Effect of Diet Protein on Food Conversion and Nitrogen Discharge during Semi-Intensive Production of *Penaeus vannamei* during the Dry Season

Interim Work Plan, Honduras Study 1 (Part II)

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Introduction

Results of previous research have demonstrated that shrimp production is similar at protein levels ranging from 20 to 40%, when shrimp are stocked at densities ranging from 5 to 11/m^2 (Teichert-Coddington and Rodriguez, 1995a). These results indicated that shrimp stocked at semi-intensive levels did not require diets containing high levels of protein. However, some think that food conversion can be improved if a high-protein diet is employed. In order for food conversion to be improved, shrimp would either need to have better growth rates with the high-protein diet, or similar growth rates with less feed. A prior feed trial in Choluteca with shrimp stocked at 7.5/m^2 demonstrated that production during the dry season was not significantly affected by a 50% reduction in the feeding rate (Teichert-Coddington and Rodriguez, 1995b). Wet season production was significantly impacted by the 50% reduction in feeding although feeding efficiency was improved (Teichert-Coddington and Rodriguez, 1995b). These results indicated that shrimp were overfed normally during the dry season and that wet season rates could potentially be reduced although not cut in half. The objective of this experiment was to determine the effect of dietary protein and feeding rate on feed conversion and nitrogen discharge in the semi-intensive production of *Penaeus vannamei*.

Materials and Methods

Twelve ponds located at a commercial shrimp farm on a riverine estuary on the Gulf of Fonseca, Honduras, were used for this dry-season study. Ponds averaged 1.67 ± 0.07 ha, 0.57 ± 0.06 m, and 9431 ± 993 m^3, in area, depth, and volume, respectively. This study was originally designed to test four treatments (two feed protein levels at two feeding rates) but was modified because results of previous studies had shown little effect of feed rate during the dry season. We also felt that increasing the number of replicates per treatment from three to four would improve our ability to detect treatment differences. As only 12 ponds were available for the study, one of the initially proposed treatments was dropped. Thus, three treatments were tested: a 20% and a 30% protein feed applied at 50% of the feeding curve, and a 20% protein feed applied at 75% of the feeding curve. A completely randomized design with four replicates per treatment was used.

Ponds were stocked with hatchery-produced post-larval (PL) *Penaeus vannamei* at 325,000/ha on 19 January 1996. Stocking rate of PL shrimp was based on a historical survival rate due to Taura Syndrome of 25%, and was selected to achieve a final stocking rate of approximately 80,000 shrimp/ha. Most Taura Syndrome mortality occurs within the first month following stocking. Ponds were harvested 87 days after stocking.

Feed protein levels tested were 20% and 30% crude protein; a commercial ration manufactured locally by ALCON was used. Shrimp were offered feed six days per week beginning on 13 February 1996. Feed rate for each treatment was 50% or 75% of the theoretical feeding curve for *P. vannamei*:

$$\mathrm{Log}_{10}Y = -0.899 - 0.561\mathrm{Log}_{10}X$$

where,
Y = feed rate as a % of biomass; and
X = mean weight of shrimp in grams.

Daily feed rate was calculated for individual ponds and then averaged by treatment. All ponds within a treatment received the same quantity of feed on a daily basis. Feed was offered once each day. Cast net samples were taken weekly to monitor shrimp growth in each pond population. Feed rate was adjusted weekly based on shrimp samples. Feed conversion ratio was calculated as the weight of feed offered divided by gross whole shrimp yield.

Water was not exchanged during the first three weeks of culture; however, water was exchanged at 20% of the pond volume once per week beginning on week four. If early morning dissolved oxygen concentration was ≤ 2.5 mg/l, 5% of the pond volume was exchanged. In all water exchanges, pond level was lowered first and then refilled. Losses to seepage and evaporation were replaced weekly. Dates and quantities of all water additions and exchanges were recorded.

Pond water quality variables were measured upon initiation of the experiment, and beginning with initiation of scheduled water exchange on week four, discharge and replacement water quality was monitored weekly. Weekly discharge water samples were collected from each pond's outfall during water exchange. Because all ponds were supplied from a common water supply canal, water samples for replacement water analysis were collected at each extreme and the middle segment of the canal supplying the ponds. At harvest, water samples were collected at 0%, 10%, and 100% of pond volume for analysis. Initial pond water and replacement water samples were obtained with a column sampler. Water samples were analyzed for the following: 1) pH measured potentiometrically; 2) nitrate-nitrogen by cadmium reduction (Parsons et al., 1992), 3) total ammonia-nitrogen (Parsons et al., 1992); 4) filterable reactive phosphate (Grasshoff et al., 1983); 5) chlorophyll-*a* (Parsons et al., 1992); 6) total alkalinity by titration to pH 4.5 endpoint; 7) salinity; and 8) BOD_2 at ambient temperature. Total nitrogen and total phosphorus were determined by nitrate and phosphate analysis, respectively, after simultaneous persulfate oxidation (Grasshoff et al., 1983).

