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Assessment of magnesium content of three fish species from three bays in Northeastern Mediterranean Sea

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ABSTRACT

Magnesium (Mg) is crucial for all cells of all known living organism. In this study, the accumulation of the magnesium in the tissues (muscle-M, skin-S, liver-L, and intestine-I) of three selected fish species (*Siganus rivulatus, Mullus barbatus, Solea solea*) from the three bays (İskenderun, Mersin, and Antalya) located in the Northeastern Mediterranean Sea was examined in a comparative context. The minimum and maximum values of the Mg accumulation (in μg g-1 w.wt) in the tissues of fish were found as 150-390 for *S. rivulatus*, 80-130 for *M. barbatus*, and 170-180 for *S. solea*. The distribution of the mean Mg accumulation among the organs of *M. barbatus* and *S. solea* from İskenderun and Mersin Bays was the same in the order of I>L>S>M, while the values for *M. barbatus* (I>S>M>L) and *S. solea* (L>I>M>S) from Antalya Bay were different. For *S. rivulatus,* the pattern was almost same in three bays as I>S>M>L. Based on the results of the Discriminant Analysis (DFA) and SIMPER (Similarity Percentage) analysis, overall average dissimilarities among the fish species and bays concerning Mg accumulations were found to be 47.37% and 44.4%, respectively. Results showed that intestines had the most dissimilarities while muscles had the lowest. From the point of view of human nutrition, Mg accumulation in muscle as an edible part of fish was found to be not significantly important among the three fish species and three bays.

Keywords
Mullus barbutus
Solea solea
Siganus rivulatus
Magnesium
Discriminant Analysis
Northeastern Mediterranean Sea

Introduction

Magnesium (Mg) is such a key mineral that over 300 enzymes require the presence of magnesium ions for their catalytic action. Therefore, it is crucial for all cells of all known living organisms (Durlach and Bara, 2000; Seelig, 2001; Laires et al., 2004; Brucha-Jastrzebska and Kawcuga, 2011). Also, high solubility of magnesium ions in water helps ensure that it is the third most abundant elements dissolved in seawater (Brucha-Jastrzebska and Kawcuga, 2011).

Fisheries products are key part of human diet due to not only their protein and unsaturated fatty acid content but also vitamins and minerals. A number of studies have been conducted on Mg accumulation in aquatic organisms. In the framework of a national project, the Mg concentrations (mg) in 100 g edible part of some fish species were reported with their means and ranges (minimum and maximum) from Turkey (www.turkomp.gov.tr). Brucha-Jastrzebska and Kawcuga (2011) studied the Mg concentrations in some freshwater fish and they found that the variations in the concentration of Mg are due to the differences of individual species and the concentration in the analyzed organs of freshwater fish varied significantly. Also, Uysal and Emre (2011) and Yılmaz et al. (2010) investigated the

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Mg content in the different organs of some marine fish species from Antalya and İskenderun Bay, respectively.

The aim of this study was to contribute to the knowledge on Mg accumulation in aquatic organisms. Therefore, it was aimed to evaluate, in a comparative context, the accumulation of the magnesium in the organs (muscle, skin, liver, and intestine) of three selected fish species (*Solea solea, Mullus barbatus, Siganus rivulatus*) from three bays (İskenderun, Mersin, and Antalya) located in North-Eastern Mediterranean Sea.

Material and Methods

Fish species

Common sole (*Solea solea*), Red mullet (*Mullus barbatus*) and Marbled spine foot (*Siganus rivulatus*) were studied for Magnesium (mg) accumulation in their organs (muscle, skin, liver, and intestine). Fish species were confirmed according to Froese and Pauly (2018). Common sole is a demersal marine fish which lives on sandy or muddy bottoms ranging from near shore to 200 m of depth. Adults feed mainly on polychaete worms, molluscs and small crustaceans. Red mullet is a benthic fish and its main habitat is muddy bottoms of the continental shelf between 5 and 300 m feeding on benthic invertebrates (crustaceans, worms, molluscs). Marbled spine foot lives in shallow waters over substrates clothed with algae including rocky and sandy areas as well as the places where algae grows among sea grass beds at depths of less than 15 m. They are herbivorous feeding mainly on algae.

