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Full Length Research Paper

Trace elements in the kidney tissue of Bluefin Tuna (*Thunnus thynnus* L. 1758) in Turkish seas

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Trace elements, namely lead (Pb), copper (Cu), manganese (Mn), nickel (Ni), zinc (Zn), and iron (Fe), found in kidney tissues were analyzed and compared between wild/fattened and female/male bluefin tuna (BFT) in the Eastern Mediterranean region of Turkey. One hundred (that is, 50 female and 50 male) individual specimens of wild and fattened tuna were investigated. The mean trace elements of the wild fish were determined to include Pb, 0.166; Cu, 1.683; Mn, 0.252; Ni, 0.322; Zn, 8.974; and Fe, 14.017 (µg g-1 wt wt). The values for the fattened fish were determined to be Pb, 0.116; Cu, 1.279; Mn, 0.208; Ni, 0.231; Zn, 8.507; and Fe, 10.364 (µg g-1 wt wt). The comparison of trace elements between wild and fattened fish was significant ($p < 0.05$). In terms of gender, the mean trace elements in the kidney tissue of wild and fattened female BFT were determined, respectively, to be Pb, 0.183, 0.124; Cu, 1.947, 1.250; Mn, 0.281, 0.217; Ni, 0.357, 0.229; Zn, 9.641, 9.205; and Fe, 14.351, 11.314. Similar values for wild and fattened male BFT were found, respectively, Pb, 0.149, 0.107; Cu, 1.418, 1.307; Mn, 0.223, 0.198; Ni, 0.286, 0.232; Zn, 8.307, 7.808; and Fe, 13.683, 9.413.

Key words: Bluefin tuna, *Thunnus thynnus,* trace elements, lead, copper, manganese, nickel, zinc, iron, kidney.

INTRODUCTION

One of the seven species of tunas, the genus *Thunnus thynnus*, is of great commercial value. Many organisations are interested in the study of the development, behaviour (that is, spawning and migration), and aquaculture of bluefin tuna (BFT). Tunas, after capture in the wild, are transferred to floating cages in order to increase their fat content. In the cages, the fish are fed with fresh or frozen food, consisting predominantly of sardines, mackerel, pilchard, and mollusc (Perçin and Tanrikul, 2006; Ottolenghi, 2008).

Trace elements have a wide spectrum of important roles in the functioning of animals (Hamilton and Hoffman 2003). Within various metabolic functions, they play a vital role, such as serving as the main components of antioxidant enzymes and within some biochemical reactions (Watanabe et al., 1997). The age, size, feeding habits, gender, reproductive status, and habitats of the fish, in terms of being wild or farmed, affect the elemental bioaccumulation among tissues (e.g., the liver, brain, muscle, heart, gills, and kidneys) (FAO, 2003; Licata et al., 2005; Percin and Sogut 2010; Vizzini et al., 2010).

The kidneys have a number of major functions. One function is to excrete any divalent ions that have been absorbed. The glomerular filtration rate is the major factor that controls urine volume and composition; with the exception of divalent ions, creatine and some organic acids are actively secreted by the proximal tubules.

The kidneys also play a role in balancing the concentration of Mg^{+2}. The fish's urinary function primarily occurs in the caudal kidney, which is also responsible for the filtration and excretion of several metabolites and microelements. Therefore, it is one of the storehouses of trace elements, like the liver, in the fish's body. The cranial kidney contains a variety of tissues that have no

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Abbreviations: BFT, Bluefin tuna; **FAAS,** flame atomic absorption spectrophotometer; **min,** minimum; **max,** maximum; **med,** median.

function in the urinary system. The lymphoid tissue is quite prominent in this portion of the fish kidney. The cranial kidney is highly vascular and contains considerable amounts of mature blood in its capillaries (Watanabe et al., 1997; Olsson, 1998; Ashraf, 2005).

Generally, trace elements assimilated from food or the environment, such as water or sediment, are transported into the blood, deposited in various tissues, and excreted or stored. Wild and fattened BFT are greedy fish that consume a wide variety of food. Their high rate of growth, extreme activity level, and rapid metabolic rates lead to a high food intake rate, a property that relates to exposure to trace elements. Hence, these factors lead to the accumulation of trace elements in the kidneys, particularly in the caudal kidney, which is responsible for excretion (Bridges et al., 2002; Kojadinovic et al., 2007; EFSA, 2009).

Consequently, the aim of this paper is to determine the patterns of lead (Pb), copper (Cu), manganese (Mn), nickel (Ni), zinc (Zn), and iron (Fe) in one of the specific target organs, the kidney tissue of BFT, with a comparison between wild and fattened and female and male fish in the Turkish region of the eastern Mediterranean.

