AN ECONOMIC ANALYSIS OF INTEGRATING HYDROPONIC TOMATO PRODUCTION INTO AN INDOOR RECIRCULATING AQUACULTURAL PRODUCTION SYSTEM

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AN ECONOMIC ANALYSIS OF INTEGRATING HYDROPONIC TOMATO PRODUCTION INTO AN INDOOR RECIRCULATING AQUACULTURAL PRODUCTION SYSTEM

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THESIS ABSTRACT

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Alabama is one of the leading states in the nation in terms of aquacultural production, ranking second among catfish producing states and fourth for tilapia. Alabama catfish farmers generated $97.6 million in sales in 2005 with 142 million pounds of food size catfish production (NASS, 2005). While production was substantial, profitability levels were somewhat less than desired. Thus, producers are interested in improving catfish production efficiency and evaluating alternative enterprises and production systems (USDA, 2005).

Indoor recirculating catfish and tilapia production systems provide intensive production yields while using only a fraction of the land that would be required with a traditional pond-oriented catfish production system. Integrating tomato production to the aquacultural system can also utilize synergistic relationships of the two production systems and substantially increase profits.

The economic and technical viability of incorporating a high-valued enterprise such as hydroponically grown tomatoes into an indoor recirculating system for channel catfish or tilapia production were evaluated. The indoor system was planned and budgeted for an annual production of 44,000 pounds of channel catfish and 27,600 pounds of tilapia. Production of catfish was complemented by the production of 33,175 pounds of tomatoes grown from the effluents produced by the channel catfish as well as from the tilapia. The break even price for catfish was determined to be $.77 per pound along with tomatoes at $.92 per pound to cover yearly fixed and variable costs of the system. The break even price for tilapia was determined to be $1.22 per pound along with tomatoes at $.92 per pound to cover yearly and variable costs of the system.

Comparative results were derived for a stand-alone system producing either channel catfish or tilapia. Analyses showed a major difference in the financial results with the catfish production system losing approximately $21,000 annually and the tilapia system losing approximately $5,000 annually. The reduction of effluents into local waterways with the integrated system helped mitigate social costs of the stand alone aquacultural system. Thus, there appears to be economic potential for integrating either channel catfish or tilapia production with tomato production using a recirculating water system.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In the United States, production of aquacultural enterprises represents a billion-dollar industry with sales of fish, shellfish and related products growing by 11.7 percent over the past seven years, according to data from the 2005 Census of Aquaculture conducted by the Department of Agriculture's National Agricultural Statistics Service (NASS). Results show that between 1998 and 2005, U.S. sales of aquacultural products grew from $978 million to nearly $1.1 billion.

Food fish (catfish, perch, salmon, hybrid striped bass, tilapia, and trout) accounted for 62 percent of all aquacultural sales in 2005 with mollusks comprising 19 percent of the 2005 sales (Census of Aquaculture, 2005). Crustaceans, such as lobsters and shrimp, each accounted for approximately 5 percent of sales. They were followed by baitfish at 4 percent and sport fish at 2 percent of the total (Census of Aquaculture, 2005).

Mississippi led the nation in sales of aquacultural products with nearly $250 million in 2005. Alabama and Louisiana were the next largest producing states with sales topping $100 million each (Census of Aquaculture, 2005).

U.S farm-raised catfish is the fifth most popular consumed fish in the United States, behind tuna, pollock, salmon, and cod, respectively. Growth of the farm-raised catfish industry in the United States is expected to continue but not at the rapid pace seen in the 1980's and 1990's (Chappell & Crews, 2006). Popularity of farm-raised catfish is due to its consistent quality, delicate flavor, firm texture, preparation versatility, year-around availability, and nutritional value. Farm-raised catfish production for food was approximately 600 million pounds liveweight in 1999 and accounted for two-thirds of the annual aquacultural production in the United States. It increased to a record high of 661 million pounds produced in 2003 and decreased 4.7 percent to 630 million pounds in 2004. Using the recent changes, production has been estimated to decrease approximately 4 percent per year, which would bring the amount of catfish produced in 2006 to be approximately 582 million pounds (Chappell & Crews, 2006). The 2005 price of catfish was 72.53 cents per pound which was up 2.8 cents per pound from 2004. In 2006, however, the price has increased to 77.6 cents per pound. Producer's income reached a high of $439 million in 2004 and has steadily decreased to $408 million in 2006 which is down 6 percent from the 2005 level of $435 million (Chappell & Crews, 2006).

The farmed-raised catfish industry is centered in the southeastern United States, primarily on the lower Mississippi River flood plain, in a region locally referred to as the Delta. A unique combination of physical and socioeconomic factors has been favorable for development of the industry. Alabama, Arkansas, Louisiana, and Mississippi account for 95 percent of catfish production, with Mississippi producing 70 percent of the total (Avery, 2000). The industry employs over 13,000 people in production, processing, feed manufacturing, and related support industries. Sales of farm-raised catfish total about $600 million annually, but the total impact on the economies of the four major catfish producing states was projected to exceed $4 billion annually in 2000 (Avery, 2000).

As of 2005, there were over 25,000 water acres of fish farms in Alabama and 215 producers, with about 200 considered as "large-scale" (Chappell & Crews, 2006). There were 172 food-fish producers, 28 fingerling producers, 8 stocker producers, and 8 broodstock producers in Alabama in 2005(Census of Aquaculture, 2005). All Alabama counties are engaged in some sort of commercial aquaculture, producing approximately 20 aquatic species. Alabama catfish producers harvested over 142 million pounds of catfish in 2005, which ranked second only to Mississippi in catfish sales. This level of production led to around $101.2 million in sales with Hale County, Alabama ranked 6th in production nationally (NASS, 2005). Not only is Alabama one of the leading catfish producers in the U.S., it is purported to have the land and water resources to support a catfish industry ten times its current size (Chappell & Crews, 2006).

Alabama's aquacultural economic impact is equally impressive. Approximately 3,000 Alabamians have jobs directly engaged in the catfish production and the processing industry. Alabama's large-scale producers sell approximately $170 million worth of catfish to all 50 states and internationally, and annual sales to catfish farmers by allied industries is approximately $80 million for feed, utilities, equipment, and services (Chappell & Crews, 2006).

Integrating Tomato Production

The U.S. is one of the world's leading producers of tomatoes, second only to China (USDA, 2006). Annual per capita use of fresh market tomatoes increased 15 percent between the early 1990s and the early 2000s to nearly 18 pounds per person (USDA, 2006). Mexico and Canada are important suppliers of fresh market tomatoes to the United States, and Canada is the leading U.S. export market for fresh and processed tomatoes. U.S. fresh and processed tomato markets together accounted for almost $2 billion in cash receipts during the early 2000s (USDA, 2006).

The rapidly growing greenhouse tomato industry has become an important part of the North American fresh tomato industry. Greenhouse tomatoes now represent an estimated 17 percent of the U.S. fresh tomato supply (Calving & Cook, 2005). Around 37 percent of all fresh tomatoes sold in U.S. retail stores are now greenhouse, compared with negligible amounts in the early 1990's (Calvin & Cook, 2005). While greenhouse tomatoes have higher per unit costs of production and generally higher retail prices in the U.S. than field tomatoes, several other characteristics have contributed to the growth in this sector. Since they are protected from the water and other conditions that affect open field tomatoes, greenhouse tomatoes generally have a much more uniform appearance than field tomatoes as well as a steady production volume (Calvin & Cook, 2005). These factors lead to greater consistency in quality, volumes, and pricing which are issues of particular concern to the retail and food service industries. Producers also capitalize on higher prices in the off season when field grown tomatoes are not being produced.

