Asian Journal of Chemistry; Vol. 25, No. 2 (2013), 1057-1062

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2013.13418

Assessments of Selected Essential Elements in Canned Tuna Marketed in Jordan

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(*Received*: 10 January 2012; *Accepted*: 30 August 2012) AJC-12042

In this study, the levels of five macroelements and eight microelements in 104 samples of canned tuna were determined by ICP-OES and flame photometer. The concentrations of macroelements were found in the range of 1947-3963 mg/kg for phosphorous, 1044-2883 mg/kg for potassium, 665-2022 mg/kg for sodium, 241- 457 mg/kg for magnesium and 107-384 mg/kg for calcium. The contents of investigated microelements in canned tuna samples were found to be in the range 4.1-21.1 mg/kg for iron, 3.0-12.1 mg/kg for zinc, 0.12-0.92 mg/kg for copper, 0.11-1.07 mg/kg for selenium, < 0.02 to 0.81 mg/kg for manganese, < 0.04-0.23 mg/kg for chromium, < 0.03-0.07 mg/kg for cobalt and < 0.04-0.06 mg/kg for molybdenum. The results were compared with the literature values.

Key Words: Canned tuna, Essential elements, Seafood, ICP-OES, Flame photometer, Jordan.

INTRODUCTION

Fish and fishery products are widely consumed in many parts of the world by humans because they are considered as healthy, good quality sources of protein and they provide various nutrients and unsaturated fatty acids that have protective effects in preventing coronary heart disease[1]. Indeed, Omega-3 fatty acids in fish have been reported to reduce the incidence of heart disease and stroke[2]. Canned fish products (tuna, sardine, mackerel, herring *etc.*) are also rich in macro essential elements such as phosphorous and calcium and microelements such as selenium[3]. The essential microelements such as zinc, copper, chromium, fluorine, iodine and selenium play important roles in biological systems and have a variety of biochemical functions in living organisms. Beside the good health benefits of fish consumption, levels of contaminants in fish are of significant concern because of their potential effects on human health. Heavy metals represent an important group of aquatic pollutants due to their toxicity, long persistence and possible bioaccumulative properties in the food chain[4]. Metals are taken up by fish through two major pathways, the ingestion of food and water and adsorption through gill surface and skin[5]. Fish is often the final chain of aquatic food web and may accumulate high levels of some metals[6]. Consequently, fish species of elevated trophic levels such as shark, swordfish and tuna may accumulate a substantial amount of heavy metals[7]. Toxic elements such as mercury, cadmium, lead and arsenic perform no beneficial biological roles and can be dangerous even at low concentrations when ingested over a long period of time[8]. Essential elements can also pose hazardous effects and health problems at high concentrations[9]. For these reasons, several organizations throughout the world such as the world health organization, food and agricultural organization and the US Food and Drug Administration (US-FDA) have provided recommendations concerning the consumptions of fish products. Several studies have reported trace elements concentrations in canned tuna from Turkey[10-13], USA[14-17], Saudi Arabia[18,19] and France[20]. However, publications on the concentrations of macro and micro elements in canned tuna marketed in Jordan are lacking. Therefore the aim of this study was to determine the concentration levels of 13 essential elements found in canned tuna to evaluate possible benefits and or risks associated with the consumption of canned tuna.

EXPERIMENTAL

Sampling: One hundred and four samples of various brands and contents of canned tuna were purchased from different supermarkets in Irbid, Amman and Ma'an cities in Jordan. Samples were transported to the laboratory, coded for easy identification. Brands, origins, contents and other information are presented in Table-1. After opening, the fish sauce and oil contents (liquids) were drained off, the meat content was homogenized in food blender, a portion of the homogenized meat was sub-sampled and weighed for elemental analysis.

