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Analysis of the Implementation of Automatic Feeding IoT Systems on the Productivity of Catfish (*Clarias* sp.) Aquaculture

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Abstract: Feed represents the largest expense in catfish (*Clarias* sp.) aquaculture, accounting for up to 70% of production costs. Improving feed efficiency is therefore essential to enhance productivity and reduce operational costs. This study developed and evaluated an Internet of Things (IoT)-based automatic feeder designed for small-scale aquaculture. The novelty of this research lies in the integration of Arduino and BARDI components into an affordable autofeeder system that supports precision feeding management for smallholders. Two feeding methods were compared: manual feeding and automatic feeding using the developed IoT-based system. Productivity indicators measured included Feed Conversion Ratio (FCR), Specific Growth Rate (SGR), Survival Rate (SR), and water quality. Results showed that conventional feeding produced lower FCR (0.29) and higher SGR (18.50%/day) during the early growth phase. Survival rates were relatively low (60–63%) but improved in later weeks. Most water quality parameters remained within the optimal range, except for temperature, which slightly exceeded tolerance levels and contributed to mortality. Although the IoT-based feeder requires further refinement to match manual feeding performance, it demonstrates strong potential to improve feeding accuracy, reduce labor dependency, and promote sustainability in small-scale catfish aquaculture.

Keywords: Aquaculture; Automatic feeding; Catfish; IoT; Productivity

Introduction

Catfish cultivation (*Clarias* sp.) is one of the subsectors of aquaculture that has great potential (Mukti & Amin, 2021; Zaman et al., 2025) and is widely engaged in by the Indonesian people. The advantages of this commodity include its rapid growth (Singh, 2025), its relatively easy maintenance (Gustiano et al., 2021) and high and stable market demand (Salsabilla et al., 2021). However, in practice, the efficiency of cultivation business is still a major challenge, especially in terms of managing production costs (Maulana & Putro, 2025). Feed is the largest cost component in catfish farming, which can reach half of the total production cost or even more (Nurlaeli et al., 2024). Feed is the largest cost component in catfish farming, reaching 60-70% of the total production cost (Kusumanto & Hidayat, 2018). Feeding efficiency is a major factor in increasing productivity (Ansari et al., 2021) and farmer profits (Andriani & Aisyah, 2025). Automated feeding systems offer solutions in optimizing feeding, reducing waste, and increasing fish growth. The feeding automation system increases the effectiveness and efficiency of cultivators in monitoring cultivation activities (Chaidir et al., 2025). Inefficient feeding, both in quantity and time, can lead to waste, worsen water quality, and

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decrease fish growth rate (Muhyun & Pi, 2025). This leads to low productivity and profits obtained by cultivators. Automatic feeding systems are present as an alternative solution in optimizing feeding (Tjhin & Riantini, 2021). This system allows for regular and scheduled feeding, with the aim of improving feed efficiency, fish growth, and business profits (Huang et al., 2025). Based on previous research, until now, further studies are still needed on the impact of the implementation of the automatic feed system on productivity and economic aspects of real catfish cultivation activities in the field (Tiarto et al., 2024).

Method

Location and Time

This research was conducted from July-September 2025 at the Muhammadiyah University of Technology, Jakarta, Campus C.

Research Design

This study was conducted using a quasi-experimental design (an experiment without replication) (Béné & Haque, 2022) with two treatments. Pond 1 received automatic feeding via an Arduino- and BARDI-based autofeeder, while Pond 2 was fed conventionally as the control. The study aimed to compare feed efficiency, growth performance, survival rate, and economic outcomes between the two feeding method.

Sampling Method

The catfish (*Clarias* sp.) seeds used have an average size of 7–8 cm (Dewi et al., 2025). The selection of seeds is carried out based on health conditions, which are characterized by active movements, bright body color, proportionality, and no physical abnormalities (Soto et al., 2019). The stocking density is set at 500 heads per pond.

