Aquatic Science and Fish Resources

http://asfr.journals.ekb.eg

Print ISSN: 2682-4086 Online ISSN: 2682-4108

Performance of Red Tilapia Hybrid and Mint under Different Density Low Saline Integrated Aquaponic Systems

Aya A. Khodary[1], M. F. Osman[1], M. A. Amer[1], M. M. Said[2]

1 Department of Animal Production, Faculty of Agriculture, Ain Shams University, Egypt.

2 Department of Aquaculture, Faculty of Fish Resources, Suez University. Egypt.

ARTICLE INFO

Article history:
Received Dec. 13, 2022
Received in revised form JAN. 17, 2023
Accepted JAN. 17, 2023
Available online JAN. 19, 2023

Keywords
Aquaponics
Low saline
Water quality
Growth performance
Plant performance
Body composition

ABSTRACT

This study determined how stocking density affected water quality, red tilapia performance, proximate body composition, and mint performance in low-saline aquaponic systems. Experimental systems were stocked with 40 fish / m3 (low density: LD) and 60 fish/ m3 (high density: HD) three replicates each. The experiment lasted for 120 days. Dissolved Oxygen (mg/l) was significantly higher in LD treatment. Water pH was significantly ($P<0.05$) decreased with increasing stocking density. Both Ammonia nor Nitrite didn't affect significantly. Weight gain and specific growth rate% were significantly higher in the LD group 150.33 ±8.95 and 1.65 ±0.006, respectively as compared with 122.0 ± 3.46 and1.48 ± 0.005 for HD. The survival rate% was 92.5%±1.25 and 88.33%±0.98 for LD and HD respectively. Total fish biomass in HD units (8.78 Kg. ± 0.24) was significantly higher than that in LD (7.18 Kg. ± 0.37). The feed conversion ratio was significantly increased with increasing stocking density whereas the protein efficiency ratio decreased with stocking density. Individual plant fresh weight, plant length, and the number of leaves didn't differ significantly with fish density. Root length significantly declined with fish density increasing 60.21±4.79 and 41.18 ± 4.20 cm, respectively. The fish body content of moisture, protein, and ash didn't differ significantly with stocking density. Significantly lower fish body fat content was found in HD group

1. INTRODUCTION

More stresses on the natural resources including land, water and nutrients become ever greater than before. There is an important need to find alternative, sustainable and reliable systems to provide food **(Goddek *et al*., 2019).**

* Corresponding author. **M. M. Said**
E-mail addresses: msaid226@yahoo.com
doi: 10.21608/asfr.2022.180624.1030

Aquaculture intensification is critical for food safety and security to meet the dramatically increase in the world population **(Tidwell, 2012)**. Keeping of desirable water quality profile for high growth performance of fish remains a noteworthy challenge for aquaculture scientists **(Rakocy *et al*., 2006; FAO, 2018).**Optimization of growth conditions for both fish and plants is the biggest challenge in order to achieve profitability **(Delaide *et al*, 2016)**. **Goddek and Keesman (2018)** reported that optimum conditions can be better obtained in aquaponics systems because they are based on independent recirculating cycles that can enhance macro and micro-nutrient recovery and bioavailability with optimized water consumption. Aquaponics, a combination of fish culture and soilless plant farming, is increasing in popularity and earning attention as an important and potentially more sustainable system for food production **(Love *et al*., 2014)**.

Many fish species can be optimally reared in aquaponic systems as they meet with the culture requirements of fresh, brackish, and marine water environments. These include species like African catfish *Clarias gariepinus* **(Baβmann *et al*., 2020)**, carps *Cyprinus carpio* ***(*Filep *et al*., 2016)***, Tilapia *Oreochromis niloticus* **(Rakocy *et al*., 2004)**. Nile tilapia *Oreochromis* genus, is the most commonly known of all tilapia species to be integrated with hydroponic system including herbs, fruits, and vegetables **(Selek *et al.*, 2017)**. Growth performance of Florida red tilapia was reported to be better in brackish and seawater than in freshwater **(Watanabe *et al*., 1988)**. In addition to improving growth rates, rearing in brackish water or seawater could minimize the usage of limited supplies of freshwater **(Uchida and Ring, 1962)**.

Harley *et al*., (1977) reported that the wild mint (*Mentha longifolia* L. family *Lamiaceae*) grows widely in Mediterranean regions, Europe, Australia and North Africa. The plant is a versatile perennial with a peppermint fragrance. Mint has been shown to be the source of 75% natural menthol, toothpaste, mouth washes and pharmaceutical manufacturing. The leaves contain 0.2% of essential oil used for human consumption, especially in the manufacture of teas and condiments, antiseptic, anesthetic, diaphoretic, carminative, febrifugal properties, stomach cancers, rheumatism, cough, rheumatism. In addition, studies of **Mimica-Dukić *et al.* (2003)** and **Neda, *et al*. (2003)** showed that plants of the genus *Mentha* have significant antimicrobial effects.

Utilization of the low saline water resources represents one from the most important prospects. Few studies were conducted on the low saline aquaponic systems which may provide an appropriate application for the usage of such environment. The current study aims to investigate the performance of hybrid Red tilapia and Mint in a combined aquaponic system using different stocking densities.

2. MATERIALS and METHODS

2.1Study location and duration

The experiment was conducted in the aquaponics unit, Faculty of Fish Resources, Suez University, Suez Government, Egypt. The experiment was lasted from June to September 2021 (120 days).

2.2 Experimental design

Six aquaponic systems were involved in the study. Two levels of fish stocking density were allocated: 40 (low density; LD) and 60 (high density; HD) / m^3, each with three replicates.

