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Effect of Environmental Conditions of Abu-Zabal Lake on Some Biological, Histological and Quality Aspects of Fish

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Abstract: The purpose of this work was to investigate the effect of environmental conditions of Abu-Zabal Lake on fish caught during March, 2005 till February, 2006. The biological, histological and quality aspects were monitored. Species composition; length-weight relation; condition factor; length-scale relation and growth in length of four cichlid species were studied. Also, histopathological alterations for testis and gills of *O. niloticus* and *T. zillii* and for muscules of *T. sp* were recorded. Moreover, physico-chemical, microbial and sensory criteria were evaluated. Results showed that the concentrations of metals in water (Cu, Zn, Cd and Pb) increased during both summer and winter. The most dominant species in this region was *O. niloticus* (more than 70%) of the total catch, while the lowest was *S. galilaeus* (4.0%). The best condition factor (K) was recorded for *T. zillii* (1.94), while the lowest was registered for *S. galilaeus* (1.74). Also, *O. niloticus* has the highest growth rate, while *T. zillii* had the lowest one. *T. zillii* had the most accumulation of heavy metals in muscles and liver than *O. niloticus*. Muscles of fish caught during spring and summer seasons were more effected by heavy metals than those during autumn and winter. Although the detected concentration of heavy metals in this study below the permissible levels, however, detectable histological changes in the gills, testis and muscles were observed. On the other hand, both additives used and cooking method were more effective in reduction of metal concentrations. Cooked fish balls (kofta) were suitable for human consumption based on the results obtained.

Key words: Abu-Zabal lake · Heavy metals · Fish · Fisheries · Histological aspects · Quality criteria

INTRODUCTION

Abu-Zabal Lake consists of three man made lakes which formed by the fracture and extract rocks covers an area of 608.05×10^{3} m^2 and its water is received from the ground and seepage water. Several studies have been carried out on this lake and lights were throw on morphometry and bathymetry [1], physico-chemical characteristics [2], pathological conditions of *Tilapia zillii* [3], phytoplankton composition [4], heavy metals accumulated in different fish organs [5], microbiological status [6] and zooplankton community [7].

Water pollution with heavy metals has deleterious effect, it inhibited the growth rate of fish [8] as well as fish larvae [9], induce degenerative changes in muscles [10], affect egg and embryo viability [11] and gonads [12],and reduce the development, growth rates and fish survival, especially at the beginning of exogenous feeding [13].

The condition factor is a good indicator for environmental conditions [14].

Copper is an essential micronutrient for fish and it is widely used in aquatic life as a very effective algaecide and molluscicide [15]. Lead lowered metabolic rate and physical changes occurred in gills [16].

Fish-based products are very popular foods in many countries, as they very nutritious and healthy [17]. Meat balls are a popular Chinese-style emulsion meat products in Taiwan [18], as well as raw meat ball (Cig köfte), the traditional Turkish meal, is commonly consumed as appetizer in Turkey [19].

This work was undertaken to investigate the effect of environmental conditions on some fisheries, histological aspects and quality evaluation of fish. Also, some relevant physico-chemical characteristics of water were determined.

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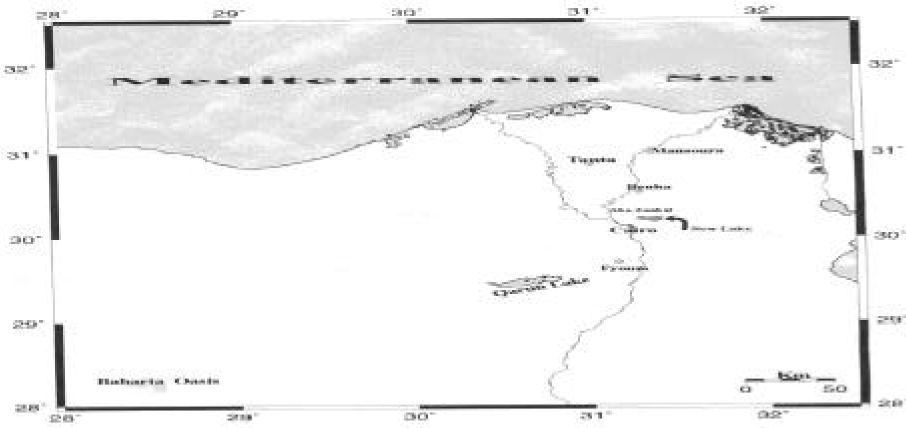


Fig. 1: Location map of the new lake (arrow) at Abu-Zabal area

MATERIALS AND METHODS

Samples of water were collected from three ponds using O_2 bottles. Gill net, trammel net and basket traps were used to collect fish samples. The most used famous mesh size in this region was 20-30 mm, local name Fiter 6–8, it means the distance between the thumb and forefinger. The opening of the net was measured by the fishermen in this region by two fingers in their hands and called "fiter".This is the expression of mesh size in this area. Fish samples were collected seasonally from the three lakes (Abu–Zabal-Fig. 1) during March 2005 till February 2006. The mean lengths (±SD) were 16.08±3.98; 12.73±1.21; 14.23±2.36 and 14.25±2.11cm and the mean weight were 86.13±77.10; 34.72±12.07; 54.74±28.03 and 45.94±16.45 g for *O. niloticus, O. aureus, T. zillii and S. galilaeus,* respectively. All fish samples were manually filleted and minced using a kitchen food processor with a pore size of 3 mm. Fish mince were divided into two batches; the first (type A) was mixed with kofta ingredients (prepared by Fine Foods Co., Egypt) and the second one (type B) was mixed with 15% pre-boiled potatoes plus kofta ingredients, 100 ml distilled water was added during mixing process and balls manually shaped. Raw balls were backed in utensils coated vegetable oil-thin layer at 180°C for 20 min. in electric oven pre-heated.

