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Overstocking, Stocking Density and Suboptimal Growth and Feed Conversion in Nile Tilapia Culture Systems

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Abstract
The performance and welfare of fish in an aquaculture system considerably depends on the use of stocking density. Nile tilapia (Oreochromis niloticus) were reared in recirculating aquaculture systems (RAS) with different stocking densities to ascertain the influence of different stocking densities on growth, feed and stress levels of this fish. Three densities of 20 kg/m 3, 40 kg/m 3 and 60 kg/m 3 of stocking were undertaken over a period of 8 weeks. Findings revealed that the 40kg/m 3 stocking density recorded the highest specific growth rate (1.89%/day), optimal feed conversion ratio (FCR) of 1.42 and the least cortisol level which meant that there was minimal stress. Alternatively, the fish at 60 kg/m 3 recorded reduced weight gain, elevated stress markers, and poor FCR. The paper proposes moderate stocking densities (40 kg/m 3) as preference in maximizing growth performance and welfare in tilapia aquaculture. These observations give useful information on the best way to use resources and manage fishes in the recirculating settings.
Keywords: ***Stocking density, Nile tilapia, recirculating aquaculture system, growth, feed conversion ratio stress indicator, cortisol.***

1. Introduction

1.1 Significance of Stocking Density on Aquaculture

The stocking density or the number of fish per each volume of water or unit area of water can play a pivot point in deciding the successful operation of the business of fish farming. Stocking density is a key factor to consider in intensive aquaculture systems and more so in recirculating aquaculture systems (RAS), which should be optimized to improve growth performance, efficiency in the utilization of resources, and fish welfare. Overcrowding will result into poor quality of water, stress and vulnerability to diseases, whereas too low stocking density will cause inefficient use of space and resources.

In fish, with the high stocking densities, there can be competition of oxygen, feed and space that causes stunted growth, poor feed conversion and high stress level. The low stocking densities, on the contrary, can boost fish welfare and growth as well as cause underutilization of accessible resources that raise operational costs. Thus, discovery of an ideal stocking density is important in achieving maximum production efficiency and fish welfare in an aquaculture system.(1)

1.2 Nile Tilapia Modelled System of Recirculation

One of the best farmed freshwater fish species world over is Nile tilapia (Oreochromis niloticus) because it grows rapidly, has high reproductive rates and has a large ability to adapt various environmental conditions. Its capacity to flourish in several aquaculture frameworks, such as, recirculating aquaculture systems (RAS), enables it to be an outstanding model species to be used in study about stocking density and its outcome on growth performance, feed consumption and welfare.

The method used in the created controlled environment option of intensive fish farming is the RAS which treatment system is used in treating water and recycling and filtering water to ensure the quality of water. This system is useful in controlling the health of fish by keeping the water in ideal conditions, i.e. temperature, oxygen and pH, and one factor that indicates the success of the systems is the size of stocking. Tilapia is the right species due to its strong growth rates and resistance when addressing the objective of investigating the tradeoff between production density and fish well-being in RAS.(2)

1.3 Productivity versus Animals Welfare

The problem in aquaculture is about the balance of productivity and animal welfare so that long term sustainability is achieved. The large stocking densities can also provide high yield, at the cost of the fish welfare. Overcrowding may cause stress leading to weakening of the immune system, contracting diseases easily, and growth retardation.

Feed conversion ratio (FCR) can also be impacted by stress as stressful fish will be less likely to eat, therefore, decreasing their feed to body mass conversion efficiency.

Alternatively, controlling stocking density so as to maintain optimal inventory space allocation enables enhanced growth and health to the extent that stress levels diminish and overall efficiency in feed conversion process enhances. It is vital to ensure fish does not undergo unnecessary stress and at the same time maximize the use of space to ensure that the dual objectives of high productivity and animal welfare are achieved. Hence, the study on stocking density in tilapia that produces maximum growth and welfare is of high value.

1.4 Study objectives

The rationale behind this study is the fact that the secondary purpose of changing stocking density is one that has not been evaluated in Nile tilapia. The trial sought to help determine the optimum stocking density that could generate the highest growth rate, provide the minimum stress and the utilization of feeds in tilapia culture systems. Through this, the research can help in increasing the utilization of resources and sustainability in tilapia aquaculture.