Studied areas

Fish samples were taken from fishermen in the Iskenderun (36°36’20.53”N, 36°10’16.47”E), Mersin (36°46’45.38”N, 34°41’0.35”E) and Antalya (36°52’35.46”N, 30°41’35.08”E) bays in the North-Eastern Mediterranean Sea. These bays are in an interaction with each other through current systems (Hamad et al., 2005).

Sample Collection, Preparation and Analysis

TThe samples were brought to the laboratory on ice immediately and then frozen at -25°C until dissection. Total fish length and weight were measured to the nearest millimeter (mm) and gram (g) before dissection. The mean length and weight of the S. solea, M. barbatus, and S. rivulatus were 25.22±2.20 cm and 135.90±43.11 g, 19.64±4.07 cm and 158.31±123.61 g and 17.29±2.08 cm and 108.34±72.52 g, respectively. The mean body length of each species from three bays were not significantly different (p>0.05).

Fish samples were dissected to get organ samples (epaxial muscle, intestine, skin and liver). All chemicals used in the study were of analytical reagent grade. Double distilled water was used throughout the study. Calibration standard solutions were prepared by stepwise dilution of the stock solution. Samples were weighted, digested in HNO3/HCl (1:3 v/v), filtered with 0.45 μm micropore membrane filter, diluted and then analyzed for Mg content in accordance with Yılmaz (2003).

Analysis was carried out in triplicate using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) (Perkin Elmer Nexion 350 X). Metal concentrations were calculated in microgram per gram wet weight (μg metal g^{-1}w.wt.).

Statistical analyses

Discriminant Analysis (DFA) was used to determine which combinations of variables (distances) discriminated the groups and detected which groups were the most different (Ruiz-Campos et al., 2003). Before conducting DFA, the variables were standardized by logarithmic transformation (log(x)). In addition to DFA, SIMPER (Similarity Percentage) analysis was used to assess which variables are primarily responsible for an observed difference between groups (Clarke, 1993).

All computations and statistical analyses were carried out using Microsoft Excel and PAST software (v. 3.23) (Hammer et al., 2001).

Results and Discussion

Table 1 and Figure 1 show mean Magnesium (Mg) concentration (in μg g^{-1}w.wt) with standard deviation and range (minimum, maximum) values in different organs of *S. solea, M. barbatus, S. rivulatus* with respect to the three studied bays, respectively.

Mg concentration in the muscle of *S. rivulatus* changed from 149.50 to 168.69 μg g^{-1} w.wt in İskenderun Bay, 146.22 to 407.22 μg g^{-1} w.wt in Mersin Bay and 124.19 to 188.75 μg g^{-1} w.wt in Antalya Bay. Similarly, Mg concentration of *M. barbatus* varied between 174.32-263.19 μg g^{-1} w.wt in İskenderun Bay, 117.23-263.19 μg g^{-1} w.wt in Mersin Bay, and 68.55-336.79 μg g^{-1} w.wt in Antalya Bay. Finally, Mg concentration in the muscle of *S. solea* in İskenderun, Mersin and Antalya Bays was found to be between 117.22-263.19 μg g^{-1} w.wt, 150.28-204.41 μg g^{-1} w.wt

Table 1. Mean Mg concentrations with standard deviations (μg metal g^{-1} wet weight [w.wt.]) in the organs of *S. solea, M. barbatus, S. rivulatus* with respect to studied bays