Each aquaponic system was consisted of fish tank with a total volume of 1000 Liter which discharged in settling tank with a volume of 220 L, which was used as mechanical filter. Biological filtration was achieved using 220 L plastic tank filled with media (white plastic bio-ball), bio-ball dimensions was 25x12 mm, made from HDPE with a specific surface area 600 m^2/ m^3. As the water volume increased in the biofilter tank, water was delivered to deep-water hydroponic unit through an outlet pipe by gravity. Deep-water hydroponic culture volume was 500 L tank with floating rafts made from styrofoam sheets with holes which fitted by net pots. Hydroponic unit was discharged on a sump tank which contains a submerged water pump (Speroni® Q. max 160 min/ L, Head max 9 m) that recycled the water from the hydroponic unit to the fish tank **(Said *et al.,* 2022)**. Each aquaponics system was one experimental unit **(Figure 1)**

2.3 Combined system formation:

Red tilapia (Florida strain) with an average body weight of 40 grams were obtained from (GAFRD) Fish Hatchery, Alex - Cairo, Egypt. Experimental fish were transferred into oxygenated plastic bags and were acclimated in the system for 2 weeks. Water salinity was adjusted to 5 ppt. After accumulation, fish were stocked in aquaponic systems with target stocking densities.

Mint *(Menthe*) seedlings were obtained from private plant nursery in Cairo, Egypt. Seedlings were introduced with a stem length of 7.5-10.8 cm and 6.5-10.5 root length. Before planting, each plant root was submerged in sterilized water for 60 seconds and then swilled and cleaned under running fresh water. Plants were then randomly planted into the floating rafts. Roots in all systems were able to access nutrients through the floating rafts.

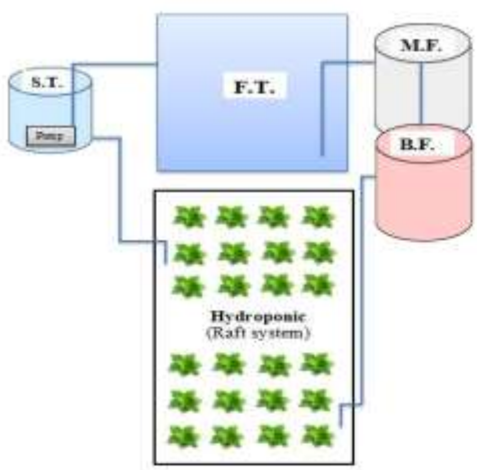

Fig. 1. Scheme of aquaponic system used in Suez University Egypt. (FT) fish tank. (MF) mechanical filter, (BF) biological filter, and (ST) sump tank.

Aquaponic systems which stocked with 40 fish / m^3 were implanted with 80 seedlings while in the higher density systems (60 fish / $m^{3)}$ each hydroponic was established with 120 seedlings. Fish to plant ratio was 1:2 **(Shete *et al*., 2015).** Grip plant holders were used to adjust the plants root submerged in the water.

2.4. Experimental management

Aquaponic systems were supplied with three air blowers (Vortex ® gas pump, Speed 2500 rpm, max pressure 36 KPA, max F 250 m^3 / h). Air blowers were substitutional used. Systems aeration was achieved through airline (1 inch PVC pipes) which connected to disk diffuser 23 cm. in each fish tank to ensure consistent air delivery.

Experimental fish were fed three times a day with a feeding ratio of 2% from the body weight using commercial diet 30 % CP which introduced from Grand Fish Feed ® (**Table 1**). The feeding regime was adjusted every two weeks according to the mean body weight which, derived from reprehensive fish sample.

Water salinity mean in all tested units during the experimental period was 5.03±0.12 ppt. Water samples were taken from each system daily to measure the temperature, pH, and DO and weekly to follow NH_3, and NO_2. Dissolved oxygen (DO) and temperature were measured using (HANNA® portable DO meter). Salinity was measured using Lovibond Senso Direct Con200 conductivity / TDS/ salinity meter. The pH level was recorded with (HANNA Microprocessor pH meter), ammonia with (Lovibond® MD 100 Ammonia) and Nitrite with API® KITS.

Table1. Proximate analysis of experimental feed.

Nutrient	CP.	EE	CF	Total Ash	Moisture
%	31.2	6.9	4.6	5.9	8.8

CP crude protein, EE ether extract, and CF crude fiber.

2.5. Measurements

2.5.1 Water quality

Water quality was compared between the different experimental treatments with the regular monitoring of dissolved oxygen, pH, salinity, Ammonia, and Nitrite.

2.5.2 Growth performance, survival rate, and feed utilization

Red tilapia performance was evaluated through the final fish weight and measuring of the following parameters: specific growth rate (SGR as % day-1) that calculated as (ln Wt – ln Wo) / t × 100, where ln= natural Logarithm, t = rearing duration by days. Weight gain (WG) = Wt – Wo, where Wt = final weight, Wo = initial weight **(Ayisi *et al.,* 2017)**. Total biomass (number of harvested fish X body weight mean) was also compared between treatments.

Feed utilization was also compared between treatments with calculating of feed conversion ratio (FCR) = Feed intake / (Weight gain), feed efficiency (FE) = weight gain/ feed intake, and protein efficiency ratio (PER) = wet weight gain (g) / total protein intake (g)

2.5.3. Mint performance

The total plant weight, stem length, root length and number of leaves were compared between the two experimental treatments. Root and stem length was measured with a ruler **(Vazquez-Cruz *et al.,* 2012).**

2.5.4. Fish body proximate analysis

By the end of the experiment ten fish were randomly sampled from each system and frozen at -20 C in polyethylene bags for further chemical analyses. Accurately, dry matter, protein, fat, and ash contents of whole fish were determined following the methods described in **AOAC (1990)**. Moisture content was estimated with heating samples in an oven at 85 ºC till constant weight. Nitrogen content was measured using a Kjeldahl apparatus and crude protein was estimated by multiplying nitrogen content by 6.25. Total lipids content was determined by ether extraction. Ash was determined by combusting samples in a muffle furnace at 550 ºC for 2h.

2.6 Statistical analysis

Results were expressed as mean ± standard error (SE), and treatment mean differences were analyzed using t-test. Level of significant difference was set at ($P<0.05$). Statistical analysis was conducted using the statistical software package (IBM, SPSS version 25) **(Kremelberg, 2010)**.

