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Research Article

Influence of Modern Cooking Techniques on Heavy Metals Concentrations of Some Freshwater Fish Fillets

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Abstract: The study examined the influence of two modern cooking techniques (microwave and halogen cooking) on the heavy metals concentrations (Al, As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sb, Se, Sn, V and Zn) of five freshwater fish fillets (*Oreochromis niloticus*, *Oreochromis aureus*, *Sarotherodon galilaeus*, *Bagrus bajad* and *Mugil cephalus*) using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The obtained results were statistically compared with those of raw fish fillets. The concentrations of almost tested heavy metals were significantly decreased ($p<0.05$) after microwave and halogen cooking. The reductions in the heavy metals concentrations in halogen cooker were much greater than on microwave. The Sb concentrations were not detected (<0.001) in all fish fillets samples. The Cd, Co, Cu, Ni and Se concentrations of microwave and halogen cooked fish fillets of Bayad catfish and mullet were significantly increased ($p<0.05$) than control but not exceed the permissible limits.

Keywords: Fish fillets, halogen, heavy metals, ICP-OES, microwave

INTRODUCTION

Fish is an important part of a healthy diet (Adams and Standridge, 2006; Mozaffarian and Rimm, 2006). It is an important source of a number of nutrients, particularly protein, retinol, vitamin D, vitamin E, iodine, selenium and the essential long-chain Polyunsaturated Fatty Acids (PUFA), i.e., Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) (Welch *et al*., 2002). It is recommended that fish and seafood products take a prominent position in the human diet due to their beneficial effect on chronic degenerative diseases. The consumption of fish may protect against cancers (Caygill *et al*., 1996; Fernandez *et al*., 1999) and cardiovascular diseases (Nestel, 2000). Therefore, health authorities and the food industry have a joint interest in increasing the consumption of fish (Bùrresen, 2008).

Many elements, which are present in seafood (Oehlenschläger, 1997) are essential for human life at low concentration (Fraustro *et al*., 1993), however, they can be toxic at high concentrations. Other elements like mercury, cadmium and lead show no known essential function in life and are toxic even at low concentration when ingested over a long period, therefore many consumers regard any presence of these elements in fish as a hazard to health (Bremner, 2002).

The heavy metals concentrations of fish fillets can be affected by processing or cooking methods and therefore, it is important to determine the concentrations of heavy metals in raw and cooked fish fillets and it is possible to reduce the heavy metal concentration in fish fillets by choosing a suitable method of cooking (Atta *et al*., 1997; Ersoy *et al*., 2006; Diaconescu *et al*., 2013). Novel processing technologies are increasingly attracting the attention of food processors once they can provide food products with improved quality and a reduced environmental footprint, while reducing processing costs and improving the added-value of the products (Pereira and Vicente, 2010). The use of microwave oven for cooking has increased greatly during the past few decades (García-Arias *et al*., 2003). Halogen heating provides near infrared radiation and has a wavelength range of 1-5 µm. Halogen is used in baking, roasting and frying as well as drying. It has also been used for thawing and pasteurization of packaging materials. The main advantages of using halogen near infrared heating are high and effective heat transfer, reduction of baking time, no heating of air in the oven, quick regulation and control and compact and flexible ovens (Ohlsson and Bengtsson, 2002). In industrial food processing, infrared heating is used for baking (roasting), drying, thawing, frying and surface pasteurization (Sakai and Hanzawa, 1994; Ranjan *et al*., 2002).

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There are many studies on heavy metals concentrations in freshwater and marine fish, but few studies on the effect of cooking methods on heavy metals concentrations in fish fillets, so the aim of this study is to examined the effects of two modern cooking techniques (microwave and halogen cooking) on heavy metals concentrations (Al, As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sb, Se, Sn, V and Zn) of five freshwater fish species fillets: Nile Tilapia, Blue, Mango Tilapia, Bayad Catfish and mullet using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES).