Pond sediment samples were collected using a core sampler (4.2-cm ID) following pond inundation and prior to pond draining. Five to six core samples were collected along a transect across the width of the pond. Samples were collected along three transects per pond: near the inlet, the center, and the outlet. The methodology described by Munsiri et al. (1995) was followed to collect the top 2.5 cm of each soil core, prepare the sample for analysis, and analyze the sample. All core samples along a transect were pooled for analysis. Soils were analyzed for total phosphorus, total nitrogen, total carbon, sulfur, dilute acid-soluble phosphorus, metal ions, cation exchange capacity, and particle size.

The economic impact of substituting one feed management strategy for another was evaluated using a partial budget analysis (Kay, 1981). The 20% protein feed costs US $16.81/45.4 kg bag and the 30% protein feed costs $18.25/45.4 kg bag. Data were analyzed by ANOVA (Haycock et al., 1992). Percent data were arcsine transformed prior to analysis and differences were declared significant at alpha level 0.05.

Table 1. Production data (mean ± SD) from 1.67-ha semi-intensively managed earthen shrimp ponds where a 20% or 30% protein feed was tested. Feeding rate using the 20% protein feed was 50% or 75% of feeding curve and the feeding rate using the 30% protein feed was 50% of feeding curve. Post-larval shrimp were stocked to achieve a final stocking rate of approximately 80,000 shrimp/ha. Four replicate ponds were used per treatment.

Treatment	Gross Yield[1] (kg/ha/87d)	Mean Final Weight (g/shrimp)	Survival (%)	Feed Conversion Ratio
20% PROTEIN FEED				
50% of Feeding Curve	412 ± 50	6.1 ± 0.3	21.1 ± 0.0	1.0 ± 0.1
75% of Feeding Curve	534 ± 67	6.0 ± 0.5	26.3 ± 0.0	1.2 ± 0.1
30% PROTEIN FEED				
50% of Feeding Curve	490 ± 99	5.7 ± 0.4	31.0 ± 1.4	0.9 ± 0.1
Comparisons				
FEED PROTEIN LEVEL:				
20% Protein Feed v. 30% Protein Feed	NS	NS	NS	*
FEED RATE WITH 20% PROTEIN FEED:				
50% v. 75% of Feeding Curve	*	NS	NS	*

* Means differed significantly ($P < 0.05$).
NS: Means did not differ significantly ($P > 0.05$).
[1] Gross yield of whole shrimp.

Results

Shrimp survival continued to decline as a result of Taura Syndrome, with mean survival ranging from 21 to 31%, and no significant differences noted among treatments (Table 1). Gross yields of head-on shrimp ranged from 412 to 534 kg/ha for the 87-day production period, and mean individual weights ranged from 5.7 to 6.1 g/shrimp (Table 1). Feed protein content did not affect gross shrimp yields significantly (Table 1). Gross yield of whole shrimp fed the 20% protein feed was significantly greater when the feed rate was 75% of the feeding curve compared with 50% of the feeding curve (Table 1). Neither mean final individual weight (Table 1) nor growth (Figure 1) of shrimp was affected significantly by feed protein content or feed rate. Feed conversion ratios (FCR) were close to one and were significantly lower with the 30% protein feed at the 50% feed rate (Table 1). Feed application was suspended during a 4 to 6-day episode of chronic low dissolved oxygen that occurred in ponds during week nine. Mean daily feed rate ranged from 8.1 to 13.1 kg/ha.

Feed additions to ponds totaled 398 kg/ha (20% protein feed-50% feed curve), 656 kg/ha (20% protein feed-75% feed curve), and 416 kg/ha (30% protein feed-50% feed curve). Quantities of 20% protein feed added to ponds were significantly greater than quantities of 30% protein feed added. Significantly more 20% protein feed was used at the 75% of feed curve rate than at the 50% of feed curve rate. Nitrogen and phosphorus additions to ponds as feed were significantly greater with the high-protein feed and the low-protein feed at the higher feed rate. However, feed nitrogen additions did not differ significantly between the 20% protein-75% feed curve treatment and the 30% protein-50% feed curve treatment, which were isonitrogenous. Nitrogen and phosphorus additions to ponds as feed were, respectively, 13.6 kg N/ha and 3.3 kg P/ha (20% protein feed-50% feed curve), 22.4 kg N/ha and 5.4 kg P/ha (20% protein feed, 75% feed curve), and 21.1 kg N/ha and 4.1 kg P/ha (30% protein feed-50% feed curve).

