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THE EFFECT OF THE EXTRACTIVE SPECIES PLACEMENT MODEL ON THE FEED CONVERSION RATIO (FCR) OF TILAPIA IN THE INTEGRATED AGRICULTURE AQUACULTURE (IAA) SYSTEM OF THE GIS-BASED FLOATING-BED MODEL

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Abstract

The two main sectors, agriculture and fisheries, play an important role in ensuring food security and community nutrition. However, limited land, water resources, and energy are problems that these two sectors often face. Research on FCR on a GIS-based floating-bed model IAA system can provide important information on how to improve the efficiency and productivity of the system. This study aims to determine the effect of the extractive species placement model on the Feed Conversion Ratio (FCR) of tilapia (Oreochromis niloticus) in the Integrated Agriculture Aquaculture (IAA) system of the GIS-based floating-bed model. The study used a Complete Random Design (RAL) with three treatments and three replicates. The treatments tested were Treatment A (no floating-bed transfer during maintenance), Treatment B (10-day interval transfer), and Treatment C (20-day interval transfer). The research was carried out for 90 days in the pool of the People's Hatchery Unit (UPR) Sipurennu, Citta District, Soppeng Regency. The main parameter observed is the FCR value. The results showed that the FCR values in Treatment A, B, and C were 1.03, 1.09, and 1.08, respectively. ANOVA analysis showed no significant difference between treatments (F=0.389, Sig.=0.694). The conclusions of the study showed that the effect of the extractive species placement model on the Feed Conversion Ratio (FCR) of tilapia (Oreochromis niloticus) in the Integrated Agriculture Aquaculture (IAA) system of the GIS-based floating-bed model effectively resulted in a low FCR value in the range of 1.03-1.09, with the lowest value at treatment A (without floating-bed transfer during maintenance).

Keywords: extractive species; FCR; floating-bed; gis; IAA

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INTRODUCTION

The two main sectors, agriculture and fisheries, play an important role in ensuring food security and community nutrition. However, limited land, water resources, and energy are problems that these two sectors often face. To address this problem, an integrated and effective approach to natural resource management is needed, (Taufiqurrahman et al., 2019). Promising solutions to integrate aquaculture and agricultural activities are available through the Integrated Agricultural Aquaculture (IAA) System. By using waste as inputs for other systems, IAA Systems improve resource utilization, increase efficiency, reduce production costs, and reduce negative impacts on the environment, (Nhan *et al.,* 2007).

Freshwater aquaculture is an important source of animal protein for human nutrition. Only 11.3% of the 2.8 million hectares of land available for fresh aquaculture in Indonesia have been utilized (KKP, 2023). Although domestic and export freshwater fish demand continues to increase (KKP, 2023; FAO, 2022), aquaculture waste is an increasingly worrying problem. In the cultivation area, feed waste accounts for 39-63% of nitrogen (N) and 18-30% of phosphate (P) (Nederlof *et al.,* 2021). Climate change has also caused the response of physical, chemical, biological, and ecological ecosystems to change, negatively impacting production systems (Predragovic *et al.,* 2023; Pereira *et al.,* 2023). Freshwater scarcity is increasing, including in Indonesia (Taskov *et al.,* 2021). Therefore, freshwater aquaculture methods that use adaptation and mitigation approaches are currently indispensable.

Diversification and environmentally friendly practices are essential components for successful aquaculture adaptation and mitigation (Maulu *et al.,* 2021). One example of good practices of aquaculture is an integrated system that nurtures various organisms simultaneously (Jumiati *et al.,* 2023). Diversification and environmentally friendly practices are essential components for successful aquaculture adaptation and mitigation (Maulu *et al.,* 2021). One example of good practices of aquaculture is an integrated system that nurtures various organisms simultaneously (Jumiati *et al.,* 2023). The IAA system combines the agriculture and fisheries sectors for diversification and intensification (Ignowski *et al.,* 2023), which can increase productivity by maximizing the utilization of soil, water, and feed resources (Hasimuna *et al.,* 2023). This system also has the potential to increase the income, efficiency, and welfare of cultivatorsi (Ignowski *et al.,* 2023), which can increase productivity by maximizing the utilization of soil, water, and feed resources (Hasimuna *et al.,* 2023). This system also has the potential to increase the income, efficiency, and welfare of cultivators (Ibrahim *et al.,* 2023).

Feed is the main source of waste in aquaculture activities (Boyd and McNavin, 2015) and its cost can reach more than 50% of the total production cost (Van *et al.,* 2017). Research shows that only 30% of feed nutrients are consumed and digested by fish, while the rest is released into water (Radiarta *et al.,* 2014). If the waste exceeds the tolerance limit, it can cause stress to the fish and even death (Puspaningsih *et al.,* 2018).

Feeding Rate (FR) is the amount of feed given to fish every day (Effendi, 2012). Increased FR can increase production, but also potentially lower water quality (Jescovitch *et al.,* 2018). Optimal FR results in the lowest Feed Conversion Ratio (FCR), allowing for a reduction in waste and production costs (Mengistu *et al.,* 2020). FCR is calculated by dividing the weight of the feed given by the increase in fish weight (Craig et al., 2017) and varies depending on the species, size, level of fish activity, environment, and aquaculture system used.

