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Growth, Survival, and Body Composition of Cage-Cultured Nile Tilapia *Oreochromis niloticus* Fed Pelleted and Unpelleted Distillers Grains with Solubles in Polyculture with Freshwater Prawn *Macrobrachium rosenbergii*

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Abstract.—A 12-wk feeding trial was conducted in cages with juvenile Nile tilapia *Oreochromis niloticus* to evaluate distillers grains with solubles (DDGS) as a direct feed, the effects of pelleting on its utilization, and the compatibility of caged tilapia and prawns in polyculture. Nine 1.0-m^3 cages were stocked with 200 juvenile (26 ± 0.9 g) tilapia. Cages were suspended in a 0.2-ha pond stocked with juvenile freshwater prawns *Macrobrachium rosenbergii* at 40,000/ha. Three replicate cages were randomly assigned to each dietary treatment. In one dietary treatment DDGS was fed as an unpelleted loose grain ration (26% protein). In a second dietary treatment fish were fed DDGS that had been steam-pelleted (23% protein). Fish in a third dietary treatment were fed a commercial catfish diet (31% protein) for comparison. After 12 wk, individual weight, individual length, and specific growth rate were significantly higher ($P < 0.05$) and feed conversion ratio was significantly lower ($P < 0.05$) for fish fed the commercial catfish diet than for fish fed either unpelleted or pelleted DDGS. Specific growth rate was significantly higher ($P < 0.05$) for fish fed pelleted DDGS than for fish fed unpelleted DDGS. Survival did not differ significantly ($P > 0.05$) among treatments (>95%). Although growth was increased in fish fed the commercial diet, their cost of production ($0.66/kg gain) was significantly higher ($P < 0.05$) than in fish fed unpelleted and pelleted DDGS ($0.26/kg gain and $0.37/kg gain, respectively). The costs of gain in fish fed unpelleted DDGS was significantly lower ($P < 0.05$) than in fish fed the pelleted DDGS. Prawn production was 1,449 kg/ha and addition of tilapia in polyculture increased total pond productivity approximately 81%. These data suggest that DDGS provides economical growth in tilapia when fed as a direct feed and that polyculture of tilapia may improve overall pond efficiency in freshwater prawn production ponds, even at temperate latitudes.

In temperate regions, production of tropical animals such as freshwater prawns *Macrobrachium rosenbergii* and tilapia *Oreochromis niloticus* are limited to a single seasonal crop. Under these conditions it becomes increasingly important to maximize per unit production (kg/ha). Prawns are self-limiting in respect to total production due to antagonistic interactions increasing the need for polyculture to maximize total pond efficiency (New 1990). Prawn polyculture has a potentially higher net return than prawn monoculture (Rouse and Stickney 1982). In polyculture fish and prawn growth are largely independent and additive (Wohlfarth et al. 1985). The primary problems reported in polyculture of prawns and fish are related to separating the different species at harvest (Heinen et al. 1989). These problems could be eliminated by culturing the fish in cages. Due to their tolerance of crowding and poor water quality, tilapia are well suited to cage culture (Masser 1997) and freshwater prawns have been reared successfully in open pond polyculture with tilapia (Mires 1987). The polyculture of tilapia in cages over freshwater prawn production ponds should be evaluated as a way to increase total pond production.

Since feed costs account for over 50% of production costs for most species another way to increase production efficiency and profitability is to lower feed costs. Distillers dried grains with solubles (DDGS) are primary fermentation residues from yeast fermentation of cereal grains and are a by-product of the distillery process. These by-products are approximately 26–28% protein, closely matching the protein requirements of both prawn (25–35%) (New 1995) and tilapia (25–35%) (Lim 1989). Prawns will consume DDGS directly (Tidwell et al. 1995; Coyle et al. 1996). DDGS has been evaluated as an ingredient in channel catfish *Ictalurus punctatus* diets at rates as high as 70% of the total diet (Webster and Tidwell 1991). In tilapia, DDGS has been evaluated at 29% of the total diet (Wu et al. 1996). However, compared to many species, tilapia require relatively low levels of dietary crude protein and can utilize relatively high levels of plant feedstuffs (Twibell and Brown 1998). This may make much higher inclusion rates possible. Direct feeding of DDGS has not been evaluated. Luquet (1991) reported that in ponds tilapia utilized meal type feeds as well as pelleted diets. However, pelleted feeds may be more important in cage culture to reduce the loss of uneaten feed.

Polyculture and use of distillery by-products as feed should be evaluated as a means of increasing pond efficiencies. This study was designed to evaluate the use of pelleted and unpelleted distillery by-products as a primary feed for cage reared tilapia in polyculture with freshwater prawns.

