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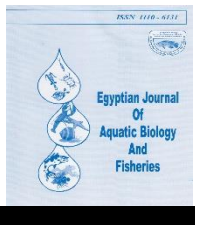

Growth Performance, Feed Utilization, and Survival Rates of Sex-Reversal Male and Mixed-Sex Red Tilapia (*Oreochromis* sp.) in Floating Net Cages: Insights from Sipin Lake

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ABSTRACT

The red tilapia (*Oreochromis* sp.) is increasingly recognized as a crucial species in aquaculture due to its rapid growth rates and adaptability to various environmental conditions. This study aimed to evaluate the growth performance, feed utilization, and survival rates of sex-reversal male versus mixed-sex red tilapia cultivated in floating net cages in Sipin Lake, Jambi. The methodology consisted of cultivating 4,000 red tilapia fish over a period of 90 days within a floating net cage measuring 3x2.5x1.5 m^3. This group included 2,000 sex-reversed males and 2,000 mixed-sex red tilapia, all derived from naturally spawned offspring of 100 males and 300 females, each with an approximate weight of 11.13g. Their diet was homemade formulated, with a protein content of 30%. The results indicated that sex-reversal male red tilapia exhibited superior growth performance, feed utilization, and survival rates compared to mixed-sex group. Weight gain, specific growth rate, feed conversion ratio, and efficiency of feed utilization were 272,87g, 3.59 %/day, 1.30, and 77.15%, respectively, compared to mixed-sex groups. Additionally, the survival rate for sex-reversal males was 54.90%, whereas mixed-sex tilapia exhibited a survival rate of 50.65%. The results indicate that the implementation of sex-reversal techniques in tilapia farming can lead to increased production of larger fish than mixed-sex, which typically command higher market prices.

INTRODUCTION

The red tilapia (*Oreochromis* sp) stands out as a pivotal species in aquaculture, celebrated for its swift growth rates, versatility in various environmental settings, and substantial role in enhancing global food security. This species, originally from Africa

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and the Middle East, has been effectively cultivated in numerous regions around the world, such as Southeast Asia, Latin America, and certain areas of Europe, resulting in its recognition as one of the most extensively farmed fish globally **(Ndiwa *et al.*, 2014; Ahmed *et al.*, 2015)**. The increasing demand for sustainable protein sources, along with the adaptability of red tilapia to different water conditions and temperatures, has positioned it as a favored option among aquaculture practitioners **(Wokeh & Orose, 2021)**. The utilization of floating net cages for tilapia aquaculture has become more prevalent, particularly in regions like Jambi, Indonesia, where the aquatic conditions are conducive to this method. This method enhances fish production while optimizing the use of current aquatic resources, thus bolstering local economies and elevating livelihoods **(Suryana & Litundzira, 2021; Samad *et al.*, 2022)**.

Recent studies underscore the significance of enhancing growth performance and survival rates in aquaculture systems, especially within floating net cages, which present unique benefits like better water quality and reduced competition with wild species **(Mehrim *et al.*, 2018)**. For example, studies show that male tilapia undergoing sex-reversal, when raised at lower stocking densities, demonstrate enhanced growth rates compared to mixed-sex groups, attributed to decreased competition for resources **(Islam & Begum, 2019; Kunda *et al.*, 2021)**. Additionally, systems that incorporate tilapia farming alongside various other species have demonstrated improved feed utilization and economic efficiency, indicating that the integration of different species can enhance aquaculture productivity **(Mehrim *et al.*, 2018; Romana-Eguia *et al.*, 2021)**. These findings highlight the importance of customized aquaculture practices that consider the unique environmental and biological conditions of fish farming.

While advancements have been achieved in the comprehension of tilapia cultivation, notable gaps in knowledge persist, especially regarding the comparative performance of sex-reversed males versus mixed-sex populations within cultural systems such as floating net cages. Although previous studies have examined different facets of tilapia growth, survival, and profitability, there is a scarcity of empirical data that directly contrasts these two methods in comparable environmental condition **(Shamsuddin *et al.*, 2022)**. The disparity is especially evident in the realm of floating net cages, where elements like water quality, stocking density, and feeding strategies can greatly affect results.