Fish Farming

The fish are kept in an outdoor round pond equipped with paranets to reduce exposure to direct sunlight and rain. Each pond is equipped with an aerator as a dissolved oxygen supply. The water drain system is installed to facilitate drainage, considering that the water quality may deteriorate during maintenance. Before use, the pond water is deposited for seven days and given a natural probiotic treatment in the form of papaya leaves and ketapang to improve the quality of the maintenance environment. Feed is given twice a day (Pangalila et al., 2025) namely at 10.30 and 19.30. The amount of feed is determined based on the results of sampling the average weight of fish and the number of fish that are still alive each week.

Internet of Things (IoT) System

IoT autofeeder system combines automated feeding with data-driven intelligence for catfish cultivation efficiency. Bardi is used for automatic scheduling, in 1 day given 2x feed at 10:30 and 19:30. While the Arduino is designed with an ultrasonic sensor to be able to detect fish if a lot of them appear on the surface of the water, then the sensor will activate the servo to provide feed automatically within 5 seconds. The way the system works is ultrasonic sensors mounted above the pond continuously monitor the water surface. The ultrasonic waves will be reflected by the surface of the water. When catfish are hungry, they will swim to the surface, causing the wave to reflect (fluctuate). Arduino (as the brain of the system) reads data from the ultrasonic sensor. If the Arduino detects a significant fluctuation pattern that indicates an active fish on the surface (hungry), it will send a command. Commands from Arduino activate the servo motor to rotate for approximately 5 seconds. This motor will turn the screw or open the valve to release a predetermined amount of feed into the pond.

For Bardi Autofeeder, it uses IoT connectivity for monitoring and scheduling. Through the WiFi module, the system is connected to the internet (Pangalila et al., 2025). Data such as feeding schedules, the amount of feed dispensed, and fish activity can be sent to the cloud/server (IoT Platform). Researchers can monitor and control feeders remotely via smartphones or computers, as well as receive notifications.

Advantages of Implementing this System (Thornburg, 2025) are feed is only given when the fish are really hungry, reducing wastage and reducing production. Feeding patterns that suit the needs of fish support better growth. Farmers also don't need to be on site all the time to feed, saving time and effort.

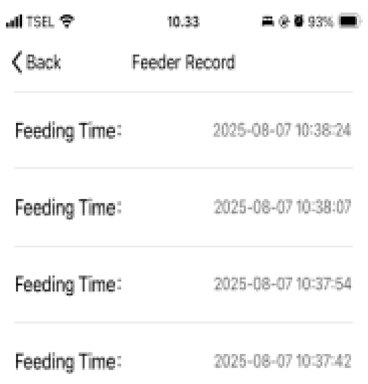

Figure 1. Autofeeder systems

Thus, the integration of IoT and ultrasonic sensors in this autofeeder transforms feeding from a manual and scheduled one to an intelligent, responsive, and connected system. IoT Autofeeder system can be seen in the Figure 1.

Observed Parameters

The parameters observed included the number of daily feeds, Feed Conversion Ratio (FCR), Specific Growth Rate (SGR), Survival Rate (SR), and water quality. Water quality is monitored daily for temperature, pH, salinity, and dissolved oxygen (DO) parameters, while ammonia is measured on a weekly basis.

Data Analysis

Technical data in the form of FCR, SGR, SR, and water quality were analyzed descriptively and tested with simple inferential analysis to compare the results between manual and automatic treatment (von Wietersheim-Kramsta et al., 2025).

Result and Discussion

General Conditions of Research Locations

This research was conducted at the Muhammadiyah University of Technology Jakarta, Campus C, which is located on Jl. Sekda Saefullah, Rorotan, North Jakarta. The research round pond is placed in an outdoor location equipped with a paranet to protect from direct sunlight exposure and rainwater. The round pond is also equipped with an aerator as a source of oxygen for catfish. One of the ponds (Pond 1) is equipped with a BARDI and Arduino autofeeder. The installation of the round pool can be seen in the Figure 2.

