Institut Riset dan Publikasi Indonesia (IRPI)
MALCOM: Indonesian Journal of Machine Learning and Computer Science
Journal Homepage: https://journal.irpi.or.id/index.php/malcom
Vol. 6 Iss. 2 April 2026, pp: 952-961
ISSN(P): 2797-2313 | ISSN(E): 2775-8575

Development of a Portable Smart Feeder Based on Scheduling and Precision Dosing for Fish Feeding in Aquaculture

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Received Feb 05th 2026; Revised Mar 19th 2026; Accepted Apr 27th 2026; Available Online Apr 30th 2026
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Abstract

Freshwater and marine fish farming is the backbone of the fisheries economy, especially for small to medium-scale farmers. Feed contributes approximately 60–70% of operational costs, so inaccurate feed scheduling and dosing can increase production costs, reduce feed efficiency, and increase waste. This research developed a Portable Smart Feeder based on precision scheduling and dosing, equipped with gradual feeding (sub-doses with intervals) and a spreader for even feed distribution. Development was carried out using a prototype method, then the system performance was tested through experiments in two ponds for 14 days (one sorting cycle): Pond A (conventional) and Pond B (using the system). Evaluation included feed consumption, mortality, and growth measured through a sorting process (grading) on the 14th day. The results showed that Pond B produced 70.90 kg of harvested biomass with 28.00 kg of feed and 13 fish mortality, while Pond A produced 68.17 kg of biomass with 33.80 kg of feed and 250 fish mortality. The FCR value of Pond B is 0.91:1, better than Pond A 1.20:1, so the system shows increased feed efficiency and maintenance stability.

Keywords: Feed Conversion Ratio, Feed Scheduling, Fish Farming, Portable Smart Feeder, Precision Measurement

1. INTRODUCTION

Fish farming is a fisheries subsector that plays a crucial role in meeting the need for animal protein at both the global and national levels[1]. Globally, a report by the Food and Agriculture Organization (FAO) shows that aquaculture's contribution to total global fisheries production has exceeded 50% since 2020 and continues to grow year after year [2]. The FAO also confirms that more than half of the fish for human consumption currently comes from aquaculture, in line with the declining trend in marine and inland capture fisheries production[3].

In Indonesia, freshwater and marine fish farming is the backbone of the fisheries economy, especially for small- to medium-scale farmers[4]. However, this sector still faces challenges in production efficiency, particularly in feed management, which significantly determines cultivation costs and yields. Feed contributes approximately 60–70% of total operational costs, so inaccurate feed scheduling and dosing can increase production costs, reduce feed efficiency, and increase waste[2]. In addition to the economic impact, uneaten feed residue can accumulate as organic matter, degrading water quality, triggering stress in fish, and, under certain conditions, increasing the risk of mortality [5]. Therefore, a more measured feeding strategy is needed to increase productivity while maintaining the quality of the cultivation environment[6].

The development of technology and automation systems has led to the emergence of various smart feeder innovations in the aquaculture sector [7]. Several quantitative studies have reported that sensor- and microcontroller-based automatic feeders can significantly reduce the Feed Conversion Ratio (FCR) and increase the specific growth rate of fish compared with conventional methods [8]. However, most of these studies still focus on testing the technical performance of the equipment, such as sensor accuracy and system stability, without comprehensively examining the relationship between scheduling variables, precision dosing, and increased cultivation productivity in an integrated research model. Several previous studies have explored automated fish feeding systems with different technological approaches. Wibowo et al. (2025) developed a smart aquaculture system capable of delivering feed at precise intervals, demonstrating improved feeding efficiency. However, the study primarily focused on scheduling accuracy without evaluating its

DOI: https://doi.org/10.57152/malcom.v6i2.2559

impact on FCR and fish growth performance [1]. Similarly, Indrawati et al. (2024) proposed an IoT-based feeding system integrated with Fuzzy Logic and Water Quality Parameters. While the system shows adaptive feeding capability, the evaluation of feed efficiency remains indirect and lacks quantitative validation using standard metrics such as FCR [9]. The implementation of automatic scheduling using a microcontroller has also been applied to freshwater pond cultivation with a focus on the basic function of providing feed according to schedule, but is still limited to operational aspects and has not been accompanied by in-depth quantitative analysis of cultivation results [10]. Other studies have implemented microcontroller-based feeding automation focusing on operational functionality, such as scheduled feeding execution. Nevertheless, these studies do not comprehensively analyze the relationship between feeding precision, dosing strategy and aquaculture productivity outcomes. Therefore, there is a research gap in integrating scheduling, precision dosing, and measurable aquaculture performance indicators (such as FCR, biomass growth, and mortality rate) within a single experimental framework.