MATERIALS AND METHODS

Fish samples preparation and cooking: Fresh fish samples were collected from El-Bahr El-Pharaony drain, El-Menoufia Governorate, Egypt during winter 2013. Fifty fresh fish samples (10 fish were taken randomly from each fish species) were as follows: Nile Tilapia (*Oreochromis niloticus*), mean length and weight were 18.45 cm and 105 g; Blue Tilapia (*Oreochromis aureus*), mean length and weight were 13.50 cm and 85.60 g; Mango Tilapia (*Sarotherodon galilaeus*), mean length and weight were 11.10 cm and 68.90 g; Bayad Catfish (*Bagrus bajad*), mean length and weight were 25.53 cm and 137.20 g and mullet (*Mugil cephalus*), mean length and weight were 25.75 cm and 87.50 g. Fish samples transported alive to Fish Processing and Technology Laboratory, National Institute of Oceanography and Fisheries (NIOF), El-Kanater El-Khairia City, El-Qaluobia Governorate, Egypt and then they were re-washed thoroughly with potable water then beheaded, gutted and again washed to get their fillets. The obtained fish fillets were washed with tap water to remove any traces of blood and viscera. After that, fish fillets were immersed in 10% sodium chloride solution for 10 min, then washed with tap water and treated with spices and finally fillets were battered using edible batter which was prepared according to Abdou *et al*. (2012) by mixing 94% wheat flour, 2% egg yolk, 2% skimmed milk, 1.8% salt and 0.2% cumin with water by 1:3 (w: w) and this ingredients were homogenized for 2 min. After the batter coating, it was covered with bread crumbs. After that, every fish species fillets were divided into three batches, the first batch was control (without coating and without cooking process), the second batch was cooked by microwave oven (Samsung, model at 980 watt) for 5 min each side of fish fillets samples. The third batch was cooked using Halogen oven (Lentel, model KYR-912A, 1300C watt) heated at 180°C for 5 min of each side of fish fillets samples. All cooked fish fillets samples were allowed to cool at ambient temperature and packaged in polyethylene bags and stored until analysis.

Heavy metals analysis: Fish fillets were prepared for heavy metals analysis according to the method described by Meche *et al*. (2010) as follows: fish fillets were dried in an oven at 105°C overnight. The samples were removed from the oven, allowed to cool and ground in a clean mortar and pestle. Approximately 0.5 g of each sample was placed in a teflon microwave digestion bomb with 10 mL of concentrated HNO_3. The samples were allowed to ramp to 180°C for 5 min, digest at 180°C for 9.5 min and cool down for 5 min in microwave digestion system (model Milestone, MLS-1200 mega, Germany). The samples were then transferred to clean volumetric flasks and diluted with H_2O to 10 mL. The samples were stored at 5°C until ready for analysis of metals. The samples were compared to a multi-element standard curve to determine the ppm of each analyte in the digested solution. The samples were analyzed three independent times on Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) Model Perkin Elmer Optima 3000. The wavelengths used for the detection and measurement were as follows: Al 396.153; As 193.696; Ba 455.403; Cd 214.440; Co 228.616; Cr 267.716; Cu 324.752; Fe 259.993; Mn 257.610; Ni 231.604; Pb 220.353; Sb 217.582; Se 203.985; Sn 189.927; V 310.230 and Zn 213.857 nm. Heavy metals concentrations were calculated in ppm dry weight.

Statistical analysis: Each reported result was the average value of the three analyses. The results were offered as means±SEM. The statistical differences of mean metal levels among fish species and cooking techniques were analyzed using multiple comparison tests (IBM SPSS statistics version 20). One-way ANOVA was utilized to compare the data by species and cooking techniques. Results were considered significant at $p<0.05$.

RESULTS

Heavy metals concentrations of raw, microwave and halogen cooked fish fillets are given in Table 1. The predominant heavy metals in investigated fish samples were Fe, Zn, Al, Mn and Pb which were higher concentrations than other tested heavy metals. On the other hand, Sb was not detectable (below the detection limits with ICP-OES <0.001) in both raw and cooked fish fillets. Concentrations of heavy metals in different fish species showed great variation capabilities for accumulating heavy metals. The highest concentrations of Al, As, Cd, Co, Fe, Pb, Se and Sn were found in the raw fillets of *B. bajad* which recorded 6.35, 0.48, 0.32, 0.19, 13.68, 1.75, 0.98 and 0.09 ppm dry weight, respectively. Raw fillets of *M. cephalus* showed highest concentrations of Cr, Cu and Mn and they were recorded 0.30, 0.58 and 1.98 ppm dry weight, respectively. Raw fillets of *O. niloticus* showed highest concentrations of Ni and V and they were recorded 1.99 and 0.85 ppm dry weight, respectively. Highest concentration of Zn 13.59 ppm dry weight was recorded in *O. aureus*, also *S. galilaeus* showed highest concentrations of Ba 0.44 ppm dry weight.