Numerous environmental factors such as water quality parameters can affect the growth performance and survival rates of the red tilapia in floating net cages. Comprehending the interplay of these factors with the sex composition of the fish will yield significant insights into refining culture conditions for improved productivity **(Shawky *et al.*, 2018)**. With the growth of tilapia farming, it is essential to evaluate the environmental sustainability of these practices to avoid negative impacts on aquatic ecosystems **(Shechonge *et al.*, 2018)**.

This study emphasized enhancing responsible aquaculture practices implications of tilapia farming in floating net cages, focusing on the potential effects on fish production through practical assessments of the growth performance, feed utilization and survival rates of both sex-reversed male and mixed-sex red tilapia in floating net cages, particularly in Sipin Lake. The results aim to widen the overall comprehension of tilapia farming dynamics and guide aquaculture practitioners in implementing optimal practices.

MATERIALS AND METHODS

1. Location and time of research

This research was carried out at Mekar Sari fish cultiver group in Sipin Lake, Jambi (Fig. 1). Sipin Lake is located at Jambi City of Jambi Province at coordinates 01°20'16.35" S. This lake is about 227 ha and water depths of 2 to 6 meters extend along the village with a basin-shaped bottom.

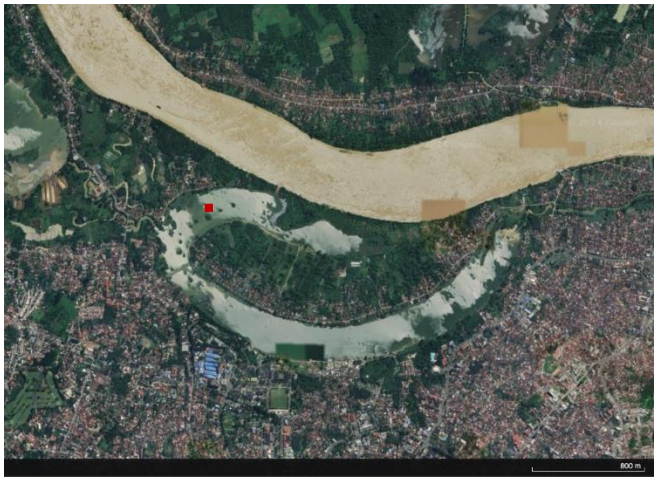

Fig. 1. Maps showing the location (red square) of Sipin Lake, the site of this study (source: https://earth.google.com)

2. Fish preparation and experimental design

Oreochromis sp. fingerling as mixed-sex and sex-reversal male were obtained from Center of Freshwater Aquaculture Development, Sungai Gelam, Jambi, Indonesia. The production of sex-reversal male red tilapia was carried out using Aromatase Inhibitor at a dose of 2,000mg/ kg of feed, starting at the larval age of 7-12 days, and then the fish were raised until they reach a size of 8- 12g for use in the next experiment.

Oreochromis sp. fingerlings, consisting of mixed-sex and sex-reversed males, with 2,000 individuals for each group, were obtained from a single batch of naturally spawned offspring produced by 100 male and 300 female broodstock. Fish with an initial body weight ranging from 11.13 ± 0.026 g to 11.13 ± 0.13 g were randomly distributed into floating net cages (3 × 2.5 × 1.5 m^3) for each group, with a stocking density of 500 fish

per cage. The experiment consisted of two groups of *Oreochromis* sp. fingerlings representing two different red tilapia treatments, each with four replications:
Treatment A (mixed-sex red tilapia), and
Treatment B (sex-reversed male red tilapia).

Fish were cultivated for 90 days, and were fed with a slow-sinking, homemade pellet feed, specifically designed to enhance the growth of red tilapia. The feed ingredients included fish meal, fine bran, tapioca, a vitamin premix (Topmix Gold®, Medion Ardhika Bhakti Ltd, Bandung, Indonesia), and Aminoliquid Boster® (Indosco Dwijaya Sakti Ltd, Surabaya, Indonesia). The ingredients were thoroughly mixed, pelleted into 2– 3mm sizes using a 100– 150kg/ hour capacity pellet machine, and sun-dried until the moisture content reached approximately 10–12% which is suitable for storage. Details of the feed ingredients and their proximate composition (% DM) are shown in Table (1).

