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Paired Production of the Nile Tilapia (*Oreochromis niloticus*) and Lettuce (*Lactuca sativa*) within an Aquaponics System in Sohag Governorate

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Abstract: Aquaponics is an eco-friendly system that integrates soilless cultivation and aquaculture. This study aimed to assess the water quality, hematological and biochemical parameters, and growth performances of tilapia (*Oreochromis niloticus*), as well as Lettuce (*Lactuca sativa*) yield, reared for 110 days in a newly developed deepwater culture (DWC), as a prototype built in the Upper Egypt Center of Development owned by the Academy of Scientific Research and Technology (ASRT) in Sohag Governorate, Egypt. The experimental work consisted of two DWC systems. Fish (n= 300 with an average weight (18 ± 0.8 g)) were fed daily for five days a week with 2% of the total biomass with a protein feed content (30%). The results showed that water quality parameters were within the optimal range for tilapia culture except for pH. The hematological and biochemical parameters and growth performances were within typical values. The growth and yield of Lettuce were measured through fresh weight, and they were better than in other studies. Aquaponics technology can be used to produce high-quality tilapia and lettuce.
Keywords: Aquaponics, Biochemical parameters, Hematological, Lettuce, Tilapia

1. Introduction

Aquaponics is a closed recirculation ecosystem, which is a combination of aquaculture and hydroponics [**1**]. It is an integrated bio-system where the plants and the fish live in symbiotic relationships. Wastewater from fish farming contains nitrogenous compounds, especially ammonia, which could be hazardous for fish, even in paucity. Additionally, toxicity depends on the temperature and pH of the water [**2**]. Therefore, it is a sustainable vegetable farming technique that uses natural biological cycles to supply nitrogen and minimizes using non-renewable resources [**3**].

In addition to its ecological merits, the aquaponics system has other additional economic advantages: saving (input) on water treatment for the aquaculture system and formulated fertilizer for the hydroponics system, benefiting from dual outputs, and the harvesting of animal and plant through a single input, fish feed [**4**]. These benefits lead to food production without the external addition of chemicals and fertilizers. Hence, aquaponics is considered a form of organic farming [**5**]. The deepwater culture (DWC), or raft method, involves suspending plants in polystyrene sheets with their roots hanging into the water. This method is the most common for large commercial aquaponics and is more cost-effective than large-scale media beds [**6,7**]. The DWC method enables the roots of plants to absorb nutrients in the water without clogging the water channel, although aeration for DWC units is vital [**6**].

Growth performance, serum biochemical parameters, and hematological parameters are indicators of water balance, nutritional status, and overall health condition of fish [**8**]. Various plants and aquatic species can be grown together within an aquaponic system. Tilapia is likely the most prominent aquaculture fish in the 21st century [**9**]. Nile tilapia (*Oreochromisniloticus*) due to its favorable characteristics, making its cultivation the most tolerant to harmful environmental conditions. Also, it can survive at low euryhaline and dissolved oxygen and has relatively fast growth and efficient food conversion [**10**].

Lettuce (*Lactuca sativa* L.) is a well-known plant among leaf vegetables. It belongs to the family of Asteraceae. Lettuce is rich in nutrients, containing essential elements such as minerals and organic substances [**11**]. The leafy green vegetables also contain vitamin C, beta-carotene, fiber, folate, and phytonutrients. It can be part of a well-balanced diet since it does not contain cholesterol and is naturally low in calories [**12**].

The present research aimed to evaluate the water quality, hematological and biochemical parameters, and growth performances of tilapia (*O. niloticus*), as well as Lettuce yield, reared in a newly developed DWC, as a prototype built in the Upper Egypt Center of Development owned by the ASRT in Sohag Governorate, Egypt.

2. Materials and Methods

2.1. Aquaponics System Design

Two deep water culture systems have been set up within the Upper Egypt Center of Development greenhouse, owned by the ASRT in Sohag Governorate, Egypt. In each DWC system (also known as the raft system), the plants are grown on Styrofoam rafts that are afloat on the top of the water (Fig. 1). A two–cubic meter tank is used as a fish tank. Water flows by gravity to a mechanical filter that removes solid waste from water. First, the water flows from the mechanical filter to the net filter. Then, the water flows from the biofilter to the building's grow bed, which is covered with vinyl. The grow bed enables plants to grow in net cups fixed in holes within the Styrofoam rafts that float over water in the plants' grow bed. Plants' roots absorb soluble nutrients in the water after the nitrification process. Afterward, water is pumped to the fish tank through a submersible pump. An air pump aerates the whole system to ensure that dissolved oxygen is enough in the fish tank and the plants' grow bed.

