Optimization of Feeding Efficiency for Cost Effective Production of *Penaeus monodon* Fabricius in Semi-Intensive Pond Culture System

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Abstract

Experiment with four different daily feeding frequencies, i.e., three (T1), four (T2), five (T3) and six times (T4) were conducted with supplementary feed (38% crude protein) in the earthen ponds (5000 m²) to determine the optimum feeding frequency for cost effective commercial production of *Penaeus monodon* Fabricius. Post larvae of black tiger shrimp (initial weight 0.02 ± 0.001 g) with stocking density of 20 m⁻² were cultured for 110 days to evaluate the growth and production by studying different parameters of feed utilization efficiency as feed conversion ratio (FCR), protein efficiency ratio (PER), feed efficiency ratio (FER), production yield; and adequate growth levels as average body weight (ABW), weight gain (WG), specific growth rate (SGR), and survival of cultured shrimp. During production cycle, various water quality parameters of the ponds were found within normal range for aquaculture except for NH₃-N, NO₂-N and PO₄-P which were significantly lower in T3 (p<0.05, 0.01) and PO₄-P in T4 (p<0.05) series than T1. After harvest ABW, WG, SGR and PER were significantly higher in T2, T3 and T4 ponds than T1 (p<0.05, 0.001). FCR, FER and PER followed the same pattern (p<0.05, 0.01, 0.001) in T2, T3 and T4 series than T1. Finally significantly higher (p<0.05) survival rate (82.5 ± 2.9%) and production yield (4562 ± 55.2 kg ha⁻¹) were found in T3 than others, which indicated an additional support towards efficient feeding management and its outcome to T3. Maximized feed utilization and production efficiency with lesser wastage of feed was observed in T3 ponds than other series of ponds. Daily five-time feeding frequency (T3) earned significantly higher net profit of INR. 503233 ha⁻¹ and return on investment (ROI) 69% compared to other treatments. Substantial improvement in growth and yield with higher profitability from ponds with daily five-time feeding frequency (T3) revealed it as the optimum feeding management for augmenting cost efficient production of *P. monodon* in a semi-intensive farming system.

Keywords: Feeding frequency; Growth; Cost efficient; *Penaeus monodon*; Yield

Introduction

In recent years, the culture of *Penaeus monodon* Fabricius received maximum importance owing to its unique taste, high nutritive value and persistent demand in world market and good profitability. Commercial shrimp farming depends largely upon formulation of high energy balanced feed, which constitutes nearly 55% of the total operation costs for shrimp culture [1]. Feed management is a key factor affecting water quality and production economics in aquaculture [2-4]. Failures in shrimp production are mainly due to post larvae (PL) quality, feed, water and soil quality or disease but in most cases origin of problem is poor feed management [5]. However, environmental, social and economic considerations demand the need to improve feed management and feed formulations [6]. Feed is the initial source of pollutants as overfeeding or poor quality feeds can severely affect water quality and production of shrimp [6]. Thus, daily inputs of supplementary feed must be reasonable and should take into account growth of the shrimp as well as nutrient capacity of the pond ecosystem. Supplementary feed in shrimp farming is not only the initial source of physiological wastes, but it accounts for 55-60% of the operational costs in intensive and 40-50% in semi-intensive culture system [7,8]. It was reported that increased feeding rate beyond the natural carrying capacity of the pond deteriorates the water quality [9]. Out of total feed applied to pond, only 16.7% (by dry weight) is converted into shrimp biomass, the rest is leached or otherwise not consumed, egested as faeces, eliminated as metabolites, etc. [10]. Negative effects of supplementary feed are not isolated but promote diseases and other water quality related problems which affect production [2,11]. Therefore, feed management strategy should be aimed at optimizing feed inputs, reducing feed conversion ratios and the potential impact on the culture and effluent water [11]. Both feed management and quality play important role in governing production and profitability [1]. As frequency of feeding is the main part of management and Smith et al. [12] described that feeding strategy can have a significant impact on pond water quality, growth, health and survival of *P. monodon* which contribute to the profitability of production. Protein is the central to feed formulation system and the most important constituent in prawn nutrition [13]. Minimum dietary protein requirement for *P. monodon* was reported to be 35-50% [14]. On the other hand, multiple daily feeding and distribution is desirable as shrimp eat slowly and almost continuously [15]. However, increased feeding frequency was reported to reduce nutrient leaching and improves feed utilization efficiency [16]. Feed management has an impact on feed conversion efficiency as well as minimizing pond bottom and water quality deterioration due to over feeding [17].