Deionized water with specific resistivity of 18.0 MW cm^{-1} was used. All glassware used in the present study were previously soaked in 10 % (v/v) HNO_3 solution for 12 h and rinsed

TABLE-1
CHARACTERISTICS OF CANNED TUNA USED IN THIS STUDY

Brand code	Net weight (g)	Drained weight (g)	Content and additives	Production date
B1	160	112	Light meat tuna (shredded), vegetable oil, salt	03/2009
B2	95	75	White meat tuna (chunks), vegetable oil, salt	07/2008
B3	120	84	Light meat tuna (slices), olive oil, salt	04/2008
B4	160	112	Light meat tuna (chunks), vegetable oil, salt	04/2009
B5	185	130	Light meat tuna (chunks), vegetable oil, salt, chili	01/2009
B6	170	119	Light meat tuna (flakes), vegetable oil, salt	02/2009
B7	95	67	Light meat tuna (chunks), vegetable oil, salt	01/2008
B8	120	84	Light meat tuna (grilled- steak), smoked, sunflower oil, salt	04/2008
B9	170	119	Light meat tuna (chunks), water, salt	11/2009
B10	95	67	Light meat tuna (chunks), vegetable oil, salt	01/2009
B11	170	119	White meat tuna (chunks), water	05/2009
B12	195	140	White meat tuna (chunks), water, salt	04/2008
B13	170	119	Light meat tuna (chunks), vegetable oil, salt	05/2009
B14	120	84	Light meat tuna (grilled- fingers), sunflower oil, salt, starch	04/2008
B15	170	119	Light meat tuna (chunks), vegetable oil, salt	11/2008
B16	120	84	White tuna (slices), sunflower oil, pepper, salt, lemon flavor	04/2008
B17	160	112	Light meat tuna (chunks), vegetable oil, salt	03/2009
B18	95	67	Light meat tuna (chunks), vegetable oil, salt	05/2008
B19	170	120	White meat tuna (chunks), vegetable oil	05/2009
B20	95	70	Light meat tuna (chunks), vegetable oil, salt	01/2007
B21	95	67	White meat tuna (chunks), water, salt	09/2008
B22	95	67	Light meat tuna (chunks), vegetable oil, salt	04/2009
B23	195	140	Light meat tuna (chunks), vegetable oil, salt	05/2008
B24	160	112	Light meat tuna (chunks), vegetable oil, salt	06/2008
B25	170	120	White meat tuna, water	05/2009
B26	160	112	Light meat tuna (flakes), vegetable oil, salt	04/2009
B27	170	120	Light meat tuna (flakes), vegetable oil	02/2009

with deionized water. Nitric acid (HNO_3, 69 %) and (H_2O_2, 30 %) were of ultrapure quality (Trace SELECTâ, Fluka). Multielement standard calibration of Fe, Zn, Cu, Cr and Mn at concentration of 1000 mg L^{-1} was used. Individual standards of Na, Ca, K, Mg, P, Co, Mo and Se were used. The standard solutions were appropriately diluted and used to calibrate the ICP-OES before metal determination. Standards of Na, K and Ca were used to calibrate the flame photometer.

Sample preparation and chemical analysis: Aliquots (about 1-3 g) of the homogenized samples were digested in 200 mL glass beakers with 20 mL of a mixture of freshly (1:1) (v/v) HNO_3 (69 %)-H_2O_2 (30 %) solution. Each beaker was covered with a watch glass and stored at room temperature for 24 h. The samples were then heated on hot plate at 150-165 ºC, aliquots of nitric acid were added until the solutions were clear. Solutions were constantly boiled until the volume for each sample reduced to about 5 mL. The solutions were then allowed to cool, filtered (glass wool) and diluted up to 50 mL with acidified (HNO_3) deionized water and then placed in acid washed 60 mL polyethylene bottles. A blank digest was carried out in the same way. All digested samples were analyzed, in triplicate, for Na, K, Ca, P, Mg, Fe, Zn, Se, Cu, Cr, Mn, Co and Mo contents using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)(VISTA-MPX instrument®). The simultaneous ICP-OES was equipped with axial vision, a radio frequency (RF) source of 30 MHz, a CCD (charge coupled device), a peristaltic pump and a glass concentric nebulizer. Flame photometer (PFP7, Jenway®) was also used for the analysis of Na, K and Ca.

The accuracy of the method was verified by analysis of standard reference material (DORM-2, Dogfish muscle) obtained from National Research Council, Canada. Accuracy was determined by comparing the measured concentrations with the certified values and was expressed as a percentage recovery (% recov.). The achieved results were in good agreement with certified values. The results are given in Table- 2.

