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Comparative growth performance of Nile tilapia (*Oreochromis niloticus*) sex groups in tank culture: A hormone-free approach for sustainable aquaculture in Dodoma, Tanzania

Angelina Michael*, Rosemary Peter Mramba

Department of Biology, College of Natural and Mathematical Sciences, University of Dodoma, Angelina Michael, ORCID No. https://orcid.org/0000-0003-3121-9630, Rosemary Peter Mramba, ORCID No. https://orcid.org/0000-0002-2216-4300

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*Corresponding author: onkyangel@yahoo.com

ABSTRACT

Male tilapia are globally preferred in aquaculture for their superior growth and uniform harvest sizes. However, hormonal sex reversal techniques used to produce all-male populations can pose health and environmental risks. This study investigated the growth performance of manually separated monosex males, monosex females, and mixed-sex groups of Nile tilapia (*Oreochromis niloticus*) in tank culture as a sustainable and hormone-free alternative. Over six weeks, the study measured various morphometric parameters, weight gain, specific growth rates, water quality parameters, and condition factors. The fish were fed isonitrogenous commercial feed, and the feeding regime was adjusted based on their weight. Results revealed that monosex tilapia groups attained higher growth rates than mixed-sex groups, with males achieving an average final weight of 56.5 g, followed by females at 53.3 g, and mixed-sex groups at 43.3 g. Males had higher morphometric values compared to females and mixed-sex groups. The water quality parameters remained optimal across all groups, indicating that sex composition does not impact water management. Monosex females and mixed-sex groups exhibited better condition factors. The study concludes that tilapia farming can be effectively conducted with either mono-sex male or mono-sex female tilapia, as their growth rates do not differ significantly. Further research and development of techniques to ease the separation of sexes and enhance the growth rates of monosex female tilapia are recommended as a viable, hormone-free alternative for sustainable aquaculture.

Keywords: Growth performance, monosex tilapia, non-hormonal sex separation, sustainable fish farming, tank culture

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INTRODUCTION

Aquaculture is the fastest-growing food production sector globally, which is critical in providing food security to a rapidly increasing human population (Cantrell, 2023; Haldén et al., 2014). With the global population projected to reach nearly 9.5 billion by 2050, the demand for sustainable and efficient food sources is intensifying (Gu et al., 2021; Lee, 2011). Innovations in aquaculture are essential to meet these growing nutritional needs while maintaining environmental sustainability. These innovations include selecting commercially valuable fish species, using nutritionally rich and sustainable feeds, proper feeding practices, and adopting suitable farming systems (Araujo et al., 2022; Lal et al., 2024).

Tilapia, the second most cultivated finfish species globally after carp, is highly preferred in aquaculture due to its rapid growth, disease resistance, and adaptability to diverse environments (El-Sayed and Fitzsimmons, 2023; El-Sayed, 2013; Miao and Wang, 2020; Prabu et al., 2019; Pradeepkiran, 2019). Commercial tilapia production often relies on all-male (monosex male) populations because of their superior growth rates, better feed conversion efficiency, and uniform harvest sizes (El-Sayed et al., 2012; Omasaki et al., 2016; Pandian and Kirankumar, 2003; Prabu et al., 2019; Sadiq, 2021). In contrast, mixed-sex tilapia populations tend to result in uncontrolled reproduction, leading to overpopulation and a higher number of unmarketable sizes (Akhand, 2014; Chen et al., 2018). However, the production of all-male tilapia is typically achieved through hormonal sex reversal, which involves administering hormones such as 17α-methyltestosterone through feeds or culture water to ensure male-dominated populations (Pandian and Kirankumar, 2003; Pandian and Sheela, 1995; Silva et al., 2023; Suseno et al., 2020).

Despite its advantages, the hormonal sex reversal technique presents significant concerns, including potential healthrisks for consumers and environmental contamination. A fraction of fish may remain unaffected (Akhand, 2014; Silva et al., 2023), thus compromising operational efficiency, while residual hormones may present health risks to consumers and the environment (Atar et al., 2009; El-Sayed et al., 2012; Hoga et al., 2018; Suseno et al., 2020). Such hormonal residues have been linked to endocrine disruption in humans, potentially causing reproductive health and developmental problems (Hoga et al., 2018). Studies also report low survival and function deficiencies among the sex-reversed fish (Pandian and Kirankumar, 2003; Pandian and Sheela, 1995).

