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Growth performance of the white shrimp *Litopenaeus vannamei* reared under time- and rate-restriction feeding regimes in a controlled culture system

Alberto J.P. Nunes *, Marcelo V.C. Sá, Esaú Aguiar Carvalho, Hassan Sabry Neto

Instituto de Ciências do Mar (Labomar), Laboratório de Ração e Nutrição de Camarão Marinho (LRNCM), Av. da Abolição, 3207, Meireles, Fortaleza, Ceará, 60.165-081, Brazil

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Abstract

When shrimp prices are low there can be economic pressure to restrict or cease feeding temporarily. Nevertheless, there is little or no information available on the effects of moderate or severe feed restriction on growth performance of *Litopenaeus vannamei*. The present study aimed at evaluating the effect of time- (TR) and rate-restricted feeding (RR) on the growth performance of *L. vannamei* raised in controlled conditions. Three separate experiments were carried out in a clear water rearing system, composed of 500-l tanks. In experiment 1, 2.8±1.20 g shrimp were stocked in 20 tanks at 46 shrimp/m^2. Animals were randomly submitted to four experimental treatments (2, 3, 4, 5 h/day of feed availability) and one control (6 h/day) for 96 days. In experiment 2, 9.1±1.44 g shrimp were stocked in 16 tanks at 36 animals/m^2 and reared for 28 days. Shrimp in the control group were fed to satiation, while in RR treatments feeding rates were reduced to 25%, 50% and 75%. In experiment 3, 9.1±1.95 g shrimp were stocked in eight tanks at 40 shrimp/m^2. The experiment consisted of collecting feed remains at consecutive 1-h intervals, starting 1 h after first feed delivery up to 8 h. Treatments were composed of 9 replicates, each with an uninterrupted observation period of 9 days. In all trials, shrimp were fed a 39.6% crude protein diet delivered in PVC feeding trays. Shrimp performed better in treatments under longer TR periods. Although survival was not affected by TR, yield and weekly growth were significantly higher for shrimp fed longer than 3 h/day. There were no statistical differences in BW when shrimp were fed to apparent satiation versus under a 25% and 50% RR ($P>0.05$). On the other hand, final BW of shrimp fed at 75% restriction was significantly lower ($P<0.05$) than that of shrimp fed to apparent satiation and with 25% restriction. In contrast, under the maximum RR (75%) shrimp showed the poorest feed efficiency and development index ($P<0.05$). Shrimp feed intake was proportional to feed exposure and BW, not ration size. Feed intake occurred in a continuous and uniform fashion over the 8-h feed exposure period. On average, hourly feed intake reached 4.09% BW. The present study has shown that longer and continuous feed exposure periods enhanced shrimp growth performance and feed intake. Also, this study has indicated it is possible to moderately reduce daily feeding rates without detrimental effects in *L. vannamei* survival, growth and feed efficiency.

Keywords: Shrimp; Feeding; Performance; Litopenaeus; Feed restriction

* Corresponding author. Tel.: +55 85 3242 6422x215; fax: +55 85 3242 8355.
E-mail address: albertojpn@uol.com.br (A.J.P. Nunes).

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1. Introduction

Feed is a major expense in farm-raised shrimp production. In shrimp grow-out, farm managers usually adopt feeding tables that provide feed near to apparent satiation and that is available during all day to the animals. However, when shrimp prices are low, there can be economic pressure to restrict or cease feeding temporarily. In shrimp farming, restricted feeding tables target desired FCRs, but may also lead to detrimental growth under adverse culture conditions (Nunes, 2003, 2004). Nevertheless, there is little or no information available on the effects of moderate or severe feed restraint on the growth performance of the white shrimp *Litopenaeus vannamei*.

In manipulative feeding experiments, feed available to the animals can be restricted in two different ways: (1) by decreasing daily feed allotment or (2) by decreasing the time for feeding (Pirhonen and Forsman, 1998). In the first approach, short-term, severe feed restrictions have reduced growth and fillet yield of Atlantic salmon (Einen et al., 1998, 1999), brown trout (Regost et al., 2001), and channel catfish (Bosworth and Wolters, 2005; Weber and Bosworth, 2005).

In the other case, trials on time-restricted feeding are scarce or rare. Alanärä (1992) working with cage-reared rainbow trout concluded that two feeding periods per day, each of about 2 h, are sufficient for optimal growth. In whitefish, Koskela et al. (1997) found that growth among the fish and the length of the feeding period had no significant effect upon feed conversion.

However, these studies have not tested feed-restricted levels in relation to animal apparent satiation, but only continuous or intermittent feed deprivation periods. Also, there is no published work on time- and rate-restricted feeding with penaeid shrimp. In this study, we have hypothesized that it is possible to restrict to some extent *L. vannamei* period of feed exposure and feeding rates without hampering shrimp growth. The present work aimed at evaluating the effects of time- and rate-restricted feeding on the growth performance of *L. vannamei* raised under controlled conditions.

2. Material and methods

2.1. Culture system, shrimp and experimental design

Three experiments were carried out at the indoor shrimp tank facilities of the Laboratório de Ração e Nutrição de Camarão Marinho (LRNCM) located at Instituto de Ciências do Mar (Labomar/UFC), State of Ceará, Brazil. Experiments 1 and 2 investigated the effects of time- and rate-restricted feeding on the growth performance of *L. vannamei*, respectively. Experiment 3 evaluated shrimp feed intake in relation to an excess meal and period of feed exposure.

The clear water rearing system is composed of 71 polypropylene tanks of 500 l in volume (bottom area of 0.57 m^2) arranged in individual cells of four or five tanks. Tanks in each cell were interconnected by a sand filter and an electrical pump which recirculated water at a capacity of 2700 l/h. Constant aeration was supplied by three 2.0-hp blowers. Animals were submitted to a 12 h light cycle, which began at 0630 h and ended at 1830 h.

In experiment 1, shrimp with a mean body weight of 2.8±1.20 g (mean±standard deviation; $n=30$) were stocked in 20 tanks at 46 shrimp/m^2. Animals were randomly submitted to four experimental treatments (2, 3, 4 or 5 h/day of feed exposure) and one control (6 h/day of feed exposure) for 96 days. Shrimp were obtained from a commercial shrimp farm (Artemisa Aqüicultura S.A, Acaraú, Ceará, Brazil) 245 km from the laboratory. Four replicates were assigned to each treatment or control group.

In experiment 2, shrimp of 9.1±1.44 g ($n=160$) from the laboratory's own supply were stocked in 16 tanks at 36 animals/m^2 and reared for 28 days. The experiment was composed of three treatments and one control, each with four replicate tanks. Shrimp from the control group were fed to apparent satiation following adjusted feeding rates based on the maximum meal (MM) determined for *Farfantepenaeus subtilis* (Nunes and Parsons, 2000). The MM is given by the power function $MM=0.0931BW^{0.6200}$, where BW is the shrimp wet body weight. In the experimental treatments, the control group feeding rates were reduced to 25%, 50% and 75% (Table 1).

In experiment 3, shrimp of 9.1±1.95 g ($n=194$) were stocked in 8 tanks at 40 shrimp/m^2. Animals were obtained from the laboratory's own stock. Prior to stocking, all shrimp were individually weighed. The experiment consisted of collecting feed remains at consecutive 1-h intervals, starting 1 h after first feed delivery up to 8 h. Treatments were composed of nine replicates, each with an uninterrupted observation period of 9 days. The time of feed exposure was shifted daily for each tank.

2.2. Feed and feeding

In all experiments, animals were fed a pelleted shrimp feed (Camaronina 35 hp, Purina do Brasil, São