The total per capita consumption of fresh tomatoes increased to 19.2 pounds in 2003 from 12.3 pounds in 1981 (USDA, 2006). As of 2004, the U.S. fresh market for tomatoes was valued at $1.3 billion. Imports make up a very large portion of the tomato consumption in the U.S. Fresh imports of tomatoes reached $900 million in 2004 with $750 million coming from Mexico, largely in the winter (USDA, 2006).

Seasonality is a major factor shaping the North American fresh tomato industry. Consumers increasingly demand a steady, year-round supply of tomato products (Calvin & Cook, 2005). These demands are better satisfied with greenhouse tomato production systems that can produce a steady predictable yield through all four seasons as compared to field grown tomatoes which are more seasonal with weather patterns and source of supply. The characteristics result in tomatoes being an excellent complementary enterprise for greenhouse aquacultural systems.

Aquaculture is a growing industry striving to satisfy a growing market for food fish while maintaining profitability. It currently is one of the fastest growing sectors of agriculture in the United States. Catfish and tilapia have been the new aquacultural cash crops since the 1990’s (Helfrich & Libey). Growing public demand for healthy, tasty, and affordable food is steadily influencing the profitability of the catfish industry. The decline in wild fish populations as a result of overharvest and water pollution has promoted the farming of catfish grown in contaminant-free, indoor recirculating aquacultural systems (Helfrich & Libey).

This study includes an assessment of the economic potential of farming channel catfish and tilapia in a system incorporating tomatoes grown hydroponically inside two separate greenhouses. Analyses are oriented to evaluate both economic and technical feasibility of these systems. Potential advantages and disadvantages of these types of integrated systems are analyzed and discussed.

JUSTIFICATION

Recirculating aquacultural systems offer fish producers a variety of important advantages over open pond culture. These advantages are:

1. a method to maximize production using a limited quantity of water and land;
2. nearly complete environmental control to maximize fish growth year round;
3. flexibility to locate production facilities near large markets;
4. efficient, and convenient harvesting; and quick and effective disease control (Helfrich & Libey).

These intensive integrated systems are designed to raise relatively large quantities of fish in relatively small volumes of water by treating the water to remove toxic waste products and then reusing it. They also allow the producer to manage fish stocks more efficiently and allow a relatively high degree of environmental control over many parameters such as water temperature, dissolved oxygen, pH, and many excreted by-products that are normally undesirable (Rakocy, 1992). Non-toxic nutrients and organic matter accumulate in the process of reusing the water. These metabolic byproducts should not be wasted and should be channeled into secondary enterprises that have economic value or in some way benefit or complement the primary production system.

Producing catfish or any other warm water fish, such as tilapia, in a non-tropical environment introduces problems to the farmer that need to be addressed in a feasible manner in order to culture them economically. A greenhouse allows the capture of renewable, solar energy by allowing the fish tanks to trap energy from the sun during the day, and, thus, somewhat lessen demand for heating at night (Lutz, 1998). A large expenditure for the fish farmer is feed, which accounts for 40 to 60 percent of the total production costs. Only 30 to 35 percent of the feed fed and consumed by the fish is utilized for growth. The rest, 65 to 70 percent, is lost to the water column (Brown, 2006). A way to recover the energy lost is to utilize an integrated fish-vegetable greenhouse production system. The system takes the effluent produced by catfish or tilapia production and delivers enriched water to the vegetables from a portion of the culture water. This process allows regular water exchanges from the catfish or tilapia culture tanks, which improve the overall water quality of the system. Also, essential nutrients, which would normally have to be purchased by the producer, are also provided to the tomatoes. The waste water would normally be discarded away from the production site, which means the loss of nutrients for which the farmer worked hard to pay. This system integrates the two technologies and cuts production costs in both aspects.

Plants, such as tomatoes, are an ideal complementary crop in an integrated system because they grow rapidly in response to the high levels of dissolved nutrients that are generated from the microbial breakdown of fish wastes. Since these systems have a small daily water exchange rate, dissolved nutrients accumulate and approach the concentrations that are beneficial to hydroponic plants. Nitrogen, in particular, occurs at very high levels in recirculating systems. Fish excrete waste nitrogen directly into the water in the form of ammonia. A biofilter can convert ammonia to nitrite and then to nitrate. Ammonia and nitrite are toxic to fish, but nitrate is relatively harmless and is the preferred form of nitrogen used for aquatic plants and vegetables such as tomatoes (Rakocy, 1992).

OBJECTIVE

The purpose of this study is to describe and analyze a new integrated aquacultural and vegetable production system. An economic analysis is conducted for growing channel catfish or tilapia with tomatoes in a closed, controlled environment inside two separate greenhouses in order to produce the products throughout the year. Evaluation and commercial use of recirculating systems have increased in recent years due to the potential of increased profits and efficiency. For high levels of water, recirculation biological filters are required. Addition of hydroponic units to biological filters for recirculating fish culture systems has potential legitimacy in that they provide complementary income from the plants produced in addition to increasing biofilter efficiency. Fish wastes that are dissolved in water can provide appropriate nutrients for sustainable plant growth. Removal of the nutrients which otherwise would accumulate in the recirculating raceways reduces water requirements in that less water has to be removed daily from the system (Malone, 1993).

The level of water renewal in the recirculating aquacultural system depends, first, on the biofilter efficiency in removing toxic nitrogen rich waste resulting from fish metabolism and, secondly, on the amount of water that is lost when removing the accumulated waste products from the biofilters. The removal of the nitrogenous compounds from the water and the incorporation of tomatoes into the recirculating system can improve water quality as well as potentially increase catfish and tilapia growth rates. This, together with the additional crop output from the combined system, gives potential to generate a greater profit than when producing aquacultural enterprises alone.

Combination of catfish production with hydroponic tomatoes in a recirculating raceway system may have other potential economic benefits compared with separate operations in terms of reduced land requirements along with the combined use of structures, equipment, and inputs. This approach includes common pumps, filters, energy and, depending on the type of system utilized, vertical space in greenhouses (Rakocy, 1989).

There are continuing studies being done on the designs and management of integrated systems, such as the one discussed in this paper, in order to meet the production requirements of both fish and vegetables. Another similar study involving tilapia and tomatoes will be discussed later for comparative purposes. A particular problem with this system is that some medications approved to control fish diseases cannot be used in an integrated production system due to toxic and cumulative effects on plants (Rakocy 1989). Similarly, some chemicals used to control pests and diseases on plants can be toxic to fish (Rakocy, 1989).

MATERIALS AND METHODS

The planned recirculating aquacultural system represents a new and unique way to produce fish. Instead of the traditional method of growing fish outdoors in open pond culture, recirculating systems produce fish at high densities, in indoor tanks, and a controlled environment. The proposed recirculating aquacultural system to be discussed consists of two separate 88’ by 12’ raceways enclosed in a 96’ by 30’ greenhouse with 6 foot sides. An adjacent 96’ by 30’ greenhouse with 8 foot sides is used for growing tomatoes using aquacultural effluents as nutrients. Figure 1 displays a diagram of the planned system.

The greenhouse for growing an aquacultural enterprise consists of two 88’ long by 12’ wide by 4’ deep raceways. There are four Sweetwater blowers, one single horsepower and three others that are 2.5 horsepower each. These provide sufficient aeration and water flow for the projected yield of 44,000 pounds of channel catfish or 27,600 pounds of tilapia. Tomatoes will be cultivated in troughs within the plant greenhouse. There will be a total of five ditches 90’ long by 2’ wide and 1.5’ deep. These ditches will be filled with 100 percent cotton gin compost, which has been shown to increase tomato production (Cole, 2002).