Shrimp tail-size distribution at harvest ranged from 51/60 count to 151/200 count, with 75% to 85% of the harvest being within the 91/110 to 131/150 range (Table 2). The value of the harvest ranged from US $1,308 to US $1,716 per hectare. Partial budget

Table 2. Mean distribution of tail sizes is expressed as a percentage of gross yield of shrimp tails and value of product by size classification.

Shrimp Tail Size Classification (count/lb)	**Tail Price (US $/kg)**	**20% Protein Feed**				**30% Protein Feed**	
		50% Feed Rate		*75% Feed Rate*		*50% Feed Rate*	
		Tail Size Distribution (%)	Value (US $/ha)	Tail Size Distribution (%)	Value (US $/ha)	Tail Size Distribution (%)	Value (US $/ha)
51/60	9.92	0.00	$0	0.25	$8	0.00	$0
61/70	8.82	1.00	$23	0.25	$8	0.00	$0
71/90	7.72	8.50	$174	14.00	$369	3.75	$87
91/110	6.61	30.75	$541	26.75	$605	21.50	$429
111/130	4.41	27.00	$317	26.25	$396	34.75	$463
131/150	3.31	20.75	$183	22.50	$254	29.25	$292
151/200	2.21	12.00	$70	10.00	$75	10.75	$72
Sum ($/ha):			$1,308		$1,716		$1,343

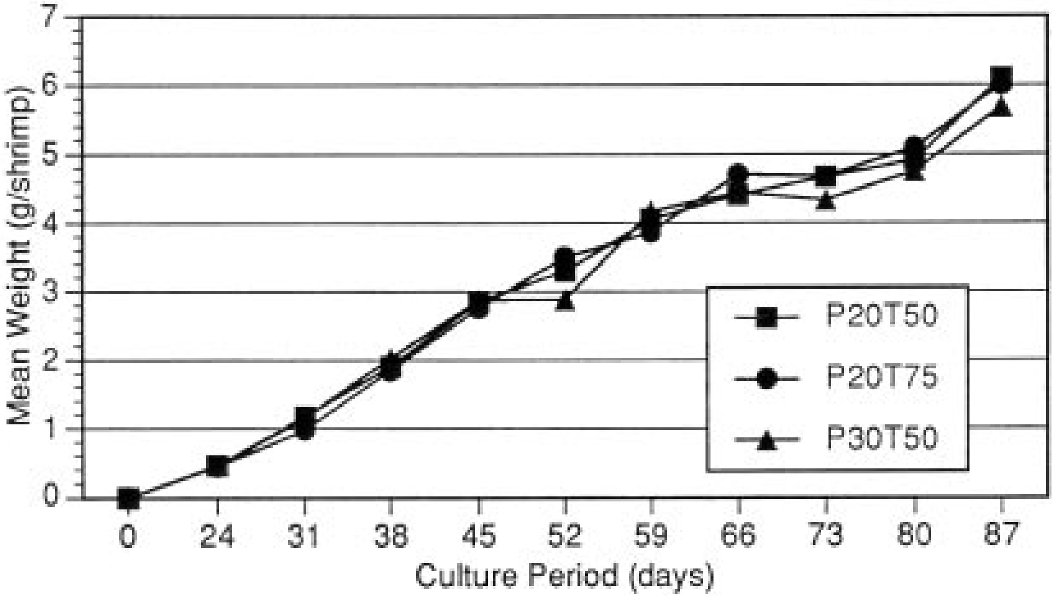

Figure 1. Growth of *P. vannamei* during an 87-day culture cycle in 1.67-ha earthen ponds receiving a 20% protein feed at 50% of feed curve (P20T50), a 20% protein feed at 75% of feed curve, or a 30% protein feed at 50% of feed curve (P30T50).

analysis of increasing feed rate from 50% to 75% of feed curve with the 20% protein feed showed a net change in profit of $313/ha. Change of feed management from a 20% protein feed-75% feed curve to a 30% protein-50% feed curve resulted in a net change in profit of $297/ha. Use of a 30% protein feed-50% feed curve in place of a 20% protein feed 50%-feed curve gave a net change in profit of $16/ha.

