Available online at www.sciencedirect.com
SCIENCE DIRECT®
Food Chemistry 99 (2006) 748–751
Food Chemistry
www.elsevier.com/locate/foodchem

Effects of four cooking methods on the heavy metal concentrations of sea bass fillets (*Dicentrarchus labrax* Linne, 1785)

Beyza Ersoy *, Yasemen Yanar, Aygül Küçükgülmez, Mehmet Çelik

Department of Fishing and Fish processing Technology, Faculty of Fisheries, University of Çukurova, 01330 Adana, Turkey

Received 9 May 2005; received in revised form 26 August 2005; accepted 26 August 2005

Abstract

Heavy metals (Pb, Cd, Cr, Co, As, Ni) were analysed in cooked sea bass (*Dicentrachus labrax*). Different cooking treatments were used (baking, grilling, microwaving and frying). The results obtained were statistically compared with those of raw fish. The Co concentrations were below limits of detection in all samples (<0.05). Furthermore, Cr in fried samples and Ni in raw fish were not detected. Cd was only detected in microwaved samples. The Pb concentrations of microwaved and baked fish were significantly decreased. The As concentrations of fried and microwaved samples were significantly increased. The Cd and As concentrations of the fillets subjected to microwave cooking were 0.741 and 1.41 mg/kg, respectively. However, the As concentration was also significantly increased in fried samples. This value was 2.66 mg/kg. Microwaving and frying are not suitable for sea bass.

Keywords: *Dicentrarchus labrax*; Cooking methods; Seafood; Minerals; Heavy metals

1. Introduction

Sea bass (*Dicentrarchus labrax* Linne, 1785) is an extensively cultured species in Turkey. Total production was 8660 tons in 1998 (Anonymous, 1999, 2000). The consumption of this species has recently increased. Fish is sometimes eaten raw, but it is usually treated by various processes, such as boiling or frying, before consumption. On the other hand, the use of the microwave oven for cooking has increased greatly during the past few decades (Arias, Pontes, Fernandez, & Muniz, 2003).

Many elements, which are present in seafood, are essential for human life at low concentrations but they can be toxic at high concentrations. Therefore, many consumers regard any presence of these elements in fish as a hazard to health (Oehlenschlager, 2002).

Chromium and nickel are considered to be essential trace nutrients (Canlı and Kargın, 1995), whereas heavy metal, such as cadmium, cobalt, lead and metalloid arsenic, are non-essential metals as they are toxic, even in traces. The consumption of seafood will impose health hazards on humans. Many metals and metallic compounds found in the marine environment pose a risk to human health through the consumption of seafood, wherein contaminant concentration and exposure are significant (Saleh & Shinwari, 2002). It is important to determine the concentrations of heavy metals in commercial fish in order to evaluate the possible risks of fish consumption for human health (Cid, Boia, Pombo, & Rebelo, 2001).

Many studies have been published on the determination of heavy metals in sea bass (Sunlu & Egemen, 1998; Topcuoğlu, Kırbaşoğlu, & Güngör, 2002; Yazkan, Özdemir, & Gölükcü, 2002), but these studies are inadequate for estimating the intake of these heavy metals by humans since they were carried out on raw fish. However, in the literature, there are some studies on cooked fish (Asiedu, Julshamn, & Lie, 1991; Atta, Sabaie, Noaman, & Kassab, 1997; Devesa & Macho et al. 2001; Dugo, Pera, Bruzzese, Pellicanò, & Turco, 2006; Gokoglu, Yerlikaya, & Cengiz, 2004; Hoffman, Prinsloo, Casey, & Theron, 1994; Khansari, Khansari, & Abdollahi, 2005). Jorhem, Engman,

* Corresponding author. Tel.: +90 322 3387213; fax: +90 322 3386439.
E-mail address: bersoy@cu.edu.tr (B. Ersoy).

0308-8146/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2005.08.055

Sundstrom, and Thim (1994) have reported that some changes occurred during cooking in the Cd, Ni, Co, Pb, Cu and Mn concentrations of Crayfish, varying according to the metal and the organ considered. The state of As is very different from other elements. Van Elteren and Slejkovec (1997) investigated the transformations of arsenobetaine (AB) into trimethylarsine oxide (TMAO) and tetramethylarsonium ion (TMA^+), dimethylarsinic acid (DMA) into monomethylarsonic acid (MMA), and MMA into As. It has been demonstrated that AB transforms into TMA^+ in cooked seafood products at temperatures of 160 °C or above (Devasa & Martínez et al. 2001).

