{-3}$
Zr (µg/g dry Wt.)	< D.L.	------	------	------

Table (5): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Crop

Element	Mean (µg/g dry Wt.) ±SD	Range (µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	26.58±3.2	0-71.36	8.74	$2.66x10^{-3}$
Ba (µg/g dry Wt.)	1.37±0.12	0-3.42	0.45	$1.36x10^{-4}$
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	0.31±0.01	0.25-0.36	0.10	$3.1x10^{-5}$
Cu (µg/g dry Wt.)	10.98±0.16	8.26-12.37	3.61	$1.1x10^{-3}$
Er (µg/g dry Wt.)	< D.L.	------	------	-------
Fe (µg/g dry Wt.)	119.18±3.37	85.57-173.49	39.20	$1.19x10^{-2}$
Mn (µg/g dry Wt.)	7.46±0.26	4.24-11.27	2.45	$7.46x10^{-4}$
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	< D.L.	------	------	-------
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	< D.L.	------	------	-------
Se (µg/g dry Wt.)	2.02±0.06	1.57-2.85	0.66	$2.02x10^{-4}$
Si (µg/g dry Wt.)	41.62±1.56	23.41-62.28	13.69	$4.16x10^{-3}$
Sr (µg/g dry Wt.)	3.4±0.12	1.19-4.21	1.12	$3.4x10^{-4}$
Th (µg/g dry Wt.)	0.40±0.02	0-0.71	0.13	$4x10^{-5}$
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	1.55±0.03	1.24-1.97	0.51	$1.55x10^{-4}$
Zn (µg/g dry Wt.)	89.38±1.52	72.41-113.45	29.40	$8.94x10^{-3}$
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

Table (6): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Eyes

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	4.76±1	0-11.4	1.59	$4.76x10^{-4}$
Ba (µg/g dry Wt.)	24.38±0.43	19.84-30.45	8.16	$2.44x10^{-3}$
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	0.31±0.01	0.19-0.52	0.10	$3.1x10^{-5}$
Cu (µg/g dry Wt.)	2.97±0.09	2.16-4.31	0.99	$2.97x10^{-4}$
Er (µg/g dry Wt.)	0.5±0.03	0-0.74	0.16	$5 x10^{-5}$
Fe (µg/g dry Wt.)	147.21±46.97	34.04-448.7	49.25	$1.47x10^{-2}$

Table (6) continued: mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Eyes

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Mn (µg/g dry Wt.)	1.83±0.07	1.15-2.96	0.61	$1.83x10^{-4}$
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	< D.L.	------	------	-------
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	< D.L.	------	------	-------
Se (µg/g dry Wt.)	< D.L.	------	------	-------
Si (µg/g dry Wt.)	34.45±4.12	0-98.97	11.52	$3.45x10^{-3}$
Sr (µg/g dry Wt.)	10.54±0.21	9.16-14.1	3.52	$1.05x10^{-3}$
Th (µg/g dry Wt.)	2.53±0.03	2.23-2.81	0.85	$2.53x10^{-4}$
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	1.45±0.05	0.87-1.25	0.48	$1.45x10^{-4}$
Zn (µg/g dry Wt.)	68.02±1.37	52.22-88.21	22.76	$6.8x10^{-3}$
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

Table (7): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Gizzard

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	11.72±0.29	8.34-15.38	4.0	$1.17x10^{-3}$
Ba (µg/g dry Wt.)	1.02±0.03	0.66-1.29	0.4	$1.02x10^{-4}$
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	0.23±0.01	0.19-0.31	0.1	$2.3x10^{-5}$
Cu (µg/g dry Wt.)	13.97±0.29	9.64-16.72	4.8	$1.4\ x10^{-4}$
Er (µg/g dry Wt.)	0.53±0.02	0.28-0.72	0.2	$5.3x10^{-5}$
Fe (µg/g dry Wt.)	112.47±1.45	94.17-129.54	38.9	$1.13x10^{-2}$
Mn (µg/g dry Wt.)	10.29±0.35	6.23-14.16	3.6	$1.03x10^{-3}$
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	0.23±0.02	0-0.43	0.1	$2.3x10^{-5}$
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	< D.L.	------	------	-------
Se (µg/g dry Wt.)	1.35±0.03.	1-1.82	0.5	$1.35x10^{-4}$
Si (µg/g dry Wt.)	31.34±1.03	21.43-47	10.8	$3.13x10^{-3}$
Sr (µg/g dry Wt.)	5.8±0.38	3-12.1	2.0	$5.8x10^{-4}$
Th (µg/g dry Wt.)	0.45±0.01	0.35-0.57	0.2	$4.5x10^{-5}$
Ti (µg/g dry Wt.)	0.14±0.013	0-0.29	0.05	$1.4\ x10^{-5}$
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	1.5±0.03	1.24-1.86	0.5	$1.5x10^{-4}$
Zn (µg/g dry Wt.)	98.3±1.62	84.33-122.98	34.0	$9.83\ x10^{-3}$
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