TABLE-2
RECOVERY OF VARIOUS ELEMENTS FROM CERTIFIED REFERENCE MATERIAL (DORM-2, DOGFISH MUSCLE)

Element	Certified values (mg/g)	Measured values (µg/g)	Recovery (%)
Zn	25.600	26.20	102.3
Fe	142.000	135.00	95.1
Mn	3.660	3.70	101.1
Cu	2.340	2.21	94.4
Co	0.182	0.19	104.4
Cr	34.700	33.10	95.4
Se	1.400	1.25	89.3

RESULTS AND DISCUSSION

One hundred and four samples of canned tuna fish (belonging to 27 various brands or contents) were analyzed for the macro elements; calcium, potassium, sodium, magnesium and phosphorous and the microelements; iron, zinc, selenium, copper, chromium, molybdenum, cobalt and manganese. The concentrations of these elements on a wet weight basis are presented in Tables 3 and 4.

Macro elements were detected in all the analyzed samples. Their concentrations were found in the ranges of 1947-3963 mg/kg for phosphorous, 1044-2883 mg/kg for potassium, 665-2022 mg/kg for sodium, 241- 457 mg/kg for magnesium and 107-384 mg/kg for calcium. The order of

TABLE-3
CONCENTRATIONS OF MACRO ELEMENTS IN CANNED TUNA FISH (mg/kg)

Brand code	No. samples	Ca	K	Mg	Na	P
B1	3	121 ± 5	1089 ± 121	360 ± 16	1033 ± 32	3774 ± 179
B2	4	132 ± 9	2811 ± 183	373 ± 11	2014 ± 91	3681 ± 192
B3	5	125 ± 5	1065 ± 119	322 ± 14	822 ± 45	3153 ± 132
B4	4	117 ± 8	2607 ± 221	327 ± 18	942 ± 67	2984 ± 163
B5	3	126 ± 6	2199 ± 236	273 ± 13	1484 ± 108	2039 ± 160
B6	4	384 ± 14	1890 ± 201	281 ± 10	1586 ± 113	2188 ± 155
B7	4	163 ± 10	2385 ± 183	305 ± 17	1228 ± 51	3000 ± 145
B8	4	245 ± 4	1074 ± 119	295 ± 13	665 ± 25	2995 ± 108
B9	3	158 ± 6	2808 ± 218	309 ± 16	1741 ± 118	2894 ± 112
B10	3	185 ± 11	1149 ± 101	322 ± 21	1611 ± 100	3151 ± 149
B11	4	141 ± 5	2415 ± 172	357 ± 21	2022 ± 69	2581 ± 169
B12	3	116 ± 6	2058 ± 146	301 ± 13	1450 ± 117	2260 ± 120
B13	3	139 ± 6	2709 ± 218	370 ± 11	1744 ± 146	3110 ± 205
B14	4	108 ± 5	1092 ± 223	311 ± 21	734 ± 31	3650 ± 217
B15	4	162 ± 8	2883 ± 236	301 ± 23	1642 ± 66	3295 ± 248
B16	5	119 ± 8	1065 ± 127	279 ± 20	856 ± 17	3326 ± 222
B17	4	125 ± 4	1203 ± 141	318 ± 21	1175 ± 75	3963 ± 187
B18	5	141 ± 7	2730 ± 253	410 ± 13	2007 ± 71	3223 ± 231
B19	5	211 ± 11	2643 ± 246	339± 14	1773 ± 85	3070 ± 225
B20	4	107 ± 7	1146 ± 179	365 ± 17	1425 ± 20	3250 ± 114
B21	3	125 ± 4	2286 ± 211	293 ± 13	1469 ± 119	2302 ± 181
B22	4	155 ± 6	1155 ± 183	308 ± 19	856 ± 45	3319 ± 240
B23	5	196 ± 5	1290 ± 166	457 ± 22	1211 ± 48	3890 ± 288
B24	3	137 ± 10	2880 ± 198	330 ± 14	1245 ± 40	2817 ± 250
B25	4	185 ± 11	1044 ± 107	241 ± 18	1185 ± 56	2685 ± 183
B26	3	315 ± 17	1656 ± 138	259 ± 11	1396 ± 93	1947 ± 173
B27	4	292 ± 13	1044 ± 187	334 ± 11	1022 ± 63	1983 ± 214