3.RESULTS and DISCUSSION

3.1. Water quality

The physical and chemical water parameters including water temperature, dissolved oxygen (DO), salinity, pH, ammonia (NH3) and Nitrite (NO2) in the experimental units are presented in **Table 2**.

Table 2. Water quality parameters in recirculating low saline aquaponic systems (Red Tilapia and Mint) stocked with different stocking density**.**

	L D	H D	Sig.
Temperature (C^{o}	30.58 ± 0.36	30.71 ± 0.04	0.75
DO (mg/l)	6.89 ±0.01	6.47 ±0.06	0.02
Salinity (mg/l)	4.96 ± 0.02	4.88 ± 0.03	0.06
pH	7.74 ±0.05	7.24 ± 0.13	0.04
NH_3 (mg/l)	0.15 ± 0.01	0.19 ± 0.03	0.2
NO_2 (mg/l)	0.25± 0.04	0.27 ± 0.05	0.77

Probability value (*p*) of less than 0.05 was used to indicate statistically significant differences

Water temperature (^{o}C) was 30.58 ± 0.36 in the lower density systems and 30.71 ± 0.04 in the 60 fish / m^3 treatment without significant differences. Dissolved oxygen (mg/l) was significantly ($P<0.05$) higher 6.89 ± 0.01 in the treatment with lower stocking density (40 fish/m^3) than of that in the HD treatment 6.47 ± 0.06. Water salinity (mg/l) was 4.96 ± 0.02 and 4.88 ± 0.03 for the LD and HD systems, respectively without significant differences. The pH was 7.24 ±0.05 for treatment with stocking density of 60 fish / m^3 and 7.74 ± 0.13 for treatment with stocking density 40 fish / m^3 with statistically significant difference ($P<0.05$). Ammonia NH_3 (mg/l) was numerically lower in the aquaponic system, which stocked with lower fish number 0.15 ± 0.01 than of those of 60 fish / m^3 units (0.19 ± 0.03). Nitrite (NO_2) did not affect significantly by different stocking densities, nitrite (mg/l) was 0.25± 0.04 for treatment with stocking density 40 fish / m^3 and 0.27 ± 0.05 for higher density treatment which were insignificantly different (**Table 2**).

The mean values of the DO obtained in the current study were within the recommended range suggested by **(Eding *et al*., 2006)**, which is between 4.0 mg L^{-1} and 6.0 mg L^{-1}.DO and essentially required in the process of nitrification **(Yildiz *et al*., 2017).** Fish, plants and bacteria in the aquaponic system require adequate amounts of DO for maximum health and growth **(Rakocy, 2007)**, both treatment of the current study showed acceptable ranges of DO**.**

Higher stocking density showed significantly lower DO level. This observation is congruent with the findings of **(Zaki *et al*., 2020)** who tested three different stocking densities (20,40 and 60 fish per m^3), DO was decreased as stocking density increased and the lowest values of DO was in the highest density group (60 fish per m^3)**.** Lower concentrations of dissolved oxygen in the higher density aquaponic systems may be explained with the fast decomposition of the fish metabolites and feed particles present in the culture system **(Yildiz *et al*., 2017).**

pH is one from the most important factors for the survival of the components of aquaponic system including fish, microbes, and plants. Water pH is not only a requirement for fish growth but also to assure the availability of nutrients and permit optimum nutrient absorption by plants for effective plant performance in soilless culture systems. In order to achieve the nitrification process in the aquaponic system water pH should be kept around of 7. Water pH below 6.5 may disrupt the nitrification process and causing the aquaponic system frailer **(Goddek *et al*., 2015; Yildiz and Bekcan, 2017).**

Optimum pH for tilapia growth was reported to be between 6.0 and 9.0 **(Ross, 2000; Delong *et al*., 2009).** Water pH of the fish tanks in this study fell between 7.0 and 8.0. Keeping of the pH within the range from 7.0 to 8.0 can save the ammonia in the form of NH4+, thus lowering the toxicity level which caused by the NH_3. It is critical to optimize the temperature and pH as both parameters affect strongly to NH_3 concentration.

Regardless of the stocking density used the pH levels were within the recommended levels for both red tilapia and Mint culture. The results revealed that pH value increased with decreasing stocking density of fish in the aquaponic system which was previously observed by several authors **(Kloas *et al*., 2015; Yildiz and Bekca, 2017).**

In the aquaponic system, ammonia is a result of fish excretion via the gills and the decomposition of uneaten feed **(Eck *et al*., 2019).** High ammonia levels slow fish growth, decrease survival rate and cause many physiological problems in fish **(Anantharaja *et al*., 2017; Yildiz *et al*., 2017).** High ionized ammonium–nitrogen levels cause low growth performance and tissue damage **(Francis-Floyd *et al*., 2009).** In a balanced aquaponic unit, fish is rarely affected by ammonium toxicity. The concentration of nitrite also could be kept as low as possible to avoid it reaching a toxic level. High nitrite concentration affects on fish's ability to transport oxygen via blood **(Yildiz *et al*., 2017).** According to **Hargreaves and Tucker (2004) and Zaki *et al.* (2020)** the accumulation of fish feces and N in the form of NH_3 and NO_2 will adversely affect on the water quality.

Results of the current study showed that the concentration of NH_3 and NO_2 were both increased with increasing fish stocking density but without significant differences. Nitrogen wastes in both experimental groups were within the acceptable ranges for red tilapia growth. Similar results were also observed with **Endut *et al*. (2016) and Makori *et al*. (2017)** whose ranges were 0.09–0.85 mg L^{-1} for NH_3 and 0.02–0.17 mg L^{-1} for NO_2, respectively. Nitrite concentration in this study increased with increasing of fish stocking density which was directly related to the amount of feed administered. Similarly, **Rahmatullah *et al*. (2010)** reported a linear increment of Nitrogen wastes with increasing fish stocking density and feed input.