Figure 2. Research Pond

Early Condition of Catfish Seeds

The fish seeds used in this study have an average body length of 7-8 cm. The selection of these sizes is based on the consideration that seeds in this size range generally have good adaptability to the cultivation environment, and are more resistant to changes in water quality than smaller seeds (Kartikasari et al., 2025). The stocking density used is adjusted to the capacity of the maintenance container so as not to cause excessive stress and high feed competition. Optimal stocking density is an important factor because it will have a direct effect on the growth rate, synthesis, and health of the seeds during the maintenance period. The stocking density in this study was 500 heads/pond. Visually, the health condition of the seeds at the beginning of the study showed proportional body characteristics, active movements, bright body color, and no signs of abnormalities or external disease attacks were found. This shows that the seeds used are in healthy condition and suitable for cultivation. Fish seeds can be seen in Figure 3.

Figure 3. Catfish seeds

Daily Feed Intake

The experimental results (Table 1) showed differences in growth and feed consumption between the two treatments (automatic and conventional feeding).

In the first week, the average body weight of fish in Pond 1 and Pond 2 was 6.5 g and 7 g per fish, respectively, with an initial stocking of 500 fish in each pond. The daily feed allocation was 97.5 g for Pond 1 and 105 g for Pond 2. By the second week, the average weight had increased to 16.4 g in Pond 1 and 25 g in Pond 2. However, due to mortality, the number of fish decreased to 315 in Pond 1 and 302 in Pond 2. The daily feed requirement consequently increased to 155 g (Pond 1) and 227 g (Pond 2).

Table 1. Daily Feed Intake

Week	Pond	Average Body Weight (g/ind)	Number of fish (ind.)	Daily Feed (kg)	Daily Feed (g)
1	1	6.5	500	0.0975	97.5
	2	7	500	0.105	105
2	1	16.4	315	0.155	155
	2	25	302	0.227	227
3	1	27	307	0.249	249
	2	41.2	301	0.372	372
4	1	45.4	307	0.418	418
	2	60	300	0.54	540

In the third week, the average weight reached 27 g in Pond 1 and 41.2 g in Pond 2. The population remained relatively stable at 307 and 301 fish, respectively, with daily feed requirements of 249 g and 372 g. By the fourth week, the average weight reached 45.4 g in Pond 1 and 60 g in Pond 2. The survival rate remained high, with 307 fish in Pond 1 and 300 fish in Pond 2. Feed consumption increased accordingly to 418 g and 540 g per day.

Overall, both treatments showed consistent growth and survival. However, Pond 2 (conventional feeding) demonstrated higher average body weight throughout the rearing period, accompanied by greater feed input. In contrast, Pond 1 (automatic feeding) produced lower growth performance but required comparatively less feed input per day. These findings suggest that while conventional feeding promoted faster growth, the automatic feeding system demonstrated potential advantages in feed efficiency and management convenience (Liliyanti et al., 2024; Thornburg, 2025).

Survival Rate (SR)

Survival rate in this study was calculated periodically because it had not reached the end of the cultivation period (harvest period). Periodic SR is calculated to monitor maintenance conditions on a regular basis. The calculation of periodic SR can be seen in the Table 2. Survival rate graph can be seen in Figure 3.

Table 2. Periodic Survival Rate

Week	Pond	Initial stock (ind.)	Final stock (ind.)	SR (%)
1-2	1	500	315	63
	2	500	302	60.4
2-3	1	315	307	97.5
	2	302	301	99.7
3-4	1	307	307	100
	2	301	300	99.7