Table 1. Ingredients, chemical composition (% DM) of feed

Ingredient	**Composition (%)**
Fish meal	65.00
Fine brand	30.00
Tapioca	2.00
Aminoliquid	1.5
Vitamin premix	1.5
Total	100
Proximate	**Composition (%)**
Crude protein (%)	29.91
Crude lipid (%)	11.13
Fiber (%)	1.26
Ash (%)	14.02
NFE	43.68
Gross energy (kcal g^{-1})*	451.21
E/P value**	15.09

Note: *Calculated based on gross energy according to Watanabe (1988); 1 g of protein contains 5.6 kcal g^{-1}, 1 g of nitrogen-free extract contains 4.1 kcal g^{-1}, and 1 g of lipid contains 9.4 kcal g^{-1}.

3. Data collection and observation

Data collected in this study included fish weight, number of fish, feed consumption, and water quality parameters. Fish weight was measured on days 0, 30, 60, and 90, by sampling 30 fish from each experimental floating net cage at each sampling point. The number of fish was recorded at the beginning and at the end of the cultivation period. Feed consumption was recorded daily from the start to the end of the cultivation. Water

quality parameters, including temperature, pH, and dissolved oxygen, were measured biweekly. Temperature was measured using a digital thermometer, pH using a pH meter (Hanna HI98107), and dissolved oxygen using a DO meter (Lutron-5510).

The parameters observed in this study included initial body weight (IBW), final body weight (FBW), weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR), efficiency of feed utilization (EFU), survival rate (SR), and water quality parameters. Growth performance parameters were assessed by sampling fish every 30 days. The calculations for weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR), and efficiency of feed utilization (EFU) were performed using standard formulas for growth performance and feed utilization, as recommended by the **National Research Council (2011)**.

$$WG\ (g) = (FBW\ (g) - IBW\ (g)$$

$$SGR\ (\%) = 100 \times (Ln\ (FBW\ (g)) - Ln\ (IBW\ (g))/(time\ period\ (days))$$

$$FCR = (Feed\ consumed\ (g))/(WG)$$

$$EFU\ (\%) = 100 \times (Final\ biomass - Initial\ biomass\ (g))/(diets\ fed\ (g))$$

$$SR\ (\%) = 100 \times (Final\ number\ of\ fish)/(Initial\ number\ of\ fish)$$

4. Data analysis

The data obtained were tabulated using Microsoft Office Excel 2016 (Microsoft Corp., Washington, USA) and were analyzed using a t-test at a 95% confidence level to evaluate differences in mean growth parameters, feed utilization, and survival rate between the different treatment groups. Water quality measurements were analyzed descriptively and compared with the recommended standards reported in the literature.

RESULTS

The growth performance and feed utilization of sex-reversal male and mixed-sex red tilapia after 90 days of cultivation in floating net cage Sipin lake are presented in Table (2).

Table 2. The growth performance and feed utilization of sex-reversal male and mixed-sex red tilapia after 90 days of experiment

Parameter	Treatment	
	A	B
	Mixed-sex	Sex-reversal male
IBW (g)	11.13±0.13[a]	11.13±0.08[a]
FBW (g)	178.02±17.20[a]	284.00±50.01[b]
WG (%)	166.89±17.27[a]	272.87±49.99[b]
SGR (% day^{-1})	3.08±0.11[a]	3.59±0.19[b]
FCR	1.51±0.09[a]	1.30±0.08[b]
EFU (%)	66.24±4.08[a]	77.15±4.87[b]

Note: Numbers followed by different superscript letters in the sameline show significant differences on the 5% level of T-test

The results of the current study indicate a significant difference in growth performance between sex-reversal male and mixed-sex red tilapia (*Oreochromis* sp.) after a 90-day rearing period in floating net cages. As shown in Table (2), the final body weight (FBW) of sex-reversal male red tilapia was 284.00±50.01 g, significantly higher than the 178.02±17.20 g observed in mixed-sex red tilapia. This difference in FBW corresponds to a weight gain (WG) of 272.87±49.99% for sex-reversal male red tilapia compared to 166.89±17.27% for mixed-sex red tilapia, demonstrating a clear advantage for the sex-reversal male red tilapia group in terms of growth efficiency.

