

# A preliminary evaluation of an integrated aquaculture-agriculture systems (tilapia and peppers) at mesocosm scale

## Abstract

A preliminary assay was conducted to evaluate the feasibility of an integrated aquaculture-agriculture production system. Tilapia (*Oreochromis niloticus*) was farmed in plastic tanks (500L), with and without bioflocs incorporated. The effluents were passed to PVC tubes for a hydroponic culture of jalapeño pepper (*Capsicum annum*). The final effluent was used to a fertigation culture of mini bell pepper (*Capsicum annum*). The production response of tilapia was little better in tanks with bioflocs. The jalapeño pepper had not a good performance in the hydroponics system. Contrarily, mini bell pepper showed a good performance. We concluded that this aquaculture-agriculture system could be efficient, but some adjustments need to be done.

**Keywords:** aquaculture, agriculture, hydroponics, tilapia, peppers

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## Introduction

One of the main concerns about the diverse activities related to food production is the environmental impact they can produce in the surrounding ecosystems. This is particularly true in the case of aquaculture, one of the most criticized productive activities because of its potential environmental impact.<sup>1</sup> For shrimp aquaculture it was estimated that for each ton of biomass produced, around 1.6 tons of organic matter nitrogen and 0.8 tons of nitrogen are discharged in the effluents with the consequent adverse effects, and similar scenarios could be expected for fish aquaculture.

Tilapia is the second most farmed group of fish around the world with annual productions over five million tons, being the Nile tilapia, *Oreochromis niloticus*, the most cultured (FAO, 2018). Similarly, in México tilapia is the most farmed fish. These huge volume of production have negative impacts on the environment.<sup>2</sup>

Some strategies have been implemented to reduce the impact of aquaculture in the effluent-receiving ecosystems. In the case of tilapia and some other fish, one of the most efficient strategies is the reduction of the protein content of aquafeeds, reducing in this way the ammonia excretion and consequently its level in the effluents.<sup>3</sup> Another environmentally friendly practice is the substitution of formulated feed by natural feed, including microorganisms immobilized in submerged fix (biofilms) or floating (bioflocs) substrates. Also, the recirculation systems and the utilization or reuse of effluents have demonstrated to be adequate and effective strategies for reducing the nutrients and organic matter destined to be discharged in the environment.

Aquaponics is a relatively novel production system which combine aquaculture and hydroponics to optimize the use of the nutrients and diminish their losses.<sup>4</sup> The idea is to use the nutrients discarded by aquaculture (organisms excretions, molts, unconsumed feed, feces, etc.) for the growth of diverse plants, mainly those with a great demand and good market price in order to maximize the incomes

of the production system.<sup>5</sup> The plants must be selected based on the environmental conditions of the site, the concentration of nutrients in the aquaculture effluents, and their demand and price in the market,<sup>6</sup> herein, several conventional greenhouse plants (cucumber, tomato, pepper, lettuce, etc.), herbs, medicinal plants, and nutraceutical plants, could be produced.<sup>7</sup> Many reports around the world have documented the success of aquaponics using diverse species of fish, crustaceans and plants. Rakocy et al.<sup>8</sup> successfully cultured tilapia and basil in an aquaponics system, while Nuwansi et al.,<sup>1</sup> reported good production of koi carp (*Cyprinus carpio*), goldfish (*Carassius auratus*) and water spinach (*Ipomea aquatica*) in a recirculating aquaponics system. Also, Ortega and Ivá<sup>9</sup> evaluated the efficiency of aquaponics, culturing the sweet basil (*Osimum basilicum*) and the giant prawn (*Macrobrachium rosenbergii*), concluding that the polyculture is feasible, and it also improves the quality of pond water by absorption of nitrogen metabolites by the plants.

Additional steps could be integrated to the system for a greater optimization of nutrients by using the final effluent from aquaponics to fertigation of another plant. In this regard, peppers are vegetables widely consumed worldwide; these can be used as a spice or as ingredient for many meals, being among the vegetable substances used for seasoning or flavoring food, stimulating the appetite for the increasing the flow of gastric juice.<sup>10</sup> Peppers have been used for antioxidant nutritive therapy and for treating cardio-vascular diseases, diabetes, erectile dysfunction, and respiratory diseases.<sup>10</sup>

The jalapeño pepper is widely consumed around the world, and is one of the most accepted by consumers in the United States due to its good flavor and low price Lilly white, while the bell pepper is less consumed and has a high price mainly during out-season. Therefore, this study was focused on preliminarily evaluate the feasibility of an integrated system to produce tilapia (aquaculture), jalapeño pepper (hydroponics), and mini bell pepper (soil fertigation), with and without using bioflocs for the cultured tilapia.