Tilapia and channel catfish were chosen for evaluation because they are warm water species which are well adapted for intensive recirculating aquacultural systems.

There is also an established market for each specie throughout the southeast. The plant specie chosen was the tomato due to its suitability to be grown in a hydroponic system, as well as its importance as a crop in the region with an already well established market. There are many advantages to the production of tomatoes in greenhouses including increased yields per acre, uniform appearance and quality, uniformity in production, and allowing farmers to more effectively sustain year-round production (Brown, 2006).

The water source will be supplied primarily from two wells which supply approximately 10-15 gallons per minute combined. The well water will be pumped into a 22,000 gallon holding tank 10 feet above the level of the greenhouse tanks to provide water for the fish and emergency water for the tomatoes. Well water often has low hardness and alkalinity. With low hardness and alkalinity, $CaCO_3$ should be added as needed to the culture water to improve productivity and eliminate wide pH swings associated with low alkalinities (Brown, 2006). Access to city water will also be available for emergency purposes, but will not be utilized frequently other than washing the inside of the greenhouses, when needed. Most city water contains chloramines which are not volatile. During emergency situations, sodium thiosulfate should be used to neutralize the toxic chlorine in the city water before being transferred to the fish culture tanks. The water supply should never be a limiting factor for production in the defined system because of the large volume of water that constantly exists.

Design of the system, the stocking rate, and the system of operation were planned with the objective of disease prevention through water quality monitoring, biological control methods, and biofilters incorporated in order to avoid any need for treatments which would be toxic to or accumulate in the plants.

The appropriate combination of tomato production and fish production was analyzed with the level of crop production dependent on the level of plant nutrients provided by the fish production. The feasible level of tomato production was determined and the requirements for hydroponic structures were calculated. The fish production and following technical requirements, such as fingerlings, feed, and physical facilities, were configured in terms of a physical plan to produce 44,000 pounds of channel catfish and 27,600 pounds of tilapia per year.

These levels of production were chosen as minimum levels for economic efficiency estimated for a system manager along with hourly laborers. The manager and hourly laborers' duties were to operate and maintain the production system daily. Additional labor was required during harvest periods for fish as well as tomatoes.

The profitability of the system was determined by performing break even analysis. The advantages of break even analysis allow the producer to know the price for which he needs to sell the fish or tomatoes to cover all costs.

PHYSICAL PLAN

The integrated system is planned on the basis of producing fish at an ideal market weight of 1.10 pounds (500 grams) for catfish and 1 pound for tilapia (Brown, 2006). Most cultured channel catfish sold for food are harvested at 340 to 680 grams (0.75-1.5lbs) in body weight (Chapman, 2006) which comes to approximately 11,000 pounds per quarter when cultured at favorable conditions for catfish. For tilapia, 6,900 pounds per quarter is the defined yield. These conditions include the desirable water temperature of 73 degrees for efficient production as well as an indoor environmental temperature between 82 and 87 degrees which will be maintained by a 200,000 BTU Grain Burner for heating and ventilation fans along with a drip cooling system for cooling (Chappell, 2006). Producing catfish, tilapia, or any other warm water fish in a non-tropical environment introduces problems to the farmer that need to be dealt with in order to culture them economically (Brown, 2006). Food availability and good sanitary conditions promote optimum growth as well.

Fingerling requirements were based on a mortality rate of 3 percent per quarter. Fingerlings were purchased at an average weight of 15 grams or half an ounce and the grow-out period was budgeted to be six months for catfish. A 28 to 32 percent protein diet of floating feed ranging in size from 1.0-5.0mm was fed (Brown, 2006) with a feed conversion ratio of 2:1 assumed. Facilities required for this study were calculated using a stocking rate of 2.50 pounds per cubic foot of system volume (Klinger, 1983). A staggered stocking process allows for a constant supply of market sized catfish while not flooding the local market. The incoming fingerlings should be graded thoroughly before stocking into the system. The fish will then be separated by dividers in the raceways with the dividers expanding the production area to ensure sufficient tank space as the fish grow (Brown, 2006).

Water flow requirements were based on average hourly oxygen consumption of 2.94 grams per pound of feed distributed (Jarboe, 1996) and a minimum dissolved oxygen level of 151 milligrams per gallon (Landau, 1991). Dissolved oxygen should be monitored twice per day with the first measurement starting in early morning and second coming just before dusk. Blowers were utilized with this system and a diffuser hose was used to ensure water circulation and proper aeration. The pH was measured in the morning and just before sunset to minimize large pH swings in the system. Supplemental water was also added every day mainly to replace water loss due to tomato watering and also the evaporation from the large surface area of the raceways. Ammonia, nitrite, and nitrate levels were recorded daily. Water hardness, alkalinity, and chlorides were monitored daily to ensure optimal production conditions. Supplemental nutrients such as fertilizers containing calcium nitrate and potassium nitrite will be mixed and added directly to the tomatoes as needed to maintain maximum production (Brown, 2006). Water flow requirements together with the total system fish volume were calculated for the maximum fish weight level present at anytime during the production cycle.

Levels of tomato production and the respective number of plants required were calculated using the ratio of .084 square feet of growing area per gallon of fish volume (Sutton/Lewis 1982). Tomato plant production density was calculated as .25 plants per square foot (Harris 1994). Tomato yield was specified at 20 pounds per plant (Sutton/Lewis 1982). Water exchanges should take place on a daily basis depending on water quality in the fish tanks and nutrient requirements by the tomatoes (Brown, 2006). Depending on the tomato plant needs, the tomatoes should be watered 3 to 12 times per day to ensure proper water and nutrient amounts. Proper watering will be accomplished by using an automatic siphon from the fish tanks to the plant greenhouse (Brown, 2006). To supply water to the catfish or tilapia raceways, there should be a 3-inch line running from the holding tank that will be capable of supplying a minimum of 200 gallons per minute. There should also be a 4 inch line originating from the reservoir pond supplying the same flow rate for emergency situations. The well water should also be used in watering the tomatoes and mixing any essential nutrients that the fish effluent water does not provide (Brown, 2006).

As stated earlier, the fish production plan was based on the purchase of one-half ounce fingerlings which are grown to market sale weights of 1.1 pounds for catfish or 1 pound for tilapia. For the annual production of 44,000 pounds of channel catfish, 43,000 one-half ounce (5 gram) fingerlings are purchased in batches of 10,638 per quarter. A total of 34,558 tilapia fingerlings are stocked per year to produce 27,600 pounds per year.

At the end of the first quarter, there are 10,319 catfish available due to the 3% mortality rate. The average weight of the fish is expected to be 4.5 ounces per fish and the total weight of all the fish would be 2,925 pounds (Table 1). The second quarter allows for continuous growth of the catfish to the market weight 1.1 pounds. Therefore, the total weight of the fish at the end of the second production cycle is 10,152 pounds (Table 1) meaning that the maximum level of catfish in the system at any time is 13,054 pounds (10,152 + 2,925) which occurs after a six month period which is the average length of a production cycle for channel catfish. As stated earlier, this staggered stocking process allows for a constant supply of market sized catfish while not flooding the market (Brown, 2006).