Analytical methods: Length-weight (L-W) relationship and condition factor (K) were calculated by the following equations: $W = a L^b$ which transformed to the logarithmic formula: $\log W = \log a + b \log L$, $K = 100\times W/ L^3$ where W, is the total weight in grams, L is the total length in cm and a & b are constants computed from least square method. For age determination, scale samples were detached, cleaned and then mounted dry between two glass slides for measurement with binocular microscope at magnification of 25 × using an ocular micrometer. Growth rate computation was performed [20]. Specimens of *O. niloticus and T. zillii* were collected and dissected quickly, each of gills, muscle and testis were removed fixed in Bouins solution,then after 24 hr, samples were dehydrated, embedded in wax, sectioned into 5 µm thickness sections, stained with haematoxyline, eosine and examined under light microscope [21, 22]. The Moisture, crude protein (TN× constant 6.25), total lipid and ash content were determined [23]. The pH value, total volatile bases nitrogen (TVB-N) and thiobarbituric acid reactive substances (TBARS) values were determined [24]. Trimethylamine nitrogen TMA was calorimetrically determined [23]. Microbiological analysis: A 10 g of sample were suspended in 90 ml sterile saline (0.85% NaCl). Decimal dilutions were plotted to determine total viable count that expressed as $\log_{10}$ cfu/g. Physico-chemical characteristics of water samples and heavy metals (Zn, Cu, Cd and Pb) in water and different organs of fish were analyzed [25] using Perkin Elmer A analyst 100 Atomic absorption USA photometry and results were expressed as ppm.

Statistical analysis: Mean and standard error (SE) were calculated using SPSS 10.0 for windows.

RESULTS

Effect of seasonal variability on physico-chemical properties of Abu-Zabal water are shown in Table 1. The lowest water temperature was 21°C during winter, while the highest one was 35°C during summer. The pH value was slightly acidic (6.2) during summer and it tends to slight alkalinty (8.20-8.22) during others seasons.

Table 1: Effect of seasonal variability on Physico-chemical properties of water obtained from Abu-Zabal lake (Mean±SE)

	Seasons			
Item	Spring	Summer	Autumn	Winter
Temperature (°C)	31	35	24	21
pH	6.98±0.30	7.55±0.30	8.20±0.27	8.22±0.15
D.O (ppm)	7.69±0.69	6.20±0.85	8.43±0.23	8.43±0.57
Heavy metals (ppm):				
Cu	0.013±0.001	0.041±0.024	0.003±0.002	0.003±0.002
Zn	0.124±0.009	0.075±0.020	0.049±0.008	0.064±0.029
Cd	0.055±0.003	0.088±0.005	0.028±0.003	0.031±0.003
Pb	0.041±0.011	0.015±0.023	0.029±0.027	0.017±0.006

Table 2: Equation parameters of length / weight and relative condition factors (K±SE) of different cichlid species in Abu-Zabal lakes

Species	a	b	r	K±SE
O. niloticus	0.0282	2.8592	0.9983	1.86±0.09
O. aureus	0.0444	2.6698	0.9802	1.89±0.13
T.zillii	0.0234	2.9234	0.9861	1.94±0.12
S.galilaeus	0.1319	2.2263	0.9942	1.74±0.13

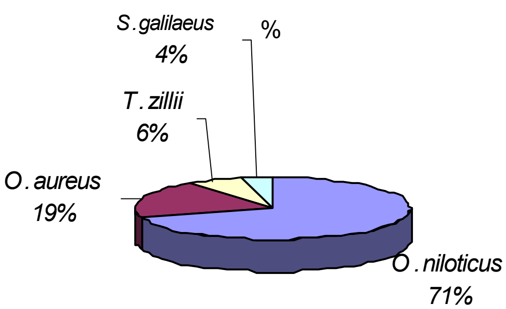


Fig. 2: Species composition of different cichlid species in Abu-Zabal lake

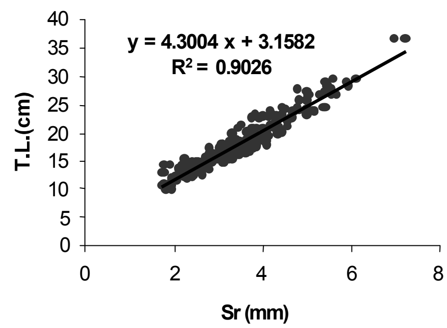


Fig. 3: L-Sr of *O. niloticus* in Abu-Zabal lake

The lowest dissolved oxygen (DO_2) (ppm) was 6.20 during summer and the maximum was 8.43 during both winter and autumn seasons. Regards heavy metals, the concentration of Cu (ppm) was 0.041 during summer and 0.003 during both autumn and winter. Zn was 0.124 during spring and 0.049 during autumn while Cd was 0.088 during summer and 0.028 during autumn. Additionally, the highest Pb (0.041) was during spring and sharply reduced during summer and autumn (Table 1).

Family cichlidae in Abu–Zabal lake were represented by four species namely; *Oreochromis niloticus, Oreochromis aureus, Tilapia zillii and Sarotheredon galilaeus*. *O. niloticus* is the most common species constituting more than 70% of the total cichlid species followed by *O. aureus*, while *S. galilaeus* was the least frequent species (3.99%) (Fig. 2).

Significant correlation (r) was observed between the length and weight of cichlid fish(Table 2).The highest value of "b" was 2.9243 for *T. zillii* followed by *O. niloticus* (2.8592), while, the least was 2.2263 for *S. galilaeus*. Concern the value of condition factor "K", the best condition was 1.94 for *T. zillii* and it coincides with the high value of "b" of *T. zillii* in the length-weight relationship. Also, the lowest "K" for *S.galilaeus* (1.74) coincides with the value of "b" based on length / weight (Table 2).

The total length-scale radius relationship of the four studied cichlid populations (Fig. 3) revealed strong linear correlations. This confirms the validity of using scales for growth assessment. The relation between length of fish and total scale radius were in the following order: L= 3.158 + 4.300 Sr, r = 0.950; L = 4.173 + 3.914 Sr, r = 0.865; L = 3.767 + 3.548 Sr, r = 0.939 and L = 1.737 + 5.208 Sr, r = 0.919 for *Oreochromis niloticus,*

Table 3: Back-calculated lengths at the end of each year of life of *O. niloticus* in Abu-Zabal lake

		Back-calculated lengths at the end of each year of life				
Age	Length at capture	L_1	L_2	L_3	L_4	L_5
I	12.74	10.43	--	--	--	--
II	16.46	10.48	14.16	--	--	--
III	19.47	10.41	14.33	16.68	--	--
IV	24.04	10.47	15.71	19.50	22.05	--
V	29.38	8.80	13.91	20.51	24.18	26.89
	Mean	10.12	14.53	18.90	23.11	26.89
	Increment	10.12	4.41	4.37	4.21	3.78
	%Increment	37.63	16.40	16.25	15.66	14.06

Table 4: Back-calculated lengths at the end of each year of life of *O. aureus* in Abu-Zable lake