Table 1: Heavy metals concentrations (ppm) of raw, microwave and halogen cooked fish fillets samples

Heavy metals	Cooking methods	Freshwater fish species				
		O. niloticus	*O. aureus*	*S. galilaeus*	*B. bajad*	*M. cephalus*
Al	C	2.62±1.14^{a}	4.35±1.23^{b}	5.37±1.69^{bc}	6.35±1.12^{c}	4.91±0.85^{b}
	M	1.68±0.76^{b}	2.63±1.15^{c}	0.72±0.16^{a}	1.29±0.90^{ab}	0.55±0.35^{a}
	H	0.70±0.15^{b}	0.52±0.02^{a}	0.54±0.11^{a}	1.11±0.65^{c}	0.50±0.38^{a}
As	C	0.34±0.67^{b}	0.24±0.12^{a}	0.38±0.10^{b}	0.48±0.02^{b}	0.21±0.01^{a}
	M	0.25±0.07^{a}	0.20±0.01^{a}	0.34±0.02^{b}	0.45±0.02^{c}	0.18±0.06^{a}
	H	0.13±0.05^{a}	0.11±0.06^{a}	0.21±0.04^{b}	0.25±0.03^{b}	0.10±0.03^{a}
Ba	C	0.13±0.14^{a}	0.14±0.01^{a}	0.44±0.13^{c}	0.22±0.01^{b}	0.22±0.10^{b}
	M	0.10±0.01^{a}	0.12±0.05^{a}	0.23±0.01^{b}	0.20±0.02^{b}	0.24±0.01^{c}
	H	0.08±0.03^{a}	0.08±0.01^{a}	0.28±0.01^{c}	0.22±0.02^{b}	0.20±0.02^{b}
Cd	C	0.23±0.30^{b}	0.26±0.04^{b}	0.11±0.01^{a}	0.32±0.16^{c}	0.27±0.06^{b}
	M	0.19±0.02^{bc}	0.15±0.03^{b}	0.08±0.03^{a}	0.15±0.01^{b}	0.30±0.08^{c}
	H	0.11±0.08^{b}	0.12±0.02^{b}	0.05±0.01^{a}	0.28±0.04^{c}	0.20±0.07^{bc}
Co	C	0.08±0.06^{a}	0.05±0.01^{a}	0.04±0.01^{a}	0.19±0.01^{b}	0.03±0.01^{a}
	M	0.07±0.01^{a}	0.04±0.01^{a}	0.03±0.01^{a}	0.15±0.08^{b}	0.05±0.02^{a}
	H	0.06±0.01^{a}	0.02±0.01^{a}	0.02±0.01^{a}	0.15±0.07^{b}	0.02±0.01^{a}
Cr	C	0.05±0.02^{a}	0.12±0.25^{b}	0.18±0.55^{b}	0.19±0.17^{b}	0.30±0.14^{c}
	M	0.04±0.01^{a}	0.11±0.03^{b}	0.11±0.02^{b}	0.36±0.08^{c}	0.14±0.01^{bc}
	H	0.03±0.01^{a}	0.04±0.01^{a}	0.10±0.03^{b}	0.32±0.04^{c}	0.25±0.05^{bc}
Cu	C	0.19±0.10^{a}	0.25±0.32^{b}	0.40±0.20^{bc}	0.40±0.13^{bc}	0.58±0.07^{c}
	M	0.15±0.04^{a}	0.19±0.07^{a}	0.38±0.03^{a}	2.23±1.20^{c}	1.97±0.45^{b}
	H	0.12±0.07^{a}	0.17±0.03^{a}	0.35±0.02^{b}	2.58±1.07^{c}	0.21±0.01^{a}
Fe	C	11.49±2.25^{a}	12.17±1.99^{b}	12.33±1.89^{b}	13.68±1.01^{c}	12.18±1.10^{b}
	M	2.33±1.01^{b}	5.23±1.11^{c}	1.75±0.05^{a}	2.00±0.80^{b}	1.27±0.90^{a}
	H	1.81±0.81^{a}	2.04±1.03^{b}	1.35±0.04^{a}	2.64±0.86^{b}	1.36±0.80^{a}
Mn	C	1.04±0.08^{a}	1.36±0.70^{a}	1.18±0.07^{a}	1.82±0.40^{a}	1.98±0.15^{a}
	M	0.50±0.11^{bc}	0.17±0.02^{a}	1.06±0.03^{c}	0.13±0.02^{a}	0.21±0.01^{b}
	H	0.44±0.06^{bc}	0.12±0.01^{a}	0.86±0.02^{c}	0.13±0.01^{a}	0.05±0.03^{a}
Ni	C	1.99±0.45^{c}	1.12±0.10^{bc}	1.02±0.09^{b}	0.28±0.19^{a}	0.22±0.44^{a}
	M	1.79±0.09^{b}	0.91±0.04^{a}	0.89±0.05^{a}	2.23±0.46^{c}	2.48±1.05^{c}
	H	1.11±0.08^{b}	0.75±0.02^{a}	0.42±0.02^{a}	2.37±1.23^{c}	1.17±1.00^{b}
Pb	C	1.29±0.19^{a}	1.45±0.11^{a}	1.35±0.08^{a}	1.75±0.65^{a}	1.68±0.49^{a}
	M	0.51±0.01^{b}	0.89±0.07^{c}	0.44±0.02^{b}	0.54±0.09^{b}	0.10±0.03^{a}
	H	0.45±0.03^{c}	0.34±0.04^{b}	0.11±0.01^{a}	0.35±0.07^{b}	0.47±0.02^{c}
Sb	C	<0.001	<0.001	<0.001	<0.001	<0.001
	M	<0.001	<0.001	<0.001	<0.001	<0.001
	H	<0.001	<0.001	<0.001	<0.001	<0.001
Se	C	0.78±0.14^{bc}	0.55±0.40^{ab}	0.67±0.06^{b}	0.98±0.78^{c}	0.45±1.15^{a}
	M	0.70±0.03^{bc}	0.48±0.01^{a}	0.60±0.04^{b}	1.05±0.70^{c}	0.58±0.05^{b}
	H	0.45±0.09^{b}	0.38±0.03^{a}	0.47±0.03^{b}	0.74±0.04^{c}	0.40±0.09^{b}
Sn	C	0.06±0.01^{a}	0.07±0.12^{a}	0.08±0.01^{a}	0.09±0.58^{a}	0.05±0.18^{a}
	M	0.04±0.02^{a}	0.06±0.01^{a}	0.07±0.02^{a}	0.10±0.07^{b}	0.04±0.01^{a}
	H	0.03±0.01^{a}	0.04±0.01^{a}	0.04±0.04^{a}	0.11±0.05^{b}	0.01±0.01^{a}
V	C	0.85±0.95^{c}	0.43±0.89^{b}	0.56±0.01^{bc}	0.47±0.11^{b}	0.22±0.23^{a}
	M	0.81±0.02^{c}	0.35±0.02^{ab}	0.44±0.03^{b}	0.40±0.08^{b}	0.20±0.01^{a}
	H	0.46±0.01^{c}	0.25±0.03^{b}	0.35±0.04^{bc}	0.25±0.09^{b}	0.17±0.02^{a}
Zn	C	9.00±1.39^{b}	13.59±0.03^{c}	11.16±1.48^{bc}	10.99±3.15^{b}	8.18±0.16^{a}
	M	2.40±0.09^{c}	1.66±0.04^{a}	2.21±1.53^{b}	1.65±0.01^{a}	1.55±0.03^{a}
	H	1.62±0.06^{a}	1.46±0.07^{a}	1.51±1.03^{a}	1.39±0.08^{a}	1.46±0.04^{a}