Environmental contamination from sex-reversal hormones can also disrupt local aquatic ecosystems, affecting non-target species and leading to bioaccumulation in the food chain (Hoga et al., 2018). For instance, Suseno et al. (2020) found residues of the 17α-methyltestosterone hormone in the flesh of five-month-old tilapia raised in cage nets, with even the untreated control fish exhibiting concentrations exceeding 5 µg/L. Similarly, Liu et al. (2011) reported higher concentrations of steroids and phenols in wild fish's liver, gills, and muscles in areas where hormone-induced fish farming occurred. These concerns have prompted the global aquaculture industry to explore safer methods to enhance productivity while ensuring sustainability and safety (Salin and Arome Ataguba, 2018). Increasing consumer demand for hormone-free fish products and regulatory pressures to minimize environmental impacts are driving this transition (Freitas et al., 2020; Newman et al., 2020).

While there has been extensive research on the growth performance of monosex male and mixed-sex tilapia, the potential of monosex female tilapia still needs to be explored. The traditional emphasis on monosex male tilapia, which tend to grow faster and attain larger sizes than females (Bhatta et al., 2012; Chen et al., 2018; El-Sayed et al., 2012; Pandian and Kirankumar, 2003), has limited the understanding of female growth potential

when cultured alone. Most studies involving female tilapia have assessed them within mixed-sex populations, where reproductive behaviors and competition can hinder accurate evaluation of their growth. For instance, Bhatta et al. (2012) investigated growth and reproductive maturation, and Bombardelli et al. (2017) assessed the influence of diet on female *Oreochromis niloticus* growth within mixed-sex groups. Additionally, Githukia et al. (2015) conducted a comparative study on the growth of sexually reversed males and mixed-sex *Oreochromis niloticus* in earthen ponds, while Chakraborty et al. (2011) explored growth in different culture systems for similar groups. Given that growth rates and productivity in tilapia are influenced by sex and culture conditions (Santos et al., 2019; Toguyeni et al., 2002), there is a need to assess monosex female tilapia growth performance in isolated cultures. This study addresses this gap by investigating the growth performance of manually separated monosex male, monosex female, and mixed-sex groups of Nile tilapia (*Oreochromis niloticus*) in a tank culture in Dodoma, a semi-arid region of Tanzania. In Dodoma, the aquaculture industry has gradually grown to address the nutritional needs of the local population. The region's population has expanded rapidly in recent years due to the establishment of the University of Dodoma and the relocation of government headquarters from Dar es
Salaam (Kisamba and Li, 2022; Mramba and Kahindi, 2023; Mubako et al., 2022). However, the semi-arid climate of Dodoma, characterized by erratic rainfall, prolonged dry seasons, water scarcity, and high temperatures (Msengi et al., 2024), poses significant risks to fish health and productivity. To ensure the viability of aquaculture in this challenging environment, it is essential to adopt safe and sustainable practices that do not exacerbate environmental issues. Implementing such practices is crucial for minimizing environmental stressors, protecting fish health and well-being, and ensuring a safe and nutritious food source for the local population. This study presents findings on the six-week growth performance of manually separated tilapia sex groups, which have significant implications for promoting sustainable, hormone-free aquaculture practices.

MATERIALS AND METHODS

Study site

The experiment was conducted at the College of Natural and Mathematical Sciences of the University of Dodoma, located in the Dodoma region. Dodoma, the capital city of Tanzania, is situated in the central part of the country, which has a semi-arid climate. The area receives an average annual rainfall of 567 mm, with a prolonged dry season lasting 7-8 months (Msengi et al., 2024; Rapp et al., 1972). In most cases, Dodoma depends on other areas for its fresh fish supply due to limited natural water supply, though the aquaculture industry is now taking its pace. Despite challenges such as fluctuating environmental conditions and water scarcity, Dodoma presents an opportunity for fish farming as the city proliferates due to the recent government shift from Dar es Salaam and the establishment of the University of Dodoma.