In the present study, the concentrations of heavy metal have been determined in cooked sea bass (*D. labrax* Linne, 1785). To evaluate the possible effect of cooking on the concentration of heavy metals, the concentrations obtained in the cooked products were compared with the concentrations found in the same raw fish.

2. Materials and methods

2.1. Sample preparation and cooking

The sea bass, *D. labrax* (28.9 ± 0.9 cm and 25 ± 24 g), used in this study were obtained from a sea bass farm in Adana, Turkey. They were kept in cold iced boxes and transported to the laboratory within 2 h. On arrival at the laboratory, fresh fish were washed with tap water several times to remove adhering blood and slime; they were then prepared using common household practices, namely eviscerating and beheading. Samples were filleted and cut into pieces and then fish fillets were divided into three groups (2 kg fish each). The first group was uncooked. The other two groups (two repetitions) were cooked in the microwave oven (2450 MHz, 10 min), baked in the oven (180 °C, 20 min), in the grill oven (180 °C, 20 min) and fried (180 °C, 4 min). Sunflower oil was used as the medium for pan-frying. Raw and cooked samples were homogenised in a stainless-steel meat mincer and blender and each group was analysed in the same way.

2.2. Digestion procedures

This approach was partly modified from that of Tüzen (2003). A sample (1.5 g) of the homogenised sample was placed in a 50 ml digestion tube, and 5 ml of concentrated HNO_3 were added, where necessary, then the samples were heated slowly to dissolve. The solution was filtered with Whatman No. 42 filter paper and made up to volume with deionized water. A blank digest was carried out in the same way. All metals were determined against aqueous standards.

2.3. Analytic procedure

Determinations of all metal concentrations were carried out by inductively coupled plasma atomic emission spectrometry (ICP-AES) (Varian model–Liberty Series II). The following absorbtion lines were used; arsenic 193.696, calcium 317.933, cadmium 226.502, cobalt 228.616, cromium 267.716, copper 324.754, iron 259.940, potassium 766.490, magnesium 279.079, manganese 257.610, sodium 330.237, nickel 231.604, lead 220.353, zinc 213.856. Metal concentrations were calculated in ppm wet weight.

2.4. Statistical analysis

Analysis of variance was used to evaluate the analysis data, and significant differences among means were determined by one-way analysis of variance (ANOVA) and duncan's multiple range test ($p = 0.05$) (SPSS 10.0 for windows).

3. Results and discussion

The concentrations of heavy metals with means ± standard deviation are given Table 1. The Pb concentration of raw fish was found to be 0.2776 mg/kg. This value is higher than that reported by Dugo et al. (2006) and lower than that reported by Sunlu and Egemen (1998). There were no significant differences in Pb concentrations between the raw, grilled, fried fish. However, the decrease in Pb concentration was significant ($P < 0.05$) for baked and microwave cooking methods when compared to the raw control. Similarly, Atta et al. (1997) have reported a decrease in the concentrations of Pb in *Tilapia nilotica* after baking.

The Cd concentrations of raw, baked, grilled and fried samples were not detectable [below limits of detection (<0.02)]. The Cd concentration of cultured sea bass muscle

Table 1
The mean heavy metal concentration of the raw and cooked sea bass fillets (mg/kg, wet weight)

	Pb	Cd	Cr	Co	As	Ni
Raw	0.278 ± 0.009^{b}	ND	0.112 ± 0.124	ND	0.372 ± 0.042^{a}	ND
Baked	0.224 ± 0.039^{ab}	ND	0.079 ± 0.014	ND	0.324 ± 0.199^{a}	0.891 ± 0.692
Grilled	0.284 ± 0.001^{b}	ND	0.05 ± 0.000	ND	0.398 ± 0.068^{a}	0.213 ± 0.002
Microwave cooked	0.156 ± 0.049^{a}	0.7413 ± 0.073	0.108 ± 0.019	ND	1.41 ± 1.67^{ab}	0.931 ± 0.635
Fried	0.277 ± 0.029^{b}	ND	ND	ND	2.66 ± 0.084^{b}	0.492 ± 0.468