In this study, the organisms used were tilapia (Oreochromis niloticus) as a fed organism, kijing shellfish (Pilsbryoconcha exilis) as an organic extractive organism, and rice (Oryza sativa) as an inorganic extractive organism. The floating-bed system was chosen as the IAA model because it allows optimal land use with plants planted on a floating raft in a fishpond. In the floating-bed model IAA system management, Geographic Information Systems (GIS) technology is integrated to help map resources, analyze land suitability, and support decision-making in system management (Nath *et al.,* 2021).

This study aims to determine the effect of the extractive species placement model on the Feed Conversion Ratio (FCR) of tilapia. The results of the research are expected to provide important information on how to improve the efficiency and productivity of IAA systems and help develop more environmentally friendly and efficient systems.

METHOD

This study used an experimental method with a Complete Random Design (RAL), consisting of nine pond plots divided into three treatments with three replicates, namely treatment without floating-bed transfer during maintenance as a control (A), floating-bed transfer with an interval of 10 days (B), and floating-bed transfer with an interval of 20 days (C), (Gomez & Gomez, 2007; Rakocy *et al.,* 2006). The research was carried out from September to December 2024 at the Sipurennu People's Hatchery Unit (UPR) pool, Citta District, Soppeng Regency. The tools used include a maintenance pond, digital scales, rockwool as a rice planting medium, tray trays for feed fermentation, and water barrels, while research materials include tilapia (Oreochromis niloticus), kijing clams (Pilsbryoconcha exilis), rice (Oryza sativa), commercial feed, vitamin boosters, probiotics, and fresh water.

The observed variables included tilapia growth expressed through the amount and weight of biomass, the amount of feed given, and water quality parameters, with fish weight measurements carried out every 10 days using digital scales. The study population consisted of 100 tilapia per pond, with a sampling technique using stratified sampling, where the population was divided into several strata and samples were taken randomly from each stratum to obtain representative data. This approach is in accordance with the principles of the design of fisheries experiments and integrated aquaculture systems that emphasize the efficiency of resource utilization as well as the stability of aquaculture ecosystems (Gomez & Gomez, 2007; Boyd, 1998; Rakocy *et al.,* 2006; Effendie, 2002; FAO, 2011). Feed Conversion Ratio (FCR) is calculated using the formula:

$$\text{FCR} = \frac{TP}{PBM}$$

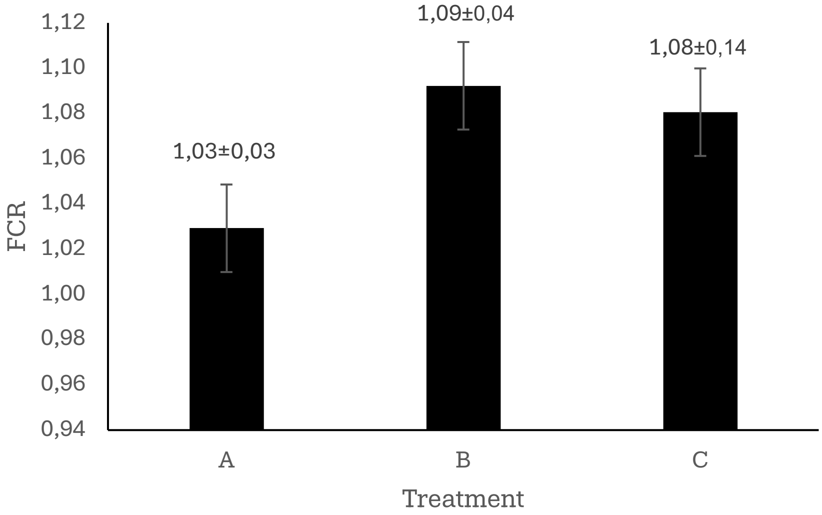
Dimana:
FCR : Feed Conversion Ratio
TP : The amount of feed used during the study (g)
PBM : Absolute weight growth (g)

Data Feed Conversion Ratio (FCR) was statistically analyzed using Analysis of Variance (ANOVA) to determine the effect of treatment. Before ANOVA, the data were tested for normality assumptions using the Shapiro–Wilk test and homogeneity of variety using the Levene test with a confidence level of 95% ($P > 0.05$). If the ANOVA results show a significant difference, it is followed by the Duncan Multiple Range Test (DMRT) at a significance level of 5% ($P < 0.05$). All statistical analysis was carried out using SPSS software version 25.0, while water quality parameter data was analyzed descriptively (Gomez & Gomez, 2007; Steel & Torrie, 1991; Montgomery, 2017).

RESULT AND DISCUSSION

The results showed that the FCR value of tilapia that was maintained for 90 days with the IAA system of the GIS-based floating bed model varied between treatments. Treatment A showed the lowest FCR value of 1.03, followed by treatment C of 1.08 and treatment B of 1.09. Low FCR values in all treatments indicate excellent feed utilization efficiency in floating bed model IAA systems.

