Growth performance of the monosex Nile tilapia, *Oreochromis niloticus* in aquaponics vs traditional earthen pond

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Abstract. The current research is part of a collaborative project aimed at facilitating the efficient transfer of innovative ecotechnology ASTAF-PRO aquaponic from Germany to Egypt for the purpose of sustainable aquaculture and food production. The present study was conducted to evaluate the growth performance of monosex Nile tilapia (*Oreochromis niloticus*) in ASTAF-PRO compared to an earthen pond as a positive control. The present results indicated that there was a significant increase in the final weight and final length of monosex Nile tilapia compared to the initial values in both groups with a remarkable increase in the average weight and length over time. The weight gain and length gain were higher for the fish reared in pond compared to aquaponic which could be linked to culture condition (habitat) since the same feed was used. Feed conversion ratio, condition factor, specific growth rate and survival rate were comparable ($p > 0.05$) in both groups. This means that both culture conditions for *O. niloticus* did not negatively affect the examined growth performance variables. Final net productivity was 42.5 kg m^{-3} for ASTAF-PRO system and 43 kg m^{-3} for POND system, at fish capacity of 227 fish m^{-3} for ASTAF-PRO and 166 fish m^{-3} for pond system. However, ASTAF-PRO unit had vegetable crop as secondary product, which increase profitability of the system, in addition of overwhelming superiority of ASTAF-PRO in water saving. This result indicates that ASTAF-PRO as an aquaponics system can compete traditional pond culture technique on large-scale farming.

Key Words: aquaponics ASTAF-Pro, earthen pond, growth performance, monosex Nile tilapia.

Introduction. Water scarcity and food insecurity are two risks in Egypt, which, combined with a significant increase in population, pose serious challenges to the country's aquaculture sector. Therefore, sustainable solutions to the aquaculture sector in Egypt must be sought within the context of sustainable development and in accordance with the global sustainable development goals (SDGs). Aquaponics is a solution to many of today's global problems, with a huge potential to become the future farming method that provides year-round, sustainable, and low-cost production of high-quality fish and vegetables (Baganz et al 2020). Aquaponics is the production of fish and hydroponic crops in a closed system with nutrient recirculation and the use of fish waste as plant fertilizer (Masabni & Niu 2022). It is a proven and environmentally sustainable farming technology that can be used by smallholder farmers in developing countries (Oladimeji et al 2020; Siringi et al 2021), producing both fish and crops in a complementary system (Osman et al 2021).

Aquaponics is now widely recognized as a viable alternative to traditional aquaculture systems, as the system is known to reduce operational costs such as labor, irrigation, land revenue, and management, as well as the ability to cultivate two types of food (Estim et al 2015, 2019). In Egypt, aquaponics has the potential to open a new market and create new jobs. It could produce nutritious food regardless of location, giving it an advantage over traditional aquaculture (El-Essawy et al 2019).

Fishes with a high growth potential and the ability to tolerate a wide range of water quality parameters are ideal for aquaponic culture. Nile tilapia (*Oreochromis niloticus*) is the second most cultured fish after common carp (*Cyprinus carpio*) (FAO 2015), and first in Egypt (GAFRD 2016). They are great for aquaponics because they are easy to raise and can handle a variety of water conditions. Locally, tilapia shares about (75.54%) of the aquaculture production activities (GAFRD 2016). The reduction of growth rates at the onset of sexual maturity is a common problem in many tilapia culture systems, resulting in various sizes of small fish production. As a result, the value of monosex male tilapia populations has been well established due to their increased potential and low management requirements.

As far as we know, the Aquaponic unit (ASTAF-PRO) in the Faculty of Science at Al-Azhar University in Assiut was the first experimental unit to be established among Egyptian universities. It was transferred from Germany as part of a cooperative project to allow Egypt to implement innovative Eco technology aquaponics for long-term aquaculture and food production. Hence, the present study was conducted to evaluate the growth performance of monosex Nile tilapia (*Oreochromis niloticus*) in aquaponics (ASTAF-PRO) compared to a traditional earthen fish farm as a positive control. This will help to bridge the gap in documented knowledge about aquaponic technology, as well as contribute to human resource development for long-term sustainability and job creation.

