ANTIOXIDANT DEFENCES IN COASTAL AND DEEP-SEA FISH: A COMPARATIVE STUDY

Ramón Lavado *, Luz M. García de la Parra, Estefanía Escartín, Cinta Porte
Environmental Chemistry Dept. IIQAB-CSIC, Barcelona, Spain - * rlpqam@cid.csic.es

Abstract

Rather low levels of oxidative stress are expected in deep-sea organisms due to both, their reduced metabolic rate and the physicochemical conditions of a dark, poorly oxygenated environment However, when antioxidant defences of coastal and deep-sea species collected from the NW Mediterranean were compared, only the activity of glutathione peroxidase was observed to decrease with depth; catalase and superoxide dismutate remained unchanged. Thus, dangers associated to reactive oxygen species (ROS) exposure did not appear to decrease in deep-sea areas, and other factors (presence of swim bladder, diet, pollutant exposure) can significantly enhance the endogenous production of ROS in deep-sea organisms.

Keywords: deep-sea fish, catalase, superoxide dismutase, glutathione peroxidase

Several reports suggest that marine organisms are exposed to high environmental concentrations of potentially deleterious oxygen derivatives, viz. superoxide anion, hydrogen peroxide. These reactive oxygen species (ROS) are abundant in the upper layers of the oceans, but their concentrations decreases with increasing depth. In deeper regions, the exposure to oxidative stress is considerable lower because of reduced light irradiance, lower oxygen levels; and reduced metabolic activity. ROS can oxidize most cellular constituents, such as DNA, proteins, and lipids, and markedly affect the physiology of the cell, leading to the initiation of cancer and cellular death (1). Consequently, organisms have developed defence systems against oxidative damage, consisting of antioxidant scavengers (glutathione, vitamin C, vitamin E, carotenoid pigments), and specific antioxidant enzymes: catalase (CAT), superoxide dismutase (SOD), and glutathione peroxidase (GPX).

This work was designed as a comparative study on the presence of antioxidant enzymes in coastal (30-50 m) and deep-sea fish (1500-1800 m depth) from the NW Mediterranean. Special attention was paid to the distribution of antioxidant enzyme systems in deep-sea fish species, and whether the reduced danger linked to oxygen toxicity could have lead to a reduction of their biochemical defences against oxidative damage. To test this hypothesis we investigated the activity of the antioxidant enzymes (CAT, SOD, GPX) in the liver of 10 fish species selected on the basis of their abundance, commercial interest and habitat. *Mullus barbatus*, *Serranus cabrilla*, *Serranus hepatus*, *Sparus aurata*, *Diplodus annularis*, *Scorpaena porcus*, and *Solea vulgaris* were collected at 30-50 m depth; *Lepidion lepidion*, *Coryphaenoides guentheri* and *Bathypterois mediterraneus* at 1500-1800 m. The number of individuals analyzed varied between 10 and 70, depending on the species. The methods used for the determination of antioxidant enzymes are described in Porte *et al.* (2).

No significant differences (Anova test, Tukey-Karamer multiple comparisons test, $P>0.05$) between coastal and deep-sea species were observed in terms of SOD activity; the highest activity detected in *S. hepatus* (18.4 ± 2.2 units/mg protein), and the lowest in *S. aurata* (5.4 ± 0.6 units/mg protein). Intermediate values were recorded for deep-sea species (8-14 units/mg protein). SOD converts $O_2^{\cdot-}$ into H_2O_2, which can in turn be detoxified into water and oxygen by either CAT or GPX, which utilizes glutathione as an electron donor. There was a significant correlation ($r=0.85$; $P<0.05$) between the activities of SOD and CAT in the studied species. CAT, which detoxifies H_2O_2 into water and oxygen, was determined in liver cytosol (broken peroxisomes) or in peroxisomes + cytosol (total activity), but no relationship with depth was observed. In agreement with other studies (3), the most active species, from both coastal (*S. aurata*) and deep-sea areas (*L. lepidion, C. guentheri*), showed higher CAT activities than the less active ones, with reduced motility (*S. cabrilla*, *S. porcus*, *B. mediterraneus*).

In contrast, the activity of GPX using H_2O_2 as a substrate decreased with depth. In shallow species, GPX ranged from 74 to 110 nmol/min/mg protein, with the exception of *S. hepatus*, that had an activity of 340 nmol/min/mg protein. Lower activities were recorded in deep-sea specimens (22-40 nmol/min/mg protein) (Fig. 1). The reason for this apparent preference for CAT in deep-sea species might be related to the limited resources available in the deep-sea, and to the fact that CAT requires neither cofactors nor energy to detoxify H_2O_2, while GPX consumes glutathione, which is oxidized and must then be recycled by a NADPH-consuming enzyme (glutathione reductase).

Despite of the reduced metabolic requirements of deep-sea fish species, this study shows that the dangers associated to ROS exposure do not decrease with increasing depth. Other factors, such as habitat, diet, exposure to pollutants, and the presence of swim bladder, can significantly increase the endogenous levels of ROS deep-sea organisms are exposed to (3). Hence, *B. mediterraneus*, a sedentary fish, well adapted to the oligotrophic deep environment, exhibited low activities of both catalase and GPX (both detoxify H_2O_2) in comparison with the other species, and this may be related to the absence of a swim bladder. It is reported that with increasing depth and increasing hydrostatic pressure, most species maintain swim bladder volume constant by increasing mainly its oxygen content that may make up to 90% of the gas mixture in deep-sea fish. Thus, the gas gland tissue operates under conditions of hyperoxia, and this enhances oxyradical production (4).

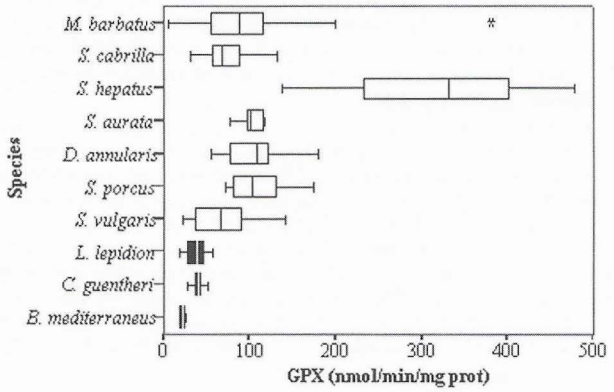

Fig. 1. Box plot of glutathione peroxidase (GPX) activity determined in liver cytosol of different fish species sampled in the NW Mediterranean. Black boxes indicate deep-sea fish species.

References

1 - Cadenas, E., 1995. Mechanisms of oxygen activation and reactive oxygen species detoxification. Pp. 1-61. *In*: Ahmad S. (ed.), Oxidative-Induced Stress and Antioxidant Defences in Biological Systems. Chapman & Hall, NY.

2 - Porte C., Escartín E., García L.M., Solé M., Albaigés J., 2000. Xenobiotic metabolising enzymes and antioxidant defences in deep-sea fish: Relationship with contaminant body burden. *Mar. Ecol. Prog. Ser.*, 192: 259-266.

3 - Wilhelm Filho D., Giulivi C., and Boveris A., 1993. Antioxidant defences in marine fish- I. Teleosts. *Comp. Biochem. Physiol.*, 106C: 409-413.

4 - Jones, D.P., 1985. The role of oxygen concentration in oxidative stress: hypoxic and hyperoxic stress. Pp. 151-195. *In*: Sies H. (ed.), Oxidative Stress. Academic Press, NY.