		Back-calculated lengths at the end of each year of life		
Age	Length at capture	L_1	L_2	L_3
I	11.79	9.26	--	--
II	13.76	9.65	12.62	--
III	18.15	11.49	13.64	16.08
	Mean	10.13	13.13	16.08
	Increment	10.13	3.00	2.95
	% Increment	63.00	18.66	18.35

Table 5: Back-calculated lengths at the end of each year of life of *T. zillii* in Abu-Zable lake

		Back-calculated lengths at the end of each year of life			
Age	Length at capture	L_1	L_2	L_3	L_4
I	10.93	8.68	--	--	--
II	12.89	9.31	11.28	--	--
III	14.95	8.86	11.27	13.39	--
IV	18.20	9.25	11.52	13.28	15.29
	Mean	9.03	11.36	13.34	15.29
	Increment	9.03	2.33	1.98	1.96
	% Increment	59.06	15.24	13.95	12.75

Table 6: Back-calculated lengths at the end of each year of life of *S.galilaeus* in Abu-Zabal lake

		Back-calculated lengths at the end of each year of life.		
Age	Length at capture	L_1	L_2	L_3
I	11.74	9.44	--	--
II	14.91	9.92	12.51	--
III	16.90	9.98	12.20	13.96
	Mean	9.78	12.36	13.96
	Increment	9.78	2.58	1.60
	% Increment	70.06	18.48	11.46

Oreochromis aureus, Tilapia zillii and Sarotheredon galilaeus, respectively.

The recorded ages in the present study for *O. aureus* and *S.galilaeus* ranged from 1-3; 4 for *T. zillii* and 5 years for *O. niloticus*. The growth rate in length of *O. niloticus* reached from 37.63% in the 1st year of life and then gradually decreased till 14.06% in the 5th year (Table 3). The increment in length of *O. aureus* was 63.00% in the 1st year and then gradually decreased to 18.35% in the 3rd year (Table 4). It decreased in *T. zillii* from 59.06% in the 1st year to 12.75% in the 4 th year (Table 5). The increment in case of *S. galilaeus* decreased from 70.06% in the 1st year to 11.46% in the 3rd year (Table 6). Table 3-6 showed that *O. niloticus* had the highest growth rate, while *T. zillii* had the lowest one.

Seasonal variations in the concentrations of heavy metals (ppm) in liver and muscle of *T. sp.* are illustrated in Table 7. In liver, Zn ranged between

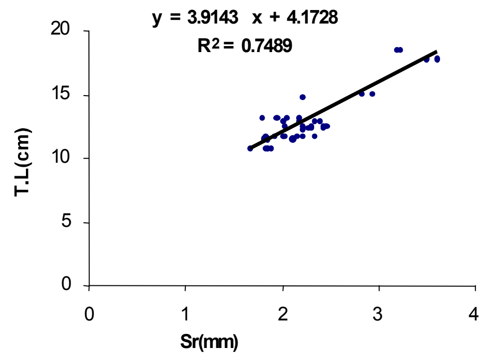


Fig. 4: L-Sr of *O. aureus* in Abu-Zabal lake

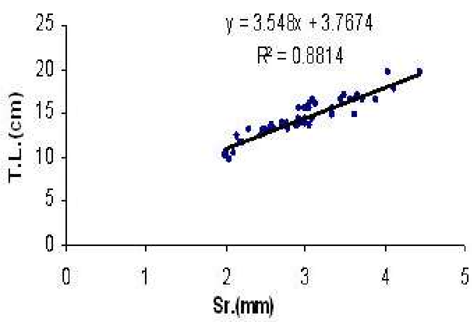


Fig. 5: L-Sr of *T. zillii* in Abu-Zabal lake

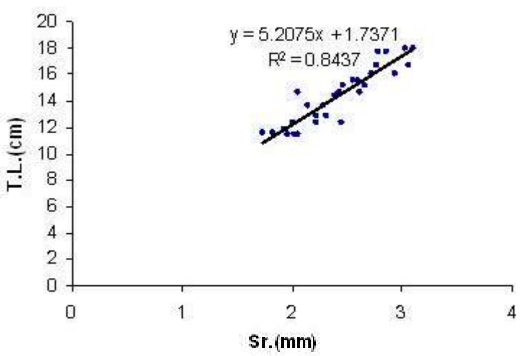


Fig. 6: L-Sr of *S. galilaeus* in Abu-Zabal lake

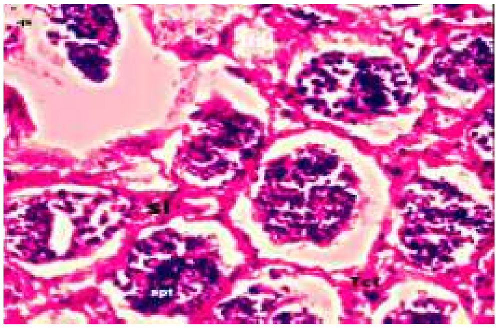
5.50-8.20 in summer and winter. Cu was 1.82-4.61 in winter and spring. Pb was 1.93-3.73, while Cd was 1.41-2.61 in summer and winter, respectively. In muscles, Zn was 2.85-4.89 in autumn and winter. Cu was 1.13-2.15 in winter and spring. Pb was 0.61-1.97 in summer and autumn. Cd was 0.41-1.96 in summer and winter, respectively.

In spring season, testis of investigated *O. niloticus* was in spawning stage, had the seminiferous lobules collapses in its size and contained only rare nests of 2 spermatocytes, spermatids and spermatozoa (Fig. 7-a). *T. zillii* was more affected by heavy metals than *O. niloticus* (Fig. 7-b). Therefore, the seminiferous lobules were radiated without any inside septa and both spermatids and sperms collected in the middle, also there was complete degeneration for some of seminifrous lobules. In summer, both *O. niloticus* and *T. zillii* had the same maturity stage (prespawning), however, necrosis at peripheral part of seminiferous lobules, edema and degeneration cells were noted in *O. niloticus* (Fig. 7-c). *T. zillii* section, Fig. (7-d) showed the faint section except spermatozoa cells, there wasn't septa between nests and degenerated occurred at outer membrane of seminifrous lobules. In autumn, at the peripheral of section no (7-e), there were necrosis and seminiferous lobules, full with different cells, especially primary and secondary spermatocytes, secondary spermatogonia and nests had scanty of spermatids and spermatozoa at spermatic duct (Fig. 7-f). Testis of *O. niloticus* in winter season represented by spent stage (Fig. 7-g), the seminiferous lobules seamed to be empty from different spermatogenesis cells. In addition, there was collapses in seminifrous lobules scanty of spermatozoa and interstitial cells attacked all nests to cause degeneration in the section.