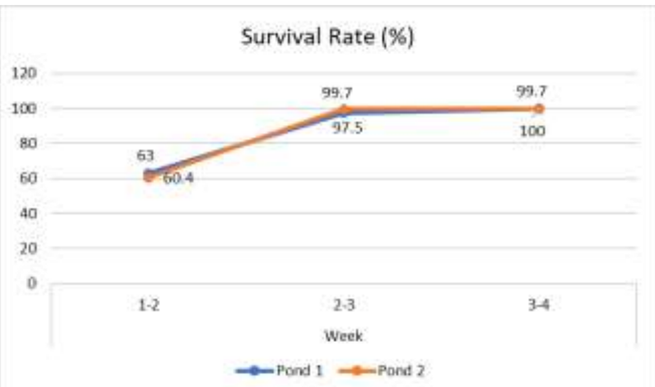

Figure 4. Survival rate graph

Survival rate of catfish (*Clarias* sp.) showed distinct patterns between automatic (Pond 1) and manual feeding (Pond 2) treatments. During the first two weeks (Week 1–2), survival was relatively low in both ponds, with 63% in Pond 1 (automatic) and 60.4% in Pond 2 (manual). This high mortality indicates that the early culture phase was critical, likely due to handling stress, adaptation to the new environment, and suboptimal water conditions. Such early-stage mortality has been reported in catfish culture, where stocking stress and temperature fluctuations can significantly affect fish survival (Septian et al., 2024).

From Week 2–3, survival increased sharply, reaching 97.5% in Pond 1 and 99.7% in Pond 2. This improvement suggests that the fish had adapted to the culture environment and feeding routines, thereby reducing stress and vulnerability. By Week 3–4, survival stabilized at 100% in Pond 1 and 99.7% in Pond 2, indicating negligible mortality in the later phase.

Comparatively, the manual feeding pond (Pond 2) achieved slightly higher survival than the automatic feeding pond during Weeks 2–3, although the difference was marginal. This may suggest that, under the present experimental conditions, conventional feeding provided a more stable feeding response for catfish juveniles than the IoT-based system. Nonetheless, both systems demonstrated excellent survival rates after the initial two weeks.

Overall, these results emphasize that the critical period of mortality occurs during the first two weeks of rearing, regardless of the feeding method. Intensive management of water quality (Zuib et al., 2024) and feeding practices during this stage is essential (Septian et al., 2024). Once fish adapt, both automatic and manual feeding systems can maintain high survival (>97%), with manual feeding showing a slight advantage in this trial.

Feed Conversion Ratio (FCR)

FCR values during the rearing period fluctuated across weeks in both treatments. In weeks 1–2, FCR was relatively low (0.35 in Pond 1 and 0.29 in Pond 2), indicating highly efficient feed utilization during the early growth stage. In weeks 2–3, FCR increased to 0.64 and 0.61, suggesting a decrease in feed efficiency as fish grew larger and feed demand increased. By weeks 3–4, FCR values shifted again, reaching 0.52 in Pond 1 and 0.67 in Pond 2. Overall, both treatments produced FCR values well below the standard benchmark for catfish culture (1.5), which indicates excellent feed efficiency (Viani & Santosa, 2025). A lower-than-standard FCR means that the fish were able to convert feed into biomass more effectively than typically expected. Between the two ponds, Pond 2 showed slightly more consistent FCR values, while Pond 1 displayed more fluctuation. However, Pond 1 achieved a more significant improvement in the final period (3–4 weeks), possibly due to more stable fish numbers and better feed distribution. This suggests that the automatic feeding system in Pond 1 may have supported steadier feed efficiency toward the end of the culture period (Dorgham et al., 2025). Calculation of periodic FCR showed in Table 3. Feed Conversion Ratio graph can be seen in Figure 5.

Table 3. Periodic FCR

Week	Pond	Initial weight (g/ind.)	Final weight (g/ind.)	Total feed intake (g/week)	FCR
1–2	1	6.5	16.4	1085	0.35
	2	7.0	25.0	1589	0.29
2-3	1	16.4	27	1245	0.64
	2	25.0	41.2	1860	0.61
3-4	1	27	45.4	2090	0.52
	2	41.2	60	2700	0.67

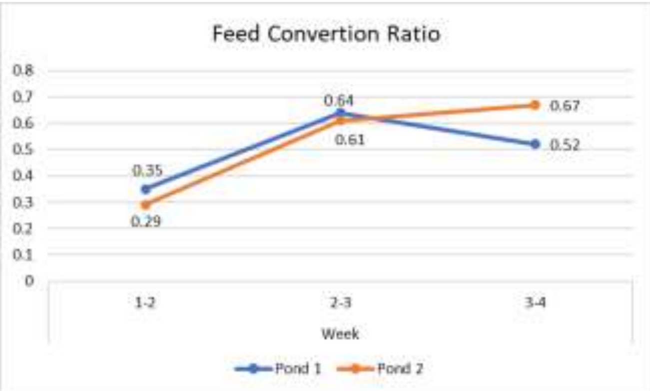

Figure 5. Feed convertion ratio graph

Specific Growth Rate (SGR)