Impact of feeding frequency inside ponds is not well understood and no clear information is available as farmers usually differ in practice applying feed 2-6 times daily. However, some information on feeding frequency of 2-4 times per day is applicable in shrimp ponds [1,12,17]. Although feed intake pattern and consumption rate of shrimp varies

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under different agro-climatic conditions, a site-specific standardized feeding program is essential for effective feeding management [1]. Information regarding feed management in shrimp farming is meager from both economic and environmental perspectives. In the present study, same quality and quantity of feed with different feeding frequencies (3-6 times per day) were used in all the experimental ponds. Efficient production of cultured shrimp was determined by estimating feed utilization efficiency (FCR, PER, FER, production yield) and growth level (ABW, WG, SGR and survival). As feed is one of the expensive inputs inside ponds, the demand of maximized feed utilization is the need of the hour and paramount important to shrimp farmers. Thus the aim of present study was to determine the optimum feeding frequency for cost effective production of Penaeus monodon in the brackishwater ponds of West Bengal, India.

Materials and Methods

Experimental ponds

Black tiger shrimp, Penaeus monodon Fabricius (1798) was cultured for 110 days between August and December, 2010 in twelve earthen ponds (0.5 ha or 5000 m2 each) randomly selected in Kar shrimp farm (Mahisadal, East Medinipur, West Bengal, India; Lat 21°3’N, Long 88º46’E). Three ponds each were used to culture the shrimp for different feeding frequencies: (i) 3 times (T1), (ii) 4 times (T2), (iii) 5 times (T3), and (iv) 6 times (T4) day−1. Ponds were selected for each treatment following the random block design (RBD) [18]. All the experimental ponds were rectangular in shape with facility of both inlet and outlet structures with average of 1.2 meter water depth. Soil was clayey loam and aeration was maintained for all ponds during the culture period.

Rearing in ponds

Similar pond management practices like sun drying, tilling, liming, and eradication of predators were performed once prior to water filling as described by Hasan et al. [19] in all the experimental ponds during culture. Culture techniques and inputs were same for all ponds of four treatments. The ponds were ploughed conventionally and limed (1.5 ton ha−1) to improve the soil condition alkaline. Initial water filling in ponds was done directly with water pumped from Haldi river creek after being filtered by fine mesh bag net of 300 micron and chlorination (30 ppm with 60% active ingredients) was done for disinfection and killing of pathogens. After three days of declorination, organic fertilizers (poultry litter @ 250 kg ha−1) and inorganic fertilizers (urea @20 kg ha−1; single super phosphate @ 5 kg ha−1) were applied to improve the primary productivity of the cultured ponds. Routine application of urea @6 kg ha−1 and single super phosphate @2 kg ha−1 were performed twice a month to maintain development of natural food. Agricultural lime and dolomite each were applied once a month @ 50 kg ha−1 during production period. No water exchange was done during initial 20 days and later it was limited to 0-10% in every alternate days from pre-treated reservoir. During raining, only surface draining was maintained to retain salinity. Good quality and disease-free post larvae of 20 days old (PL20) of P. monodon were procured from a private hatchery (Vaisakhi Hatchery, A.P, India), then acclimatized and stocked @ 20 pieces m−2 in all the ponds where water quality were almost in same ranges within aquaculture standard (temperature 28.4-28.6°C, dissolved oxygen >4.0 mg l−1, pH 7.9-8.1, Secchi’s disc transparency 35-45 cm and salinity 7-8 g l−1) [20]. Harvesting happened after 110 days of culture as per market demand and good quality of shrimps. A bag net was fitted on outlet canal with 20 # mesh (pore size) of width 1 meter and length of 4 meter. The water level in the pond was reduced to 60 - 70 cm and outlet was opened and shrimp was caught at night, collected with ice and sold to processors on farm-gate price.