Source of experimental fish and initial stocking

The Nile tilapia, *Oreochromis niloticus* fry of unidentified sex, averaging 1.1 g, were obtained from a commercial private hatchery within the country. They were carefully transported in styrofoam containers to the University of Dodoma. Upon arrival at the university, the fish were acclimatized for 15 minutes before being stocked in a concrete tank of 25 m3. A total of 150 fry were initially stocked in this tank and reared for twelve weeks, from February to April 2023, until their genitalia became visibly distinguishable, typically at a body weight of 20 to 25 g. At this stage, the fish were separated into sex groups, and only those with successfully identified sex were selected for the experiment. Throughout the rearing period, the fish were fed an iso-

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nitrogenous commercial feed. The initial feeding ratio was set at 15% of body weight until the fish reached an average weight of 6.25 g, after which the feeding ratio was adjusted to 10% of body weight.

Sex separation and experimental setup

The fingerlings were manually separated into three groups: monosex males, monosex females, and mixed-sex, by visually inspecting their genitalia. Each group was stocked in a white plastic tank with a volume of 1 m^3 at a density of 15 fingerlings per tank, with three replicates per group. The mixed-sex group was stocked at a female-to-male ratio of 5:1. The experimental period was six weeks between the months of May and June 2023. The fingerlings in all tanks received similar treatment in tank management and feeding regimes. They were fed commercial feed three times daily, with the feeding ratio adjusted every two weeks based on body weight. Tanks were intermittently aerated using an electric air pump, and siphoning was performed every morning to remove uneaten feed and feces. Water exchange was conducted at 25% every three to seven days, with additional replacements made to account for high evaporation rates.

Assessment of growth performance of the fish

Fish growth was measured in terms of change in weight and length at fourteen-day intervals during the experiment. The weight parameters included the weight gain (WG) and specific growth rates (SGR). In contrast, length measurements included morphometric parameters such as total length (TL), fork length (FL), standard length (SL), head length (HL), and anal length (AL). The condition factor (K) was also determined by using the length-weight relationship on the initial and final day of the experiment to determine the health status of the fish. Initial measurements were taken before stocking each sex group in the respective tanks. The fish were carefully handled to minimize stress and injury. Three fingerlings were randomly selected from each tank for morphometric assessments to ensure a representative sample while reducing the potential stress associated with prolonged handling.

In contrast, weight measurements were taken for all fish in each tank using a digital balance. Morphometric parameters were measured using a ruler. The weight was recorded in grams (g), while morphometries were recorded in centimeters (cm). The growth parameters, weight gain (WG), and specific growth rate (SGR), as well as the condition factor (K), were calculated as follows;

$$WG\ (g) = FW - IW \quad (1)$$

$$SGR\ (\%\ day^{-1}) = 100 \times (\ln[FW] - \ln[IW]) / (Time\ (days)) \quad (2)$$

$$K = 100x\ W/L^3 \quad (3)$$

Note: FW = Final weight, IW= Initial weight

TL = The length from the tip of the snout to the end of the tail

FL = The length from the tip of the snout to the fork of the tail

SL = The length from the tip of the snout to the end of the vertebral column (excluding the tail fin).

HL = The length from the tip of the snout to the end of the operculum (gill cover).

AL = The length of the anal fin

W = weight in grams

L = length in centimetres

Measurement of water quality parameters

Throughout the experimental period, three water quality parameters, i.e., water temperature, dissolved oxygen (DO), and pH, were measured and monitored with a specific focus on the potential variations among monosex males, monosex females, and mixed-sex tilapia groups. These parameters were assessed daily at three specific time intervals: morning (09:00), noon, and evening (04:00) before feeding the fish. All the measurements were taken in situ and triplicated using standard laboratory equipment. Dissolved oxygen was measured by dipping the DO meter (Hanna, Germany). In contrast, temperature and pH (Hanna, Germany) were measured by a pH meter

(Hanna Instruments HI 99100IN, Germany) in the same manner as the instrument was dipped.