Material and Method

Experimental design. The current experiment consists of two parallel units:

1- ASTAF-PRO unit: aquaponics system with one-way valve ((Figure 1);
2- Retherm pond (POND) unit.

ASTAF-PRO unit consisted of three rearing tanks (each of 1 m^3), a sedimentation tank (1 m^3), bio-filter (1 m^3), three hydroponic rins, two separate pump units, and one one-way valve (Figure 1) in a wooden greenhouse. This design followed the method of Kloas et al (2015) with minor changes (Osman et al 2021).

Figure 1. The design of the basic ASTAF-PRO aquaponic unit connecting RAS and hydroponic by a one-way valve (Osman et al 2021).

POND unit consists of small earthen fish farm in Al-Azhar University (Assiut Branch), Assiut, Egypt for farming Nile tilapia during the time of the experiment and serve as a positive control for commercial conventional aquaculture (Figure 2).

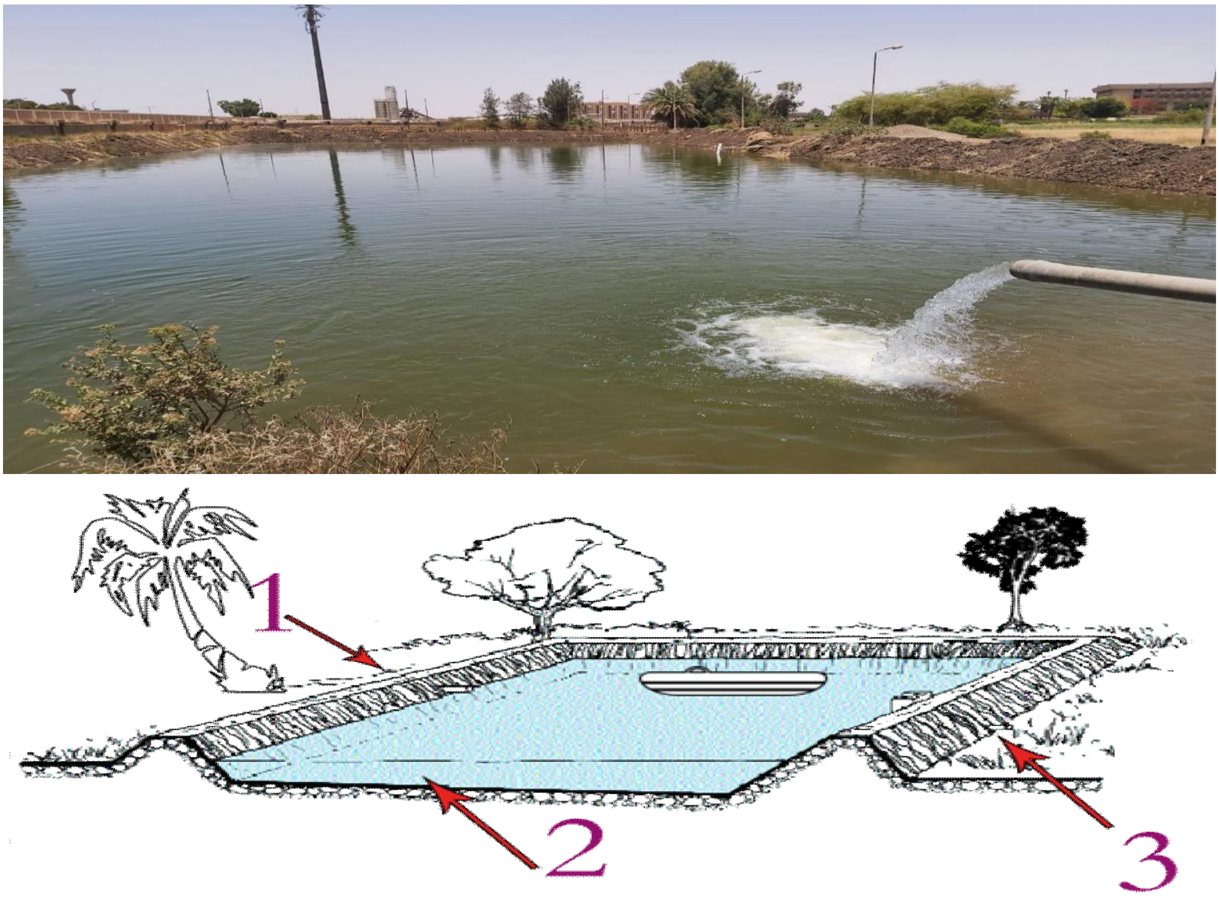

Figure 2. The open fish farm in the Faculty of Science, Al-Azhar University, Assiut, Egypt: 1 = irrigating source, 2 = water body, 3 = water draining.

Fish culture. Fingerlings of monosex *O. niloticus* from the same strains and same ages were used in ASTAF-PRO (total weight = 31.0±3.2) and POND (35.0±0.89). The fish were obtained from a fish farm at Al-Azhar University (Assiut Branch), Assiut, Egypt. The densities of fingerlings were 50 kg m^{-3} of rearing tank in each ASTAF-PRO and POND units. The fish were manually fed 5% of their body weight six days a week in two portions per day, at 8:00 h and 16:00 h during the time of the experiment. The diet containing 30% protein used in the experiment was formulated to cover all nutrients required for the tilapia as recommended by the NRC (1993) (Table 1).

Table 1

The composition of the experimental diets

Items	*Percentage (%)*
Fish meal (65% protein content)	7.0
Soybean meal	25.0
Corn gluten	8.0
Yellow corn	10.0
Wheat bran	15.0
Rice bran	30.0
Fish oil	2.0
Premix	3.0
Total	100.0

The feeding amounts at each sampling event were then changed for the following days after taking into account the decreasing number of fish per tank between sampling times. All fingerlings were fed on the main experimental diet for 6 months extending from May to October 2020.

Evaluation of growth performance. The following parameters were used to evaluate tilapia growth performance according to Kumar & Garg (1995):

Body weight gain (WG) = (W1−W0)

Specific growth rate (SGR) = (lnW1−lnW0) / t x 100

Feed conversion ratio (FCR) = feed fed (g) (dry weight) / WG (g),

Survival rate (%) (SR)= Ni x 100 N0

Condition factor (K) = Fish weight (g) x 100 L^3 (cm)