The water flow required for the stated amount of production is 3,000 feet per hectare as produced by the four blowers. Since the catfish are stocked at 2.5 pounds per cubic foot of the system volume (Klinger, 1983), the total water volume required is slightly over 39,000 gallons (Table 2). The hydroponic tomato growing area required is 3,294 square feet (39,000*.084 square feet) and consequently, 826 (.25 plants per square foot of hydroponics growing area*3294) plants are needed per cycle (Table 2). The expected tomato output was 16,587 pounds per cycle and 33,175 pounds per year based on two production cycles per year (Table 2). The first crop was transplanted in August and harvested from November to the end of December and a second crop was transplanted at the first of January and harvested from March through early June (Brown, 2006).

A total of 34,558 tilapia were stocked per year which was broken into two month stocking regimes (Brown, 2006). With an estimated total production of 13,800 pounds produced per tank per year, the estimated grow-out time for each individual tilapia cohort was six months to reach one pound which results in a minimum of 27,600 pounds produced per year (Brown, 2006).

FINANCIAL PLAN

Costs for the equipment required to operationalize the physical plan for the production of the fish along with hydroponic tomato production were determined from commercial suppliers and retailers, including two greenhouses, generators, an irrigation system, lumber, aerators, and a Polyurea waterproof liner for the two raceways. The catfish output was budgeted to be marketed at 77.6 cents per pound while tilapia was priced at $1.80 per pound (USDA, 2006). Due to the seasonality of prices of tomatoes, an average market price from 2000 to 2005 was used to determine the expected return from tomato production. The average market price of tomatoes in 2000 was $1.38 per pound and the average market price in 2005 was $1.61 per pound (USDA, 2006). Therefore, the tomato price used in the analysis to determine the expected return was $1.50 per pound.

Investment Costs

Financial requirements for the initial investment to establish a system that produces 44,000 pounds of channel catfish or 27,600 pounds of tilapia is shown to be $70,640 with an annual depreciation of $6,455 (Table 3). The greenhouse that would house 33,175 pounds of tomatoes per year would cost approximately $43,072 with an annual depreciation of $3,474(Table 4). Therefore, the total initial investment for the system was estimated to be $113,712 with an annual depreciation of $9,930 (Table 5).

Break even analysis for each system was utilized to determine break even prices and yields to cover all costs at given output levels and output prices. The following formulas were used for determining the break even prices and yields.

Break even price= total cost / expected yield

Break even yield= total costs/ output price

(Kay & Edwards, 1999).

Catfish and Tomato Production

Break even analysis for this system was determined displaying that the break even price was $.77 per pound for 44,000 pounds of catfish. The break even production level was 43,755 pounds at $.77 per pound (Table 5). The break even price for tomatoes was determined to be $.92 per pound for 33,175 pounds of tomatoes. The break even production level was 20,378 pounds at $1.50 per pound. The break even prices and production levels shown are good estimates of how much the catfish and tomatoes must be sold for or how many pounds need to be sold to cover costs for producing both catfish and tomatoes in the greenhouse system. With total annual cash inflow being $83,642 and total annual cash outflow of $74,189, the annual net cash flow was determined to be $9,453 (Table 6). Therefore, integrated greenhouse systems using catfish and tomatoes are shown to be profitable.

Tilapia and Tomato Production

Total tilapia production was estimated to be a minimum of 27,600 pounds per year with an estimated grow out time of six months to reach the market size of one pound (Brown, 2006). With two crops of tomatoes produced per year, the estimated total production of tomatoes in the greenhouse system was 33,175 pounds per year.

Using these production yields, break even analysis and annual cash flows were determined. Break even analysis for this system was determined displaying that the break even price was $1.22 per pound for 27,600 pounds of tilapia. The break even production level was 18,717 pounds at $1.80 per pound (Table 7). The break even price for tomatoes was determined to be $.92 per pound for 33,175 pounds of tomatoes. The break even production level for tomatoes was 20,378 pounds at $1.50 per pound (table 7). The break even prices and production levels shown are good estimates of how much the tilapia and tomatoes must be sold for or how many pounds need to be sold to cover costs for producing both catfish and tomatoes in the greenhouse system. With total annual cash inflow being $99,442 and total annual cash outflow of $74,189, the annual net cash flow was determined to be $25,253 (Table 8). Therefore, integrated greenhouse systems using tilapia and tomatoes are also profitable.

Fish Only Production Systems

The differences in capital requirements for the production of the same quantity of channel catfish or tilapia without the hydroponic tomato production unit result in the purchase of biofilters. Since this system only consists of fish (with no tomatoes), a biofilter is required with the recirculation capacity of 3,000 feet per hectare which is estimated to cost approximately $7,500. Since the cash values of tomatoes are foregone, the only source of income is the channel catfish or tilapia. If the expected 44,000 pounds of catfish or 27,600 pounds of tilapia are produced and sold at 77.6 cents per pound for catfish and $1.80 per pound for tilapia(USDA, 2006), the total cash inflows would be $33,880 for catfish and $49,680 for tilapia. These cash inflows do not cover the annual expenditure costs and annual depreciation which amount to $55,147 annually (Table 9). This system would be losing approximately $21,000 annually producing only catfish (Table 9) and losing approximately $5,500 annually producing only tilapia (Table 10). Break even analysis for this system was determined displaying that the break even price was $1.11 per pound for 44,000 pounds of catfish and 1.76 per pound for 27,600 pounds of tilapia. The break even production level was 63,236 pounds at $.77 per pound for catfish (Table 11) and 27,051 pounds at $1.80 per pound for tilapia (Table 12). The break even prices and production levels shown are good estimates of how much the catfish or tilapia must be sold for or how many pounds need to be sold to cover costs for producing only catfish or only tilapia in the greenhouse system. Therefore, producing only catfish or tilapia without integrating hydroponic tomatoes into this type of system is unprofitable.

Sensitivity Analysis

Given the uncertainty of various prices and yields of the aquacultural system, sensitivity analysis was performed. Sensitivity analysis is a procedure for assessing the riskiness of a decision by using several possible price and/or production outcomes to budget the results, and then comparing them (Kay & Edwards, 1999). The analysis was performed for each variation of the system with yield variations of 10 and 20 percent and price variations of 5 and 10 cents per pound of production.

Sensitivity analysis of annual cash flows for catfish and tomato production determined that catfish and tomato yields could decrease by 10 percent of the 44,000 pounds of catfish and 33,175 pounds of tomato production to 39,600 pounds of catfish and 29,857 pounds of tomatoes, and still have positive annual cash flows of $1,088 (Table 13) at the current price of 77 cents per pound of catfish and $1.50 per pound of tomatoes. Analysis also determined that a 10 percent increase in production yields and a 5 cent increase in price per pound could more than double the annual cash flows to $22,061 (Table 13).

Sensitivity analysis of annual cash flows for tilapia and tomato production determined that tilapia and tomato yields could decrease by 20 percent of the 27,600 pounds of tilapia and 33,175 pounds of tomato production to 20,080 pounds of tilapia and 26,540 pounds of tomatoes, and still have positive annual cash flows of $502 (Table 14) at the current price of $1.80 per pound of tilapia and $1.50 per pound of tomatoes. Analysis also determined that a 20 percent increase in production yields could increase the annual cash flows by approximately $20,000 to $45,141 (Table 14).