The heart samples of ***C. japonica*** were found to contain 11trace, ultra-trace elements and REE, Table (8). The highest element in concentration was found to be Fe that ranged from 254.39 to 305.9 and had average concentration of 275.82±2.6 µg/g dry Wt. which represented 66.18% of total detected elements. The ultra-trace elements Ba, Cr, Se, and W were found to have concentrations of $1.3x10^{-4}$% w/w, $2.5x10^{-5}$% w/w, $1.49x10^{-4}$% w/w, and $1.74x10^{-4}$% w/w respectively. The determined concentrations of these elements in the ***C. japonica*** heart were found to be in the range of trace elements which is between 10^{-6}% and 10^{-2}% [5].

In the ***C. japonica*** Intestines, 16trace, ultra trace elements and REE were detected and determined, Table (9). The highest element in concentration was found to be Fe that ranged 142.01-281.23 and had an average concentration of 210.3±6.64 µg/g dry Wt. which represented 37.32% of total detected elements. The ultra-trace elements Ba, Co, Cr, Ni, Sb, Se, Th, and W and the REE Er were found to have concentrations of $6.76x10^{-4}$% w/w, $7\ x10^{-5}$% w/w, $7.92\ x10^{-4}$% w/w, $3.39x10^{-4}$% w/w, $5.5x10^{-5}$% w/w, $8.8x10^{-5}$% w/w, $1.23x10^{-4}$% w/w, $2.54x10^{-4}$% w/w, and $1.41x10^{-4}$% w/w respectively. The determined concentrations of these elements in the ***C. japonica*** intestines were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5].

The Kidneys samples of ***C. japonica*** were found to contain 12trace, ultra trace elements and REE, Table (10). The highest element in concentration was found to be Fe that ranged 206.32-327.25 and had an average concentration of 267.89±4.49 µg/g dry Wt. which represented 66.04% of total detected elements. The ultra-trace elements Cr, Se, and W were found to have concentrations of $2.9x10^{-5}$ w/w, $4.47x10^{-4}$% w/w, and $1.17x10^{-4}$% w/w respectively. The determined concentrations of these elements in the ***C. japonica*** kidneys were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5].

In the ***C. japonica*** Lungs, 11 trace, ultra trace elements and REE were detected and determined, Table (11). The highest element in concentration was found to be Fe that ranged from 545.06 to 808.6 and had an average concentration of 676.83±18.64µg/g dry Wt. which represented 78.35% of total detected elements. The ultra trace elements Se, Th, and W and the REE Er were found to have concentrations of $9.2x10^{-5}$% w/w, $2.2x10^{-5}$% w/w, $9.9x10^{-5}$% w/w, $8.9x10^{-5}$% w/w, respectively. The determined concentrations of these elements with respect to the organ weight of ***C. japonica*** lungs were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5].