Materials and Methods

Juvenile prawns (average individual weight ± SD, 0.4 ± 0.1 g) obtained from a commercial hatchery (Aquaculture of Texas, Weatherford, Texas, USA) were stocked at 40,000/ha (by weight) on 3 June 1998 into a 0.2-ha pond with an average depth of 1.5 m located at Dunreath Farm, Lexington, Kentucky, USA. A 1-hp aspirating type aerator operated continuously in the center of the pond to provide aeration, circulation, and prevent thermal stratification. Initially, prawns were fed unpelleted DDGS dispersed over the pond at a rate of 25 kg/ha per d until an average individual weight of 5 g was achieved. At sizes of 5 to 20 g, prawns were fed a percentage of body weight based on a feeding schedule reported by Daniels and D'Abramo (1994). Feeding rates were adjusted weekly based on an assumed 2.5 feed conversion (D'Abramo et al. 1989). After reaching 20 g, prawns were fed a custom formulated 32% protein diet containing 40% DDGS (Tidwell et al. 1993) at 28 kg/ha.

Mixed sex juvenile tilapia (average individual weight ± SD, 26.0 ± 0.9 g) obtained from a commercial supplier (Til-Tech Aqua Farm, Robert, Louisiana, USA) were stocked (17 June 1998) into nine 1.0-m^3 cages at 200 fish/m^3. Cages were attached to a floating dock at the deepest end (2 m) of the 0.2-ha prawn production pond. Each cage had a frame made of 1.25-cm polyethylene tubing with a hinged lid, and 1.0-cm polyethylene mesh covered the frame. A 12-cm feed ring of 2-mm mesh extended down from the top to prevent feed from being splashed out of the cage. Each cage was randomly assigned one of three diets: unpelleted DDGS (25.6% protein, 7.3% fat, 4.2% ash), DDGS that had been steam-pelleted into 1-mm sinking pellets (22.5% protein, 7.7% fat, 2.7% ash), or a commercial sinking catfish diet (30.7% protein, 3.4% fat, 8.2% ash) (Purina Mills, Inc., St. Louis, Missouri, USA) as a control. There were three replicate cages per dietary treatment. The lower protein level of steam-pelleted DDGS (22.5%) versus unpelleted DDGS (25.6%) was a result of dilution by addition of 2.5% binder during the pelleting process. Fish were fed twice daily (0800 and 1600 h) to apparent satiation over a 30-min period. The long feeding period was to ensure efficient utilization of the meal type feed (unpelleted DDGS) and sinking pellets in cages.

Tilapia were harvested 8 September 1998 and were not fed 24 h prior to harvest. Total number and weight of fish in each cage were determined at harvest. Twenty-five fish were randomly sampled from each cage and measured for total length to the nearest 0.5 cm. Treatment comparisons were based on cage means. Five fish were randomly

TABLE 1. *Mean survival, average weight, length, production, weight gain (% increase from initial weight), specific growth rate (SGR), feed conversion ratio (FCR), percent protein deposited, and relative feed costs of Nile tilapia fed unpelleted distillers grains with solubles (DDGS), steam-pelleted DDGS, or a commercial catfish diet. Values are means ± SD from three replicate cages. Means in the same row with different letters are significantly different (P ≤ 0.05).*

Diet	Unpelleted DDGS	Pelleted DDGS	Commercial catfish diet
Survival (%)	97.2 ± 2.8a	96.3 ± 2.3a	95.5 ± 1.3a
Average weight (g)	108.3 ± 6.1b	119.4 ± 3.9b	149.4 ± 6.4a
Average length (cm)	17.8 ± 0.2b	18.4 ± 0.1b	19.7 ± 0.48a
Production (kg/m^3)	15.8 ± 0.8b	17.8 ± 0.6b	23.3 ± 1.5a
Weight gain (%)	416.7 ± 23.9b	459.7 ± 14.7b	574.5 ± 24.7a
Specific growth rate (%/d)	1.74 ± 0.07c	1.86 ± 0.04b	2.13 ± 0.05a
Feed conversion ratio	2.26 ± 0.19a	2.07 ± 0.07a	1.66 ± 0.09b
Percent protein deposited	31.70 ± 3.30b	37.34 ± 0.46a	35.75 ± 2.85ab
Feed cost ($)/kg gain[1]	0.26 ± 0.02c	0.37 ± 0.02b	0.66 ± 0.04a

[1] Feed cost ($)/kg gain = Feed cost ($/kg) × feed conversion ratio.

sampled from each cage, homogenized in a blender, and the pooled sample was analyzed for protein, fat, ash, and moisture (AOAC 1990). Each of the three diets were also analyzed for protein, fat, ash, and moisture (AOAC 1990) and results are on an as received (wet-weight) basis.

Prawns were harvested on 24 September 1998. Total weight of prawns was determined at harvest and total number recovered (survival). Three random samples of at least 100 animals were weighed and counted to determine average weight.

