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ORIGINAL ARTICLE

Seasonal variations in the body composition and bioaccumulation of heavy metals in Nile tilapia collected from drainage canals in Al-Ahsa, Saudi Arabia

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Abstract The body composition of Nile tilapia (*Oreochromis niloticus*) collected from drainage canals in Al-Ahsa, Saudi Arabia and the concentration of four heavy metals; zinc (Zn), cadmium (Cd), cobalt (Co) and lead (Pb) in both fish muscles and the water collected from this environment were assessed across the four seasons. The body composition was found to change with the seasons, with the best body composition being recorded in autumn and winter, where higher levels of protein (17.24, 17.65%), and fat (0.58, 0.71%) and lower water content (80.15, 79.86%) respectively were noted. The concentration of heavy metals in both fish muscles and the water body also varied significantly with the seasons. In the fish muscles, the highest content of Zn (0.409 mg/kg dry weight) and Cd (4.140 mg/kg dry weight) was recorded in winter, however, the highest concentration of Co (0.318 mg/kg dry weight) and Pb (1.96 mg/kg dry weight) was observed in spring and summer respectively. On the other hand, the water samples collected in autumn showed the maximum concentration of Cd (1.385 mg/L), Co (0.762 mg/L) and Pb (0.18 mg/L) however, the maximum concentration of Zn (0.0041 mg/L) was recorded in winter. With the exception of Cd, the accumulation of the studied heavy metals in fish muscles was within the safe limits for seafood recommended by various organizations.

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1. Introduction

Al-Ahsa, about 60 km inland from the Persian Gulf, is a traditional oasis region within the Eastern Province and is home to the largest oasis in the world. Natural freshwater springs have surfaced at oases in the region for millennia, encouraging

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human habitation and agricultural production (especially date palm cultivation). The Al-Ahsa oasis is important since there are few freshwater resources in Saudi Arabia. Sources of freshwater in the country can be divided into (a) natural sources of water: such as springs, seasonal streams, pools, wetlands and marshes; (b) artificial sources of water: such as agricultural drainage and treated effluent outflows, wells, dams and irrigation canals fed by water pumped from deep underground aquifers in order to supply agricultural irrigation projects and expanding human demand, (NCWCD, 2005). Whether natural or artificial in origin, these freshwater wetlands attract and support a diverse assemblage of plants and animals and are important centres of endemism (NCWCD, 2005) but they are also highly vulnerable biological sites in the arid landscape of Saudi Arabia. A sparse fish fauna would be expected in Saudi Arabia in view of its arid environment and their distribution is related to the availability of freshwater dispersal routes (NCWCD, 2005). Nile tilapia (*O. niloticus*) is, however, one of the most important fish species in the freshwater habitats of Saudi Arabia.

The pollution of freshwater sources by sewage, industrial waste, oil and agricultural fertilizers and pesticides, endangers the existence of both flora and fauna. Fish are often considered as an important bioindicator for aquatic ecosystems, because they obtain a high trophic level, and because they have the inherent potential to accumulate heavy metals in their muscles (Rahman et al., 2012). Therefore and because fish are an important source of balanced protein in the human diet, the present study was carried out to determine the chemical composition of Nile tilapia, *O. niloticus* and to evaluate the bioaccumulation of some heavy metals in this fish species collected from the two main drainage canals of Al-Ahsa, Saudi Arabia relevant to their environment.

2. Materials and methods

2.1. Sample collection

Samples of water and Nile tilapia, *O. niloticus*, were collected from one canal only of the two main drainage canals in Al-Ahsa during each of the four seasons (spring, summer, autumn, and winter in 2012) whereas there is no fish was recorded or collected from the other canal. The water samples were transported in plastic bottles while the collected fish were immediately packed in polythene bags fitted with oxygen and transferred to the laboratory.

2.2. Tissue sampling

Fish were killed by a blow on their head, an incision was made along one side of the dorsal fin and the skin was carefully and quickly peeled down, avoiding tissue squeezing. A sample of white muscle was removed from the dorso-lateral side just behind the head and taken for further processing and analysis.

2.3. Determination of fish body composition

The proximate chemical composition (Love, 1980) of the white muscle (i.e. moisture, protein, lipids and ash) was determined according to the standard analytical procedures of AOAC (1995).

2.4. Determination of heavy metals in fish muscles

The contents of Zinc (Zn), Cadmium (Cd) Cobalt (Co) and Lead (Pb) was determined in both the fish muscles and the water samples using an Atomic Absorption Spectrophotometer (Model AA-680/ Shimadzu) according to the method described by AOAC (1995).