The Liver samples of ***C. japonica*** were found to contain 14 trace, ultra-trace elements and REE, Table (12). The highest element in concentration was found to be Fe that ranged from 206.32 to 327.25 and had an average concentration of 267.89±4.49 µg/g dry Wt. which represented 66.04% of total detected elements. The ultra-trace elements Cr, Sb, Se, Th and W were found to have concentrations of $0.22x10^{-5}$ %w/w, $4.5x10^{-5}$% w/w, $2.26x10^{-4}$% w/w, $1.2x10^{-5}$ %w/w and $1.3x10^{-4}$% w/w respectively. The determined concentrations of these elements with respect to the organ weight of the ***C. japonica*** Liver were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5]. The ovaries samples of ***C. japonica*** were found to contain 10 trace, ultra-trace elements and REE, Table (13). The highest element in concentration was found to be Zn that ranged from 42.51 to 55.68 and had an average concentration of 52±3.47 µg/g dry Wt. which represented 48.28% of total detected elements. The ultra-trace elements Cr, Ni, Sb, Se and W were found to have concentrations of 1.4 $x10^{-5}$%w/w, $2.32x10^{-4}$% w/w,2 $x10^{-5}$%w/w ,$1.33x10^{-4}$% w/w and $9.6x10^{-5}$ respectively. The determined concentrations of these elements with respect to the organ weight of the ***C. japonica*** Liver were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5].

In the ***C. japonica*** Skeletal Muscles, 7 trace, ultra-trace elements and REE were detected and determined, Table (14). The highest element in concentration was found to be Fe that ranged from 3.62 to 8.76and had an average concentration of 5.81±0.08µg/g dry Wt. which represented 86.69% of total detected elements. The ultra trace elements Se and Tl were found to have concentrations of $9.2x10^{-5}$ % w/wand$0.41x10^{-5}$% w/w, respectively. The determined concentrations of these elements with respect to the organ weight of ***C. japonica*** muscles were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5].

In the ***C. japonica*** Coagulated blood, 7 trace, ultra-trace elements and REE were detected and determined, table (15). The highest element in concentration was found to be Fe that ranged from 223.47to 321.49and had an average concentration of 275.64±4.8µg/g dry Wt. which represented 95.5% of total detected elements. The ultra-trace elements Se and Tl were found to have concentrations of $5.4x10^{-5}$w/wand$9.1x10^{-5}$ % w/w, respectively. The determined concentrations of these elements with respect to the organ weight of ***C. japonica*** muscles were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5]. The blood serum samples of ***C. japonica*** were found to contain 6 trace, ultra-trace elements and REE, Table (16). The highest element in concentration was found to be Fe that ranged from 2.84 to 16.12 and had an average concentration of 10.1±0.67 µg/g dry Wt. which represented 48.28% of total detected elements. From the six detected elements, four ultra-trace elements were detected which are Th, Tl, W and Zr and were found to have concentrations of $2.4x10^{-5}$ %w/w, $2.3x10^{-5}$% w/w,3 $x10^{-5}$%w/wand $6.2x10^{-4}$respectively. The determined concentrations of these elements with respect to the organ weight of the ***C. japonica*** blood serum were found to be in the range of trace elements which is between 10^{-6}% to 10^{-2}% [5]. The concentrations in terms of µg/g of all measured elements are summarized in Table (17) which showed that the most abundant detected element in studied organs and parts was Fe which was found to have the highest distribution in body parts and organs and its mean concentration was found to be uppermost in eleven of the studied organs and parts which are the brain, crop, gizzard, heart, intestines, kidneys, lungs and ovaries, Fig. (1). In the beak and eyes Ba had the highest concentration. The highest number of detected element types was in intestines which contained twenty-one detectable elements, Table (9), and the lowest number of detected element types was ten which was in blood serum, Table (16). On the other hand, the lungs were found to have the highest total mean concentration of element content which was 863.85 µg/g while the lowest recorded organ in total mean concentration of element content was the serum which had mean total element concentration of 12.96 µg/g. There are types of elements which were detected in only one organ, namely, Co in intestines and Tm in Beak. Other elements were detected in two or three organs and body parts, Mo in kidneys and liver, Pb in liver and coagulated blood, Ti in gizzard and beak, Ni in Gizzard intestines and Gonads, Zr in skeletal muscles, coagulated blood and blood serum. Sb was detected in four organs only which were intestines, liver, kidneys and gonads. Tl was also detected in only four organs which were beak, skeletal muscles, coagulated blood and blood serum. The presence of some detected elements was not recorded as normal elemental content in biological systems these elements are Tm, Tl, and Er [2,4,6]. Er was found mainly in the bird gastro intestinal tract (GIT) parts which are Beak, intestines and gizzard with mean concentrations 10.5, 1.5, 0.53 ppm respectively. It was also detected in the brain and liver with mean concentrations of 1.5 ppm in the brain, which is the same as in intestines, and 0.1 ppm in the liver. Er distribution in the analyzed parts and organs suggests that it may have a function that is not yet studied in the ***C. japonica*** body parts and organs in which it was concentrated. Tl was also detected in Beak with a relatively noticeable mean concentration of 1.7 ppm, in addition to its presence of coagulated blood, serum and skeletal muscles with mean concentrations 0.91, 0.23 and 0.41 ppm respectively. Tl detected distribution suggests that it may be absorbed and circulated in the blood stream of ***C. japonica*** with possible contribution in the metabolic and physiological functions of skeletal muscles which is not yet known. Tm was only found in beak with mean concentration of 0.95 ppm, with no detectable amounts at any other part of the GIT, this suggest that Tm may accumulate in the beak but its role as a component in this body part it yet to be discovered.