Results are expressed as mg /kg wet weight

TABLE-4
LEVELS OF SELECTED MICROELEMENTS IN CANNED TUNA EXPRESSED AS mg/kg WET WEIGHT

Brand code	No. samples	Zn	Co	Se	Mo	Mn	Cu	Fe	Cr
B1	3	6.83 ± 0.38	< 0.03	0.56 ± 0.05	< 0.04	0.15 ± 0.04	0.49 ± 0.03	9.16 ± 0.23	< 0.04
B2	4	3.76 ± 0.30	0.07 ± 0.03	0.11 ± 0.03	0.06 ± 0.03	0.20 ± 0.04	0.24 ± 0.04	4.13 ± 0.27	0.23 ± 0.03
B3	5	4.83 ± 0.48	< 0.03	0.99 ± 0.10	0.05 ± 0.02	0.09 ± 0.02	0.34 ± 0.05	4.89 ±0.24	< 0.04
B4	4	8.10 ± 0.25	0.07 ± 0.04	1.03 ± 0.08	0.04 ± 0.03	< 0.02	0.57 ± 0.04	10.34 ± 0.35	0.22 ± 0.05
B5	3	8.69 ± 0.18	0.04 ± 0.03	0.54 ± 0.02	< 0.04	< 0.02	0.36 ± 0.04	5.03 ± 0.22	< 0.04
B6	4	4.87 ± 0.71	0.05 ± 0.02	0.97 ± 0.04	< 0.04	< 0.02	0.84 ± 0.06	9.52 ± 0.23	< 0.04
B7	4	7.04 ± 0.92	< 0.03	0.83 ± 0.04	< 0.04	< 0.02	0.80 ± 0.07	13.17 ± 0.25	< 0.04
B8	4	3.01 ± 0.43	< 0.03	0.45 ± 0.08	0.04 ± 0.03	0.12 ± 0.05	0.30 ± 0.02	4.43 ± 0.21	0.18 ± 0.02
B9	3	7.83 ± 0.19	< 0.03	0.24 ± 0.02	< 0.04	< 0.02	0.36 ± 0.03	21.1 ± 0.81	< 0.04
B10	3	5.90 ± 0.35	0.07 ± 0.03	0.85 ± 0.07	0.06 ± 0.04	0.20 ± 0.06	0.45 ± 0.05	7.20 ± 0.31	0.14 ± 0.03
B11	4	12.12 ± 0.41	0.06 ± 0.04	0.95 ± 0.04	0.04 ± 0.02	< 0.02	0.29 ± 0.02	6.16 ± 0.90	< 0.04
B12	3	4.32 ± 0.54	< 0.03	1.01 ± 0.09	0.04 ± 0.03	< 0.02	0.21 ± 0.01	7.01 ± 0.18	< 0.04
B13	3	8.80 ± 0.37	0.07 ± 0.06	0.91 ± 0.07	0.06 ± 0.04	< 0.02	0.50 ± 0.04	11.53 ± 0.46	0.05 ± 0.02
B14	4	4.39 ± 0.21	< 0.03	0.76 ± 0.07	< 0.04	0.08 ± 0.03	0.22 ± 0.04	6.77 ± 0.23	< 0.04
B15	4	6.52 ± 0.46	0.04 ± 0.02	0.92 ± 0.10	< 0.04	< 0.02	0.48 ± 0.03	10.75 ± 0.32	0.05 ± 0.02
B16	5	4.36 ± 0.32	< 0.03	0.89 ± 0.11	0.05 ± 0.03	0.43 ± 0.03	0.41 ± 0.07	4.74 ± 0.25	< 0.04
B17	4	8.53 ± 0.29	< 0.03	0.59 ± 0.05	< 0.04	< 0.02	0.36 ± 0.02	9.02 ± 0.37	0.06 ± 0.04
B18	5	11.02 ± 0.25	< 0.03	0.76 ± 0.05	< 0.04	< 0.02	0.63 ± 0.05	7.82 ± 0.36	< 0.04
B19	5	8.51 ± 0.33	< 0.03	0.15 ± 0.04	< 0.04	0.07 ± 0.03	0.30 ± 0.02	4.93 ± 0.40	< 0.04
B20	4	9.84 ± 0.17	< 0.03	0.92 ± 0.08	0.05 ± 0.05	< 0.02	0.57 ± 0.04	14.13 ± 0.30	0.09 ± 0.03
B21	3	3.42 ± 0.26	< 0.03	0.71 ± 0.04	0.04 ± 0.02	0.07 ± 0.03	0.12 ± 0.03	4.9 ± 0.20	0.11 ± 0.04
B22	4	9.73 ± 0.0.21	0.05 ± 0.04	0.98 ± 0.05	< 0.04	< 0.02	0.52 ± 0.07	6.42 ± 0.21	< 0.04
B23	5	8.13 ± 0.45	0.07 ± 0.03	1.07 ± 0.06	0.06 ± 0.03	0.14 ± 0.05	0.92 ± 0.06	10.84 ± 0.29	< 0.04
B24	3	8.39 ± 0.72	< 0.03	0.40 ± 0.03	< 0.04	0.11 ± 0.04	0.53 ± 0.03	5.88 ± 0.23	< 0.04
B25	4	8.54 ± 0.34	< 0.03	0.89 ± 0.08	< 0.04	0.15 ± 0.02	0.36 ± 0.02	4.52 ± 0.22	< 0.04
B26	3	8.2 ± 0.65	0.07 ± 0.02	0.85 ± 0.06	0.05 ± 0.02	0.20 ± 0.05	0.55 ± 0.08	8.62 ± 0.53	0.14 ± 0.03
B27	4	6.72 ± 0.32	0.06 ± 0.04	1.03 ± 0.09	0.05 ± 0.03	0.81 ± 0.06	0.86 ± 0.06	4.17 ± 0.20	0.09 ± 0.02