MATERIALS AND METHODS

Sampling area and materials

Wild BFT were taken by purse seine around the Levantine Sea and the Bay of Antalya. The farmed BFT were obtained from the cages and a processing plant in Ildir Bay, Cesme-Izmir. The cages were conical in shape and had diameters of 50 m on the surface and 30 m on the bottom and were 30 m deep. The farm fattening process is approximately 6–10 months long (Percin and Konyalioglu, 2008). The BFT were fed *ad libitum* at approximately 10–12% of their average overall body weight. Feedings occurred twice per day with fresh or defrosted food fish, such as herring (*Clupea harrengus*), sardines (*Sardina pilchardus*, *Sardinella aurita*), mackerel (*Scomber scombrus*), and squid (*Sephia officinalis*) (Percin and Akyol, 2010a). Wild and fattening specimens were collected from winter to spring. Water-quality parameters in the study areas, such as temperature, dissolved oxygen, and salinity, were measured using the Oxyguard Handy Gamma (Oxyguard Int. A/S, Denmark), pH was measured using a digital pH meter (Hanna Inst., Woonsocket, RI, USA), and turbidity was determined using a Secchi disk. The farming area did not contain any pollutants.

The fork length, total weight, and gender of all fish were determined. The wild fish were captured by purse seine, and then they were placed on the deck for 5 to 10 min. Later, BFT were slaugthered and gutted. Kidney tissues were taken from the dorsal area and immediately stored in liquid nitrogen. All collected specimens were transferred to the laboratory and washed with distilled water, dried with filter paper, homogenized, packed in polyethylene bags, and stored at -80°C prior to analysis. The fattened fish were confined in the cages, and then they were shot with lupara (Perçin and Akyol, 2010b). After that, BFT were obtained from the pens and prepared for the aforementioned analysis, after which all specimens were dried for 48 h at 110°C.

Reagents and chemical analysis

Deionized water from the Milli-Q system (Millipore, MA, USA) Was used to prepare all aqueous solutions. The perchloric acid, nitric acid, and standard solutions (1000 mgL^{-1}) were supplied by Merck (Darmstadt, Germany). All plastic and glassware was cleaned by soaking overnight in a 10% (w/v) nitric acid solution and then rinsed with de-ionized water. After that, a wet sample of 0.5 g of kidney tissue was dried for 48 h at 110°C. The specimens were digested with a mixed solution of perchloric (70%) and nitric (65%) acids (3:7, v/v) and slowly heated to 80°C until complete digestion.

The beaker contents were transferred to a 30 mL plastic measuring bottle with small portions of 1% nitric acid. A blank was also prepared in order to incorporate the same method of determining the elements. A flame atomic absorption spectrophotometer (FAAS) with Varian-Spectra-AA 10 plus was used for analysis. The standard addition technique was used to measure Pb, Cu, Mn, Ni, Zn, and Fe, where aqueous calibration was conducted for each element. The detection limit values of elements in FAAS were found to be between 0.010 and 0.020 mgL^{-1}. Detection limit is determined as three times the standard deviation of 10 blanks. The values of the recovery were nearly quantitative (>92%) The method accuracy was evaluated by means of trace metals determined in NRCC-DORM-2 Dogfish Muscle standard reference material (SRM). The achieved results were in good agreement with the certified values.

Statistical analysis

All detected data were subjected to statistical analysis. Correction matrices were produced in order to examine the inter-relationships between the investigated trace element concentrations of the specimens. Minimum (min), maximum (max), and median (med) values were determined. The mean and standard error (SE) value were detrmined and compared using Student's *t*-test. The mean differences of microelements in the kidney tissue were determined for wild and fattened and for female and male BFT, and one-way analysis of variance (ANOVA) was performed on the avaliable data. Differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Biometric measurements

The fork length and weight of the BFT (100 wild and 100 fattened) were determined to be 154.9 ± 1.1 cm and 54.0 ± 1.1 kg and 157.5 ± 1.7 cm and 57.0 ± 1.3 kg, respectively. Among the wild fish, 50 of the specimens were female (156.2 ± 1.2 cm and 55.3 ± 1.3 kg) and 50 of the specimens were male (153.6 ± 0.9 cm and 52.8 ± 1.1 kg). Meanwhile, among the fattened BFT, 50 of the specimens were female (158.7 ± 2.1 cm and 57.8 ± 1.9 kg) and 50 of the specimens were male (156.3 ± 1.4 cm and 56.2 ± 1.5 kg). Wild and farmed BFT were determined to have nearly identical fork lengths and weights.

The fish were specifically harvested in order to obtain specimens within a similar age class. Trace element accumulations increase on a daily basis in the tissues of various animals, including BFT; thus, older specimens have a higher accumulation of trace elements than those that are younger (Olsson, 1998; Licata et al., 2005). Attempts were made to decrease the possibility of age-related differences in trace-element accumulation by choosing specimens of similar fork lengths and weights.

Table 1. Range values of water quality parameters in both sampling areas.