The removal of NH_3 and nitrite may be due to plant uptake **(Zarantoniello *et al*., 2021)**. Microorganisms which present in the system assimilate the nitrate in the water or the root of the plants grown with the help of biofilms **(Azam and Ifzal, 2006)**. These nutrients are important for the growth of mint. The unsignificant response of NH_3 and No_2 to stocking density under aquaponic system could be attributed to the nature of ammonia is very volatile and highly labile, suggesting that it was likely the N species that was most up taken by the plants. Similar sentiments on plant uptake of ammonium in the aquaponic systems were also observed by **Gichana *et al.* (2018)**. Ammonium also transformed into other forms of N (nitrite and nitrate) by biogeochemical processes which mediated with changes in pH and dissolved oxygen concentrations **(Goddek *et al*., 2015; Goddek, 2017)**.

3.2. Growth performance, survival rate, and feed utilization

Growth performance parameters and survival rate of red tilapia under low saline aquaponic systems with different stocking densities are shown in **Table 3**.

Table 3. Growth performance and survival rate of red tilapia under low saline aquaponic systems with different stocking densities.

Parameter	L D	H D	Sig.
Initial weight (g)	44.00 ± 2.31	43.67 ± 1.45	0.9
Final weight (g)	194.33 ±11.26	165.67 ± 4.91	0.03
Weight gain (g)	150.33 ±8.95	122.0 ± 3.46	0.04
SGR %/day	1.65 ±0.00	1.48 ± 0.00	0.00
Total biomass (Kg)	7.18±0.37	8.78±0.24	0.02
Survival Rate%	92.5±1.25	88.33±0.98	0.04

Probability value (*p*) of less than 0.05 was used to indicate statistically significant differences.

Final weight of red tilapia differs significantly according to the stocking density. Both weight gain and specific growth rate were significantly higher in the lower density when compared with the higher density treatment (150.33 ±8.95 and 1.65 ±0.006 vs 122.0 ± 3.46 and1.48 ± 0.005), respectively. On the other hand, total biomass was significantly higher in the higher density units (8.78 ±0.24 Kg.) than of that which obtained from the lower density group (7.18 ± 0.37 Kg.). Survival rate decreased significantly with increasing stocking density (92.5±1.25 in LD and 88.33±0.98 in HD treatment)

Stocking density is one of the most critical factors which can influence the fish reared in the aquaponic systems. Stocking density was reported to affects fish growth, feed utilization, survival rate, behavior, health, water quality, and fish yield **(Oké and Goosen, 2019; Maucieri *et al*., 2019).** Generally, the current growth performance of red tilapia in aquaponic systems were in acceptable range, perhaps because of the better water recirculation condition and the system efficiency. The results indicated that the growth rates with differ in stocking density which coincides with the results of **Kohinoor *et al*. (2009)** and **da Costa *et al*. (2019).** Fish which stocked at 40 fish m^{-3} showed highest growth parameters as compared to fish stocked at density of 60 fish m^{-3}; indicated that lower stocking density reduced the competition among the fishes, which influenced them to take feed properly which might be absent in the treatment with higher fish stocking density**. Ahmed *et al*. (2013) and Rayhan *et al*. (2018)** mentioned comparable results, where stocking density was found to relate with the average weight gain of tilapia. Findings by **Sace and Fitzsimmons (2013); Ferdous *et al*. (2014); Diem *et al*. (2017); and Rayhan *et al*. (2018)** were all also agree with these results as fish weight gain is inversely related with stocking density.

The specific growth rate of red tilapia in the present study was 1.65±0.006 and1.48±0.005 for LD and HD, respectively. Similar results in aquaponic systems were reported by **(Ani *et al*., 2022),** the highest value of specific growth rate was observed in the lowest stocking density. Growth performance are adversely affected by high stocking densities **(Pouey *et***

***al*., 2011 and Sorphea *et al*., 2010**) but in some cases this effect is either temporary **(Garr *et al*., 2011)** or absent **(Gokcek and Akyurt, 2007; Southworth *et al*., 2009).**

The survival rate of red tilapia was significantly decreased with increasing stocking density. This probably due to the crowded condition which created as a result of the higher fish density and the resulting competition for space and food. **(Gibtan *et al*., 2008 and Person-Le Ruyet *et al*., 2008).**

However, significantly higher fish biomass was observed in the higher-density group. These findings agreed with the results of **Wang *et al*. (2017),** fish biomass was positively correlated with stocking density**. Buhmann and Papenbrock (2013)** investigated the biomass yield from aquaponic systems and concluded that, an efficient aquaponic system should show high yields of plant and fish biomass with low amount of nitrogen loss. The nitrogen transformations between plants biomass and gas loss are affected with microbial growth on the surface area of plant roots, carbon source for microbial consumption, and contact duration which is affected by hydraulic loading rate**.**

Table 4. Feed utilization of red tilapia under low saline aquaponic systems with different stocking densities.

Parameter	L D	H D	Sig.
FCR	1.38±0.05	1.54±0.01	0.03
FE	0.73 ± 0.02	0.64 ± 0.00	0.00
PER	2.42±0.09	2.02 ±0.01	0.00

Probability value (*p*) of less than 0.05 was used to indicate statistically significant differences.

Feed utilization parameters were significantly better in the lower density treatment **(Table 4)**. Feed conversion ratio was lower in the LD units (1.38 ±0.05) than that of HD (1.54±0.01). Feed efficiency and protein efficiency ratio were both significantly higher in the lower density group when compared with 60 fish / m^3 treatment (0.73 ±0.02 and 2.42±0.07 *vs* 0.64 ±0.00 and 2.02±0.01, respectively).

Feed conversion ratio (FCR) represents the ratio of the total weight of fish feed to total wet weight gained by fish at the end of the culture duration **(Endut *et al*., 2010**). FCR value mainly depends on fish species and consumed feed **(Hu *et al*., 2014**). In the current study FCR values ranged between 1.38 and 1.54, which were higher than of the productive recirculating aquaculture with an FCR value of 1.25 reported by **(El-Sayed, 2006**; **Timmons and Ebeling, 2013)**. On the other hand, FCR values in present study were lower and more preferable than those reported by **(Rakocy *et al*., 2006)**, which were between 1.70 to 1.80. Significant reduction in feed utilization was observed with increasing stocking density. These results were agreed with **(Ani, 2022)** who studied the effect of stocking density on FCR of tilapia and lettuce in an aquaponic system.