Sensitivity analysis of annual cash flows was also performed for producing only catfish or only tilapia. The analysis determined that the catfish only system would continue to be unprofitable with a 20 percent increase of annual production yield to 52,800 pounds and a 10 cent price increase to .87 per pound. The catfish only system would still be losing approximately $9,000 annually (Table 15). The analysis determined that the tilapia only system would have positive annual cash flows if the production yield increased by 20 percent to 33,120 pounds per year allowing the system to have annual cash flows of $4,468 (Table 16). The system could also increase production by 10 percent along with a 5 cent price increase to 1.85 per pound to get positive cash flows of $1,018 annually (Table 16).

Due to the unprofitability of producing only tilapia or catfish without the integration of tomatoes, possible changes in the fish only production system were analyzed. Some suggestions to increase the profitability would be to use less expensive equipment or integrate technology into the system which could possibly reduce labor hours and costs. Integrating the technology may increase initial investment costs, but should decrease the initial annual labor costs substantially. Assuming there is already an established niche market; another option would be to become strictly a fingerling production by the system to commercial buyers (Goodman & Trimble, 2006).

ENVIRONMENTAL AND NATURAL RESOURCE ADVANTAGES

This analysis has been made from the viewpoint of an individual investor. When one considers the externalities associated with both production systems, there are further potential benefits from combining fish and tomato cultures into recirculating systems.

The effluents discharged into bodies of water from the recirculating system that are not integrated with hydroponic plants, such as tomatoes, do not have an immediate serious pollution effect, but the cumulative effect may contribute to problems which would conflict and limit other activities that would utilize the same water resource. Areas that face significant pollution problems may cause concern for the local population causing the investor to possibly be internally charged for the effluent discharges into the local bodies of water by means of taxes or other fees. These additional taxes and fees make the integrated fish and tomato production system to be a more desirable system instead of strictly fish production because the effluents are utilized and not disposed into waterways.

Combination of fish and plant production within an indoor water recirculating production system reduces the total water requirement compared with outdoor flow-through systems and plant irrigation systems. This advantage would be very desirable in areas with limited water supplies.

Integrating hydroponic plants such as tomatoes to utilize waste products from fish production reduces the dependency on artificial fertilizers produced from nonrenewable oil resources.

If the combination of hydroponic tomatoes with fish production improves the economics of recirculation systems, the inherent environmental advantages of such systems will be more widely realized in that there will be reduced effluent discharges into bodies of water, reduced land use compared with conventional aquacultural systems, and greater flexibility in locating such units because of the great reduction in water requirements (Timmons and Losordo, 1997).

CONCLUSION

Incorporating hydroponic tomatoes along with either, an indoor recirculating catfish or tilapia production facility inside two adjacent greenhouses has been shown to be profitable and is also desirable to environmental and land use conscious investors as well. This type of system has the potential to provide both financial and environmental benefits in terms of shared resources, reduced labor input hours, reduced effluent discharges into local bodies of water, improved water quality, and lower water use.

Analysis of this system and the comparison of the alternative system without the hydroponic tomatoes unit indicated that the differences in the potential financial return between the integrated system of catfish or tilapia and tomatoes and the system producing only catfish or tilapia varied greatly. The integrated tomato and catfish production system would have positive annual cash flows of $9,453 (Table 5) as compared to the system producing only catfish which had a negative cash flow of about $21,000 annually (Table 6). Production of tomatoes hydroponically using the effluents of the catfish or tilapia was a major element in contributing to the total profit of the integrated system. It also demonstrated that tilapia and tomatoes produced in the integrated system are profitable as well with positive cash flows of $25,253 annually (Table 10) as compared to the system producing only tilapia which had a negative cash flow of about $5,500 annually (Table 11). Further study should be undertaken to quantify the potential gains in catfish or tilapia performance as a result of improved water quality in that even a relatively small growth rate increase could possibly have a significant effect on the economic advantage of the integrated production system.

There are important potential economic and environmental advantages of integrating hydroponic tomatoes and indoor recirculating catfish or tilapia production systems, particularly in relation to reducing effluent discharges into local bodies of water, the amount of water used, and the amount of land used. The apparent trend of internalizing these costs in terms of charges on water use and effluent discharges along with increased production numbers and profits will increasingly support the economics of such systems.

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APPENDIX OF TABLES AND FIGURES

TABLE 1
Physical Plan for Channel Catfish Production in the Aquacultural System

Year 1

Quarter 1

Purchases	**End Stocks**		
Number of fish (.5 ounce)	Number of fish	Weight (ounces)	Total (lb)
10,638	10,319	4.50	2,902.22

Quarter 2

Purchases	**Sales**	**End Stocks**		
Number of fish (.5 ounce)	Number of fish (1.1lb)	Number of fish	Weight (ounces)	Total (lb)
10,638	10,000	10,319	4.50	10,152.00

Quarter 3

Purchases	**Sales**	**End Stocks**		
Number of fish (.5 ounce)	Number of fish (1.1lb)	Number of fish	Weight (ounces)	Total (lb)
10,638	10,000	10,319	4.50	2,902.22

Quarter 4

Purchases	**Sales**	**End Stocks**		
Number of fish (.5 ounce)	Number of fish (1.1lb)	Number of fish	Weight (ounces)	Total (lb)
10,638	10,000	10,319	4.50	10,152.00

Years 2-10

Quarter 1

Purchases	**Sales**	**End Stocks**		
Number of fish (.5 ounce)	Number of fish (1.1lb)	Number of fish	Weight (ounces)	Total (lb)
10,638	10,000	10,319	4.50	2,902.22

Quarter 2

Purchases	**Sales**	**End Stocks**		
Number of fish (.5 ounce)	Number of fish (1.1lb)	Number of fish	Weight (ounces)	Total (lb)
10,638	10,000	10,319	4.50	10,152.00

Quarter 3

Purchases	**Sales**	**End Stocks**		
Number of fish (.5 ounce)	Number of fish (1.1lb)	Number of fish	Weight (ounces)	Total (lb)
10,638	10,000	10,319	4.50	2,902.22

Quarter 4

Purchases	**Sales**	**End Stocks**		
Number of fish (.5 ounce)	Number of fish (1.1lb)	Number of fish	Weight (ounces)	Total (lb)
10,638	10,000	10,319	4.50	10,152.00

TABLE 2
Expected Catfish and Tomato Production Yields from the Aquacultural System

	Units	
Growing area per gallon of catfish volume	sq. ft/gal	0.08
Tomato plant density	plants/ sq. ft	0.25
Tomatoes per plant	lb/plant	20.06
Fingerling weight	ounces	0.53
Catfish Market weight	lbs	1.10
Days for Catfish to Reach Market Weight	days	185.00
Expected Annual Catfish Yield	lbs	44,000.00
Maximum level of fish present at any time	lbs	13,054.22
Waterflow for Catfish	cu. ft/ h	3,000.00
Catfish Stocking Rate	lb/cu. Ft	2.50
Total System Water Volume Required	gal	39,060.93
Tomato Growing Area Required	sq. ft	3,294.40
Tomato Plants per cycle	plants	826.89
Expected Tomato Output per Cycle	lbs	16,587.50
Number of Tomato Cycles per Year	cycles	2.00
Tomato Output per Year	lbs	33,175.00

TABLE 3
Investment Costs and Variable Costs for the Fish Greenhouse in the Aquacultural System