Water quality	Area	Winter	Spring (early)	Spring (late)
Temperature (°C)	Ildir Bay	15.3 - 16.8	16.0 - 18.2	18.9 - 22.1
	Antalya Bay	16.1 - 17.6	17.2 - 18.6	21.8 - 23.6
Dissolved oxygen (mgL^{-1})	Ildir Bay	8.05 - 8.27	7.90 - 8.14	7.66 - 8.16
	Antalya Bay	7.94 - 8.36	7.73 - 8.23	7.58 - 8.07
Salinity (gL^{-1})	Ildir Bay	35.9 - 36.2	36.2 - 36.5	37.1 - 37.3
	Antalya Bay	37.4 - 37.8	37.8 - 38.1	38.0 - 38.3
pH	Ildir Bay	8.06 - 8.11	8.09 - 8.16	8.18 - 8.21
	Antalya Bay	7.80 - 7.86	7.94 - 8.03	8.08 - 8.13
Turbidity (m)	Ildir Bay	35.9 - 38.3	37.3 - 39.7	38.5 - 40.02
	Antalya Bay	37.4 - 39.9	38.2 - 40.6	37.6 - 40.05

Table 2. Trace elements and significance in kidney tissue of wild and fattened bluefin tuna (µg g-1 w wt).

Trace element	Wild (*n* = 100)					T.S.	Fattened (*n* = 100)				
	Min	Max	Med	Mean	s.e.	p < 0.05	Min	Max	Med	Mean	s.e.
Pb	0.042	0.248	0.158	0.166	0.037	*	0.054	0.192	0.115	0.116	0.036
Cu	0.317	2.776	1.624	1.683	0.121	*	0.498	1.851	1.304	1.279	0.102
Mn	0.070	0.497	0.256	0.252	0.042	*	0.083	0.360	0.167	0.208	0.024
Ni	0.071	0.603	0.319	0.322	0.052	*	0.102	0.485	0.211	0.231	0.035
Zn	5.482	13.093	8.006	8.974	0.810	*	4.688	13.526	9.230	8.507	0.647
Fe	5.758	24.632	13.725	14.017	0.944	*	4.005	19.255	10.510	10.364	0.710

Thus, the BFT in this study were approximately 6 to 7 years old (Cort, 1991; Perçin and Akyol, 2009; Santamaria et al., 2009; Percin and Akyol, 2010a).

Water quality

The temperature, dissolved oxygen, salinity, pH, and Secchi disk depth values for the winter and early and late spring were obtained at Ildir Bay and Antalya Bay (Table 1). Ten samplings were measured in each area for each season. According to the results, the dissolved oxygen and pH values were higher at Ildir Bay than at Antalya Bay, while the salinity and temperature were lower. Hence, the results were within the acceptable limits for aquacultured areas such as farms for bluefin tuna and other types of fish in Ildir Bay, Turkey.

Analysis of specimens

The results of microelement concentrations are detailed in the tables. The kidney tissue results of wild and fattened fish are addressed in Table 2, the kidney tissue results of wild and fattened female/male BFT are detailed in Table 3, and the significance of female and male BFT are presented in Table 4.

According to Table 2, all measurements of trace elements (Pb, Cu, Mn, Ni, Zn, and Fe) in kidney tissues were higher among the wild BFT and statistically significant when wild and fattened BFT were compared ($p < 0.05$). Higher amounts of microelements in the kidney tissue of the wild BFT might be related to diet, the environment, and the effects of pollution. Wild BFT were fed mostly with sardines, herrings, mackerels, and squid. Mackerels and squid contain biomagnified trace elements, such as copper, lead, and manganese, which they obtain from their feedings and environmental area. Thus, high consumption of these fish might cause the accumulation of trace elements in the kidney tissue of BFT.

Moreover, BFT are highly migratory fish species that move in a wide area for spawning and feeding. Thus, BFT might feed in some polluted areas. Therefore, these elements probably come from polluted areas or environments in the Mediterranean (Watanabe et al., 1997; Olsson, 1998; Bridges et al., 2002; Licata et al., 2005; Percin and Sogut 2010).

Table 3. Trace elements in the kidney tissue of female and male wild/fattened bluefin tuna (µg g^{-1} w wt).