Analysis of Specific Growth Rate (SGR) showed differences between the two feeding treatments across the observation periods. During the first week (Week 1–2), fish in Pond 2 with conventional feeding demonstrated a higher SGR (18.5%/day) compared to Pond 1 with autofeeder treatment (14.1%/day). This result suggests that in the early phase, fish responded more positively to direct feeding, which provided immediate access to feed and allowed them to adapt more quickly.

In the following period (Week 2–3), both treatments exhibited almost identical SGR values, with Pond 1 recording 6.21%/day and Pond 2 recording 6.24%/day. This similarity indicates that the initial growth advantage of conventional feeding diminished over time, and growth performance between the two feeding strategies became comparable (Munguti et al., 2025).

By Week 3–4, a reversal in trend was observed. Fish in Pond 1 (autofeeder) showed a higher SGR (7.42%/day) compared to Pond 2 (5.37%/day). This suggests that once the fish had adapted to the autofeeder system, the consistent and evenly distributed feed supply promoted more efficient growth compared to conventional feeding, which may have been affected by feed competition or irregular feeding frequency (Stromberg & Barnes, 2024).

Table 4. Periodic Specific Growth Rate

Week	Pond	Initial weight (g/ind.)	Final weight (g/ind.)	Rearing period (days)	SGR (%/day)
1–2	1	6.5	16.4	7	14.1
	2	7.0	25.0	7	18.5
2-3	1	16.4	27	7	6.21
	2	25.0	41.2	7	6.24
3-4	1	27	45,4	7	7.42
	2	41.2	60	7	5.37

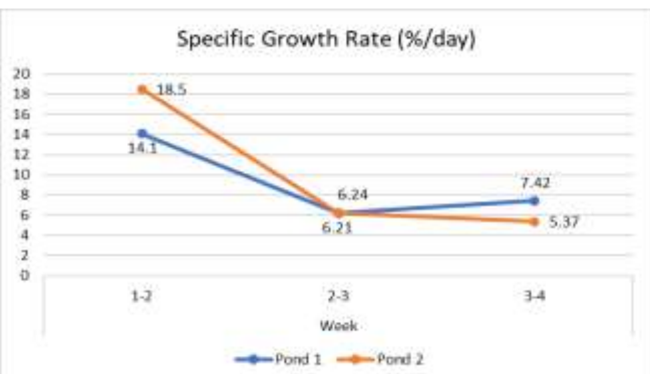

Figure 6. Specific growth rate graph

The fluctuation of SGR values observed across the rearing period is a common phenomenon in aquaculture. Several factors may contribute to these variations, including the adaptation of fish to new feeding strategies, differences in feed utilization efficiency, and natural metabolic changes as the fish increase in size (Yadav et al., 2024). Smaller fish typically grow faster in relative terms, while larger fish exhibit slower relative growth, leading to changes in SGR values (Spada et al., 2024). In addition, environmental conditions such as water quality, temperature, and stocking density, as well as feeding strategies, can also influence the consistency of growth (Zhang et al., 2025).

Overall, although conventional feeding initially resulted in higher SGR, the autofeeder treatment provided more sustainable and efficient growth in the later stages of the rearing period. Calculation of periodic Specific Growrh Rate shown in Table 4. Specific Growth Rate graph can be seen in Figure 6.

Water Quality

The daily water quality parameters measured include temperature, acidity degree (pH), salinity and dissolved oxygen (DO) (Melo et al., 2024). The weekly water quality parameter measured is ammonia (Andalia et al., 2024) to determine the level of toxicity in the pond (Anasiru et al., 2024). The water quality rod graph in this study is presented in Figure 7.

