High density aquaculture of white shrimp (*Litopenaeus vannamei*) in controlled tank

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**Abstract.** The study was aimed to evaluate the growth, survival rate and production of white shrimp (*L. vannamei*) culture under different stocking density in controlled tank. This research was conducted at Experimental Pond Installation. Research Institute for Coastal Aquaculture and Fisheries Extension in Maros Regency, South Sulawesi. Indonesia. Juveniles of white shrimp size in weight 0.14 g/ind were cultured for 70 days in three different stocking densities: 100, 200 and 300 ind/m$^3$ in a total of nine fibre tanks sized of 2 m$^3$. The study used Completely Randomized Design (CRD), with three replications for each treatment. The parameters observed were growth rate, survival rate, production, feed conversion ratio of white shrimp and water quality condition. The results showed that the different stocking density had a significant effect ($P < 0.05$) on growth, survival rate and production of white shrimp. The final weight and absolute weight of vaname shrimp decreased as density increased to 300 ind/m$^3$. The final weight of vaname shrimp in treatments A, B and C were 13.70 g/ind, 12.27 g/ind and 10.90 g/ind respectively. Survival rate and production of white shrimp in this study ranged from 80-95% and 1.24-2.42 kg/m$^3$ respectively. Water quality measured during the experiment was suitable for the growth of white shrimp.

**1. Introduction**

White shrimp (*Litopenaeus vannamei*) is one of the main fishery products in fisheries sector. It has many advantages, such as the ease of its farming, stable production, available in high stocking density, and resistance to diseases. Thus, most farmers in Indonesia choose to cultivate vannamei shrimp. Moreover, there are still other advantages of vanamei shrimp, namely its *euryhaline* characteristic [1]. Since white shrimp is introduced as one of the aquaculture commodities in Indonesia, the performance of shrimp farming has shown an increase in production, especially through intensive technology. The development of white shrimp farming has penetrated into national shrimp farming centers, such as East Java, Central Java, West Java, Yogyakarta, Lampung, West Borneo, West Nusa Tenggara, Bali, and South Sulawesi [2, 3].

Land potential for its farming by applying intensive technology is limited and requires a relatively high investment. Besides intensive farming technology, shrimp farming with a super-intensive system and high stocking density is used. Such method requires more facilities and infrastructure, cost-consuming, and high production, but with a large risk of failure. The growth and survival depend on density, which is a typical response in intensive shrimp farming due to a combination of several factors, including decreased availability of natural feed sources and space, increased cannibalism, decreased water quality, and unwanted accumulation of organic matter in bottom sediments [4]. states that a very high increase in shrimp density in an intensive system causes a reduction in biomass yield due to low survival and growth [5]. Response to high stocking density in intensive shrimp farming system is to show that high stocking density causes stress and affects shrimp growth performance [6]. Super-intensive and intensive shrimp farming are not possible for small communities because it requires high capital. However, technically, it can be done using a small tank based on the capital.
This farming technology can be carried out on land that is not large, such as in the farmer’s yard so that this system can be categorized as a household business. This farming system aims to create jobs for fishermen/farmers and their families, to reduce unemployment, to increase income, and to improve the economy of coastal communities. Thus, this research focuses on high stocking density white shrimpfarming in controlled tank to complement sustainable household-scale farming technology without being much influenced by place, time, and season. The objectives of this research were to evaluate the growth, survival, and production performance of white shrimp (L. vannamei) in controlled tank at different stocking densities.

2. Materials and Method

2.1. Location
The research was carried out at the Experimental Pond Installation, Research Institute for Brackishwater Aquaculture and Fisheries Extension in Mattirotasi Village, Maros Regency, South Sulawesi. This research used 9 units of 2,000 L, cylinder-shaped fiber glass tank equipped with an aeration system.

2.2. Research preparation and experimental treatment
The testing animal used was PL-42 white shrimp with an average initial weight of 0.14 g/ind. This study was designed using a completely randomized design with stocking density treatment of A = 100 ind/m³, B = 200 ind/m³, and C = 300 ind/m³ each in three replications. They were fed 4 times a day at a dose of 2-10% of the biomass weight. The rearing period was 70 days.