Trace element	Wild (*n* = 100)										Fattened (*n* = 100)									
	Female (*n* = 50)					Male (*n* = 50)					Female (*n* = 50)					Male (*n* = 50)				
	Min	Max	Med	Mean	s.e.	Min	Max	Med	Mean	s.e.	Min	Max	Med	Mean	s.e.	Min	Max	Med	Mean	s.e.
Pb	0.056	0.248	0.178	0.183	0.040	0.042	0.204	0.141	0.149	0.029	0.054	0.192	0.118	0.124	0.028	0.059	0.151	0.111	0.107	0.039
Cu	0.568	2.776	1.893	1.947	0.124	0.317	2.199	1.445	1.418	0.110	0.523	1.786	1.212	1.250	0.095	0.498	1.851	1.318	1.307	0.104
Mn	0.086	0.497	0.273	0.281	0.044	0.070	0.465	0.234	0.223	0.038	0.101	0.346	0.220	0.217	0.024	0.083	0.360	0.115	0.198	0.027
Ni	0.128	0.603	0.344	0.357	0.050	0.071	0.518	0.295	0.286	0.054	0.102	0.485	0.204	0.229	0.033	0.106	0.474	0.217	0.232	0.043
Zn	6.908	13.093	9.752	9.641	0.845	5.482	12.663	7.902	8.307	0.778	5.230	13.526	10.704	9.205	0.891	4.688	12.035	7.732	7.808	0.519
Fe	5.758	24.632	13.955	14.351	0.968	6.052	22.704	13.490	13.683	0.921	4.005	19.255	11.220	11.314	0.806	4.852	13.711	9.980	9.413	0.620

Table 4. Significance between female and male wild/fattened bluefin tuna.

	W_{Female} - W_{Male}	W_{Female} - F_{Female}	F_{Female} - F_{Male}	F_{Male} - W_{Male}
Pb	*	*	*	*
Cu	*	*	- - -	- - -
Mn	*	*	- - -	*
Ni	*	*	- - -	*
Zn	*	- - -	*	- - -
Fe	- - -	*	*	*

*: Significance ($p < 0.05$); W_{Female}, wild female; W_{Male}, wild male; F_{Female}, fattened female; F_{Male}, fattened male.

According to the detail female/male wild and fattened BFT (Tables 3 and 4), the Pb, Cu, Mn, Ni, Zn, and Fe values were higher in wild female BFT and statistically significant between wild females and males, with the exception of Fe ($p < 0.05$). The accumulation of these elements in female fish might be related to their reproduction period and gonad development. This stage might stimulate and increase the basal metabolism and storage of microelements, especially in the kidney, liver, and gonads (Schaefer, 2001; Licata et al., 2005).

On the other hand, although the Pb, Mn, Zn, and Fe values were higher in fattened females, the values for Cu and Ni were higher in fattened male BFT (Table 3). However, according to Table 4, the Pb, Zn, and Fe values were statistically significant between fattened female and male BFT ($p < 0.05$). Zn and Fe are essential to various cellular enzymatic and detoxifying reactions, such as superoxide dismutase, and biochemical processes, such as the manufacture of hemoglobin in erythrocyte cells in the kidney. Therefore, fattened females might use these microelements more frequently, and such an occurrence might be related to gonad development, reproduction, and basal metabolism (Watanabe et al., 1997; Bridges et al., 2002; Licata et al., 2005; Vizzini et al., 2010).

According to the comparison of the two studied areas, the Pb, Cu, Mn, Ni, Zn, and Fe values were higher in wild female BFT than they were among fattened females and the values for Pb, Cu, Mn, Ni, and Fe were statistically significant ($p < 0.05$). Similarly, among male BFT, all of the measured microelements were higher in wild fish, but only

Table 5. Trace element levels (mean or range, µg g^{-1} w wt) in the kidney, liver, and muscle tissues from selected studies.

Species	*n*	Sex	Weight (kg)	Length (cm)	Pb	Cu	Mn	Ni	Zn	Fe	Reference
Kidney											
Bluefin tuna, *T. thynnus*						8.6					Jenkins (1980)
	17				0.41	0.80	0.19		9.17	7.68	Jaffar and Ashraf (1988)
	50	Wf	55.3	156.2	0.18	1.95	0.28	0.36	9.64	14.35	This study
	50	Wm	52.8	153.6	0.15	1.42	0.22	0.29	8.31	13.68	This study
	100	W	54	154.9	0.17	1.68	0.25	0.32	8.97	14.02	This study
	100	WFf	56,6	157.4	0.15	1.60	0.25	0.30	9.43	12.83	This study
	100	WFm	54,5	155	0.13	1.37	0.21	0.26	8.06	11.55	This study
	100	F	57	157.5	0.12	1.28	0.21	0.23	8.50	10.36	This study
Longtail tuna, *T. tonggol*	18	F/M			0.25	1.02	2.28		30.6	4.42	Jaffar and Ashraf (1988)
Skipjack tuna, *K. pelamis*	27	F/M			0.05	2.43	0.52		39.8	361	Kojadinovic et al. (2007)
Liver											
Bluefin tuna, *T. thynnus*	17				0.17	0.86	0.25		7.65	17.1	Jaffar and Ashraf (1988)
	73	F/M	3.6	58.5	0.21						Storelli et al. (2005)
	7	F	50 - 190	162 - 235	0.06 - 1.29	5.06 - 79.26	0.53 - 1.09		0.67 - 9.21		Licata et al. (2005)
	7	M	55 - 101	162 - 195	0.06 - 0.88	4.65 - 34.70	0.54 - 0.97		0.79 - 9.96		Licata et al. (2005)
Longtail tuna, *T. tonggol*	18				0.28	1.42	2.32		39.7	14.6	Jaffar and Ashraf (1988)
Skipjack tuna, *K. pelamis*	38	F/M	9	68	0.04	31.2	1.61		69.3	432	Kojadinovic et al. (2007)
Muscle											
Skipjack tuna, *E. pelamis*								0.5 - 2.0			Jenkins (1980)
Skipjack tuna, *K. pelamis*								0.7			Sharif et al. (1993)
Mackerel, *S. scombrus*								2.11			Tuzen (2009)