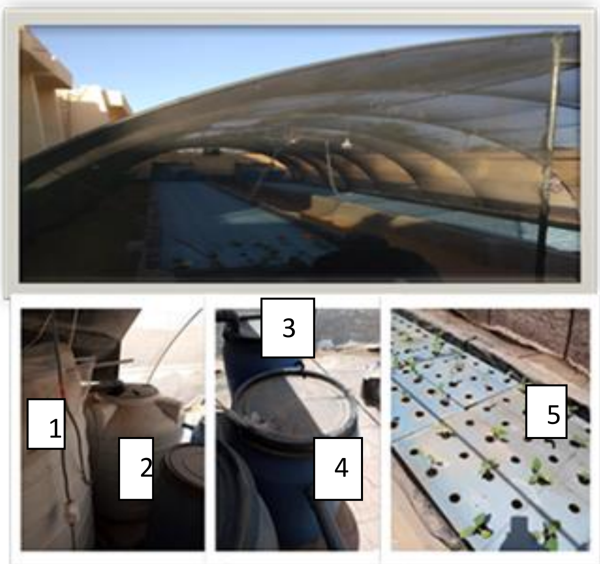

Fig. 1: A newly developed DWC, a prototype built in the Upper Egypt Center of Development owned by the ASRT in Sohag Governorate, Egypt (1- Fish tank, 2- Mechanical filter, 3- Net filter, 4- Biofilter, 5- Hydroponic part).

2.2. Water Quality Parameters

A portable oxygen meter measured the dissolved oxygen (mg. l-1). A portable pH meter measured the pH and water temperature (°C). A portable conductivity meter measured TDS, salinity, and electrical conductivity (mS.cm-1). The concentration of ammonium (mg. l^{-1}) and nitrate (mg. l^{-1}) were measured by UV-spectrophotometer (Unico1200).

2.3. Fish growth performance

The average individual weight (g) of the fish was gauged at the start and end of the experiment. At the end of the trial, the weight gain (g), growth rate (g/day), feed conversion ratio, feed efficiency ratio, and survival rate (percentage) was calculated as (mean±SD).

Weight gain (g) = final weight – initial weight.

Growth rate (g/day) = final weight – initial weight/experiment period.

Feed conversion ratio (FCR) = food intake/weight gain.

Feed efficiency ratio(FER) = weight gain/feed fed × 100.

2.4. Hemato-Biochemical Parameters

The following hematological parameters were measured and calculated: Red Blood Cells (RBCs), White Blood Cells (WBCs), Platelets (PL), Hematocrit (HCT), Hemoglobin (Hb), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), and Mean Corpuscular Hemoglobin Concentration (MCHC) according to Dacie and Lewis [13] and Fazio [14]using the following formulae:

$$MCV\ (\mu m^3) = HCT/RBCs \times 10,$$

$$MCH\ (pg) = Hb/RBCs \times 10.$$

$$MCHC\ (\%) = Hb/HCT \times 100.$$

The biochemical parameters: Creatinine (CR), Uric Acid (UA), AsparticAminotransferase (AST), Alanine Aminotransferase (ALT), Glucose (GL), Alkaline Phosphatase (ALP), cholesterol, and Total Protein (TP) were measured using a spectrophotometer (Jasco- V530, Ottawa, Canada) as defined by Cerozi and Fitzsimmons [15].

2.5. Plant Yield

A digital balance weighted fresh weights of Lettuce.

3. Results

3.1. Water Quality Parameters

The temperature was 20°C. The pH was 8.2. As for the dissolved oxygen concentration (DO), this value was 6.5 mg/L. The electric conductivity (EC) value was 0.84 (mS), the TDS value was 0.41 ppt, the salinity value was 0.3 ppm, the ammonia value was 0.43 mg/L, and the nitrate value was 27 mg/L (Table 1).

3.2. Growth Performance

The growth performance parameters of tilapia (*O. niloticus*) are illustrated in Table (2) and Figure (2). The weight gain (g) value was 118 ± 4.0. The growth rate (g per day) value was 1.1 ± 0.03. The food conversion ratio was 1.2±0.0. FER (in percentages) value was 80.2±2.7.

3.3. Hematological Parameters

The determined hematological parameters of tilapia (*O. niloticus*) in the system are shown in Table (3). All of the analyzed hematological parameters were within the normal values in the system compared to standard values.

3.4. Biochemical Parameters

Table (4) illustrates the investigated biochemical parameters in the serum of tilapia (*O. niloticus*). All of the analyzed biochemical parameters were within the normal values in the system compared to standard values.