nd: not detected

decreasing mean concentrations (mg/kg) for these elements was P (3024) > K (1841) > Na (1335) > Mg (326) > Ca (168). The basic macro elements essential to proper body function in human are calcium and phosphorus, they mainly found in bones as calcium phosphate and hydroxyapatite. In comparison to our results, phosphorous and calcium concentrations in canned tuna were reported as 1290 ± 176 mg/kg (wet weight) and 473 ± 189 mg/kg (wet weight), respectively[3]. In bluefin tuna from the Northwest Atlantic (Newfoundland, Canada) calcium concentration was determined as 215 mg/kg (dry weight)[21]. In another study, the concentrations of phosphorous and calcium in tuna fish were reported as 2220 mg/kg and 290 mg/kg, respectively[22]. In the edible parts of three deep water fish species, concentration ranges were reported as 2341-7341mg/kg for phosphorous and 187-1105 mg/kg for calcium[23]. Our results for the concentration range of phosphorous and calcium were in good agreements with the results of previous studies mentioned above.

Potassium and sodium, along with calcium and magnesium are important electrolytes to the human nervous system, muscle function and fluid balance[24]. Sodium is most often found outside the cell, in the plasma of the bloodstream, while potassium is the major cation found inside of cells. The average concentration of potassium in canned tuna obtained in this study was 1841 mg/kg (wet weight) and data ranged from 1044 to 2883 mg/kg. Potassium concentration in tuna was reported slightly higher than our values, being 4070 mg/kg[22]. Sodium concentration reported in this work (1335 mg/kg, wet wt) was in good agreement with that reported for canned tuna commercialized in Venezuela with average value of 2345 mg/kg, dry wet (equivalent to 797 mg/kg, wet wt.) and data ranged from 1710 to 3200 mg/kg, dry weight (equivalent to581-1088 mg/kg, wet wt)[25]. Magnesium is important for body's enzyme system and necessary for energy metabolism[24]. The mean Mg level in canned tuna obtained in this work was 326 mg/kg and data ranged from 241 to 457mg/kg. Similar results were reported for the mean magnesium level in tuna fish, being 340 mg/k[22] and 680 mg/kg (dry wet)[21]. It has also been reported that magnesium level in front dorsal ordinary muscles of wild bluefin tuna was 487.6 mg/kg, with data ranged from 281.2 to 622.8 mg/kg[26].

Among the microelements, iron, zinc, selenium and copper were detected in all the analyzed samples. However, chromium, cobalt, molybdenum and manganese were detected in 38, 43, 56 and 59 % of the analyzed samples, respectively. The order of decreasing mean concentrations (mg/kg) for these elements was: Fe = Zn > Se = Cu > Mn > Cr > Co = Mo. comparisons of our results with those of other studies conducted on the concentrations of various elements in tuna fish are presented in Table-5. Concentration levels obtained in this work were in general comparable to those previously reported.