Wf, Wild female; Wm, wild male; W, wild; WFf, wild + fattened female; WFm, wild + fattened male; F, fattened.

Pb, Mn, Ni, and Fe were statistically significant ($p < 0.05$). As previously indicated, microelements might be more metabolized among the wild female and male BFT. Such an effect might be related to hormonal, endocrinal gland, and enzyme activity, such as detoxifying free radicals, lactate dehydrogenize enzyme and other dehydrogenization mechanisms in kidney tissue (Watanabe et al., 1997; Bridges et al., 2002; Licata et al., 2005; Vizzini et al., 2010). It has been concluded that microelements come from foods or environmental areas. Such a finding indicates that wild specimens have a greater likelihood of bioaccumulating microelements because BFTs consume various nutrients throughout their migration area (that is, the Mediterranean).

In the literature, the research studies on the accumulation of trace elements mainly examined the muscle and liver tissues, but it has rarely studied the kidney tissue. On the other hand, the liver and kidney organs were both accepted as storehouses of trace elements in various fish species, including BFT (Olsson, 1998; Ashraf, 2005; Kojadinovic, 2007). Hence, the results of this study were compared with those of other studies that specifically examined the liver and kidney tissues in Table 5. According to the references on kidney

tissue, Jenkins (1980) reported Cu concentration in BFT as 8.6 µg g^{-1} w wt. This was higher than our results and might be related to Cu pollution and its effect on the kidney tissue of fish.

On the other hand, the findings of trace element concentrations in our study were in line with the results of Jaffar and Ashraf (1988) obtained from specimens collected from the Arabian Sea. They found that the Zn and Fe values were higher than the Cu and Mn levels, similarly to our research; however, the Pb levels they detected were higher than our results. This might show that there is magnification and toxicity of Pb in the kidney tissue of BFT from the Arabian Sea. In addition, both the Zn and Fe levels were higher in the liver tissue of BFT - 7.65 and 17.1 µg g^{-1} w wt - but the Cu, Mn, and Pb levels were lower (Jaffar and Ashraf, 1988). This indicates that Zn and Fe accumulated more in the kidney and liver.

On the other hand, Jaffar and Ashraf (1988) and Kojadinovic et al. (2007) detected trace elements in the kidney and liver tissues of two different tuna species, longtail tuna (*Thunnus tonggol*) and skipjack tuna (*Katsuwonus pelamis*). According to Jaffar and Ashraf (1988), Zn had the highest concentration among the trace elements in kidney tissue, but the Mn level was extremely high compared to the results of other research studies on the kidney tissues of tuna species. In addition, similar findings with respect to trace element concentrations were detected in the liver tissue of longtail tuna by the same researchers. It has been indicated that the biomagnifications and distributions of Zn and Fe were higher in the detoxifying-excretion organs, the kidney and liver. On the other hand, the accumulation of Mn was much higher in the kidney and liver tissues of longtail, which could be related to Mn pollution in the research area. Generally, our results were lower than those of Jaffar and Ashraf (1988), which may reflect the tolerated range for the health and welfare of BFT and the meat quality (Olsson, 1998; FAO, 2003; Hamilton and Hoffman, 2003).

Additionally, the findings of trace element accumulations in the kidney tissue of skipjack tuna from the Western Indian Ocean by Kojadinovic et al. (2007) were much higher than our data indicated, except Pb (0.05 µg g^{-1} w wt). The Fe (361 µg g^{-1} w wt) and Zn (39.8 µg g^{-1} w wt) concentrations were major and the Cu level (2.43 µg g^{-1} w wt) ranks the third in the kidney tissue of skipjack tuna, similar to the findings of our research. However, the Fe (432 µg g^{-1} w wt), Zn (69.3 µg g^{-1} w wt), and Cu (31.2 µg g^{-1} w wt) concentrations in the liver tissue were much higher, as in the kidney tissue of skipjack tuna. The results for both the kidney and liver tissues could indicate pollution and toxicity of the organs in skipjack tuna, specifically Fe contamination. Our findings for the Fe and Zn concentrations were much lower than those of Kojadinovic et al. (2007).

