p-ISSN. 2406-9825
e-ISSN. 2614-3178

Acta Aquatica: Aquatic Sciences Journal, 11:3 (December, 2024): 256-260

Acta Aquatica
Aquatic Sciences Journal

Laju metabolisme pasca larva udang vanamei (*Litopenaeus vannamei*) dalam hal konsumsi oksigen dan eksresi amoniak pada salinitas berbeda

The post-larval metabolism rate of vannamei shrimp (*Litopenaeus vannamei*) in terms of oxygen consumption and ammonia excretion at different salinities

Received: 11 June 2024, Revised: 04 September 2024, Accepted: 09 November 2024
DOI: 10.29103/aa.v11i3.16649

Burhanuddin[a], Abdul Malik[a]*, Abdul Haris[a], Asni Anwar[a], dan Eva Ayuzar[b]

[a] *Department of Fisheries, Faculty of Aquaculture Study Program, University of Muhammadiyah Makassar, Jalan Sultan Alauddin No. 259, Rappocini, Kota Makassar 90221, South Sulawesi, Indonesia*
[b]*Department of Aquaculture, Faculty of Agriculture, Universitas Mulikussaleh, Aceh Utara.*

Abstrak

Perkembangan budidaya udang vanamei (*Litopenaeus vannamei*) masih banyak menemui permasalahan. Salah satu diantaranya adalah ketersediaan benih yang pertumbuhannya lambat dan bervariasi, serta mortalitas yang tinggi setelah ditebar di tambak. Tujuan penelitian ini adalah untuk melihat laju metabolisme pasca larva udang windu dalam hal konsumsi oksigen dan ekskresi amoniak pada salinitas berbeda. Penelitian telah dilaksanakan Nopember – Desember 2023 di unit Tambak Intensif Takalar, pasca larva udang vanamei dengan kepadatan 100 ekor/l dipelihara untuk pengaklimasian selama dua minggu dalam bak berisi air media bersalinitas 10, 20, dan 30 ppt. Diakhir masa aklimasisasi udang uji, respirometer disiapkan untuk pengukuran konsumsi oksigen dan ekskresi amoniak. Hasil penelitian menunjukkan nilai rata-rata konsumsi oksigen pasca larva udang vanamei terjadi pada salinitas 10 ppt, kemudian disusul berturut turut pada salinitas 30 dan 20 ppt. Hasil analisis sidik ragam menunjukkan salinitas berpengaruh sangat nyata (P<0,01) terhadap konsumsi oksigen pasca larva udang vanamei, tetapi dalam uji lanjut LSD rupanya hanya perlakuan 10 ppt yang berbeda sangat nyata (P<0,01) dan hasil yang sama terjadi pada eksresi amoniak, meskipun dalam uji sidik ragam (LSD) tidak berpengaruh nyata. Tingkat Kelangsungan Hidup dan pertumbuhan pasca larva udang vanamei mencapai nilai rata-rata tertinggi pada salinitas 20 ppt dengan hasil sidik ragam yang sangat berbeda nyata. Berdasarkan hasil pengukuran diatas laju metabolisme optimum pasca larva udang vanamei terjadi pada salinitas 20 ppt (kondisi isotonik terjadi antara cairan tubuh udang dengan medianya).

Kata kunci: *Ekskresi Amoniak; Laju Metabolisme; Konsumsi Oksigen; Udang vanamei*

Abstract

The development of vannamei shrimp (*Litopenaeus vannamei*) cultivation still faces many problems. One of them is the availability of seeds whose growth is slow and variable, as well as high mortality after being stocked in ponds. This study aimed to examine the post-larval metabolic rate of tiger prawns in terms of oxygen consumption and ammonia excretion at different salinities. The research was carried out November - December 2023 in the Takalar Intensive Pond Unit, after which vannamei shrimp larvae with a density of 100 individuals/l were reared for acclimation for two weeks in tanks containing media water with a salinity of 10, 20 and 30 ppt. At the end of the acclimation period for the test shrimp, a respirometer was prepared to measure oxygen consumption and ammonia excretion. The results of the research showed that the average value of oxygen consumption after vannamei shrimp larvae occurred at a salinity of 10 ppt, then followed respectively at a salinity of 30 and 20 ppt. The results of the analysis of variance showed that salinity had a very significant effect (P<0.01) on oxygen consumption after vannamei shrimp larvae, but in the LSD follow-up test it appeared that only the 10 ppt treatment was very significantly different (P<0.01) and the same results occurred. on ammonia excretion, although the test of variance (LSD) had no significant effect. The survival rate and post-larval growth of vanamei shrimp reached the highest average value at a salinity of 20 ppt with very significantly different variance results. Based on the measurement results above, the optimum metabolic rate after vannamei shrimp larvae occurs at a salinity of 20 ppt (isotonic conditions occur between the shrimp's body fluids and the medium).