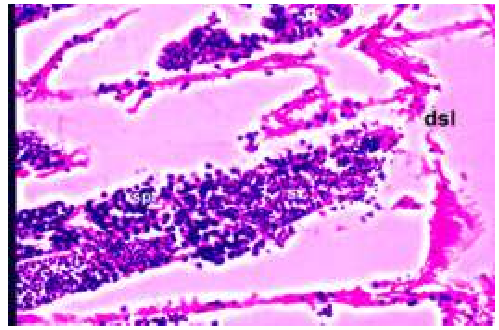
Gills of *T. zillii* showed more damages than that of *O. niloticus* in spring (Fig. 8 a&b). In summer, section

Table 7: Effect of seasonal variability on heavy metals content (ppm) in livers and muscles of fish (on wet weight basis) of Abu-Zabal lake(Mean±SE)

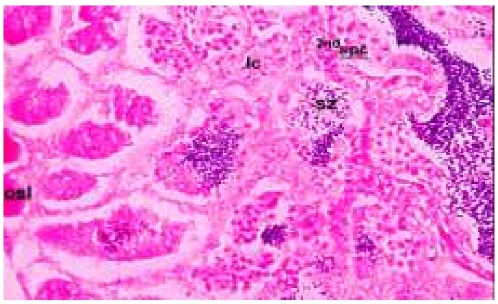
	Seasons;							
	Spring		Summer		Autumn		Winter	
Heavy metals (ppm)	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle
Cu	4.61±0.65	2.15±1.11	2.19±0.85	1.49±0.18	3.50±1.46	2.10±0.96	1.82±1.47	1.13±0.24
Zn	7.23±0.21	4.51±1.24	5.50±1.60	3.23±0.50	6.82±0.90	2.85±1.24	8.20±1.40	4.89±0.87
Cd	1.92±0.02	0.68±0.28	1.41±0.43	0.41±0.06	1.57±3.36	0.97±0.13	2.61±1.08	1.96±0.69
Pb	3.52±1.07	1.03±0.20	1.93±0.26	0.61±0.26	3.73±0.11	1.97±0.36	2.20±0.27	1.20±0.19



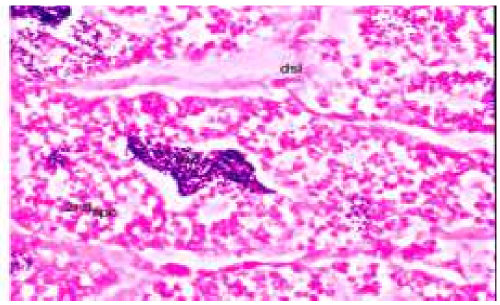
(a)-Testis of *O. niloticus* in spring. H&E (X400)



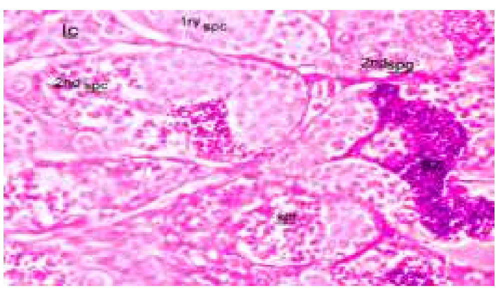
(b)-Testis of T . zillii in spring. H&E (X400)



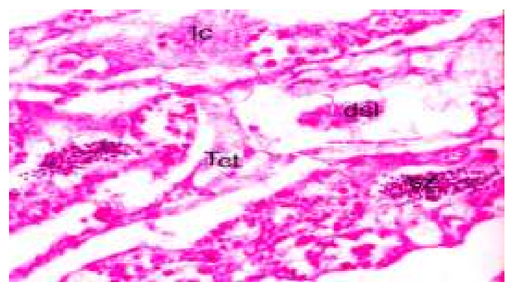
(c)-Testis of *O. niloticus* in summer. H&E (X400)



(d)-Testis of *T. zillii* in summer. H&E (X400)



(e)-Testis of *O. niloticus* in autumn. H&E (X400)

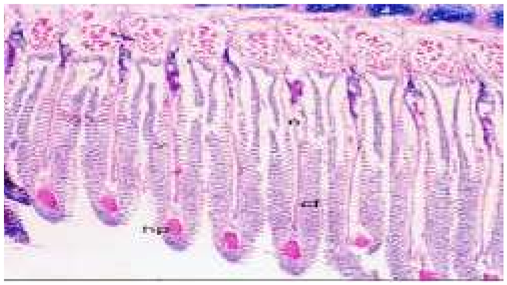


(f)-Testis of *O. niloticus* in winter. H&E (X400)

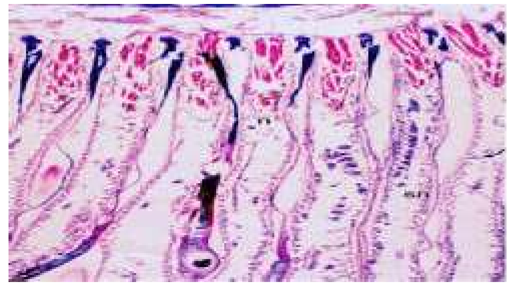
Fig. 7(a-f): Testis of *O. niloticus* and *T. zillii* in spring season (spawning stage): (a) collapse in semniferous lobules (sl)- rear of (2^{nd} sp.cyt), spermatides (spt) and spermatozoa (spz), (b) radiated (sl) without any inside septa- (spt) and (spz) collected in the middle of (dsl)- complete degenerated for some (sl). Testis of *O. niloticus* and *T. zillii* in summer season in prespawning stage showing; (c) rare of necrosis at the peripheral of (sl) and degeneration. (d) More degenerations occurred at outer membrane of (sl)- degenerated for inactive cells. Testis of *O. niloticus* only in autumn and winter seasons recovery and spent stage respectively showing; (e) full nests with different cells especially (1^{y} sp.c- 2^{nd} sp.c). Nests have rear of (spt) and spz). (f) Empty (sl) of different cells–collapse in (sl) - rear of (spz) - thick interstitial cells (ic)- degeneration (dsl)

(8-d) reflected the contamination of water with heavy metals. Edema, telangactasis and explosion of Pillary cells in secondary lamellae were noted in *T. zillii* section. In autumn, *O. niloticus* (Fig. 8-e), fusion between secondary lamellae, shortening of second epithelial were found and there were more of dark spots at the apical of these fusions. While, in winter (Fig. 8-f), edema between the secondary lamellae, infiltration of inflammatory cells and necrosis of epithelial lining was noted.

