# Improved feed management strategy for *Litopenaeus vannamei* in limited exchange culture systems

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Beside great losses to viral disease outbreaks, the shrimp farming industry is under increasing pressure by the regulatory agencies to meet effluent water quality requirements and to limit potential negative impacts on receiving streams. Shrimp farmers and researchers are looking for cost-effective and sustainable culture methods to minimize environmental impact and reduce their crop losses to diseases. Production of shrimp in limited or zero water exchange systems can provide more biosecurity while addressing both issues (Thakur and Lin 2003, Cohen *et al.* 2004). Feed is a primary source of macronutrients for shrimp and a major source of pollution in pond effluent (Tacon and Forster 2003). Protein is an important component of shrimp feed, contributing a substantial portion of the manufacturing cost (Kureshy and Davis 2002). With the recent trend in shrimp farming intensification under limited discharge, the use of suitable feed ingredients, feed formulations and feeding practices are key factors affecting the viability of these systems. A study by McIntosh *et al.* (2001) in a small tank system with limited discharge showed significantly better survival, mean final weight, yield and feed conversion ratio (FCR) for shrimp fed a commercial 31 percent crude protein (CP) diet over those fed the 21 percent CP diet. These results suggest that under the conditions of the study, shrimp utilized the higher protein feed more efficiently. Protein in feed has also been associated with the nitrogen load in the effluent from aquaculture activities (Cho *et al.* 1994). A substantial portion of the feed goes unutilized and, subsequently, ends up adding to the organic load of the culture system (Thakur and Lin 2003). Sustainable growth of the shrimp farming industry requires placing greater emphasis on feed quality and feeding practices that can reduce cost and pollution without compromising productivity. Only limited information is available concerning the effect of feeding high-protein feed, when it is fed at lower ration sizes to match the protein level of low-protein feed, on shrimp and fish performance. Cho and Lovell (2002), while working with channel catfish, did not find significant differences between 28 percent CP feed offered at satiation (100 percent) and a diet with 32 percent, which was fed at 87.5 percent of the satiation rate. In another study, Kureshy and Davis (2002) reported significantly better weight gain for *L. vannamei* juveniles when fed a 32 percent CP feed compared to 16 percent and 48 percent CP feeds when the feeds were offered on an isonitrogenous basis. A few studies have also been carried out where shrimp were fed based on their dietary energy and protein requirements. The optimal digestible energy:crude protein raatio (DE:CP) was reportedly 11.9 kcal/g protein for *L. vannamei* (Cousin *et al.* 1993). Working with the same species, Lawrence *et al*. (1993) reported the protein dietary requirement at 15 percent and the optimum DE:CP ratio at 28.57 kcal/g protein. The current study evaluated the effect of feeding commercial 30 percent and 36 percent CP diets on Pacific white shrimp *L. vannamei* growth, survival and FCR in tanks and ponds under limited water discharge conditions when the high protein feed was fed on a isonitrogenous basis to the low protein feed.

## Tank Study

A 118-day study was conducted in 22 outdoor tanks (10.5 $m^2$ bottom area, 6.8 $m^3$ working water volume) at the Texas Agricultural Experiment Station, Shrimp Mariculture Research Facility, Corpus Christi, Texas USA. Tanks were filled with chlorinated water two days prior to stocking. Experimental tanks were positioned in a shaded area with 73 percent light reduction. Aeration was provided by air stones (10 air stones/tank with air flow of 6 to 8 L/min/air stone). Tanks were stocked with juvenile *L. vannamei* (0.8 g) at a density of 75/$m^3$. Each tank was covered with plastic netting to prevent shrimp from jumping out. Except for emergency releases because of heavy rains, no water was discharged from the system. Municipal water was added to the tanks to compensate for evaporation and to maintain salinity. Two commercial shrimp diets, 30 percent and 36 percent CP (Rangen Inc., Buhl, Idaho), were tested at different ration sizes. The experimental design for the study is summarized in Table. 1. The higher protein diet (36 percent CP) was fed at lower ration size and was calculated to provide the shrimp with an equal nitrogen level to the lower protein diet (30 percent CP). Thus, for each 100 g of the 30 percent CP

Table 1. Experimental design of a tank study with two commercial diets (30% and 36% CP) when fed at different ration sizes.

