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Influence of Salinity on the Growth and Body Composition of Juvenile Tiger Shrimp, *Penaeus monodon*

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Abstract

Giant tiger prawn dominated the global shrimp aquaculture industry before giving way to Pacific white shrimp in the early 21st century. This study evaluated the influence of salinity on the survival, growth and body composition of early juveniles. They were exposed to salinities ranging from freshwater (0‰) to marine (35‰) under ambient rearing conditions. Response parameters like survival, growth and body compositions were tested over the salinity range of 0, 10, 20, 30, and 35 ‰. The survival obtained was above 95% except in freshwater, wherein total mortality was observed by the third week of rearing. Growth was found to vary with salinity significantly and was found to be higher at 20‰ with an SGR of 7.31. Apart from its role in survival and growth, salinity was found to influence body composition. It was observed that body protein and carbohydrate content showed significant variations with the salinity. The body protein content was high at 20 ‰ with 14.45 mg/100mg wet weight, and carbohydrate of 1.01mg/100mg at 30 ‰. However, variations in lipid, ash, and moisture content did not have any significant difference. Though found insignificant, the lipid content was higher (2.15 mg/100mg) at lower salinity of10‰. The present study provides insights into the possible impact of rearing environment on the physiological and biochemical changes in this species.

Keywords: *Penaeus monodon*, Shrimp farming, Salinity, Growth, Survival, Body composition

1. Introduction

Successful shrimp farming depends heavily on the efficient management of the rearing environment. Several biotic and abiotic factors contribute to this success in production as well as the product quality. Among the abiotic factors, salinity plays a crucial role in survival, growth, maturation, spawning, and distribution of penaeid shrimps (Cheng and Liao, 1986; Ye *et al.*, 2009). Black tiger, *Penaeus monodon*, dominated and accounted for more than half of aquaculture shrimp production until the introduction of Pacific white shrimp *Litopenaeus vannamei*. They are markedly euryhaline and was considered to be one of the most efficient osmotic and ionic regulators among the penaeids (Ferraris *et al*., 1987), and because of this favorable characteristic, they can be farmed in a wide range of salinities. Penaeid shrimp farming is widely recognized as a promising alternative to the marginal farmers of developing countries.

The influence of salinity on the survival and growth were reported in many commercially important penaeids (Zein-Eldin and Aldrich,1965; Nair and Krishnankutty, 1975; Raj and Raj, 1982; Preston, 1985; Harpaz and Karplus, 1991). Black tiger shrimp, *Penaeus monodon*, is known to tolerate salinity from 1 to 57 ‰ (Chen, 1990). Even though they tolerate a wider range of salinities, its iso-osmotic point is 750 mOsm kg^{-1} which was equated to 25‰ (Cheng and Liao, 1986). This indicates that *P. monodon* is under osmotic stress when exposed to extreme salinities; it exhibits hyper-osmotic regulation at low salinities and *vice versa*. In tiger shrimp, salinity impact on the immune system and susceptibility to pathogens were also reported (Joseph and Rosamma, 2020).

Comparatively, meager studies were done on the influence of salinity on body composition of penaeids. However, reports were available on body composition such as protein (Dallavia, 1986; Ferraris *et al.*, 1986; Penaflorida, 1990; Fang *et al.*, 1992), lipid (Gaury *et al.*, 1974; Colvin, 1976; Clarke and Wikins, 1980), and carbohydrates (Maghraby *et al.*, 1976; Hall, 1988) composition in shrimp meat. The lower salinity was found to affect the physiology of the marine shrimp, and thereby survival (Jiang *et al.*, 2000). Li *et al.* (2017) extensively reviewed the physiological changes in the Pacific while shrimp reared under low saline conditions.

Though the black tiger farming is now in a dormant phase, it has the potential to emerge again as the primary species. The results of selective breeding and SPF production are critical to its revival. As per the recent Food and Agriculture Organization data, only 0.7 million tons (9%) of aquacultured tiger prawns were produced when compared to 4.1 million tons (53%) of white leg shrimp (FAO, 2018). The present study was aimed at evaluating the influence of variation in salinity on the survival, growth and body composition of the juvenile tiger shrimp.