Feeding management

Shrimps were fed with standard commercial pattered feeds (crude protein-38%, fat-5%, fiber-4%, ash-12-15%, calcium-2.2-2.5% and phosphorus-1.5-1.8%) and applied as prescribed by feed company (Chorean Pokhpand-Novo, Chennai, India). The feeding regime (frequency, time of feeding and percentage ration) for cultured shrimp was presented in Table 1. Feeding was administered according to their body weight and days of culture in a fixed quantity in all treatments (Table 2). Small post larvae were fed two times a day (1-15 days) for providing more availability of feed and they are accustomed to feed on natural foods; slowly increased to three times a day as it grows bigger (16-44 days). Later (45-110) feeding was followed as mentioned in Table 2 for the experiment that was pallet feed with more quantity. Feed was broadcasted by rope method, i.e., floats tied and moved with rope in lines horizontally in all ponds [21]. Aeration (4-10 hours as per biomass) was kept off for two hours during feed application.

Evaluation of growth and feed utilization efficiency

Cast net was used to measure the growth rate of shrimps during early hours. Shrimps were sampled every fortnight by cast net for monitoring the growth, survival and health conditions of shrimp and for estimation of production yield in the experimental ponds. During stockage average weight of post larvae (PL20) was 0.02 gm and the first sampling was taken after 15 days of grow out phase from four locations of each pond. The average body weight (ABW) was measured at fortnightly intervals till harvest. For measuring ABW, 100 samples of shrimp collected by cast net randomly & mean weight was calculated. For estimation of survival, measured cast net was thrown to ponds randomly 4 times and density calculated as per available shrimps in cast net and total pond area in relation to initial stock density. FCR (Feed conversion ratio) is calculated as total feed utilized divide by total shrimp yield. Survival, FCR, yield were calculated from 45 days onwards as shrimps were smaller in size. Weight gain (WG), FCR and specific growth rate (SGR) was measured as per conventional method [22] in every fifteen days. Protein efficiency ratio (PER) and feed efficiency ratio (FER) were estimated by routine methods [23,24]; and ABW, survival rate and production yield were calculated following the method of Hasan et al. [19]. Health conditions were recorded during same samplings for gut and abnormalities. Samplings of shrimps were regularly performed every 15 days until harvest. The formulae to calculate different parameters are as follows:

Average body weight (ABW)=Total weight of 100 shrimps (g) / 100

Weight gain (WG) = Final weight (g) - initial weight (g)

Food conversion ratio (FCR) = Total feed consumed (kg)/total yield (kg)

Survival rate=Average no. of shrimps caught/cast net area (m²) ×pond area (m²) × 100/number of post larvae stocked

Specific growth rate (SGR) = 100×(Wf - Wi) / period (days) [Wf = final weight; Wi = initial weight]

Protein efficiency ratio (PER) = Wet weight gain (g)/Protein fed(g)

Feed efficiency ratio (FER) = Final weight (g)-initial weight (g) / total feed intake (g)
Production yield = Survived shrimps number x ABW

Water characteristics

Different water quality parameters like temperature, dissolved oxygen, pH were monitored twice a day (6-00 and 16-00 hrs); salinity and transparency once a week (11-00 hours) in situ at farm site by multi-parameter device YSI, MP556 mode and secchi disc. Other nutrient parameters (NH₃-N, NO₂-N, PO₄-P), total alkalinity were monitored in monthly intervals during the production cycle [2,25].