Investment Costs

Item	Unit	Price/Unit	Quantity	Cost	Yrs of Life	Annual Depreciation
Greenhouse (30' x 96' x 6' side, Atlas Greenhouse Systems)						
Basic Structure	per	6,500	1	6,500.00	20	325.00
Poly Roof Covering (2ply)	per	3,500	1	3,500.00	20	175.00
Ventilation	per	2,760	1	2,760.00	20	138.00
Shade Cover	per	330	1	330.00	20	16.50
Door (3' x 6' 8")	per	180	1	180.00	20	9.00
Door (10' x 10', roll up)	per	560	1	560.00	20	28.00
Freight	per	450	1	450.00	20	22.50
Installation	per	5,000	1	5,000.00	20	250.00
Baseboard (2' x 8', treated with clamps)	per	550	1	550.00	20	27.50
Subtotal: Greenhouse			**Total**	**$19,830.00**		**$991.50**
Raceway System (2 raceways @ 88' x 12' x 3 ½' each)						
Wooden posts (4" x 4" x 8' treated, 100 @ $5 each)	per	5	100	500.00	15	33.33
Plywood (5/8" x 4' x 8' Treated, 48 @ $40 each)	per	48	40	1,920.00	15	128.00
Wooden Caps (2" x 4" x 16', 18 @ $10 each)	per	10	18	180.00	15	12.00
Drain Stuctures (two 8" x 4' PVC pipe plus two 8" ells)	per	60	2	120.00	20	6.00
Walkway (Crushed Limestone)	cu yds	25	4	100.00	5	20.00
Tank Dividers	per	400	3	1,200.00	15	80.00
Waterproofing						
Polyurea waterproof liner (All Coat, Inc.)	per	12,300	1	12,300.00	5	2,460.00
Aeration						
One Sweetwater S41 Blower, 1hp	per	500	1	500.00	5	100.00
Three Sweetwater S51 Blowers, 2.5 hp	per	750	3	2,250.00	5	450.00
Aeration Hose + PVC pipe and fittings	per	500	1	500.00	5	100.00
Subtotal: Raceway system			**Total**	**$19,570.00**		**$3,389.33**
Machinery and Equipment						
Corn Boiler and accessories	per	7,000	1	7,000.00	15	466.67
Generator	per	560	1	560.00	5	112.00
Garden Hose (100', heavy duty, adjustable flow nozzle)	per	90	1	90.00	5	18.00
Dissolved Oxygen Meter	per	760	1	760.00	3	253.33
Dissolved Oxygen Monitoring System	per	940	1	940.00	5	188.00
Water Quality Test Kit (Hach Fish Farm Kit, FF-1A)	per	240	1	240.00	2	120.00
Harvesting Dip Net (heavy duty, 22" x 18" x 24" deep, two)	per	60	2	120.00	5	24.00
Baskets, Polyethylene (10.4 gal, 19" x 14" deep, Delta Twine, six)	per	15	6	90.00	3	30.00
Scale (Mettler Model XWS60MS: 100 lb capacity, 0.02 resolution) & Platter (Toledo XIS: heavy wash down, stainless, a/c adapter)	per	625	2	1,250.00	5	250.00
Temperature Controller and DO Probe	per	940	1	940.00	5	188.00
Well	per	1,050	1	1,050.00	10	105.00
Water Tank: 22,000 gallons	per	3,200	1	3,200.00	10	320.00
Reservior Pond: one acre	acre	15,000	1	15,000.00		0.00
Subtotal: Machinery and Equipment			**Total**	**$31,240.00**		**$2,075.00**
TOTAL INVESTMENT COSTS: FISH GREENHOUSE			**Total**	**$70,640.00**		**$6,455.83**

Variable Costs

Item	Unit	Price/Unit	Quantity	Cost
Fingerlings	per	0.15	43,000.00	6,450
Labor (avg 10 hrs/week)	hr	10.00	520.00	5,200
Electrical	Kwh	0.08	25,000.00	2,000
Water (city)	total	500.00	1.00	500
Feed	tons	280.00	10.00	2,800
Corn (Fuel for heat)	bushel	2.00	771.00	1,542
Chemicals	total	100.00	1.00	100
System Manager	total	30,000.00	0.50	15,000
Maintenance	total	100.00	1.00	100
TOTAL VARIABLE COSTS: FISH GREENHOUSE			**Total**	**$33,692.00**

TABLE 4
Investment Costs and Variable Costs for theTomato Greenhouse in the Aquacultural System

Fixed Costs

Item	Unit	Price/Unit	Quantity	Cost	Yrs of Life	Annual Depreciation
Greenhouse (35' x 100' x 8' side, Atlas Greenhouse Systems)						
Basic Structure	per	8,500	1	8,500.00	20	425.00
Poly Roof Covering	per	6,250	1	6,250.00	20	312.50
Ventilation and Cooling	per	6,500	1	6,500.00	20	325.00
HAF Fans (4)	per	100	4	400.00	20	20.00
Door (10' x 10', double sliding)	per	750	1	750.00	20	37.50
Shade Cloth	per	900	1	900.00	20	45.00
Freight	per	500	1	500.00	20	25.00
Installation	per	6,000	1	6,000.00	20	300.00
Drainage	per	500	1	500.00	20	25.00
Baseboard (2" x 8", treated)	per	550	1	550.00	20	27.50
Subtotal: Plant Greenhouse			**Total**	**$30,850.00**		**$1,542.50**
Machinery and Equipment						
Generator	per	560.00	1	560.00	5	112.00
Irrigation System	per	500.00	1	500.00	5	100.00
Support Wire for Poly Duct	spool	5.00	2	10.00	10	1.00
Posts	per	113.00	12	1,356.00	15	90.40
Pipe (20' sections at $210 each, 12)	per	210.00	12	2,520.00	15	168.00
Tee (one per post @ $50 each 12)	per	50.00	12	600.00	15	40.00
Caps ((two per post) @ $35 each, 24))	per	35.00	24	840.00	15	56.00
Eye bolts (stainless, 6" x 3/8" includes washer and nut @ $3/each, two/post, :	per	3.00	24	72.00	15	4.80
Quikcrete (three bags/post @ $4/bag, 36 bags)	per	4.00	36	144.00	15	9.60
Subtotal: Posts			**Total**	**$6,602.00**		**$581.80**
Support wire for tomatoes	spool	10	5	50.00	10	5.00
Extension Cord (100')	per	40	1	40.00	5	8.00
Hose (100'. Heavy duty)	per	90	1	90.00	5	18.00
Hose Reel	per	30	1	30.00	7	4.29
Backpack Sprayer	per	100	1	100.00	2	50.00
Respirator	per	100	1	100.00	1	100.00
Spray Suit	per	20	1	20.00	1	20.00
Pruning Sears	per	30	1	30.00	15	2.00
Wheelbarrow	per	100	1	100.00	5	20.00
Plant Calipers	per	10	1	10.00	5	2.00
Trashcans (50 gallon, 2)	per	20	2	40.00	3	13.33
Ladder (6', aluminum)	per	60	1	60.00	15	4.00
Rake	per	10	1	10.00	3	3.33
Utility Cart	per	200	1	200.00	3	66.67
Meter: EC, pH	per	420	1	420.00	3	140.00
Meter: Potassium	per	310	1	310.00	3	103.33
Meter: Nitrate	per	320	1	320.00	3	106.67
Hydrometer: Wet-Dry Bulb	per	30	1	30.00	3	10.00
Recorder: Humidity and Temperature	per	350	1	350.00	3	116.67
Thermalarm III	per	50	1	50.00	5	10.00
Solar Irrigation Controller	total	800	1	800.00	5	160.00
Sensaphone plus 1 Remote Sensor	per	450	1	450.00	5	90.00
Cotton Gin Compost	cu yds	16	60	960.00	5	192.00
Well	per	1,050	1	1,050.00	10	105.00
Subtotal: Machinery and Equipment			**Total**	**$5,620.00**		**$1,350.29**
TOTAL INVESTMENT COSTS: TOMATO GREENHOUSE			**Total**	**$43,072.00**		**$3,474.59**