The specific growth rate (SGR) also favored sex-reversal male red tilapia, with values of 3.59±0.19%/day compared to 3.08±0.11%/day for mixed-sex red tilapia. During 90 days of cultivation in the sex-reversal male red tilapia cage, the growth was faster compared to mixed-sex red tilapia, at 284 grams per fish compared to 178.2 grams per fish, as shown in Fig. (2).

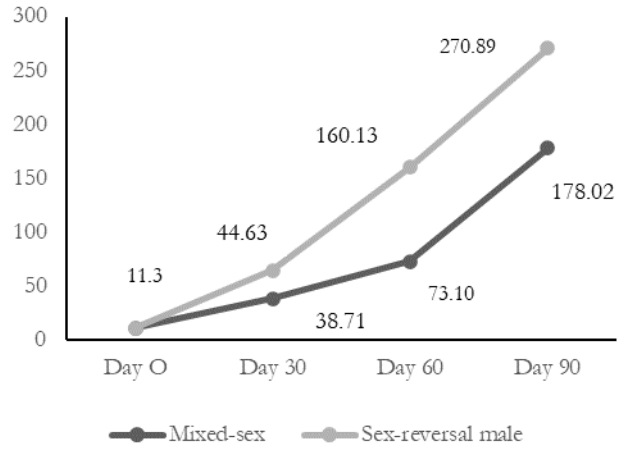

Fig. 2. Average weight during 90 days of red tilapia cultivation

Furthermore, feed conversion ratio (FCR) was significantly better in sex-reversal male red tilapia (1.30±0.08) than in mixed-sex red tilapia (1.51±0.09), indicating that red tilapia utilized feed more efficiently. Similarly, the efficiency of feed utilization was significantly better in sex-reversal male red tilapia (77.15±4.87) than in mixed-sex red tilapia (66.24±4.08). These findings align with previous research that highlights the benefits of sex-reversal male culture systems, particularly in enhancing growth rates and feed efficiency due to reduced competition among fish **(Elfeki *et al*., 2018)**.

The percentage of sex-reversal male and mixed-sex red tilapia that survived in floating net cage cultivation in Sipin Lake is depicted in Fig. (3). Sex-reversal male and mixed-sex red tilapia exhibit statistically significant differences. The survival rates observed in this study indicate that sex-reversal male red tilapia achieved a survival rate of 54.90%, while mixed-sex red tilapia had a slightly lower survival rate of 50.65%. These results suggest a trend favoring sex-reversal male red tilapia in terms of resilience

and adaptability in the floating net cage environment. The difference in survival rates can be attributed to several factors, including genetic predisposition, competition for resources, and environmental conditions, particularly water quality fluctuations in Sipin Lake.

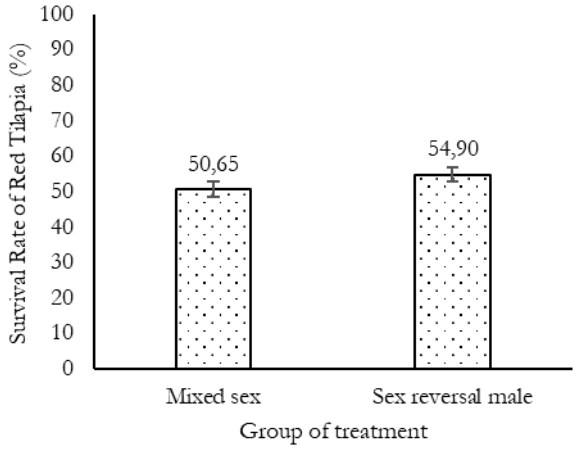

Fig. 3. Survival rate of red tilapia fingerlings

The water quality data collected from Sipin Lake at varying depths (25cm, 50cm, and 1m) reveal important insights into the environmental conditions that may influence the growth performance and survival rates of red tilapia (*Oreochromis* sp.). The key indicators measured including dissolved oxygen (DO), temperature, and pH levels are presented in Table (3).