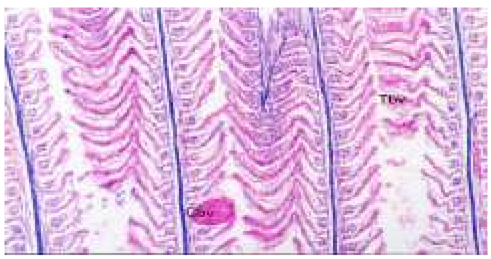
Muscles of fishes caught during spring and summer seasons were more affected by heavy metals than were those in autumn (Fig. 9-1&2) and winter (Fig. 9-3&4). It could be noted that there were no arrangement for muscle bundles, fragmented muscles fibers and there was deep myolysis which leaving remains of nuclei, while vacuoles, fibrosis, myolysis and some of eosinophilia of sarcoplasma at hypodermis were found in summer.



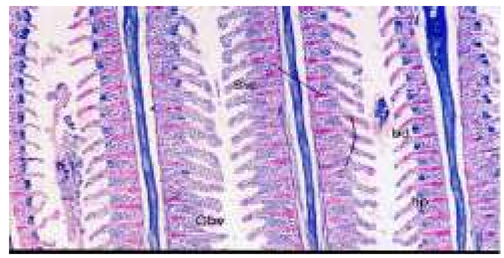
(a)- Gills of *O. niloticus* in spring. H&E (X 40)



(b)- Gills of *T. zillii* in spring. H&E (X 40)

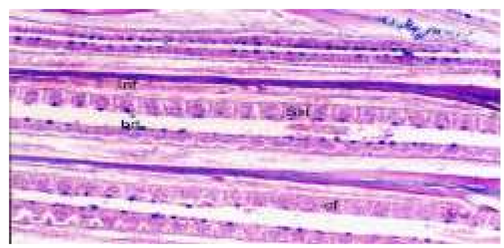


(c)-Gills of *O. niloticus* in summer. H&E (X100)

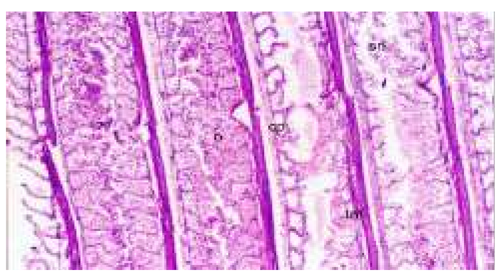


(d)- Gills of *T. zillii* in summer. H&E (X 100)

(e)-Gills of *O. niloticus* in autumn. H&E (X100)



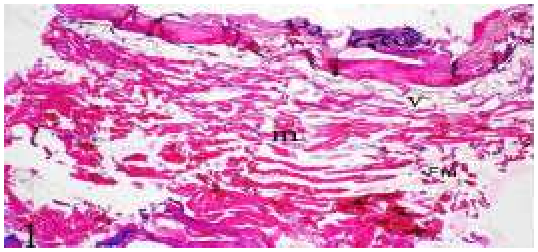
(f)-Gills of *O. niloticus* in autumn. H&E (X100)



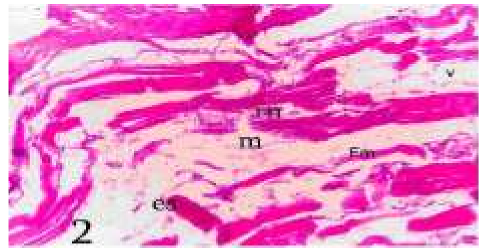
(g)-Gills of *O. niloticus* in winter. H&E (X100)

Fig. 8(a-g): Sections of gills of *O. niloticus* (s) and *T. zillii* (b) in spring, respectively showing: (a) hyperplasia (hy) and haptoral clamps (hc); (b) sever necrosis (sn). In summer: (c) congestion of blood vessels of 2nd lamellae and blue drops (bd) of heavy metals (CBV); (d) cellular proliferation (CP)-Edema (o). In autumn and winter seasons respectively for *O. niloticus* only: (e) complete fusion of epithelial (CF)-Hyperplasia (HP) and (g) Hyperplasia (HP)- necrosis (n)-Edema (o) infiltration of inflammatory cells (Inf)

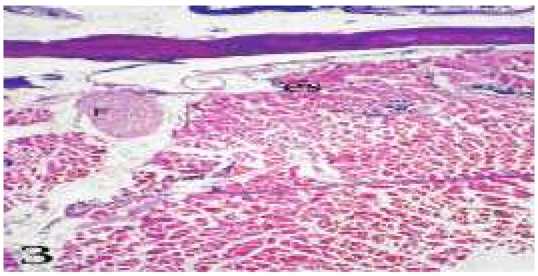
(Fg.9 a-d). There was adherance between the muscle bundles with scanty of myolysis and fragmented muscle fibers which were noted at hypodermis in autumn and winter seasons.



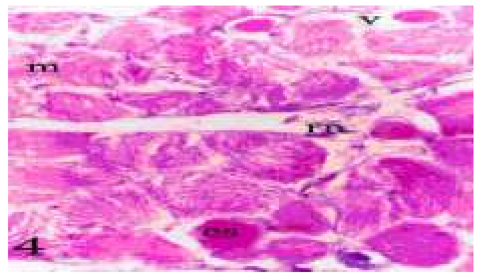
(1)-Muscles of *O. aureus* in spring. H&E (X 40)



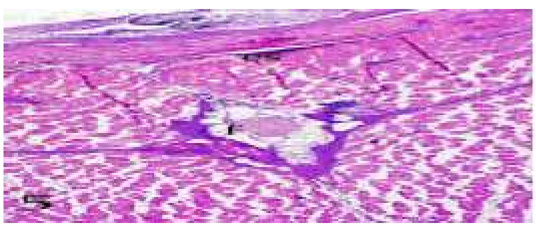
(2)-Muscles of *O. aureus* in spring. H&E (X400)