Data analysis

The experimental data were coded and cleaned using Microsoft Excel to ensure accuracy and consistency. After this preliminary step, the data were imported into R version 4.3.2 for statistical analysis. Morphometric parameters (total length, fork length, standard length, head length, and anal length), weight parameters (specific growth rate and weight gain), and water quality parameters (temperature, pH, and dissolved oxygen) were compared across monosex male, monosex female, and mixed-sex tilapia groups.

Before analysis, the response variables were assessed for normality using histograms and the Shapiro-Wilk test. Since the variables conformed to the normal distribution, one-way ANOVA was performed to compare the means of the water quality parameters, morphometric parameters, and weight parameters between the sex groups. When the ANOVA results indicated significance, post-hoc pairwise comparisons were conducted to identify specific group differences. Additionally, Pearson correlation analysis was performed to evaluate relationships between water quality parameters. Goodness-of-fit was verified through quantile-quantile (Q-Q) plots, which assessed whether residuals from the linear models followed a normal distribution. Any deviations observed in the Q-Q plots were investigated to ensure model accuracy, with adjustments made if necessary. A p-value of < 0.05 was considered statistically significant.

RESULTS

Water quality parameters

The recorded water quality parameters fell within the normal range of tilapia, though variations occurred between the months and tilapia sex groups. Temperature had no significant difference between the three tilapia sex groups ($F = 0.723$; $p = 0.486$). However, considerable variations were observed between the months ($F = 25.294$, $p < 0.05$) and times of the day ($F = 48.735$; $p < 0.05$). Higher water temperatures were recorded in the evening (24.08 ± 1.24°C), followed by noon (23.84 ± 1.57°C), with the lowest temperatures in the morning, averaging 22.19 ± 1.71°C. May had the highest average temperature (23.60 ± 1.74°C), while June had a lower average (22.75 ± 1.56°C). The dissolved oxygen (DO) values showed no significant variation among sex groups ($F = 1.254$; $p = 0.286$), though female groups had the highest average DO (6.88 ± 3.95 mg/l), followed by mixed sex (6.57 ± 3.94 mg/l), and males (6.21 ± 4.44 mg/l). Significant variation was noted between months ($F = 33.623$; $p < 0.05$) and times of the day ($F = 10.854$; $p < 0.05$), with the highest DO values at noon (8.02 ± 4.85 mg/l), followed by evening (6.73 ± 3.69 mg/l), and morning (5.01 ± 2.20 mg/l). An interactive variation was observed between months and sampling time ($F = 4.294$; $p = 0.014$).

The pH values ranged from 6.5 to 8.5, suitable for tilapia culture, with no significant differences among sex groups. Significant monthly variation was observed ($F = 20.554$; $p < 0.05$), with higher pH in June (8.85 ± 0.84) compared to May (8.18 ± 1.32). There was no significant variation with time of day ($F = 1.422$; $p = 0.243$), although slightly higher values were noted at noon (8.26 ± 1.40) and evening (8.25 ± 1.34), with the lowest in the morning (8.01 ± 1.22). Significant correlations were among the measured water quality parameters in each sex group. In the mono sex male group, a weak but significant correlation among water quality parameters was noted ($R2= 0.379$, $F = 18.668$, $p < 0.001$), with positive relationships between temperature and DO (0.538) and negative relationships between temperature and pH (-0.526), and DO and pH (-0.493). The monosex female group exhibited similar weak correlations ($R2 = 0.391$, $F = 20.639$, $p < 0.001$), with positive correlations between temperature and DO (0.552) and negative between temperature and pH (-0.545) and DO and

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pH (-0.502). The mixed-sex group showed a positive relationship between temperature and DO (0.579), DO and pH (0.433), and a negative relationship between temperature and pH (-0.394), with an overall model yielding R2 = 0.360, F = 5.092, and p = 0.026.

