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The effects of thermal amplitude on the growth of Chinese shrimp *Fenneropenaeus chinensis* (Osbeck, 1765)

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Abstract

Effects of thermal amplitude of diel fluctuating temperature on the growth, food consumption, food conversion efficiency and apparent digestibility coefficient of Chinese shrimp, *Fenneropenaeus chinensis* (Osbeck), with initial body weight of 0.36 ± 0.04 g were studied at average temperature 25, 28 and 31 °C from May to July, 2000. Among four diel different fluctuation amplitudes of ± 1, ± 2, ± 3 and ± 4°C, the growth rate of shrimp at 25 ± 2, 25 ± 3, 28 ± 2 and 31 ± 1 °C were significantly higher than those at corresponding constant temperatures of 25, 28 and 31 °C, respectively, while growth rate at 31 ± 4 °C was significantly lower than at 31 °C. There is a trend that the optimal thermal amplitude for shrimp growth decreased with the increase of average temperature in the present study. The growth rate of Chinese shrimp was a quadratic function of the thermal amplitude at the same average temperature. Such a growth model may be described by

$$G = \beta_0 + \beta_1(TA) + \beta_2(TA)^2$$

where G represents the specific growth rate on a 33-day basis, TA is thermal amplitude in degree Celsius, β_0 is intercept on G axis, and β_1 and β_2 are the regression coefficients. The optimal thermal amplitude for the growth of shrimp at sizes of this experiment at average temperature of 25, 28 and 31 °C was estimated to be ± 2.0, ± 2.2 and ± 1.4 °C, respectively. The changes of food conversion efficiency were similar to the growth rate, while the trends of food consumption of shrimp between fluctuating temperature and constant temperature were variable at different average temperatures. There was no significant difference in apparent digestibility coefficient between diel fluctuating temperatures and corresponding constant temperatures. Therefore, more food consumption, high food conversion efficiency and more energy partitioned into growth might account for the enhancement in the growth of shrimp at the diel fluctuating temperatures in the present study.

Keywords: Diel fluctuating temperature; Specific growth rate; Food consumption; Food conversion efficiency; *Fenneropenaeus chinensis* (Osbeck)

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1. Introduction

Studies on the influence of temperature on the growth of aquatic animals have been conducted usually under constant temperature regimes. However, temperatures in natural aquatic systems fluctuate diurnally and seasonally. It is desirable, therefore, to determine whether or not accurate predictions of an animal's response to fluctuating temperature regimes can be made from data gained at constant temperatures. Many studies have been conducted to investigate the effects of fluctuating temperatures on a variety of aquatic ectotherms, such as zooplankton (Halbach, 1973; Van As et al., 1980), bivalves (Widdows, 1976; Pilditch and Grant, 1999) and crustaceans (Dame and Vernberg, 1978; Miao and Tu, 1993, 1996), but most have focused on fishes (Biette and Geen, 1980; Cox and Coutant, 1981; Diana, 1984; Konstantinov et al., 1989, 1996; Lyytikäinen and Jobling, 1998, 1999; Sierra et al., 1999; Zdanovich, 1999; Baras et al., 2000). Due to the differences in species and thermal regimes, the results from different studies were quite different from each other.

Chinese shrimp *Fenneropenaeus chinensis* (Osbeck) is a migratory species mainly distributed in the Yellow Sea, which usually migrates for reproduction and overwintering twice yearly among Bohai Sea, Yellow Sea and East China Sea in their natural life cycles (Ge and Wang, 1995; Miao and Tu, 1995). Thus, not only do Chinese shrimp experience temperatures that fluctuate diurnally and seasonally, but they are normally exposed to varying temperatures when they move in water masses, vertically and horizontally, during feeding, swimming or predator avoidance. Until now, although many investigations on the effects of temperature on the growth of Chinese shrimp have been conducted, most of them focus on the effects of constant temperatures (Zhang et al., 1983; Wang et al., 1984; Miao and Tu, 1995; Zhang et al., 1998) and only a few work with the effect of fluctuating temperature on the growth of the shrimp (Miao and Tu, 1996).

This study was designed to compare the growth of Chinese shrimp at constant temperatures and fluctuating thermal regimes and to determine the effects of amplitude of diel thermal fluctuations at different daily average temperatures on the growth of the shrimp. The study will be helpful to elucidate the influence of fluctuating temperature on penaeid shrimp and its mechanism and promote the integration of theory and practice for the bioenergetics of crustacean.

2. Materials and methods

2.1. Experimental shrimp and acclimation

Chinese shrimp juveniles were obtained from the pond of Hongdao Shrimp Farm, Qingdao, PR China. The shrimp were cultured in aerated fiberglass tanks with seawater and maintained at about 25 °C for least 3 days. Then some of them were transferred into two other tanks to be further acclimated to constant temperature of 28 and 31 °C. The ascending or descending rate was 1.5 °C or so per day. When the final temperature was reached, it was maintained for 3 days to ensure complete thermal adaptation. During acclimation, the shrimp were fed twice daily to satiation with a commercial pellet manufactured by the Mawei Fishery Feed Co. Ltd., Fujian, China (Table 1). A 14 h light : 10 h dark photoperiod was maintained.

2.2. Experimental design and facility

Thermal treatments consisted of 3 constant temperatures, 25, 28 and 31 °C, and 12 diel temperature fluctuations ($t \pm \Delta t$ °C) with daily means of 25, 28 and 31 °C. For treatment of diel fluctuating temperature, temperature fluctuations imitated the natural rhythm of field water temperature at the site of the present experiment (36°1′ N, 120°3′ E) and amplitudes of temperature fluctuations ($\pm \Delta t$ °C) were ±1, ±2, ±3 and ±4 °C, respectively. The minimum temperature ($t - \Delta t$ °C) was set at 0600 hours and was increased gradually to the maximum one ($t + \Delta t$ °C) at 1400 hours, then was decreased to the minimum once again at 0600 hours the next day (refer to Tian et al., 2004b).

The experiment was conducted in a room whose temperature was controlled at 20 ± 0.5 °C using an air conditioner. Four glass aquaria (45 × 25 × 30 cm,

Table 1
Proximate composition (%, mean ± S.E.) of the experimental diet

Protein (%)	Lipid (%)	Ash (%)	Energy (kJ/g)	Moisture (%)
43.39 ± 0.22	9.74 ± 0.30	9.91 ± 005	16.88 ± 0.11	8.41 ± 0.06