Bay	Species	Muscle (M) (mean± sd)	Skin (S) (mean± sd)	Liver (L) (mean± sd)	Intestine (I) (mean± sd)
Iskenderun	*S. rivulatus*	158.16 ±8.86	403.29± 114.58	135.07±26.59	617.62±219.95
		149.50-168.69	248.61-534.16	108.63 - 166.61	421.52-874.85
	M. barbatus	197.54±24.43	225.09± 89.98	292.70±6.17	848.21±752.12
		174.32 - 263.19	100.89-315.61	288.34-297.06	249.74-1654.56
	S. solea	181.75±73.31	198± 87.54	214.66±34.44	561.31±305.85
		117.22-263.19	125.59-321.59	177.22-251.06	290.16-859.753
Mersin	*S. rivulatus*	266.41 ±120.70	187.38± 41.21	117.20±27.01	451.27±252.20
		146.22 - 407.22	137.43-237.17	97.86 to 155.70	100.73-672.48
	M. barbatus	181.75±73.31	198.07± 87.54	214.66±34.44	561.31±305.85
		117.23-263.19	128.53-236.68	177.22-251.06	290.16-859.75
	S. solea	176.73±27.09	186.29± 40.31	268.30±212.01	660.37±193.14
		150.28-204.41	128.53-236.68	134.16-584.75	448.45-849.95
Antalya	*S. rivulatus*	160.60 ±27.88	174.70± 52.32	143.29±69.39	319.13±206.79
		124.19 -188.75	122.31-231.49	101.59 - 266.03	194.53-557.83
	M. barbatus	194.33±111.01	681.74± 313.68	178.42±4.62	1531.98±751.32
		68.55-336.79	100.90-217.21	175.15-181.68	527.48-2345.22
	S. solea	170.01±105.87	153.61± 58.99	283.59±146.67	270.25±214.30
			100.90-217.21	134.16-584.75	131.01-583.41

and 101.21-327.06 μg g^{-1} w.wt, respectively. The highest concentration was observed in *S. rivulatus* from Mersin Bay and the lowest concentration was observed in *M. barbatus* in Antalya Bay (Figure 1).

Mg accumulation level in the skin was found to be 248.61-534.16, 137.43-237.17, 122.31-231.49 μg g^{-1} w.wt for *S. rivulatus*; 100.89-315.61, 125.59- 321.58, 376.08-1108.59 μg g^{-1} w.wt for *M. barbatus* and 125.59-321.59, 128.53-236.68, 100.90-217.21 μg g^{-1}w.wt for *S. solea* in İskenderun, Mersin and Antalya bays, respectively (Figure 1).

Mg concentration in the liver of *S. rivulatus* was found to have changed from 108.63 to 166.61 μg g^{-1}w.wt in Iskenderun Bay, 97.86 to 155.70 μg g^{-1}w.wt in Mersin Bay and 101.59 to 266.03 μg g^{-1}w.wt in Antalya Bay. Similarly, Mg concentration of *M. barbatus* varied between 288.34-297.06 μg g^{-1} w.wt in İskenderun Bay, 177.22-251.06 μg g^{-1} w.wt in Mersin Bay, and 175.15-181.68 μg g^{-1} w.wt in Antalya Bay. Lastly, Mg concentration in the liver of *S. solea* was found between 177.22-251.06 μg g^{-1} w.wt in İskenderun Bay, 134.16-584.75 μg g^{-1} w.wt in Mersin Bay and 156.70-429.11 μg g^{-1} w.wt in Antalya Bay (Figure 1).

Highest Mg accumulation levels were observed in the intestine tissue and the values varied between 421.52-874.85, 100.73-672.48, 194.53-557.83 μg g^{-1} w.wt in Iskenderun, Mersin and Antalya bays for *S. rivulatus*, respectively. The same ranking was observed as 249.74-1654.56, 290.16-859.75, and 527.48-2345.22 μg g^{-1} w.wt for *M. barbatus* in İskenderun, Mersin and Antalya Bays, respectively. Lastly, it varied between 290.16-859.753, 448.45-849.95, and 131.01-583.41 μg g^{-1} w.wt for *S. solea* in İskenderun, Mersin and Antalya bays, respectively. The highest and lowest accumulation values were observed in *M. barbatus* and *S. solea*, respectively, from the Antalya Bay.

The pattern of the mean Mg accumulation among the organs for *M. barbatus* and *S. solea* from İskenderun and Mersin Bays was the same as I>L>S>M while the patterns for *M. barbatus* (I>S>M>L) and *S. solea* (L>I>M>S) from Antalya Bay were different. For *S. rivulatus,* the pattern was almost same in three bays as I>S>M>L (Table 1).