Morphometric parameters

The initial and final morphometric parameters show that males are generally larger than females and mixed-sex groups across all measured parameters (Tables 1 & 2). The values in female tilapia groups were approaching those of the males, while those of mixed sex were coming off the females. The variations among the tilapia sex groups were statistically significant ($p < 0.05$). The post hoc pairwise comparisons test (Table 3) showed statistically significant differences among the sex groups for initial and final morphometries. Monosex male tilapia showed significantly larger morphometric measurements than females and the mixed-sex group, whereas the differences between females and mixed-sex groups were generally not statistically significant (Table 3 A& B).

Table 1. Comparison of initial morphometric parameters (cm) between tilapia sex groups.

Group type	Initial total length	Initial fork length	Initial standard length	Initial head length	Initial anal fin length
Males	12.7	12.6	11.5	3.3	2.1
Females	10.4	10.3	8.5	2.8	1.6
Mixed-sex	10.3	10.2	8.3	2.7	1.7
F-value	13.58	10.00	7.93	6.43	7.99
P-value	0.006	0.012	0.021	0.032	0.020

Table 2. Comparison of the final morphometric parameters (cm) between tilapia sex groups.

Group type	Final total length	Final fork length	Final standard length	Final head length	Final anal fin length
Males	16.3	16.2	14.0	4.5	3.3
Females	14.3	13.8	12.2	4.1	3.0
Mixed-sex	13.7	13.6	11.5	3.9	3.0
F-value	25.46	30.84	51.47	42.45	13.95
P-value	0.001	< 0.001	< 0.001	< 0.001	0.005

Table 3. Post-hoc pairwise comparisons of the initial and final morphometries between the tilapia sex groups.

A: Initial morphometrics parameters

Variable	Groups	Female	Male
Total length	Male	0.004	-
	Mixed sex	0.878	0.003
Fork length	Male	0.009	-
	Mixed sex	0.816	0.007
Standard length	Male	0.017	-
	Mixed sex	0.756	0.011
Head length	Male	0.030	-
	Mixed sex	0.636	0.016
Anal fin length	Male	0.008	-
	Mixed sex	0.391	0.027

B: Final morphometrics parameters

Total length	Male	0.001	-
	Mixed sex	0.189	0.001
Fork length	Male	0.001	-
	Mixed sex	0.494	0.001
Standard length	Male	0.001	-
	Mixed sex	0.125	0.001
Head length	Male	0.001	-
	Mixed sex	0.311	0.001
Anal fin length	Male	0.013	-
	Mixed sex	1.00	0.010

Change in weight among the tilapia sex groups

All groups started with almost similar initial average weights (Figure 1), and there was no statistical variation among the groups ($F = 0.352$, $p = 0.705$). However, from the second week to the sixth week, body weight increased significantly in all groups. Male and female groups exhibited similar growth trends, but males showed a slightly higher increase in weight compared to females, starting from week 2. This weight increase did not significantly differ between the two monosex tilapia groups but significantly differed from the mixed-sex group ($p < 0.001$). At the end of the experiment, the male group was slightly heavier on average, reaching 56.5 g, compared to 53.3 g in the female group (Figure 1). The mixed-sex group, however, exhibited a noticeably lower growth trend, attaining a maximum weight of 43.3 g.

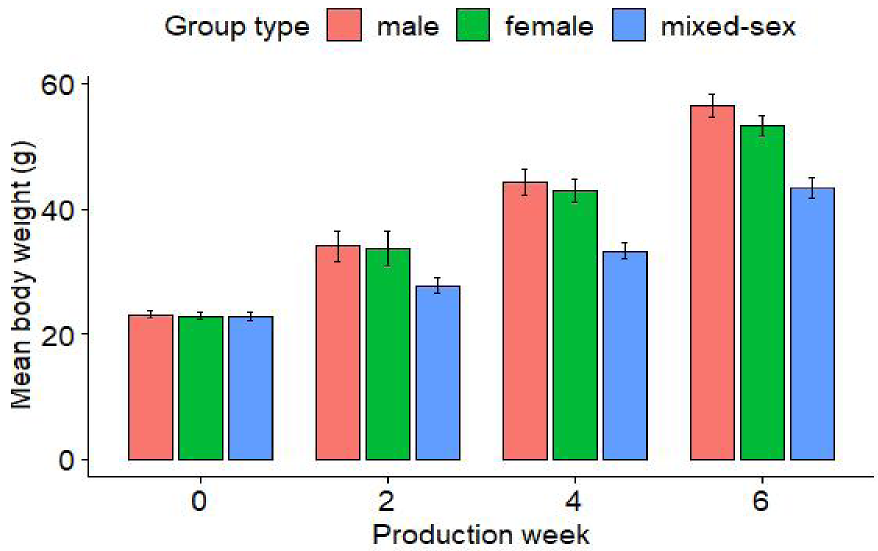

Figure 1. Mean body weight of Nile tilapia sex groups per week during the experiment.