| Treatment ID | % CP in the Diet | n | % Protein in Ration |
|---|---|---|---|
| 30 - 100% | 30 | 6 | 30 |
| 36 - 84.2% | 36 | 5 | 30 |
| 30 - 84.2% | 30 | 5 | 25.3 |
| 36 - 70.9% | 36 | 6 | 25.3 |

Table 2. The effects of two commercial diets (30% and 36% CP), when fed at different ration sizes, on daily water parameters in an outdoor tank study with *Litopenaeus vannamei* when operated under limited water discharge.

| Treatment ID | DO (mg/L) | | Temperature (°C) | | pH | |
|---|---|---|---|---|---|---|
| (% CP-Ration) | am | pm | am | pm | am | pm |
| 30% CP-100% | 6.6±0.42 | 7.0±0.20 | 27.1±1.46 | 28.1±1.81 | 7.7 | 8.0 |
| 36% CP-84.2% | 6.6±0.37 | 7.0±0.22 | 27.1±1.47 | 28.1±1.68 | 7.7 | 8.0 |
| 30% CP-84.2% | 6.6±0.38 | 7.0±0.20 | 27.1±1.48 | 28.2±1.74 | 7.7 | 8.0 |
| 36% CP-70.9% | 6.7±0.38 | 7.1±0.20 | 27.1±1.50 | 28.2±1.91 | 7.8 | 8.0 |

diet fed, shrimp on the higher protein diet were fed only 84.2 g of 36 percent CP diet. To make sure the shrimp offered the lower protein diet were not overfed, the study also evaluated the effect of offering that diet at a reduced ration size, 84.2 percent of the full ration. That dietary protein was matched by feeding the higher protein diet at further reduced rate; for each 84.2 g of the 30 percent CP diet, the shrimp were fed only 70.9 g of the 36 percent CP diet. Feed was distributed manually four times daily. Growth was monitored weekly in one tank per treatment. Rations were calculated weekly based on the observed growth, estimated survival and an assumed FCR of 1:1.5 for all treatments.

Dissolved oxygen temperature, pH and salinity were measured twice daily in each tank. Ammonium-nitrogen nitrite-N and nitrate-N were monitored weekly in selected tanks. Shrimp production and water quality data were analyzed using SPSS software (SPSS Inc., Chicago, Illinois). The Repeated Measures ANOVA test was used to identify differences in water quality indicators between treatment means. One way ANOVA served to identify differences between treatments in final weight, survival, yield, FCR and growth. The Student Newman Keuls test was used as a mean separation tool.

## Results

There were no significant differences in daily mean water quality indicators among treatments (Table 2). Salinity varied between 25 and 28 ppt. The means for ammonium-nitrogen and nitrite-nitrogen were 0.26 ± 0.46 and 0.46 ± 2.31 ppm, respectively. Mean daily water renewal, including rain and added freshwater, varied between 0.85 and 0.90 percent. Mean shrimp survival varied between 87.7 percent and 94.9 percent with no significant difference among treatments (Table 3). The yields varied between 0.98 kg/m$^3$ and 1.14 kg/m$^3$ with the latter representing shrimp fed the higher protein diet at the 84.2 percent rate of the lower protein diet. This yield was significantly higher than the one obtained when the shrimp were fed the lower protein diet at the reduced rate. No significant differences were found among treatments in yields. No differences were found among treatments in average weight, yield, survival and growth when shrimp were fed the higher protein feed on an isonitrogenous basis to the 30 CP feed. This was also the case when the shrimp were fed on an isonitrogenous basis aimed to provide 25.3 percent protein; however, those shrimp were significantly smaller than those fed the diets at the 30 percent protein level. Of importance is the fact that the FCR of shrimp fed the higher protein diet at both levels, 30 percent and 25.3 percent, were significantly lower than those obtained when shrimp were fed the lower protein diet at full and at reduced rations.

Although digestible energy and the protein were not determined in our study, the good performance of the higher protein feed, when offered at a lower ration rate that met the nitrogen level offered by the lower protein ration, suggests that the ratio of digestible energy to protein in the higher protein feed was adequate.