2. Materials and Methods

The postlarvae (PL-24) of *P. monodon* were procured from commercial tiger shrimp hatchery and maintained at the wet lab of CMFRI at Kochi. Each experimental container of 70-liter capacity was stocked with forty postlarvae. The study was conducted for thirty days (PL30 to PL60) duration in triplicate with a completely randomized block design with frequent sampling for growth. The samples were blotted to remove excess water before weighing in the electronic balance.

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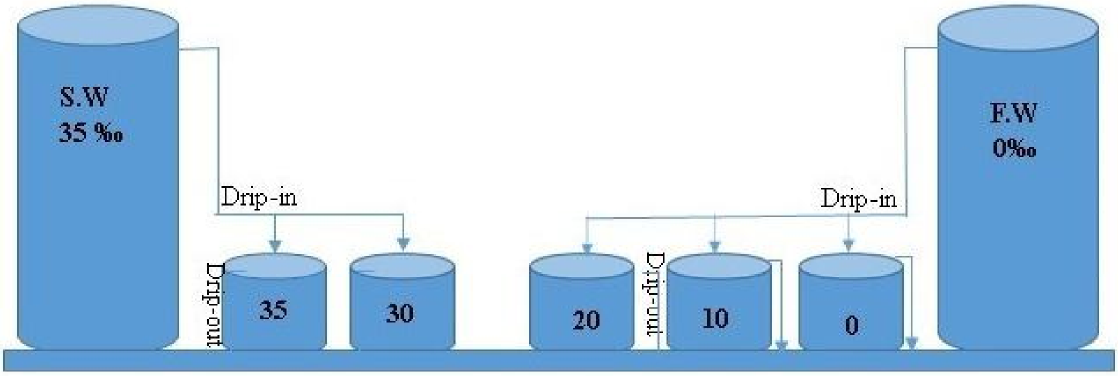

Fig. 1. Acclimatization set-up used for *Penaeus monodon* postlarvae (initial salinity 23‰)

Postlarvae were exposed to a linear increase or decrease from the initial 23 ‰ to the desired salinity over a period of 5 days @ 4-5 ‰ per day (Fig. 1). In a preliminary test, complete mortality was observed in 0 ‰, and 75% mortality in 10 and 35 ‰ within three days when the acclimatization was done within a day. Hence, modified linear acclimatization technique developed can be used for increasing or decreasing salinity or any other water parameter gradually without affecting the organism. The stored water was passed through a narrow tube, which had a valve to regulate flow of water. Simultaneously an out-flow was also setup to regulate the water level to allow gradual variation in water parameters. Source water was replenished at regular intervals to maintain water flow (Fig.1).

The water parameters were continuously monitored and sufficient water exchange was done. The postlarvae were fed twice a day with a commercial feed (Higashimaru feeds, 39% crude protein). Random samples of thirty-six postlarvae per treatment were taken on weekly intervals to assess growth. The biochemical analyses were carried out for total protein (Lowry *et al.*, 1951), total carbohydrate (Dubois *et al.*, 1956), and total lipid (Barnes and Blackstock, 1973). The moisture and ash were determined by conventional methods (AOAC, 1990). Statistical analysis was carried out by using one way ANOVA at p<0.01 level.

3. Results and Discussion

The acclimatization procedure and its duration are critical factors that ultimately decided the survival in the present study; it may also have influenced growth by limiting the stress factors, which is detrimental in the normal growth and development. In the present study, a modified linear variation technique was used. Though similar salinity gradient was used in an earlier study the method adopted was not described (Ye *et al.*, 2009). Survival of postlarvae was high at tested saline treatments; however, in the freshwater acclimatized postlarvae, total mortality was observed. Among the tested salinities, brackishwater, *i.e.*, 10 to 30 ‰, showed higher survival of 97.5 %, whereas it was slightly lower under marine conditions (35 ‰) at 96.7%. In the freshwater acclimated postlarvae, the mortality increased gradually, and the total loss was observed by the end of the third week. The survival rates of black tiger shrimp, early juveniles at different salinities were given in Table 1.