Overall weight gains and specific growth rates

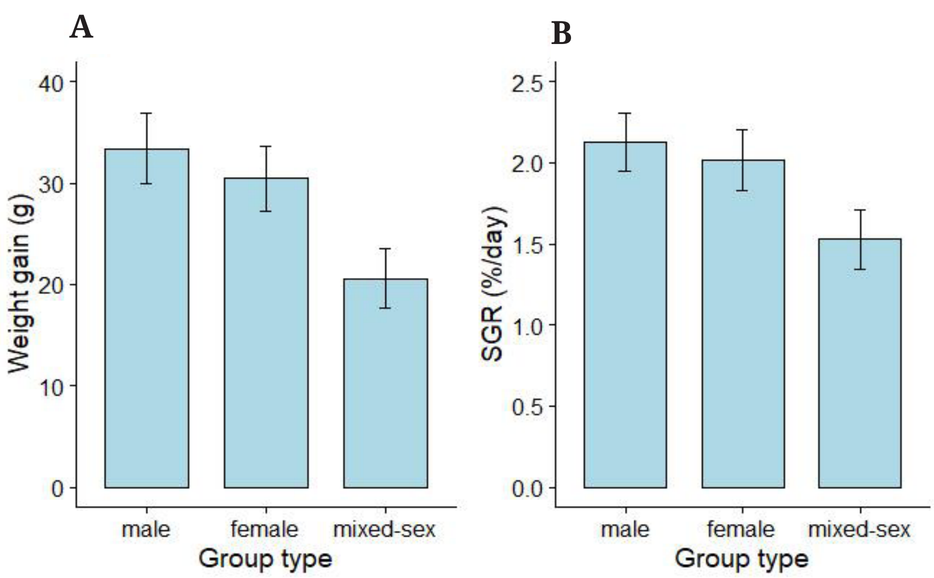

Figure 2. Overall weight gains (A) and specific growth rate (SGR) (B) of tilapia used in the experiment.

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The monosex tilapia groups attained higher weights and SGR than the mixed-sex group, which recorded relatively lower values (Figure 2). The weight gain was 33.4, 30.4, and 20.5g for the monosex male, monosex female, and mixed-sex, respectively (Figure 2a). The SGR also followed a similar trend, with monosex males attaining 2.3% day-1, followed by monosex females (2.1% day-1), and finally mixed sex (1.5% day-1) (Figure 2b). There were indeed significant differences in weight gains ($F = 65.58$; $p < 0.001$) and SGR ($F = 44.78$; $p < 0.001$) among the tilapia sex groups. Specifically, the post hoc pairwise comparisons test showed that monosex males and monosex females had statistically similar growth rates with no significant variations in weight gain and SGR (Table 4). The variations in weight gains and SGR occurred between the monosex groups and the mixed-sex group (Table 4).

Table 4. Post-hoc pairwise comparisons of weight gain and specific growth rate (SGR) between the tilapia sex groups.

Growth parameters		Female	Male
Weight gain	Male	0.063	-
	Mixed sex	< 0.001	< 0.001
Specific growth rate (SGR)	Male	0.11	-
	Mixed sex	< 0.001	< 0.001

Condition factor (K)

All tilapia sex groups showed a change in the 'K' value from the day of the start of an experiment to the final day (Table 5). The values ranged from 1.13 to 2.09. The mixed group and mono sex females had higher initial values, which declined. In comparison, the monosex males had lower initial values, which increased at the end of the experiment.

Table 5. The condition factors (K) of tilapia sex groups.