In addition, the limitations of previous studies are also evident in the minimal development of smart feeders, which are portable and adaptable to small- to medium-scale cultivation conditions [11]. However, the characteristics of cultivators in Indonesia are dominated by small-scale businesses that generally have limited infrastructure, limited affordability of equipment, and a need for equipment mobility[1]. A number of studies have integrated sensors and monitoring. *real-time*, such as the system-feeder ESP32-based systems with water quality monitoring, have demonstrated the device's technical capabilities for automatic feeding but are still limited to functional demonstrations without direct evaluation of the impact on fish growth performance or feed efficiency [12]-[13]. This condition indicates a research gap regarding the impact of the use of smart feeders, portable scheduling-based, and precision dosing on feeding efficiency and fish growth.

Based on this review, quantitative testing is still needed to assess the impact of an automated feeding system that is not only scheduled but also implements precision dosing based on FCR targets to improve feed efficiency and fish growth performance [14]-[15]. This research developed a portable smart feeder that calculates feed requirements based on the number of fish and average weight, targets an FCR of 0.8–0.9, and applies gradual feeding in each feeding cycle and a sowing mechanism to ensure even feed distribution [16]. The system was then tested through controlled experiments, compared with conventional ponds under the same cultivation treatment, to evaluate feed efficiency, feed wastage, and fish growth [17].

2. MATERIALS AND METHOD

The initial stage is used to identify the system's needs. Activities at this stage include observing the feeding process, conducting discussions and/or interviews with users and system owners, and recording functional and non-functional requirements [18]. In addition, the required components/devices, including the feed spreading mechanism, are identified as the basis for system design. Based on the requirements collection results, the second stage is the preparation of an initial prototype that represents the system's main functions. The prototype is developed with input from users/system owners to suit operational conditions in the field[19]. In the third stage, the prototype that has been created is evaluated with users and system owners to assess its suitability to needs. If the prototype is not suitable, improvements are made by returning to the initial stage according to the iteration flow in Figure 1. If the prototype is declared suitable, the research continues to the next stage. In the fourth stage, the approved prototype is translated into a full system implementation through software development using an appropriate programming language and platform[20]-[21].

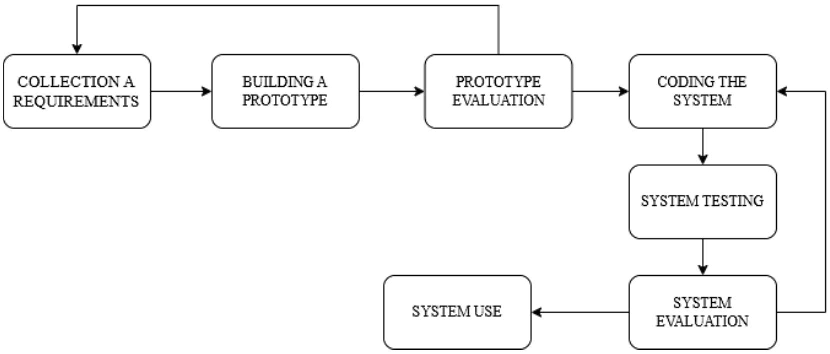

Figure 1. Research Stages

The fifth stage is system testing to ensure the system performs as designed, including functional tests such as accuracy of feeding schedules and servo responses, and integration testing.inter-module, as well as checking for adjustment needs based on user/system owner input. The sixth stage is a system evaluation to ensure system performance meets requirements, including component performance verification. If the evaluation results are not satisfactory, improvements are made by returning to the next stage.coding. At the final stage, the system is declared feasible and ready to operate, then used by the user/owner of the system as an automatic feeding device according to established procedures[17].