Variable Costs

Item	Unit	Price/Unit	Quantity	Cost
Tomato Seeds	per	0.25	1,000.00	250.00
Labor (15 hrs/week)	hr	10.00	780.00	7,800.00
Electrical	Kwh	0.08	35,000.00	2,800.00
Corn (fuel for heat)	Bushel	2.00	771.00	1,542.00
Water (city)	total	500.00	1.00	500.00
Fertilizer	total	55.00	1.00	55.00
Chemicals	total	250.00	1.00	250.00
Poly Duct	roll	280.00	2.00	560.00
Beneficial insects	total	810.00	1.00	810.00
Water Sample Analysis	per	70.00	6.00	420.00
Leaf Tissue Analysis	per	80.00	6.00	480.00
System Manager	total	30,000.00	0.50	15,000.00
Maintenance	total	100.00	1.00	100.00
TOTAL VARIABLE COSTS: TOMATO GREENHOUSE				**$30,567.00**

TABLE 5
Gross Receipts for Producing Catfish and Tomatoes in the Aquacultural System

	unit	price/unit	# units (lbs)	TOTAL (S)
Catfish	lbs	0.77	44,000.00	33,880.00
Tomatoes	lbs	1.50	33,175.00	49,762.49
			Total	**83,642.49**

Catfish		
Variable Cost		33,692.00
Investment Cost		70,640.00
	Total cost	**104,332.00**
Tomato		
Variable Cost		30,567.00
Investment Cost		43,072.00
	Total Cost	**73,639.00**
Total Variable Costs		64,259.00
Total Investment Costs		113,712.00
	Total Cost	**177,971.00**

Break Even Analysis

Break even price to cover variable expenses	
Break even cost per lb Catfish	**0.77**
Break even cost per lb Tomatoes	**0.92**
Break even price to cover investment expenses	
Break even cost per lb Catfish	1.61
Break even cost per lb Tomatoes	1.30
Break even price to cover total expenses	
Break even cost per lb Catfish	2.37
Break even cost per lb Tomatoes	2.22
Break even production levels to cover variable costs	
Catfish (lbs)	**43,755.84**
Tomatoes (lbs)	**20,378.00**
Break even production levels to cover investment costs	
Catfish (lbs)	91,740.26
Tomatoes (lbs)	28,714.67
Break even production levels to cover total costs	
Catfish (lbs)	135,496.10
Tomatoes (lbs)	49,092.67

TABLE 6
Annual Cash Flows for Channel Catfish and Tomato Production in the Aquacultural System

Receipts	
Channel Catfish	33,880.00
Tomatoes	49,762.49
Total cash inflow	**83,642.49**
Expenditure	
Catfish Total Variable Costs (System Manager Included)	33,692.00
Tomato Total Variable Costs (System Manager Included)	30,567.00
Annual Depreciation	9,930.42
Total cash outflow	**74,189.42**
Net Cash Flow	**9,453.07**

TABLE 7

Gross Receipts for Producing Tilapia and Tomatoes in the Aquacultural System

	unit	price/unit	# units (lbs)	TOTAL (S)
Tilapia	lbs	1.80	27,600.00	49,680.00
Tomatoes	lbs	1.50	33,175.00	49,762.49
			Total	**99,442.49**

Tilapia		
Variable Cost		33,692.00
Fixed Cost		70,640.00
	Total cost	**104,332.00**
Tomato		
Variable Cost		30,567.00
Fixed Cost		43,072.00
	Total Cost	**73,639.00**
Total Variable Costs		64,259.00
Total Fixed Costs		113,712.00
	Total Cost	**177,971.00**

Break Even Analysis	
Break even price to cover variable expenses	
Break even cost per lb Tilapia	**1.22**
Break even cost per lb Tomatoes	**0.92**
Break even price to cover fixed expenses	
Break even cost per lb Tilapia	2.56
Break even cost per lb Tomatoes	1.30
Break even price to cover total expenses	
Break even cost per lb Tilapia	3.78
Break even cost per lb Tomatoes	2.22
Break even production levels to cover variable costs	
Tilapia (lbs)	**18,717.78**
Tomatoes (lbs)	**20,378.00**
Break even production levels to cover fixed costs	
Tilapia (lbs)	39,244.44
Tomatoes (lbs)	28,714.67
Break even production levels to cover total costs	
Tilapia (lbs)	57,962.22
Tomatoes (lbs)	49,092.67

TABLE 8
Annual Cash Flows for Tilapia and Tomato Production in the Aquacultural System

Receipts	
Tilapia	49,680.00
Tomatoes	49,762.49
Total cash inflow	**99,442.49**
Expenditure	
Tilapia Total Variable Costs (System Manager Included)	33,692.00
Tomato Total Variable Costs (System Manager Included)	30,567.00
Annual Depreciation	9,930.42
Total cash outflow	**74,189.42**
Net Cash Flow	**25,253.07**

TABLE 9
Annual Cash Flows for Producing Only Catfish in the Aquacultural System

Receipts	
44,000 pounds of channel catfish	33,880.00
Total Cash Inflow	**33,880.00**
Expenditure	
Catfish Total Variable Costs plus System Manager	48,692.00
Annual Depreciation	6,455.83
Total cash outflow	**55,147.83**
Net Cash Flow	**-21,267.83**

TABLE 10
Annual Cash Flows for Producing Only Tilapia in the Aquacultural System

Receipts	
27,600 pounds of tilapia	49,680.00
Total Cash Inflow	**49,680.00**
Expenditure	
Tilapia Total Variable Costs plus System Manager	48,692.00
Annual Depreciation	6,455.83
Total cash outflow	**55,147.83**
Net Cash Flow	**-5,467.83**

TABLE 11

Gross Receipts for Producing Only Catfish in the Aquacultural System

	unit	price/unit	# units (lbs)	TOTAL (S)
Catfish	lbs	0.77	44,000.00	33,880.00
			Total	**33,880.00**

Catfish

Variable Cost plus System Manager		48,692.00
Investment Cost plus Biofilter		78,140.00
	Total cost	**126,832.00**

Total Variable Costs		48,692.00
Total Investment Costs		78,140.00
	Total Cost	**126,832.00**

Break Even Analysis

Break even price to cover variable expenses

Break even cost per lb Catfish	**1.11**

Break even price to cover investment expenses

Break even cost per lb Catfish	1.78

Break even price to cover total expenses

Break even cost per lb Catfish	2.88

Break even production levels to cover variable costs

Catfish (lbs)	**63,236.36**

Break even production levels to cover investment costs

Catfish (lbs)	101,480.52

Break even production levels to cover total costs

Catfish (lbs)	164,716.88

TABLE 12
Gross Receipts for Producing Only Tilapia in the Aquacultural System

	unit	price/unit	# units (lbs)	TOTAL (S)
Tilapia	lbs	1.80	27,600.00	49,680.00
			Total	**49,680.00**

Tilapia		
Variable Cost plus System Manager		48,692.00
Investment Cost plus Biofilter		78,140.00
	Total cost	**126,832.00**

Total Variable Costs		48,692.00
Total Investment Costs		78,140.00
	Total Cost	**126,832.00**

Break Even Analysis

Break even price to cover variable expenses
Break even cost per lb Tilapia — **1.76**

Break even price to cover investment expenses
Break even cost per lb Tilapia — 2.83