According to Uysal et al. (2008), the rank of Mg bioaccumulation in the different organs of *Lithognathus mormyrus, Liza aurata, Chelon labrasus, Mugil cephalus, Sparus aurata, Liza ramada* was found as Gill (G) >Muscle (M) >Skin

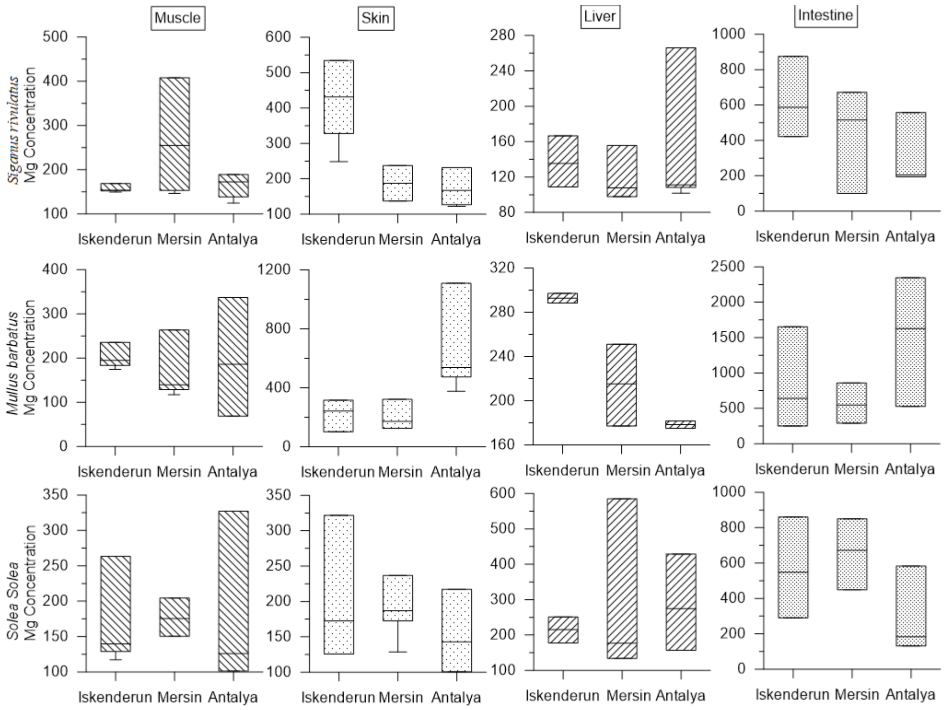

Figure. 1. Box and whisker plots of Mg concentrations (μg g^{-1} w.wt) in the different organs of *S. rivulatus, M. barbatus* and *S. solea* with respect to studied bays

(S). They also reported the Mg accumulation (mg/kg w.wt.) in the different organs of several species including *L. mormyrus* (M: 304.20 ± 22.9, S: 215.60 ± 11.7, G: 659.16±12.8), *L. aurata* (M: 278.60 ± 5.2, S: 173.06 ± 8.6, G: 560.50±4.7), *C. labrasus* (M: 323.40 ± 9.9, S: 168.73 ± 3.7, G: 451.80±20.2), *M. cephalus* (M: 295.70 ± 4.3, S: 188.23 ± 9.8, G: 486.73±4.1), *S. aurata* (M: 332.56 ± 10.5, S: 211.56 ± 28.4, G: 545.93±13.4), and *L. ramada* as (M: 262.53±15.1, S: 233.56±36.5, G: 617.23±4.7).

Uysal and Emre (2011) investigated the Mg content in the different tissues of *Diplodus sargus, S. rivulatus, L. mormyrus, L. aurata, C.* labrasus from Antalya Bay. They reported that Mg level varied from 204.33 to 784.30 μg g^{-1} w.wt depending on

Table 2. The magnesium concentrations (mg) of 100 g edible part of some fish species from Turkish Food Composition Database (URL).