The present findings and results showed that although elements are generally classified into macro trace and ultra-trace elements according to their concentration relative to total body weight [5], this is not the case if the body organs and parts were analyzed individually. It was found that on organ level, some elements levels concentrations were higher than their recorded range of level ranges as in the case of Cr which is classified as ultra-trace element with a concentration below 10^{-6} % [5]. However, it was found that its measured levels were in the range of trace elements that ranged from 10^{-6} % to 10^{-2}% [5]. Concentrations of individual elements also varied from one organ to another as in the case of some macro elements that recorded levels at the range of trace elements as in the case of Mg in blood components. It was also detected the noticeable levels of Tm, Tl, and Er which are not recorded to be normally present in higher bio-organisms. These elements were detected in specific organs.

Conclusions

The present study recorded the distribution of 47 elements in various parts and organs of ***C. japonica*** as a laboratory model animal. The above recorded concentrations and distributions of various elements may be related to their roles in structures and functions of organs in which they were distributed with various levels. According to the above findings, a deeper classification of elements according to distribution and concentration levels in individual organs is recommended. We recommend investigation of the existence of Tm, Tl, and Er in other living species and a further investigation of the role of Tm, Tl, and Er in structure and metabolism of *Cotornix japonica* parts and organs in which they were detected.

Table (8): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Heart

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	13.58±1.378	0-31.06	3.20	$1.36x10^{-3}$
Ba (µg/g dry Wt.)	1.3±0.18	0-4.2	0.31	$1.3x10^{-4}$
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	0.25±0.01	0.08-0.48	0.06	$2.5x10^{-5}$
Cu (µg/g dry Wt.)	14.28±0.14	12.14-15.96	3.43	$1.43x10^{-3}$
Er (µg/g dry Wt.)	< D.L.	------	------	-------
Fe (µg/g dry Wt.)	275.82±2.6	254.39-305.9	66.18	$2.76x10^{-2}$
Mn (µg/g dry Wt.)	1.4±0.03	1.13-1.25	0.34	$1.4x10^{-4}$
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	< D.L.	------	------	-------
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	< D.L.	------	------	-------
Se (µg/g dry Wt.)	1.49±0.05	0.83-2.15	0.36	$1.49x10^{-4}$
Si (µg/g dry Wt.)	31.34±1.03	21.43-47	5.10	$3.13x10^{-3}$
Sr (µg/g dry Wt.)	1.74±0.06	0.18-6.99	0.46	$1.74x10^{-4}$
Th (µg/g dry Wt.)	< D.L.	------	------	-------
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------

W (µg/g dry Wt.)	1.74±0.06	1.16-2.81	0.42	1.74×10^{-4}
Zn (µg/g dry Wt.)	83.99±1.14	68.8-100.60	20.15	8.4×10^{-3}
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

Table (9): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Intestines

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	101.88±5.97	22.92-168.02	101.9	1.02×10^{-2}
Ba (µg/g dry Wt.)	6.76±0.31	2.34-9.99	6.8	6.76×10^{-4}
Co (µg/g dry Wt.)	0.7±0.01	0.53-0.87	0.7	7×10^{-5}
Cr (µg/g dry Wt.)	7.92±0.67	1.92-15.48	7.9	7.92×10^{-4}
Cu (µg/g dry Wt.)	17±0.67	11.23-27.7	17.0	1.7×10^{-3}
Er (µg/g dry Wt.)	1.41±0.18	0-4.05	1.4	1.41×10^{-4}
Fe (µg/g dry Wt.)	210.3±6.64	142.01-281.23	210.3	2.1×10^{-2}
Mn (µg/g dry Wt.)	59.07±1.99	32.13-79.48	59.1	5.91×10^{-3}

