

COMPARISON OF FEED CONVERSION RATIO (FCR) OF TILAPIA AND CATFISH IN MAGGOT-BASED AQUAPONIC CULTIVATION SYSTEM

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Abstract

This study compared the Feed Conversion Ratio (FCR) of Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias* sp.) cultured in a maggot-based aquaponic system. The experiment was conducted from March to May 2025 using a completely experimental approach with two treatments and three replications. Nile tilapia and African catfish were fed dried Black Soldier Fly (*Hermetia illucens*) larvae as the sole protein source, while mustard greens were cultivated as the plant component of the aquaponic system. Feed utilization efficiency was evaluated using Feed Conversion Ratio (FCR), and differences between treatments were analyzed using an independent-samples *t*-test. The results demonstrated that Nile tilapia exhibited a significantly lower FCR (0.41) than African catfish (0.70), indicating superior feed utilization efficiency. Statistical analysis confirmed a significant difference between the two treatments ($p = 0.037$), suggesting that fish species significantly influenced the efficiency of maggot utilization under identical aquaponic conditions. The lower FCR observed in Nile tilapia was attributed to its omnivorous feeding behavior, greater digestive adaptability to insect-based diets, and better compatibility with the nutrient recycling processes occurring within the aquaponic system. Overall, the findings indicate that integrating Black Soldier Fly larvae with aquaponic technology can substantially improve feed efficiency while reducing production costs and nutrient waste. Nile tilapia demonstrated greater suitability than African catfish for sustainable maggot-based aquaponic production systems.

Keywords: Aquaponics; Black Soldier Fly; Catfish; Feed Conversion Ratio; Tilapia

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INTRODUCTION

Aquaculture has become one of the fastest-growing food production sectors worldwide and plays a crucial role in ensuring food security, improving rural livelihoods, and supporting sustainable economic development (Food and Agriculture Organization [FAO], 2024). In Indonesia, freshwater aquaculture contributes substantially to national fish production, with Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) representing the two most commercially important cultured species because of their rapid growth, high market demand, and adaptability to diverse farming environments (KKP, 2024). Continuous increases in the production of these species reflect both expanding consumer demand and improvements in aquaculture technology (Wijaya et al., 2014). Nevertheless, achieving higher productivity while maintaining environmental sustainability remains a significant challenge for intensive aquaculture systems.

Intensive freshwater aquaculture generally relies on high stocking densities and formulated commercial feeds to maximize production. Although this approach significantly increases fish yield, it also generates considerable environmental impacts through the accumulation of organic waste and dissolved nutrients derived from uneaten feed and fish excretion (Boyd et al., 2020; FAO, 2022). Previous studies have shown that cultured fish utilize only approximately 20–30% of the nutrients supplied in formulated diets, whereas the remaining nutrients are released into the culture water as ammonia, urea, feces, and suspended organic matter (Boyd et al., 2020; Heriansah et al., 2022). Consequently, excessive

nutrient loading often deteriorates water quality, increases ammonia concentration, accelerates eutrophication, and reduces fish health and production efficiency (Nederlof et al., 2021; Dauda et al., 2019).

Feed waste represents one of the greatest obstacles to sustainable aquaculture because it simultaneously reduces feed efficiency and increases production costs. Approximately 18% of dietary nitrogen and more than 50% of phosphorus supplied through commercial feeds may eventually enter aquatic environments as waste, contributing substantially to nutrient pollution (Nederlof et al., 2021). In addition to environmental concerns, feed constitutes the largest operational expense in freshwater aquaculture, accounting for approximately 60–70% of total production costs (Kordi, 2019; Tacon & Metian, 2015). Improving feed utilization efficiency therefore has direct implications for both economic profitability and environmental sustainability.

One promising approach to addressing these challenges is aquaponics, an integrated production system that combines fish culture with hydroponic plant cultivation in a recirculating water system. In aquaponic systems, dissolved nutrients originating from fish metabolism are biologically converted by nitrifying bacteria into plant-available forms, allowing vegetables to utilize these nutrients while simultaneously improving water quality for fish (Goddek et al., 2019; Love et al., 2015). Compared with conventional aquaculture, aquaponics substantially reduces water consumption, minimizes nutrient discharge, and promotes circular nutrient utilization, making it an environmentally sustainable production strategy (Somerville et al., 2014; FAO, 2022).