where W1: final wet weight, W0: initial wet weight, t: time interval in days, Ni: number of fishes at the end, N0: number of fishes initially stocked. Besides, total mortality and survival for each treatment were obtained at the end of the experiment.

Statistical analysis. Data were presented as mean±SD (standard deviation). The results were subjected to a one-way analysis of variance (ANOVA) to test the effect of treatment inclusion on fish performance. Data were analyzed using SPSS (1997) program, Version 16. Differences between means were compared using Duncan's (1955) multiple range tests at $p < 0.01$ level.

Results and Discussion. Egypt faces a significant challenge in terms of water scarcity, population growth, and climate change, all of which have direct implications for food security. Aquaponics is a viable option with a great deal of potential. Egypt can greatly benefit from aquaponics, as it saves a lot of water and solves the problem of food quality. Aquaponic systems were created to provide the best possible water quality for fish growth.

Growth performance is an important tool in aquaculture management. It plays a significant role in determining the relative health of cultured fish. It is a crucial factor in determining the success of fish farming. The growth performance indices of monosex *O. niloticus* cultured in aquaponics and pond are presented in Table 2. It could be observed that there was a significant increase in the final weight and final length compared to the initial values in both, treatments (Table 2, Figures 3 and 4). In the present study, all values obtained were similar to those obtained by other researchers with tilapia of similar sizes (Ogunji et al 2008; Yildirim et al 2009; Chowdhury 2011; Antache et al 2013; Ferdous et al 2014; Githukia et al 2015; Day et al 2016). For both treatments the average weight and length of monosex *O. niloticus* increased over time (Figures 3 and 4). Progressive increment in WG, LG and SGR were observed in both groups, recording good growth for fish in aquaponic and pond. WG and LG were higher for the fish reared in pond compared to aquaponic (Table 2). The superiority in growth performance exhibited in this study for *O. niloticus* maintained in an earthen pond compared to aquaponic system is corroborated by Ifedayo et al (2020). Although the same quality of feed was given to *O. niloticus* reared in both two systems, the variation in growth performances of *O. niloticus* in earthen pond to aquaponics system could be attributed to the availability of natural food (plankton) induced by decomposed and degraded uneaten artificial feed given to *O. niloticus* in earthen pond to consume (Ifedayo et al 2020) and it could be linked to culture condition (habitat).