2.3. Observed variables
The variable observed was the weight growth of white shrimp, including final weight, absolute weight, and daily growth rate. The weight was measured using electric scales in an accuracy of 0.01 g. The number of white shrimp is 30-50, which were weighed once every 10 days. Survival, production, and feed conversion ratio of white shrimp were observed by weighing all live shrimps at the end of the study. Observation of water quality variable (temperature and dissolved oxygen (DO meter), salinity (refractometer), pH (pH meter), ammonia (spectrophotometric technique, indophenol method), nitrate (spectrophotometric technique, cadmium reduction method), and alkalinity (acid titration method sulfate) were observed once every 10 days along with shrimp growth sampling.

2.4. Data analysis
The data on the growth, survival, production, and feed conversion ratio of white shrimp were analyzed using the SPSS program, while the water quality obtained was analyzed descriptively.

3. Result and Discussion

3.1. The growth and survival rate of white shrimp
The observation results of white shrimp growth obtained during 70 days of farming increase within the farming period. The growth performance of the final weight of white shrimp is getting lower along with the increasing stocking density (Figure 1). The final average weight of white shrimp at the stocking density of 100 ind/m³ (treatment A) is 13.70 g/ind. Meanwhile, the stocking density of 200 ind/m³ (treatment B) is 12.27 g/ind. Finally, the lowest average final weight was obtained at the stocking density of 300 ind/m³ (treatment C), which is 10.90 g/ind. The results of the analysis of variance show that the difference in stocking density tested has a significant effect on the growth of white shrimp (P <0.05). This means that there has been competition for space and food, which can affect their growth. Several research results state that the growth of white shrimp is influenced by stocking density [7]-[11]. High shrimp stocking density has a negative impact on the growth and causes low shrimp production [12]. Growth and survival rate of intensive white shrimps decrease as
the increasing stocking density of 300 ind/m³ [13]. Shrimp growth is influenced by many factors, namely internal and external factors. Internal factors include sex, age, size, and maturity level of the gonads, while external factors are divided into two groups, namely biotic and abiotic factors. Biotic factors are feed and stocking density, while the dominant abiotic factors are temperature, oxygen, salinity, light, and toxic materials [14]. That besides being supported by good feed and environment. Shrimp growth is also determined by stocking density. High stocking density of shrimp will result in slow growth due to competition for space and feed. Such condition will affect the growth of the reared shrimp [15]. The growth of white shrimp is influenced by a combination of several factors, namely water quality (including water temperature), seed quality, feed quality, amount of feed, and stocking density [16].

![Figure 1](image)

**Figure 1.** The growth rate of white shrimp (*L. vannamei*) during 70 days rearing period with different stocking densities

The growth rate of white shrimp obtained in this study is in the range of 0.14-0.19 g/day (Table 1). The daily growth rate obtained in this study is not much different from previous studies. Daily growth rates of white shrimp ranging 0.12-0.17 g/day, which are reared semi-intensively (25 ind/m²) for 98 days [17]. Daily growth rate of white shrimp ranging 0.142 - 0.144 g/day reared at a stocking density of 500 - 600 ind/m² [18], and 0.17-0.19 g/day at a stocking density of 530 ind/m³ [19]; 0.19± 0.01 g/day at a stocking density of 450 ind/m³; 0.26 ± 0.01 g/day at a stocking density of 500 ind/m³, and 0.21 ± 0.01 g/day at the stocking density of 390 ind/m³ [20]. Daily growth rate of white shrimp of 0.17 g/day reared at a stocking density of 162 ind/m² [21]. Daily growth rate of white shrimp of 0.14-0.16 g/day reared at a stocking density of 600 ind/m² with different number of aeration points [22]. The individual growth rate shows a decrease as the increasing average weight within the farming period [23].
The highest survival rate is obtained in treatment A (100 ind/m$^3$), which is 95%, followed by treatment B (200 ind/m$^3$), which is 84%, and treatment C (300 ind/m$^3$), which is 80%. The results of the analysis of variance show that the stocking density treatments applied have a significant effect (P<0.05) on their survival rate. The survival obtained decreases as the stocking density increases, where the lowest survival is found at high stocking density. This means that the higher the stocking density, the lower the survival rate of the white shrimp will be. The same results are reported by [10, 13, 24, 25]. The stocking density will affect the competition for space, feed, and environmental conditions, which in turn can affect the growth and survival, determining the production. There is an optimal stocking density, which will result in a maximum response to white shrimp survival because it is related to space utilization competition, opportunities for contact between individuals regarding cannibalism, pathogen distribution, and competition for feed [26].