The system requirements analysis is divided into two categories: functional requirements and non-functional requirements. Details of functional requirements*Portable Smart Feeder*presented in Table 1, while the non-functional requirements are shown in Table 2.

Table 1. Functional Requirements of Portable Smart Feeder

Functional Requirements	Description	Target	Verification
Fish data input	The system accepts input of the number of fish and the average weight per fish.	Must	Input testing and validation
Data update while sorting	The system receives updates on fish counts and average weights at sorting/reweighing times.	Must	Update test & recalculation
Determining the FCR target	The system provides a target FCR option as a reference for feed calculations.	Must	Parameter selection test
Calculation of daily feed requirements	The system calculates daily feed requirements based on input cultivation data and FCR targets/feeding requirements.	Must	Test the calculation results based on the formula
Feeding schedule 3x/day	The system runs a feeding schedule 3 times a day (morning, afternoon, evening) according to the specified time.	Must	Scheduling Time Test
Dose division per cycle	The system divides the daily feed requirement into doses per feeding cycle.	Must	Dose distribution test
Gradual feeding in one cycle	In one feeding cycle, the system does not sow feed all at once, but gradually with certain time intervals.	Must	Phased sowing pattern test
Setting the interval between sowing stages	The system provides a setting of 8–15 minutes between sowing in one cycle.	Must	Test pause settings
Feed spreading mechanism	The system activates the spreader so that the feed is spread evenly and not concentrated in one spot.	Must	Feed distribution test (observation)
Servo actuator control	The system controls the servo/actuator to open and close the dosing mechanism according to the calculated dose.	Must	Actuator test (on/off, duration)

Table 2. Non-Functional Requirements of Portable Smart Feeder

Non-Functional Requirements	Description	Target/Measure	Verification
Accuracy of feed measurement	The accuracy of the feed dose is close to the value calculated by the system.	5–10%	Weighing test
Data update while sorting	The system receives updates on fish counts and average weights at sorting/reweighing times.	Must	Update test & recalculation
Schedule consistency	The system executes the schedule on time and stably from day to day.	Deviation ≤ 1 minute	Execution time test
Operational reliability	The system can work continuously without frequent failures/stops.	High uptime during testing	Uji running period
Environmental sustainability	Components are protected from water splashes, moisture and feed dust.	Protective case	Field test
Portability	The device is easy to move and install in different pools.	Easy to carry and quick to install	Installation test
Ease of maintenance	Easy to clean and the feed components do not get clogged easily.	Simple disassembly and assembly	Cleaning test
Parameter scalability	Schedule, interval, and dosage parameters can be changed as needed.	Parameters can be set	Test settings changes

The Portable Smart Feeder system's workflow for scheduling and precision dosing feed delivery. The process begins with the Start state, then the system enters the Feed Dosing stage, the main stage in preparing feed delivery. At this stage, the system determines the feed rate for a single feeding cycle based on user-input parameters and system-set parameters. The system workflow is shown in Figure 2.

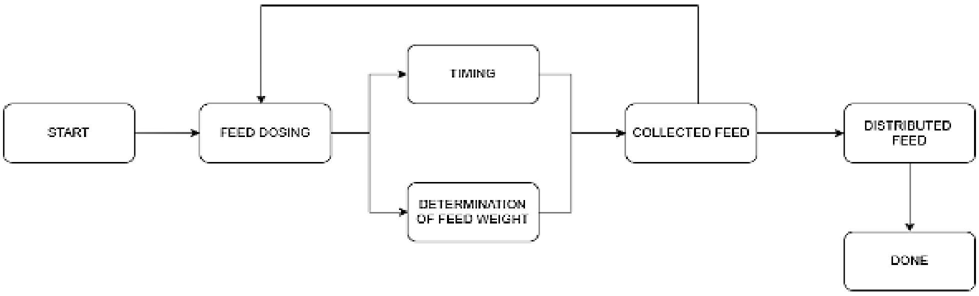

Figure 2. Flowchart of the Portable Smart Feeder system workflow

The next step is to calculate the feed dosage for the Portable Smart Feeder based on fish biomass, daily feeding rate, and feed efficiency evaluation using the Feed Conversion Ratio (FCR). This calculation serves as the primary reference to ensure the system's measurable and consistent feed output across each feeding cycle. Fish biomass is calculated from the number of fish (N) and the average weight per fish (W) using the biomass formula (B) using Equation 1.