C: Control (raw) fish fillets; M: Microwave cooked fish fillets; H: Halogen cooked fish fillets; Each value is an average of three representative samples with its standard error; The value with a different letter in the same raw is different (p<0.05)

Higher value of Al concentrations (6.35 ppm dry weight) was recorded in raw fish fillets of *B. bajad*, while lower value (2.62 ppm dry weight) was recorded in raw fish fillets of *O. niloticus*. There were significant differences (p<0.05) in Al concentrations between raw, microwave and halogen cooked fish fillets samples. However, the reduction in Al concentrations were significant (p<0.05) in all fish species and the higher value of Al (2.63 ppm dry weight) was recorded in microwave cooked fillets of *O. aureus*, while lower value (0.50 ppm dry weight) was recorded in halogen cooked fillets of *M. cephalus*. Microwave and halogen cooking caused a significant loss (p<0.05) of Al concentration by about average 66.10 and 87.58%, respectively.

Raw fillets of *B. bajad* showed highest concentrations 0.48 ppm dry weight of As, while *M. cephalus* showed the lowest concentration 0.21 ppm dry weight. There were significant differences (p<0.05) in As concentrations between raw, microwave and halogen cooked fish fillets samples. However, the reduction in As concentration was significant (p<0.05) in all fish species cooked using halogen and the higher value of As (0.45 ppm dry weight) was recorded in microwave cooked fillets of *B. bajad*, while lower value (0.10 ppm dry weight) was recorded in halogen cooked fillets of *M. cephalus*. Microwave and halogen cooking methods caused a significant loss ($p<0.05$) of As concentration by about average 14.84 and 49.80%, respectively.