The survival rate obtained in this study is quite good and not much different from the survival rate of white shrimp reared in ponds. The survival rate of white shrimp maintained with the traditional plus pattern is 72.09% [27] and 81.03% [28]. The stocking density of 150 ind/m$^2$ result in a survival rate of 92.0%, followed by stocking densities of 300 and 450 ind/m$^2$, namely 81.2% and 75.0% respectively [10]. The survival rate of vannamei is quite variable, namely 83.0% (390 ind/m$^2$); 95.5% (450 ind/m$^2$); 81.6% (500 ind/m$^2$); and 82.3% (530 ind/m$^2$) [20]. The survival rate of superintensive white shrimp farming of 85.6% and 92.4% with stocking density treatment of 500 and 600 ind/m$^3$ [18]. The survival rate of superintensive vanname shrimp farming with a density of 600 ind/m$^2$ range from 80.70-93.60% for 70 days of cultivation [22]. The survival rates of white shrimp obtained from the indoor system using the Recirculation Aquaculture System with different densities of 500 ind/m$^3$, 750 ind/m$^3$, and 1,000 ind/m$^3$ are respectively 70.0%, 53.67%, and 44.0 % [29]. The survival rate of intensive vanname shrimp farming varies considerably and is lower at higher densities, namely 93.2% (100 ind/m$^3$), 91.4% (300 ind/m$^3$), 74.0% (500 ind/m$^3$), 65.7% (700 ind/m$^3$), and 55.7% (900 ind/m$^3$) respectively [13].

**Table 1.** Growth, survival rate, production and feed conversion ratio of white shrimp *L. vannamei* with different densities in a fiber tank after 70 days

| Variable                  | Treatment |
|---------------------------|-----------|
|                           | A         | B          | C          |
| Container volume (m$^3$)  | 2         | 2          | 2          |
| Stocking densities (ind/m$^3$) | 100   | 200        | 300        |
| Reraring period (day)     | 70        | 70         | 70         |
| Initial body weight (g/ind.) | 0.14  | 0.14       | 0.14       |
| Final body weight (g/ind.) | 13.70±1.32$^a$ | 12.27±0.90$^{ab}$ | 10.90±0.95$^b$ |
| Absolut growth (g/ind.)   | 13.56±1.32$^a$ | 12.08±0.92$^{ab}$ | 10.06±0.99$^b$ |
| Daily growth rate (g/day) | 0.19±0.02$^a$ | 0.17±0.01$^{ab}$ | 0.14±0.01$^b$ |
| Survival rate (%)         | 95.00±1.00$^a$ | 84.00±2.00$^b$ | 80.00±1.52$^b$ |
| Production (kg/2 m$^3$)   | 2.48±0.06$^a$ | 3.96±0.15$^b$ | 4.84±0.57$^c$ |
| FCR                       | 1.10±0.18$^a$ | 1.23±0.15$^a$ | 1.40±0.15$^a$ |

Note: *Values with the same superscript within the same row are not significantly different at P < 0.05.*
3.2. Production and feed conversion ratio of white shrimp

Production is determined by the number of live shrimp and the final weight. Production of white shrimp in treatment A, B, and C are 2.48 kg (1.24 kg/m³), 3.96 kg (1.98 kg/m³), and 4.84 kg (2.42 kg/m³), respectively. Based on production data for 70 days of cultivation, it is seen that the higher the stocking density, the higher the production obtained, but the weight per shrimp is smaller. This is in line with [30], statement that too low stocking density will result in low production although the size of each shrimp is larger. On the other hand, too high stocking density will cause the size of each shrimp to be small even though the production increases. In addition, the level of density is also influenced by the ability of pond to accommodate a number of individual organisms that are reared, so that the organisms can maintain their survival. Higher stocking density of shrimp can lower the growth rate of shrimp although more biomass could be produced. Furthermore, it is said that a high stocking density of shrimp can be reared as long as water quality is maintained [25]. The production output is limited by reduced growth and survival as stocking densities increase [31]. Maximization of biomass of L. vannamei can be obtained using the highest stocking density, the smallest ponds or container, the earliest start of aeration, and the longest duration of cultivation [12].