$$B\ (kg) = (N \times \bar{W}) / 1000 \tag{1}$$

The formula used for daily feed requirements is determined based on a certain percentage of the biomass of the daily feeding rate (r) determined in this study to be 5%. The formula for daily feed requirements (Fh) uses Equation 2.

$$Fh\ (kg/hari) = r \times B \tag{2}$$

After the daily feed requirements are known, it is determined that feeding in this study is carried out 3 times a day, namely in the morning, afternoon, and evening. The formula for feed requirements per cycle (Fs) uses Equation 3.

$$Fs\ (kg/siklus) = Fh / 3 \tag{3}$$

Furthermore, the system implements a gradual feeding mechanism within a single cycle. The dose per cycle (Fs) is not sprinkled all at once, but rather divided into several sub-doses and administered at specific intervals until the total cycle dose is met. This aims to improve even feed consumption and reduce potential feed waste. Feed efficiency evaluation is performed using the 4-step formula for FCR:

$$FCR = Ftotal / \Delta B \tag{4}$$

Where Ftotal is the total feed given during the test period (kg), while ΔB is the increase in biomass (kg). The increase in biomass is calculated from the difference in average fish weight at the beginning and end of the observation period.$\Delta B\ (kg) = (N \times (\bar{W}t - \bar{W}0)) / 1000$, with $\bar{W}0$ the initial average weight (g/head) and $\bar{W}t$ the final average weight (g/head). In this study, the system aimed to achieve a target FCR of 0.8–0.9. Then it was compared with a conventional pond. Based on these calculations, the system was then implemented into the designed Portable Smart Feeder. Operationally, users simply need to input the number of fish and the average weight per fish. The system will calculate daily feed requirements, divide them into three feeding schedules, and automatically measure and distribute feed according to predetermined parameters.

Next, the system executes two interrelated processes: Timing and Feed Weight Determination. The Timing process ensures that feeding is executed at the scheduled time, while Feed Weight Determination determines the feed weight to be provided in that cycle based on the calculation results. After the execution time is met and the feed weight is determined, the system prepares the feed at the Collected Feed stage, where the feed is measured/collected according to the predetermined weight. The measured feed is then distributed and distributed to the pond through a spreading mechanism for more even feed distribution. Once the feed spreading process is complete, the system reaches the completion state for one feeding cycle. Next, the system returns to the Feed Dosing stage to wait and execute the next feeding cycle as scheduled.

The Portable Smart Feeder implementation design uses two rectangular test ponds, each measuring 4 m × 6 m × 1 m (24 m² in area and 1 m in depth). The first pond is used as pond A without the system, while the second pond is pond B equipped with the Portable Smart Feeder system. Both ponds are equipped with water drainage channels to support water management activities during maintenance. The layout of the control pond and the treatment pond is shown in Figure 3.

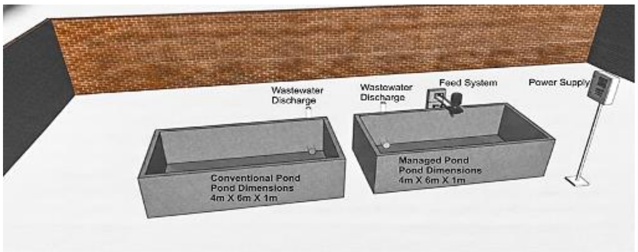

Figure 3. Design of the layout of the control pool and the pool

The Portable Smart Feeder device is placed in the treatment pond and mounted on a steel pipe support frame to ensure stability and prevent direct contact with water. The electronic components and electrical circuitry are housed in a panel box integrated with the feeder unit to protect the device from water splashes, feed dust, and environmental disturbances. A power source is provided on the side of the pond area via an electrical panel/installation, as shown in Figure 3.

