A Comparison of Two Feeding Technologies in Freshwater Prawns, *Macrobrachium rosenbergii*, Raised at High Biomass Densities in Temperate Ponds

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ABSTRACT. Recent developments in prawn production technologies (i.e., added substrate, increased stocking densities, size grading, and increased feed rates) have increased production rates from 900-1,000 kg/ha to over 2,500 kg/ha. While prawn can receive substantial nutritional benefit from natural foods at the lower biomass densities, at higher production rates prawn are likely to be more dependent on prepared diets. To ensure that maximum production is being achieved by these new production technologies, production rates must not be nutritionally constrained. This study was conducted to compare the current recommended technology of phase feeding of different quality feedstuffs to prawns of different sizes with the feeding of a high-quality penaeid diet throughout the production season. Two treatments were evaluated: Treatment 1 was phase feeding (current technology-control) where prawns were fed unpelleted distillers' grains with solubles (DDGS) for the first four weeks, then a 28%-protein prawn diet for weeks 5-12, and finally a 40%-protein

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penaeid diet for weeks 13-16. In Treatment 2, prawn were fed the 40%-protein penaeid diet throughout the entire production period. Feeding rates in both treatments were based upon a feeding table. Three 0.04 ha ponds were used for each treatment. All ponds were stocked at 59,280 juveniles/ha and were provided with artificial substrate in the form of a polyethylene "safety fence" oriented vertically to increase available surface area by 50%. After 106 culture days, no significant differences ($P >$ 0.05) were observed between treatments in terms of yield, average individual weight, food conversion ratio (FCR), or survival, which averaged 2,575 kg/ha, 46 g, 2.3, and 94%, respectively, overall. Due to the higher cost of the penaeid diet (US$0.84/kg), feeding costs for the penaeid diet treatment (Treatment 2) were 38% higher than those for Treatment 1. No benefit to using higher protein diets during the first 12 weeks of prawn pond production was observed.

KEYWORDS. *Macrobrachium*, freshwater prawn, feeding, diets

INTRODUCTION

The commercial culture of the freshwater prawn, *Macrobrachium rosenbergii*, in temperate climates has increased considerably in recent years. In the US temperate zone, the growing season is limited to 100-150 days. As a result, US temperate zone prawn culture is limited to a single-batch culture system. With these inherent constraints, it is essential that production rates be maximized to increase commercial viability.

Compared to freshwater prawns, penaeid shrimp are raised at higher stocking and biomass densities. This limits the nutritional contributions from natural foods, and high quality nutritionally complete diets are usually fed. Prawns are usually fed lower-protein diets containing less fish meal than penaeid diets. However, recent developments in prawn production technologies (i.e., added substrate, increased stocking densities, size grading, and increased feed rates) have increased production rates in prawns from 900-1,000 kg/ha to over 2,500 kg/ha (Tidwell et al. 1999).

While prawns can receive substantial nutritional benefit from natural foods at relatively low biomass densities (< 1,000 kg/ha) (Tidwell et al.

1997), at higher prawn production rates, especially large, high-value individuals may be more dependent on prepared diets (Tidwell et al. 1999). Nutrition research has shown that physiologically, freshwater prawn appear to have nutritional requirements similar to those of penaeid shrimp and other crustaceans (D'Abramo 1998, D'Abramo and Sheen 1993, and D'Abramo et al. 1994). Consequently, to ensure that maximum production is being achieved by use of these new technologies, prawn production rates must not be nutritionally constrained.

In a recent study, several new prawn management technologies were combined. These included the use of size graded prawns (Daniels et al. 1995), prawns stocked at high densities (Tidwell et al. 1998), and prawns stocked in ponds containing added substrate (Tidwell et al. 2000). In addition, a new feeding regimen was used in all ponds, which utilized increasingly nutrient-dense diets as the resident biomass density of prawns in culture ponds increased (D'Abramo and New 2000). To ensure that feed availability was not a limiting factor in the study, feed amounts were increased 20% above a previously-used feed table recommended by D'Abramo et al. (1995). The combined effects of these "best management practices" resulted in total production rates in excess of 2,400 kg/ha in the 110-day culture period (Tidwell et al. in press).

Due to the dramatic production increases in that study, it was speculated that prawns could potentially benefit from a more nutrient-dense diet, such as a penaeid diet, throughout the production period. This study was conducted to compare the current recommended technology of phase feeding different feedstuffs with feeding a high-quality penaeid diet throughout the entire production season.