Salinity, total nitrogen and phosphorus, chlorophyll-*a*, and BOD_2 concentrations in inlet water were significantly lower than in pond water (Table 3). Nitrate was not detected in either inlet water or pond water. No significant differences were detected among treatment water quality means (Table 3); however, inorganic nitrogen and phosphorus introduced to ponds in inlet water were converted to organic forms. Although there

Table 3. Mean concentrations (± SD) of water quality variables from 1.67-ha shrimp ponds and water supply canal. Shrimp in four replicate ponds each were offered a 20% protein feed at 50% or 75% of feeding curve or 30% protein feed at 50% of feeding curve.

Variable	Treatments			Water Supply Canal
	20% Protein Feed		*30% Protein Feed*	
	50% Feed Rate	75% Feed Rate	50% Feed Rate	
Salinity (g/l)	28.6 ± 0.3 ab	29.0 ± 0.3 b	29.1 ± 0.5 b	28.2 ± 0.2 a
Total Ammonia Nitrogen (mg/l)	0.022 ± 0.005 a	0.025 ± 0.006 a	0.020 ± 0.008 a	0.017 ± 0.006 a
Total Nitrogen (mg/l)	1.77 ± 0.09 b	1.8 ± 0.22 b	1.78 ± 0.13 b	0.69 ± 0.05 a
Soluble Reactive Phosphorus (mg/l)	0.10 ± 0.11 a	0.06 ± 0.02 a	0.11 ± 0.05 a	0.05 ± 0.01 a
Total Phosphorus (mg/l)	0.25 ± 0.10 b	0.26 ± 0.04 b	0.32 ± 0.08 b	0.12 ± 0.01 a
Total Alkalinity (mg/l as $CaCO_3$)	154.6 ± 19.9 a	146.2 ± 5.3 a	147.7 ± 5.2 a	-
Chlorophyll-*a* (mg/m^3)	54.96 ± 8.08 b	66.06 ± 13.70 b	53.19 ± 13.41 b	24.21 ± 7.63 a
BOD_2 (mg/l)	9.84 ± 1.21 b	9.57 ± 0.90 b	9.69 ± 1.32 b	5.52 ± 0.44 a

ab: Variable means followed by the same letter are not significantly different ($P > 0.05$).

Table 4. Initial and final mean (± SD) soil nutrient concentrations in 1.67-ha shrimp ponds. Top 2.5 cm of pond sediment was collected for analysis.

Pond	Calcium (mg/kg)		Potassium (mg/kg)		Magnesium (mg/kg)	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*
VN6	1493.8 ± 318.8	2250.6 ± 644.2	683.6 ± 134.4	1294.3 ± 143.0	2081.7 ± 519.6	3451.0 ± 646.6
VN7	905.0 ± 33.64	1844.7 ± 468.9	640.1 ± 32.2	1166.3 ± 183.1	1808.4 ± 178.5	3149.6 ± 981.3
VN8	1396.0 ± 681.0	2253.5 ± 205.8	676.9 ± 72.8	1118.7 ± 115.9	1737.2 ± 380.5	2691.3 ± 506.5
VN10	1071.6 ± 146.4	1413.1 ± 430.0	691.9 ± 37.5	904.2 ± 141.5	2202.5 ± 513.8	2082.8 ± 271.5
VN11	1286.2 ± 525.7	1820.2 ± 669.7	700.6 ± 48.2	1094.3 ± 237.4	2001.7 ± 317.2	2587.4 ± 297.0
VN12	1336.0 ± 275.4	1862.1 ± 553.0	810.3 ± 31.9	1080.7 ± 124.8	2254.0 ± 171.9	2408.3 ± 326.1
VN13	1165.2 ± 176.9	2014.0 ± 430.5	739.9 ± 84.6	1136.9 ± 271.8	1871.0 ± 414.7	2702.7 ± 695.5
VN14	1248.8 ± 200.4	1722.2 ± 232.4	799.8 ± 68.9	1114.7 ± 142.2	2145.8 ± 212.0	2441.7 ± 299.4
VN15	1147.5 ± 255.0	1643.5 ± 263.8	738.9 ± 114.9	1146.5 ± 62.8	1921.5 ± 377.7	2965.3 ± 66.6
VN16	1286.2 ± 293.0	2052.7 ± 765.4	751.0 ± 38.7	1168.0 ± 174.0	2055.5 ± 123.9	2796.1 ± 442.7
VN17	1194.2 ± 161.6	1584.4 ± 118.5	788.4 ± 116.3	1267.1 ± 56.7	2069.8 ± 338.8	2981.1 ± 311.1
VN18	1306.2 ± 22.8	2116.9 ± 61.6	755.9 ± 111.4	1271.5 ± 83.5	2161.0 ± 462.4	2987.2 ± 330.3