In the system design as shown in Figure 4, the Load Cell sensor functions as a weight or force sensor. This sensor converts mechanical quantities (pressure or load) into electrical signals that are then sent to the ESP32 for processing. The RTC is used to provide real-time time information, such as hours, minutes, seconds, date, and year. Step Down is used to lower the voltage from the Power Supply to a lower and more stable voltage level so that it is safe for use by the ESP32 and other components. The Power Supply functions as the main voltage source for the entire circuit. The ESP32 microcontroller is the core of the system, all input data is processed according to the program embedded in the ES32. The results of this data management are then used to determine the actions or outputs that must be executed by the system. Servo A functions to pause the feed during weighing time and Servo B to regulate the feed sprinkling pause for 1 feeding cycle. Then the relay aims to break and connect the current to the load so that both servos can work according to system commands without burdening the control circuit. The I2C LCD functions to display the feed weight and feeding time, so that the dosing and scheduling of the feed can be monitored. Dynamo dynamo functions as a mechanical drive for spreading feed.

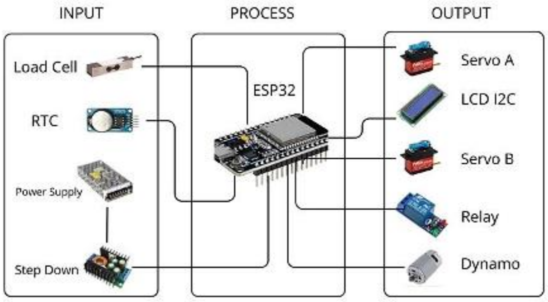

Figure 4. System Plan

3. RESULTS AND DISCUSSION

This section presents the design and implementation results of the Portable Smart Feeder system and the analysis of component integration in the system box, as shown in Figure 5. The entire circuit is placed in a closed space to protect the components from water splashes, feed dust, and environmental disturbances that commonly occur in cultivation areas. The components are well arranged and integrated to facilitate field installation and minimize the risk of damage due to exposed cables. Based on the assembly results, the main components inside the box consist of a microcontroller that functions as the system control center, an electronic switch module (relay) to control the load/actuator, and a power supply module that functions to stabilize the voltage supply for the control system. In addition, there are terminals/connectors to connect the power cable and actuator cable so that maintenance and component replacement processes can be carried out without dismantling the entire circuit. The circuit is also arranged on a circuit board (PCB) for stronger connections and to reduce the risk of loose contact due to vibration.

Additionally, on the control side, the microcontroller processes the logic for scheduling and dosing feed, then sends control signals to the two servos according to the system algorithm. The first servo serves to pause the feed during weighing time and the second servo to regulate the feed scattering interval for 1 feeding cycle. Then, the relay module in the box functions as a current breaker and connector to the load, so that the servos and others can work according to system commands without burdening the control circuit.

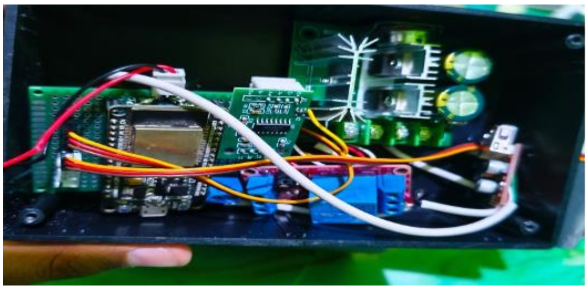

Figure 5. Placement of the main components of the Portable Smart Feeder in the system box

The next section shows the realization of the Portable Smart Feeder device that has been assembled and tested as a single system, which can be seen in Figure 6. This device is composed of several main parts, namely the feed hopper as a feed storage container, where the size can be enlarged to increase the desired feed content. Feed holding container as a temporary storage container for the dosing process, load cell as a load sensor to measure feed weight in real time, two servos as actuators to control feed flow, and a spreader driven by a dynamo to spread the feed evenly. All of these components are integrated with a controller as a control center that runs scheduling logic, precise dosing, and actuator control according to the system algorithm.