## Materials and methods

The study was conducted during eight weeks (mid-September to mid-November) in the facilities of the Departamento de Agricultura y Ganadería, Universidad de Sonora at Hermosillo, Sonora, México. It was done into a greenhouse used for agriculture and hydroponics of diverse plants, mainly peppers. The system consisted of three phases: 1) Aquaculture phase, using six plastic tanks (500L in capacity and managed at 400L) for the culture of tilapia; 2) Hydroponics phase, consisting of six PVC tubes (4" diameter and 6m length) with perforations each 40 cm to fit the jalapeño peppers using sponge strips; 3) Soil fertigation phase, consisting of six soil grooves for the culture of mini bell peppers.

For culturing tilapia each plastic tank was stocked with 30 (75/m<sup>3</sup>; 2.1±0.9g) fry of *O. niloticus*, donated by the Institute of Aquaculture of the State of Sonora (IAES). Constant aeration was applied to maintain dissolved oxygen levels over 5mg/L. Water quality parameters (temperature, DO, and pH) were monitored every day at 10:00 h using a multiparameter YSI sonde. Total ammonia concentration was measured weekly by spectrophotometry, using a Hanna programmable equipment and the kits provided by the manufacturer. Tilapia were fed at satiation with a commercial (Ziegler) diet containing 30 % crude protein. Three of the tanks were additionally supplied with bioflocs produced in a single bioreactor, consisting of a plastic tank (300L) provided with clean freshwater and constant aeration by means a blower through porous tubing. An inoculum of the microalgae *Scenedesmus* sp. was introduced at the beginning of the trial. The bioreactor was fertilized with Triple 17 (17% N, 17% P, and 17% K) when necessary, to maintain levels of phosphorous over 1mg/L. Wheat brand (100g) and amaranth seeds

(100g) were supplied as nucleation substrates at the beginning of the study and when was necessary to maintain levels of total suspended solids around 20mL/L (measured by Imhoff cones).

The jalapeño pepper plants (15cm tall) were obtained by donation (Agroquimicos Jam S.A de C.V, Hermosillo, Sonora, Mexico). These were fixed to the hydroponics tubes one week after the tilapia stocking. The Mini bell pepper plants (12cm tall) were obtained from the same enterprise. These were planted in the soil grooves at the same time than jalapeños.

Every three days the water from the hydroponics tubes was verted to the grooves, and then replaced with water from the tilapia tanks. Three of the fish tanks were refilled with clean freshwater and three other with water from the biofloc reactor.

Tilapia were monitored weekly to measure weight (digital Ohaus balance), size (ichtiometer±1mm), and estimate survival. At the end of the trial, all fish were weighed, sized, and counted to know the final growth, survival, biomass, and feed conversion ratio.

The jalapeño and mini bell peppers were also monitored continuously to detect floriation time, plant growth, and number of fruits. At the end of the trial, all fruits were harvested, counted, and weighed.

## Results and discussion

The water quality parameters in the aquaculture tanks were most of the time within the range recommended for the culture of the species (Table 1). However, the TAN registered values out of the recommended range for tilapia<sup>11</sup> but no massive mortalities were observed in the tanks.

**Table 1** Ranges of the water quality variables during the trial

	Temperature (°C)	Salinity (UPS)	Oxygen (mg/L)	pH	Ammonia (mg/L)
With Biofloc	14.3 to 33.2	0.2 to 0.4	5.4 to 8.3	7.9 to 9.3	2.3 to 6.7
Without Bioflocs	14.2 to 33.3	0.2 to 0.4	5.6 to 8.5	7.8 to 9.9	1.9 to 5.7

Most of the production parameters of tilapia recorded values into the range considered suitable for this type of culture (Table 2). Weight gain was grater in the tanks supplied with bioflocs (120.3±26.3g) when compared to the tanks without bioflocs (89.7±19.6g); however, the differences were not significant. Survival was similar between the two conditions (82.6±2.3 % and 80.4±1.9% for tanks with and

without bioflocs, respectively). The final biomass was significantly greater in the treatment using bioflocs (2960±182g/tank) as compared with that using formulated feed only (2160±103g/tank). The feed conversion ratio was also better (lower) for tilapia reared with bioflocs (1.1±0.1 vs 1.4±0.1). These results are not surprising considering that the presence of biofloc represents an additional and high-nutritional value food source for tilapia.<sup>13</sup>

