

Growth Response of *Penaeus setiferus* to Four Commercial Feeds Under Controlled Laboratory Conditions

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Shrimp farmers have access to and have evaluated a diverse number of shrimp species; however, due to culture and market considerations three penaeid species (*Penaeus monodon*, *P. orientalis* and *P. vannamei*) account for 80% of the world production (Weidner and Rosenberry 1992). Although culture techniques for these species have been extensively studied and are relatively well established, they are not native to U.S. coastal waters and hence possess problems associated with the use of exotic species. Three native species *P. aztecus*, brown shrimp; *P. duorarum*, pink shrimp; and *P. setiferus*, white shrimp, support commercial fisheries along the Gulf states (Gulf of Mexico Fishery Management Council 1981). The commercial culture of these species would avoid the inherent problems associated with the culture of exotic species and allow shrimp farmers in the Caribbean basin to more effectively expand operations.

A variety of studies have evaluated the culture potential of native species (Broom 1968; Latapie et al. 1972; Neal and Latapie 1972; Parker et al. 1974). Based on low density pond studies, *P. setiferus* has consistently produced better results than *P. aztecus* and consequently may be more suitable to commercial culture. Recent studies have demonstrated that *P. setiferus* can be cultured at higher densities, although growth rates are lower than those of *P. vannamei* (Browdy et al. 1991). These results would indicate that there may be inherent differences in the culture requirements of the two species and that further research is required

if commercially applicable techniques are to be developed.

The reduced growth rates observed in *P. setiferus* cultured under semi-intensive pond conditions may be due to nutritionally inadequate feeds, which are essential for the optimization of intensive production systems. Consequently, the objective of these trials was to evaluate the ability of commercial feeds to support growth of *P. setiferus* in the absence of natural foods.

Four commercial feeds were selected on the basis of availability and the reputation of the producers to provide quality feeds. Three of the feeds (45% protein, 9% lipid, 10% squid; 40% protein, 8.5% lipid, 5% squid; and 35% protein, 8% lipid, 2.5% squid) were obtained from Rangen Inc. (Buhl, Idaho, USA), whereas the fourth feed (40% protein, 9.5% lipid, without squid) was obtained from Zeigler Bros., Inc. (Gardners, Pennsylvania, USA). Postlarval *Penaeus setiferus* were obtained from the Lone Star Hatchery (Port Isabel, Texas, USA) and raised to the desired size in semi-closed systems under controlled laboratory conditions. All growth trials were conducted in a semi-closed seawater system consisting of a biological-filter, sand-filter, 1-hp pump and 12 circular tanks each containing 150 L of culture water. Each tank was equipped with aeration, a water supply (4 L/min), automatic electric feeder and netting to cover the tank. In the first two experiments a fine mesh net with a 20-cm diameter hole (required to allow the feed to fall through the net) was utilized. In the third experiment a large mesh net which would allow the feed to easily pass was used to completely seal the tanks. For each experiment, three replicate groups of shrimp were used to eval-

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uate each dietary treatment. The first growth trial (49 d) was stocked with 30 shrimp per tank having a mean initial weight of 0.285 g. The second and third growth trials (56 d) were stocked with 15 shrimp per tank having an initial mean weight of 3.6 and 7.7 g, respectively. Upon initiation and termination of the growth trials, the shrimp from each tank were counted, weighed and the average shrimp weight per tank calculated. Additionally, in the first two growth trials, at day 28 the shrimp were counted and weighed. All feeds were offered to the shrimp at levels in excess of satiation and dispersed into the tanks by means of continuous automatic feeders. On a daily basis, feeders were refilled and the tanks siphoned to remove buildups of feed, feces and exuviae.