Pond	Phosphorus (mg/kg)		Copper (mg/kg)		Iron (mg/kg)		Manganese (mg/kg)	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*
VN6	73.5 ± 60.7	35.0 ± 12.8	1.2 ± 0.2	0.7 ± 0.5	34.9 ± 7.0	55.8 ± 6.3	371.4 ± 98.1	802.6 ± 164.3
VN7	77.0 ± 32.6	52.4 ± 24.2	1.6 ± 0.8	1.1 ± 0.8	41.1 ± 14.8	94.5 ± 28.0	195.5 ± 39.1	499.9 ± 136.2
VN8	123.7 ± 117.5	70.9 ± 66.5	1.7 ± 0.4	1.0 ± 0.7	43.2 ± 9.8	124.7 ± 23.3	254.1 ± 83.9	536.2 ± 126.1
VN10	85.4 ± 39.0	86.2 ± 46.5	2.4 ± 0.8	2.0 ± 1.0	51.3 ± 18.7	116.2 ± 14.2	223.7 ± 40.2	370.3 ± 103.8
VN11	114.9 ± 92.4	136.9 ± 158.3	1.8 ± 0.7	1.3 ± 0.8	49.4 ± 16.5	112.4 ± 22.4	341.2 ± 110.9	545.8 ± 278.5
VN12	99.6 ± 52.5	121.9 ± 142.9	1.3 ± 0.2	1.1 ± 0.5	37.1 ± 10.1	93.2 ± 34.0	421.1 ± 27.5	498.8 ± 61.3
VN13	112.2 ± 67.0	140.5 ± 183.0	1.5 ± 0.7	0.8 ± 0.7	33.5 ± 1.5	87.3 ± 42.5	332.8 ± 124.8	607.4 ± 226.1
VN14	73.6 ± 30.4	129.6 ± 118.0	1.4 ± 0.8	1.3 ± 1.0	55.1 ± 32.5	97.5 ± 38.9	326.1 ± 111.2	385.7 ± 97.1
VN15	115.5 ± 106.6	45.4 ± 15.7	1.8 ± 0.6	0.7 ± 0.5	49.2 ± 6.7	31.1 ± 14.1	271.6 ± 80.7	561.9 ± 104.3
VN16	78.5 ± 47.2	37.7 ± 10.2	1.8 ± 0.8	0.6 ± 0.6	55.7 ± 22.0	67.7 ± 39.1	288.6 ± 70.7	465.0 ± 39.1
VN17	81.3 ± 68.3	59.7 ± 47.9	1.7 ± 0.8	1.0 ± 0.7	46.7 ± 12.2	100.9 ± 24.9	319.0 ± 47.7	498.5 ± 92.3
VN18	96.5 ± 90.2	70.3 ± 39.2	1.4 ± 0.8	0.9 ± 0.2	57.5 ± 18.0	106.4 ± 41.5	260.3 ± 109.8	349.5 ± 107.6

were significant differences in nitrogen and phosphorus additions to ponds, there were no significant differences among treatments in nitrogen or phosphorus concentrations in water discharged from ponds.

Soil calcium, potassium, magnesium, iron, manganese, boron, sodium, and nitrogen concentrations were higher in the final soil sample (Table 4). Concentrations of phosphorus, copper, zinc, barium, cobalt, chromium, total phosphorus,

Table 4. Continued.