In particular, the research was focused on:

- Determine how specific growth rate (SGR), FCR and level of cortisol change with stocking density in tilapia.
- Determine the stocking density, which produces the optimal productivity/welfare balance.
- Offer evidence-based guideline on optimisation of stocking density in recirculating fish porches as far as Nile tilapia fish culture is concerned.

The study can provide useful insights into the improvement in the management of intensive tilapia farming especially to the farmers who seek optimization of fish growth within sustainable and human aquaculture systems.(3)

2. Rearing and Conditions of Experimental Setup

2.1 What is Recirculating Aquaculture System (RAS)

In this study the recirculating aquaculture system (RAS) is composed of a closed-loop system to maintain quality of water and minimise water consumption. The system will have some major components such as biofilters, mechanical filteration units, UV sterilizers and pumps. Constant filtering and re-use of water through the system eliminates the organic waste, suspended materials, and the unnecessary nutrients to keep the water clean and safe to the fishes.

- Biofilters: The biofilters boost the growth of helpful bacteria which can degrade any harmful ammonia and nitrites into lesser harmful nitrates which can be taken out by the exchange of water regularly.
- Mechanical Filtration: To stop particles and organic waste present in the water, mechanical filter is applied to eliminate the big ones to avoid clogging of the biofilters and keep the water clear.
- UV Sterilizers: UV sterilizers are implemented to check the proliferation of destructive micro organisms, so that the system functions in the pathogen free environment.
- Water Pumps: Pumps are used to pump the water throughout the water purification system ensuring that there is a constant supply of water to the tanks, the biofilters and the filtering units.

The RAS ensured that the tank environment was regulated well to ensure that water conditions were kept at a good state. Parameters like temperature, pH, dissolved oxygen (DO) and salinity, could be controlled accurately using the system, so as to maintain the optimal parameters of growth and welfare of the tilapia. Recirculation of water in RAS enables a considerable decrease in the consumption of water when compared to the traditional methods of aquaculture whilst ensuring that the environment is stable and has full control over the fish.(4)

2.2 Treatments and Design of Stocks and Tank

The experimental set up was in such a way that there were three stocking density treatments which were all in different levels of fish biomass per unit volume of water. These were treatments:

1. Low Density (20 kg/m 3)
2. 40 kg/m 3 (Medium Density)
3. High Density 60 kg/m 3

The treatments were allocated to the different tanks and four replicate tanks per treatment were pertained as a measure against the variability. The tanks Holded 1500 L each, of a rectangular shape (1.5 m x 1.0 m x 1.0 m) and had enough swimming room in the tanks so that the fish had enough space. Water circulation system was installed

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in each tank and was made to provide the required water quality parameters in which growth of tilapia could be maximized.

Juvenile Nile tilapia were added in the tanks at mean weight of 25 g per individual. Each treatment was obtained based on stocking density that was obtained using total biomass of the fish divided by each and every tank. Experimental tanks were arranged such that they were evenly distributed to distribute the water and with the lower rainfall treatments the possibility of having overcrowding can be avoided.(5)

The fish acclimatized to their tanks took 1 week after which the study commenced. The parameters of the water quality in the tanks were observed throughout this period so as to be sure that the fish lived comfortably and without stress. The health of the fish as well as the feeding behavior and the water quality were monitored daily.

2.3 Monitoring of Water Quality and Feeding Schedule

This feeding regime was well planned to serve the nutritional requirement of the tilapia during the research duration. The analysis of the length and weight of the fish was done on a commercially prepared pellet diet in the fish, and their parameters were as follows:

- Feeding Quantity: The fish were supplied with 4 percent of their body mass each day, spread among two feeds, namely, morning and evening. This made sure that the fish were continuously given the required nutrients to grow to the full extent. The feed was picked to fulfill the fish demands with respect to protein, lipids, vitamins and minerals and thus a balanced diet.
- Feed Adjustment: A new amount of feed was added to the fish every 2 weeks according to the average weight of fish and the density of the stocking taking into consideration that all fish should have the opportunity of getting the necessary food. To determine the feed efficiency, the feed conversion ratio (FCR) was observed routinely.