On the other hand, our results were compared with those of Storelli et al. (2005) and Licata et al. (2005). The researchers examined trace elements in the liver tissue, but the sampling areas were important. The first researcher worked in the Ionian Sea and the second obtained specimens from Messina, Italy, in the Mediterranean.

Storelli et al. (2005) found a Pb concentration of 0.21 µg g^{-1} w wt in small bluefin tuna (58.5 cm, 3.5 kg). The Pb levels in wild and fattened fish were determined to be 0.17 µg g^{-1} w wt and 0.12 µg g^{-1} w wt, respectively, in the kidney tissues of BFT in our research. The Pb level in the liver tissue was a bit higher than our results and it could be explained by the fact that the liver is the major organ for detoxifying or storing trace elements.

Licata et al. (2005) determined the trace element contents in the liver tissue of wild female and male bluefin tuna. The ranges of Zn accumulation (mean 4.47 µg g^{-1} w wt) for female and male fish were similar to our findings (wild female and male, wild and fattened female, and wild and fattened male); however, the ranges of Mn concentration (0.53 to 1.09 and 0.54 to 0.97 µg g^{-1} w wt) were higher than our results (indicated in Table 5 as Wf, Wm, WFf, and WFm). In addition, the mean Pb accumulation (0.31 µg g^{-1} w wt) in the liver tissue was higher than the data for our wild (0.17 µg g^{-1} w wt) and fattened (0.12 µg g^{-1} w wt) specimens, although the minimum Pb concentrations were found for both female and male (0.06 µg g^{-1} w wt) BFT. Furthermore, Licata et al. (2005) determined the Cu levels to be 18.45 µg g^{-1} w wt, and the Cu concentrations reflected wide ranges in females and males (5.06 to 79.26 and 4.65 to 34.70 µg g^{-1} w wt); thus, our results were lower than those of Licata et al. (2005) for all groups of female and male individuals.

Licata et al. (2005) indicated that the high concentration of trace elements in the liver tissue of BFT came from the water or food fish and was strongly related to water pollution in the sea around Messina. In our research, the levels of Cu in the kidney tissues of fish in both studied areas were lower and probably come from the food fish, as indicated by Licata et al. (2005), because the wild and farmed areas were not polluted with Cu. Furthermore, the cause of the results might be related to fish size, as Licata et al. (2005) studied big fish: females 162 to 235 cm and 50 to 190 kg and males of 162 to 195 cm and 55 to 101 kg.

On the other hand, Vizzini et al. (2010) compared the Cu, Zn, and Pb concentrations in the liver tissues of wild and farmed BFT. Cu concentrations were found to be approximately 15 µg g^{-1} w wt in both wild and farmed fish, but the Zn concentration was higher in the wild fish (approx. 60 µg g^{-1} w wt) than the farmed (approx. 40 µg g^{-1} w wt) fish. These results were considerably higher than our Cu (1.68 and 1.28 µg g^{-1} w wt) and Zn (8.50 and 8.97 µg g^{-1} w wt) findings in wild and farmed fish. However, the Pb concentrations in both wild and farmed fish were determined to be approximately 0.10 µg g^{-1} w

wt, and these values were lower than our findings. In addition, Vizzini et al. (2010) determined Cu, Zn, and Pb concentrations in the food fish, round sardinella (*Sardinella aurita*), of farmed BFT, and the concentrations were found to be higher round sardinella. Vizzini et al. (2010) concluded that the higher Cu (approx. 1.05 µg g^{-1} w wt) and Zn (approx. 17 µg g^{-1} w wt) concentrations in the liver tissues of farmed and wild BFT might have come from food fish such as sardines, round sardinella, etc., which are the main food types of both wild and farmed BFT. Similarly, the Cu and Zn values in our research were higher with Fe levels in wild and fattened BFT. Thus, the cause of the concentrations might be related to the food fish because the same types of fish were consumed by the BFT.

Nickel was another trace element detected in our study. In the literature, few studies have been published on tuna species and mackerel and were concerned mainly with muscle tissues (Table 5). Tuzen (2009) determined the Ni concentration in the muscle tissue of mackerel and found that it was higher than our results. Similarly, Jenkins (1980) and Sharif et al. (1993) studied Ni levels in another tuna species, skipjack tuna. The results of the two research studies were higher than our findings, which may be explained by the fact that Ni accumulates more in the muscle tissue than in the kidney tissue. Another possible explanation is that the skipjack tuna specimens might have been fed with food fish such as sardines, squid or mackerel which are consumed by skipjack tuna in the Ni-polluted waters.

