TILAPIA[(10)]

Project Termination Report for the Period
September 1, 1998 to August 31, 2002

NCRAC FUNDING LEVEL: $150,000 (September 1, 1998 to August 31, 2002)

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Non-Funded Collaborators:		
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Dan Helfrich	ADM (Archer, Daniels, Midland), Decatur	Illinois
Chris Shimp[(11)]	Grayson Hills Farms, Harrisburg	Illinois
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REASON FOR TERMINATION

The project objectives were completed.

PROJECT OBJECTIVES

(1) Compare feeds developed through the first North Central Regional Aquaculture Center (NCRAC)-funded Tilapia project as well as the Wastes/Effluents project to standard commercial feeds in different commercial scale recirculating aquaculture systems based on growth, performance (survival, health, feed conversion), water quality, and economic impacts. To ensure the applicability of results to commercial systems, the minimum size of an experimental recirculating unit must be 18,927 L (5,000 gal) per biofilter and the minimum replicate tank size must be at least 3,785 L (1,000 gal).

(2) Conduct "break-even analysis" for raising tilapia in a recirculating aquaculture system on a commercial scale with a minimum recirculating system size of 18,927 L (5,000 gal) per biofilter, capable of producing a minimum of 11,340 kg/yr (25,000 lb/yr).

PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

In the first Tilapia project, researchers at Purdue University (Purdue) found that a minimum of 28% crude protein was required in fish meal free grow-out diets for maximum weight gain. They also explored the optimum energy to protein ratio using the 28% crude protein concentration. The Purdue researchers found the optimum energy and lipid concentrations of grow-out tilapia (Nile tilapia, *Oreochromis niloticus*) were similar to values developed for smaller fish using purified diets (3,000-3,200 kcal/kg [1,361-1,452 kcal/lb], or 4-6% dietary lipid). Dress-out percentages and nutritional composition were not significantly impacted at dietary lipid levels of 8% and lower.

Additional research conducted by Purdue in the first year of the present project indicated that choline is a required vitamin in diets fed to tilapia when methionine concentrations are at the minimum requirement and that phosphatidylcholine exerts a beneficial effect on weight gain and feed conversion. Both nutrients are limiting in all-plant diets fed to tilapia.

Researchers at Purdue, using data generated in previous NCRAC projects and projects funded by other groups, formulated an experimental diet for use with tilapia raised in recirculating systems. That diet was free of fish meal, contained 32% crude protein, and the minimum amount of essential amino acids and dietary energy. Minimizing essential amino acid concentrations should help reduce ammonia excretion and place less of a load on the biological filtration system. Minimizing energy should reduce carbon dioxide excretion, which will reduce the need for bicarbonate addition to systems and reduce the drop in pH caused by excess carbon dioxide excretion. The diet was manufactured by a private feed mill (Nelson and Sons, Murray, Utah) and shipped to ADM in Decatur, Illinois for testing. Three separate diets were tested in 302,832-L (80,000-gal) production tanks. The experimental diet from Purdue, the standard ADM diet, and a standard tilapia production diet acquired from a commercial feed mill were fed to duplicate groups of fish for a portion of the production cycle. Mean initial weight of fish was 14 g (0.5 oz).

Total consumption of the Purdue diet was less than the other two diets; consumption of the ADM diet was highest. Mean weight gain, determined from a sample of fish, was lowest in fish fed the Purdue diet and highest in fish fed the commercial diet. Total bicarbonate addition was almost 50% lower in the tanks fed the Purdue diet compared to fish fed the ADM diet, which required the highest amount of bicarbonate addition. Average ammonia-nitrogen (NH_3-N) concentration was lowest in fish fed the ADM diet, intermediate in fish fed the Purdue diet, and highest in fish fed the commercially-available diet. Average nitrite-nitrogen (NO_2-N) concentration was lowest in fish fed the Purdue diet, intermediate in fish fed the commercial diet, and highest in fish fed the ADM diet. Average nitrate-nitrogen (NO_3-N) concentration was lowest in fish fed the Purdue diet, intermediate in fish fed the commercial diet and highest in fish fed the ADM diet. Costs associated with this project prohibited extending the experiment to a complete grow-out cycle.