3.3 Mint performance

Mint performance under low saline aquaponic systems with different stocking density of red tilapia is shown in **Table 5**.

Table 5. Mint performance under low saline aquaponic systems with different stocking density of red tilapia.

Parameter	LD	HD	Sig.
Fresh weight (g.)	454.00 ± 72.94	343.57± 28.36	0.06
Stem length (cm)	68.07 ± 3.64	68.14 ± 6.39	0.99
Root length (cm)	60.21 ± 4.79	41.18 ± 4.20	0.00
No. of leaves	720.71 ± 165.17	681.00 ± 93.48	0.83

Probability value (*p*) of less than 0.05 was used to indicate statistically significant differences.

Stocking density of red tilapia didn't affect significantly on the individual plant fresh weight, plant length, and the number of leaves. Root length in the lower density systems was 60.21±4.79, which was significantly ($P<0.05$) higher than the root length in the higher density group 41.18±4.20 cm.

Aquaponics is the combination of hydroponics (plants without soil) and aquaculture (fish in a recirculating system). In aquaponics, wastewater of the fish tank is used to fertilize hydroponics production beds beside plant roots, and associated rhizosphere bacteria clean up the water from nutrients, especially ammonia as a toxic element to fish **(Rakocy *et al*., 2006; Graber and Junge, 2009; Rakocy, 2012).**

In this study, two different fish stocking densities of red tilapia were examined in order to investigate its effects on mint growth in a medium-scale production. The main difference among the different stocking densities in aquaponic systems was the concentration of nutrients produced, which in turn, affected the growth and development of the mint. The nutrient requirements for leafy plants increase with time during vegetative growth. **Rakocy (2007**) stated that low yield in aquaponics system might be associated with low the nutrient solution**. Rakocy *et al*. (2004)** reported that aquaculture effluent provides most of the nutrients which required by plants if the optimum ratio between daily fish feed input and plant growing area is maintained.

Plant growth and production in aquaponic system affected by different component ratios. Fish to plant ratio of 1:2 showed better performance than 1:1 and 1:3 ratios **(Shete *et al*., 2015**). performance of mint in 1:3 ratio may be due to lack of nutrients. In the present study, mint was grown in deep water system (raft) and was supplied with fish wastewater with 1:2 fish to plant ratio. Mint growth in both studied stocking densities were insignificantly differ in most measured traits that indicate the efficiency of the experimental systems.

3.4. Proximate body composition

Proximate chemical composition of red tilapia under low saline aquaponic systems with different stocking density is shown in **Table 6**.

Table 6. Proximate chemical composition of red tilapia reared under low saline aquaponic systems with different stocking density.

Nutrient	LD	HD	Sig.
Moisture	1.76 ± 0.03	1.16 ± 0.36	0.21
Protein	36.17 ± 2.12	38.74 ± 3.21	0.50
Fat	24.22 ± 1.29	21.44 ± 2.80	0.03
Ash	22.22 ±0.94	24.71 ± 1.11	0.09

Probability value (*p*) of less than 0.05 was used to indicate statistically significant differences

Whole-body moisture, protein and ash contents didn't differ significantly with stocking density **(Table 6)**. However, significantly lower fat content of fish body was found in HD ($P<0.05$) 21.44± 2.80 as compared with 24.22 ± 1.29 in LD treatment. The fish body protein content was 36.17 ± 2.12 03 in the stocking density of 40 fish / m^3 which is lower than 38.74 ± 3.21 in 60 fish / m^3 without significant difference. Fish body ash content was 24.71 ± 1.11 in the treatment higher density and 22.22 ± 0.94 in the lower density treatment without significant difference.

The results demonstrated that HD with stocking density (60 fish/m^3) group fish contained low amount of fat compared to LD with stocking density (40 fish/m^3). This may due to over expenditure of body energy for maintaining normal metabolic activity by the fish (60 fish/m^3) during the experimental period. Stocking density influenced fish body composition, as lipid level decreased in the higher stocking density. Similar, fast growing channel catfish, *Ictalurus punctatus*, are generally high in lipid and low in moisture and protein concentrations when compared to slow growing fish **(Li et *al.,* 2003).** Similarly**,** lower stocking densities (200, and 300 fish/m^3) exhibited higher significant content of lipids as compared with the higher stocking densities (400, and 500 fish/m^3) **(Moniruzzaman, 2015).** At the end of the experiment apparently fish which reared in LD with stocking density 40 fish / m^3 was more robust than in HD**.**

4. CONCLUSION

Growth parameters of red tilapia decreased with increasing stocking density under aquaponic system. Better feed utilization was achieved with the lower density. Total fish biomass was significantly increased with increasing stocking density. Water quality in lower stocking density was relatively better in terms of pH and DO. Elevation of stocking density didn't affect negatively on the plant fresh weight, stem length, and number of leaves while the root length was decreased significantly with the higher fish density. Generally, red tilapia performed better in aquaponic system with mint under lower density (40 fish/ m^3) while water quality, mint performance, and fish body composition didn't go beyond the acceptable limits under the examined higher density (60 fish/ m^3). The superior fish growth and feed utilization, doesn't rule out the fact that higher stocking density can still be used especially with good water quality parameters and higher yield.

5. REFERENCES

Ahmed, G. U.; Sultana, N.; Shamsuddin, M., and Hossain, M. B. (2013). Growth and Production Performance of Monosex Tilapia (*Oreochromis niloticus*). Pakistan Journal of Biological Sciences, 16(23): 1781-1785.