Sex group	Initial K	Final K
Males	1.13	1.30
Females	2.03	1.82
Mixed sex	2.09	1.68

DISCUSSION

Tilapia are known to exhibit sexual dimorphism in growth patterns, with males generally attaining larger sizes than females (Bhatta et al., 2012; Hernández et al., 2014; Lind et al., 2015; Nguyen et al., 2007). This size disparity has led to a strong commercial preference for male tilapia in aquaculture, primarily due to their superior growth rates (El-Sayed, 2013; Prabu et al., 2019; Sadiq, 2021). However, the findings of this study challenge this conventional view by demonstrating that monosex male and female Nile tilapia can achieve statistically comparable weight gains and growth rates in controlled aquaculture environments. This aligns with the findings of Lind et al. (2015), who reported minimal body weight differences between male and female Nile tilapia, though in mixed culture. With optimal management practices and suitable culture systems (Santos et al., 2019), female tilapia can grow at rates comparable to males, making them equally viable for aquaculture without manipulating the sexes. By considering that the process of producing monosex males often involves complex procedures (Budd et al., 2015), typically requiring the use of hormones that raise environmental concerns (Atar et al., 2009; Suseno et al., 2020), farmers could benefit from using either monosex females or males without relying on hormones. Moreover, our findings indicate that sexual dimorphism is more pronounced in morphometric traits than in overall body weight, suggesting that culturing both monosex male and female tilapia offers a viable, sustainable alternative to hormonal sex reversal techniques.

Monosex tilapia in isolation culture has the advantage of reaching higher weights due to the absence of sexual behaviors driven by the presence of both sexes (Bardhan et al., 2021). In this context, female tilapia have equal growth opportunities, as they are not burdened by maternal behaviors such as mouth brooding. Additionally, Toguyeni et al. (2002) reported that genetic factors related to sexual genotypes in tilapia play a significant role in growth differences, with some populations demonstrating superior female growth. Bhatta et al. (2012) also noted that cortical alveoli development influences growth rates in tilapia during critical reproductive stages in female oocytes and spermatogenesis in males. In the absence of reproductive pressures, as was the case with separated sex groups in this study, tilapias were able to focus on growth rather than reproduction. Additionally, research by Shoko et al. (2015) found that early breeding in female tilapia is not influenced by the culture system itself but by poor food quality and inadequate protein levels (Gunasekera et al., 1995).

Previous studies on other fish species also support the viability of monosex female groups in aquaculture, demonstrating that female fish can outperform males in growth. For instance, Ojolick et al. (1995) found that diploid female rainbow trout (Oncorhynchus mykiss) exhibited robust growth and survival rates, making them suitable for the aquaculture industry. Similarly, Sheehan et al. (1999) found that raising female rainbow trout presented a promising opportunity for aquaculture. They grew faster than male trout, which matured earlier and lost their flesh quality. Ghosh et al. (2007) also observed that female ornamental fish, when farmed separately, showed superior growth in both weight and length when fed a diet supplemented with probiotics. Additionally, Imsland et al. (1997) noted that female turbot fish (*Scophthalmus maximus*) achieved greater average final weights than males despite starting with similar initial weights. Similar growth variability was also observed in Japanese flounder (*Paralichthys olivaceus*), where females grew faster and reached larger sizes than their male counterparts (Yoneda et al., 2007).

The significantly lower growth rate observed in the mixed-sex group is likely due to competitive interactions and differential growth rates between sexes (Hernández et al., 2014). The cohabitation of both sexes can elevate stress levels, primarily due to mating behaviors and social interactions, which in turn may negatively affect growth (Toguyeni et al., 2002). Male tilapia often expend considerable energy on courtship and territorial displays, while females channel their energy into egg production (Bozynski, 1998; Huntingford et al., 2012). Wootton (1985) further reports that the onset of sexual maturation and associated breeding behaviors can significantly divert energy from growth to reproduction. Additionally, the increased stress and competition in mixed-sex populations, as highlighted by Binuramesh et al. (2006), could further cause growth inefficiencies. Therefore, mixed-sex populations may not be ideal for commercial production where maximizing growth and efficiency is critical.