During the first two years of this project, Southern Illinois University-Carbondale (SIUC) researchers worked with Grayson Hills Farms in Harrisburg, Illinois to modify their greenhouses to accommodate tilapia production. Eight 18,927-L (5,000-gal) concrete tanks were constructed. Four of these tanks were equipped with bead biofilters and pumps and stocked with 3,000 tilapia (*O. niloticus*) fingerlings. Water from the tanks was distributed through tomato plant roots grown directly above the fish tanks hydroponically. The bead biofilters served to collect solid wastes while providing media for bacterial nitrification. The tomato plants served to remove dissolved nutrients from the system. As a consequence, inorganic fertilization use was reduced by half for the tomato production. Unfortunately, the first crop of fish were lost in late fall 1999 when new electrical generators were being installed and water temperatures dropped to lethal levels when the installations took longer than anticipated. Grayson Hills Farms subsequently decided to reconfigure their aquaculture units from eight 18,927-L (5,000-gal) units to four, 37,854-L (10,000-gal) units and to incorporate solids removal systems. These modifications were never completed. Accordingly, the production and economical studies were switched to the ADM tilapia facility in Decatur, Illinois.

ADM initially allocated nine 37,854-L (10,000-gal) aquaculture units, each equipped with a bead filter, to this study. Two diets (isonitrogenous and isocaloric) were formulated and manufactured (5,443 kg; 6 tons each) by Farmland Feeds/Land of Lakes (Denzil Hughes) to be consistent with the nutritional requirements of tilapia raised under intensive culture conditions (crude protein 36%; estimated digestible energy [catfish] 3,080 kcal/kg [1,397 kcal/lb). Fat was varied with beet (fiber) level to conserve energy content. A third dietary treatment formulated and typically used by ADM could not be replicated adequately and was therefore dropped from the study. The treatment diet (beet pulp) was modified relative to the control diet by decreasing dietary carbohydrate sources (grain-based feedstuffs) and increasing lipid to allow conservation of proximate composition. A trial starting October 18, 2001 and ending December 21, 2001 (duration 65 days) was carried out with culture systems and day-to-day labor provided by ADM. Bead filter operation was interrupted for back flushing when a gauge measuring backpressure reached 15 psi. Filtration was offline for approximately 15 min while particulate waste retained by the filter was separated from the beads and subsequently drained from the system. The normal interval between back flushing events was approximately 2 days (range: 1-4). Six systems (3 control, 3 fiber) were operated in a manner consistent with ADM's normal tilapia production procedure for early grow out. Fish were fed by hand approximately twice daily. As biomass within each culture system increased, feed application rate increased until limited by water quality (~36 kg [79 lb] of feed/system/day) and or feeding activity of the tilapia. Sodium bicarbonate was used to control pH (targeted range 7.0-7.25) as a method for reducing the toxic affects of NH_3-N. During the period of normal operation the intervals between back flushing and pressures, as well as temperature and dissolved oxygen were recorded. Immediately prior to back flushing, culture and wastewater was sampled for NH_3-N, NO_2-N, and biochemical oxygen demand (BOD). Production in terms of specific growth rate and feed conversion ratio did not vary as a function of dietary fiber. System dissolved oxygen, oxygen infusion rate, and bead filter backpressure did not vary as a function of dietary treatment. Filter backpressure and water quality variables monitored did not vary significantly.

Intensive water quality observations (2-h intervals) occurred during the final 12 h that started and ended with a back flushing. Filter backpressure did not differ significantly between treatments as measured at 4-h intervals, nor did the water quality parameters measured. Concentrations of NH_3-N and NO_2-N were consistently high (5-13 mg/L (ppm) and 2-39 mg/L (ppm), respectively). BOD was not affected in the culture or waste water by incorporation of dietary beet pulp. Photoperiod was natural for Decatur, Illinois and daily temperatures during the feeding trial were less than considered optimal for tilapia (ranged 24.0-27.5°C; 75.2-81.5°F).

OBJECTIVE 2

Michigan State University completed an extension publication on feeding methods for tilapia to enhance production in recirculating aquaculture systems (NCRAC Fact Sheet Series #114, in press).