Table (9) continued: mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Intestines

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	3.39±0.09	2.32-4.51	3.4	3.39×10^{-4}
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	0.55±0.05	0-1.3	0.08	5.5×10^{-5}
Se (µg/g dry Wt.)	0.88±0.04	0.38-1.49	0.13	8.8×10^{-5}
Si (µg/g dry Wt.)	135.84±8.98	51.45-255.39	19.39	1.36×10^{-2}
Sr (µg/g dry Wt.)	26.97±0.71	21.83-38.89	3.85	2.7×10^{-3}
Th (µg/g dry Wt.)	1.23±0.04	0.744-1.86	0.18	1.23×10^{-4}
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	2.54±0.05	1.89-3.03	0.36	2.54×10^{-4}
Zn (µg/g dry Wt.)	124.27±2.25	90.26-153.15	17.73	1.24×10^{-2}
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

Table (10): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Kidneys

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	6.81±0.81	0-18.23	1.63	6.81×10^{-4}
Ba (µg/g dry Wt.)	< D.L.	------	------	-------
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	0.29±0.01	0.22-0.49	0.07	2.9×10^{-5}
Cu (µg/g dry Wt.)	12.41±0.05	11.93-13.04	3.06	1.24×10^{-3}
Er (µg/g dry Wt.)	< D.L.	------	------	-------
Fe (µg/g dry Wt.)	267.89±4.49	206.32-327.25	66.04	2.68×10^{-2}
Mn (µg/g dry Wt.)	7.91±0.28	5.34-11.8	1.95	7.91×10^{-4}
Mo (µg/g dry Wt.)	3.83±0.04	3.5-4.43	0.94	3.83×10^{-4}
Ni (µg/g dry Wt.)	< D.L.	------	------	-------
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	0.21±0.01	0-0.3	0.05	2.1×10^{-5}
Se (µg/g dry Wt.)	4.47±0.06	3.88-5.3	1.10	4.47×10^{-4}
Si (µg/g dry Wt.)	24.8±1.8	10.68-51.43	6.11	2.48×10^{-3}
Sr (µg/g dry Wt.)	< D.L.	------	------	-------
Th (µg/g dry Wt.)	0.22±0.02	0-0.4	0.06	2.2×10^{-5}
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	1.17±0.02	0.96-1.46	0.29	1.17×10^{-4}
Zn (µg/g dry Wt.)	75.82±2.3	62.07-110.17	18.69	7.58x10-3
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

Table (11): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Lungs

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	52.34±4.8	12-105.5	6.06	$5.23x10^{-3}$
Ba (µg/g dry Wt.)	< D.L.	------	------	-------
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	0.38±0.03	0.19-0.74	0.04	$3.8x10^{-5}$
Cu (µg/g dry Wt.)	3.17±0.13	2.04-4.55	0.37	$3.17x10^{-4}$
Er (µg/g dry Wt.)	0.89±0.08	0.38-1.87	0.10	$8.9x10^{-5}$
Fe (µg/g dry Wt.)	676.83±18.64	545.06-808.6	78.35	$6.78x10^{-2}$
Mn (µg/g dry Wt.)	3.3±0.10	2.54-4.45	0.38	$3.3x10^{-4}$
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	< D.L.	------	------	-------
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	< D.L.	------	------	-------
Se (µg/g dry Wt.)	0.92±0.06	0.32-1.46	0.11	$9.2x10^{-5}$
Si (µg/g dry Wt.)	44.22±2.5	27.59-73.09	5.12	$4.42x10^{-3}$
Sr (µg/g dry Wt.)	< D.L.	------	------	-------
Th (µg/g dry Wt.)	0.75±0.025	0-0.84	0.09	$2.2x10^{-5}$
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	0.99±0.06	0.55-1.69	0.11	$9.9x10^{-5}$
Zn (µg/g dry Wt.)	80.09±5	30.06-129.6	9.27	$8.01x10^{-3}$
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