3.5. Lettuce Yield

The fresh weight of the Lettuce was 740 ± 100 g. The steps of lettuce growth are shown in Fig.4.

Table 1. Water quality Parameters for the aquaponic system

PARAMETERS	TEMPERATURE (°C)	DISSOLVED OXYGEN (MG/L)	ELECTRIC CONDUCTIVITY (MS/CM)	PH	TOTAL DISSOLVED SALTS (PPT)	SALINITY (PPM)	AMMONIA (MG/L)	NITRATE (MG/L)
Values	20	6.5	0.84	8.2	0.41	0.3	0.43	27
Standard values	25 – 30	3 – 20	≈1.4	6 9–	0.56-0.84	0.13	1.0	1 to 500

Table 2. Growth performance parameters of tilapia (*O.niloticus*)reared in the aquaponic system

PARAMETERS	INITIAL WEIGHT (G)	FINAL WEIGHT (G)	WEIGHT GAIN(G)	GROWTH RATE (G PER DAY)	FOOD CONVERSION RATIO	FEED EFFICIENCY RATIO (%)	SURVIVAL RATE (%)
Values	18 ±0.8	136 ±4.6	118 ±4.0	1.1 ±0.03	1.2 ±0.0	80.2±2.7	90

Data are mean ±SD

Fig. 2. Production of Tilapia (*O. niloticus*) in the aquaponic system.

Table 3. Hematological parameters of the Nile tilapia (*O. niloticus*) reared in aquaponic system.

Hematological parameters	Values	Standard values
(RBCs) (million/mm^3)	2.2±0.04	1.91-2.83
Hemoglobin (Hb) (g/dl)	8.9±0.14	7.0-9.8
Ht (PCV) (%)	35.4±0.1	27-37
MCV (µm³)	115.7±1.9	115-183
MCH (Pg)	28.3±0.3	28.3-42.3
MCHC (%)	25.4±0.5	22-29
Thrombocytes (Thou./mm^3)	213±0.5	25-85
(WBC's) (Thou./mm^3)	10.9±0.2	2.15-15.4
Lymphocytes (%)	84.8±0.3	42-71
Monocytes (%)	2.8±0.3	1-3
Neutrophils (%)	10.5±0.3	58-28
Eosinophils (%)	2±0	1-3

Table 4. Biochemical parameters of the Nile tilapia (*O. niloticus*) reared in the aquaponic system.

Biochemical parameters	Values	Standard values
AST activity (U/l)	34.1±0.9	9-102
ALT activity (U/l)	17.4±0.4	15-112
ALP activity (U/l)	30±0.7	15-39
Glucose (mg/dl)	73.7±2.8	30-69
Cholesterol(mg/dl)	194±0.1	110-318
Total protein (mg/dl)	4.1±0.3	2.9-6.6
Creatinine (mg/dl)	0.35±0.01	0.1-0.5
Uric acid (mg/dl)	2.3±0.1	1- 8.9

Data are mean ±SE

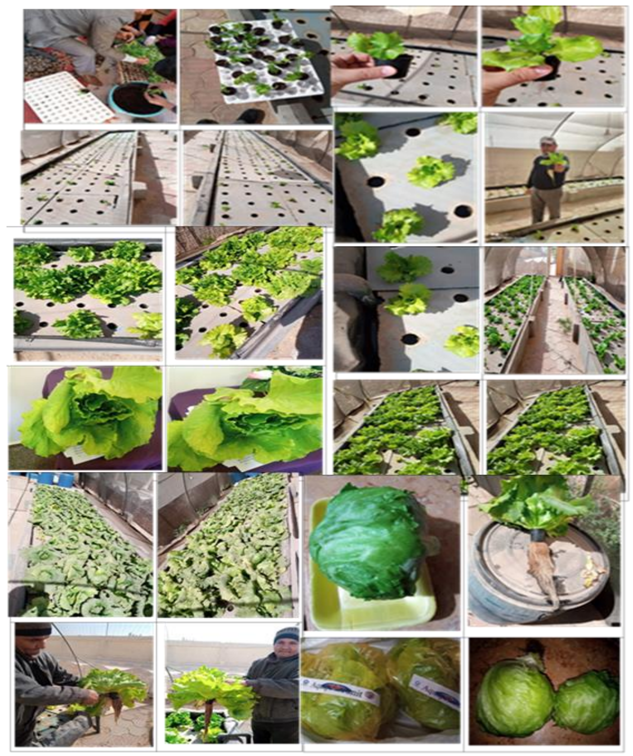

Fig. 4. Growth of Lettuce during the experimental period.