Anantharaja, K.; Mohapatra, B. C.; Pillai, B. R.; Kumar, R., Devaraj, C., and Majhi, D. (2017). Growth and survival of climbing perch, Anabas testudineus in Nutrient Film Technique (NFT) Aquaponics System. *Int. J. Fish. Aquat. Stud*, *5*(4): 24-29.

Ani, J. S.; Manyala, J. O.; Masese, F. O.; and Fitzsimmons, K. (2022). Effect of stocking density on growth performance of mono sex Nile Tilapia (*Oreochromis niloticus*) in the aquaponic system integrated with lettuce (*Lactuca sativa*). *Aquaculture and Fisheries*, *7*(3): 328-335.

AOAC, (1990). cial Methods of Analysis. Association of Official Analytical Chemists, Arlington, VA.aquaponic system integrated with lettuce (Lactuca sativa). Aquaculture and Fisheries, 7(3): 328-335.

Ayisi, C. L.; Zhao, J.; and Rupia, E. J. (2017). Growth performance, feed utilization, body and fatty acid composition of Nile tilapia (Oreochromis niloticus) fed diets containing elevated levels of palm oil. Aquaculture and Fisheries, 2 (2): 67-77.

Azam, F. and Ifzal, M. (2006). Microbial populations immobilizing NH4+-N and NO3−-N differ in their sensitivity to sodium chloride salinity in soil. Soil Biology and Biochemistry, 38(8): 2491-2494.

Baßmann B.; Harbach H.; Weißbach S. and Palm H.W. (2020) Effect of plant density in coupled aquaponics on the welfare status of African catfish, Clarias gariepinus

Buhmann, A. and Papenbrock, J. (2013). Biofiltering of aquaculture effluents by halophytic plants: Basic principles, current uses and future perspectives. Environmental and Experimental Botany, 92: 122-133.

da Costa, O. T. F.; Dias, L. C.; Malmann, C. S. Y.; de Lima Ferreira, C. A.; do Carmo, I. B.; Wischneski, A. G.; ... and Dos-Santos, M. C. (2019). The effects of stocking density on the hematology, plasma protein profile and immunoglobulin production of juvenile tambaqui (*Colossoma macropomum*) farmed in Brazil. Aquaculture, 499: 260-268.

Delaide, B.; Goddek, S.; Gott, J.; Soyeurt, H. and Jijakli, M. H. (2016). Lettuce (Lactuca sativa L. var. Sucrine) growth performance in complemented aquaponic solution outperforms hydroponics. Water, 8(10): 467.

DeLong D. P.; Losordo, T.M. and Rakocy J.E. (2009). Tank culture of tilapia. Online; SRAC Publication No. 282. Southern Regional Aquaculture Center. 2009.Available at https://thefishsite.com/articles/tank-culture-of-tilapia.

Diem, T. N. T.; Konnerup, D., and Brix, H. (2017). Effects of recirculation rates on water quality and Oreochromis niloticus growth in aquaponic systems. *Aquacultural Engineering*, 78: 95-104.

Eck, M.; Sare, A. R.; Massart, S.; Schmautz, Z.; Junge, R.; Smits, T. H. and Jijakli, M. H. (2019). Exploring bacterial communities in aquaponic systems. Water, 11(2): 260.

Eding, E. H.; Kamstra A.; Verreth J. A. J.and Huisman E. A. and Klapwijk. A. (2006)"Design and operation of nitrifying trickling filters in recirculating aquaculture: a review." *Aquacultural engineering* 34, no. 3 : 234-260.

El-Sayed, A.F.M. (2006). Tilapia Culture; CABI Publishing: Oxfordshire, UK.

Endut, A.; Jusoh, A.; Ali, N.; Wan Nik, W.B. and Hassan, A. (2010). A study on the optimal hydraulic loading rate and plant ratios in recirculation aquaponic system. Bioresour Technol. 101: 1511–1517.

Endut, A.; Lananan, F.; Abdul Hamid, S. H.; Jusoh, A. and Wan Nik, W. N. (2016). Balancing of nutrient uptake by water spinach (Ipomoea aquatica) and mustard green (Brassica juncea) with nutrient production by African catfish (Clarias gariepinus) in scaling aquaponic recirculation system. Desalination and Water Treatment, 57(60): 29531-29540.

FAO, (2018). The State of World Fisheries and Aquaculture 2018- Meeting the sustainable development goals.Rome. licence: CC BY-NC-SA 3.0 IGO. opportunities for marine fish species production, pp. 514521.

Ferdous, Z.; Nahar, N.; Hossen, M. S.; Sumi, K. R. and Ali, M. M. (2014). Performance of different feeding frequency on growth indices and survival of monosex tilapia, Oreochromis niloticus (Teleostei: Cichlidae) fry. *Int J Fish Aquat Stud*, 1(5): 80-83.

Filep, R. M.; Diaconescu, Ş.; Costache, M.; Stavrescu-Bedivan, M. M.; Bădulescu, L. and Nicolae, C. G. (2016). Pilot aquaponic growing system of carp (*Cyprinus Carpio*) and basil (*Ocimum Basilicum*). *Agriculture and Agricultural Science Procedia*, 10: 255-260.

Francis-Floyd, R.; Watson, C.; Petty, D. and Pouder, D. B. (2009). Ammonia in Aquatic Systems: FA16/FA031, rev. 2/2009. *EDIS*, *2009*(6).

Garr, A. L.; Lopez, H.; Pierce, R. and Davis, M. (2011). The effect of stocking density and diet on the growth and survival of cultured Florida apple snails, Pomacea paludosa. *Aquaculture*, 311(1-4): 139-145.

Gibtan, A.; Getahun, A. and Mengistou, S. (2008). Effect of stocking density on the growth performance and yield of Nile tilapia [Oreochromis niloticus (L., 1758)] in a cage culture system in Lake Kuriftu, Ethiopia. *Aquaculture Research*, *39*(13): 1450-1460.

Gichana, Z. M.; Liti, D.; Waidbacher, H.; Zollitsch, W.; Drexler, S. and Waikibia, J. (2018). Waste management in recirculating aquaculture system through bacteria dissimilation and plant assimilation. Aquaculture International, 26(6): 1541-1572.