Raw fillets of *S. galilaeus* recoded higher concentration of Ba 0.44 ppm dry weight, while *O. niloticus* recoded lower concentrations 0.13 ppm dry weight. There were significant differences ($p<0.05$) in Ba concentrations between raw, microwave and halogen fish fillets samples. The reduction in the concentrations of Ba were significant ($p<0.05$) in all fish species and the higher value of Ba (0.28 ppm weight) was recorded in halogen cooked fish fillets of *S. galilaeus*, while lower value (0.08 ppm dry weight) was recorded in halogen cooked fish fillets of *O. niloticus* and *O. aureus*. Microwave and halogen cooking caused a significant loss ($p<0.05$) of Ba concentration by about average 23.54 and 31.69%, respectively.

Higher value 0.32 ppm dry weight of Cd concentrations was recorded in raw fish fillets of *B. bajad*, while lower value 0.23 ppm dry weight was recorded in raw fish fillets of *O. niloticus*. There were significant differences ($p<0.05$) in Cd concentrations between raw, microwave and halogen cooked fish fillets samples. However, the reduction in Cd concentrations were significant ($p<0.05$) in all fish species, the microwave cooking caused a slight increase in *B. bajad* fish fillets, while halogen cooked caused significant decrease ($p<0.05$). The higher value of Cd in processed fish fillets was 0.30 ppm dry weight and recorded in microwave cooked fillets of *M. cephalus*, while lower value (0.05 ppm dry weight) was recorded in halogen cooked fillets of *S. galilaeus*. Microwave and halogen cooking caused a significant loss ($p<0.05$) of Cd concentration by about average 35.02 and 39.80%, respectively.

Cobalt concentrations of raw fillets of *O. niloticus*, *O. aureus*, *S. galilaeus B. bajad* and *M. cephalus* were 0.08, 0.05, 0.04, 0.19 and 0.03 ppm dry weight, respectively. Microwave and halogen cooking caused a significant loss ($p<0.05$) of Co concentration by about average 19.63 and 37.87%, respectively. Microwave cooking caused a slight increase of Co concentration from 0.03 to 0.05 ppm dry weight in *M. cephalus.*

The minimum and maximum of Chromium concentrations were 0.05 and 0.30 ppm dry weight and they were recorded in raw fillets of *O. niloticus* and *M. cephalus*, respectively. Modern cooking techniques caused a significant decrease ($p<0.05$) in the concentrations of Cr of all fish species except *B. bajad* fillets which showed significant increase ($p<0.05$) in Cr concentrations in both two cooking methods and it recorded in raw, micro waved and halogen cooked 0.19, 0.36 and 0.32 ppm dry weight, respectively. Otherwise, microwave and halogen caused a significant loss ($p<0.05$) of Cr concentration by about average 30.13 and 41.94%, respectively.

The highest value of Cu concentration was recorded in raw fillets of *M. cephalus* 0.58 ppm dry weight, while the lowest Cu value 0.19 ppm dry weight was recorded in *O. niloticus*. Cooking process caused a significant decrease ($p<0.05$) of Cu concentrations in three fish species *O. niloticus*, *O. aureus* and *S. galilaeus*, while significant increase ($p<0.05$) of Cu concentrations were observed in *B. bajad* and microwaved fillets of *M. cephalus*. Microwave and halogen caused a significant loss ($p<0.05$) of Cu concentration by about average 16.66 and 36.28%, respectively.

Iron concentrations were generally highest and recorded 11.49, 12.17, 12.33, 13.68 and 12.18 ppm dry weight in *O. niloticus*, *O. aureus*, *S. galilaeus*, *B. bajad* and *M. cephalus*, respectively. Fe concentrations of microwaved fillets were recorded 2.33, 5.23, 1.75, 2.00 and 1.27 ppm dry weight, while halogen cooked recorded 1.81, 2.04, 1.35, 2.64 and 1.36 ppm dry weight for *O. niloticus*, *O. aureus*, *S. galilaeus*, *B. bajad* and *M. cephalus*, respectively. The cooking methods also showed higher percentage reduced efficiency of Fe. Microwave and halogen caused a significant loss ($p<0.05$) by about average 79.48 and 85.43%, respectively.

Manganese concentrations showed lowest value 1.04 ppm dry weight in raw fillets of *O. niloticus*, while higher value 1.98 ppm dry weight was recorded in *M. cephalus*. Microwave and halogen cooking methods showed a significantly decrease ($p<0.05$) in Mn concentrations at all studied samples by about average 66.37 and 77.16%, respectively.