Due to the closure of the Grayson Hill Farms' facility and the poor water quality that occurred in the ADM commercial system, SIUC researchers were unable to conduct a meaningful "real-world" cost of production analysis. Accordingly, the annual operating costs for a hypothetical system capable of producing 4,000,000 lb (all values expressed in English units except for fingerling weights where both metric and English units are given) of tilapia per year were estimated to provide tilapia producers in the North Central Region (NCR) with useful information on variable costs which are indicated in bold. Information for the estimates was obtained, in general, from the American Tilapia Association 2001 Situation and Outlook Report and Southern Regional Aquaculture Center Publication #456.

Fingerlings: Four million 10-g (0.35-oz) fingerlings are needed annually, assuming 80% survival at harvest and a mean individual market weight of 1.25 lb. At a cost of $0.25/fish, total fingerling cost would be **$1,000,000** (4,000,000 × 0.25).

Feed: Feed is invariably the highest variable cost in raising fish. Fingerlings from 10-100 g (0.35-3.53 oz) in weight require higher quality feed (~$0.30/lb compared to grow-out diets at ~$0.20/lb for fish to reach market size). Assuming the higher costing feed represents approximately 25% of the feed purchased, the average cost of the feed will be ~$0.225/lb. Assuming a total feed conversion ratio of 1.5, the annual feed bill to rear 4,000,000 lbs of tilapia would be **$1,350,000** (4,000,000 × 1.5 × 0.225).

Labor Costs: Labor costs will include a manager, assistant manager, and six hourly employees, one of which would serve in a clerical role. The annual payroll is estimated as follows:

Manager	$60,000
Assistant manager	$40,000
Other Professionals (6 @ $25,000 ea)	$150,000

Subtotal	$250,000
Fringe benefits (30%)	$75,000
Total	**$325,000**

Energy: In SRAC publication #456 detailing cost in recirculating aquaculture systems, the authors estimate a requirement of 2.3 kwh/lb of production. Therefore, for this hypothetical system, at a price of $0.05/kwh, the cost of energy would be **$460,000** (4,000,000 × 2.3 × 0.05).

Oxygen: Injection of oxygen is necessary to maintain high levels of production in a recirculating aquaculture system. The amount of oxygen required per pound of feed is 0.3 lb. Accordingly, multiplying pounds of feed by 0.3 and multiplying this figure by a conversion factor of 12.05 to determine cubic feet, annual oxygen use can be calculated. Oxygen cost at a price of $\$0.003/ft^3$ would, therefore, be **$65,070** for 6,000,000 lb of feed fed (6,000,000 × 0.3 × 12.05 × 0.003).

Bicarbonate: Bicarbonate (as sodium bicarbonate, i.e., common baking soda) must be added to a recirculating aquaculture system to counter acids released in the oxidation of ammonia and nitrites to form nitrates (this takes place in the biofilters), as well as production of carbon dioxide by bacteria in the biofilters and the fish themselves. The goal is to maintain pH near neutrality (pH = 7.0). Buffering needs will be 0.175 lb of sodium bicarbonate per pound of feed fed. Bicarbonate costs at a price of $0.19/lb would, therefore, be **$199,500** for 6,000,000 lb of feed fed (6,000,000 × 0.175 × 0.19).

Maintenance: General maintenance of the system, estimated at approximately $0.03 per pound of fish produced, would cost **$120,000** (4,000,000 × 0.03).

Chemicals: Chemicals (excluding sodium bicarbonate), estimated at $0.01 per pound of production, would cost **$40,000** (4,000,000 × 0.01).

Interest: The amount of interest on all of the variable costs (subtotal of above), estimated at 9%, would be **$320,361** (3,559,570 × 0.09).

Fixed Costs: Fixed costs, estimated at 15% of the total operating costs (variable costs plus interest) would be **$581,990** (3,879,931 × 0.15).

Total Operating Cost: Variable costs ($3,559,570) + interest ($320,361) + fixed costs ($581,990) = **$4,461,921**.

In summary, breakeven cost per pound live weight of fish is projected at **$1.12** (4,000,000 lb fish costing $4,461,921 to produce). This equates to $3.36/lb of fillets (excluding processing charges and assuming a 33% dress out). This projection is based solely on the fixed and variable costs and does not take into account capital investment.