Figure 6. Portable Smart Feeder System

When the feeding schedule is active, the controller determines the feed dosage per cycle based on the cultivation parameters entered by the user. Next, the first servo regulates the feed flow opening from the hopper to the reservoir, while the load cell reads the feed weight until it reaches the target value set by the system. Once the target weight is reached, the feed flow is stopped so that the dosage is according to the needs. Next, the feed in the reservoir is released to the spreading mechanism via the second servo, then the dynamo drives the spreader to spread the feed so that it is not concentrated in one spot. This mechanism supports the strategy of gradual feeding in a single cycle (with certain intervals), while also improving the even distribution of feed on the pond surface to provide a more even opportunity for all fish to consume it.

3.1. Tool Testing

Portable Smart Feeder component testing is used to verify that each component works according to its function and is well integrated in the system, the test table can be seen in Table 3.

Table 3. Portable Smart Feeder Component Testing

Component	Testing Parameters	Test Procedure	Test Results	Conclusion
Controller	Booting and program stability	System is turned on 10×	Powers up normally 10/10, no restarts occur	Passed
Controller (schedule)	Accuracy of time execution	3 schedules were determined, with a total of 9 executions.	9/9 successful executions, deviation 0–30 seconds	Passed
Controller (dosing)	Dose output per cycle	Input the number and average weight of fish for the dose calculation system.	The dose is displayed according to the calculation (difference	Passed

Component	Testing Parameters	Test Procedure	Test Results	Conclusion
			0)	
Load cell (accuracy)	Reading stability and measurement error	Uji beban 0 g, 100 g, 200 g, 500 g	Stable reading (fluctuation ±2–5 g)	Passed
Servo 1 (measurement)	Feed door open-close response	20 kcal ON/OFF	Works 20/20, no crashes	Passed
Servo 2 (pause/exit)	Gradual administration per cycle	1 cycle divided into 4 subdoses	4 sub-doses running, total feed achieved	Passed
Spreader	Even distribution of feed	Observation of distribution on the surface	The feed is spread out widely, not piled up at one point.	Passed
1 cycle integration	Work sequence: weigh, remove and distribute	Run 5 cycles	5/5 cycles successful without error	Passed

The functional test results in Table 3 indicate that the Portable Smart Feeder system functioned as designed. The controller ran the program stably and executed the feeding schedule at the specified time. The load cell showed stable readings and could be used as dosing feedback, enabling the target feed weight to be achieved with errors still within the tolerance limit. Two servos consistently regulated feed flow during the dosing and dispensing stages, while the dynamo and spreader spread the feed so it was not concentrated in one spot.

3.2. Monitoring

In this study, the fish used for research were catfish, carried out in two test ponds with the same size, namely 4 m × 6 m (area 24 m²) and a pond depth of 1 m. Pond A was used as a control pond (without a system), while Pond B was a treatment pond using a Portable Smart Feeder. At the beginning of the observation, each pond was filled with 4,000 catfish seeds measuring 8–10 cm, ponds A and B cultivation can be seen in Figure 7. In the context of controlling environmental variables, water quality parameters such as dissolved oxygen (DO) and temperature were not quantitatively measured, as the primary focus of this study was evaluating the feeding system. Nevertheless, the environmental conditions of both ponds were maintained to be comparable through uniform management practices, including pH monitoring using a commercial pH meter and simultaneous water addition. Furthermore, all cultivation treatments applied followed the common daily practices of fish farmers, without any additions or reductions in standard procedures. Therefore, any observed differences in this study are primarily attributed to the feeding methods employed.

During the maintenance period, both ponds in Figure 7 received the same cultivation treatment, including water management (adding or replacing water at the same time with the same actions), pond maintenance, and a three-times-daily feeding schedule spanning morning, afternoon, and evening. Monitoring was conducted for 14 days to observe fish responses, growth, and feed efficiency indicators in each treatment. The main difference between the two ponds lies in the feeding method, namely Pond A using a conventional method based on fish feeding aggressiveness, while Pond B uses an automated system with measured dosing and gradual feeding according to the research design.