Within aquaponic systems, feeding management is particularly important because feeding rate directly influences fish growth, feed conversion efficiency, water quality, and nutrient availability for plant production. Feeding Rate (FR) refers to the quantity of feed administered daily relative to fish biomass (Effendie, 2012). Excessive feeding increases uneaten feed and organic waste, whereas insufficient feeding suppresses fish growth. Therefore, determining an optimal feeding strategy is essential for maximizing production efficiency while minimizing environmental impacts (Mengistu et al., 2020).

Feed Conversion Ratio (FCR) is widely recognized as one of the most important indicators of feed efficiency in aquaculture. FCR is calculated as the ratio between total feed consumed and fish biomass gain, with lower values indicating greater feed utilization efficiency (Craig & Helfrich, 2017; Glencross, 2020). Besides feeding rate, FCR is influenced by species characteristics, feed quality, environmental conditions, fish size, stocking density, and culture management practices (Boyd et al., 2020). Comparative evaluations of FCR among economically important freshwater species are therefore valuable for identifying efficient production strategies.

The search for alternative protein sources has recently intensified because fishmeal-based commercial feeds are becoming increasingly expensive and environmentally unsustainable. Black Soldier Fly (*Hermetia illucens*) larvae (BSF maggot) have emerged as one of the most promising alternative feed ingredients owing to their high nutritional value, rapid production cycle, and ability to convert organic waste into high-quality biomass (Makkar et al., 2014; Henry et al., 2015). Depending on the rearing substrate, BSF larvae generally contain 40–45% crude protein, 25–35% lipid, essential amino acids, minerals, and antimicrobial peptides that enhance fish immunity and disease resistance (Azir et al., 2017; Indariyanti & Rakhmawati, 2018). Furthermore, BSF production supports the principles of the circular economy by transforming organic waste into valuable aquaculture feed ingredients (Van Huis, 2020).

Although numerous studies have independently investigated aquaponic systems or BSF-based diets, comparative studies evaluating the feed conversion performance of Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) fed BSF maggot under



aquaponic conditions remain limited. Differences in digestive physiology, feeding behavior, and metabolic efficiency among these species may lead to distinct feed conversion responses when cultured under identical environmental conditions. Therefore, this study aimed to compare the Feed Conversion Ratio (FCR) of Nile tilapia and African catfish fed Black Soldier Fly maggot in an aquaponic cultivation system. The findings are expected to provide scientific evidence regarding the effectiveness of maggot-based feeding strategies in improving feed efficiency while supporting environmentally sustainable freshwater aquaculture.

METHOD

This study employed a quantitative experimental design to compare the Feed Conversion Ratio (FCR) of Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias* sp.) cultured in a maggot-based aquaponic system. The experiment was conducted from March to May 2025 at an aquaponic culture facility located in Mandalle Village, Mandalle District, Pangkep Regency, South Sulawesi, Indonesia. The culture system consisted of freshwater fish tanks integrated with hydroponic units planted with mustard greens (*Brassica rapa* var. *parachinensis*) to facilitate nutrient recycling. Experimental facilities included culture tanks, water pumps, net pots, water quality meters, digital balances, measuring boards, fish nets, plastic containers, and recording equipment. Dried Black Soldier Fly (*Hermetia illucens*) larvae (maggot) were used as the sole feed source throughout the experiment. Two experimental treatments were established with three replicates each: Treatment A consisted of Nile tilapia (*Oreochromis niloticus*) fed a maggot-based diet, while Treatment B consisted of African catfish (*Clarias* sp.) fed the same diet. This experimental arrangement enabled a direct comparison of feed utilization efficiency between the two species under identical environmental and nutritional conditions (Boyd et al., 2020; FAO, 2022; Goddek et al., 2019; Glencross, 2020).

The primary response variable was Feed Conversion Ratio (FCR), calculated according to Handayani and Widodo (2010) using the equation:

$$FCR = \frac{F}{(W_t - W_o)}$$

Where F represents the total feed supplied (g), W_t is the final fish biomass (g), and W_o is the initial fish biomass (g). Fish populations consisted of approximately 300 Nile tilapia and 80 African catfish per culture tank. Sampling followed a non-probability sampling approach, with approximately 10% of the fish population in each tank selected for periodic biomass measurements to represent growth performance while minimizing handling stress (Creswell & Creswell, 2018). Feed consumption and biomass data were recorded throughout the culture period using standardized logbooks before being compiled in Microsoft Excel for preliminary processing. Statistical analyses were performed using IBM SPSS Statistics version 25. Independent-samples t -tests were applied to evaluate significant differences in mean FCR between the two fish species after verifying the assumptions of normality and homogeneity of variance, while descriptive statistics were used to summarize water quality parameters, including temperature, dissolved oxygen, pH, and ammonia concentration (Field, 2018; Montgomery, 2020; Pallant, 2020).