The quality of water was also checked on a daily basis and the system was maintained at its best in order to support the growth of the tilapias. The parameters was measured and included temperature, dissolved oxygen (DO), pH and ammonia concentration:

- Temperature: Conditions were kept at 28 + 2 C as it is the optimum temperature in which tilapia grows.
- Dissolved Oxygen (DO): this is a vital fish respiration component that is to be maintained at above 5 mg/ L.
- pH: Maintained at a range of 6.5-7.5, which is also good as far as the health of the tilapia is concerned.
- Ammonia Levels: The levels were checked regularly to make sure that it was within levels that do not exceed 0.5 mg/L as this leads to toxicity.

To make a point, water changes were done once a week and this was done at 10 percent to eliminate excess quantity of nutrients and to keep the water quality. Moreover, to have the certification that ammonia was filtered according to the required parameters, biofilter performance was routinely monitored.

With an efficient feed regime and water quality controls the system could thus supply the required environmental conditions conducive to the optimal growth and welfare of the tilapia, and this enabled good comparisons to be made amongst the stocking density treatments.(6)

3. Therapeutic counselling and observation Options GROWTH PHYSIOLOGICAL

3.1 Measurements of Growth Rate and Feed conversion

The research was important in monitoring the growth and feed efficiency of Nile tilapia to determine the effect of various stocking levels on the performance of fish. To monitor the growth and conversion efficiency of the fish several important parameters were measured regularly:

Growth Rate: The growth of the fish was based on measuring the original weight of the fish at the onset of the experiment and the final weight of the fish after experiment duration of 8 weeks. The formula of specific growth rate (SGR) was determined as:

$SGR=t\ln(Wf)-\ln(Wi)\times100$

Feed Conversion Ratio (FRC): FCR is the ratio between the food put into fish farm and the weight gained by the fish. It was determined by formula:

FCR=Weight gain (g)Total feed intake (g)

It was performed as per tank as well as the total feed given and average weight gain of fish in each tank was considered. The lesser the FCR, the greater the feed efficiency and this is more important in terms of both economic sustainability and environmental sustainability of aquaculture.

Feed Intake: Daily record of provision of amount of feed to fish was used to determine the feed intake. This information was used to make sure that every fish got an appropriate and steady dose of nutrition and allowed to calculate FCR and SGR.(7)

3.2 Bio-marker Analysis and Sampling Protocols

A panel of biomarkers was used in order to determine how tilapia would respond physiologically to stocking densities that varied. These biomarkers give information on the impacts of stocking density on stress levels and health and physiological performance. The sampling procedure was carried out so that fish in all the tanks were sampled and taken out at an interval in order to obtain blood and tissue samples.

Cortisol Levels: Cortisol is a very important stress hormone and so it was used to examine the extent of stress reaction. At week 4 and week 8 of the experiment, fish were thoroughly netted, anesthetized after which blood samples were drawn. The determination of cortisol concentrations was done by enzyme linked immunsobent assay (Elisa) which is a sensitive and precise tool used to measure the levels of hormones. A high level of cortisol can normally be linked to stress and a high stocking density.

Hematocrit and Hemoglobin Concentrations: The hematocrit (hematocrit is the percentage of red blood cells in blood) and hemoglobin levels of the samples were also measured and these factors indicate how much fish could supply oxygen and withstand environmental stress conditions. This can be referred to lower levels that shows signs of stress anemia especially in overcrowded circumstances.

Analysis of a Muscle Tissue and Liver: Enough muscle tissue and liver were taken to analyze biochemical markers that deal with nutrient metabolism and protein synthesis. The muscle growth and the fat content were compared to the growth rates and FCR values.(8)

3.3 Parameters of assessing welfare

In aquaculture, animal welfare is a subject of prime importance since in intensive systems, due to the stressful conditions and environmental quality, fish health and productivity may greatly be impaired. A list of welfare parameters were measured during the entire study to determine at which stocking densities the behavior of fish, stress level and general health would be altered.