Table 3. Water quality of Sipin Lake during experiment

Parameter	Water Depth			*Optimum value*
	25 cm	50 cm	100 cm	
T (ºC)	29.7-31.1	29.1-30.1	29.8-30	25-30*
pH	7.19-8.26	7.01-8.19	7.00-7.69	6.5-8.5*
DO (mg L^{-1})	2.5-6.91	2.55-6.75	2.17-5.55	>5**

Note: ***Makori *et al.* (2017)**; ** **Öz and Aral (2023)**.

The dissolved oxygen levels at different depths show variability, with the highest recorded value at 25cm (6.91mg/ L) and the lowest at 1m (2.17mg/ L). The average dissolved oxygen levels across the depth indicate that oxygen availability is a critical factor for fish survival. It is worth mentioning that, dissolved oxygen levels above 5mg/ L are generally considered optimal for tilapia growth, while levels below this threshold can lead to stress increasing mortality rates. The observed fluctuation in oxygen levels,

particularly the drop to 2.17mg/ L at 1m depth, may explain the lower survival rate of mixed-sex red tilapia (50.65%) and sex-reversal male red tilapia (54.90%).

Temperature readings across the depths ranged from 29.07 to 31.1°C, remaining within a suitable range for the red tilapia culture. Research indicates that the red tilapia thrive in temperatures between 25 and 32°C, making the conditions in Sipin Lake conducive for growth. The pH levels recorded in Sipin Lake ranged from 7.0 to 8.26, which falls within the acceptable range for the red tilapia culture (6.5 to 9.0). The pH levels at different depths indicate a slightly alkaline environment, which is favorable for the growth of the red tilapia.

DISCUSSION

The findings in this study regarding the growth performance and survival rates of sex-reversal male and mixed-sex red tilapia (*Oreochromis* sp.) in floating net cages provide significant insights that align with and expand upon recent research in the field. Various studies have shown that the use of sex-reversal male red tilapia can enhance growth efficiency and survival rates compared to mixed-sex populations.

Recent research also shows that the use of hormones such as 17α-methyltestosterone (MT) to produce sex-reversal male tilapia populations can enhance growth performance. Various studies, including one conducted by **Berhanu (2023)**, show that the inclusion of MT in the diet can result in better growth and the desired sex ratio. This is consistent with research by **Zhang *et al*. (2019)**, which indicates that hormone use can affect gonadal development and fish growth.

A study by **Ndour *et al*. (2021)** demonstrated that the use of plant-based feed additives significantly improved the growth performance and survival rates of tilapia, suggesting that dietary composition plays a crucial role in optimizing fish growth. This supports the notion that nutritional strategies, alongside sex control, can enhance the overall performance of tilapia in aquaculture settings. Similarly, **Suwannatrai (2023)** reported acceptable protein levels in the Nile tilapia, which is critical for growth performance, reinforcing the importance of dietary protein in achieving optimal growth rates.

Moreover, research by **Suryaningrum and Samsudin (2020)** highlighted the positive effects of incorporating green seaweed into tilapia diets, which did not interfere with growth performance and feed conversion ratios. This finding suggests that alternative feed ingredients can be explored to further enhance the growth of the red tilapia, particularly in sex-reversal male red tilapia populations that already demonstrate superior growth characteristics.

The superior growth performance of the sex-reversal male Nile tilapia can be attributed to several factors, including reduced aggression and competition for resources, which are often more pronounced in mixed-sex populations **(Elfeki *et al*., 2018)**.

Additionally, sex-reversal male red tilapia, particularly males, are known to exhibit faster growth rates due to their hormonal treatment during the fry stage, which promotes muscle development. This aligns with findings from studies that have shown enhanced growth performance in male tilapia compared to mixed-sex populations across various aquaculture systems **(Hussein, 2011; Elfeki *et al*., 2018)**.