RESULT AND DISCUSSION

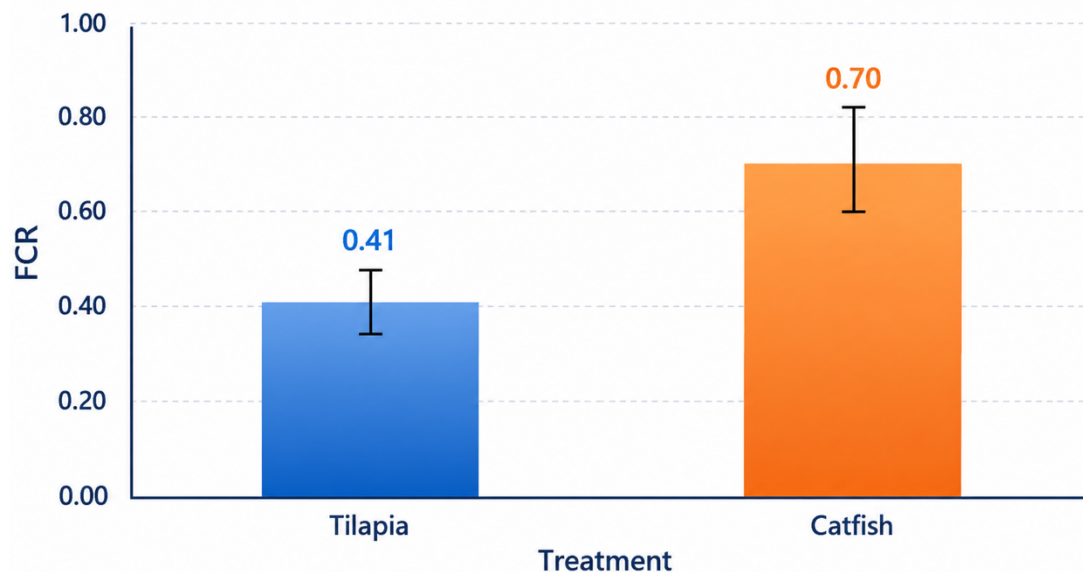
Table The comparison of Feed Conversion Ratio (FCR) between Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias* sp.) cultured in a maggot-based aquaponic system revealed clear differences in feed utilization efficiency (Figure 1). After 30 days of culture, Nile tilapia achieved a significantly lower FCR (0.41) than African catfish (0.70), indicating that tilapia converted the supplied feed into body biomass more efficiently. In aquaculture, a lower



FCR reflects superior feed efficiency because less feed is required to produce a unit increase in fish biomass, thereby reducing production costs and nutrient waste released into the culture environment (Glencross, 2020; Boyd et al., 2020). Since feed typically represents 50–70% of total operational expenses in intensive aquaculture, improvements in FCR directly enhance both economic profitability and environmental sustainability (Tacon & Metian, 2015; FAO, 2022).

Figure 1.

Feed Conversion Ratio (FCR) of Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias* sp.) cultured in a maggot-based aquaponic system



Statistical analysis using an independent-samples *t*-test demonstrated that the difference in FCR between the two fish species was statistically significant ($p = 0.037$), confirming that the two species responded differently to the same feeding strategy under identical aquaponic conditions. This finding suggests that species-specific physiological characteristics strongly influence feed utilization efficiency despite similar environmental conditions and dietary composition (Glencross, 2020; NRC, 2011). The lower FCR recorded for Nile tilapia indicates a greater capacity to digest, absorb, and convert nutrients derived from Black Soldier Fly (*Hermetia illucens*) larvae into tissue growth, whereas African catfish required a relatively larger quantity of feed to achieve comparable biomass gain.

The excellent FCR values observed in both treatments also demonstrate the effectiveness of the aquaponic production system in maintaining favorable environmental conditions for fish growth. Aquaponics integrates fish production with hydroponic plant cultivation, allowing dissolved nutrients originating from fish metabolism to be recycled by plants and nitrifying bacteria instead of accumulating within the culture water (Goddek et al., 2019; Somerville et al., 2014). This biological nutrient recycling maintains water quality, reduces ammonia toxicity, and minimizes physiological stress on cultured fish, ultimately improving feed utilization efficiency (Love et al., 2015; Yep & Zheng, 2019). Consequently, the observed FCR values were considerably lower than those commonly reported for conventional freshwater culture systems.