Economic analysis: Production costs, net profit, benefit cost ratio (BCR) and return on investment (ROI) were calculated as method described by Hari et al. [24].

Statistical analysis: Data obtained from the results were subjected to statistical analysis. One-way analysis of variance (ANOVA) was done with the help of computer software SPSS (version 7.5) and the sample means compared [18]. For the analysis of data, student’s t test was conducted between data of T1 (lowest feeding frequency) with other series and to test the level of significance the Fisher and Yates statistical tables were used [26].

Results

Water quality parameters

There were no significant differences in physical parameters such as temperature, salinity, transparency, pH, dissolved oxygen (DO) among treatments and they were all at optimum level for P. monodon culture (Table 3). Although DO level (morning) before feeding at the last part of culture period in T1 and T4 showed lesser value than others but afternoon DO levels were higher than morning in all days throughout the culture in all treatments (Figure 1). However, the concentration of nutrient parameters (ammonium-N, nitrate-N, and orthophosphate) varied with the feeding frequency in the cultured ponds. The level of nitrate-N and ammonium-N in T3 pond was found significantly reduced than T1 ponds (p<0.05, 0.01). On the other hand, the amount of orthophosphate reduced significantly (p<0.05, 0.01) in both the T3 and T4 ponds than T1 ponds during the culture period. Total alkalinity across the treatment ponds ranging between 113-122 mg l⁻¹ was not significantly different (p>0.05, 0.01).

Growth and feed utilization efficiency

ABW, WG, SGR and survival were used to evaluate the growth performance of cultured shrimp with the frequency of feed applied in different cultured ponds. Initial SGR of P. monodon was almost same (9.7-11.6%) in all the ponds which increased steadily between DOC 60-75 in all ponds and it was higher in T3 ponds. After DOC 75, it reduced and collapsed after 90 days (11.3%) till harvest (Figure 2). It was also observed in T3 ponds followed by T2 ponds (4058 kg ha⁻¹), was obtained in T3 ponds followed by T2 ponds (4058 kg ha⁻¹). In other two ponds (T1 and T4) the production was relatively lower than T2 and T3 (Figure 6 and Table 5). Protein efficiency ratio (PER) in culture time progressed in all ponds. At harvest, the highest ABW increased as treatment ponds and they were all at optimum level for P. monodon culture (Figure 2). It was also different cultured ponds. Initial SGR of P. monodon with that of other treatment ponds it was found that average body weight (ABW) of (9.7-11.6%) in all the ponds which increased steadily between DOC 60-75. The highest ABW was observed in T1 ponds with that of other treatment ponds it was found that average body weight (ABW) of (9.7-11.6%) in all the ponds which increased steadily between DOC 60-75. The highest ABW was observed in T1 ponds (22.9 ± 0.2 g) followed by T2 (26.3 ± 0.27 g), T3 (27.67 ± 0.26 g) and T4 (24.17 ± 0.23 g) (Figure 3). While comparing culture time progressed in all ponds. At harvest, the highest ABW increased as treatment ponds and they were all at optimum level for P. monodon culture (Figure 2). It was also different cultured ponds. Initial SGR of P. monodon with that of other treatment ponds it was found that average body weight (ABW) of (9.7-11.6%) in all the ponds which increased steadily between DOC 60-75. The highest ABW was observed in T1 ponds (22.9 ± 0.2 g) followed by T2 (26.3 ± 0.27 g), T3 (27.67 ± 0.26 g) and T4 (24.17 ± 0.23 g) (Figure 3). While comparing culture time progressed in all ponds. At harvest, the highest ABW increased as treatment ponds and they were all at optimum level for P. monodon culture (Figure 2). It was also different cultured ponds. Initial SGR of P. monodon with that of other treatment ponds it was found that average body weight (ABW) of (9.7-11.6%) in all the ponds which increased steadily between DOC 60-75. The highest ABW was observed in T1 ponds (22.9 ± 0.2 g) followed by T2 (26.3 ± 0.27 g), T3 (27.67 ± 0.26 g) and T4 (24.17 ± 0.23 g) (Figure 3). While comparing culture time progressed in all ponds. At harvest, the highest ABW increased as treatment ponds and they were all at optimum level for P. monodon culture (Figure 2). It was also different cultured ponds. Initial SGR of P. monodon with that of other treatment ponds it was found that average body weight (ABW) of (9.7-11.6%) in all the ponds which increased steadily between DOC 60-75. The highest ABW was observed in T1 ponds (22.9 ± 0.2 g) followed by T2 (26.3 ± 0.27 g), T3 (27.67 ± 0.26 g) and T4 (24.17 ± 0.23 g) (Figure 3). While comparing
harvested shrimp (ha⁻¹) of T2 and T3 respectively than T1. Net profit and benefit cost ratio (BCR) among the treatments followed the significance same as gross revenue. Significantly higher BCR (0.69) in ponds with five feeding frequency as compared to others amply speaks for effective net profit (INR. 503233) and return on investment (69%) after the harvest of 110 days of culture period (Table 6). Production cost was found to be higher as the feeding frequency increases (INR. 1500 frequency⁻¹) due to involvement of additional laborers for every higher feeding frequency.