Goddek, S. (2017). Opportunities and challenges of multi-loop aquaponic systems. *PQDT-Global*.

Goddek, S. and Keesman, K. J. (2018). The necessity of desalination technology for designing and sizing multi-loop aquaponics systems. *Desalination*, *428*: 76-85.

Goddek, S.; Delaide, B.; Mankasingh, U.; Ragnarsdottir, K. V.; Jijakli, H. and Thorarinsdottir, R. (2015). Challenges of sustainable and commercial aquaponics. *Sustainability*, 7(4): 4199-4224.

Goddek, S.; Joyce, A.; Kotzen, B. and Burnell, G. M. (2019). Aquaponics food production systems: combined aquaculture and hydroponic production technologies for the future (p. 619). Springer Nature.

Gokcek, C. K. and Akyurt, I. (2007). The effect of stocking density on yield, growth, and feed efficiency of himri barbel (Barbus luteus) nursed in cages. Israeli Journal of Aquaculture-Bamidgeh, 59: 20517.

Graber, A. and Junge, R. (2009). Aquaponic Systems: Nutrient recycling from fish wastewater by vegetable production. *Desalination*, *246*(1–3):, 147–156.

Hargreaves, J. A. and Tucker, C. S. (2004). Managing ammonia in fish ponds (Vol. 4603). Stoneville: Southern Regional Aquaculture Center.

Harley, R. M. and Brighton, C. A. (1977). Chromosome numbers in the genus Mentha L. *Botanical Journal of the Linnean Society*, *74*(1): 71-96. https://doi.org/10.3390/w9010013.

Hu, Z.; Lee, J.W.; Chandran, K.; Kim, S.; Sharma, K. and Khanal, S.K., (2014). Influence of carbohydrate addition on nitrogen transformations and greenhouse gas emissions of intensive aquaculture system. Sci. Total Environ. 470–471: 193–200.

Kloas, W.; Groß, R.; Baganz, D.; Graupner, J.; Monsees, H.; Schmidt, U.; ... and Rennert, B. (2015). A new concept for aquaponic systems to improve sustainability, increase productivity, and reduce environmental impacts. Aquaculture environment interactions, 7(2): 179-192.

Kohinoor, A. H. M.; Jahan, D. A.; Khan, M. M.; Ahmed, S. U. and Hussain, M. G. (2009). Culture potentials of climbing perch, Anabas testudineus (Bloch) under different stocking densities at semi-intensive management.

Kremelberg, D. (2010). *Practical statistics: A quick and easy guide to IBM® SPSS® Statistics, STATA, and other statistical software*. SAGE publications.

Li, M. H.; Mannning, B. B.; Robinson, E. H. and Bosworth, B. G. (2003). Effect of dietary protein concentration and stocking density on production characteristics of pond-raised channel catfish Ictalurus punctatus. Journal of the World Aquaculture Society, 34(2): 147-155.

Love, D. C.; Fry, J. P.; Genello, L.; Hill, E. S.; Frederick, J. A.; Li, X. and Semmens, K. (2014). An international survey of aquaponics practitioners. PloS one, 9(7): e102662.

Makori, A. J.; Abuom, P. O.; Kapiyo, R.; Anyona, D. N. and Dida, G. O. (2017). Effects of water physico-chemical parameters on tilapia (Oreochromis niloticus) growth in earthen ponds in Teso North Sub-County, Busia County. *Fisheries and Aquatic Sciences*, *20*(1): 1-10.

Maucieri, C.; Nicoletto, C.; Van Os, E.; Anseeuw, D.; Van Havermaet, R. and Junge, R. (2019). Hydroponic technologies. *Aquaponics food production systems*, *77*.

Mimica-Dukić, N.; Božin, B.; Soković, M.; Mihajlović, B. and Matavulj, M. (2003). Antimicrobial and antioxidant activities of three Mentha species essential oils. *Planta medica*, *69*(05): 413-419.

Moniruzzaman, M.; Uddin, K. B.; Basak, S.; Mahmud, Y.; Zaher, M. and Bai, S. C. (2015). Effects of stocking density on growth, body composition, yield and economic returns of monosex tilapia (Oreochromis niloticus L.) under cage culture system in Kaptai Lake of Bangladesh. *Journal of Aquaculture Research & Development*, *6*(8): 1.

Neda, M.D.; Biljana, B.; Marina, S.; Biserka, M.; Milan, M. 2003. Antimicrobial andantioxidant activities of three Mentha species essential oils. Plant Med 69:413–419.

Oké, V. and Goosen, N. J. (2019). The effect of stocking density on profitability of African catfish (Clarias gariepinus) culture in extensive pond systems. *Aquaculture*, 507: 385-392.

Person-Le Ruyet, J.; Labbé, L.; Le Bayon, N.; Sévère, A.; Le Roux, A.; Le Delliou, H. and Quéméner, L. (2008). Combined effects of water quality and stocking density on welfare and growth of rainbow trout (Oncorhynchus mykiss). *Aquatic Living Resources*, *21*(2):185-195.

Pouey, J. L. O. F.; Piedras, S. R. N.; Rocha, C. B.; Tavares, R. A.; Santos, J. D. M. and Britto, A. C. P. (2011). PRODUCTIVE PERFORMANCE OF SILVER CATFISH, Rhamdia quelen, JUVENILES STOCKED AT DIFFERENT DENSITIES/Desempenho produtivo de juvenis de Jundiá (Rhamdia quelen) submetidos a diferentes densidades de estocagem. *Ars Veterinaria*, *27*(4): 241-245.

Rahmatullah, R.; Das, M. and Rahmatullah, S. M. (2010). Suitable stocking density of tilapia in an aquaponic system.

Rakocy J.E.; Shultz R.C.; Bailey D.S. and Thoman E.S. (2004). Aquaponic production of tilapia and basil: comparing a batch and staggered cropping system. Acta Horticulturae (ISHS) 648: 63-69.