2.5. Statistical analysis

Data collected were subjected to statistical analysis using a one way Analysis of Variance (ANOVA). The average values (mean ± standard deviation) were compared by using Fisher's Least Significant Differences test (LSD-test), as described by Snedecor and Cochran (1989).

3. Results

3.1. Chemical composition of fish muscles

The chemical composition of muscles of *O. niloticus* (as a percentage based on the fresh weight) is shown in Table 1. Overall, significant differences ($p < 0.05$) were observed in the chemical composition of fish muscles between the four seasons. The highest moisture content (82.43%) was observed in summer followed by spring, albeit without a significant difference. The lowest average moisture content was observed in fish muscles in winter (79.86%) followed by autumn, with these values being significantly less than those obtained in summer and spring.

Analysis of fish muscles showed that the highest protein value was achieved in the samples collected in winter (17.65%), which were close to autumn values (17.24%). There was a significant decrease in the protein content of fish muscles in spring (16.00%) and summer (15.68%), however, with the latter representing the lowest protein value recorded in this study.

The lipid content of fish muscles also differed significantly ($p < 0.05$) between the various fish samples. The highest value (0.71%) was observed in the fish collected in winter, whereas the lowest level (0.37%) was found in spring fish samples.

Table 1 Muscle composition of Nile tilapia (*O. niloticus*) collected from drainage canals in Al-Ahsa, Saudi Arabia.

Season of Collection	Moisture%	Protein%	Fat%	Ash%
Spring	82.21 ± 0.34^{a}	16.00 ± 0.58	0.37 ± 0.12	1.07 ± 0.16^{b}
Summer	82.43 ± 1.59^{a}	15.68 ± 0.37^{b}	0.51 ± 0.09^{bc}	1.02 ± 0.11^{b}
Autumn	80.15 ± 1.85^{b}	17.24 ± 0.38^{a}	0.58 ± 0.13^{ab}	1.30 ± 0.07^{a}
Winter	79.86 ± 1.06^{b}	17.65 ± 0.21^{a}	0.71 ± 0.04^{a}	1.23 ± 0.15^{a}

Each reading represents (Mean ± SD: Percentage based on the fresh weight).
Different letters in the same column means that there was significant difference at $p < 0.05$.

The highest ash content (1.30%) was obtained in the muscles of fish captured in the autumn followed by the winter samples (1.23%), although there was no significant difference between these two results. The lowest value (1.02%) was found in the summer fish samples which were close to the ash content in the spring samples (1.07%). Again, there was a significant difference ($p < 0.05$) between the results of the spring and summer samples compared to the autumn and winter ones.

3.2. Heavy metal contents in fish muscles

Data on the average heavy metal content of the fish muscles for the various seasons are shown in Table 2, with significant differences ($p < 0.05$) again being evident between the different seasons. The results indicated that the highest concentration of zinc (Zn) was observed in the winter fish samples (0.409 mg/kg dry weight), followed by the autumn ones (0.352 mg/kg) with no significant decrease ($p > 0.05$). There were, however, significant differences compared to the accumulation of this metal in fish muscles collected in summer (0.315 mg/kg) and spring (0.298 mg/kg). The highest level of cadmium (Cd) was also recorded in the fish muscle samples collected in winter (4.140 mg/kg) with significant differences compared to the autumn (3.436 mg/kg) and summer samples (3.344 mg/kg), which represented the lowest level. The concentration of cobalt (Co) differed significantly in throughout the four seasons, with the highest concentration being observed in fish muscles collected in spring (0.318 mg/kg) while, on the other hand, the summer samples showed the lowest concentration (0.155 mg/kg). The lead (Pb) accumulation in the fish muscles, meanwhile, was at its highest in summer, (1.96 mg/kg) followed by winter (1.86 mg/kg), although there was not a significant difference between these two results. There were significant differences, however, between spring (1.76 mg/kg) and autumn (1.63 mg/kg) results, with the latter representing the lowest accumulation value.