Pond	Zinc (mg/kg)		Boron (mg/kg)		Molybdium (mg/kg)		Aluminum (mg/kg)	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*
VN6	4.4 ± 0.6	3.8 ± 0.4	15.1 ± 3.8	23.9 ± 2.7	1.8 ±0.4	2.2 ± 2.3	173.3 ± 13.2	66.4 ± 42.5
VN7	4.4 ± 0.6	5.7 ± 1.2	13.2 ± 0.8	21.8 ± 7.0	7.8 ± 10.5	1.9 ± 1.4	187.4 ± 49.6	123.2 ± 41.7
VN8	5.1 ± 0.8	6.0 ± 0.8	12.2 ± 2.9	16.5 ± 2.6	4.0 ± 4.1	1.6 ± 0.8	186.6 ± 31.9	122.7 ± 32.5
VN10	4.8 ± 0.5	5.3 ± 0.2	14.8 ± 1.9	14.3 ± 2.7	3.3 ± 2.8	1.4 ± 0.5	214.2 ± 52.7	185.1 ± 26.6
VN11	4.7 ± 0.5	5.7 ± 1.0	13.3 ± 0.9	18.0 ± 2.6	2.8 ± 2.0	1.4 ± 0.5	192.3 ± 38.0	146.3 ± 26.3
VN12	4.7 ± 0.9	5.5 ± 1.2	13.6 ± 0.3	16.9 ± 3.3	2.6 ± 1.4	1.2 ± 0.4	181.4 ± 33.7	134.3 ± 26.8
VN13	5.0 ± 0.7	5.0 ± 0.4	12.8 ± 2.0	18.6 ± 5.0	2.3 ± 1.0	1.3 ± 0.3	172.1 ± 7.0	112.9 ± 31.6
VN14	5.9 ± 2.8	5.8 ± 1.4	14.2 ± 0.8	15.7 ± 3.3	2.1 ± 1.0	1.3 ± 0.2	148.9 ± 37.4	184.2 ± 45.0
VN15	4.9 ± 1.0	4.5 ± 1.3	13.5 ± 1.9	21.2 ± 0.9	2.0 ± 0.7	1.3 ± 0.2	182.9 ± 19.4	119.4 ± 28.4
VN16	5.0 ± 0.6	4.9 ± 1.3	13.8 ± 0.1	21.3 ± 4.5	1.9 ± 0.6	1.1 ± 0.2	182.9 ± 35.4	88.1 ± 49.7
VN17	5.2 ± 1.2	5.8 ± 3.0	15.0 ± 3.2	21.2 ± 2.8	2.1 ± 1.0	1.1 ± 0.6	176.1 ± 27.5	117.7 ± 50.5
VN18	5.0 ± 1.4	5.2 ± 2.1	14.0 ± 3.5	20.1 ± 1.6	1.8 ± 0.6	1.1 ± 0.3	164.6 ± 33.8	109.6 ± 12.3

Pond	Barium (mg/kg)		Cobalt (mg/kg)		Chromium (mg/kg)		Lead (mg/kg)	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*
VN6	2.9 ± 0.3	3.4 ± 0.6	0.9 ± 0.2	0.8 ± 0.3	0.6 ± 0.3	1.0 ± 0.9	2.4 ± 0.4	0.9 ± 0.0
VN7	2.7 ± 0.5	3.0 ± 0.5	0.8 ± 0.1	1.0 ± 0.5	0.4 ± 0.1	0.7 ± 0.4	2.4 ± 0.5	0.9 ± 0.0
VN8	2.2 ± 0.3	3.5 ± 0.3	0.9 ± 0.1	1.0 ± 0.2	0.5 ± 0.2	1.0 ± 0.5	2.3 ± 0.6	0.8 ± 0.1
VN10	2.2 ± 0.2	2.6 ± 0.6	0.9 ± 0.1	1.1 ± 0.1	0.6 ± 0.0	0.8 ± 0.5	3.1 ± 0.9	2.7 ± 3.1
VN11	2.3 ± 0.2	2.2 ± 0.5	1.0 ± 0.2	0.9 ± 0.0	0.7 ± 0.1	0.5 ± 0.5	2.6 ± 0.4	0.9 ± 0.0
VN12	2.5 ± 0.1	2.3 ± 0.1	1.1 ± 0.1	0.9 ± 0.2	0.8 ± 0.1	0.6 ± 0.4	2.4 ± 0.4	0.9 ± 0.0
VN13	2.6 ± 0.2	3.6 ± 1.2	1.1 ± 0.2	1.0 ± 0.2	0.6 ± 0.3	0.8 ± 0.4	2.4 ± 0.5	0.9 ± 0.0
VN14	2.3 ± 0.5	2.4 ± 0.8	1.0 ± 0.5	1.0 ± 0.1	0.6 ± 0.2	0.8 ± 0.3	2.7 ± 1.5	0.9 ± 0.0
VN15	3.0 ± 1.0	2.6 ± 0.4	1.0 ± 0.1	0.7 ± 0.2	0.6 ± 0.3	0.7 ± 0.2	2.5 ± 0.4	0.9 ± 0.0
VN16	2.8 ± 0.6	2.6 ± 0.4	0.9 ± 0.1	0.6 ± 0.2	0.6 ± 0.1	0.9 ± 0.3	2.5 ± 0.5	0.9 ± 0.0
VN17	2.8 ± 0.4	3.0 ± 0.6	0.9 ± 0.1	1.0 ± 0.4	0.6 ± 0.2	0.8 ± 0.2	2.4 ± 0.4	0.9 ± 0.0
VN18	2.8 ± 0.2	3.3 ± 0.2	0.9 ± 0.0	0.8 ± 0.1	0.7 ± 0.3	0.8 ± 0.1	2.6 ± 0.4	0.9 ± 0.0

Table 4. Continued.