Figure 7. Fish Farming Pond for Monitoring

During the 14-day observation period, Pond A without a system or conventional, the amount of feed was not determined based on biomass calculations or FCR targets, but was given according to the aggressiveness of the fish until the feeding response decreased. This caused the daily amount of feed in Pond A to fluctuate, as seen in Table 4, with a daily total ranging from 2.40 kg/day to 2.85 kg/day. This variation occurs in the conventional method because the feed dosage is based on the condition of the fish at the time of feeding, this causes differences in dosage between days even though other cultivation treatments are made the same.

Table 4. Feeding for 14 Days (Pond A and Pond B)

Day	Pool A Morning	Pool A Afternoon	Pool A Night	Total Pool A (kg/day)	Pool B Morning	Pool B Afternoon	Pool B Night	Total Pool B (kg/day)
1	0,85	0,95	0,6	2,4	0,67	0,67	0,66	2
2	0,7	0,8	0,65	2,15	0,67	0,67	0,66	2
3	1,1	0,9	0,75	2,75	0,67	0,67	0,66	2
4	0,8	0,7	0,6	2,1	0,67	0,67	0,66	2
5	0,95	0,85	0,7	2,5	0,67	0,67	0,66	2
6	0,75	1	0,6	2,35	0,67	0,67	0,66	2
7	1,05	0,85	0,8	2,7	0,67	0,67	0,66	2
8	0,65	0,75	0,55	1,95	0,67	0,67	0,66	2
9	0,9	0,8	0,7	2,4	0,67	0,67	0,66	2
10	0,8	1,05	0,75	2,6	0,67	0,67	0,66	2
11	0,7	0,85	0,6	2,15	0,67	0,67	0,66	2
12	1	0,9	0,75	2,65	0,67	0,67	0,66	2
13	0,85	0,75	0,65	2,25	0,67	0,67	0,66	2
14	1,1	0,95	0,8	2,85	0,67	0,67	0,66	2
	Total Feed for Pond A			33,80 kg	Total Feed for Pond B			28 kg

In contrast, Pond B uses a Portable Smart Feeder, implementing a measured and consistent feeding schedule based on initial calculations, namely 2 kg/day, or 5% of the initial biomass, divided into three feeding cycles. Table 4 shows that the feed dosage in Pond B is fixed at 0.67 kg in the morning, 0.67 kg in the afternoon, and 0.66 kg in the evening to ensure a daily total of exactly 2 kg. In addition to consistent feed amounts, the system also implements a phased feeding strategy within a single cycle: the feed is divided into several sub-doses with a 10-minute interval, and a spreader mechanism evenly distributes the feed across the pond surface. Based on direct observations, phased feeding within a cycle tends to improve the even distribution of feed consumption because feeding aggressiveness decreases after the initial feed is consumed, allowing fish that have not received feed to receive it in the next sub-dose. The presence of the spreader also allows the feed to reach a wider area of the pond, preventing it from concentrating in one spot. The differences in feeding patterns between the two ponds provide a basis for analyzing feed efficiency and achieving the FCR target. Pond B was controlled to achieve the FCR target of 0.8–0.9, while in Pond A there was a possibility of overfeeding on days when fish aggressiveness was high, which could increase the risk of feed not being consumed optimally and trigger digestive problems in some fish, such as over-fullness and ultimately death. Based on records for 14 days, the total feed of Pond A reached 33.80 kg, while Pond B was controlled in a measured manner with a fixed dose of 2.00 kg/day so that the total feed for 14 days was 28.00 kg.

Fish growth was evaluated at the end of the rearing period (day 14) using a grading process in tiered sorting tanks to group fish by size class. The sorting tanks were arranged sequentially from the largest to the smallest holes. After the fish were separated and uniform in each size class, a manual count was performed, followed by weighing, and all results were recorded for each size class. Based on the sorting results in Table 5, the size distribution and biomass of fish in the two ponds showed direct differences in growth. In the 9–10 cm size class, the number of fish was relatively small in both ponds: 180 in Pond A and 150 in Pond B. In the middle size class, namely 11–12 cm and 12–14 cm, the number of fish in both ponds was relatively large. Pond A had 1,650 individuals in the 11–12 cm class and 1,600 individuals in the 12–14 cm class, while Pond B had 1,500 individuals in the 11–12 cm class and 1,650 individuals in the 12–14 cm class. The most striking difference occurred in the largest size class (5 cm), where Pond B produced 687 individuals, significantly more than Pond A's 320.