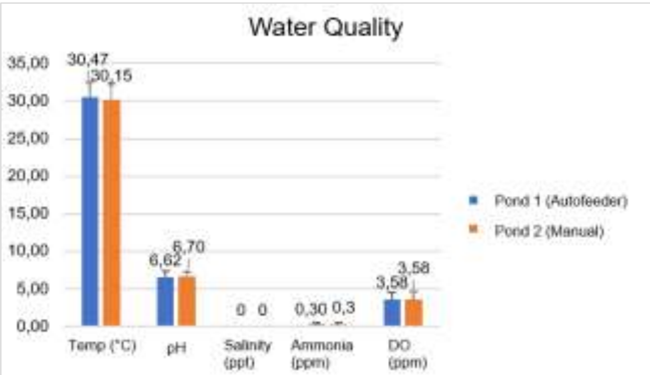

Figure 7. Water quality

Average temperature measurement result of Pool 1 is 30.47°C, while Pool 2 is 30.15°C. The average pH of pool 1 is 6.62, while pool 2 is 6.70. The average salinity of ponds 1 and 2 is 0 ppt. The average ammonia of ponds 1 and 2 was 0.3 and the average DO of ponds 1 and 2 was 3.58. This indicates that the calculation of water quality is still included in the optimal range of catfish cultivation, except for temperature parameters. The optimal temperature range for catfish cultivation is 23-30°C, pH 6.5-8.5 and DO >3 mg/L (Caesar et al., 2021). The optimal range of salinity is 0-10 ppt (Lingam et al., 2025) as well as ammonia <0.5 mg/L (Pamaharyani et al., 2025). In this study, the temperature level exceeded the optimal limit which can cause the fish's appetite to decrease because their metabolism is disrupted (Setyono et al., 2024).

Conclusion

This study demonstrated that both conventional and IoT-based automatic feeding systems were able to support the growth and survival of catfish (*Clarias* sp.), although with different performance outcomes. In the early stages of culture, conventional feeding achieved higher growth performance, as indicated by a higher Specific Growth Rate (SGR) and lower Feed Conversion Ratio (FCR). However, as the rearing period progressed, the autofeeder treatment showed more consistent growth, better feed efficiency in the later weeks, and comparable survival rates to the manual method. Despite higher initial mortality in both treatments, survival stabilized above 97% after the second week. Water quality remained within optimal ranges, except for temperature, which slightly exceeded the tolerance threshold and likely contributed to early mortality. Overall, while the conventional method yielded superior short-term results, the autofeeder system demonstrated potential advantages in feed management efficiency, reduced labor input, and sustainable growth performance once the fish adapted to the technology. Further refinement of the IoT-based autofeeder system is recommended to improve its performance in the early culture phase, particularly in optimizing feed response and reducing initial stress on fish. Future research should focus on integrating adaptive feeding algorithms that adjust feed quantity and timing based on real-time fish behavior and environmental conditions. In addition, trials with larger sample sizes and replication are needed to strengthen the reliability of findings and to evaluate the long-term economic benefits of autofeeder adoption. From a practical perspective, fish farmers may adopt automatic feeding systems as a complementary technology to conventional methods, especially for reducing labor costs and ensuring consistent feed distribution. With continued development, IoT-based autofeeders have the potential to enhance productivity and sustainability in catfish aquaculture.

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Author Contributions

Conceptualization, Amanda, T., Kaunang, S., Miswanto; methodology, Amanda, T., Kaunang, S., Miswanto.; software, Amanda, T., Kaunang, S., Miswanto.; validation, Amanda, T., Kaunang, S., Miswanto.; formal analysis, Amanda, T.; investigation, Amanda, T., Kaunang, S., Miswanto., Apriandi, M., Faqih, R; resources, Amanda, T., Kaunang, S., Miswanto.; data curation, Amanda, T., Kaunang, S., Miswanto.; writing—original draft preparation, Amanda, T., Kaunang, S., Miswanto; writing—review and editing, Amanda, T., Kaunang, S., Miswanto; visualization, Amanda, T.; supervision, Amanda, T., Kaunang, S., Miswanto; project administration, Amanda, T.; funding acquisition, Amanda, T.

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Conflicts of Interest

The authors declare no conflict of interest.

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