Figure 1:
Feed Conversion Ratio (FCR)



Source: data analysis results

ANOVA analysis showed no significant difference in FCR values between treatments (F=0.389, Sig.=0.694), indicating that the three extractive species placement models had relatively equal effectiveness in improving feed utilization efficiency.

Feed Conversion Ratio is a key parameter in the evaluation of the efficiency of a fishery aquaculture system which is defined as the ratio between the weight of the feed used and the weight of the biomass produced. A low FCR value indicates a high feed utilization efficiency, where less feed is needed to produce fish weight gain (Fry *et al.,* 2018). In the context of tilapia farming, this parameter has substantial economic significance considering that feed costs can reach more than 50% of the total production cost.

The IAA system integrates fish farming with agriculture, where waste from fish ponds is used as fertilizer for plants, creating a closed ecosystem that supports resource efficiency. Plants on floating beds help improve water quality and reduce stress on fish. Plant roots absorb nutrients directly from pond water, thus participating in maintaining water quality and improving the balance of the ecosystem. By utilizing fish organic waste for plant nutrition, FCR can be lowered because the rest of feed and feces are not only waste but also a source of nutrients for plants.

Treatment A showing the lowest FCR value indicates that the stability of the floating-bed position during the maintenance period provides more optimal environmental conditions for tilapia growth. In treatments B and C, floating-bed displacement caused changes in the dynamics of microhabitats in the pond that were reflected in slightly higher FCR values. Interestingly, treatment C with a longer transfer interval (20 days) showed a lower FCR value than treatment B (10 days), indicating that the longer interval duration provides sufficient time for the microecosystem to reach a stage of stability before the next disruption occurs.

The integration of organic (kijing shellfish) and inorganic (rice) extractive organisms in the floating-bed system creates an effective biofiltration mechanism. Kijing clams act as a filter feeder that filters out suspended organic particles, while the rice root system absorbs dissolved nutrients such as nitrogen and phosphorus. This synergy significantly improves water quality by lowering the concentration of ammonia, nitrite, and phosphorus, thus creating a more conducive environment for tilapia growth.

The feeding protocol three times a day at 07.00, 12.00, and 17.00 with a feeding rate of 5% contributed to the low FCR value in all treatments. Proper feeding frequency ensures the continuous availability of nutrients for tilapia that are continuous grazers, thereby reducing the possibility of overeating and nutrient malabsorption.

The fermentation process of feed for 15 minutes before feeding has been shown to improve feed digestibility and contribute to low FCR values. This short fermentation increases nutrient availability and reduces anti-nutrient factors in commercial feed. The combination of feed fermentation with the addition of probiotics and vitamin boosters (Grotop and Premix Aquavita) resulted in synergies that improved the digestion process and nutrient absorption in tilapia, which significantly contributed to the low FCR values in all three treatments.

The IAA system designed with the integration of three biological components (tilapia, kijing shellfish, and rice) on the floating bed shows positive synergies in nutrient utilization and water quality management. The FCR value in this integrated IAA system reaches 1.03-1.09, significantly lower than conventional tilapia monoculture cultivation which ranges from 1.6-1.8.

The integration of GIS technology in this study provides a crucial spatial dimension for the monitoring and management of IAA systems. GIS-based spatial mapping enables the identification and visualization of nutrient dynamics in aquaculture ponds, thus supporting more precise decision-making in floating-bed placement and feed distribution.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the application *of the Integrated Aquaculture–Agriculture* (IAA) system of *the GIS-based floating-bed* model has proven to be effective in increasing the efficiency of feed utilization in tilapia (*Oreochromis niloticus) cultivation*, which is shown by the value of *the Feed Conversion Ratio* (FCR) is low and relatively stable across treatments, ranging from 1.03–1.09. The FCR value reflects the IAA system's ability to create aquaculture environmental conditions that support optimal fish growth through the integration of aquaculture and agricultural components in a synergistic production system. Treatment without *floating-bed* displacement during the maintenance period resulted in the lowest FCR value of 1.03, indicating that the stability of *the floating-bed* placement is able to maintain the balance of water quality, increase nutrient utilization, and reduce stress on fish, so that biomass growth can take place more efficiently. The presence of rice plants and extractive organisms in this system plays an important role in absorbing fish feed residues and metabolic waste, which indirectly improves water quality and suppresses the accumulation of organic matter in aquaculture ponds. Meanwhile, treatment with *floating-bed* removal at 10 and 20-day intervals still yielded relatively low FCR values, although slightly higher than control treatments, indicating that the IAA system has a good level of adaptability to treatment changes but still requires system stability to achieve maximum feed efficiency. Overall, the results of this study confirm that the GIS-based floating bed model IAA system has great potential to be developed as an efficient, sustainable, and environmentally friendly tilapia cultivation technology, and can be a strategic alternative in supporting increasing the productivity of aquaculture while maintaining the balance of aquatic ecosystems.

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