Dietary treatments in the tilapia were compared on the basis of average weight, weight gain, survival, and feed conversion using ANOVA procedures (Steel and Torrie 1980). Specific growth rate (SGR, % body wt/d) was calculated from SGR = $[(\ln W_f - \ln W_i)/t] \times 100$, where W_f = final weight, W_i = initial weight, and t = time in days (Ricker 1975). Relative feed cost was calculated from feed cost ($/kg) × feed conversion ratio. If significant differences were indicated by ANOVA ($P < 0.05$), means were separated using the Least Significant Difference test. All percentage and ratio data were transformed to arc sin values prior to analysis (Zar 1984).

Results and Discussion

Prawns were harvested at 113 d post-stocking. Prawns averaged 35.6 g and survival was approximately 84%. Total prawn production was 1,449 kg/ha with a production rate of 12.8 kg/ha per d. This is similar to rates reported by Tidwell et al. (1994) (11.5 kg/ha per d) and much higher than rates reported in warmer regions (Smith et al. 1981; D'Abramo et al. 1989) (5.9 and 6.6 kg/ha per d, respectively). Incorporation of tilapia in polyculture increased total pond productivity to 2,625 kg/ha, a 81% increase over prawn monoculture.

After 12 wk, tilapia survival averaged 96.3% overall and did not differ significantly ($P > 0.05$) among dietary treatments (Table 1). Based on feed response diets were readily consumed. Average individual weight, individual length, and specific growth rate were significantly higher ($P < 0.05$) for fish fed the commercial catfish diet than for fish fed either unpelleted or steam-pelleted DDGS (Table 1). Feed conversion ratio was significantly lower ($P < 0.05$) in fish fed the commercial catfish diet (1.7) than for either pelleted or unpelleted DDGS rations (2.1 and 2.3, respectively). Specific growth rate and percent protein deposited were significantly higher ($P < 0.05$) in fish fed pelleted DDGS than in those fed unpelleted DDGS. There was no significant difference in the percentage of dietary protein deposited in fish fed the commercial diet and fish fed the DDGS diets. There was

TABLE 2. *Percent moisture, protein, lipid, and ash of whole body samples of Nile tilapia fed unpelleted distillers grain with solubles (DDGS), steam-pelleted DDGS, or a commercial catfish diet. Values are means ± SD of three replicate samples and did not differ* ($P > 0.05$) *significantly between dietary treatments.*

Whole body	Unpelleted DDGS	Pelleted DDGS	Commercial catfish diet
Moisture (%)	67.8 ± 1.3	68.0 ± 1.4	68.4 ± 0.3
Protein (%)[1]	56.6 ± 1.0	55.9 ± 2.3	57.0 ± 1.5
Lipid (%)[1]	21.9 ± 2.4	24.9 ± 0.6	25.1 ± 2.09
Ash (%)[1]	21.4 ± 2.1	19.2 ± 2.4	17.9 ± 0.8

[1] Presented on a dry weight basis.

no significant difference ($P > 0.05$) in the whole-body proximate composition of fish fed any of the three diets (Table 2).

Steam pelleting DDGS significantly improved ($P < 0.05$) specific growth rate and percent protein deposited (Table 1). However, there was no significant difference ($P > 0.05$) in average harvest weight, length, production, weight gain or feed conversion ratio in tilapia when fed DDGS as a loose grain ration or as a steamed pellet. These data agree with those of Luquet (1991) who found that pelleting resulted in no conclusive advantage over meal diets in tilapia. Pelleting costs increased diet cost 30% and only resulted in a 12% increase in total production. Also, pelleted DDGS contained a lower protein level than unpelleted DDGS due to dilution by binding agents.

Although, the commercial catfish diet resulted in the most rapid growth of tilapia, the most economical growth was provided by DDGS rations. Diets which produce the fastest growth are not always the most profitable. Feed cost per kilogram of gain for tilapia fed the catfish diet ($0.66/kg gain) was significantly higher ($P < 0.05$) than for fish fed unpelleted and pelleted DDGS ($0.26/kg gain and $0.37/kg gain, respectively). These figures represent 61% and 44% decreases in feed cost, respectively compared to tilapia fed the commercial catfish diet. The cost of gain in tilapia fed unpelleted DDGS was also significantly lower ($P < 0.05$) than in tilapia fed pelleted DDGS. This represents a 30% reduction in feed costs compared to even pelleted DDGS.

These data suggest that efficient and economical tilapia growth can be obtained using direct feeding of dried distillery by-products in situations where optimum growth is not essential. Large reductions (40–60%) in feed costs should positively impact production economics; however, these savings could be offset by the higher costs of the larger fingerlings that would be required to achieve market sizes within the limited growing season of temperate culture. Tilapia proved well suited to cage culture and polyculture substantially increased total pond production above prawn monoculture.

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