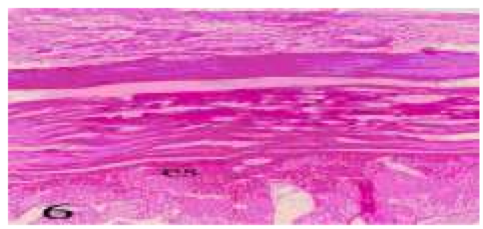
(3)-Muscles of *O. niloticus* in summer. H&E (X 40)



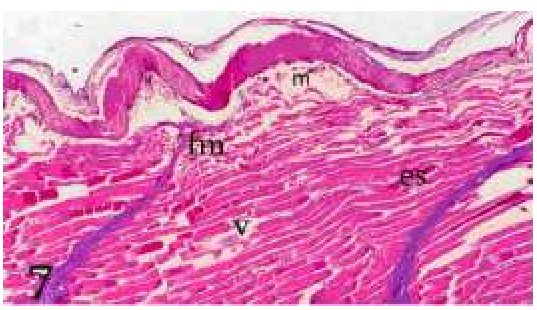
(4)-Muscles of *O. niloticus* in summer. H&E (X400)



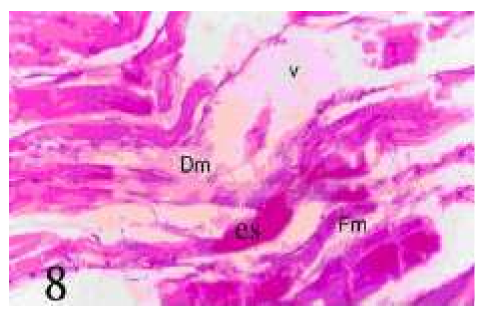
(5)-Muscles of *T. zillii* in autumn. H&E (X 40)



(6)-Muscles of *T. zillii* in autumn. H&E (X400)



(7)-Muscles of *O. niloticus* in winter. H&E (X 40)



(8)-Muscles of *O. niloticus* in winter. H&E (X400)

Fig. 9(1-8): Sections of muscles in T. species: muscles of *O. aureus* in spring season: (1&2) fragmented muscle fibers (Fm) and myolysis (m), vacuoles (v), leaving remains of nuclei (rn) and eosinophilia of sarcoplasm (es). Muscles of *O. niloticus* in summer season: (3&4) vacuoles (v), fibrosis (f)-myolysis (m) and some of eosinophilia of sarcoplasm (es) at hypodermis. Muscles of *T. zillii* in autumn season: (5&6) adhearing some bundles of muscles at hypodermis. Muscles of *O. niloticus* in winter season: (7&8) myolysis (m) - fragmented of muscles fibers (fm).

The proximal analysis of *Tilapia* flesh caught during different seasons is shown in Table 8. It was ranged between 79.52-80.23% moisture, 16.71-17.56% protein, 1.18-1.83% lipid and 0.94-1.55% ash content (on wet wt. basis).

In addition, the quality criteria of *Tilapia sp*. flesh during different seasons was recorded in Table 9. The results showed that pH ranged between 6.70-7.21, TVB-N/100 g was 16.00-17.50 mg, TMA/100 g was 0.57-1.27 mg and MA/kg was

Table 8: The proximal analysis of *Tilapia* flesh during different seasons (Mean±SE)

	Seasons			
Constituent (%)	Spring	Summer	Autumn	Winter
Moisture	79.87±0.2	79.52±0.40	80.23±0.23	80.16±0.30
Protein	16.71±0.28	17.56±0.33	17.01±0.16	17.26±0.27
Lipid	1.83±0.13	1.76±0.11	1.34±0.25	1.18±0.05
Ash	1.55±0.06	0.94±0.11	1.34±0.08	1.20±0.06

Table 9: The quality criteria (Mean±SE) of *Tilapia* flesh during different seasons

	Seasons			
Criterion	Spring	Summer	Autumn	Winter
pH	6.70±0.06	6.89±0.10	7.21±0.01	7.06±0.20
TVB(mg/100g flesh)	17.50±1.97	19.50±1.84	17.60±0.85	16.00±0.28
TMA(mg/100 g flesh)	0.78±0.50	1.27±0.62	0.67±0.22	0.57±0.13
TBA (mg MA/kg flesh)	1.73±0.19	0.50±0.50	0.89±0.42	0.85±0.07
TVC (Log_{10} CFU/g)	3.55±0.12	4.29±0.13	3.59±0.06	2.08±0.67

TVB-N: total volatile basic nitrogen, TMA-N: trimethylamine nitrogen, TBA: thiobarbituric acid, TVC: total viable count.

Table 10: The proximal analysis of baked *Tilapia* balls (kofta) during different seasons. Mean±SE)

	Seasons							
	Spring		Summer		Autumn		Winter	
Constituent (%)	Product (A)	Product (B)	Product (A)	Product (B)	Product (A)	Product (B)	Product (A)	Product (B)
Moisture	65.10±1.06	56.90±0.75	63.41±0.02	56.75±0.42	66.80±0.07	58.48±1.48	65.21±0.98	57.33±0.95
Protein	68.77±1.29	62.11±0.52	66.74±0.52	63.05±0.08	66.82±0.48	62.71±0.67	66.73±0.84	63.17±0.98
Lipid	7.57±0.20	6.36±0.46	7.49±0.38	6.39±0.14	6.11±0.0.26	5.17±0.29	6.04±0.01	5.23±0.16
Ash	7.74±0.08	8.25±0.23	7.44±0.15	7.61±0.25	8.62±0.42	9.34±1.61	8.09±0.53	8.18±0.04

0.50-1.73 mg sample. In addition, TVC was 2.08-4.29 log_{10} cfu/g samples.

The proximate analysis of *Tilapia* balls made from tilapia flesh during different seasons is shown in Table 10. The chemical composition of backed fish balls–type A (on wet wt. basis) was 63.41- 66.80% moisture, 66.73-68.77% protein, 6.04-7.57% lipid and 7.44-8.09% ash content. The corresponding values in type B were 56.75-58.48, 62.11-63.17, 5.23-6.39 and 7.61-9.34%, respectively. The remaining part is expressed as carbohydrate content.