The condition factor (K) is a widely used parameter in aquaculture to assess fish's general health, well-being, and robustness (Dutta, 1994). The higher values indicate better condition and growth efficiency (Dutta, 1994; Otieno et al., 2014; Shalloof and El-Far, 2017). The monosex male group had lower 'K' values than all the experimental sex groups at the initial and end of the experiment. In contrast with other sex groups, the value was

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increasing, while in the female and mixed-sex groups, it decreased. The increase in the 'K' value in the male group may indicate that the fish allocated energy towards growth and maintenance rather than expenditure on reproductive activities (Azaza et al., 2008; Dan and Little, 2000). The monosex and mixed-sex groups started with higher values, which subsequently decreased at the end of the experiment. This decline may imply the presence of physiological stressors that negatively impact their condition. Studies show that females, when reaching the maturation stage, devote much of their energy to reproduction rather than growth (Dan and Little, 2000; Tran-Duy et al., 2008).

On the other hand, the sharp decline in the 'K' value observed in the mixed-sex group might be attributed to social competition and stress resulting from the presence of both male and female fish that have reached gonadal maturation. According to Dutta (1994), variations in fish 'K' value are linked to either gonadal maturation or changes in feeding intensity. Other factors affecting the condition include seasonal variations and associated environmental conditions (Karrar et al., 2016; Shalloof and El-Far, 2017).

The study demonstrated that all recorded water quality parameters remained within the optimal range for tilapia growth, consistent with previous findings (Azaza et al., 2008; DeLong et al., 2009; Makori et al., 2017). The minimal variation in these parameters across the different sex groups, with no significant differences observed, suggests that sex composition does not critically impact water quality management. Therefore, farmers can prioritize growth rates and market preferences when selecting the appropriate tilapia sex composition for culture. These findings align with previous studies, which reported no significant differences in water quality parameters between *O.niloticus* sex groups, particularly between male and mixed-sex populations (Dagne et al., 2013; Githukia et al., 2015). Nevertheless, maintaining water quality within optimal ranges through regular monitoring and effective tank management remains crucial. Optimal water temperatures for tilapia typically range between 25°C and 30°C (Azaza et al., 2008; DeLong et al., 2009; El-Sayed & Kawanna, 2008). However, the semi-arid climate of Dodoma resulted in minimum temperatures dropping to 22°C during the experiment, which may not support robust growth of tilapia (DeLong et al., 2009). The observed slightly elevated dissolved oxygen levels in the female group compared to the male group may suggest lower oxygen consumption among females, as previously reported by Cech et al. (1985) for mosquitofish (*Gambusia affinis*). This could be advantageous for female tilapia, potentially enabling them to survive in environments with very low DO levels (Kolding et al., 2008). The higher DO levels recorded at noon could be attributed to increased photosynthetic activity during daylight hours (Chang and Ouyang, 1988; Datta, 2012), a common phenomenon in aquaculture systems. On the other hand, the lack of significant difference in pH levels between times of the day suggests that the water quality in the tanks was relatively stable. Similar to DO, a slight increase in pH at noon and evening is likely due to photosynthetic activity by aquatic algae in the tanks (Datta, 2012).

CONCLUSIONS AND RECOMMENDATION

This study evaluated the growth performance of monosex males, monosex females, and mixed-sex tilapia cultured in tanks over six weeks. Contrary to common industry beliefs, our findings indicate that the growth rates between male and female tilapia do not significantly differ. Both sexes exhibited comparable growth metrics, suggesting that female tilapia have the potential to match males in growth performance under similar cultural conditions. Given these findings, farmers and aquaculture practitioners should reconsider the reliance on monosex male populations for optimal growth. When cultured separately, female tilapia offer a viable alternative without compromising growth performance. This approach promotes sustainable and non-hormonal aquaculture practices and expands the potential for diverse tilapia farming strategies, enhancing overall productivity and meeting evolving market demands. Further research could explore the specific management practices that optimize growth in monosex female tilapia cultures and assess their viability across different climatic conditions. In addition, the development of efficient sex separation techniques is also recommended, as manual separation may prove impractical in large-scale production systems.

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