The higher survival rates indicate the efficiency of the new acclimatization procedure. The mortality in the case of 0‰ was because of certain unknown factors and mostly occurred during moulting or just after that, which indicates the ionic imbalances in the rearing media and consequent physiological stressors. The cannibalistic behaviour observed under freshwater conditions further justify these nutrient imbalances. These results imply that the survival was independent of salinity except in the extremely low salinities under controlled conditions. In *P. monodon* higher mortalities were reported in juveniles when salinity is below 5‰ (Ye *et al.*, 2009). The higher survival and growth in 15 to 25 ‰ was observed for *P. monodon* by Raj and Raj (1982). However, Rajalakshmi and Chandra (1987) reported higher survival at 15‰. The least survival obtained in the highest (35‰) and the lowest (0‰) salinities suggest a lack of adaptation of *P. monodon* juveniles to extreme variations.

The growth study showed significant variation among tested salinities in terms of both length and weight (p< 0.01). Postlarvae reared at 20 and 30 ‰ salinities had

Table 1. Survival and growth of Penaeus monodon reared at varying salinities

Salinity (‰)	Total protein (mg/100mg)	Total lipid (mg/100mg)	Total carbohydrate (mg/100mg)	Moisture (%)	Crude ash (%)
35	7.67±0.61[c]	1.76±0.40	0.71±0.05 [a]	74.11±1.4	5.09±0.6
30	8.29±0.24 [c]	1.91±0.32	1.01±0.06 [c]	74.11±1.2	4.84±0.6
20	14.45±0.54 [a]	1.82±0.12	0.76±0.01 [ab]	74.03±1.1	4.84±0.5
10	12.28±0.71[b]	2.15±0.26	0.83±0.01 [ab]	77.43±3.6	3.88±0.8

Different superscripts indicate significant difference using ANOVA (P< 0.01)
0 ‰ observed complete mortality after 20 days of rearing

higher weight gain and consequent specific growth rate (SGR) of 7.31 and 7.03, respectively (Table 1). But the weight gain was comparatively lower in 35 and 10 ‰ (Fig. 2). The growth in total length was maximum at salinities 30 ‰ and 20 ‰ with 0.597 mm and 0.565 mm increase per day and was lower in 35 and 10 ‰ salinities. The higher growth obtained at 20-30‰ was in line with the life-history traits reported for the species, such as migration. As per Cheng and Liao (1986) the iso-osmotic point of tiger shrimp was within this range. Ye *et al.*, (2009) also reported optimum growth, survival, and feed conversion ratio of *P. monodon* at a similar salinity range. They attributed higher growth and survival to the lower portion of the energy utilized for respiration and excretion. However, in the present investigation growth was superior at higher salinities of 30-35‰ until PL 45, which was later shifted to lower salinities during the estuarine migration phase.

The growth varied significantly with salinity and had better SGR at 20 ‰ and 30 ‰. Variation in salinities influences the physiological responses and which ultimately affects survival and growth (Young *et al.*, 1989). The poor growth obtained in lower salinities tested was in contradiction to that obtained by Pantastico and Oliveros (1980), and Deshimaru *et al*. (1985). In contrast, Cawthorne (1983) got the highest survival and growth in full-strength seawater. According to Cheng *et al*. (2005), *L. vannamei* reared at low salinities; weight gain was lower than those maintained in seawater.

After the termination of the experiment, postlarvae were analyzed for their protein, carbohydrate, lipid, ash, and moisture contents (Table 2). Results clearly show a significant difference in body protein with the salinity P<0.01). The total protein showed a steady increase from 35 ‰ down to 20 ‰, and it then declined at 10 ‰ salinity. The total proteins on a wet weight basis were 7.69, 8.29, 14.45, and 12.28 mg/100mg for 35, 30, 20 and 10 ‰. The total carbohydrates showed a significant difference, and the highest value was at 30 ‰, followed by 10 ‰ with 1.61 and 0.83 mg/100mg, respectively. Total lipid content didn't vary significantly with salinity; the values obtained are 1.71, 1.91, 1.82, and 2.15 mg/100mg for 35, 30, 20, and 10 ‰. No significant differences were observed in the ash and moisture levels. The moisture showed the highest value at 10 ‰, and the crude ash was high at 35 ‰.