3.3. Heavy metals content in water samples

Data on the average heavy metal content in water samples collected through the four seasons are shown in Table 3, with significant differences ($p < 0.05$) again evident across the four seasons. The ranking order of zinc (Zn) concentrations in the water samples was as follows: winter (0.0041) > spring (0.0014) > summer (0.0012) > autumn (0.0006) (Mean; mg/l). In the water from the drainage canals studied here therefore, there was a significant difference in the concentration of Zn between the winter samples and those collected in the other seasons. The results of the water content of cadmium (Cd) showed a significant difference between the values of the autumn samples (1.385 mg/l) which represent the highest levels and the values of the summer (0.799 mg/l), winter (0.718 mg/l) and spring (0.212 mg/l) samples, with the latter representing the lowest level. The highest concentration of cobalt (Co) was observed in the water samples from autumn (0.762 mg/l) followed by the winter samples (0.567 mg/l), with no significant differences ($p > 0.05$). There were, however, significant differences when comparing the concentrations of this metal in water samples collected in spring (0.426 mg/l) and summer (0.283 mg/l). The lead (Pb) content of water samples collected in the different seasons showed that the highest level of this metal was achieved in the autumn samples (0.18 mg/l) followed by the summer samples (0.11 mg/l), which showed very similar levels to the winter samples (0.10 mg/l). The lowest level was recorded in the spring (0.06 mg/l). There were therefore significant differences in the concentration of this metal (Pb) among the water samples collected in the different seasons.

4. Discussion

Knowledge of fish composition is essential in order to maximize their utilization (Silva and Chamul, 2000). Proximate body composition is the analysis of water, fat, protein and

Table 2 The average content of selected heavy metals in the muscle of Nile tilapia (*O. niloticus*) collected from drainage canals in Al-Ahsa, Saudi Arabia.

Season of collection	Zinc (Zn)	Cadmium (Cd)	Cobalt (Co)	Lead (Pb)
Spring	0.298 ± 0.0553^{b}	3.644 ± 0.2946^{ab}	0.318 ± 0.0653^{a}	1.76 ± 0.3027^{bc}
Summer	0.315 ± 0.0319^{b}	3.344 ± 0.0670^{b}	0.155 ± 0.0592^{c}	1.96 ± 0.1181^{a}
Autumn	0.352 ± 0.0774^{ab}	3.436 ± 0.2642^{b}	0.169 ± 0.0536^{bc}	1.63 ± 0.1019^{b}
Winter	0.409 ± 0.0407^{a}	4.140 ± 0.1766^{a}	0.179 ± 0.0580^{b}	1.86 ± 0.1821^{ac}

Each reading represents (Mean ± SD in mg/kg dry weight).
Different letters in the same column means that there was significant difference at $p < 0.05$.

Table 3 The average content of selected heavy metals in water samples collected from drainage canals in Al-Ahsa, Saudi Arabia.

Season of Collection	Zinc (Zn)	Cadmium (Cd)	Cobalt (Co)	Lead (Pb)
Spring	0.0014 ± 0.0002^{b}	0.212 ± 0.0213^{c}	0.426 ± 0.0373^{b}	$0.06 \pm .0039^{c}$
Summer	0.0012 ± 0.0003^{b}	0.799 ± 0.0613^{b}	0.283 ± 0.0339^{c}	0.11 ± 0.0498^{b}
Autumn	0.0006 ± 0.0001^{c}	1.385 ± 0.4096^{a}	0.762 ± 0.0593^{a}	0.18 ± 0.447^{a}
Winter	0.0041 ± 0.0003^{a}	0.718 ± 0.0559^{b}	0.567 ± 0.0724^{ab}	0.10 ± 0.0356^{b}

Each reading represents (Mean ± SD in mg/L).
Different letters in the same column means that there was significant difference at $p < 0.05$.

ash content of the fish (Love, 1980) and is a good indicator of its physiological condition and health (Saliu et al., 2007). The present study has shown changes in the chemical composition of Nile tilapia which appear to be related to the seasons; a result which is in agreement with that of Javaid et al. (1992) and Oliveira et al. (2003) who each reported that, in different environmental conditions, the body composition of the same fish may change in relation to differences in water quality, feeding conditions, sex, state of maturity and the period during which the fish was captured. The results of our study also indicated that, an increase in protein and fat and a decrease in water content were evident in autumn and winter. This coincides in general with Saeed (2013) who reported that the best condition and proximate body composition of fish (*O. niloticus, Oreochromis aureus* and *Tilapia zillii*) were recorded in the spring and winter seasons with an increase in protein and fat and a decrease in water content evident in these seasons and vice versa in summer and autumn. According to FAO (1999) the moisture and lipid content in fish fillets are inversely related, which is supported by our findings. A number of investigators have attempted to relate changes in body composition to seasonal variables (Jarboe and Grant, 1996; Saeed, 2013). Both the condition and quality of fish in lakes are known to be affected by the environmental conditions (Ibrahim et al., 2008) and other biotic and abiotic variables, such as hydrologic level, food availability and water temperature (Wassef and Shehata, 1991; Touhata et al., 1998).

