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The effect of cooking on the content of heavy metals in fish (*Tilapia nilotica*)

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Fish (*Tilapia nilotica*) were grown in polluted water with some heavy metals namely cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn). The concentrations of metals in fish water environment were 5, 10 and 15 ppm for Cd, Cu and Zn, respectively, while Pb concentrations were 20, 40 and 80 ppm. The results revealed that heavy metal contents in fish parts varied according to concentrations in the environment and the type of fish tissue. The highest levels (all examined metals) were found in visceral tissues followed by the head. The lowest value was found in fish flesh. The heavy metal content in all fish parts decreased on steaming and baking. The reduction in the metal content on baking was much greater than on steaming. Copyright © 1996 Published by Elsevier Science Ltd

INTRODUCTION

Environmental pollution represents a major problem in both developed and underdeveloped countries. Egypt is one country which suffers from high biosphere pollution (air, soil and water). Many ecological changes occur in water as a result of human activities, including agricultural, industrial and municipal wastes (Katz *et al.*, 1969). Cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn) salts are usually found in agricultural and industrial liquid wastes (USEPA, 1975; Simon, 1977; McCrea & Fischer, 1986; El-Gamal, 1993) which are discharged into water resources. These metals are toxic to aquatic life at low concentrations, particularly in soft-water environments (USEPA, 1977). Such metals may be accumulated from water to higher levels in fish tissues (Forstner & Wittman, 1983). Evidently these metals accumulate frequently in fish flesh (Causeret, 1962; Jaakkola *et al.*, 1973; Underwood, 1977; Glover, 1979) and internal organs (Venugopal & Luckey, 1975; Salanki *et al.*, 1982; Nishihara *et al.*, 1985; Wageman, 1989). Cadmium and lead are not essential elements to human life, but copper and zinc are essential for human health (Sittig, 1985). The excess of Cd intake under certain conditions may cause renal hypertension (Schoerder, 1965). Impairments specifically related to lead toxicity in humans include abnormal size and haemoglobin content of the erythrocytes, hyperstimulation of erythropoiesis and inhibition of haeme synthesis (Venugopal & Luckey, 1975). Diseases suspected to be caused by excessive ingestion of copper are arthritis and scleroderma, while there are no reports of zinc being harmful, although its salts are considered as hazardous substances (Simon, 1977).

In the work presented in this paper a study has been made of the distribution of heavy metals in *Tilapia nilotica* held in water containing extreme concentrations of cadmium, copper, lead and zinc salts. The influence of cooking on the concentrations of the metals was also determined.

MATERIALS AND METHODS

Materials

Fish *Tilapia nilotica* were supplied from Fewa Fish Hatchery, Kafr El-Sheikh, Egypt. Twenty-five specimens were placed in a glass tank (70×35×35 cm) containing 80 litres of dechlorinated and aerated tap water under controlled conditions (24–26°C; pH 7.5–7.7). Fish were acclimatized for two months prior to the test initiation under laboratory conditions (until the specimen weight reached about 20–30 g). Heavy metals, namely cadmium (Cd), copper (Cu) and zinc (Zn) were added individually to the water at three levels (5, 10 and 15 ppm), whilst lead (Pb) was added to the water at concentrations of 20, 40 and 80 ppm. A control was carried out for each examined metal by growing fish in dechlorinated and aerated tap water (no metal was added) under the same conditions. The period of each experiment was two months.

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Methods

Fish preparation for analysis
Fish grown in polluted and unpolluted water were washed with twice-distilled water, and then each treatment was divided into three groups (eight fish each). The first eight specimens were dissected to separate head, viscera and flesh. The separated flesh fragments were collected and homogenized using a stainless steel hand grinder. The fish head and viscera were also homogenized, individually, following the same procedure used for flesh. The homogenized samples were kept in tightly sealed polyethylene bags for the heavy metals determination.

Cooking methods
The remaining two groups were taken for technological treatments. The first group was steam-blanched by autoclave at 105°C for 10 min, while the second group of fish was baked in an electric oven at 300°C for 10 min. Both the baked and steam-blanched fish were dissected individually to separate the three parts. Each part was homogenized and prepared for metal analysis following the procedure used for uncooked samples.

Determination of heavy metals
Fish samples were digested as described by Kopito (1970) using a nitric–perchloric acid mixture (4:1 v/v). The digest was quantitatively transferred to a 25 ml volumetric flask with twice-distilled water, adjusted to pH 2 with nitric acid, and the volume made up to the mark. Heavy metals were measured using Atomic Absorption Spectroscopy (Laboratory Instrumentation Model AAC 105). The metal concentration was expressed as μg metal/g fish tissue dry weight.