Nickel was recorded the maximum concentration 1.99 ppm dry weight in raw fillets of *O. niloticus*, while the minimum concentration 0.22 ppm dry weight of Ni concentration was recorded in raw fillets of *M. cephalus*. A significant increases ($p<0.05$) were observed in Ni concentrations of microwave and halogen cooked *B. bajad* and *M. cephalus*, when compared with the control fish, while significant decreases ($p<0.05$) was observed in *O. niloticus*, *O. aureus* and *S. galilaeus* and the decrease percent recorded 13.85 and 45.36% for both microwaved and halogen cooked, respectively.

Lead concentrations in all investigated raw fish fillets samples had values ranged between 1.29-1.75 ppm dry weight. The lowest value recorded in *O. niloticus*, while the highest value recorded in *B. bajad*. There were significant differences ($p<0.05$) in Pb concentrations between the raw, microwave and halogen cooked fish fillets. Cooking raw fish fillets caused a significant decrease ($p<0.05$) of Pb concentrations in investigated cooked fish fillets. Microwave and halogen cooking methods showed a significantly decrease ($p<0.05$) in Pb concentrations at all studied samples by about average 65.12 and 80.11%, respectively.

Selenium concentrations of raw fillets of *O. niloticus*, *O. aureus*, *S. galilaeus*, *B. bajad* and *M. cephalus* were 0.78, 0.55, 0.67, 0.98 and 0.045 ppm dry weight, respectively. Microwave and halogen cooking caused a significant decrease ($p<0.05$) of Se concentration by about average 11.14 and 27.73%, respectively. However, microwave cooking caused a slight increase of Se concentration in *B. bajad* and *M. cephalus*.

The highest value (0.09 ppm dry weight) of Sn concentration was recorded in raw fillets of *B. bajad*, while the lowest Sn value 0.05 ppm dry weight was recorded in *O. niloti* and *M. cephalus*. Cooking of fish fillets caused a significant decrease ($p<0.05$) of Sn concentrations in all fish species except *B. bajad*, while significant increase ($p<0.05$) of Sn concentrations were observed in *B. bajad*. Microwave and halogen caused a significant decrease ($p<0.05$) of Sn concentration by about average 20.03 and 55.71%, respectively.

Higher concentration value of vanadium (0.85 ppm dry weight) was recorded in raw fish fillets of *O. niloticus*, while lower value (0.22 ppm dry weight) was recorded in raw fish fillets of *M. cephalus*. There were significant differences ($p<0.05$) in V concentrations between raw, microwave and halogen cooked fish fillets samples. However, the reduction in V concentrations were significant ($p<0.05$) in all fish species and the higher value of V (0.81 ppm dry weight) was recorded in microwave cooked fillets of *O. niloticus*, while lower value (0.17 ppm dry weight) was recorded in halogen cooked fillets of *M. cephalus*. Microwave and halogen cooking caused a significant loss ($p<0.05$) of V concentration by about average 13.74 and 37.23%, respectively.

Zinc (Zn) concentrations were significantly varied among almost all fish species and processing treatments. Raw fillets of *O. niloticus*, *O. aureus*, *S. galilaeus*, *B. bajad* and *M. cephalus* recorded 9.00, 13.59, 11.16, 10.99 and 8.18 ppm dry weight, respectively. The cooking methods showed significant effects on reducing amount of zinc concentrations and the halogen oven found to be more effect than microwave. Microwave and halogen cooking methods showed a significantly decrease ($p<0.05$) in Zn concentrations at all studied samples by about average 81.47 and 86.31%, respectively.

DISCUSSION

Concentrations of heavy metals in different fish species showed great variation capabilities for accumulating heavy metals. The observed variability of heavy metals levels in different species depend on, feeding habits (Romeo *et al*., 1999), ecological needs, metabolism (Canli and Furness, 1993), age, size and length of the fish and their habitats (Canli and Atli, 2003), species, sex, biological cycle and on the part of the fish analyzed (Tuzen, 2003). Moreover, ecological factors such as season, location/environment of development, nutrient availability and temperature and salinity of the water, may contribute to variations in the metal concentrations in fishes (Bashir *et al*., 2012).