**Table 2** Means (± SD) of the production parameters of tilapia

	Weight gain (g/fish)	Survival (%)	Biomass (g/tank)	FCR
With Bioflocs	120.3 ± 26.3a	82.6 ± 2.3a	2969 ± 182b	1.1 ± 0.1a
Without Bioflocs	89.7 ± 19.6a	80.4 ± 1.9a	2160 ± 103a	1.4 ± 0.1b

The jalapeño pepper did not have a good performance in the hydroponics system (Table 3). The mean survival was 63.5±4.6% in the tubes filled with water of tanks with bioflocs and 66.6±7.3% in those without; no significant differences were recorded among the two conditions. The growth (height) of the plants were similar, registering 26.4±2.4 and 27.1±2.0cm for plants cultured with the water of tilapia tanks with and without bioflocs, respectively. The floriation in all the

units began 16 days after planting, and the fruits were detected six days later. The number of fruits per plants ranged from 1 to 3 and the biomass from 22.2±2.1 to 23.3±3.6g/plant, in the two conditions, without significant differences among them. These production parameters are very poor when compared to those reported in other studies with peppers in similar systems.<sup>14</sup> This was probably related to adaptation problems of the plant to the hydroponics conditions

(nutrients concentrations, flows, aeration, lack of substrate, and etcetera). It has been suggested that some peppers need to be amended with substrates to develop better under soilless farming. Graber et al.,<sup>11</sup> reported that pepper plant development in biochar-treated pots

was significantly enhanced compared with the unamended controls, in terms of leaf area, canopy dry weight, number of nodes, and yields of buds, flowers, and fruit.

**Table 3** Means (± SD) of the production parameters of jalapeño pepper

	Height (cm)	Survival (%)	Floriation (DAP)	Fructification (DAP)	Fruits per plant	Biomass (g per plant)
With Bioflocs	26.4 ± 2.4a	63.5 ± 4.6a	16 ± 1a	22 ± 1a	1.6 ± 0.3a	22.2 ± 2.1a
Without Bioflocs	27.1 ± 2.0a	66.6 ± 7.3a	16 ± 1a	22 ± 1a	1.7 ± 0.3a	23.3 ± 3.6a

DAP = Days after planting

The mini bell peppers had a relatively good performance in the soil fertigation conditions (Table 4). No significant differences in production parameters were found among units irrigated with water from hydroponics using biofloc or not in the tilapia culture. Growth (38.8±4.3cm vs 39.7±5.1cm), survival (93.3±3.3 % vs 100±0.0),

floriation time (12 days after plantation for both conditions), time of appearance of fruits (18 days for both), number of fruits per plant (12.4±2.4 vs 12.9±2.6), and biomass of fruits per plant (138.6±12.4 g vs 151.1±16.3g) resulted to be similar among treatments.

**Table 4** Means (± SD) of the production parameters of mini bell pepper

	Height (cm)	Survival (%)	Floriation (DAP)	Fructification (DAP)	Fruits per plant	Biomass (g per plant)
With Bioflocs	38.8 ± 4.3a	93.3 ± 3.3a	12 ± 1a	18 ± 1a	12.4±2.4a	138.6 ± 12.4a
Without Bioflocs	39.7 ± 5.1a	100 ± 0.0b	12 ± 1a	18 ± 1a	12.9 ± 2.6a	151.1 ± 16.3a

DAP=Days after planting

Therefore, the jalapeño pepper resulted not to be an adequate candidate for hydroponics under the conditions established in this trial; however, the mini bell pepper could be produced in these kinds of systems including those using bioflocs, contributing to the reuse of effluents. In this regard, Palada et al.<sup>15</sup> demonstrated the positive benefits of using aquaculture effluents (tank water and sludge) in pepper production. Developing techniques for water conservation and reuse is relevant for the aqua- and agri-business in arid and semi-arid regions, and in this sense the irrigation with nutrient-rich aquaculture effluents sounds being an adequate management technique.<sup>16,17</sup>

The results of this preliminary study suggest that the multiphase integrated system could be efficient for the culture of tilapia and pepper; however, further research is required in terms of adjustment of nutrients and flow of the effluents from tilapia culture, as well as the selection of the best vegetable species for the hydroponics conditions. Moreover exploring the possibility of substrates for the hydroponics phase and selection of the best period of the year for the production should be considered.

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## Conflicts of interest

The author declares that there are no conflicts of interest.

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