4.Discussion

The parameters of water quality of the rearing tanks in the aquaponics systems were within the recommended range for aquaculture, except pH and temperature. The pH range was appropriate for tilapia. The study of Cerozi and Fitzsimmons[16]supported that pH between 6.5 and 7.2 is the optimum for the process of nitrification, fish growth, and maximum plant biomass production. In the present study, dissolved oxygen was 6.5 mg/L. Also, Pattillo [17] stated that the average values of dissolved oxygen ranged between 6.8 and 7.4 mg/l. Boyd [18]had suggested that dissolved oxygen should be above 5 mg/L to support the survival and development of aquatic life in any culture system. Kamal [19]reported that 6.6–6.8 mg DO/l is suitable for the growth of Nile tilapia (*O. niloticus*).

Meanwhile, the temperature values recorded were slightly outside the optimum range because the experiment was done during the winter months, where heaters were used to overcome the cold weather. Gui *et al*. [20] found that the average temperature of 28°C was optimal for the growth of Nile tilapia. Ammonia (NH_3) was within the optimum level of the aquaponic system during the experiment, which was less than 1.0 ppm, based on Somerville *et al.* [6]. Ionized ammonia (NH_4^+) stimulates plant growth, but very low levels of unionized ammonia (NH_3) may cause stress and death in fish. Visvanathan *et al*. [21] and Mullen [22] note an upper lethal limit of nitrate at about 500 mg/L. Liedl*et al*. [23] and Rakocy*et al*. [24] suggested that the acceptable levels of nitrogen for plants at the outset are optimal at around, 100 mg/L, while it should be at 200 mg/l during growth. Yet, the apparent health of most of the plants (especially the leafy vegetables) indicated that even these low average levels of nitrate around 5.0 mg/L were sufficient to yield healthy vegetation, especially in the Swiss chard, lettuce, celery, and spring onions. Increasing the fish density would have increased the nitrate supply and most probably, further surged the growth of most of the vegetables and herbs; the increase of fish densities is indeed possible as mentioned beforehand [25]. Rakocy*et al.* [26] suggests that it is viable to stock tilapia at around 75 to150/m3 of water, varying with the species. The EC for the freshwater system was 0.84 mS/cm. As noted in Kotzen& Appelbaum [25] states that EC should be around 1.4 mS/cm for lettuce in aquaponic systems.

In the present study, Weight gain (g) value was 118 ± 4.0. Growth rate (g per day) value was 1.1 ± 0.03. The food conversion ratio was 1.2 ± 0.0. FER (in percentages) value was 80.2±2.7. Rakocy*et al*. [27] stated that mean harvest weight was 813.8 g and survival rate 98.3%, and a lower feed conversion ratio was lower at 1.7 in tilapia. Rahmatullah*et al*. [28] found that weight gain (g) of tilapia was within 19.41–32.6 7 g and was inversely related to stocking density. Percentage weight gain varied between 2553.99 and 4298.68% and was significantly different among the treatments. SGR ranged from 3.09 to 3.59% per day and varied significantly. FCR varied from 2.19 to 2.69. Goda*et al*. [29] observed that Feed Conversion Ratio (FCR) was recorded as 1.69 and 1.8 for Nile tilapia in the aquaponic system. Kotzen& Appelbaum [30] recorded a surge of 0.78 g/day/fish for the brackish water system and 1.1 g/day/fish in the freshwater system. Tilapia increased its biomass by almost 47 (g), and each fish increased its total length by 3 cm. Lower FCR means that the feed was utilized more efficiently by the fish. FCR became better at the endof the experiment, which was equal to 1.74. FCR is related to the feed and rearing water quality. Moreover, tilapia would have an FCR within 1.4–1.8 if the conditions were better and more optimal [31]. Stathopoulou*et al.* [32] stated that no fish mortality occurred. Weight gain was statistically significantly higher in the first aquaponics system (system I) (WG) (95.8 ± 13.62 g) than in the second system II, where it was 51.7 ± 9.90 g. The specific growth rate was higher in the system I (SGR%/day, 1.8 ± 0.17) than in system II (1.2 ± 0.16%/ day) but was not statistically significant. FCR values were 0.7 and 1.1 for systems I and II, respectively. Akter*et al.* [33] mentioned that the length and weight percentage gain were 33.81% and 174.06%. It was found that the survival rate and FCR were 98.33% and 1.56, respectively. The total production of fish was 29.44 tons/ha/90 days. Setiadi*et al*.[34]stated that the highest survival rate, weight, and length were found in Red tilapia were 96.00 ± 1.73%, 32.31 ± 0.74g, and 7.57 ± 0.21 cm. Hundley et al. (2018) observed that the mean gain in weight record was 54.11 ± 22, while the gain of 164.01 ± 55.25 g was reported by Palm *et al*.[35]for Nile tilapia cultured in an aquaponic system. Saufie*et al*.[36]mentioned that the low value of FCR (1.04–1.13) is a good indication of the high-quality feed that the fish can efficiently convert into tissues and thus requires it in smaller quantities to produce a unit weight gain. It can help in predicting the growth of the fish and the profitability of aquaponics. Thus, in this study on GIFT, the high value of SGR (2.02–2.04) can be interpreted in terms of efficient nutritional management as reflected by low FCR. Hussein et al. (2020) stated that the final mean weight for the mixed-sex tilapia yielded from seven harvests in the aquaponic system was 285.3 g/fish. FCR averaged 1.4 for the mixed-sex population and 1.3 for all-male tilapia. The Specific Growth Rate (SGR) values were 1 and 1.1% for mixed-sex and all-male tilapia, respectively. Survival was lowest for mixed-sex tilapia, averaging 95.8% compared to 99% for all-male tilapia. FCR averaged 1.4, ranging from 1 to 1.7 in the aquaponic system.