Within the column values with different letters are significantly different ($P < 0.05$), values without letters are not significantly different ($P > 0.05$).
ND, not determined [below the limits of detection].
Values are shown as means ± standard deviation of duplicates, $n = 2$.

tissues from the sea of Sicily was also not detectable in the study of Dugo et al. (2006), although Topcuoğlu et al. (2002) reported that Cd concentration of raw samples of sea bass was 0.24 μg/g dry wt. The mean Cd concentration of fillets subjected to microwave cooking method was 0.7413 mg/kg. According to the regulations made by the Commission of European Union and Turkey, the permissible limit for Cd in sea bass is 0.1 mg/kg wet weight (Anonymous, 1997; EC no. 466/2001, 2001). In the microwaving methods, the concentration of Cd increased significantly, but the factors responsible for the increase are not known. In our opinion, the increase of metal may be related to the changes in moisture concentration that occur during cooking.

The mean Cr concentration of the fillets was not obtained in the frying method [below limit of detection (<0.04)]. The Cr concentration determined in raw samples was 0.112 mg/kg. This result is similar to the Cr concentration of sea bass reported as 0.18 μg/g by Topcuoğlu et al. (2002). The changes in Cr concentration were found to be insignificant ($P > 0.05$).

Although the Co concentration was below the limits of detection in all cooking methods (<0.05), Topcuoğlu et al. (2002) have reported that the mean Co concentration of sea bass was 0.24 μg/g; however, as in our study, the mean Co concentrations of shad and whiting were not detectable [below limits of detection (<0.05)] in their study.

The As concentration of raw fish was found to be 0.372 mg/kg. The highest value found in the fried samples, was 2.66 mg/kg; while the lowest value was in the baked samples (0.3244 mg/kg). The increase in As concentration was significant ($P < 0.05$) for fried and microwave-cooked samples, while it was not significant for either raw or other methods. Devasa and Macho et al. (2001) have reported that, after cooking, there was a significant increase in the concentration of inorganic As for bivalves and squid; but sardines, crustaceans, anchovies and Atlantic horse mackerel showed no significant differences among them. In all types of seafood observed by Devasa and Macho et al. (2001), the concentrations of inorganic As varied between 0.008 and 1.08 μg/g dry wt. In the white fish group, the As concentration was generally low and did not exceed 0.1 μg/g dry wt.

The Ni concentration of raw samples was below the limit of detection (<0.06). Topcuoğlu et al. (2002) have reported that Ni concentration of raw sea bass (*D. labrax*) was 0.06 μg/g. The highest value was detected in the microwave-cooked samples (0.93 mg/kg). Analysis of variance showed insignificant ($P > 0.05$) differences between measured concentrations in all samples. No previous studies were found on Ni concentration in cooked seafood.

4. Conclusion

In the frying and microwaving methods, the concentrations of As and Cd increased significantly. Therefore, these methods were found to be inappropriate.

The investigation indicates that the increases were statistically insignificant for the heavy metal of baked and grilled fish. However, the Pb concentration was significantly decreased in baked samples.

It can be recommended that grilling and baking are the most suitable methods for human consumption. The reduction depends on cooking conditions, such as time, temperature and medium of cooking. Therefore, it is possible to reduce the metal in fish parts by choosing a suitable method of cooking.

Acknowledgement

This study was supported by the research fund of the University of Çukurova.

References

Anonymous. (1997). Türk gıda kodeksi yönetmeliği. Dünya yayıncılık, İstanbul, 214.

Anonymous. (1999). 1988–1997 Aquaculture production statistics. FAO Fisheries Circular, No: 815, Rev 11, 203, p. 7.

Anonymous. (2000). 1998 Yılı Su ürünleri İstatistikleri. T.C. Başbakanlık Devlet İstatistik Enstitüsü, Ankara (unpublished).

Arias, M. T. G., Pontes, E. A., Fernandez, M. C. G., & Muniz, F. J. S. (2003). Freezing/defrosting/frying of sardine fillets. Influence of slow and quick defrosting on protein quality. *Journal of the Science of Food and Agriculture, 83*, 602–608.

Asiedu, M. S., Julshamn, K., & Lie, O. (1991). Efficiency of local processing methods (cooking, frying and smoking) on three fish species from Ghana. Part I. Proximate composition, fatty acids, minerals, trace elements and vitamins. *Food Chemistry, 40*(3), 309–321.