Iron is vital component of human life. It acts as a catalyst and it is an essential part of hemoglobin, myoglobin and the non-heme complexes such as ferritin[24]. The recommended dietary allowances (RDA) of iron for adult males and females are 8 mg/day and 18 mg/day, respectively[27]. Iron deficiency causes anemia and excessive iron causes health problems. In this study, the average iron concentration in canned tuna was 7.9 mg/kg with data ranged from 4.1 to 21.1 mg/kg. These results were in good agreements with other results of previous studies (Table-5). For instance, the mean iron level in tuna was reported as 8.45 mg/kg[13] and 9.13 mg/kg[20]. However, mean iron concentrations in canned tuna were reported slightly higher than our values, being 30 mg/kg with data ranged from < 0.1to 80.7 mg/kg[10], 15.8 mg /kg with data ranged from 0.01 to 88.4 mg/kg[14] and 14.9 mg/kg[11]. Mean iron level has also been reported lower than our mean value, being 2.94 mg/kg with data ranged from 1.11 to 5.32 mg/kg[18]. According to our results, the consumption of 150 g of canned tuna will provide

TABLE-5
MEANS AND RANGES (IN BRACKETS) OF MICROELEMENTS CONCENTRATIONS (mg/kg, WET WEIGHT) IN CANNED TUNA REPORTED IN VARIOUS STUDIES

Country	Cr	Zn	Co	Se	Mo	Mn	Cu	Fe	References
Jordan	0.05 (0.0-0.23)	7.15 (3.0-12.1)	0.03 (0.0-0.07)	0.76 (0.11-1.07)	0.02 (0.0-0.06)	0.11 (0.0-0.81)	0.47 (0.12-0.92)	7.90 (4.1-21.1)	This study
Turkey	--	10.15 (3.68-30.1)	--	--	--	--	0.55 (0.08-1.77)	30 (<0.1-80.7)	10
	1.08	17.8	--	2.98	--	0.9	2.5	14.9	11
	--	(54.3-62.6)	--	--	--	--	(8.1-11.9)	--	12
	--	5.033 f	--	--	--	0.09 f	0.69 (0.35-1.165)	8.45 f	13
USA	0.006 (0.0-0.068)	4.78 (0.14-9.87)	0.0068 (0-0.021)	--	--	0.22 (0.08-0.63)	0.25 (0.01-0.51)	15.8 (0.01-88.4)	14
	0.2f	--	--	0.75f	--	0.15f	--	--	15
				0.43-0.47					16
	--	--	--	--	0.01	--	--	--	17
Saudi Arabia	0.18 (0.07-0.33)	10.38 (3.8-17.7)	--	--	--	--	1.02 (0.13-1.87)	2.94 (1.11-5.32)	18
	0.38 (0.1-0.57)	--	--	--	--	--	0.27 (0.02-0.33)	--	19
France	0.294 f	4.35 f	0.012 f	0.566 f	0.063 f	0.069 f	0.613 f	9.13 f	20
Poland	--	--	--	0.29	--	--	--	--	3
Korea	--	--	--	0.453	--	--	--	--	27

f: fresh/frozen, --: not available

1.18 mg of iron which represents 14.8 % and 6.6 % of the RDA for adult males and females, respectively.

Zinc is an essential element for the normal functioning of the cell and involved in most metabolic pathways in humans,. It also presents as a co-factor for enzymes such as arginase. The recommended dietary allowances of zinc for adult males and females are 11 mg/day and 8 mg/day, respectively[28]. The average concentration of zinc in canned tuna obtained in this study was 7.15 mg/kg (wet weight) and data ranged from 3 to 12.1 mg/kg. Similarly, Mol[10], Percin *et al*.[13] and Ashraf *et al*.[18] reported average zinc concentrations in canned tuna as 10.15, 5.03 and 10.38 mg/kg, respectively. On the other hand Tuzen and Soylak[11] reported higher zinc concentration, being 17.8 mg/kg. According to our results, the consumption of 150 g of canned tuna will provide 1.07 mg of zinc which represents 9.7 % and 13.4 % of the RDA for adult males and females, respectively.

Copper and selenium are essentials for good health. The recommended dietary allowances of copper and selenium for adults are 900 µg/day and 55 µg/day, respectively[28]. In the present study, copper levels obtained for canned tuna ranged from 0.12 to 0.92 mg/kg, with an average value of 0.47 mg/kg and selenium levels ranged from 0.11 to 1.07 mg/kg with an average value of 0.76 mg/kg. In good agreements with our results, the Canadian total diet study reported the copper and selenium concentrations in canned fish as 0.415 mg/kg and 0.666 mg/kg, respectively[28]. Our obtained results for copper and selenium were also in good agreements with those listed in Table-5. However, Tuzen and Soylak reported higher values of copper and selenium concentrations in canned tuna being 2.5 mg/kg and 2.98 mg/kg, respectively[11]. Celik and Oehlenschläger also reported the levels of copper in canned tuna in the range of 8.1-11.9 mg/kg[12]. Based on our results, the consumption of 150 g canned tuna will provide 114 µg of selenium and 70 µg of copper which represent 207 % and 7.8 % of the RDA of the two elements, respectively. The Institute of Medicine of the National Academy of Sciences (USA) has set a tolerable upper intake level (UL) for selenium at 400 micrograms per day for adults[29]; our calculated value (114 µg selenium/day) was less than the UL value. Therefore, this level of selenium is unlikely to constitute any health problem.