Moreover, the implications of these findings extend beyond mere growth performance. The ability to produce larger, more uniform fish in monosex cultures can lead to increased economic returns for aquaculture operations, as larger fish typically command higher market prices **(Elfeki *et al*., 2018)**. This economic advantage is crucial for aquaculture sustainability, particularly in regions where tilapia farming is a significant source of livelihood **(El-Sayed & Fitzsimmons, 2023)**.

In terms of survival rates, the study by **Hossain *et al*. (2022)** indicated that stocking density significantly affects the growth and survival of tilapia, with lower densities yielding better performance. This is particularly relevant to the current study, as the management of stocking densities in floating net cages could further optimize the growth and survival of both sex-reversal male and mixed-sex red tilapia.

The correlation between water quality parameters and the survival rates of sex-reversal male and mixed-sex red tilapia in Sipin Lake is evident. The higher survival rate of sex-reversal male population (54.90%) may be attributed to their ability to better cope with the fluctuating oxygen levels and the stable temperature and pH conditions present in the lake. In contrast, the mixed-sex population, which may experience increased competition and aggression, could be more susceptible to the adverse effects of lower dissolved oxygen levels, particularly at greater depths.

The water quality parameters observed in Sipin Lake, particularly dissolved oxygen (DO), temperature, and pH, play a crucial role in determining the health and survival rates of red tilapia (*Oreochromis* sp.). The dissolved oxygen levels fluctuating significantly across different depths are critical, as dissolved oxygen is a vital factor for aquatic life, influencing metabolic processes and overall fish health. Research indicates that adequate levels of DO (generally above 5mg/ L) are essential for optimal growth and survival in fish populations **(Ali *et al*., 2022)**. The lower survival rate in this study may be attributed to the reduced oxygen availability at greater depths, which could lead to increased stress and mortality rates, as highlighted by previous studies **(Ali *et al*., 2022)**.

Temperature readings in Sipin Lake ranged from 29.07 to 31.1°C, remaining within the optimal range for red tilapia growth. However, fluctuations in temperature can have significant effects on water quality parameters including dissolved oxygen levels. As noted by **Abouelsaad *et al*. (2022)**, higher water temperatures can lead to decreased DO levels and increased concentrations of nutrient pollutants, which may exacerbate the effects of eutrophication. The relatively stable temperatures observed in this study suggest that thermal stress is not a primary concern; however, the interplay between temperature and dissolved oxygen levels must be closely monitored to ensure the health

of the fish populations. Maintaining stable pH levels is crucial, as significant fluctuations can lead to stress and in turn affect metabolic processes in fish **(Ali *et al.*, 2022)**. The observed pH levels align with the acceptable range for tilapia, which is typically between 6.5 and 9.0.

Furthermore, the findings of this study coincide with the work of **Mehrim *et al.* (2018)**, which assessed the impact of monoculture and polyculture systems on growth performance and feed utilization in tilapia. Their results indicated that monoculture tilapia systems could yield higher growth rates and better feed conversion ratios. The practical applications of these findings are significant for aquaculture practitioners.

The demonstrated advantages of sex-reversal male red tilapia culture suggest that farmers should consider adopting this practice to maximize yield and profitability. Additionally, the insights gained from this study can guide the development of best practices for feeding strategies and environmental management in floating net cage systems **(Elfeki *et al.*, 2018)**.

However, it is essential to consider the potential limitations of this study, including the specific environmental conditions of Sipin Lake, which may not be generalizable to other aquaculture settings. Future research should aim to replicate these findings across different environments and with varying stocking densities to validate the robustness of the results **(Hussein, 2011)**. While the findings are promising, several limitations must be acknowledged. The study was conducted over a relatively short duration of 90 days, which may not fully capture the long-term growth trends and survival rates of the red tilapia in floating net cages.

CONCLUSION

These results suggest that sex-reversal male red tilapia not only grow faster but also demonstrate better survival rate under the conditions tested. The findings underscore the advantages of utilizing sex-reversal male red tilapia in aquaculture practices, particularly in enhancing growth performance and feed efficiency. Overall, this study provides valuable insights into the potential benefits of sex-reversal male red tilapia culture in floating net cage, especially in Sipin Lake, which can contribute to more sustainable and productive aquaculture systems.

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