Name	Scientific name	Mean	Min	Max	Reference
Marbled spinefood	*Siganus rivulatus* (Forsskål & Niebuhr, 1775)	20	15	39	This study*
Red Mullet	*Mullus barbatus* (Linnae, 1758)	19	8	31	
Common Sole	*Solea solea* (Linnaeus, 1758)	18	7	28	
Rainbow trout	*Oncorhynchus mykiss*	38	33	44	Turkomp (2019)
Red mullet	*Mullus barbatus* (Linnae, 1758)	33	26	39	
European hake	*Merluccius merluccius* (Linnaeus, 1758)	30	21	40	
European anchovy	*Engraulis encrasicholus* (Linnae, 1758)	30	28	34	
Atlantic and Mediterranean horse mackerel	*Trachurus trachurus* (Linnaeus, 1758) and *Trachurus mediterraneus* (Steindachner, 1868)”	36	31	45	
Turbot	*Scophthalmus maximus* (Linnaeus, 1758)	34	21	39	
Golden mullet	*Mugil auratus* (Linnaeus, 1761)	29	23	37	
Whiting	*Merlangius merlangus euxinus* (Nordmann, 1840)	27	21	30	
Atlantic bonito	*Sarda sarda* (Bloch, 1793)	34	32	37	

**Results of this study were converted to mg/100 g*

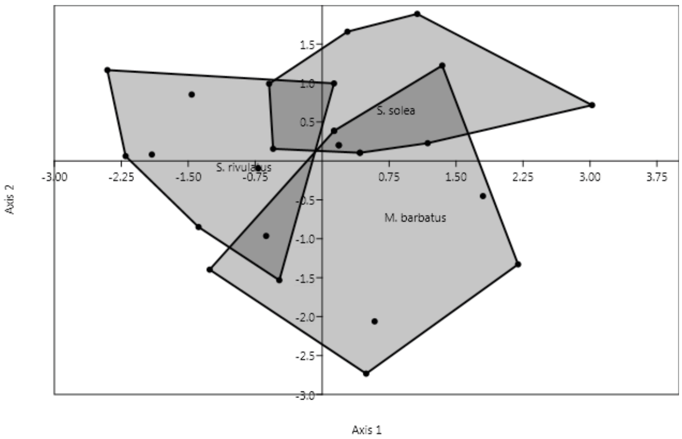

Figure 2. Result of Discriminant Analysis (DFA) on three fish species with convex hulls.

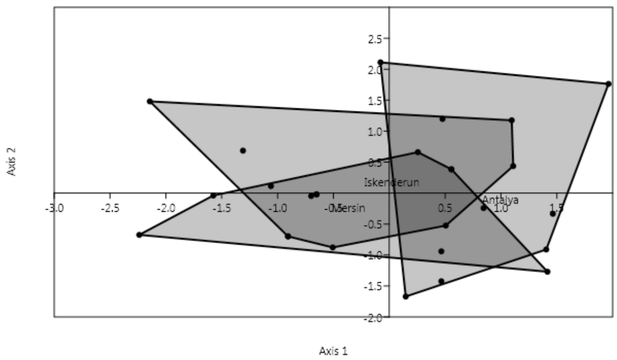

Figure 3. Result of Discriminant Analysis (DFA) on three bays with convex hulls.

species and tissue. The Mg content ranking of *S. rivulatus* was reported to be skin>gill>muscle.

Yılmaz et al. (2010) reported the mean Mg content (as µg metal g^{-1} w.wt.) in the *Triglia lucerna, Lophius budegassa, Solea lascais* collected from İskenderun Bay as 21.7±5.57, 16.6±8.34, 9.05±3.28 µg g^{-1} w.wt in liver, 19.2±1.93, 16.4±3.28, 12.9±7 µg g^{-1} w.wt in skin, and 17.9±4.34, 7.34±3.22, 23.3±12.3 µg g^{-1} w.wt in muscle, respectively.

Brucha-Jastrzebska and Kawczuga (2011) studied the Mg content (mg.kg-1 w.wt.) of muscle tissue of some freshwater species namely Common carp, Rainbow throut, Siberian sturgeon, Northern pike and Grass carp and they found the concentrations as 85.4±24.1, 87.2±33.5, 63.6±16.2, 125.7±32.7 and 72.4±24.3 mg.kg^{-1} w.wt, respectively.