Table (12): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Liver

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	1.88±0.29	0-6.91	0.49	$1.88x10^{-4}$
Ba (µg/g dry Wt.)	< D.L.	------	------	-------
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	0.22±0.01	0.12-0.32	0.06	$0.22x10^{-5}$
Cu (µg/g dry Wt.)	12.24±0.15	10.68-14.81	3.19	$1.22x10^{-3}$
Er (µg/g dry Wt.)	0.06±0.007	0-0.17	0.01	$6 x10^{-6}$
Fe (µg/g dry Wt.)	251.67±1.9	228.24-270.51	65.64	$2.51x10^{-2}$
Mg (µg/g dry Wt.)	243.31±5.11	199.83-315.95	0.41	$2.43x10^{-2}$
Mn (µg/g dry Wt.)	7.85±0.07	6.83-8.71	2.05	$7.85x10^{-4}$
Mo (µg/g dry Wt.)	1.59±0.02	1.4-1.73	0.01	$1.59x10^{-4}$
Ni (µg/g dry Wt.)	< D.L.	------	------	-------
Pb (µg/g dry Wt.)	1.8±0.37	0-8.39	0.47	$1.8x10^{-4}$

Table (12) continued: mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Liver

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Sb (µg/g dry Wt.)	0.45±0.01	0.3-0.56	0.12	$4.5x10^{-5}$
Se (µg/g dry Wt.)	2.26±0.04	1.8-2.69	0.59	$2.26x10^{-4}$
Si (µg/g dry Wt.)	14.8±0.79	7.25-27.76	3.86	$1.48x10^{-3}$
Sr (µg/g dry Wt.)	< D.L.	------	------	-------
Th (µg/g dry Wt.)	0.12±0.01	0.0.07-0.19	0.03	$1.2x10^{-5}$
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	1.3±0.05	0.7-2	0.34	$1.3x10^{-4}$
Zn (µg/g dry Wt.)	87.16±2.86	53.21-126.95	22.73	$8.71x10^{-3}$
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

Table (13): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Ovaries

Element	Mean (µg/g dry Wt.) ±SD	Range (µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	< D.L.	------	------	-------
Ba (µg/g dry Wt.)	< D.L.	------	------	-------
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	0.14±0.01	0.11-0.17	0.13	$1.4 x10^{-5}$
Cu (µg/g dry Wt.)	4.25±0.28	2.59-5.61	3.94	$4.25x10^{-4}$
Er (µg/g dry Wt.)	< D.L.	------	------	-------
Fe (µg/g dry Wt.)	35.52±2.37	30.25-39.65	32.98	$3.55x10^{-3}$
Mn (µg/g dry Wt.)	1.28±0.09	0.96-1.57	1.19	$1.28x10^{-4}$
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	2.32±0.16	1.62-3.11	2.18	$2.32x10^{-4}$
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	0.2±0.01	0.13-0.35	0.19	$2 x10^{-5}$
Se (µg/g dry Wt.)	1.33±0.09	1.1-1.54	1.23	$7.9x10^{-5}$
Si (µg/g dry Wt.)	9.7±0.65	5.21-12.65	9.01	$9.7x10^{-4}$
Sr (µg/g dry Wt.)	< D.L.	------	------	-------
Th (µg/g dry Wt.)	< D.L.	------	------	-------
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	< D.L.	------	------	-------
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	0.96±0.06	0.4-1.2	0.89	$9.6x10^{-5}$
Zn (µg/g dry Wt.)	52±3.47	42.51-55.68	48.28	$5.2x10^{-3}$
Zr (µg/g dry Wt.)	< D.L.	------	------	-------