RESULTS AND DISCUSSION

As shown in Table 1, type and proportion of the heavy metal in the water ecosystem reflected its concentration in fish parts. Moreover, the accumulation of metal in fish depended on the property of the examined fish part. For instance, fish viscera accumulated greater amounts of heavy metals than other fish parts. Fish flesh had the lowest concentration of metals. These results are in agreement with those found in the literature. It has been reported that Cd and Cu tend to accumulate in fish gills (Anderson & Brower, 1978), fish kidney (Salanki *et al.*, 1982; Nishihara *et al.*, 1985) and fish liver (Wageman, 1989). According to Murphy (1978), fish muscle tissue contained a low percentage of Cd and Cu compared with other fish parts. The same results were observed by Coombs and George (1978), Ray (1978) and Nishihara *et al.* (1985) for Pb. Meanwhile, Kagi and Vallee (1960), Thomson (1982) and Thomson and George (1985) found the same results for Zn. The metal contents in all fish parts could be arranged in the decreasing order: Zn > Cu > Pb > Cd.

Table 1. Mean concentrations of Cd, Cu, Pb and Zn (μg g^{-1} dry weight) in raw fish (*Tilapia nilotica*) grown in waters at three levels of metal concentrations

Concentration of metal (ppm)		Fish parts: Head	Flesh	Viscera
Cd	0[a]	3.34	1.92	6.43
	5	142	25.2	261
	10	140	24.0	188
	15	143	28.1	276
Cu	0[a]	20.9	18.0	50.5
	5	64.3	54.3	325
	10	72.2	64.4	491
	15	97.6	71.0	639
Pb	0[a]	16.3	12.1	25.0
	20	306	84.7	1379
	40	366	217	1394
	80	416	241	1488
Zn	0[a]	149	101	289
	5	789	108	861
	10	844	110	949
	15	893	112	1398

[a]Fish grown in aerated tap water (control).

The metal content in the fish parts increased with increasing concentration of metal in the water environment. The average concentrations of metals in fish parts were elevated about 19–34-fold for Cd, 3–13-fold for Cu, 19–26-fold for Pb and 55–60-fold for Zn. These results are supported by those of Murphy (1978) who reported that fish in an ecosystem heavily contaminated by trace metals accumulated significantly more metal in the edible muscle tissue than fish in an uncontaminated ecosystem. The rate of Cd accumulation in the raw fish head and viscera did not show marked changes upon increasing the amounts in the water environment from 5 to 15 ppm. This may be due to the achievement of Cd and Zn balance when their concentration in water is more than 5 ppm. The balance is maintained by a mechanism regulating the metal absorption by gills and excretion through urine, faeces and body surface (Bryan, 1967).

Heat treatment by either steam-blanching or baking of polluted fish led to a decrease of the heavy metal content in all the tested fish parts (Table 2). The decrease of metals which occurred during steam-blanching of fish was lower than that detected after the baking process. The reduction in the metal contents of the fish during cooking may be related to the release of these metals with the loss of water as free salts, possibly in association with soluble amino acids and uncoagulated proteins (Bryan & Hummerstone, 1971). Howarth and Sprague (1978) found that the cooking process decreased the protein content of the fish parts; hence, heavy metals usually bind with proteins.

In conclusion, Cd, Cu, Pb and Zn metals are predominantly accumulated in fish viscera, head and flesh tissues. Fish viscera had the highest contents of heavy metals followed by the fish head. The lowest values were detected in fish flesh. Cooking is of limited value as a means of reducing the concentrations of heavy metals. The reduction depends on cooking conditions (time,

Table 2. Mean concentrations of Cd, Cu, Pb and Zn (μg g^{-1} dry weight) in cooked fish (*Tilapia nilotica*) grown in waters at three levels of metal concentrations

Concentration of metal (ppm)		Steam-blanched fish			Baked fish		
		Head	Flesh	Viscera	Head	Flesh	Viscera
Cd	0[a]	2.41	1.82	5.07	2.17	1.39	4.98
	5	72.1	17.8	158	51.5	16.7	107
	10	69.8	21.4	175	71.3	19.4	119
	15	150	22.1	251	90.3	20.5	172
Cu	0[a]	18.5	15.0	44.3	15.7	11.1	41.2
	5	37	46.3	174	31.3	28.0	114
	10	70.0	54.6	189	44.2	29.3	140
	15	69.7	68.0	193	56.1	48.8	142
Pb	0[a]	14.6	8.85	19.4	11.1	6.94	16.8
	20	272	66.6	1154	270	64.9	668
	40	346	108	1307	318	102	704
	80	412	130	1319	362	123	943
Zn	0[a]	112	51.1	114	62.7	37.2	77.1
	5	368	93.6	801	252	73.8	314
	10	650	95.7	822	499	75.2	463
	15	681	108	826	540	81.9	777

[a]Fish grown in aerated tap water (control).

temperature and medium of cooking). Therefore, it is possible to reduce the metal in fish parts by choosing a suitable method of cooking. Baking had a more pronounced effect on the heavy metals content in fish parts than steam blanching. Although fish flesh had the lowest contents of heavy metals, it lost a moderate amount of these during cooking. Consequently, such fish flesh should only be eaten after cooking.

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