MATERIALS AND METHODS

Pond Preparation and Stocking

Two weeks prior to the anticipated stocking date, six ponds located at the Aquaculture Research Center (ARC), Kentucky State University, Frankfort, KY were drained and allowed to dry. Less than one week prior to stocking, ponds were filled with water from a reservoir that collects run-off from the surrounding watershed. The water-surface area of each experimental pond was 0.04 ha, and average water depth was approximately 1.1 m. A 0.5-hp vertical-pump surface aerator (Airolator, Kansas City, Missouri[1]) modified with a "deep-draw" tube operated

1. Use of trade or manufacturer's name does not imply endorsement.

continually at the surface of the deepest area of each pond to aerate and prevent thermal stratification. Two applications of liquid fertilizer (NPK, 10:34:0) were added to each pond one week apart, at a rate of 9.0 kg phosphorous/ha, to achieve an algae bloom. Water to replace evaporative losses was obtained from the reservoir.

Post-larval prawn were shipped by air from a commercial hatchery (Aquaculture of Texas, Weatherford, Texas), nursed in a greenhouse at ARC for 60 days, and stocked on 6 June 2000. The mean stocking weight was determined from a sample of 100 prawns that were blotted free of surface water and individually weighed. Individual mean stocking weight ($\bar{x}$±sd) was 0.67±0.23 g. Prawns were hand-counted and stocked at 59,280/ha into the six ponds. There were three replicate ponds per treatment.

Ponds were provided with artificial substrate to increase available bottom surface area by 50% (Tidwell et al. 2000). Substrate consisted of 120-cm-wide panels of polyethylene "safety fence" with a mesh opening (length × width) of 7.0 cm × 3.5 cm. The substrate was hung vertically and stretched the length of each pond between metal fence posts. The substrate was positioned approximately 30-cm above the pond bottom, with a 30-cm separation between panels. Surface area of the substrate was calculated based on dimensions of one side of the mesh (length × width), with open area within the mesh subtracted from surface area calculations.

Samples

A 3.2-mm mesh seine (3.5 m long × 1.0 m deep) was used to collect a sample of prawn from each pond every three weeks. Substrate materials were not removed, and only open areas in the pond were seined. Each sample was group-weighed (drained weight) to the nearest 0.1 g, counted, and then returned to the pond. In the last two samples prior to harvest, prawns were also individually weighed and classified into either one of three female morphotypes: berried (egg carrying [BE]), open (previously egg carrying [OP]), and virgin (VF); or one of three male morphotypes: blue claw (BC), orange-claw (OC), and small (SM) (< 20 g) as described by Cohen et al. (1981) and modified by D'Abramo et al. (1989). For data presented here, BE and OP females were combined into a composite group of mature females termed reproductive females (RF).

Feeds and Feeding

In the phase-fed treatment; for the first four weeks prawn were fed unpelleted distillers' grains with solubles (DDGS) (22% protein, 7% fat) (Tidwell et al. 1997); for weeks 5-12 a 28%-protein, 4%-fat prawn diet (Bagdad Roller Mills, Bagdad, Kentucky) as described in Tidwell et al. (1997) was fed; and for weeks 13-16 prawns were fed a 40%-protein, 8%-fat penaeid-shrimp diet (Rangen Inc., Buhl, Idaho). The penaeid diet treatment received the same penaeid diet the entire time at the same rate as the phase-fed control: One-half of the daily ration was distributed over the entire surface of each pond twice daily between 0900 and 1000 h and between 1500 and 1600 h. Prawns were initially fed at a set rate of 25 kg/ha/day until an average individual weight of 5 g was achieved in samples from each pond. For weights greater than 5 g, prawns were fed a percentage of body weight, based on a feeding schedule modified from D'Abramo et al. (1995) by increasing daily allotments 20% above table values (Table 1). A daily upper limit was set at 90 kg/ha/day to avoid potential water quality problems. Feeding rates were adjusted weekly, based on an assumed feed conversion ratio (FCR) of 2.5 and an assumed survival of 100%. Rates for all ponds within a treatment were based on the treatment average, not on individual pond sample weights.

TABLE 1. Comparison of different weight-dependent feeding rates for pond grow-out of the freshwater prawn, *Macrobrachium rosenbergii*.