According to the analysis of the trace elements, the concentration values followed the order Fe > Zn > Cu > Ni > Mn > Pb in wild and fattened and female and male BFT. In addition, according to Jaffar and Ashraf (1988) and Kojadinovic et al. (2007), the accumulation levels in the kidney tissues of tuna species followed the order Zn > Fe > Cu > Pb > Mn in wild BFT, Zn > Fe > Mn > Cu > Pb in longtail tuna, and Fe > Zn > Cu > Mn > Pb in skipjack tuna. On the other hand, according to the Jaffar and Ashraf (1988) and Licata et al. (2005), the mean concentration of the tested elements in the liver tissues of BFT followed the order Fe > Zn > Cu > Mn > Pb and Cu > Zn > Mn > Pb, respectively. For the longtail and skipjack tunas, these parameters followed the order Zn > Fe > Mn > Cu > Pb (Jaffar and Ashraf, 1988), and also Fe > Zn > Cu > Mn > Pb (Kojadinovic et al., 2007). In our study, the trace elements with the highest accumulations were Fe and Zn, similar to the results of other research studies. This occurred due to specific metabolic processes and coenzyme-catalyzed reactions occurring in the kidney that involve Fe and Zn. Also, their formation occurred through the formation of tetrahedral metalloproteins and metalloenzymes in kidney tissues (Licata et al., 2005; Vizzini et al., 2010).

Pb is generally soluble in natural waters, so increased levels of Pb in fish tissues come from Pb-contaminated waters, food grown in polluted areas, or Pb stored in the body of food such as squid (Olsson, 1998; Kojadinovic et al., 2007). In the study, the prevalence of Pb in the kidney tissue was attributed to the ability of Pb to form stable chelates with the available binding sites, which occurs more often among wild BFTs. In addition, the third-highest accumulated trace element in the kidney tissues of both wild and fattened fish was Cu, which contains a cystine-rich copper binding protein, which is thought to have either a detoxifying or a storage function. Meanwhile, zinc, copper, and manganese play a role in enzymatic reactions, especially the superoxide dismutase of metalloenzymes such as Mn and Cu. Due to its important functions, Cu is usually found at high levels in various fish tissues (Eisler, 1998a; Olsson, 1998; Wu, 2006). In our study, the highest Cu and Mn levels were detected in wild females, which may be related to the increased hormonal or endocrinal enzyme activity of female fish.

Nickel is another essential element that activates some enzymes such as carboxylase, and it takes part in lipid metabolism, the transformation of nucleocides, and the stabilization of the nucleic acid structure. It also increases gonad and hormone functions (Eisler, 1998b; Wu, 2006). However, an excessive amount of Ni is hazardous and carcinogenic, and it comes mostly from polluted water in the Mediterranean or from the fishes' diet when contaminated fish is consumed. The highest Ni concentration was found in the group of wild females, which may be related to the gonad and hormone functions. However, the Ni levels in all BFT groups were lower than those of the selected studies listed in Table 5.

As a result, the data for trace elements such as Pb, Cu, Mn, Ni, Zn, and Fe in the kidney tissues of all BFT (n = 200) were determined to be 0.141, 1.481, 0.230, 0.277, 8.741, and 12.191 (µg g^{-1} w wt), respectively. In addition, the biometric measurements of BFT were determined to be 156.2 cm in fork length and 55.5 kg in weight, respectively. According to Cort (1991), Perçin and Akyol (2009), Santamaria et al. (2009), and Percin and Akyol (2010a), the possible age range for all fish was approximately 6 to 7 years in this study. Thus, the findings might be valid only for this age group.

Conclusions

In this research, the values indicated that the groups of wild BFT had higher accumulations of trace elements than the fattened BFT. In addition, female BFT accumulated more trace elements than males. The former result might be attributed to polluted water in the Mediterranean or to the food chain when sardines, mackerel, or squid that have accumulated trace elements are consumed. The second result could be related to gonad development and the reproduction period of

female BFT, since they feed more frequently through such periods. Hence, trace elements are more frequently accumulated by various organs, such as the liver, gills, and kidney, during this stage. Moreover, the findings in the study were lower or similar when compared with those of the selected studies listed in Table 5.

Consequently, the trace elements found within the kidney tissues of tuna species have rarely been studied. This manuscript provided information on the accumulation of some trace elements in the kidneys of wild/farmed and female/male BFT. Moreover, it emphasized the need for additional, detailed research on the trace element burdens within different organs of BFT and other tuna species.

REFERENCES

Ashraf W (2005). Accumulation of heavy metals in kidney and heart tissues of *Epinephelus Microdon* fish from the Arabian Gulf. Environ. Monit. Assess. 101:311-316.

Bridges CR, Gordin H, García A (2002). Domestication of the Bluefin tuna (*Thunnus thynnus thynnus*). Cahiers Options Méditerranéennes, vol. 60, Chieam-IAMZ, 2002, p. 203.

Cort JL (1991). Age and growth of bluefin tuna *Thunnus thynnus* (L.) of the Northeast Atlantic. ICCAT Rep. SCRS/94/66. Madrid-Spain. p. 86.

EFSA (2009). Scientific Opinion of the Panel on Animal Health and Welfare on a request from the European Commission on the species-specific welfare aspects of the main systems of stunning and killing of farmed tuna. The EFSA (European Food Safety Authority) J. (2009). 1072, p. 53.