Keywords: Ammonia Excretion; Metabolism Rate, Oxygen Consumption; Vanname Shrimp

***** *Korespondensi: Department of Fisheries, Faculty of Aquaculture Study Program, University of Muhammadiyah Makassar. Indonesia.*
Tel: +62-85255306454
e-mail: malik@unismuh.ac.id

1. Introduction

The development of vannamei shrimp (*Litopenaeus vannamei)* farming continues to face challenges that often limit the success of the industry. One conventional problem is the availability of seeds with slow and variable growth rates, as well as high mortality rates after being released into ponds. This occurs despite efforts to provide commercial feed and utilize proper farming techniques, such as manipulation and control of environmental water quality, especially salinity. According to Armis *et al.* (2017) and Alfionita *et al*. (2019), farmers and stakeholders have limited knowledge about the biology of penaeid shrimp (including vannamei shrimp) concerning water quality parameters like salinity, which significantly affects the osmoregulation process (metabolic rate in terms of oxygen consumption and ammonia excretion).

Research on the osmoregulatory behaviour of crustaceans concerning salinity changes has been documented by several researchers on various penaeid shrimp species, such as *Penaeus marguensis*, *P. indicus*, and *Litopenaeus vannamei* (Alavandi, 2019; Chen, *et al*, 2019, and Chen. *et al*, 2020). Their discussions speculate that high mortality rates and slow shrimp growth outside the optimal salinity range, particularly at high salinity levels, are due to the high energy used in the osmoregulation process. Unfortunately, the researchers' information does not provide metabolic rate data, which can be determined through oxygen consumption (Li and Graham, 2018).

Furthermore, in 2013, a breakthrough emerged regarding research on the relationship between oxygen consumption and shrimp size conducted by Suwoyo, *et al*. (2013). However, the data was considered less representative because the method used was the incubation method, which has many weaknesses, such as oxygen diffusion occurring when the test animals are placed in the respirometer. According to Liao and Huang (2015) and McLean, *et al* (1993), oxygen consumption measurements in aquatic animals, such as penaeid shrimp, must be conducted with a closed water flow system (to prevent diffusion).

Subsequent developments have led to the improvement of research on oxygen consumption concerning salinity using a closed water flow respirometer system on Penaeus indicus and Penaeus monodon (Anan *et al*., 2019). However, this research did not include data on ammonia excretion, even though metabolic rates are simultaneously related to oxygen consumption and ammonia excretion. While there is information on ammonia excretion research, it is partial and limited to studies on shrimp such as *Crangon crangon* and *Penaeus esculentus* (Anderson, *et al.,* 2017).

Based on the explanation mentioned earlier, a study on metabolic rates related to the measurement of oxygen consumption and ammonia excretion concerning salinity needs to be conducted. This research aims to observe the metabolic rate of post-larval vannamei shrimp in terms of oxygen consumption and ammonia excretion at different salinities (10, 20, and 30 ppt).

2. Materials and Methods

This research was conducted from November to December 2023 at the Takalar Intensive Shrimp Farming Unit and the Water Quality Laboratory of the Fisheries Department at Hasanuddin University, Makassar. The study comprised three treatments and three replications using a Completely Randomized Design (CRD), resulting in nine experimental units (Sari, *et al*., 2023). In this study, post-larvae of vannamei shrimp with a density of 100 individuals/l were acclimated for two weeks in a 50-litre basin filled with 30 litres of water at salinities of 10, 20, and 30 ppt. At the end of the acclimation period, a respirometer was prepared for measuring oxygen consumption and ammonia excretion (based on the combined guidelines of Anggoro *et al*., 2018a; and Anggoro *et al*., 2018b). The metabolic rate parameters observed in this study included oxygen consumption. Supporting data collected during maintenance included observations of survival, growth, and several water quality parameters.

