Available online at www.sciencedirect.com
ScienceDirect
Comparative Biochemistry and Physiology, Part A 146 (2007) 514–519
CBP
www.elsevier.com/locate/cbpa

Seasonal variation of energy metabolism in ghost crab *Ocypode quadrata* at Siriú Beach (Brazil)☆

Anapaula Sommer Vinagre *, Ana Paula Nunes do Amaral, Fabiana Pinto Ribarcki, Eliane Fraga da Silveira, Eduardo Périco

Faculty of Biology, Lutheran University of Brazil (ULBRA), Canoas, Rio Grande do Sul State, Brazil

Received 15 August 2005; received in revised form 27 December 2005; accepted 8 February 2006
Available online 14 February 2006

Abstract

The aim of this study was to analyze the seasonal variations of carbohydrate and lipid metabolism of the ghost crab *Ocypode quadrata* (Fabricius, 1787) on a sandy beach in the southern region of Brazil. Crabs and hemolymph samples were collected monthly in the field. Hepatopancreas, gills, gonads and claw muscles were used for glycogen determination. In males, blood glucose levels increased in the summer and in the winter. The glycogen values increased significantly in the hepatopancreas in the winter, but remained constant in the muscle, gonads and gills. In females, hemolymph glucose levels, glycogen values in the hepatopancreas and in the gills remained constant throughout the year; however, muscular glycogen increased in the spring and gonad glycogen decreased in the summer. Hemolymph triglyceride levels of males and females and total cholesterol of males decreased significantly in the spring. In females, a significant increase of total cholesterol levels was found in the winter. The findings suggest that in *O. quadrata* lipids seem to be an important reserve of energy used during reproduction, both in males and females, while glycogen may be used during periods of intense activity or fasting.

Keywords: Carbohydrates; Cholesterol; Crustacean; Energetic metabolism; Glycogen; Lipids; *Ocypode quadrata*; Seasonal variations; Triglycerides

1. Introduction

The energy metabolism of crustaceans is characterized by high intra- and inter-specific variability, which makes it difficult to determine a standard metabolic profile (Oliveira et al., 2003). This variability is explained by the many environmental variables that the animals are exposed to during the year, depending on the geographical region (Kucharski and Da Silva, 1991b). It is also influenced by the stage of the moulting cycle, sexual maturity, reproductive process, feeding state and activity level (Schirf et al., 1987).

Nutritional deprivation is a natural part of the life cycle of many aquatic organisms as the result of winter torpor, seasonal elimination of a food source or behavioral modifications during mating/spawning. Most species reduce their metabolic rate and deplete protein, glycogen and lipid reserves during nutritional stress (Vinagre and Da Silva, 1992; Oliveira et al., 2004; Comoglio et al., 2005). The relative importance of these reserves and their order of utilization vary with species, recent feeding history, diet composition and length of fast (Schirf et al., 1987; Vinagre and Da Silva, 2002; Oliveira et al., 2003; Ferreira et al., 2005).

Glucose is the main monosaccharide in crustacean hemolymph, and is used for chitin, glycogen, ribose and pyruvate production (Chang and O'Connor, 1983). Stable glucose hemolymph levels are very important for the regular functioning of the nervous, muscular and reproductive systems. Glucose can be accumulated in the form of glycogen in the hepatopancreas and

☆ This paper is part of a special issue of CBP dedicated to "The Face of Latin American Comparative Biochemistry and Physiology" organized by Marcelo Hermes-Lima (Brazil) and co-edited by Carlos Navas (Brazil), Rene Beleboni (Brazil), Tania Zenteno-Savín (Mexico) and the editors of CBP. This issue is in honour of Cicero Lima and the late Peter W. Hochachka, teacher, friend and devoted supporter of Latin American science.

* Corresponding author. Curso de Biologia, Universidade Luterana do Brasil, Av. Farroupilha, 8001, CEP 92450-900, Canoas/RS, Brazil. Tel.: +55 51 3477 9104; fax: +55 51 3477 4000.
E-mail address: apvinagre@uol.com.br (A.S. Vinagre).

1095-6433/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.cbpa.2006.02.004

in other tissues, such as the muscles and the gills (Vinagre and Da Silva, 1992; Oliveira et al., 2003).

In the absence of an adipose tissue in crustaceans, the hepatopancreas seems to be the main site of lipid storage (O'Connor and Gilbert, 1968; Muriana et al., 1993; García et al., 2002), although lipids can also be accumulated in the muscle tissue and in the female gonad (Komatsu and Ando, 1992). In *Chasmagnathus granulatus* (Dana, 1851) for example, Kucharski and Da Silva (1991b) found that total lipids represent more than 20% of the weight of the hepatopancreas.

Egg yolk, the non-organular content of the oocyte, is the major source of nutrients for the developing embryo. Crustacean egg yolk is composed of proteins, mainly a lipoprotein (lipovitellin), lipids, carbohydrate and carotenoids (Avarre et al., 2003). Lipids represent 18–41% of the dry weight of mature ovaries in various crustaceans. These ovarian lipids originate from ingested food, either directly or after storage in the hepatopancreas, and must be transported via the hemolymph to the ovaries (Avarre et al., 2003). According to Oberdörster et al. (2000), lipovitellin is produced in large quantities during crustacean oocyte development. The site of synthesis may be the hepatopancreas or ovary, or both, depending on the species, and it is accumulated in the developing oocytes during primary vitellogenesis (Oberdörster et al., 2000; Tseng et al., 2001; Abdu et al., 2002).