Pond	Sodium (mg/kg)		Total Phosphorus (mg/kg)		Carbon (%)		Nitrogen (%)	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*	*Initial*	*Final*
VN6	7964.3 ± 3356.9	23014.5 ± 8028.4	1150.4 ± 151.6	1167.4 ± 109.3	1.2 ± 0.3	1.6 ± 0.4	0.1 ± 0.1	0.2 ± 0.0
VN7	6401.6 ± 338.8	19682.9 ± 7699.7	1113.9 ± 193.6	1220.8 ± 49.6	1.0 ± 0.4	1.5 ± 0.3	0.1 ± 0.1	0.2 ± 0.0
VN8	6977.8 ± 2268.1	18669.8 ± 4091.9	1262.1 ± 59.7	1269.4 ± 52.6	1.0 ± 0.2	1.5 ± 0.3	0.1 ± 0.0	0.2 ± 0.0
VN10	8758.8 ± 2329.9	11733.1 ± 2176.0	1077.5 ± 132.9	1007.0 ± 191.1	0.9 ± 0.2	1.0 ± 0.6	0.1 ± 0.0	0.2 ± 0.1
VN11	8185.0 ± 3067.8	14904.1 ± 3811.1	1245.1 ± 157.1	1432.2 ± 416.8	1.1 ± 0.5	1.3 ± 0.4	0.1 ± 0.1	0.2 ± 0.1
VN12	8863.8 ± 1457.3	14604.5 ± 2624.8	1337.4 ± 23.4	1347.2 ± 270.4	1.2 ± 0.4	1.3 ± 0.4	0.1 ± 0.0	0.2 ± 0.0
VN13	6843.4 ± 1164.5	17610.1 ± 5867.9	1315.6 ± 36.0	1337.4 ± 204.4	1.3 ± 0.6	1.3 ± 0.5	0.1 ± 0.1	0.2 ± 0.0
VN14	8923.2 ± 1219.3	15023.7 ± 3506.3	1359.3 ± 99.5	1194.1 ± 88.2	1.5 ± 0.4	1.0 ± 0.5	0.2 ± 0.0	0.2 ± 0.1
VN15	6625.1 ± 2141.6	16786.5 ± 209.8	1223.2 ± 146.0	1147.9 ± 49.6	1.1 ± 0.5	1.7 ± 0.4	0.1 ± 0.0	0.2 ± 0.0
VN16	7467.0 ± 792.3	17674.6 ± 3388.1	1179.5 ± 120.7	1194.1 ± 67.7	1.1 ± 0.4	1.6 ± 0.2	0.1 ± 0.0	0.2 ± 0.0
VN17	8320.8 ± 2001.5	17865.3 ± 2194.1	1237.8 ± 97.9	1242.7 ± 21.0	1.2 ± 0.4	1.4 ± 0.4	0.1 ± 0.0	0.2 ± 0.0
VN18	7848.3 ± 2072.8	19418.3 ± 1894.4	1242.7 ± 116.3	1352.0 ± 147.3	1.2 ± 0.5	1.3 ± 0.1	0.1 ± 0.1	0.2 ± 0.0

and carbon were similar in initial and final sediment samples (Table 4). Molybdium, aluminum, and lead concentrations in pond sediments were lower in the final sample (Table 4). Particle size distribution of pond sediments showed a predominance of clay (48.7%), followed by silt (39.7%), and then sand (11.6 %) (Table 5).

Discussion

Taura Syndrome is endemic in southern Honduras and observed shrimp survivals in this experiment were typical for animals exposed to Taura Syndrome (Lightner and Redman, 1994; Brock et al., 1995). While shrimp farmers have adjusted their management strategy to compensate for this mortality by stocking up to four times the target stocking rate, the economic impact of this strategy has become significant.

Dietary protein level did not affect shrimp yields. Results of this study confirm results of previous studies that evaluated the effect of dietary protein on shrimp growth and yield in semi-intensive culture. Teichert-Coddington and Rodriguez (1995a) tested a 20% and 40% protein diet in ponds stocked with 5 or 11 *P. vannamei*/ha. Shrimp yield and growth were similar for the high and low protein feeds within each stocking rate (Teichert-Coddington and Rodriguez, 1995a). In another study, provision of a 29% or 37% protein feed did not significantly affect shrimp yields from semi-intensive culture ponds stocked with 4-8 *P. vannamei*/ha (Teichert-Coddington and Arrue, 1988).