Oxygen consumption was measured following the guidelines of Anggoro *et al*. (2018a) as follows:

$$Oxygen\ consumption\ (ml\ o_2/g/hour) = \frac{(DO\ A - DO\ B)\times flow\ rate}{shrimp\ mass}$$

Notes:
DO A = dissolved oxygen in the respirometer without test shrimp (mg/l)
DO B = dissolved oxygen in the respirometer with test shrimp (mg/l)
Flow rate is expressed in l/hour, shrimp mass in grams (g), and ml O2/g/hour is obtained from converting ppm (mg/l) O2/g/hour x 0.7 (Anggoro *et al*, 2018b).

Ammonia excretion was calculated as follows:

$$Ammonia\ excretion\ (mg\ NH_3/g/hour) = \frac{(NH_3A - NH_3B)\times flow\ rate}{shrimp\ mass}$$

Notes:
NH_3A = ammonia concentration in the respirometer with test shrimp
NH_3B = ammonia concentration in the respirometer without test shrimp
Flow rate is expressed in l/hour, shrimp mass in grams (g), and ml NH3/g/hour is obtained from converting ppm (mg/l) NH3/g/hour x 0.7 (Anggoro *et al*, 2018b).

The survival rate was calculated based on the guidelines of Effendie (2003):

$$SR\ (\%) = \left(\frac{Nt}{No}\right) \times 100$$

The daily biomass growth rate was calculated using the specific growth rate formula (Hopkins e*t al*, 1991):

$$SGR\ (\%) = \left(\frac{\ln wt - \ln wo}{t}\right) \times 100$$

Water quality parameters measured included dissolved oxygen, temperature, pH, and ammonia. To determine the effect of treatments, an analysis of variance (ANOVA) was conducted (Anita *et al*., 2018). If a significant effect was found, it was followed by the Least Significant Difference (LSD) test.

3. Results and Discussion

3.1. Results

The average oxygen consumption values of vannamei shrimp post-larvae can be seen in Table 1 below:

Table 1
Average Oxygen Consumption (ml O_2/g/hour) of vannamei shrimp post-larvae (*Litopenaeus vannamei*) for each treatment

Treatment Salinity (ppt)	1	2	3	Average
10	0,15	0,16	0,12	$0,14^a$
20	0,04	0,03	0,04	$0,04^b$
30	0,05	0,05	0,04	$0,05^b$

ab = different letters in the same column indicate significantly different average values (P < 0.01).

Table 1 shows that the highest average oxygen consumption of vannamei shrimp post-larvae occurred at a salinity of 10 ppt, followed by 30 ppt and 20 ppt, respectively. Analysis of variance indicated that salinity had a highly significant effect (P < 0.01) on the oxygen consumption of vannamei shrimp post-larvae. However, the LSD test revealed that only the 10 ppt salinity treatment had a significantly different average oxygen consumption (P < 0.01) compared to the other two salinity treatments. Previous studies (Valderama *et al*., 2017) on the effect of salinity on oxygen consumption in *P. aztecus* and Anan *et al*. (2019) on the effect of salinity on the metabolic rate of oxygen consumption in *P. indicus* showed similar results, where the lowest oxygen consumption occurred at 20 ppt salinity. Below and above this salinity level, oxygen consumption increased, especially at low salinity. However, compared to *P. indicus, P. merguiensis*, and *P. monodon*, the euryhalinity of vannamei shrimp is slightly lower (Salsabiela, 2020). The average survival rate (SR) and specific growth rate (SGR) of vannamei shrimp post-larvae for each treatment are presented in Table 2:

Table 2
Average survival rate (SR) and specific growth rate (SGR) of vannamei shrimp post-larvae (*Litopenaeus vannamei*) for each treatment

Treatment Salinity (ppt)	SR (%)	SGR (%/day)
10	61,3[a]	0,84[a]
20	88,0[b]	7,77[b]
30	74,7[c]	3,24[c]

abc = different letters in the same column indicate significantly different average values ($P < 0.01$).

Despite the lowest oxygen consumption (Table 1) and ammonia excretion (Table 3) at 20 ppt salinity, the average survival rate and specific growth rate of vannamei shrimp post-larvae were the highest, with significant differences ($P < 0.01$) compared to the other salinity treatments. On the contrary, at 10 ppt salinity, where both oxygen consumption (Table 1) and ammonia excretion (Table 3) were highest, the average survival rate and growth were significantly the lowest ($P < 0.01$) (Table 2). Several researchers (Jia *et al*., 2014; Kiruthika *et al*., 2018; Maicá *et al*., 2014) have reported and confirmed these findings that penaeid shrimp (*P. monodon, P. merguiensis, and L. vannamei*), as marine animals spending their juvenile stages in estuarine areas, exhibit higher metabolic rates, specifically osmoregulation, at lower salinities compared to their natural environmental salinity range of around 20 ppt. Similar findings were reported by Anderson, e*t al*. (2017) studying the effect of salinity on the metabolic rate of *Palaemonetes* varians.