In each growth trial, dissolved oxygen and salinity were measured daily. Total ammonia-nitrogen, nitrite-nitrogen and pH were measured three times per week utilizing methods described by Spotte (1979). Growth and survival data from each growth trial were analyzed using a one-way analysis of variance to determine significant differences ($P < 0.05$) among treatment means. Student-Newman-Keul's multiple range test (Steel and Torrie 1980) was used to identify significant differences among treatment means. Additionally, to increase the sensitivity of the statistical analyses and to evaluate the overall effects of the diets on final weight and survival of the shrimp, a combined data set was created and the data examined with analysis of covariance utilizing the initial weight of the shrimp as the covariate. Significant ($P \leq 0.05$) differences between adjusted treatment means were determined by pairwise comparisons. All statistical analyses were conducted using the Statistical Analysis System (SAS Institute Inc. 1988).

Mean (\pm standard deviation) temperatures and salinities for the three growth trials were: 27.4 ± 1.4 C, 32.7 ± 2.1 ppt; 27.0 ± 2.6 C, 30.2 ± 1.9 ppt; and 26.5 ± 1.8 C, 25.3 ± 1.8 ppt, respectively. In all three growth trials, dissolved oxygen values were

maintained near saturation, and ammonia and nitrite values were within acceptable limits (Chen and Lei 1990; Chen et al. 1990). Consequently, water quality parameters should not have had a significant influence on the growth and survival of the shrimp tested.

With the exception of the second growth trial, survival was good for all dietary treatments (Tables 1–3) with no significant differences observed between dietary treatments. Poor survival during the latter portion of the second growth trial was due to losses incurred when shrimp jumped through the feeding hole and was hence not related to the dietary treatments. Once identified this problem was corrected, for the third growth trial, by sealing the tanks with a 2.4 cm mesh netting. Based on these results, the commercial feeds tested appear adequate to support good survival for the three sizes of *P. setiferus* tested.

The growth response of the shrimp to the various feeds was similar for all three sizes of shrimp tested (Table 1–3). In all three experiments, shrimp maintained on feeds containing 40 and 45% protein with squid outperformed shrimp maintained on the 40% protein feed without squid and the 35% protein feed with 2.5% squid. To increase the sensitivity of data analyses, analyses of covariance was utilized to evaluate the three growth trials as a combined data set. The adjusted means (means adjusted for the covariate, initial weight) for the final weight of shrimp offered feeds containing 45% protein with 10% squid and 40% protein with 5% were 9.3 and 8.9 g, respectively. The adjusted means for the final weight of shrimp offered feeds containing 35% protein with 2.5% squid and 40% protein without a squid supplement were 7.5 and 7.6 g, respectively. Although, there were no significant differences between the adjusted means within the two groups, the groups were significantly different from each other, thus confirming that feeds for *P. setiferus* should contain at least 40% protein and 5% squid. Additionally, since there was no significant interac-

TABLE 1. Final weight and survival of *P. setiferus* offered one of four commercial feeds during the first growth trial.^a

Protein (%)	Squid (%)	Initial weight (g)	Weight (g) (% weight gain)		Survival (%)	
			Day 28	Day 49	Day 28	Day 49
45	10	0.28 ^{zb}	2.78 ^z (873%)	5.92 ^z (1,973%)	99.0 ^z	92.3 ^z
40	5	0.30 ^z	2.74 ^z (814%)	6.08 ^z (1,928%)	97.7 ^z	93.3 ^z
35	2.5	0.28 ^z	1.87 ^y (561%)	3.96 ^y (1,299%)	97.7 ^z	91.3 ^z
40	0	0.28 ^z	2.08 ^y (634%)	4.24 ^y (1,396%)	99.0 ^z	93.3 ^z

^a 49-d feeding trial.

^b Means of three replicates. Means in each column sharing the same superscript are not significantly different ($P > 0.05$).

tion observed between dietary treatment and shrimp size, a size dependent response to the feeds was not observed.

The growth rates observed in these experiments were higher than those reported by Chen et al. (1985) and Fenucci et al. (1980) for *P. setiferus* offered practical diets under laboratory conditions. Although the commercial feeds tested were not designed specifically for this species, the increased growth response over early studies demonstrates the advances in shrimp nutrition and practical diet formulations. However, a comparison of growth rates (1.56 g/wk) obtained with low density pond-culture (Robertson et al. 1993) to the relatively poor growth rates (0.57–0.39 g/wk) observed in the third growth trial indicates that some aspect of the culture technique is limiting. Since the biomass observed at the conclusion of the first and third growth trials were similar (1.134-kg shrimp/m³ vs 1.130-kg shrimp/m³), a density dependent response is unlikely, possibly indicating a nutritional problem.