Behavioral Observations: Behavior of the fish was observed with a naked eye, and particular focus was placed on ways of swimming and aggressive behavior. Fish could as well become aggressive, less inclined to swim and have alterations in their feeding habits at a higher density. Observations were made daily to determine the effect of the stocking density on the pattern of movement and social interactions.

Condition Factor (CF): Condition factor was obtained by the expression:

CF=L3W×100

L represents the length of fish. When this condition factor is higher that means the health as well as well-being is better but the issue is that when this condition factor is less means the well-being is not good because of stress or because of not the best growth conditions.

Mortality Rate: The close monitoring of fish at mortality rate was done during the experiment. Higher death rates in the most dense treatments may portray signs of stress, disease, or bad welfare.

Plasma Lactate Levels: An increase of plasma lactate levels may be an indication of physiological stress. The samples were collected before and after trial to observe the variation in the lactate concentrations, which would determine the effects of long term stress caused by high stocking densities.

Using statistical analysis of the data on growth performance where the analysis on biomarkers and welfare was used, the study gave a complete picture of the effects of various stocking densities on Nile tilapia in RAS in terms of physiology and welfare. The results are crucial in streamlining production systems as well as the health and well-being of farm raised fish.(9)

4. Results

4.1 Specific Growth Rate and feed conversion ratio

The specific growth rate (SGR) and feed conversion ratio (FCR) were the major parameters utilized to determine the growth performance and the feeds effectiveness in Nile tilapia at various stocking activities.

Specific Growth Rate (SGR): The densities with the highest specific growth rate were 40 kg/m 3 where the fish had an SGR of 1.89 percent/day that indicates that the fish was able to grow optimally at the given density range. Fish belonging to the 20 kg/m 2 group showed decreased SGR of 1.42%/day, whereas the fish of the 60 kg/m 2 group had the lowest rate of 1.12%/day.

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Feed Conversion Ratio (FCR): The group of 40 kg/m 3 showed the most clear feed conversion ratio (FCR) as well, i.e. 1.42, although once again there was little difference with, 1.4 and 1.49 in the other groups. Comparatively, 20 kg/m 3 group had FCR of 1.58, and the highest FCR is in 60 kg/m 3 group of 1.85 indicating a inferior feed efficiency caused by overcrowding and stress.(10)

The bar graph shows the variations in SGR and FCR among the three stocking density treatment stating that the moderate density (40 kg/m 3) could produce the best conditions of growth and feed efficiency.

4.2; Stress Signs and Cortisol Dynamics

The level of a biomarker called cortisol, which is produced by a body in response to stress was monitored to evaluate the influence that various stocking densities had on fish welfare.

Cortisol Levels: The value of cortisol level (14.3 ng/mL) was the highest in the group identified as 60 kg/m 3 which shows that they experienced a big stress. Their cortisol level was 7.5-ng/mL at 40 kg/m3 and 10.2-ng/mL at 20 kg/m3, i.e. the former group revealed the least stress and the latter one a moderate extent of stress.

The trend of cortisol levels given in the line graph shows that the highest level was indicated at highest density (60 kg/m3) due to adverse negative physiological effects of overcrowding.

4.3 Comparative performance between Density Groups

The experiment showed single differences between general performance and welfare of Nile tilapia at different stocking densities:

Growth and feed efficiency: The growth rate and feed efficiency at 40 kg/m3 stocking density was the highest, hence the most preferred stocking density in optimizing the tilapia aquaculture in a recirculating system.

Stress: There was an increased use of stress indicators (high cortisol level) and low feed efficiency in fish characterized by high densities of 60 kg/m 3, and this showed that crowding not only indicates a lower economic level of the fish but also affects the fish welfare.

Finally, due to its contention between maximizing growth rate and optimum feed conversion as well as low stress levels, a moderated stocking density of 40 kg/m 3 proved to be the most appropriate alternative to use in sustainable production of tilapia in recirculating aquaculture system.