Table (14): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Skeletal Muscles

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	< D.L.	------	------	-------
Ba (µg/g dry Wt.)	< D.L.	------	------	-------
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	< D.L.	------	------	-------
Cu (µg/g dry Wt.)	0.45±0.01	0.38-0.59	6.78	$4.5x10^{-5}$
Er (µg/g dry Wt.)	< D.L.	------	------	-------
Fe (µg/g dry Wt.)	5.81±0.08	3.62-8.76	86.69	$5.81x10^{-4}$
Mn (µg/g dry Wt.)	< D.L.	------	------	-------
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	< D.L.	------	------	-------
Pb (µg/g dry Wt.)	< D.L.	------	------	-------
Sb (µg/g dry Wt.)	< D.L.	------	------	-------
Se (µg/g dry Wt.)	0.79±0.01	0.24-0.87	11.8	$7.9x10^{-5}$
Si (µg/g dry Wt.)	1.48±0.01	0.86-2.16	22.16	$1.48x10^{-4}$
Sr (µg/g dry Wt.)	< D.L.	------	------	-------
Th (µg/g dry Wt.)	< D.L.	------	------	-------
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	0.41±0.01	0.0.32-0.52	6.13	$0.41x10^{-5}$
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	< D.L.	------	------	-------
Zn (µg/g dry Wt.)	2.8±0.06	0.66-1.28	41.87	$2.8x10^{-4}$
Zr (µg/g dry Wt.)	1.21±0.08	0.42-1.97	18.03	$1.21x10^{-5}$

Table (15): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Coagulated Blood

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g dry Wt.)	< D.L.	------	------	-------
Ba (µg/g dry Wt.)	< D.L.	------	------	-------
Co (µg/g dry Wt.)	< D.L.	------	------	-------
Cr (µg/g dry Wt.)	< D.L.	------	------	-------
Cu (µg/g dry Wt.)	0.76±0.02	0.6-1.02	0.26	$7.6x10^{-5}$
Er (µg/g dry Wt.)	< D.L.	------	------	-------
Fe (µg/g dry Wt.)	275.64±4.8	223.47-321.49	95.50	$2.76x10^{-2}$
Mn (µg/g dry Wt.)	< D.L.	------	------	-------
Mo (µg/g dry Wt.)	< D.L.	------	------	-------
Ni (µg/g dry Wt.)	< D.L.	------	------	-------
Pb (µg/g dry Wt.)	0.5±0.04	0.18-0.98	0.17	$5 x10^{-5}$
Sb (µg/g dry Wt.)	< D.L.	------	------	-------
Se (µg/g dry Wt.)	0.62±0.01	0.54-0.73	0.21	$5.4x10^{-5}$

Table (15) continued: mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Coagulated Blood

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Si (µg/g dry Wt.)	2.16±0.11	0.89-3.16	0.75	$2.16x10^{-4}$
Sr (µg/g dry Wt.)	< D.L.	------	------	-------
Th (µg/g dry Wt.)	< D.L.	------	------	-------
Ti (µg/g dry Wt.)	< D.L.	------	------	-------
Tl (µg/g dry Wt.)	0.91±0.02	0.7-1.16	0.32	$9.1x10^{-5}$
Tm (µg/g dry Wt.)	< D.L.	------	------	-------
W (µg/g dry Wt.)	< D.L.	------	------	-------
Zn (µg/g dry Wt.)	< D.L.	------	------	-------
Zr (µg/g dry Wt.)	8.04±0.23	5.57-10.18	2.79	$8.04x10^{-4}$

Table (16): mean concentrations, ranges and Abundances of detected Elements in *C. japonica* Blood Serum

Element	Mean(µg/g dry Wt.) ±SD	Range(µg/g dry Wt.)	Abundance (%)	Concentration % w/w
Al (µg/g)	< D.L.	------	------	-------
Ba (µg/g)	< D.L.	------	------	-------
Co (µg/g)	< D.L.	------	------	-------
Cr (µg/g)	< D.L.	------	------	-------
Cu (µg/g)	< D.L.	------	------	-------
Er (µg/g)	< D.L.	------	------	-------
Fe (µg/g)	10.1±0.67	2.84-16.12	56.16	$1.01x10^{-3}$
Mn (µg/g)	< D.L.	------	------	-------
Mo (µg/g)	< D.L.	------	------	-------
Ni (µg/g)	< D.L.	------	------	-------
Pb (µg/g)	< D.L.	------	------	-------
Sb (µg/g)	< D.L.	------	------	-------
Se (µg/g)	< D.L.	------	------	-------
Si (µg/g)	< D.L.	------	------	-------
Sr (µg/g)	< D.L.	------	------	-------
Th (µg/g)	0.24±0.01	0-0.31	1.32	$2.4x10^{-5}$
Ti (µg/g)	< D.L.	------	------	-------
Tl (µg/g)	0.23±0.01	0.12-0.36	1.26	$2.3x10^{-5}$
Tm (µg/g)	< D.L.	------	------	-------
W (µg/g)	0.3±0.01	0.18-0.47	1.65	$3 x10^{-5}$
Zn (µg/g)	0.92±0.03	0.66-1.28	5.13	$9.2x10^{-5}$
Zr (µg/g)	6.2±1.1	0.27-22.74	6.2	$6.2x10^{-4}$