The level of white shrimp production is lower than what is stated by [32], where the productivity level of white shrimp reared in the race way pond at the stocking density of 500 ind/m² reaches 9.58 kg/m². The productivity level of white shrimp at a stocking density of 500 ind/m² is 6.3 kg/m³ or 3.64 kg/m² and the productivity level at a stocking density of 600 ind/m² is 8.4 kg/m³ or 4.80 kg/m³ [33]. White shrimp cultivation with the indoor system uses the Recirculation Aquaculture System with different densities, namely 500 ind/m³, 750 ind/m³, and 1,000 ind/m³, resulting in shrimp productivity of 5.20 kg/m³, 5.24 kg/m³ and 4.99 kg/m³ respectively [29]. Intensive treatment of white shrimp production increases along with the higher densities, namely 0.86 kg/m³ (100 ind/m³); 2.40 kg/m³ (300 ind/m³); 3.75 kg/m³ (500 ind/m³); 4.2 kg/m³ (700 ind/m³); and 4.5 kg/m³ (900 ind/m³) [13].

The results of the calculation of the feed conversion ratio for each treatment obtained are directly proportional to the density level. Feed conversion ratio in treatment A = 1.14, B = 1.25, and C = 1.44. It is shown that density affects the feed conversion ratio. The higher the density level, the bigger the shrimp biomass, so the feed conversion ratio is increasing as well. The feed conversion ratio in this study is not much different from that obtained by several previous studies. According to [34], white shrimp feed conversion ratio ranges 1.3 - 1.4. Feed conversion ratios for white shrimp are 1.64, fed with high protein content (40%), and 1.68, fed with low protein content (25%), for 16 weeks of cultivation [35]. Feed conversion value of 1.97 in a research on white shrimp farming in ponds at a stocking density of 35 ind/m² reared for 112 days [36]. White shrimp feed conversion ratio of 1.40 [37]. Intensive technology grow-out of white shrimp using PL-27 can save feed with a lower feed conversion ratio, which is 1.096 ± 0.034, compared to the grow-out of PL-12 fry, which is 1.257 ± 0.048, reared for 80 days [28]. Feed conversion ratio of white shrimp of 1.53-1.60 at a stocking density of 450 ind/m³, and 1.21-1.40 at a stocking density of 530 ind/m³ [19]. 1.77 at the stocking density of 390 ind/m³, 1.48 at the stocking density of 500 ind/m³ [20]. Feed conversion ratio in superintensive vanname shrimp farming at a stocking density of 600 ind/m², which ranges 1.12 to 1.51, reared for 70 days [22]. The feed conversion ratio in intensive vanname shrimp farming at stocking density of 100-300 ind/m³ ranges from 1.2-1.4 [13].

3.3. Water quality

Water quality plays an important role in supporting the growth and survival of the reared shrimp. The result of water quality observation during the study is presented in Table 2. The measured water temperature in treatment A, B, and C are respectively 25–31°C; 25.3–30°C and 25–30.4°C. The temperature conditions in all treatments are relatively the same. The water temperature in the dominant fiber tank is influenced by the air temperature. The lowest water temperature is at night
before dawn and the highest temperature is during the day. Water temperature in all treatments is still suitable for the life and growth of white shrimps. Shrimps will die if they live at a temperature below 15°C or above 33°C for 24 hours or more. Sub lethal occurs at temperature of 15–22°C and 30-33°C. The optimum temperature for white shrimps is between 23-30°C [38]. The optimal temperature for the growth of white shrimps is between 26-32°C. If the temperature is more than the optimum number, the metabolism in the shrimp body will run fast so that the demand for dissolved oxygen increases [39].

| Variable                  | Treatment A | Treatment B | Treatment C |
|---------------------------|-------------|-------------|-------------|
| Temperature (°C)          | 25.0-31.0   | 25.3-30     | 25.0-30.0   |
| Salinity (ppt)            | 15-25       | 15-26       | 15-25       |
| pH                        | 7.0-8.0     | 7.0-8.5     | 7.0-8.0     |
| DO (mg/L)                 | 4.0-5.5     | 3.6-5.0     | 3.8-5.5     |
| Alkalinity (mg/L)         | 124-156     | 124-140     | 124-165     |
| NO$_3$-N (mg/L)           | 0.003-0.080 | 0.027-0.051 | 0.02-0.071  |
| NH$_3$-N (mg/L)           | 0.03-0.12   | 0.05-0.17   | 0.03-0.14   |

The results of salinity measurements in treatment A, B, and C are respectively 15-25 ppt, 15-26 ppt, and 15-25 ppt. The salinity range in all treatments is optimal for growth and survival of white shrimps. White shrimps can live in a wide range of 0.5-45 ppt [40]. The optimal salinity range for white shrimp is 15–30 ppt [39].