In terms of harvest weight, the total fish biomass at the end of the period also showed the superiority of Pond B. Pond A produced a total weight of 68.17 kg, while Pond B achieved 70.90 kg. The final biomass difference was 2.73 kg, equivalent to approximately a 4% increase in Pond B compared to Pond A. Pond B achieved higher biomass with lower feed usage. Based on the recording of feeding for 14 days, Pond A consumed 33.80 kg of feed, while Pond B consumed 28 kg. Thus, Pond B used approximately 17% less feed than Pond A. This finding indicates that the system implementation in Pond B reduced feed consumption and increased fish weight.

Feed efficiency was analyzed using Feed Conversion Ratio (FCR), which is the ratio between total feed and biomass increase during the maintenance period, with the formula Equation 3. With an initial biomass of 40 kg (4,000 fish × 10 g/fish), Pond B which consumed 28.00 kg of feed and produced a final biomass of 70.90 kg had a biomass increase of 30.90 kg, so that Pond B's FCR was 0.91 to 1. Meanwhile, Pond A consumed 33.80 kg of feed with a final biomass of 68.17 kg (biomass increase of 28.17 kg), so that Pond A's FCR was 1.20 to 1. In addition, fish mortality is an important factor that affects actual production results. In Pond B, the number of deaths recorded was very low, namely 13 fish and live fish were recorded at 3,987 fish. In contrast, Pond A experienced a higher mortality rate of 250 fish, with 3,750 live fish recorded, resulting in losses for the fish farm. The low mortality rate in Pond B can be attributed in part to the measured and gradual feeding and more even distribution of feed, which allows smaller fish to receive more food and reduces the risk of illness due to bloating due to overfeeding. The Portable Smart Feeder has been shown to increase fish biomass, reduce feed consumption, and reduce mortality. The implementation of a gradual feeding mechanism may facilitate a more uniform distribution of feed, thereby potentially reducing competition among fish and improving growth uniformity.Overall, the integration of feeding schedules and precision dosing appears to enhance not only economic efficiency but also biological performance within aquaculture systems.

Table 5. Catfish Growth Data

No	Size class (cm)	Pool A: Number of live (tails)	Pool A: Average weight (g/head)	Pool A: Total live weight (kg)	Pool B: Number of live (tails)	Pool B: Average weight (g/head)	Pool B: Total live weight (kg)
1	9–10	180	14	2,52	150	13,5	2,03
2	11–12	1.650	17	28,05	1.500	16,5	24,75
3	12–14	1.600	18,5	29,6	1.650	18	29,7
4	15	320	25	8	687	21	14,43
Total live fish (harvest)		3.750		68,17	3.987		70,9

4. CONCLUSION

Based on the results from the analysis, testing, and system implementation stages, it can be concluded that this research has succeeded in developing a Portable Smart Feeder based on scheduling and precision dosing, equipped with a gradual feeding mechanism (sub-doses with pauses) and a spreader for even feed distribution. The application of the system in Pond B for one maintenance cycle (14 days) provided better performance than Pond A (conventional method), indicated by a higher harvest biomass of 70.90 kg compared to 68.17 kg, lower feed usage of 28.00 kg compared to 33.80 kg, and a much lower mortality of 13 fish compared to 250 fish. The sorting results also showed that Pond B produced a larger number of fish, namely 15 cm.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to Universitas Teknokrat Indonesia for the institutional support that enabled this research to be conducted and completed. Appreciation is also extended to the Head of the Study Program for academic support and facilities provided throughout the research process. The authors are especially grateful to the Academic Supervisor for valuable guidance, constructive feedback, and continuous support during the preparation and refinement of this article. The authors also acknowledge all parties who contributed directly or indirectly to this work. Any remaining limitations of this article are solely the responsibility of the authors. Appreciation is given to OpenAI's ChatGPT for assisting in translating this paper from Indonesian to English, ensuring clarity and accessibility for a broader audience.

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