Mean wet weight (g)	Daily feeding rate (% of body weight/day)[1]	
	Original (D'Abramo et al. 1989)	Modified (Tidwell et al. in press)
< 5[2]	0	25
5-15	7	10
15-25	5	7
> 25	3	7[3]

[1] As-fed weight of diet/wet biomass of prawns × 100.
[2] Units are kg/ha/day for this weight class only.
[3] Not to exceed 90 kg/ha/day.

Water Quality Management

Dissolved oxygen (DO) and temperature of all ponds was monitored twice daily (0900 h and 1530 h) using a YSI Model 57 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio). Levels of total ammonia-nitrogen (TAN) and nitrite-nitrogen were determined weekly from water samples collected from each pond at approximately 1300 h according to outlined procedures for a HACH DR/2000 spectrophotometer (Hach Co., Loveland, Colorado). The pH of each pond was determined daily at 1300 h using an electronic pH meter (Hanna Instruments, Ltd., Woonsocket, Rhode Island).

Harvest

Prawn were cultured for 106 days. One day prior to harvest, 20 September 2000, the water levels in each pond were lowered to approximately 0.5 m at the drain end. On the following day, substrates were removed, and each pond was seined three times with a 1.3-cm square-mesh seine (3.5 m long × 1.0 m deep) and then completely drained. Remaining prawns were manually harvested from the pond bottom, and all prawns were purged of mud by holding in tanks with flowing water. Total bulk weight and number of prawns from each pond were recorded. A random sample of ≥500 prawn from each pond was then individually weighed and classified into one of the six previously-described sexual morphotypes. Mean data from these random samples were then compared; open (OP) and berried (BE) morphotypes were later combined into a composite group of sexually mature, reproductive females (RF).

Statistical Analyses

Treatment effects were evaluated by two sample t-tests using Statistix version 4.1 (Analytical Software, Tallahassee, Florida) to compare water quality and harvest data. Growth performance and feed conversion were measured in terms of final individual weight (g), percentage survival, total yield (kg/ha), and FCR. Production/size index (PSI), was calculated as PSI = production (kg/ha) × average weight (g) ÷ 1,000 (Tidwell et al. 2000). Percentage and ratio data were converted to arc sine values prior to analysis. These data are presented untransformed to facilitate comparison and interpretation. Level of significance was determined at $P = 0.05$.

RESULTS AND DISCUSSION

There was no significant difference between treatments in measured water quality variables, either monthly or overall. Overall means±s.e. for water quality variables were as follows: temperature: 25.6±0.3°C; dissolved oxygen: 5.8±0.2 mg/L; pH: 8.9±0.1; TAN: 0.90±0.1 mg/L; un-ionized ammonia-nitrogen: 0.34±0.01 mg/L; total nitrite-nitrogen: 0.05±0.01 mg/L. Over the duration of the study, all water quality samples for the above parameters represented suitable conditions for prawn culture (Boyd and Zimmerman 2000).

There was no significant difference ($P > 0.05$) in average weight between treatments on any of the sample dates (Figure 1). At harvest, there were no significant differences ($P > 0.05$) between treatments in terms of total yield, average individual weight, FCR, or survival which averaged 2575 kg/ha, 46 g, 2.3, and 94%, respectively, overall (Table 2). Initially, it was speculated that larger, faster-growing individuals would

FIGURE 1. Mean sample weights of prawn sampled every three weeks from earthen ponds where prawns were fed either unpelleted distillers' grains with solubles (DDGS) for the first four weeks (22% protein), a 28%-protein prawn diet for weeks 5-12, and a 40%-protein penaeid diet for weeks 13-16 (phase treatment) or a 40%-protein penaeid diet throughout the entire 16-week season (penaeid treatment). Values are means±SE of three replicate ponds (n = 3).