Concern biochemical criteria, Fig (10-A) shows pH values of two types of fish balls. The value of pH in backed fish balls type A was slight higher (6.71) than that B (6.66) throughout different seasons, especially in winter. The same trends were found in cases of TVB (Fig. 10-B), TMA (Fig. 10-C), TBARS (Fig. 10-D) content and TVC (Fig. 10-E) of cooked fish balls. Beside, the mean scores of overall acceptability of baked fish balls were higher in case of fish balls with potatoes paste than fish balls during different seasons (Fig. 10-F).

The effect of additives and baking method on the metals content in fish balls during seasonal variation are shown in Table 11. The ranges of Cu, Zn, Cd and Pb in cooked fish balls type A were 0.85-1.74, 2.20-4.04, 0.11-0.37 and 0.20-0.30 ppm (on wet weight basis), respectively. The corresponding ranges in type B were 0.52-1.45, 0.97-2.90, 0.07-0.21 and 0.12-0.24 ppm, respectively.

On the other hand, the chemical composition of tilapia by-products was ranged between 70.19-73.72% moisture, 41.87-43.44% protein, 15.18-22.76% lipid and 28.51-33.72% ash content (Table 12). These values were changed after boiling process.

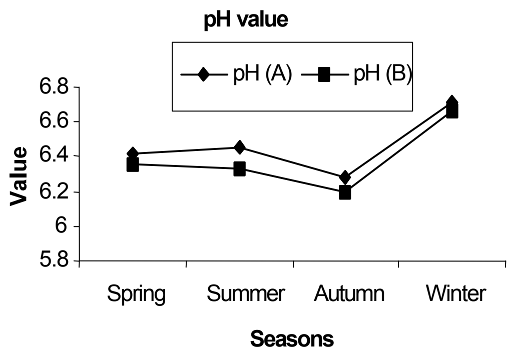


Fig. (A): pH value of Tilapia balls

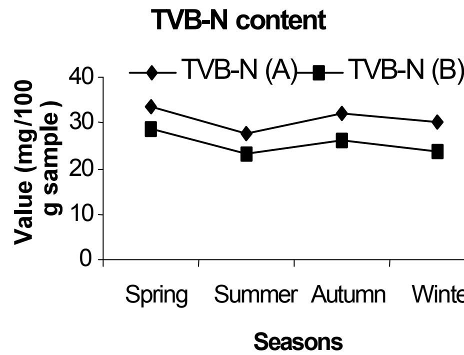


Fig. B: TVB-N content of Tilapia balls

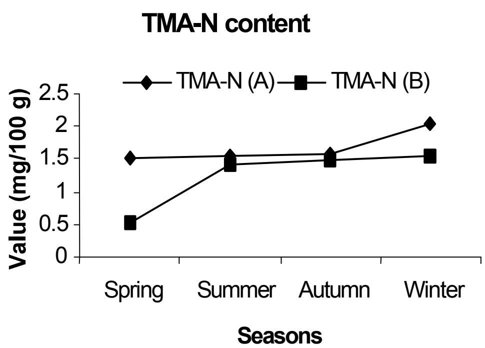


Fig. (C): TMA-N content of Tilapia balls

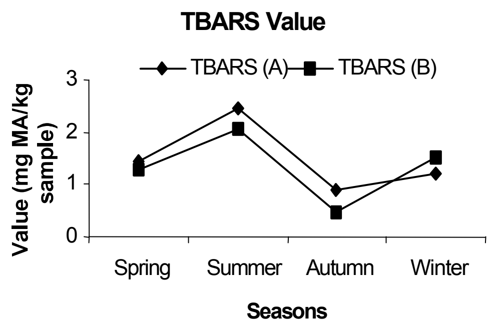


Fig. (D): TBARS value of Tilapia balls

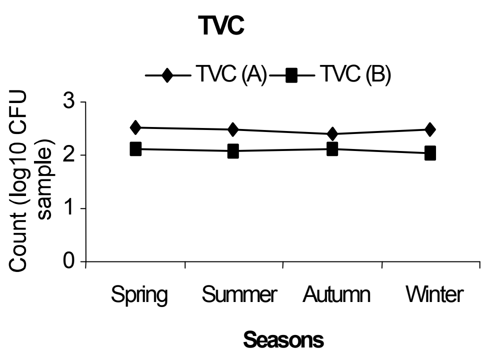


Fig. (E): TVC of Tilapia balls

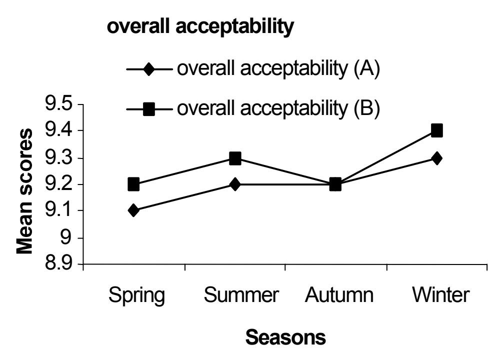


Fig. (F): Overall acceptability of Tilapia balls

Fig. 10(A-F): Show the quality criteria of baked fish balls made from Abu-Zabal fish

Table 11: Effect of seasonal variability on metals content in *Tilapia* balls (Kofta) products (on wet weight basis) of Abu-Zabal lake. (Mean±SE)

	Seasons							
	Spring		Summer		Autumn		Winter	
Heavy metals (ppm)	Product (A)	Product (B)	Product (A)	Product (B)	Product (A)	Product (B)	Product (A)	Product (B)
Cu	1.74±0.60	1.45±0.45	0.85±0.39	0.68±0.22	1.39±0.64	1.13±0.47	1.04±0.58	0.89±0.29
Zn	4.04±1.65	2.90±0.81	2.71±0.77	2.16±0.96	2.25±1.21	1.78±0.48	2.20±0.88	1.67±0.32
Cd	0.11±0.09	0.07±0.02	0.30±0.11	0.15±0.08	0.35±0.14	0.20±0.07	0.37±0.22	0.25±0.10
Pb	0.20±0.14	0.14±0.09	0.30±0.17	0.23±0.11	0.29±0.16	0.22±0.14	0.23±0.10	0.17±0.07

Table 12: The proximal analysis of raw and boiled *Tilapia* by-products during different seasons (Mean±SE)

