INFLUENCE OF HYPOXIA EXPOSURE ON THE ENERGY METABOLISM OF COMMON CARP (CYPRINUS CARPIO L.)

by

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ABSTRACT

Hypoxic conditions is a common adverse environmental condition in an aquatic environment. To study the responses of fish to this phenomenon common carp (Cyprinus carpio L.) were exposed to a graded hypoxia load and the oxygen consumption was measured continuously. At 30%AS (air saturation) 20%AS, 10%AS, 5%AS and 3%AS blood, liver and white muscle samples were collected. In the blood, haematological parameters, substrates (FFA, lactate and glucose), as well as the stress hormone cortisol were measured. High-energy phosphorylated compounds and lactate were measured in liver and white muscle tissue. During hypoxia, ATP concentrations and the adenylate energy charge (AEC) remained constant in white muscle, whereas both declined in liver tissue. The critical oxygen tension, which reflects the onset of a physiological or biochemical response at a certain hypoxia load, indicates that rapid changes were recorded in the blood, followed by the liver while white muscle (except for phosphocreatine (PCr)) is rather insensitive to environmental hypoxia. It is concluded that the impaired oxidative phosphorylation is compensated by the creatine kinase equilibrium reaction (depletion PCr pool) and the anaerobic glycolysis (lactate production).

KEY WORDS: common carp, fish, hypoxia, critical oxygen tension, muscle, liver, blood, anaerobic glycolysis, phosphocreatine.

INTRODUCTION

Several studies have been published on the energy metabolism of fish after exposure to anoxic conditions (DiANGELO & HEATH, 1987; VAN WAARDE et al., 1990; VAN RAAIJ et al., 1994). However, little information is available regarding the metabolic responses of fish species to fixed hypoxia levels. This lack of knowledge of physiological and biochemical responses of fish to hypoxic conditions may be disadvantageous because hypoxia is a more common condition in aquatic environments than anoxia. E.g., the oxygen

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concentration of the Dutch surface water has decreased in the period 1978-1989 by 20%, mainly due to pollution with oxygen consuming compounds (AALDERINK, 1991).

The common carp (*Cyprinus carpio*, Linnaeus 1758) is found throughout the world (review KOMEN, 1990). A possible explanation for this cosmopolitan distribution, apart from the eurythermal character of this species, may be the carp's tolerance to hypoxic conditions. For cyprinids the following responses to lowered oxygen concentrations are described. First, an increased respiration frequency and volume of gill ventilation under conditions of hypoxia (GAREY, 1967; LOMHOLT & JOHANSON, 1979; GLASS et al., 1990) in combination with a bradycardia (GAREY, 1967). Second, a depletion of the creatine phosphate pool via the creatine kinase equilibrium reaction to stabilize the ATP pool in white muscle (VAN GINNEKEN et al., 1995a). Third, a depletion of the glycogen pool resulting in the build up of the endproduct lactate (HEATH et al., 1980; ALBERS et al., 1983; HUGHES et al., 1983; FUCHS & ALBERS, 1988). Fourth, the production of anaerobic endproducts like succinate and alanine (JOHNSTON, 1975; SMITH & HEATH, 1980; DRIEDZIC & HOCHACHKA, 1975). These endproducts indicate the role of aminoacids as substrates via a coupling of carbohydrate and amino acid catabolism (VAN DEN THILLART & VAN WAARDE, 1985), although the mechanism may not be quantitatively significant. Fifth, a decrease of the free fatty acid pool in plasma of carp under conditions of hypoxia (MAZEAUD et al., 1977), which may be indicative for a role as substrate of these compounds. And sixth, the strategy of metabolic depression which is important in some species (VAN WAVERSVELD, 1989a, b; VAN GINNEKEN et al., 1994, 1995b, 1996a, b). Two members of the cyprinid family presumably exploit this mechanism, *Rasbora daniconius* (MATHUR, 1967) and the hibernating crucian carp (*Carassius carassius*) (BLAZKA, 1958; HOLOPAINEN & HYVARINEN, 1985). This mechanism may explain their remarkable ability to survive under anoxic conditions for several months.

In this study, we want to elucidate two questions: first, what is the critical oxygen tension for several physiological parameters from blood, liver and white muscle compartment. This is important because the critical oxygen tension gives information about the hypoxia load in relation to the physiological and/or biochemical response of an animal. Second, we intend to elucidate the anaerobic response in carp during a graded hypoxia load.