Table 2

Growth parameters indices (mean±SD) of monosex *O. niloticus* cultured in aquaponic (ASTAF-PRO) and earthen pond (POND) systems during six months of experiment

Growth parameters	*ASTAF-PRO*	*POND*
Initial weight (g fish)	31.0±3.2*	35.0±0.89*
Initial length (cm fish)	11.86±0.1**	12.43±0.2**
Final weight (g fish)	187.0±1.7**	258.3±14.3**
Final length (cm fish)	18.73±0.1**	20.5±1.3**
Total weight gain (g fish)	156±61.1**	223.3±81.3**
FCR	1.51±0.02 NS	1.52±0.31 NS
Condition factor (K)	2.45±0.3 NS	2.44±0.46 NS
SGR (% day^{-1})	1.27±0.6 NS	1.44±0.7 NS
Survival rate (%)	99.10±60 NS	99.89±0.14 NS

Note: (*) significant value; (**) highly significant value;(NS) non-significant value.

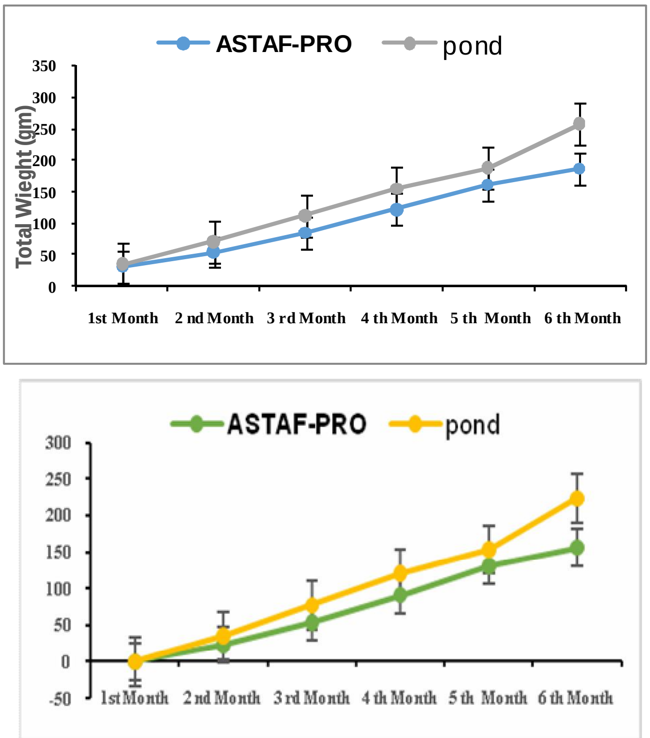

Figure 3. Monthly mean weight±SE and weight gain±SE of monosex Nile tilapia cultured in aquaponic (ASTAF-PRO) and earthen pond (POND) systems during six months of experiment.