Eisler R (1998a). Copper hazards to fish, wildlife, and invertebrates: A synoptic review. Contaminant Hazard Reviews Report No.33. Biological Science Report USGS/BRD/BSR-1998-002 January p. 120.

Eisler R (1998b). Nickel hazards to fish, wildlife, and invertebrates: A synoptic review. Contaminant Hazard Reviews Report No.34. Biological Science Report USGS/BRD/BSR-1998-001 January p. 95.

Hamilton SJ, Hoffman DJ (2003). Trace element and nutrition interactions in fish and wildlife. In: Hoffman DJ, Rattner BA, Burton GA, Cairns J (eds). Handbook of Ecotoxicology, CRC press, FL. USA.

Jaffar M, Ashraf M (1988). Selected trace metal concentrations in different tissues of fish from coastal waters of Pakistan (Arabian Sea). Indian J. Mar. Sci. 17: 231-234.

Jenkins DW (1980). Biological monitoring of toxic trace metals: vol: 2. Toxic trace metals in plants and animals of the world. Part III. U.S. Environmental Protection Agency Report 600/3-80-092. p. 290.

Kojadinovic J, Patier M, Le Corre M (2007). Bioaccumulation of trace elements in pelagic fish from the Western Indean Ocean. Environ. Poll. 146: 548-566.

Licata P, Trombetta D, Cristani M, Naccari C, Martino D, Calò M, Naccari F (2005). Heavy metals in liver and muscle of bluefin tuna (*Thunnus thynnus*) caught in the straits of Messina (Sicily, Italy). Environ. Monit. Assess. 107: 239-248.

Olsson P-E (1998). Disorders associated with heavy metal pollution. In: Leatherland JF, Woo PTK (eds). Fish Diseases and Disorders, Non-infectious disorders. vol: 2. CABI Publishing London, U.K., pp. 105-133.

Ottolenghi F (2008). Capture-based aquaculture of bluefin tuna. In: Lovatelli A, Holtus PF (eds). Capture-based aquaculture. Global overview. FAO Fisheries Technical Paper. No. 508. pp. 169-182.

Perçin F, Tanrikul TT (2006). Effects of negative factors on tuna health in fattening farms. J. Fisheries Aqu. Sci. 23: 479-484 (in Turkish).

Percin F, Konyalioglu S (2008). Serum biochemical profiles of captive and wild northern bluefin tuna (*Thunnus thynnus* L. 1758) in the Eastern Mediterranean. Aquac. Res. 39: 945-953.

Perçin F, Akyol O (2009). Length–weight and length–length relationships of the bluefin tuna, *Thunnus thynnus* L., in the Turkish part of the eastern Mediterranean Sea. J. Appl. Ichthyol. 25: 782-784.

Percin F, Akyol O (2010a). Some morphometric relationships in fattened bluefin tuna, *Thunnus thynnus* L., from the Turkish Aegean Sea. J. Anim. Vet. Adv. 9 (11):1684-1688.

Perçin F, Akyol O (2010b). A new harvesting techniques for tunas: Lupara. J. Fisheries Sci. 4: 190-194 (in Turkish).

Percin F, Sogut O (2010). Magnesium levels in vital organs of bluefin tuna, *Thunnus thynnus* L., from the Turkish Region of eastern Mediterranean. J. Anim. Vet. Adv. 9 (21):2768-2773.

Santamaria N, Bello G, Corriero A, Deflorio M, Vassallo-Agius R, Bök T, De Metrio G (2009). Age and growth of Atlantic bluefin tuna, *Thunnus thynnus* (Osteichthyes: Thunnidae), in the Mediterranean Sea. J. Appl. Ichthyol. 25: 38-45.

Schaefer KM (2001). Reproductive Biology of Tunas. In: Block BA, Stevens ED (Eds.) Tuna: Physiology, ecology and evolution. vol: 19. Academic Press, San Diego, pp: 225-270.

Sharif AKM, Mustafa AI, Amin MN, Safiullah S (1993). Trace element concentrations in tropical marine fish from the Bay of Bengal. The Science of the Total Environment ,138: 223-234.

Tuzen M (2009). Toxic and essential trace elemental contents in fish species from the Black Sea Turkey. Food Chem. Toxicol. 47: 1785-1790.

Vizzini S, Tramati C, Mazzola A (2010). Comparison of stable isotope composition and inorganic and organic contaminant levels in wild and farmed bluefin tuna, *Thunnus thynnus*, in the Mediterranean Sea. Chemosphere, 78: 1236-1243.

Watanabe T, Kiron V, Satoh S (1997). Trace minerals in fish nutrition. Aquaculture 151: 185-207.

Wu AHB (2006). Tietz Clinical Guide to Laboratory Tests, 4th edn. WB Saunders Company, Philadelphia, USA.