Manganese is an essential trace mineral that is necessary for the normal functioning of brain, needed for bone development and involved in the formation of thyroxin in the thyroid gland[24]. Manganese was detected in 59 % of the analyzed canned tuna samples with an average concentration of 0.11 mg/kg (wet weight) and data ranged from < 0.02 to 0.81 mg/kg. Previous studies reported similar results for manganese concentrations in tuna (Table-5). For instance, Burger and Gochfeld[15], Guérin *et al*.[20] and Percin *et al*.[13] reported the mean manganese concentrations in tuna fish as 0.15 mg/kg (ww), 0.069 mg/kg (ww) and 0.09 mg/kg (wet wt), respectively. The Canadian total diet study also reported a similar result for the mean manganese concentration in canned fish, being 0.197 mg/kg (ww)[28]. However, Tuzen and Soylak reported higher mean value for manganese in canned tuna, being 0.9 mg/kg(wet. wt.)[11]. The consumption of 150 g canned tuna will provide 16.5 µg of manganese which is lower than the adequate intakes (AI) of 2.3 mg/day and 1.8 mg/day for adult males and females, respectively. Chromium (III) has been identified as the active ingredient of the glucose tolerant factor and affects the action of insulin in protein metabolism[24]. In this work, chromium was detected in 38 % of the analyzed canned tuna samples with an average concentration of 0.05 mg/kg (wet weight) and data ranged from < 0.04 to 0.23 mg/kg. In good agreement with our results, Ashraf *et al*. reported the range of chromium concentrations in canned tuna from 0.07 to 0.33 mg/kg[18]. However, several studies reported higher mean chromium concentrations in tuna, being 1.08 mg/kg[11], 0.38 mg/kg[19], 0.294 mg/kg[20] and 0.2 mg/kg[15]. Ikem and Egiebor[14] reported the mean chromium concentration in canned tuna as 0.006 mg/kg with data ranged from 0.0 to 0.068 mg/kg, these values were lower than our reported values for chromium. By using the mean Cr concentration of 0.05 mg/kg, the consumption of 150 g canned tuna will provide 7.5 µg of chromium which is lower than the adequate intakes (AI) of 35 µg /day and 25 µg /day for adult males and females, respectively.

Cobalt and molybdenum are essential elements needed in trace amounts; cobalt is an integral part of vitamin B_{12} in human and molybdenum has been shown to act as a cofactor for three enzymes: sulfite oxidase, xanthine oxidase and aldehyde oxidase[24]. In the present study, cobalt levels obtained for canned tuna ranged from < 0.03 to 0.07 mg/kg, with an average value of 0.03 mg/kg and the molybdenum average concentration was 0.02 mg/kg with data ranged from < 0.04 to 0.06 mg/kg. Literature data concerning cobalt and molybdenum levels in canned tuna are limited. Cobalt concentration in canned tuna has been reported as 0.0068 mg/kg with a range of 0-0.021 mg/kg[14] and molybdenum mean concentration was reported as 0.01 mg/kg[17]. In a recent study, cobalt and molybdenum average concentrations in tuna fish were reported as 0.012 mg/kg and 0.063 mg/kg, respectively[20]. Our results for cobalt and molybdenum concentrations were similar to the previously mentioned studies (Table-5).

Conclusion

The levels of five macroelements (Ca, K, Na, P and Mg) and eight microelements (Fe, Zn, Se, Cu, Cr, Mo, Co and Mn) in canned tuna samples marketed in Jordan were determined and compared with the literature values. The concentrations of the studied elements were found to be close to the results of related previous studies. Based on the recommended dietary allowances and a tolerable upper intake level (UL) of the microelements, the levels of these microelements were unlikely to constitute any health problem to the consumers.

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