Discussion

In the present study it is found that feeding frequency has a profound influence on cost effective production of P. monodon. There was no effect on changes of water quality parameters for feeding frequencies in different treatment ponds as earlier finding [12], although some nutrients were on higher level in T1 and T4 and all parameters were within optimum ranges (Table 3). Fluctuation of DO in all treatment ponds was almost same although slightly higher DO (p>0.05) observed in T3 ponds in morning and afternoon (Figure 1) than others. Different growth and feed efficiency parameters have been found to be modulated by changed feeding frequency although feed constituents, feed amount and distribution were similar in all the culture ponds. SGR increased steadily between 60-75 DOC in all ponds but the maximum value of SGR (38.4%) in T3 ponds was observed in DOC 60 with gradual declining trend thereafter (Figure 2) corroborated the previous finding [27]. This may be due to the fact that larval shrimp generally depend on planktonic food at the early stage, after which they gradually acclimatize to the supplementary feed [26]. At harvest, the highest ABW was observed in T3 (27.67 ± 0.26 g) and lowest in T1 (22.9 ± 0.2 g) (Figure 3). Previous study found almost similar (T3) growth (29.24 ± 1.4 g) pattern for 40% protein feed in 120 days of culture [27]. Therefore, it can be substantiated that decline in temperature below 25°C could decrease feed consumption and growth rate [28], thus lower temperature at the end of culture (22.1°C) in ponds caused poor consumption of feed and was responsible for slow growth rate of shrimp. However, ideal water stability ensures better feed consumption and good pond bottom and water quality [20]. As shrimp live on or near to bottom of pond, higher concentration of NH₃-N and NO₃-N found in T1 and T4 ponds affected the health, feed intake and growth; and possibly lower survival [29]. Lower level of orthophosphate in T3 ponds was found to be suitable for good growth of shrimp. Matias et al. [20] observed that this was happened as a result of less feed wastes which can be substantiated by lower FCR value in these ponds (Table 5). Furthermore, feed pellets that are known to disintegrate faster in water facilitate only economic loss and pollution of water [30]. Thus, frequent occurrence of black soil formation in T1 and T4 ponds causing gills choking due to accumulation of feed wastes (unconsumed) resulted in higher FCR that showed clear temporal variation during the culture period and this increased as time progressed (Figure 4). FCR value was found lowest (1.31 ± 0.02) in T3 pond and highest in T1 (1.86 ± 0.11). Feed is one of the essential inputs in shrimp production and decides for profitability. The cost of labor for feeding of shrimp ponds can be a significant component of the fixed costs [31] as found in this study (Table 6). However, moderate feed inputs of 2-4 times per day (depending on shrimp size) are often