The information on the body composition gives proper guidelines to the maintenance of an optimum environment and proper diet for the organism. Huang *et al.* (2004) found that the biochemical composition, lipids, and proteins of penaeid shrimp varies with salinity. The highest value of body protein was obtained at 20‰ which is in conformity to the better growth observed. A similar decrease in body protein to increasing salinities were reported in *Litopenaeus vannamei* (Li *et al*., 2007; Perez-Velazquez *et al.*, 2007). Chen *et al.* (1994) reported lower haemolymph protein with an increase in salinity. However, contrasting results were also reported in the same species (Huang *et al.*, 2004; Liang *et al.*, 2008). Ferraris *et al.* (1986) concluded that salinity might not be an essential factor in determining protein concentration on the hemolymph except in unusually high or low salinities. In

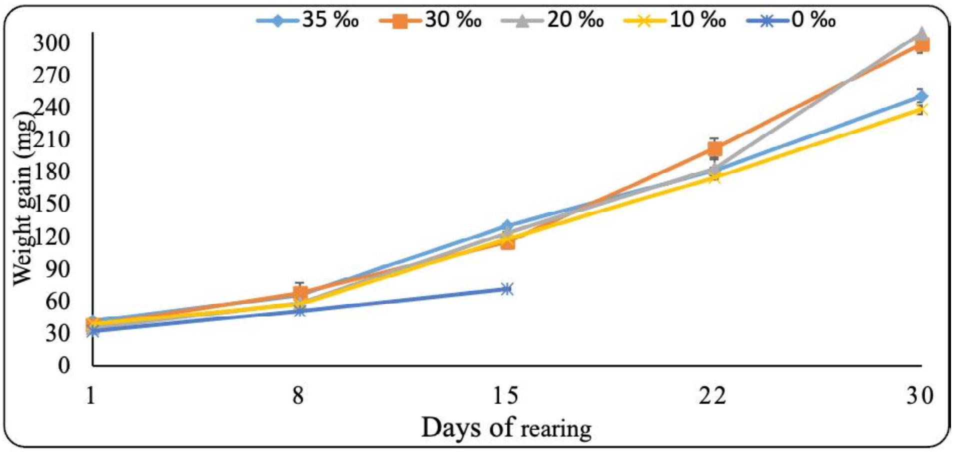

Fig. 2. Effect of salinity on weight gain of juvenile *Penaeus monodon*

Table 2. Body composition of *Penaeus monodon* reared at different salinities

Salinity (‰)	Survival (%)	Weight gain (mg)	SGR	Length gain (mm/day)
35	96.7±1.4	209.7±0.4	6.0±0.2[a]	0.49±0.01[a]
30	97.5±2.5	271.4±0.8	7.0±0.1[b]	0.60±0.00[b]
20	97.5±2.5	274.3±0.1	7.3±0.1[b]	0.57±0.01[b]
10	97.5±0.0	199.3 ±0.4	6.0±0.1[a]	0.48±0.00[a]

Different superscripts indicate significant difference using ANOVA (P< 0.01) the present investigation the carbohydrates showed significant difference between treatments and lipid values were found insignificant. The highest values for these nutrients were obtained at 30 ‰. However, these components were found to be independent of salinity in *L. vannamei* (Li *et al*., 2007; Liang *et al*., 2008).

The moisture content was influenced by salinity (Kalyanaraman, 1983); higher water content was observed in *P. indicus* at lower salinity of 5 and 10 ‰. Ferraris *et al*. (1986) recorded variations in tissue water content with moult stages and salinity in *P.monodon*. An inverse proportion between salinity and moisture content in the tissue was reported by Parado-Estepa *et al.* (1987). In the present study, though insignificant moisture content varied with salinity, it tends to decrease with an increase in salinity. Similar results were obtained in other penaeids (Huang *et al*., 2004; Liang *et al.*, 2008).

The study indicates that *P. monodon* grows best at 20 ‰ salinity during the first month of culture with good protein retention. This information is essential as it indicates variation in the growth of tiger prawns with its rearing environment. So it is advisable to use feeding protocols as per the rearing environment for improving production. At 30 ‰ salinity, even though the growth was comparable, protein retention was found to be lower, affecting the nutritive value of the product. Results also indicate the possibility of culturing the species during the monsoon period, which otherwise is off-season along the southwest coast of India. If proper acclimatization to lower salinities around 5 ‰ was done, the animals can withstand further reduction in salinity during the season. It is advisable to study the physiological changes during lower salinities and develop suitable culture protocols to suit the new regime.

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