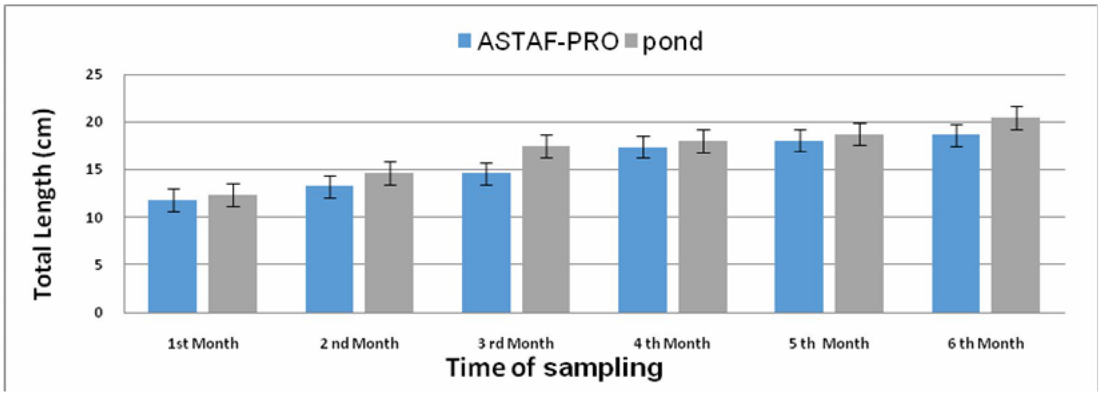

Figure 4. Monthly mean length±SE and weight gain±SE of monosex Nile tilapia cultured in aquaponic (ASTAF-PRO) and earthen pond (POND) systems during six months of experiment.

FCR, SR, and K were comparable ($p > 0.05$) in both, groups (Table 2). The FCR is the amount of feed (kg) required to produce one kilogram of fish meat. FCR is an important indicator of the quality of fish feed, a lower FCR indicate better utilization of the fish feed (Mugo-Bundi et al 2013; Opiyo et al 2014). The FCR values (1.51 and 1.52 in aquaponic and pond, respectively were within the recommended values (1.5-2) for intensively cultured tilapia (Stickney 2005). El-Sayed (2006) & Timmons & Ebeling (2013) reported an FCR value of 1.25 for productive recirculating aquaculture performance. Furthermore, the FCR values in the present study were lower and better than those reported by Rakocy et al (2016), which ranged from 1.70 to 1.80.

The survival rate SR of tilapia did not significantly different between pond and aquaponic systems (99.8-99.1% respectively) (Table 2) and it was within the normal range for tilapia as reported by El-Sayed (2006). The survival value of tilapia in this study is better than those reported by Mulqan et al (2017) & Andriani et al (2019) in aquaponics using water spinach. However, overall survival rate of tilapia in this study was quite high because it was above 80% (SNI 2009).

The condition factor K is an index that reflects interactions between biotic and abiotic factors in the physiological condition of fish (Ali et al 2015). It depicts the welfare of fish at various stages of their life cycle. K has been used to compare different fish growth conditions. A high K indicates that the environment is in good shape, whereas a low K indicates that the environment is in bad shape. The results of the present study indicated that the fish in both, groups exhibited high and nearly the same condition factor (Table 2).

According to Gichana et al (2019) water quality parameters had a significant influence on the growth and intern on growth performance and feed utilization efficiency of *O. niloticus*. As apart from the current work, Osman et al (2021) confirmed that the water quality of the current study were within recommended limits for the culture of *O. niloticus* in pond and aquaponics which could be attributed the good performance of fish recorded during the present work. This means that both culture conditions for *O. niloticus* did not negatively affect the examined growth performance indices in this study.

Final fish weight for aquaponic ASTAF-PRO system was 187.0±1.7 g fish^{-1} at fish capacity 227 fish m^{-3} and for POND system was 258.3±14.3 g fish^{-1} at 166 fish m^{-3}, giving final net productivity 42.5 kg m^{-3} for ASTAF-PRO system and 43 kg m^{-3} for POND system. However, ASTAF-PRO unit had vegetable crop as secondary product, which increase profitability of the system, in addition of overwhelming superiority of ASTAF-PRO in water saving. This result indicates that ASTAF-PRO as an aquaponics system can compete traditional POND culture technique on large-scale farming.

Conclusions. Better growth performance in term of FCR, WG, LG, SGR, and K were recorded for the fish in both aquaponic and pond system, confirming that they did not negatively affect the examined growth performance indices in this study. Final productivity in kilogram per cubic meter was better in ASTAF-PRO unit according to the amount of fish and crops cultivated. ASTAF-PRO farming system used far less water than traditional aquaculture.

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Conflict of interest. The authors declare that there is no conflict of interest.

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