Saptiani *et al*. (2012) claimed that salinity changes induce differences in osmotic pressure between the animal's body fluids and its medium, resulting in increased energy usage marked by increased oxygen consumption rates. They also stated that the lowest oxygen consumption rate is achieved at optimal salinity. Saptiani and Pabrianto (2013) and Selvam *et al*. (2012) argued that maximum growth in animals should occur in an isosmotic (isotonic) medium, as the animal would not expend energy on osmotic work. Although this argument was rejected by Valderama *et al*. (2017) in their study on the giant freshwater prawn (*Macrobrachium rosenbergii*) and not entirely accepted by Jia *et al*. (2014) due to the complexity of growth factors, recent studies on post-larval tiger shrimp and vannamei shrimp support this hypothesis. It is strongly suspected that 20 ppt salinity is the optimum salinity for vannamei shrimp post-larvae, where an isotonic condition occurs between the shrimp's body fluids and its medium (Bagheri *et al*., 2010).

The following Table 3 presents the average ammonia excretion values of vannamei shrimp post-larvae.

Table 3
Average Ammonia Excretion (mg NH_3/g/hour) of vannamei shrimp post-larvae (*Litopenaeus vannamei*) for each treatment.

Treatment Salinity (ppt)	1	2	3	Average
10	0,0014	0,0019	0,0009	0,0014[ns]
20	0,0004	0,0004	0,0004	0,0004[ns]
30	0,0010	0,0010	0,0009	0,0010[ns]

ns = non-significant ($P > 0.01$).

Similar to oxygen consumption (Table 1), the average ammonia excretion increased at salinities above and below 20 ppt. Although salinity did not significantly affect ($P > 0.05$) ammonia excretion, the average values were consistent with oxygen consumption (Table 1), survival rate, and growth (Table 2), where higher oxygen consumption corresponded with higher ammonia excretion, and the best conditions occurred for survival and growth. The ammonia measurement data during the acclimation period in the adaptation containers showed a relatively uniform range across the different salinity treatments (10, 20, and 30 ppt), with values ranging from 0.07 to 0.12 mg/l. According to Saptiani *et al*. (2012) and Anggoro (2012), this range is still within tolerable limits for shrimp.

3.2. Discussion

From several previous studies, the relationship between ammonia excretion and salinity has not been widely reported. The available research information primarily covers the correlation between ammonia excretion and shrimp size (Saptiani and Pabrianto, 2013; Selvam, *et al*., 2012). They reported that ammonia excretion in shrimp significantly varies with size; smaller tiger shrimp (1.6 g) excrete 0.93 mg NH_3/g/day, while larger shrimp (27 g) excrete 0.30 mg NH_3/g/day. It was further explained that smaller shrimp excrete more ammonia than larger shrimp based on unit body weight. Other information on ammonia excretion was reported by Saptiani *et al*. (2012) concerning the relationship between ammonia excretion and starvation in Crangon crangon shrimp, where starved shrimp tended to have increased ammonia excretion, reaching 30% above control values. Furthermore, Saptiani and Pabrianto (2013) and Selvam *et al*. (2012) reported that, unlike oxygen consumption, ammonia excretion in P. esculentus increased by approximately 46-73% with starvation.

From the above explanation, it seems that this research complements previous studies, providing more complex data on metabolic rate relationships, including both oxygen consumption and ammonia excretion simultaneously.

4. Conclusion

Based on the measurements of oxygen consumption, ammonia excretion, survival rate, and growth, it is suspected that the optimal metabolic rate for vannamei shrimp post-larvae occurs at a salinity of 20 ppt, where an isotonic condition exists between the shrimp's body fluids and the medium. As marine animals, vannamei shrimp post-larvae find it more challenging to adapt to low salinities below the optimal level than to high salinities above the optimal level.

Acknowledgement

With the completion of this research and the writing of this scientific article, the author would like to thanks the Head of the Intensive Shrimp Farming Unit in Takalar and the Head of the Water Quality Laboratory at the Department of Fisheries, Hasanuddin University, Makassar. Gratitude is also extended to the Rector, Dean, and Head of the Aquaculture Program at the Faculty of Agriculture, Muhammadiyah University, Makassar, as well as fellow researchers, lab technicians, and the crew of the intensive shrimp farming unit in Takalar.

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