It was interesting to note that, in most cases, fish fillets showed significant decrease ($p<0.05$) in heavy metal concentrations after cooking by microwave and halogen. Similar results were recorded by Atta *et al*. (1997) who found a significantly decrease in the concentrations of Mn, Pb and Zn in Nile tilapia after cooking methods. However, Gokoglu *et al*. (2003) found a significant effect on mineral content due to cooking. Moreover Ersoy *et al*. (2006) reported that, the heavy metals content in all fish parts decreased after baking. Similarly, Hassanin (2008) found a significant decrease in Pb content of fillets after cooking by baking and microwave oven methods. The reduction in Pb depends on cooking conditions, such as time, temperature and medium of cooking. Also, Diaconescu *et al*. (2013) found that, frying showed a more pronounced effect on the heavy metal content, while baking, microwaving and grilling lead to a moderate decrease in heavy metals load during the cooking process. The reduction in trace metals concentrations as affected by cooking methods may be due to the release of these metals with the loss of drip as free salts, possibly in association with soluble amino acids and un-coagulated proteins bounded with metals (Atta *et al*., 1997; Ersoy *et al*., 2006; Ganbi, 2010).

The increases of some heavy metals concentrations especially Cd, Co, Cu, Ni and Se in some cooked fish fillets as affected by cooking methods are similar to those reported by Devesa *et al*. (2001) and Diaconescu *et al*. (2013). This increase may be due to loss of moisture and resultant concentration of meat or could be due to the ingredients used in cooking and, recent studies indicate that spices could contain high levels of lead due to contamination (Morgan *et al*., 1997; Woolf and Woolf, 2005; Musaiger and D'Souza, 2008). On the other hand, (Gokoglu *et al*., 2003; Ersoy *et al*., 2006; Ganbi, 2010) reported that, the increase in some heavy metals in cooked fish may be attributed to the loss of moisture throughout cooking that caused the concentration of some metals in fish muscles.

CONCLUSION

Concentrations of heavy metals in different fish species showed great variation capabilities for accumulating heavy metals. Modern cooking techniques microwave and halogen showed considerable effect on reducing trace metals concentrations in most investigated fish species and the halogen cooking method was the best on heavy metals reduction. The Cd, Co, Cu, Ni and Se concentrations of microwave and halogen cooked fish samples were significantly increased ($p<0.05$) than control but not exceed the permissible limits.

REFERENCES

Abdou, E.S., A.S. Nagy Osheba and M.A. Sorour, 2012. Effect of chitosan and chitosan-nanoparticles as active coating on microbiological characteristics of fish fingers. Int. J. Appl. Sci. Tech., 2(7): 158-169.

Adams, S.M. and J.B. Standridge, 2006. What should we eat? Evidence from observational studies. Southern Med. J., 99(7): 744-748.

Atta, M.B., L.A. Sabaie, M.A. Noaman and H.E. Kassab, 1997. The effect of cooking on the concentration of heavy metals in fish (*Tilapia nilotica*). Food Chem., 58: 1-4.

Bashir, F.A., M. Shuhaimi-Othman and A.G. Mazlan, 2012. Evaluation of trace metal levels in tissues of two commercial fish species in Kapar and Mersing coastal waters, peninsular Malaysia. J. Environ. Public Health, 2012: 1-10, Article ID 352309.

Bremner, A., 2002. Safety and Quality Issues in fish Processing. Woodhead Publishing Ltd., Cambridge, England, pp: 507.

Bùrresen, T., 2008. Improving seafood products for the consumer. 1st Edn., Woodhead Publishing Ltd., Abington Hall, Granta Park, Great Abington, Cambridge CB21 6AH, England, pp: 612.

Canli, M. and G. Atli, 2003. The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environ. Pollut., 121(1): 129-136.

Canli, M. and R.W. Furness, 1993. Toxicity of heavy metals dissolved in sea water and influences of sex and size on metal accumulation and tissue distribution in the Norway lobster Nephropsnorvegicus. Mar. Environ. Res., 36: 217-236.

Caygill, C.P.J., A. Charlett and M.J. Hill, 1996. Fat, fish, fish oil and cancer. Brit. J. Cancer, 74(1): 159-164.

Devesa, V., M.L. Macho, M. Jalón, I. Urieta, O. Muñoz, M.A. Súñer, F. López, D. Vélez and R. Montoro, 2001. Arsenic in cooked seafood products: Study on the effect of cooking on total and inorganic arsenic content. J. Agr. Food Chem., 49: 4132-4140.

Diaconescu, C., Fantaneru, G.L. Urdes, L. Vidu, B. Vasile and S. Diaconescu, 2013. Influence of cooking methods over the heavy metal and lipid content of fish meat. Rom. Biotech. Lett., 18(3): 8279-8283.

Ersoy, B., Y. Yanar, A. Küükgülmez and M. Çelik, 2006. Effects of four cooking methods on the heavy metal concentrations of the sea bass fillets (*Dicentrarchus labrax* Linne, 1785). Food Chem., 99(4): 748-751.