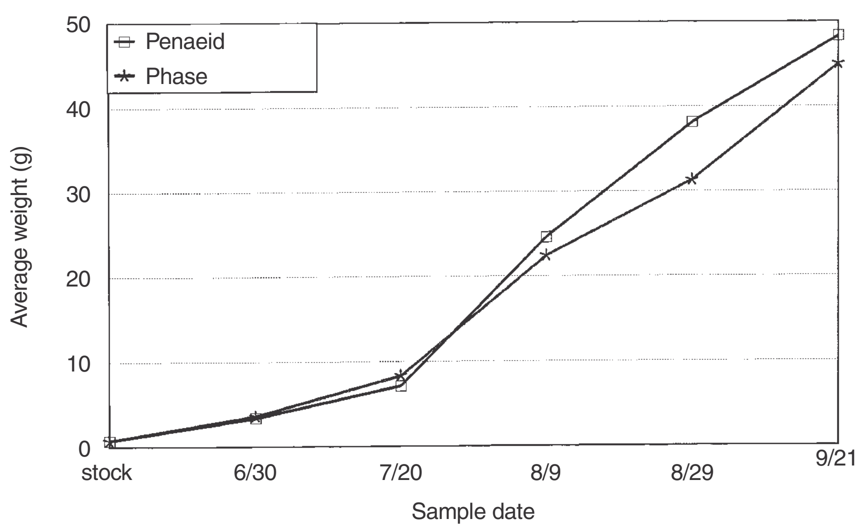

TABLE 2. Mean (±SE) harvest weight, total yield, survival, FCR, and daily yield of prawns cultured in ponds for 106 days and fed either unpelleted DDGS for the first four weeks (22% protein), a 28%-protein prawn diet for weeks 5-12, and a 40%-protein penaeid diet for weeks 13-16 (phase treatment) or a 40%-protein penaeid diet throughout the entire 18-week season (penaeid treatment). Values are means±SE of three replicate ponds (n = 3). Treatment means within a row followed by a different letter are significantly different ($P < 0.05$) by two sample t-tests.

	Phase	Penaeid
Avg. Wt. (g)	45.0±0.8a	48.3±1.8a
Survival (%)	96.1±4.6a	91.4±4.6a
Production (kg/ha)	2,548.8±121.9a	2,602.0±88.5a
FCR	2.3±0.4a	2.3±0.2a
PSI[1]	114.7±6.3a	125.4±6.9a
% Marketable (> 30g)	78.6±1.8a	77.8±2.7a

[1]PSI = production (kg/ha) × average weight (g) ÷ 1,000.

benefit from the penaeid diet, due to a lesser ability to utilize natural food items (Tidwell et al. 2000). However, there was also no significant difference in the percentage of prawns (that averaged 78.3% overall) attaining a market size of > 30 g (Table 2).

There was no significant difference in morphotype average weights or percentages between treatments on any of the sample dates (Table 3). At harvest, dietary treatments had no significant impact on numbers or sizes of females classified into each of the two female morphotypes (Table 3). There were also no significant differences among the numbers of males classified into each of the three male morphotypes (Table 3). However, the average weight of animals classified as SM was significantly larger in phase-fed prawns than in those fed the penaeid treatment; however the actual magnitude of the difference was small (Table 3).

Due to the relatively high cost of the penaeid diet ($0.84 US/kg), feeding costs in the penaeid diet treatment were 38% higher than those in the Phase fed treatment. With no production advantage for prawns fed the penaeid diet exclusively, there appears to be no benefit to using higher protein diets during the first 12 weeks of prawn pond production. Although it is inevitable that increased competition for natural food will occur at higher densities and will eventually become a limiting factor, it

TABLE 3. Mean (±SE) for average weight (g) and percent distribution (% of sex) of each male and female morphotype for prawns cultured in ponds for 106 days and fed either unpelleted DDGS for the first four weeks (22% protein), a 28%-protein prawn diet for weeks 5-12, and a 40%-protein penaeid diet for weeks 13-16 (phase treatment) or a 40%-protein penaeid diet throughout the entire 18-week season (penaeid treatment). Values are means ± SE of three replicate ponds (n = 3). Means within a row followed by different letters are significantly different ($P < 0.05$) by two sample t-tests.

	Phase	Penaeid
BC, g	78.2±6.9a	85.8±4.2a
OC, g	53.7±0.9a	57.9±3.1a
SM, g	10.2±0.4a	9.6±0.0b
RF, g	43.2±1.1a	46.5±2.8a
VF, g	31.6±1.7a	32.3±2.5a
BC as % of males	7.7±2.2a	8.5± 2.4a
OC as % of males	73.5±1.8a	67.6±5.4a
SM as % of males	18.8±0.7a	18.9±3.2a
RF as % of females	53.5±7.4a	60.7±6.0a
VF as % of females	46.5±6.4a	39.3±11.6a

appears that supplemental feeds are sufficient for at least the first 84 days.

Feed rates in this study were substantially greater than those used in earlier studies (Table 1). This was initiated to compensate for the lack of nutritional contribution from natural food items at the high-biomass densities. New management practices and increased production rates represent a shift from semi-intensive culture to intensive culture as described by Valenti and New (2000). However, additional research is needed to quantify appropriate feed rates for different production technologies and to determine the most economical use of phase-feeding techniques.

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