Comparison of our findings with the previous studies revealed that even though Mg bioaccumulation levels are different among species, accumulation level ranking is similar. Liver and intestine had the highest bioaccumulation concentration compared to other organs. Intestines accumulate a lot of heavy metal since it is related with the digestive system. Similarly, liver acts as a target organ in heavy metal accumulation since it is metabolically active organ (Romeo et al., 1999; Yılmaz et al., 2010). Therefore, the present study proves that even though Mg is not a heavy metal, it acts like a heavy metal in terms of bioaccumulation.

The magnesium (Mg) concentrations (mg) of 100 g edible part of some fish species from TurKomp database were given in Table 2.

It is difficult to generalize a mineral content of fish species due to the variations occurring based on several internal and external factors such as mineral type, specimen, sex, biological cycle, location, climate, nutrient availability, temperature, salinity etc. (Martinez et al., 1998; Martinez-Valverde et al., 2000; Yılmaz et al., 2010). For that reason, wide variations in the Mg level were observed depending on fish species, location (bay), and fish tissue (Table 1). However, in a general point of view, our results are consistent with the previous literature and the ministry database.

Discriminant Analysis (DFA) carried out both on species and bays yielded two functions that are accounted the total variance as (70.5% and 29.5% for fish species) and (92.09% and 7.90% for bays), respectively (Figure 2 and Figure 3).

The variations of Mg consternations in organs by the three fish species and the three bays with contribution to dissimilarities based on DFA and SIMPER analyses were shown in Table 2 and Table 3, respectively. Overall average dissimilarities among the fish species and bays concerning the Mg accumulations were 47.37% and 44.4%, respectively. On the other hand, their similarities were 52.63% and 55.60%, respectively.

Table 3. Contribution rates (%) of organs on dissimilarities among the species

Organs	Contribution %	Cumulative %	Pattern
Intestine	43.84	43.84	*M. barbatus>S.solea>S.rivilatus*
Skin	27.49	71.33	*M. barbatus>S.rivilatus> S.solea*
Liver	17	88.33	*S.solea>M. barbatus>S.rivilatus*
Muscle	11.67	100	*M. barbatus>S.solea>S.rivilatus*

Results indicate that differences depending on the three fish species arise from intestine, skin, liver and muscle tissue (Table 3). Patterns showed that intestine with *M. barbatus* interactions produced the most dissimilarities while muscle with *S. rivulatus* had the lowest. Similarly, differences in the Mg accumulation levels depending on the three bays arise from intestine, skin, liver and muscle with the contribution rate of 0.19, 0.13, 0.07 and 0.06, respectively (Table 4). The patterns for contribution rates (%) of organs on dissimilarities among the bays showed that intestine with İskenderun bay interactions

Table 4. Contribution rates (%) of organs on dissimilarities among the bays

Organs	Contribution %	Cumulative %	Pattern
Intestine	0.19	43.83	İskenderun>Antalya>Mersin
Skin	0.13	28.24	Antalya>İskenderun>Mersin
Liver	0.07	15.26	İskenderun >Antalya>Mersin
Muscle	0.06	12.67	Mersin>İskenderun>Antalya

Conclusion

In this study, the accumulations of magnesium (In this study, the accumulations of magnesium (Mg) in the organs (muscle, skin, liver, and intestine) of three selected fish species (*Solea solea, Mullus barbatus, Siganus rivulatus*) from three bays (İskenderun, Mersin, and Antalya) located in Northeastern Mediterranean Sea were examined in a comparative context. Key findings and conclusions of the study are given below:

1. The pattern of the mean Mg accumulation among the organs of *M. barbatus* and *S. solea* from İskenderun and Mersin bays was the same in the order of I>L>S>M while it was different for *M. barbatus* (I>S>M>L) and *S. solea* (L>I>M>S) from Antalya bay. For *S. rivulatus*, the pattern was almost same in all three bays as I>S>M>L.

2. Overall average dissimilarities among the three fish species and the three bays concerning Mg accumulations were 47.37% and 44.4%, respectively. On the other hand, their similarities were 52.63% and 55.60%, respectively.

3. Patterns showed that intestine with *M. barbatus* interactions produced the most dissimilarities while muscle with *S. rivulatus* had the lowest. The patterns for contribution rates (%) of organs on dissimilarities among the three bays showed that intestine with İskenderun bay interactions produced the most dissimilarities while muscle with Antalya Bay had the lowest.