recommended for better growth [1,12,17]. From the present result it is clear that feeding of five times a day in T3 ponds fetched best net profit and BCR (Table 6) amongst all treatments. Feed conversion improves with increasing feeding frequency [23] but the interesting feature of the study is that FCR improves for 5- time feeding frequency (T3) but not for further increment of frequency (T4) (Figure 4 and Table 5). Protein being the most important and expensive nutrient in shrimp feed, nutritionally well-balanced diet is important for profit [5]. The best value observed for protein efficiency ratio (PER) in this study was 2.0 as almost similar value of 2.55 was reported in ponds feeding with same protein content [34]. Thus, five times feeding is the best to utilize the protein conversion to shrimp as found in this study. In this study highest Feed efficiency ratio (FER) in T3 ponds (0.76) indicated maximum utilization of feed for 5 times feeding and it is more improved than earlier finding (0.47) [35]. In the present study, black tiger shrimp achieved highest growth (ABW, WG and SGR) from same diet with 5 times feeding frequency (T3) (Figure 4 and Table 5). Protein being the most important and expensive nutrient in shrimp feed, nutritionally well-balanced diet is important for profit [5]. The best value observed for protein efficiency ratio (PER) in this study was 2.0 as almost similar value of 2.55 was reported in ponds feeding with same protein content [34]. Thus, five times feeding is the best to utilize the protein conversion to shrimp as found in this study. In this study highest Feed efficiency ratio (FER) in T3 ponds (0.76) indicated maximum utilization of feed for 5 times feeding and it is more improved than earlier finding (0.47) [35]. In the present study, black tiger shrimp achieved highest growth (ABW, WG and SGR) from same diet with 5 times feeding frequency (Table 4).
Highest survival rate (mean 82.5%) in T3 ponds with 5 feeding frequencies and lowest in T1 (70.5%) ponds with three feeding frequency was observed (Figure 5 and Table 4). An average survival of 70 to 80% is quite possible if the ideal condition is maintained for P. monodon [32]. It indicates that five times feeding reduced cannibalism (during molting and natural mortality) because gut evacuation is completed in about 3 hours for penaeid shrimps as a way to reduce or eliminate excess uneaten feed waste, which might have happened in T4. And in T1 and T2, less feeding frequency might induce cannibalistic behavior of shrimps as feed availability was not enough throughout the day [33]. As survival and growth was better in T3, production yield was substantially higher in ponds with five feeding frequency than other treatments (Figure 6 and Table 5). Less frequent feeding in T1 (3 times) and more frequent feeding in T4 (6 times) significantly limited ABW, WG, SGR, FCR, PER and FER in comparison to T3 and T2 ponds (Table 4, Table 5). This study was not corroborated with the findings