The results from this study showed that feeding the higher protein diet on an isonitrogenous basis to the lower protein diet resulted in significant improvement in FCR. Although one can expect to pay more for the higher protein feed, the lower ration size used in the case of the higher protein diet can easily offset the differences in feed cost. Furthermore, the uses of smaller amounts of feed translates to less pollutants being released into the environment.

## Pond Study

A concurrent 138 day growout study was conducted in two HDPE membrane-lined ponds, each with working water volume of 2,450 m$^3$, using the same commercial diets, 30 percent and 36 percent CP, made by the same feed mill. That study evaluated the effect of feeding the higher protein feed at reduced ration rate, which provided the shrimp with same nitrogen level offered by the lower protein diet. Both ponds were stocked with juvenile (0.8 g) *L. vannamei* at a density of 74/m$^3$ (106/m$^2$). Shrimp in one pond were fed the lower protein feed, while those in the other pond were fed the higher protein feed. The higher protein feed was fed on a isonitrogenous basis to that of the lower protein feed, so shrimp fed the 36 percent CP diet received only 84.2 percent of the ration fed to the shrimp offered the 30 percent protein diet. Rations were adjusted weekly assuming a fixed FCR of 1:1.4, weekly growth of 1.2 g and weekly mortality of one percent. The daily and weekly water quality indicators in the ponds during the experiment were within the acceptable limits for the species. Shrimp fed the higher protein feed on an isonitrogenous basis at the reduced ration level had lower FCR, higher survival and greater yield than those fed the lower protein feed at full ration (Table 4). Although the treatments in the ponds had no replication, the data suggest better performance with the higher protein feed than the lower protein feed when the former was fed on an isonitrogenous basis.

Table 3. The effect of two commercial diets (30% and 36% CP), when fed at different ration sizes, on mean weights, weekly growth rates, yields, survival and FCR rates in an outdoor tank study with *Litopenaeus vannamei* when operated under limited water discharge.

| Treatment CP–Ration | Av. Wt* (g) | Yield (kg/$m^3$) | Survival (%) | Growth (g/wk) | FCR |
|---|---|---|---|---|---|
| 30% CP-100% | 16.69 ±2.54 $^{a}$ | 1.03±0.08 $^{ab}$ | 87.7±7.45 $^{a}$ | 0.95±0.05 $^{a}$ | 1.82±0.13 $^{a}$ |
| 36% CP-84.2% | 16.01 ±2.14 $^{a}$ | 1.14±0.10 $^{b}$ | 89.2±3.43 $^{a}$ | 0.91±0.03 $^{a}$ | 1.38±0.19 $^{b}$ |
| 30% CP-84.2% | 14.46 ±2.09 $^{b}$ | 0.98±0.10 $^{a}$ | 94.9±4.92 $^{a}$ | 0.82±0.07 $^{b}$ | 1.66±0.13 $^{a}$ |
| 36% CP-70.9% | 13.92 ±2.57 $^{b}$ | 1.02±0.05 $^{ab}$ | 94.0± 9.76$^{a}$ | 0.79±0.05 $^{b}$ | 1.33±0.60 $^{b}$ |

** Mean weight at harvest*

*Column with the same superscript letters suggest no statistically significant differences*

Table 4. The effect of two commercial diets with 30% and 36% CP, when the higher protein diet was fed at lower ration, on growth, survival and FCR of *Litopenaeus vannamei* in outdoor ponds under limited water discharge.

| Diet | Av. Wt.*(g) | Time (d) | Yield (kg/$m^3$) |
|---|---|---|---|
| Survival (%) | Growth (g/wk) | FCR | |
| P-30% CP | 16.4 | 137 | 0.67 |
| 55.1 | 0.84 | 2.58 | |
| P-36% CP | 15.8 | 137 | 0.80 |
| 69.0 | 0.80 | 1.88 | |

** Final mean weight*

## Conclusion

The studies demonstrated that under limited discharge conditions, better feed utilization can be expected when shrimp are offered a higher protein diet at a reduced ration level compared to a lower protein diet fed at a higher level. Using this strategy as a management tool, a significant reduction in feed utilization can be achieved. The results of the studies clearly depict that under the present experimental conditions shrimp can effectively be raised at high stocking densities with limited water exchange without compromising productivity and with reduced negative environmental impacts from the culture pond effluent.

## Notes

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