Plasma lipid transport in crustaceans, as in other animals, is carried out by the association with proteins, forming lipoproteins. The main lipoprotein in crustacean hemolymph seems to be HDL (high-density lipoprotein) although LDL (low-density lipoprotein) and VHDL (very high-density lipoprotein) may also be present (Kang and Spaziani, 1995; García et al., 2002; Avarre et al., 2003). García et al. (2002) observed two different forms of HDL in the hemolymph of the shrimp *Macrobrachium borellii*, one that is found in males and females and another HDL, found exclusively in females, during the reproductive season. According to Walker et al. (2003), these lipoproteins are called high-density lipoprotein I (LpI) and II (LpII), and LpI plays an important role in the transfer of lipids from the hepatopancreas to peripheral tissues and in crustacean immune recognition, while LpII, also called lipovitellin, is involved in vitellogenesis and is the major source of energy for the developing embryo (Avarre et al., 2003; Walker et al., 2003).

In *C. granulatus*, a crab that lives in the supralittoral and mesolittoral zones of the salt marshes of the southern Brazilian coast, Kucharski and Da Silva (1991b) described a seasonal pattern of variation in the carbohydrate and lipid metabolism of male animals. In this crab, hemolymph glucose levels were increased in winter and summer and decreased in spring and fall, while the glycogen content in the hepatopancreas and muscle is higher in the fall and winter, and decreases during spring and summer. The muscle lipids are higher in the summer, and decrease during the fall and the winter whereas hepatopancreas lipids are higher, except in the fall.

Oliveira et al. (2003) also found a different pattern of seasonal variation in the energetic metabolism of an anomuran crustacean *Aegla ligulata* (Crustacea: Anomura: Aeglidae). In this freshwater animal, males presented higher glycemic levels than females in the summer, but in the spring females had higher glucose values in the hemolymph. In the autumn, no difference was found between males and females. In spring, the hemolymph glucose levels, both in males and females, were significantly higher than those found in summer, autumn and winter. No seasonal variations in tissue glycogen levels were found in females. The males in winter, however, showed hepatopancreatic glycogen levels 3 and 2,5 times as high as those verified in summer and autumn, respectively.

Ocypode quadrata (Fabricius, 1787), popularly known as the ghost crab, is a cosmopolitan crab, commonly found on sandy beaches along the western Atlantic coast, from Rhode Island in the USA (42°N and 70°W) to Rio Grande do Sul state (30°S and 50°W) in the southern region of Brazil (Melo, 1999; Negreiros-Fransozo et al., 2002). Few studies about the biology of this species have been undertaken in Brazil: two studies in São Paulo state (Negreiros-Fransozo et al., 2002; Fransozo et al., 2002); two in Rio Grande do Sul state, one at Itapeva Beach (Zimmer et al., 2003) and another at Pinhal Beach (Alberto and Fontoura, 1998) and one in Santa Catarina State, at Siriú Beach (Bernardes et al., 2004). According to these studies, adults of *O. quadrata* are mainly found near the dunes, while the younger animals are distributed near the water line. According to Negreiros-Fransozo et al. (2002), the reproductive period of *O. quadrata* at Ubatuba Beach follows a seasonal trend and can extend from October to May.

According to Fales (1976) and Wolcott (1978), *O. quadrata* is a carnivore, feeding on live or dead organic material, mainly *Emerita talpoida* (Say) and *Donax variabilis* (Say) on the coast of North America. Robertson and Pfeiffer (1982) also described that *O. quadrata* can extract up to 70% of the available algae from the substratum, thus demonstrating a deposit-feeding behavior. *O. quadrata* probably alter their feeding behavior according to the food availability of the habitat (Negreiros-Fransozo et al., 2002). Because crabs of the genus *Ocypode* demonstrate high-speed locomotion, they have been studied as models for exercise physiology (Full and Herreid, 1986; Weinstein and Full, 1992; Blikhan et al., 1993; Weinstein, 1995). Since there is little information regarding the nutritional aspects of the physiology and metabolism of *O. quadrata* in its natural environment, the objective of this study was to verify the seasonal variations of its carbohydrate and lipid metabolism on a sandy beach in the southern region of Brazil.

2. Materials and methods

2.1. Experimental animals

Crabs *O. quadrata* (Crustacea, Decapoda, Brachyura, Ocipodidae) (10±2 animals) were collected during the day by

Table 1
Environmental (ET) and water temperatures (WT) in Siriú Beach during the field work

	Summer	Autumn	Winter	Spring
ET (°C)	29.90±1.5 (3)	27.25±2.95 (3)	23.57±1.28 (3)	26.17±1.75 (3)
WT (°C)	22.90±2.0 (3)	22.95±0.95 (3)	19.23±0.28 (3)	20.57±1.44 (3)

Values are expressed as means±S.E.M. The number of data used is indicated in parentheses.