<table>
<thead>
<tr>
<th>Variable</th>
<th>T1 (3 times)</th>
<th>T2 (4 times)</th>
<th>T3 (5 times)</th>
<th>T4 (6 times)</th>
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<tbody>
<tr>
<td>ABW(g)</td>
<td>22.9 ± 0.20</td>
<td>26.3 ± 0.27</td>
<td>27.67 ± 0.26</td>
<td>24.17 ± 0.23</td>
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<td>WG (g)</td>
<td>22.86 ± 0.20</td>
<td>26.28 ± 0.26</td>
<td>27.64 ± 0.26</td>
<td>24.14 ± 0.23</td>
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<td>SGR (%)</td>
<td>20.8 ± 0.31</td>
<td>23.9 ± 0.24</td>
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<td>21.9 ± 0.21</td>
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<td>Survival (%)</td>
<td>70.5 ± 4.1</td>
<td>77.2 ± 2.9</td>
<td>82.5 ± 2.91</td>
<td>73.0 ± 4.52</td>
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</tbody>
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* a, b, c in the same row with different superscripts are significantly different. p values: a<0.05; b<0.01; c<0.001. Values in each row with no superscript are non-significant

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<td>FCR</td>
<td>1.86 ± 0.11</td>
<td>1.48 ± 0.03</td>
<td>1.31 ± 0.02</td>
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<td>PER</td>
<td>1.42 ± 0.05</td>
<td>1.75 ± 0.06</td>
<td>2.0 ± 0.02</td>
<td>1.55 ± 0.04</td>
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<td>FER</td>
<td>0.54 ± 0.02</td>
<td>0.67 ± 0.01</td>
<td>0.78 ± 0.01</td>
<td>0.59 ± 0.02</td>
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<tr>
<td>Increase in biomass (kg d⁻¹ ha⁻¹)</td>
<td>29.35 ± 1.0</td>
<td>36.89 ± 0.73</td>
<td>41.47 ± 0.45</td>
<td>32.07 ± 0.87</td>
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<td>Yield (kg ha⁻¹)</td>
<td>3229 ± 112.9</td>
<td>4058 ± 80.5</td>
<td>4562 ± 56.2</td>
<td>3528 ± 95.5</td>
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* a, b, c in the same row with different superscripts are significantly different. p values: a<0.05; b<0.01; c<0.001. Values in each row with no superscript are non-significant

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<th>T3 (5 times)</th>
<th>T4 (6 times)</th>
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<td>Total shrimp yield (kg ha⁻¹)</td>
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<td>4058</td>
<td>4562</td>
<td>3528</td>
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<tr>
<td>Price of shrimp (INR kg⁻¹)</td>
<td>245</td>
<td>260</td>
<td>270</td>
<td>250</td>
</tr>
<tr>
<td>Total production costs (INR)</td>
<td>725377</td>
<td>726942</td>
<td>728507</td>
<td>730072</td>
</tr>
<tr>
<td>Gross revenue (INR)</td>
<td>791105</td>
<td>1055080</td>
<td>1231740</td>
<td>882000</td>
</tr>
<tr>
<td>Net profit (INR)</td>
<td>65728</td>
<td>328138</td>
<td>503233</td>
<td>151928</td>
</tr>
<tr>
<td>Benefit /cost ratio (BCR)</td>
<td>0.09</td>
<td>0.45</td>
<td>0.69</td>
<td>0.21</td>
</tr>
<tr>
<td>Return on investment (ROI)</td>
<td>9.0%</td>
<td>45%</td>
<td>69%</td>
<td>21%</td>
</tr>
</tbody>
</table>

* a, b, c in the same row with different superscripts are significantly different. p values: a<0.05; b<0.01; c<0.001. Values in each row with no superscript are non-significant

Table 4: Variations of different growth parameters after harvest.

Table 5: Variations of different feed efficiency parameters in different treatments.

Table 6: Cost (in INR.*) and economic analysis of P. monodon on-farm trial in different feeding frequencies (per hectare).

*1 US $=49.2 Indian Rupees (INR).
[1,12,17] for two to four feeding frequency for achieving better growth and yield. Although similar result was found elsewhere [15] where feed conversion and production increased with feeding frequency but sealed to five feedings day⁻¹ in this study. In both the cases (T1 and T4), feed quantity might have been wasted more as reflected in pond sediments (black soil) and deterioration in water quality (nutrients) higher than T3.

The realistic economic analysis performed in the on-farm trial showed five feeding frequency substantially increased net profit and return on investment when compared to other frequencies of feeding. Furthermore, the combined effect of higher shrimp yield, bigger size and better market price of shrimps in this frequency significantly increased the gross revenue and net profit. Thus five feedings day⁻¹ in commercial ponds of black tiger shrimp has optimized production and profitability with less wastage of feed.

The present study has developed maximized production efficiency, reducing feed wastage and no deterioration of water quality as observed in T3 ponds. Lesser or higher than five times feeding day⁻¹ showed comparatively lesser growth and poor economic benefit. Thus, in a semi-intensive shrimp culture system, five-time feeding frequency was the most efficient and cost effective feeding management technique that resulted in highest production yield with better economic benefit and business stability to farmers and stakeholders.

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References