During the study, it is shown that the water pH of all treatments was relatively the same, ranging from 7.0–8.5. The pH range obtained is optimal for the growth of white shrimp. pH range of water suitable for intensive vannamei shrimp farming is 7.4-8.9 with an optimum value of 8.0. [38]. The ideal pH range for life and growth of white shrimp is 7.5–8.5 [39].

Dissolved oxygen in water is a limiting factor for shrimp health. Dissolved oxygen concentration in treatment A ranges from 4–5.5 mg/L, in treatment B ranges from 3.6–5.0 mg/L, and in treatment C ranges from 3.8–5.5 mg/L. This range is still feasible for the maintenance of white shrimp. Good dissolved oxygen levels range from 4–6 mg/L [39]. Dissolved oxygen that has the potential to cause death is ≤ 2.0 mg/L, while optimal dissolved oxygen for white shrimp farming is ≥ 3 mg/L with a tolerance of 2 mg/L [41].

It is important to pay attention to alkalinity, which is a water quality parameter. Alkalinity in treatment A ranges from 124-156 mg/L, in treatment B ranges from 124-140 mg/L, and in treatment C ranges from 124-165 mg/L. The alkalinity value obtained from the three treatments show a decent range for the growth of vannamei shrimp. Alkalinity levels for optimal shrimp growth are 90–150 mg/L [42]. The alkalinity value of water in the ponds is used as a pH stabilizer and normal growth of phytoplankton. It is recommended that the water alkalinity value of shrimp medium be > 100 mg/L or in the range of 120-160 mg/L [43]. The standard value of total pond water alkalinity is ≥ 80 mg/L. If the pond water’s alkalinity is below standard, it can be improved by using lime [44]. The optimal range of alkalinity is 90-150 mg/L. The harder the water is, the better the water for shrimp farming with an optimal value of 120 mg/L and a maximum of 200 mg/L [21].

Nitrate is one of the nutrients that determines fertility and affects aquatic productivity. The results of the observation of nitrate content in treatment A, B, and C are respectively 0.003-0.08 mg/L, 0.027-0.051 mg/L, and 0.02- 0.071 mg/L. The nitrate content in all treatments is considered low. This happens because water changes are carried out every day at the end of the study. NO$_3$-N content of 0.039-0.072 mg/L is low [45]. The nitrate content needed for algae growth in waters is 0.2-0.9 mg/L and is optimal in the range 0.1-4.5 mg/L [46].
Ammonia measurement results in treatment A ranges from 0.03-0.12 mg/L, in treatment B ranges from 0.05-0.17 mg/L, and in treatment C ranges from 0.032-0.14 mg/L. They are still the proper range for growth and survival of white shrimps. The optimal ammonia concentration for white shrimp farming is 0.03–0.25 mg/L [42]. Ammonia level tolerance value for white shrimp farming is ≤ 0.8 mg/L [47]. Ammonia LC50 values for juvenile white shrimp at immersion 24, 48, 72, and 96 hours. The 33 ppt of salinity is 2.78, 2.18, 1.82, and 1.60 mg/L [48]. Ammonia is toxic when accumulating to a certain level, so that in intensive to superintensive farming systems, water must be changed frequently to remove the ammonia levels [26]. TAN, nitrate, and total phosphorus in water quality are significantly higher at higher densities [13].

4. Conclusion
The stocking density differences had a significant effect on growth, survival rate and production. Vaname shrimps could be cultivated and grew normally in high density in 2 m³ fiber tank, it could be cultivated in household cultivation scale by coastal communities with 300 individuals/m³ density. It is necessary to study of increasing vaname stocking density over 300 ind/m³ to optimize production limit.

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