Producers would need to substitute their own costs wherever possible to arrive at a closer breakeven cost for their particular operation.

IMPACTS

It seems clear from these studies that improvements can be made in diets fed to fish in recirculating systems. By careful dietary formulation, carbon dioxide excretion can be reduced, which, in turn, will reduce the amount of bicarbonate needed to buffer the system from decreases in pH. This represents a significant reduction in total production costs. It also seems clear that ammonia excretion can be reduced, which reduces the toxic compounds on fish raised in the system, which, in turn, will reduce the level of stress on the fish caused by degraded water quality.

Incorporation of dietary fiber sources (beet pulp and cellulose) up to a level of 8% does not affect growth of tilapia during grow out in water reuse systems. Dietary fiber did not influence water quality or production parameters in a commercial-scale tilapia production facility that utilized bead filters alone for filtration in water reuse systems. Incorporation of beet pulp into diets for tilapia grow out using water reuse system with bead filters provided no obvious benefits for improving water quality parameters of NH_3-N, NO_2-N, and BOD in the culture volume or the waste effluents. Dietary formulation had no effect on water quality. Survival is unknown owing to the production cycle duration not allowing for generation of marketable size animals that could be inventoried. Regardless of fiber content, filtration was inadequate, thus constraining the maximum feed ration to be less than 3% body weight daily. NH_3-N and NO_2-N concentrations were chronically high in all culture units and were used as the guide for limiting feed application rates. Prolonged exposure of waste in bead filter to water cycling between the filter and culture tank resulted in apparent leaching of nitrogenous waste back into the culture water.

Gross formulation guidelines for grow-out diets that are free of fish meal have been developed. The basic formulation will be expanded to incorporate other ingredients that are readily available in the NCR. These formulations could be taken to local feed mills, which should significantly reduce feed costs, one of the most expensive annual variable costs in tilapia production.

A NCRAC Fact Sheet (#114) on feeding tilapia in intensive recirculating systems is in press. The publication summarizes the results of practical feed recommendations and feeding strategy research that was developed during the first Tilapia project. In order to maximize production efficiency, minimize demands on the biofilter, and minimize costs, tilapia should be fed:

- nutritionally complete diets formulated to meet their dietary requirements,
- the optimum crumble or pellet size,
- at the optimum feeding rate (% of fish weight),
- at the optimum time intervals (4-5 h depending on the energy and composition of the diet), and
- based on the size of the fish and the culture conditions.

Although SIUC researchers were unable to conduct a meaningful "real-world" cost of production analysis due to the closure of the Grayson Hill Farms' facility and the poor water quality that occurred in the ADM commercial system, the annual operating costs for a hypothetical system capable of producing 4,000,000 lb of tilapia per year were estimated to provide tilapia producers in the NCR with useful information on variable costs. Information for the estimates was obtained, in general, from the American Tilapia Association 2001 Situation and Outlook Report and Southern Regional Aquaculture Center Publication #456.

RECOMMENDED FOLLOW-UP ACTIVITIES

In this first attempt to control water quality through diet, consumption of feed and resulting weight gain were lower than in commercial diets. Addition of flavor additives to diets might alleviate this decreased consumption. However, if fish consume more of a diet that contains the minimum amount of dietary nitrogen and energy, whether or not the improved water quality parameters will remain is unknown. This needs to be explored. Additionally, the possibility that improved water quality might result in the same weight gain if fish had been grown for the entire grow-out cycle needs to be studied.

Further studies should be concentrated with systems that are designed to minimize contact time between waste products. Bead filters as used at the ADM facility retain organic waste too long and force the culture system to degrade materials that consume oxygen and liberate nitrogenous waste products while being digested. Cost of production estimates on specific systems may not be as useful as information on variable and fixed costs obtained from a variety of locations and recirculating system configurations.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Tilapia activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1998-99	$74,773	$82,052				$82,052	$156,825
1999-00	$75,227	$82,642	$5,000			$87,642	$162,869
2000-01			$25,000			$25,000	$25,000
TOTAL	$150,000	$164,694	$30,000			$194,694	$334,694

TILAPIA

Publications in Print

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