Rakocy, J. E. (2012). Aquaponics-integrating fish and plant culture. Aquaculture Production Systems, 1: 343–386.

Rakocy, J. E., (2007). Ten Guidelines for Aquaponic Systems. Aquaponics Journal, 46: 14–17. Retrieved from http://santarosa.ifas.ufl.edu/wp-content/uploads/2013/06/Aquaponics-Journal-10-Guidelines.pdf.

Rakocy, J.E.; Masser, M.P. and Losordo, T.M. (2006). Recirculating aquaculture tank production systems: aquaponics—integrating fish and plant culture. SRAC Publication, 454: 1–16.

Rayhan, M. Z.; Rahman, M. A.; Hossain, M. A.; Akter, T. and Akter, T. (2018). Effect of stocking density on growth performance of monosex tilapia (Oreochromis niloticus) with Indian spinach (Basella alba) in a recirculating aquaponic system. *International Journal of Environment, Agriculture and Biotechnology*, *3*(2): 239073.

Ross, L.G. (2000). Environmental physiology and energetics. In: Beveridge, M.C.M., McAndrew, B.J. (eds) Tilapias: Biology and Exploitation. Fish and Fisheries Series, vol 25. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-4008-9_4

Sace, C. F. and Fitzsimmons, K. M. (2013). Vegetable production in a recirculating aquaponic system using Nile tilapia (Oreochromis niloticus) with and without freshwater prawn (*Macrobrachium rosenbergii*). *Academia Journal of Agricultural Research*, *1*(12): 236-250.

Said M. M.; Zaki F. M. and Mamoun O. A. (2022). Effect of the Probiotic (*Bacillus* spp.) on Water Quality, Production Performance, Microbial Profile, and Food Safety of the Nile Tilapia and Mint in Recirculating Aquaponic System. Egyptian Journal of Aquatic Biology and Fisheries, 26 (6): 351-372.

Selek, M.; Endo, M.,; Yiğit, M. and Takeuchi, T. (2017). The integration of fish and plant production: Nile tilapia (*Oreochromis niloticus*) and basil (*Ocimum basilicum*) culture in recirculating and aquaponic systems. *Journal ofaquaculture engineering and fisheries research*, *3*(1): 28-43.

Shete, A. P.; Verma, A. K.; Chadha, N. K.; Prakash, C. and Chandrakant, M. H. (2015). A comparative study on fish to plant component ratio in recirculating aquaponic system with common carp and mint. *J. Environ. Biol. Sci*, *29*(2): 323-329.

Sorphea, S.; Lundh, T.; Preston, T. R. and Borin, K. (2010). Effect of stocking densities and feed supplements on the growth performance of tilapia (Oreochromis spp.) raised in ponds and in the paddy field. *Livestock Research for Rural Development*, *22*(11).

Southworth, B. E.; Engle, C. R. and Ruebush, K. (2009). The effect of understocking density of channel catfish stockers in multiple-batch production. Journal of Applied aquaculture, 21(1): 21-30.

Tidwell, J.H. (2012). Characterization and Categories of Aquaculture Production Systems. *Aquaculture Production Systems*, 64–78.

Timmons, M.B. and Ebeling, J, M. (2013). Recirculating Aquaculture (3rd ed.). Reading, United Kingdom: Ithaca Publishing Company. Retrieved from https://www.amazon.in/Recirculating-Aquaculture-3rd-Michael-Timmons/ dp/0971264651

Uchida R.N. and king,J.E. (1962) Tank culture of the tilapia fishery bulletin of the fish and wildlife sevice, 62, 17..

Vazquez-Cruz, M.A.; Luna-Rubio, R.; Contreras-Medina, L.M.; Torres-Pacheco, I. and Guevara-Gonzalez, R.G.(2012) Estimating the response of tomato (*Solanum lycopersicum*) leaf area to changes in climate and salicylic acid applications by means of artificial neural networks. Biosyst. Eng., 112: 319–327.

Wang, L.; Li, J.; Jin, J. N.; Zhu, F.; Roffeis, M. and Zhang, X. Z. (2017). A comprehensive evaluation of replacing fishmeal with housefly (Musca domestica) maggot meal in the diet of Nile tilapia (Oreochromis niloticus): growth performance, flesh quality, innate immunity and water environment. Aquaculture Nutrition, 23(5): 983-993.

Watanabe, W.O.; Ellingson, L.J.; Wicklund, R.I. and Olla, B.L., (1988). The effects of salinity on growth, food consumption and conversion in juvenile, monosex male Florida red tilapia.

Yıldız, H. Y. and Bekcan, S. (2017). Role of stocking density of tilapia (Oreochromis aureus) on fish growth, water quality and tomato (Solanum lycopersicum) plant biomass in the aquaponic system. International Journal of Environment, Agriculture and Biotechnology, 2(6): 238971.

Yildiz, H. Y.; Robaina, L.; Pirhonen, J.; Mente, E.; Domínguez, D. and Parisi, G. (2017). Fish welfare in aquaponic systems: Its relation to water quality with an emphasis on feed and faeces-A review. Water (Switzerland), 9(1): 1–17.

Zaki, M.A.; Alabssawy, A.N.; Nour, A.E.A.M.; El Basuini, M.F., Dawood, M.A.; Alkahtani, S. and Abdel-Daim, M.M. (2020). The impact of stocking density and dietary carbon sources on the growth, oxidative status and stress markers of Nile tilapia (*Oreochromis niloticus*) reared under biofloc conditions. Aquaculture Reports, 16, p.100282. doi.org/10.1016/j.aqrep.2020.100282

Zarantoniello, M.; Randazzo, B.; Nozzi, V.; Truzzi, C.; Giorgini, E.; Cardinaletti, G.; ... and Olivotto, I. (2021). Physiological responses of Siberian sturgeon (Acipenser baerii) juveniles fed on full-fat insect-based diet in an aquaponic system. Scientific reports, 11(1): 1-13.