Table (17): summarized concentrations of detected Elements in all studied organs of *C. japonica*#

Organ / Element	Beak	Brain	Crop	Eyes	Gizzard	Heart	Intestines	Kidneys	Lungs	Liver	Ovaries	B.Clot	Serum	Muscle	Element Total µg/g	Element %
	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g	Ave. µg/g		
Al	36.9	16.3	26.6	4.8	11.72	13.4	101.9	6.6	52.3	1.9	0.0	0.0	0.0	0.0	272.32	5.4824
Ba	48.6	0.0	1.4	24.4	1.02	1.3	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.44	1.6798
Co	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.70	0.0141
Cr	0.6	0.9	0.3	0.3	0.23	0.3	7.9	0.3	0.4	0.2	0.1	0.0	0.0	0.0	11.62	0.2339
Cu	4.7	12.0	11.0	3.0	13.97	14.3	17.0	12.4	3.2	12.2	4.2	0.76	0.0	0.45	109.22	2.1989
Er	10.5	1.5	0.0	0.5	0.53	0.0	1.4	0.0	0.9	0.1	0.0	0.0	0.0	0.0	15.31	0.3081
Fe	208.9	164.1	119.2	147.2	112.47	275.8	210.3	267.9	676.8	251.7	35.5	275.64	10.11	5.81	2761.47	55.5945
Mn	14.9	1.8	7.5	1.8	10.29	1.4	59.1	7.9	3.3	7.9	1.3	0.0	0.0	0.0	117.06	2.3567
Mo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	1.6	0.0	0.0	0.0	0.0	5.41	0.1090
Ni	0.0	0.0	0.0	0.0	0.23	0.0	3.4	0.0	0.0	0.0	2.3	0.0	0.0	0.0	5.93	0.1195
Pb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.50	0.0	0.0	2.30	0.0463
Sb	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.5	0.2	0.0	0.0	0.0	1.41	0.0284
Se	0.0	0.0	2.0	0.0	1.35	1.49	0.9	4.5	0.9	2.3	1.3	0.62	0.0	0.79	16.12	0.3246
Si	90.4	46.2	41.6	34.4	31.34	21.3	135.8	24.8	44.2	14.8	9.7	2.16	0.0	1.48	498.31	10.0320
Sr	23.5	0.0	3.4	10.5	5.80	1.9	27.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.06	1.4508
Th	3.4	0.0	0.4	2.5	0.45	0.0	1.2	0.2	0.7	0.1	0.0	0.0	0.24	0.0	9.39	0.1891
Ti	5.9	0.0	0.0	0.0	0.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.23	0.0	6.23	0.1254
Tl	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.91	0.0	0.41	3.03	0.0611
Tm	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.95	0.0192
W	2.9	0.9	1.6	1.4	1.50	1.7	2.5	1.2	1.0	1.3	1.0	0.0	0.30	0.0	17.31	0.3485
Zn	136.4	42.9	89.4	68.0	98.30	84.0	124.3	75.8	80.1	87.2	52.0	0.0	0.92	2.80	942.11	18.9668
Zr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.04	6.20	1.21	15.45	0.3110
OrganTotal µg/g	590.29	286.67	304.24	298.92	289.32	416.79	700.71	405.66	863.85	383.42	107.70	288.63	18.00	12.96	4967.17	
Grand %	11.884	5.7713	6.1251	6.018	5.8246	8.391	14.107	8.1668	17.391	7.719	2.1683	5.8106	0.3623	0.2609		

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