The superior performance of Nile tilapia can largely be explained by its digestive physiology and feeding ecology. As an omnivorous species, Nile tilapia possesses a relatively long digestive tract and diverse digestive enzymes, enabling efficient utilization of nutrients derived from both plant- and animal-based feed ingredients (El-Sayed, 2020). Black Soldier Fly



larvae contain high concentrations of crude protein (40–55%), essential amino acids, lipids, minerals, antimicrobial peptides, and bioactive compounds that support growth and improve nutrient assimilation (Makkar et al., 2014; Henry et al., 2015; Surendra et al., 2016). Previous studies have similarly reported that partial or complete replacement of fishmeal with BSF larvae can maintain or even improve growth performance and feed efficiency in Nile tilapia without negatively affecting survival or health (Devic et al., 2018; Abdel-Tawwab et al., 2020).

Conversely, African catfish exhibited a significantly higher FCR despite receiving the same maggot-based diet. Although catfish are highly adaptable and capable of consuming diverse feed ingredients, their predominantly carnivorous feeding strategy generally requires protein sources with amino acid profiles closely resembling those of fishmeal (NRC, 2011). Differences in amino acid composition, chitin content, and lipid profile between insect meal and conventional fishmeal may partially reduce nutrient digestibility and feed utilization efficiency in carnivorous fish species (Gasco et al., 2018; Henry et al., 2015). The chitin contained in the exoskeleton of BSF larvae, although beneficial as an immunostimulant, may slightly reduce protein digestibility when included at relatively high levels in aquafeeds (Makkar et al., 2014; Gasco et al., 2018).

The observed differences may also be associated with behavioral and ecological characteristics of the two species within the aquaponic environment. Nile tilapia generally exhibit stable feeding behavior and adapt rapidly to recirculating systems, whereas African catfish display more aggressive feeding behavior and produce relatively greater nitrogenous waste due to their higher protein metabolism (Rakocy et al., 2006; Boyd et al., 2020). Increased nitrogen excretion may elevate ammonia concentrations if nutrient assimilation by plants and microbial communities is insufficient, thereby reducing water quality and increasing metabolic energy expenditure for osmoregulation and detoxification (Goddek et al., 2019; Dauda et al., 2019). Although the aquaponic system effectively recycled nutrients throughout the experiment, species-specific metabolic differences likely contributed to variations in feed conversion efficiency.

Feeding management also contributed to the overall results. Fish were fed three times daily at approximately 5% of total biomass, a feeding strategy widely recommended for juvenile freshwater fish because it balances growth requirements while minimizing feed losses (Craig & Helfrich, 2017; El-Sayed, 2020). This feeding regime appeared particularly suitable for Nile tilapia, whereas African catfish may benefit from alternative feeding schedules or improved feeding techniques that better match their nocturnal feeding behavior and reduce feed competition.

Overall, the present findings demonstrate that combining aquaponic technology with Black Soldier Fly larvae as an alternative protein source can substantially improve feed utilization efficiency while supporting environmentally sustainable aquaculture production. Among the two cultured species, Nile tilapia exhibited significantly better feed conversion performance than African catfish, suggesting that tilapia is more compatible with maggot-based aquaponic production systems. These findings reinforce the growing evidence that insect-based feeds and integrated aquaponic systems represent promising strategies for reducing dependence on conventional fishmeal, lowering production costs, minimizing nutrient discharge, and improving the sustainability of freshwater aquaculture (FAO, 2022; Goddek et al., 2019; Van Huis, 2020).

CONCLUSION

The present study demonstrated that fish species significantly affected feed utilization efficiency in a maggot-based aquaponic cultivation system. Nile tilapia (*Oreochromis niloticus*) achieved a significantly lower Feed Conversion Ratio (0.41) than African catfish (*Clarias* sp.) (0.70), indicating superior efficiency in converting Black Soldier Fly (*Hermetia*



illucens) larvae into body biomass. Statistical analysis confirmed that the difference between treatments was significant ($p < 0.05$), suggesting that species-specific physiological and digestive characteristics influenced the utilization of insect-based feed. The integration of aquaponics with maggot feeding effectively supported efficient nutrient recycling and favorable culture conditions, contributing to excellent feed conversion performance in both species. However, Nile tilapia exhibited greater compatibility with the maggot-based diet and aquaponic environment, making it a more suitable candidate for sustainable freshwater aquaculture. These findings provide scientific evidence that the combined application of aquaponic technology and Black Soldier Fly larvae can improve feed efficiency, reduce production costs, minimize nutrient discharge, and support environmentally sustainable aquaculture practices. Future studies should evaluate different maggot inclusion levels, longer culture periods, and additional freshwater species to further optimize sustainable aquaponic production systems.

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