Robertson et al. (1993) conducted a similar study utilizing bottomless pens in an outdoor pond to evaluate the growth response of juvenile *P. setiferus* to three commercial feeds containing 30% protein without squid,

TABLE 2. Final weight and survival of *P. setiferus* offered one of four commercial feeds for the second growth trial.^a

Protein (%)	Squid (%)	Initial weight (g)	Weight (g) (% weight gain)		Survival (%)	
			Day 28	Day 56	Day 28	Day 56 ^c
45	10	3.45 ^{zb}	6.42 ^z (186%)	9.72 ^z (276%)	95.5 ^z	64.8 ^z
40	5	3.61 ^z	6.45 ^{yz} (179%)	9.36 ^{yz} (240%)	100.0 ^z	62.4 ^{yz}
35	2.5	3.63 ^z	5.37 ^y (148%)	7.51 ^y (222%)	95.5 ^z	50.0 ^y
40	0	3.58 ^z	5.60 ^y (157%)	7.75 ^y (223%)	88.9 ^z	51.7 ^z

^a 56-d feeding trial.

^b Means of three replicates. Means in each column sharing the same superscript are not significantly different ($P > 0.05$).

^c The poor survival during the later portion of the growth trial was due to the shrimp jumping through the feeding hole.

40% protein with 5% squid and 50% protein with 15% squid. Under the reported conditions, stocking densities of 40, 3.6-g shrimp per square meter, shrimp growth increased positively to protein and/or squid content of the diets, indicating that in high density pond systems, feed quality (protein and squid content) can significantly affect growth rates.

TABLE 3. Final weight and survival of *P. setiferus* offered one of four commercial feeds during the third growth trial.^a

Protein (%)	Squid (%)	Initial weight (g)	Weight (g) (% weight gain)	Survival (%)
45	10	7.76 ^{zb}	12.4 ^z (59%)	91.1 ^z
40	5	7.76 ^z	11.4 ^{yz} (47%)	88.9 ^z
35	2.5	7.65 ^z	11.0 ^y (44%)	88.9 ^z
40	0	7.77 ^z	10.9 ^y (40%)	95.5 ^z

^a 56-d feeding trial.

^b Means of three replicates. Means in each column sharing the same superscript are not significantly different ($P > 0.05$).

Based on the limited information on this species the feeds utilized in the current study were felt to be nutritionally adequate and contained protein in excess of the reported requirement (Andrews et al. 1972; Chen et al. 1985; Lee and Lawrence 1985; Dokken 1987). However, feeds containing 40% protein and 5% squid produced significantly higher weight gain than shrimp offered the 40% protein diet without squid or the 35% protein diet with 2.5% squid. Based on these results and those reported by Fenucci et al. (1980), the presence of squid meal ($\geq 5\%$ diet) may be responsible for the observed increases in growth rate, presumably by supplying essential nutrients and/or through increased attractability and/or palatability of the feeds.

Based on the current results, it is clear that in the absence of natural productivity, commercial feeds are capable of sustaining good growth and survival of *P. setiferus*. However, reduced growth rates of larger sub-adult shrimp and the poor growth response of shrimp maintained on feeds containing low levels of protein and squid indicate a need for continued research in the area of nutrient requirements and feed formulation for this species. Recent studies such as those of Sandifer et al. (1990), Browdy et al. (1991), and Robertson et al. (1993) demonstrate the applicability of current technology and the potential of *P. setiferus* for commercial culture. As noted by Robertson et al. (1993) the need for high quality feeds to sustain acceptable growth rates will increase the production costs for this species. Consequently, if this species is to be produced at a minimal cost, subsequent research will be required to continue development of both culture techniques and nutritional data required for the production of optimal diets designed specifically for this species.

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