In the present study, all the analyzed hematological and biochemical parameters were within the typicalvalues in the system compared to standard values. Also, Osman *et al*.[37]found no significant difference in the values of nearly all the hematological parameters in the blood of fish reared in the aquaponic system and those reared in pond systems, being always within the normal ranges for healthy Nile tilapia. Most of the measured biochemical variables exhibited an improvement in the blood of fish reared in the ASTF-PRO system compared with that of the pond. Moreover, Soliman *et al*.[38]observed that the hematological, biochemical parameters, hepatic, and intestinal histological structure did not significantly differ among the two systems and were within typicalvalues. Anantharaja*et al*.[39]stated that RBC and hemoglobin content in blood were higher in fish reared in aquaponic systems. Gao *et al*.[40]noted that the glucose levels of Qihe crucian Carp (*Carassius auratus*) ranged between 3.31 and 6.14 mmol L^{-1} in the aquaponics system.

In the present study, the average fresh weight of lettuce was 740 g $plant^{-1}$,which washigher than the mean weight obtained in different studies: Pantanella*et al*.[41]noticed the weight of lettuce was 6.0 kg m^{-2} in the hydroponic system and the 5.7 and 5.6 kg m^{-2} in the high and low-density aquaponic treatments, respectively. Pineda-Pineda *et al*.[42]observed that the average fresh weight of lettuce was 200 g. Delaide*et al*.[43]stated that the FM of the lettuces was in aquaponics (37.72 g $plant^{-1}$) and hydroponics (39.64 g $plant^{-1}$) systems, respectively. Johnson *et al*.[44]noticedthat the weight of lettuce was 418 g m^{-2}. Al Tawaha*et al*.[45]showed that the highest total yield, 448 g m^{-2} was obtained at a low stocking density. Lenz *et al*.[46]noticed FM of the lettuce in the float method was 44.50 g $plant^{-1}$ in the first cycle. Amin *et al*.[47]indicated that the fresh weight of shoot of lettuce plants values 206.71, 297.38, and 212.30 and 190.27, 236.81, and 182.53 g $plant^{-1}$ for 1.0, 1.5, and 2.0 L $h^{-1}plant^{-1}$, respectively, in nutrients solution and water discharged of the fish farm, respectively, for A shape hydroponic system.

For the gutter hydroponic system, the fresh weight of shoot of lettuce plants values were 238.37, 315.82, and 254.22 and 223.80, 286.13, and 201.90 g plant^{-1} for 1.0, 1.5, and 2.0 L h^{-1} plant^{-1}, respectively, in nutrients solution and water dischargeof the fish farm, respectively. While the fresh weight of shoot of lettuce plants values were 189.37, 250.19 and 191.62 and 177.80, 215.42, and 176.33 g plant^{-1} for 1.0, 1.5, and 2.0 L h^{-1} plant^{-1}, respectively, in nutrients solution and water discharged of the fish farm, respectively, for deep water hydroponic system.

5. Conclusion

The present study demonstrated that paired cultivation of tilapia with Lettuce in the same deepwater aquaponics was highly effective for producing healthy fish, plants and water conservation.

Acknowledgment

The research was performed within a newly developed Deepwater Culture (DWC), a prototype built in the Upper Egypt Center of Development owned by the ASRT in Sohag Governorate, Egypt, which was financially supported by the ASRT. The authors are grateful for all the support.

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