The accumulation of heavy metals in fish due to anthropogenic activities has become an important issue internationally, not only because of the threat to fish but also due to the health risks associated with fish consumption and concerns over these issues are increasing, particularly in developing parts of the world (Chen et al., 2011). Fish are also often considered as an important bioindicator for aquatic ecosystems because they obtain a high trophic level and are an important source of balanced protein in the human diet (Rahman et al., 2012). Muscles are the main edible part of fish and can directly influence human health and, as a result, the consequences of excessive metal residue in fish tissues are potentially serious (Pintaeva et al., 2011). Many governments have, therefore, established toxicological limits for heavy metals in seafood, but such limits are often not defined for all the elements (Agah et al., 2009). The study of fish muscle tissues is one means of investigating the amount of heavy metals reaching man through the food chain.

In the current study, the concentrations of the heavy metals (Zn, Cd, Co and Pb) in muscles of the Nile tilapia have been shown to vary considerably with the seasons. The level of Zn recorded in fish muscles ranged from 0.298 to 0.409 mg/kg dry wt. and it was a negligible level compared to the standard of 1000 mg/kg set by the WHO (1996). The concentrations of Zn detected in our study were in agreement with the findings of Mahboob et al. (2014) who reported that the level of Zn ranged from 292 to 313 mg/kg dry wt. for Nile tilapia collected from Wadi Haneffah, Riyadh, Saudi Arabia in the pre-monsoon and post-monsoon seasons, respectively. Saeed (2013), meanwhile, recorded a much higher level of Zn in the muscles of Nile tilapia, varying from 23.74 μg/g dry wt. in summer to 47.20 in winter.

The Cd concentrations in the muscles of Nile tilapia collected in this study ranged from 3.344 to 4.140 mg/kg dry wt. These results were higher than the concentrations recorded by Mahboob et al. (2014) which varied between 1.6 and 1.88 mg/kg. The Cd results in the present study were also much greater than the results of Saeed (2013), who recorded values of Cd between 0.13 μg/g dry wt. in autumn and 0.49 in winter for Nile tilapia collected from Lake Edku, Egypt. From our findings, it was clear that the Cd concentrations in the muscles of fish studied were above the maximum recommended limits of 2.00 ppm (WHO, 1996; FEPA, 2003) in fish food.

The cobalt (Co) level reported in this study, meanwhile, varied from 0.155 to 0.318 mg/kg dry wt. with the maximum level being lower than the findings of Eralagere and Bhadravathi (2008) who reported that 0.039–1.44 ppm of Co was recorded in *Oreochromis mossambicus* from Jannapura Lake in India. The concentration of lead (Pb) recorded in our study (1.63–1.96 mg/kg dry wt.) was also lower than the value reported by Mahboob et al. (2014) (3.09–3.48 mg/kg), but was greater than the findings of Saeed (2013), who reported that the concentration of Pb in the muscles of Nile tilapia ranged from 0.14 μg/g dry wt. in spring up to 0.92 in summer. It was evident, however, that the muscle content of Pb remained under the maximum recommended limits of 2.0 ppm (WHO, 1996; FEPA, 2003; FAO, 1983) in fish food.

The environmental conditions in water bodies are constantly changed by various naturally and anthropogenically induced factors. Also, water quality may be affected by the source of the water, rate of flow, nutrients and algae. Other factors like sewage and agricultural runoffs, various hazardous chemicals and natural contaminants (e.g. animal faeces) reach the natural sources of water and also pollute the ground water by seepage. Heavy metals in water are considered to be the most dangerous source of water pollution (El-Wakil et al., 2008).

Abdel-Baki et al. (2011) recorded lower levels of heavy metals in water samples collected from another freshwater body of Saudi Arabia (Wadi Haneffah, Riyadh) compared to the levels reported in our study. The evaluation of the freshwater environment in this study indicated that the water body has been contaminated with heavy metals released from domestic, industrial and other human activities.

5. Conclusion

The results of this study proved that the body composition of the same fish species may vary depending on changes in the environmental conditions (seasonal variations). Water pollution is the most important factor affecting quality of fish production in its natural habitats. The results have also indicated that the metal content in fish muscle varies depending on the area of study and the period of catching.

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