Increased feeding rate (as a percentage of the feeding curve) with the 20% protein feed did result in significantly greater shrimp yield. However, neither final individual shrimp weight nor survival differed significantly between treatments. It is unlikely that treatment differences were responsible for the significant difference in yields observed between the two feeding rates for the 20% protein feed but rather they may have been responsible for shrimp survival. Although no significant differences in survival were detected, observed survival in the 20% protein-50% feed curve treatment was 5.2% lower than in the 20% protein-75% feed curve treatment. Given the absence of a difference in mean final weight, survival alone could account for the observed difference in yields. Similar growth curves for shrimp in both treatments provided further evidence of a lack of treatment differences.

Table 5. Particle size distribution, cation exchange capacity (CEC), and sulfur concentration in top 2.5 cm of shrimp pond sediment.

Pond	Sand (%)	Silt (%)	Clay (%)	CEC (meq/100 g)	Sulfur (%)
VN6	6.5	44.02	49.48	32.45	0.15
VN7	9.5	39.98	50.52	21.92	0.01
VN8	10.5	41.38	48.12	27.69	0.08
VN10	14.4	44.32	41.28	25.73	0.06
VN11	13.4	39.28	47.32	23.33	0.13
VN12	7.2	43.04	49.76	25.77	0.15
VN13	5.9	43.02	51.08	22.76	0.17
VN14	6.3	41.94	51.76	27.19	0.14
VN15	32.5	26.98	40.52	20.02	0.08
VN16	17.4	35.24	47.36	24.98	0.19
VN17	11.6	36.40	52.00	56.49	0.16
VN18	4.2	41.04	54.76	29.67	0.19

Shrimp yields observed in the present research were similar to dry season yields reported by Teichert-Coddington and Rodriguez (1995a and 1995b) and Teichert-Coddington et al. (1996) for 95- to 112-day culture periods. In the present trial, shrimp appeared to have grown little since day 66, and ponds were harvested after 87 days. Evaluation of data from Teichert-Coddington and Rodriguez (1995a and 1995b) and from Teichert-Coddington et al. (1996) indicated that little shrimp growth occurs after 11 to 12 weeks of culture during the dry season in Honduras. Continuation of culture beyond 12 weeks likely results in reduced profit because increased costs for feed and water pumping are not offset by increased production.

Feed conversion ratios in the present experiment were low, which indicated the following:

1) efficient feed management;
2) formulated feed only served to supplement natural productivity as a source of nutrients for shrimp growth; and
3) ponds were harvested before shrimp growth had ceased.

In fact, FCRs observed in this study were the lowest reported for shrimp research during the dry-season in Honduras. Dry-season FCRs reported from other research in Honduras ranged from 1.3 to 5.2, with a mean of 3.2 (Teichert-Coddington et al., 1991; Teichert-Coddington and Rodriguez, 1995a and b; Teichert-Coddington et al., 1996). One factor that contributed to the high value of the reported FCRs was that feed was applied at 100% of the feed curve (Teichert-Coddington et al., 1991; Teichert-Coddington and Rodriguez, 1995a and 1995b), compared with application of 50 and 75% of the feed curve in the present experiment. Another factor that affected reported FCRs was continued feeding of shrimp during the 14- to 16-week dry-season culture period despite insignificant shrimp growth beyond weeks 11 and 12 (Teichert-Coddington and Rodriguez, 1995a and 1995b).

An additional benefit of reduced FCRs is that less nitrogen and phosphorus are added to ponds, thereby reducing the potential pollution impact of pond effluents. Significantly greater quantities of nitrogen and phosphorus were added to ponds as feed in the 20% protein-75% feed rate treatment. However, significant differences in water quality variables of discharge water were not observed among treatments possibly because the differences among treatments in terms of total quantity of feed applied were not large enough for water quality differences to be manifested.

Although shrimp yield was not significantly greater and FCR was significantly greater for the 20% protein feed-75% feed rate treatment, this treatment resulted in the highest income from the sale of product. Increasing dietary protein from 20 to 30% was not justified either in terms of production or economics. Partial budget analysis showed an increase in net profit of $313/ha if the 20% protein feed-75% feed rate was used instead of the 20% protein feed-50% feed rate. However, because shrimp survival has been so variable and does affect yield, additional research on reduced feed rates is necessary before the 75% feed rate is adopted over the 50% feed rate.

Anticipated Benefits

Results of this experiment show that a 30% protein feed is not necessary for dry-season production of *P. vannamei* in semi-intensive culture in Honduras. Feeding a 20% protein feed at 75% of the feed curve does not result in statistically greater yield than applying the same feed at 50% of the feed curve; however, it does result in higher income. This was a result of slightly greater shrimp survival, so additional research is needed to confirm or reject this 50% feed rate. Use of the lower feed rate would result in a significantly lower need to add nitrogen and phosphorus to ponds.

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