Break even price to cover total expenses
Break even cost per lb Tilapia — 4.60

Break even production levels to cover variable costs
Tilapia (lbs) — **27,051.11**

Break even production levels to cover investment costs
Tilapia (lbs) — 43,411.11

Break even production levels to cover total costs
Tilapia (lbs) — 70,462.22

TABLE 13
Sensitivity Analysis of Annual Cash Flows at Varying Yields and Prices for Catfish and Tomato Production

Yield (lb)			Price($/lb.)		
Catfish **Tomato**	**0.67** **1.40**	**0.72** **1.45**	**0.77** **1.50**	**0.82** **1.55**	**0.87** **1.60**
35,200.00 **26,540.00**	-13,449.42	-10,362.42	-7,275.42	-4,188.42	-1,101.42
39,600.00 **29,857.50**	-5,856.92	-2,384.05	1,088.83	4,561.70	8,034.57
44,000.00 **33,175.00**	1,735.58	5,594.32	9,453.07	13,311.82	17,170.57
48,400.00 **36,492.50**	9,328.07	13,572.70	17,817.32	22,061.95	26,306.57
52,800.00 **39,809.99**	16,920.57	21,551.07	26,181.57	30,812.07	35,442.57

TABLE 14
Sensitivity Analysis of Annual Cash Flows at Varying Yields and Prices for Tilapia and Tomato Production

Yield (lb)			Price($/lb.)		
Tilapia **Tomato**	**1.70** **1.40**	**1.75** **1.45**	**1.80** **1.50**	**1.85** **1.55**	**1.90** **1.60**
22,080.00 **26,540.00**	502.58	2,933.58	5,364.58	7,795.58	10,226.58
24,840.00 **29,857.50**	9,839.08	12,573.95	15,308.83	18,043.70	20,778.57
27,600.00 **33,175.00**	19,175.58	22,214.32	25,253.07	28,291.82	31,330.57
30,360.00 **36,492.50**	28,512.07	31,854.70	35,197.32	38,539.95	41,882.57
33,120.00 **39,809.99**	37,848.57	41,495.07	45,141.57	48,788.07	52,434.57

TABLE 15
Sensitivity Analysis of Annual Cash Flows at Varying Yields and Prices for Producing Catfish Only

Yield (lb)	Price($/lb.)				
Catfish	**0.67**	**0.72**	**0.77**	**0.82**	**0.87**
35,200.00	-31,563.83	-29,803.83	-28,043.83	-26,283.83	-24,523.83
39,600.00	-28,615.83	-26,635.83	-24,655.83	-22,675.83	-20,695.83
44,000.00	-25,667.83	-23,467.83	-21,267.83	-19,067.83	-16,867.83
48,400.00	32,428.00	34,848.00	37,268.00	39,688.00	42,108.00
52,800.00	35,376.00	38,016.00	40,656.00	43,296.00	45,936.00

TABLE 16
Sensitivity Analysis of Annual Cash Flows at Varying Yields and Prices for Producing Tilapia Only

Yield (lb)	Price($/lb.)				
Tilapia	**1.70**	**1.75**	**1.80**	**1.85**	**1.90**
22,080.00	-17,611.83	-16,507.83	-15,403.83	-14,299.83	-13,195.83
24,840.00	-12,919.83	-11,677.83	-10,435.83	-9,193.83	-7,951.83
27,600.00	-8,227.83	-6,847.83	-5,467.83	-4,087.83	-2,707.83
30,360.00	-3,535.83	-2,017.83	-499.83	1,018.17	2,536.17
33,120.00	1,156.17	2,812.17	4,468.17	6,124.17	7,780.17

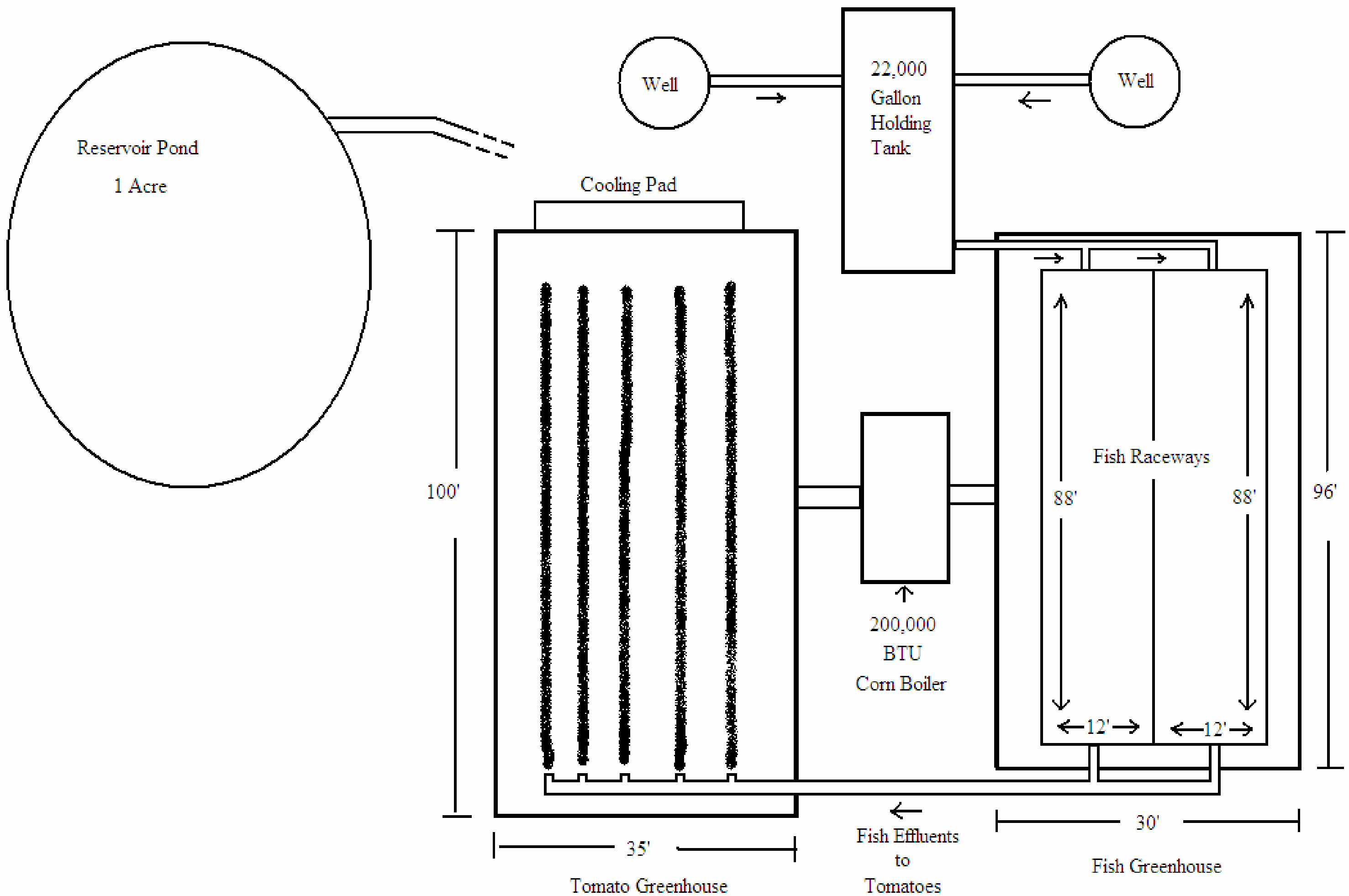

Figure 1. Design of the Tomato and Fish Production System