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

Canlı, M., & Kargın, F. (1995). A comparative study on heavy metal (Cd, Cr, Pb and Ni) accumulation in the tissue of the carp *Cyprinus carpio* and the nile fish *Tilapia nilotica*. *Turkish Journal of Veterinary and Animal Sciences, 19*, 165–171.

Cid, B. P., Boia, C., Pombo, L., & Rebelo, E. (2001). Determination of trace metals in fish species of the Ria de Aveiro (Portugal) by electro-thermal atomic absorbtion spectrometry. *Food Chemistry, 75*, 93–100.

Devesa, V., Macho, M. L., Jalón, M., Urieta, I., Muñoz, O., Súñer, M. A., López, F., Vélez, D., & Montoro, R. (2001). Arsenic in cooked seafood products: Study on the effect of cooking on total and inorganic arsenic concentrations. *Journal of Agriculture of Food Chemistry, 49*, 4132–4140.

Devesa, V., Martínez, A., Súñer, M. A., Vélez, D., Almela, C., & Montoro, R. (2001). Effect of cooking temperatures on chemical changes in species of organic arsenic in seafood. *Journal of Agriculture of Food Chemistry, 49*, 2272–2276.

Dugo, G., Pera, L. L., Bruzzese, A., Pellicanò, T. M., & Turco, V. L. (2006). Concentration of Cd (II), Pb (II), Se (IV) and Zn (II) in cultured sea bass (*Dicentrarchus labrax*) tissues from Tyrrhenian Sea and Sicilian Sea by derivate stripping potentiometry. *Food Control, 17*, 146–152.

European Community, rule no. 466 (2001). European Official Gazette 16th March 2001.

Gokoglu, N., Yerlikaya, P., & Cengiz, E. (2004). Effects of cooking methods on the proximate composition and mineral concentrations of rainbow trout (*Oncorhynchus mykiss*). *Food Chemistry, 84*, 19–22.

Hoffman, L. C., Prinsloo, J. F., Casey, N. H., & Theron, J. (1994). Effects of five cooking methods on the proximate, fatty acid and mineral composition of fillets of the African Sharptooth Catfish. *Die SA Tydskrif vir Voedselwetenskap en Voeding, 6*(4), 146–152.

Jorhem, L., Engman, J., Sundstrom, B., & Thim, A. M. (1994). Trace elements in crayfish: Regional differences and changes induced by cooking. *Archives of Environmental Contamination and Toxicology, 26*, 137–142.

Khansari, F. E., Khansari, M. G., & Abdollahi, M. (2005). Heavy metals concentration of canned tuna fish. *Food Chemistry, 93*, 293–296.

Oehlenschlager, J. (2002). Identifying heavy metals in fish. In H. A. Bremmer (Ed.). *Safety and quality issues in fish processing* (Vol. 507, pp. 95–113). USA: CRC Press LLC.

Saleh, I. A., & Shinwari, N. (2002). Preliminary report on the levels of elements in four fish species from the Arabian Gulf of Saudi Arabia. *Chemosphere, 48*, 749–755.

Sunlu, U., & Egemen, Ö. (1998). Homa Dalyanı ve İzmir Körfezinin (Ege Denizi) farklı bölgelerindeki kirlenme durumu ile bazı ekonomik balık türlerinde ağır metal düzeylerinin karşılaştırılması. *Journal of Fisheries and Aquatic Sciences, 15*(3-4), 242–261.

Topcuoğlu, S., Kırbaşoğlu, Ç., & Güngör, N. (2002). Heavy metals in organisms and sediments from Turkish Coast of the Black Sea 1997–1998. *Environment International, 27*(2002), 521–526.

Tüzen, M. (2003). Determination of heavy metals in fish samples of the middle Black Sea (Turkey) by graphite furnace atomic absorbtion spectrometry. *Food Chemistry, 80*, 119–123.

Van Elteren, J. T., & Slejkovec, Z. (1997). Ion-exchange separation of eight arsenic compounds by high-performance liquid chromatography – UV decomposition-hydride generation-atomic fluorescence spectrometry and stability test for food treatment procedures. *Journal of Chromatography, 789*, 339–340.

Yazkan, M., Özdemir, F., & Gölükcü, M. (2002). Antalya körfezinde avlanan bazı balık türlerinde Cu, Zn, Pb ve Cd içeriği. *Turkish Journal of Veterinary and Animal Sciences, 26*, 309–1313.