	Seasons							
	Spring		Summer		Autumn		Winter	
Constituent (%)	Raw	Boiled	Raw	Boiled	Raw	Boiled	Raw	Boiled
Moisture	73.72±0.33	65.51±0.28	71.41±0.61	63.64±0.10	72.08±0.35	64.52±0.10	70.19±0.56	66.16±0.21
Protein	41.87±0.88	43.97±0.35	43.59±0.61	46.07±1.07	43.44±0.47	46.56±0.51	41.9±0.50	43.88±1.77
Lipid	15.18±0.23	10.33±0.32	16.51±0.09	11.20±0.02	18.61±0.85	14.05±0.41	22.76±0.60	16.84±1.62
Ash	31.43±0.21	33.72±0.06	32.59±0.11	33.21±0.07	28.51±0.25	30.13±0.76	29.70±1.58	30.14±1.31

Table 13: Effect of seasonal variability on metals content in *Tilapia* by-products (on wet weight basis) of Abu-Zabal lake (Mean±SE)

	Seasons							
	Spring		Summer		Autumn		Winter	
Heavy metals (ppm)	Raw	Boiled	Raw	Boiled	Raw	Boiled	Raw	Boiled
Cu	16.86±7.21	14.50±4.69	16.31±2.64	14.77±3.11	7.77±2.55	6.16±2.29	9.93±3.40	7.33±3.26
Zn	10.35±1.25	7.80±2.16	8.82±2.85	6.78±3.54	7.89±3.21	6.45±1.48	12.42±5.16	9.46±6.08
Cd	0.16±0.11	0.13±0.06	0.65±0.22	0.58±0.24	1.02±0.41	0.88±0.38	0.79±0.43	0.70±0.51
Pb	1.30±0.78	1.01±0.04	1.37±0.63	0.98±0.37	0.65±0.17	0.45±0.19	0.30±0.14	0.22±0.06

In addition, Table 13 represents metals content in raw and boiled tilapia by-products. The ranges of Cu, Zn, Cd and Pb in raw by-products were 7.77-16.86, 7.89-12.42, 0.16-1.02 and 0.30-1.37 ppm, respectively and then decreased after boiling process.

DISCUSSION

The highest value of DO in the present study was found in winter and autumn seasons(8.22 ppm for both), this could be mainly attributed to the prevailing wind action that permits increased the solubility of atmospheric oxygen gas, adding to decreased temperature in winter [26]. Oxygen solubility in water has an inverse relationship with water temperature (Table 1). This is in agreement with [27]. Furthermore, the high concentrations of heavy metals were found in summer and spring and dropped in autumn and winter, this means that a relation between temperature and concentrations of heavy metals was exist [28]. The increase in toxicity may result from the excessive production of bioactivated free radicals that are more toxic than the parent compound [29]. Concern length-weight relationship, the highest value of "b" and the best condition were 2.9243 and 1.94 for *T. zillii*. This may be due to the feeding behavior of *T. zillii* (voracious species) and the state of gonads may be playing an important role in the highest condition of this species. Adding to the ability of *T. zillii* to environmental conditions varied [30]. On the other hand, *S. galilaeus* had the lowest condition "K" and the value of "b". This may be attributed to the sensitivity of *S. galilaeus* to the alternations in various environmental conditions. Although *O. niloticus* was the dominant species, "K" was lowest than *T. zillii* and *O. aureus*. This may be attributed to the abnormality feature (lesions) especially deformation which observed several time along this investigation and also was recorded by [3]. The previous phenomenon may be explained as follows, increasing in the number of *O. niloticus* caused crowding in the space which led to competition for feeding and breathing leading to making additional stress due to deficiency in the available oxygen. This may be the reason of decreasing condition factor of *O. niloticus* in the present study. The variations observed in the growth of length for studied fish means that, *O. niloticus* had the highest growth rate, while *T. zillii* has the lowest one and may be referred to the effect of heavy metals which led to deformation in fish spawning and decrease in producing of egg numbers. Similar findings were observed by [11]. The present study proved that the lowest growth in length of this species than *O. niloticus*. Similar findings were recorded by [31]. This may be due to species difference in physiological and biological activities; and the herbivorous habit of *T. zillii* may be a factor incriminated in raising its sensitivity to copper due to swallowing of all macroscopically food particles of plant origin that containing higher $CuSO_4$ levels [33]. The highest concentration of Zn in relation to the other heavy metals might be due to the pollution from broken stones. The low concentration of Cd in *Tilapia* might be due to its low tendency to bioaccumulation or good ability to it's excreting from the body [34]. The order of metals distribution in both liver and muscles were Zn, Cu, Pb, Cd. These findings are similar to [35]. Moreover, muscles of fish had under permissible levels as set by [36] and Western Australian Food and Drink Regulations; Zn 40 mg/kg,Cu 20 mg/kg, Pb and Cd 2.0 mg/g.

Regards histopathological examination for muscles, muscles had a little changes, some of degeneration (myolysis) and unarrangment of muscle bundles were found at hypodermis. On the other hand, the gills showed degeneration, necrosis, edema which attributed to increase in the diffusion distance from surrounding water to capillaries and simultaneously increase the amount of tissue in the secondary lamellae. These results were confirmed by [37-39]. Testicular histopathology showed that there was degenerated and collapse occurred to seminifrous lobules and their nests of cells especially during spring and winter. These findings are in accordance with [40].

The variation in chemical composition of *Tilapia* species as affected by seasonal variation is confirmed by [41] and results are in agreement with reported by [42-44]. Regards quality criteria of *Tilapia* flesh, data in Table 9 showed that TVB content was under the permissible limit of acceptability for raw fish (30 mg TVBN/100g flesh) as set by Egyptian Standard Specifications [45]. Chemical composition of cooked fish balls (Table 10) are similar to the findings of [46- 47]. Moreover, variation in different products in the chemical, bacteriological and sensory changes is depending on the type of product and processing [41]. The values of TVB, TMA, TBA and pH increased in backed fish product are in agreement with those found by [47-48] who attributed the increase in the TBARS value to the high temperature that promoted lipid oxidation. On the other hand, bacterial load in the present study didn't exceed the acceptable limit (10^6cfu/g) as reported by [45] and it was lower count compared with reported by [49]. Although fish balls are a delicious product but potatoes added improved the sensory quality and decreased metals content of cooked balls type B compared with type A (Table 11). Furthermore, the chemical composition of fish-by products in our study (Table 12) is similar with findings by [50]. Boiling for fish-by products caused reduction in heavy metals concentrations in fish meal produced as shown in Table 13.

In conclusion, this study proved that Abu-Zabal lake fishes are safe because heavy metals (Zn, Cu, Pb and Cd) concentration levels are comparable to international limits.

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