4. From the point of view of human nutrition, it was found that Mg accumulations in muscles as an edible part of fish were not significantly different both among the three fish species and three bays included in the study.

References

Brucha-Jastrzebska, E. & Kawczuga, D. (2011). Level of magnesium in tissues and organs of freshwater fish. *Journal of Elementology,* 16(1): 7-20.

Clarke, K. R. (1993). Non-parametric multivariate analysis of changes in community structure. *Australian Journal of Ecology,* 18(1): 117-143.

Durlach, J. & Bara, M. (2000). Le Magnésium en Biologieet en Médecine. Editions médicales internationales, 2 nd ed., Cachan, França

Froese, R., &Pauly, D. (2018). FishBase 2018, version (January, 2018). World Wide Web electronic publication. Retrieved in March 13, 2019 from http://www.fishbase.org.

Hamad, N., Millot, C. & Taupier-Letage, I. (2005). A new hypothesis about the surface circulation in the eastern basin of the Mediterranean Sea. *Progress in Oceanography,* 66(2-4): 287-298.

Hammer, Ø., Harper, D. A. T. & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia*

Electronica, 4(1): 262 p.

Laires, M. J., Monteiro, C. P. & Bicho, M. (2004). Role of cellular magnesium in health and human disease. *Front Biosci,* 9: 262-276.

Martinez, I., Santaella, M., Ros, G., & Periago, M. J. (1998). Content and in vitro availability of Fe, Zn, Mg, Ca and P in homogenized fish-based weaning foods after bone addition. *Food Chemistry,* 63(3): 299-305.

Martinez-Valverde, I., Periago, M. J., Santaella, M. & Ros, G. (2000). The content and nutritional significance of minerals on fish flesh in the presence and absence of bone. *Food Chemistry,* 71(4): 503-509.

Roméo, M., Siau, Y., Sidoumou, Z. & Gnassia-Barelli, M. (1999). Heavy metal distribution in different fish species from the Mauritania coast. *Science of the Total Environment,* 232(3): 169-175.

Ruiz-Campos, G., Camara-Rosales, F., Varela-Romero, A., Sánchez-González, S., De la Rosa-Vélez, J. (2003). Morphometric variation of wild trout populations from northwestern Mexico (Pisces: Salmonidae). *Reviews in Fish Biology and Fisheries,* 13(1): 91-110.

Seelig, M. S. (2001). Epidemiologic data on magnesium deficiency-associated cardiovascular disease and osteoporosis: consideration of risks of current recommendations for high calcium intakes. In: Advances in Magnesium Research. Nutrition and Health. Eds: Rayssiguier, Y., A. Mazur, J. Durlach, John Libbey& Company Ltd., London, UK, pp. 177- 190.

TurKomp. (2019). Turkish Republic ministry of agriculture and forestry, turkish food composition database. Retrieved in October 11, 2019 from http://www.turkomp.gov.tr/database?type=foods&group=4

Uysal, K. & Emre, Y. (2011). Bioaccumulation of copper, zinc, mangan, iron and magnesium in some economically important fish from the western shores of Antalya. *Anadolu University Journal of Science and Technology C - Life Sciences and Biotechnology,* 1(1): 95-102.

Uysal, K., Emre, Y. & Köse, E. (2008). The determination of heavy metal accumulation ratios in muscle, skin and gills of some migratory fish species by inductively coupled plasma-optical emission spectrometry (ICP-OES) in Beymelek Lagoon (Antalya/Turkey). *Microchemical Journal,* 90(1): 67-70.

Yılmaz, A. B., Sangün, M. K., Yağlıoğlu, D. & Turan, C. (2010). Metals (major, essential to non-essential) composition of the different organs of three demersal fish species from Iskenderun Bay, Turkey. *Food chemistry,* 123(2): 410-415.

Yılmaz, A. B. (2003). Levels of heavy metals (Fe, Cu, Ni, Cr, Pb, and Zn) in tissue of *Mugil cephalus* and *Trachurus mediterraneus* from Iskenderun Bay, Turkey. *Environmental Research,* 92(3): 277-281.