Fernandez, E., L.A. Chatenoud, C. Vecchia, E. Negri and S. Franceschi, 1999. Fish consumption and cancer risk. Am. J. Clin. Nutr., 70(1): 85-90.

Fraustro, D.A., J.J.R. Silva and R.J.P. Williams, 1993. The Biological Chemistry of the Elements: The Inorganic Chemistry of Life. Clarendon Press, Oxford.

Ganbi, H.H.A., 2010. Heavy metals pollution level in marine Hammour fish and the effect of popular cooking methods and freezing process on these pollutants. World J. Dairy Food Sci., 5(2): 119-126.

García-Arias, M.T., E.A. Pontes, M.C. Fernandez and F.J. Muniz, 2003. Freezing/defrosting/frying of sardine fillets. Influence of slow and quick defrosting on protein quality. J. Sci. Food Agr., 83: 602-608.

Gokoglu, N., P. Yerlikaya and E. Cengiz, 2003. Effects of cooking methods on the proximate composition and mineral contents of rainbow trout (*Oncorhynchus mykiss*). Food Chem., 84: 19-22.

Hassanin, S.I.A., 2008. Metals residues, histological alterations and cooking methods of fish cultured in wastewater ponds. Proceeding of the 8th International Symposium on Tilapia in Aquaculture, pp: 569-588.

Meche, A., M.C. Martins, Bruna E.S.N. Lofrano, Carey J. Hardaway, M. Merchant and L. Verdade, 2010. Determination of heavy metals by inductively coupled plasma-optical emission spectrometry in fish from the Piracicaba River in Southern. Brazil Microchem. J., 94:171-174.

Morgan, J.N., M.R. Berry and R.L. Graves, 1997. Effects of commonly used cooking practices on total mercury concentration in fish and their impact on exposure assessments. J. Expo. Anal. Env. Epid., 7(1): 119-133.

Mozaffarian, D. and E.B. Rimm, 2006. Fish intake, contaminants and human health-evaluating the risks and the benefits. J. Amer. Med. Assoc., 296(15): 1885-1899.

Musaiger, A.O. and R. D'Souza, 2008. The effects of different methods of cooking on proximate, mineral and heavy metal composition of fish and shrimps consumed in the Arabian Gulf. Arch. Latinoam. Nutr., 58(1): 103-109.

Nestel, P.J., 2000. Fish oil and cardiovascular disease: Lipids and arterial function. Am. J. Clin. Nutr., 71(1): 228S-231S.

Oehlenschläger, J., 1997. Marine Fish-a Source for Essential Elements? In: Luten J.B., T. Bo¨rresen and J. Oehlenschla¨ger (Eds.), Seafood from Producer to Consumer, Integrated Approach to Quality. Elsevier Science BV, Amsterdam, Netherlands, pp: 641-52.

Ohlsson, T. and N. Bengtsson, 2002. Minimal Processing of Foods with Thermal Methods. In: Ohlsson T. and N. Bengtsson (Eds.), Minimal Processing Technologies in the Food Industry. Woodhead Publishing Ltd., Cambridge, England, pp: 13-14, 23.

Pereira, R.N. and A.A. Vicente, 2010. Environmental impact of novel thermal and non-thermal technologies in food processing. Food Res. Int., 43:1936-1943.

Ranjan, R., J. Irudayaraj and S. Jun, 2002. Simulation of infrared drying process. Dry. Technol., 20(2): 363-379.

Romeo, M., Y. Siau, Z. Sidoumou and M. Gnassia-Barelli, 1999. Heavy metal distribution in different fish species from the Mauritania coast. Sci. Total Environ., 232: 169-175.

Sakai, N. and T. Hanzawa, 1994. Applications and advances in far-infrared heating in Japan. Trends Food Sci. Tech., 5: 357-362.

Tuzen, M., 2003. Determination of heavy metals in fish samples of the middle Black Sea (Turkey) by graphite furnace atomic absorption spectrometry. Food Chem., 80(1): 119-123.

Welch, A. A., E. Lund, P. Amiano, M. Dorronsoro, M. Brustad, M. Kumle *et al*., 2002. Variability of fish consumption within the 10 European countries participating in the European Investigation into Cancer and Nutrition (EPIC) study. Public Health Nutr., 5(6B): 1273-1285.

Woolf, A.D. and N.T. Woolf, 2005. Childhood lead poisoning in 2 families associated with spices used in food preparation. Pediatrics, 116(2): 314-318.