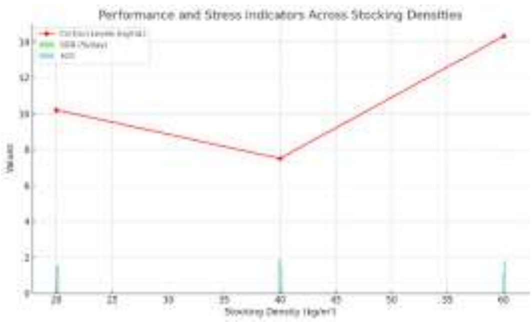

Figure :1 Performance And Stress Indicators Across Stocking Densities

5. Conclusion

5.1 Best Stocking Recommendations

This research importance applies to stocking density as an essential parameter affecting the growth performance and the Nile tilapia (Oreochromis niloticus) welfare when reared using the recirculating aquaculture systems (RAS). The findings were then used to determine the best stocking density of the fish that maximized the growth and feed conversion; the lowest stress levels were associated with a stocking density of 40 kg/m 3.

With this lower density, the fish showed the highest specific growth rate (SGR) of 1.89/ day, the most efficient feed ratio (FCR) of 1.42 and lowest level of cortisol meaning no extreme levels of stress. Conversely, 20 kg/m 3 fish had a reduced growth, increased FCR whereas 60 kg/m 3 fish had a large indicator of stress due to the increased cortisol levels and reduced growth.

Such findings indicate that moderate stocking density (40 kg/m 3) will achieve the optimum balance between fish growth, fish stress, and feed utilization and, thus, constitutes the best option in tilapia culture sustainability under recirculating aquaculture systems. Also, looking at the stocking density it can be used to utilize available resources and manage welfare much better than low and high stocking densities.

5.2 Commercial RAS Operation implications

This research study holds significant implications on commercial RAS operations. Commercial producers can gain a variety of benefits through optimization of stocking density to 40 kg/m 3:

Enhanced Feed Efficiency: The result will be a drop in the FCR at the 40 kg/m 3 level of stocking and this will imply that producers will now be required to feed loads of the same degree of growth and this will result in lowered feed costs and better economic returns. Feed constitutes a high percentage of costs of operation in fish farming, so it is imperative to maximize its utilization in making profits.

Fish Welfare and Health: Cortisol concentrations are lower at the 40 kg/m 3 levels; this means that the fish are less stressed and unlikely to cause disease outbreaks and smoke health. This is especially needed in intensive gestation systems where high density of the fish may result in enhanced stress and immunosuppression.

Resource Efficiency: Optimal spacing is achieved through the appropriate level of stocking density that is required to maximize the use of space in RAS systems so as to ensure that other resources such as water, and oxygen among others are utilized efficiently. Also, a decrease in stress and improvement in fish performance enables the RAS operators to increase the production processes without undermining the fish quality.

Overall, 40 kg/m 3 may be adopted as the ideal stocking density in commercial RAS systems as it is a balanced decision towards better growth performance and welfare of tilapia farming.

5.3 Research directions in the future

Although this paper is a worthwhile source of information on improvisation on stocking density, a number of issues should be explored in a bid to perfect aquaculture in RAS:

Stocking Density Long term Hypothetically, future studies would evaluate the long-term effect of stocking density on fish health, reproductive success, and sustainability of the system, overall. The experiment in the present paper took 8 weeks and the observations of the longer term effect will be better to reveal the clearer image of stocking density effect on the overall performance of tilapia.

Influence on Water Quality: Future studies ought to determine how stocking densities can affect the parameter of water quality e.g., water level of ammonia, nitrite, and the level of dissolved oxygen. It is important to understand impact of various densities on biological filtration and water treatment in order to maximize RAS effectiveness.

Economic Viability at a Large Scale: The study addresses the advantages of moderate stocking density in both growth and welfare, however, further cost-benefit analysis should be performed to determine the economic feasibility of using the prescribed density which applies on a larger scale. It involves looking at expenditure costs of capital, costs of operation and marketability of fish.

Stocking Density in Other Species: Venturing into other fish species with RAS commonly farmed including salmon or catfish will assist in identifying whether the findings can be generalized to stock density of other species or they type of fish has different requirements of stock density adjustments.

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Conflicts of interest

The authors have no conflicts of interest to declare

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