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Automated Smart Feeder System for Catfish Cultivation: IoT Integration for Improved Feeding and Health Management

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ABSTRACT The rearing of catfish in 80-liter containers has become more favored by small-scale aquaculture practitioners owing to its ease, modest spatial demands, and inexpensive initial capital outlay. Nonetheless, considerable obstacles remain, especially high incidences of cannibalism and low growth performance, frequently due to irregular feeding methods and insufficient probiotic supplements. This work introduces the design and implementation of an automated Internet of Things (IoT)-based system for accurate feeding and probiotic delivery. The system is governed by a microprocessor, with an ESP8266 module enabling wireless connection. Mechanical functions, including feed distribution and probiotic administration, are controlled by a servo motor and water pump, respectively, while an ultrasonic sensor oversees feeding schedules. Furthermore, an ESP32-CAM module facilitates real-time video surveillance, while a specialized mobile application allows for remote monitoring and management. All operational data is delivered to a centralized database, accessible through the Android application. Experimental findings indicate that the automatic feeder significantly enhances culture outcomes. Following one week, containers outfitted with the system demonstrated a survival rate of 86% (43 out of 50 fish), with average fish lengths rising from around 7–8 cm to 10–11 cm. Conversely, control groups devoid of the device exhibited a survival rate of merely 58% (29 fish), with average growth increments restricted to approximately 1 cm. The introduction of the intelligent feeder system markedly diminishes cannibalism and improves growth rates in small-scale catfish aquaculture.

INDEX TERMS Smart Feeder, Automatic Feeding, Internet of Things, Catfish, Fish Cultivation.

I. INTRODUCTION

Fish farming has emerged as a vital sector in Indonesia's economy, particularly through catfish aquaculture. The practice of using 80-liter bucket systems for small-scale catfish farming has gained traction due to its low entry costs and minimal spatial requirements, making it especially suitable for urban or constrained residential contexts [1], [1]. Catfish, particularly species like Clarias gariepinus, are in constant demand, both domestically and globally, leading to increased interest in efficient growing systems that can boost household income [2], [3]. The utilization of bucket systems presents various advantages. Economically, they allow for significant biomass production without requiring expansive space, rendering them an attractive option for individuals seeking to enhance their financial status through aquaculture. Additionally, these systems can operate sustainably with a reduced environmental footprint compared to traditional aquaculture methods [1]. However, challenges persist, specifically in maintaining consistent feeding protocols and administering probiotics, which are crucial for optimizing growth, reducing instances of cannibalism, and ensuring overall fish health [4], [5]. Addressing feeding management through technology has become a focal point of research. Existing solutions, such as IoT-enabled automatic feeding systems, have shown potential but often lack comprehensive features, such as internet connectivity for remote operation. For instance, while some automated systems were developed, they did not incorporate remote monitoring capabilities [6]. Moreover, other systems integrated a mobile application for automated feeding but did not address the simultaneous delivery of probiotics, which is essential for maximizing growth and health in catfish [7]. The current initiative aims to build on these technological advancements by creating an intelligent feeding system that incorporates automatic feed dispensing and integrates probiotic delivery according to a user-defined schedule. Utilizing an Android application to control the feeding system remotely enhances operational efficiency and allows farmers to monitor fish health in real time, thus addressing the core issues of inconsistent feeding and health management [2]. Researchers have shown that the integration of probiotics can significantly improve growth metrics, enhance the immune response in fish, and lead to better feed conversion ratios, which further supports the case for their incorporation in catfish farming regimes [3], [8]. Through systematic control over feeding schedules and probiotic administration, this project endeavors to mitigate cannibalism and enhance survival rates in catfish grown in 80-liter buckets. This approach aims not only to improve productivity for small-scale farmers but also to elevate the economic viability of household-level aquaculture across Indonesia [2], [1]. In conclusion, while catfish aquaculture in Indonesia using 80-liter bucket systems offers substantial economic potential, it also encounters specific hurdles related to feeding practices and growth management. The incorporation of IoT technologies and probiotics represents a promising pathway toward overcoming these challenges, supporting sustainable aquaculture that can contribute significantly to both household economies and the national market [6], [1], [2].

II. LITERATURE REVIEW

Extensive studies have focused on the development of microcontroller-driven automatic fish feeders, mainly aimed at improving feeding efficiency and reliability in aquaculture. An automated feeding protocol designed for catfish was showcased, allowing scheduled programming while posing usability challenges for individuals lacking technical expertise [9]. An automated feeding device specifically for catfish in bucket systems was developed, employing Arduino components and ultrasonic sensors. At the same time, the method achieved tri-daily feeding with low-feed alerts, but it lacked mobile interaction capabilities and remote monitoring, limiting operational flexibility [10]
.

In contrast, an IoT framework was implemented via the ESP8266, providing online control of the feeder but relying on generic third-party applications, which often complicate user interfaces and may deter adoption among inexperienced users [11]. A feeder equipped with a load cell sensor for precise feeding was introduced; however, its functionality remained localized without provisions for real-time monitoring [12]. Furthermore, despite advancements using NodeMCU and Firebase for real-time observation, the approach failed to incorporate scheduling automation and probiotic delivery [13].

An analysis of these studies reveals persistent deficiencies such as inadequate remote monitoring capabilities, a reliance on generic applications not tailored for aquaculture, limited options for user-friendly adjustments, insufficient feeding schedule automation, and minimal integration for probiotic delivery systems [14].

This research thus proposes the development of a Smart Feeder system combining automated scheduling for feed and probiotics, allowing for remote control and monitoring functionalities through a dedicated Android application. The objective is to deliver a user-centric solution that enhances the management efficiency of household catfish farming by overcoming the limitations identified in previous systems, thereby fostering more productive aquaculture practices.

III. METHODOLOGY

An empirical methodology was employed to design and assess a Smart Feeder system for catfish farming within 80-liter containers. This process involved measuring the effects of automation on crucial parameters such as fish survival rates and growth performance [15]. Data collection techniques included field observations, interviews with stakeholders, literature reviews, and systematic experimental methods. Fieldwork was conducted at a local aquatic facility, where challenges like irregular feeding schedules and increased cannibalism were recorded [16]. Comprehensive interviews provided valuable insights into user needs, operational preferences, and maintenance practices necessary for overseeing remote systems [16]. Prior studies on IoT-enabled feeding systems were also examined to identify existing shortcomings that the proposed method could rectify [11].

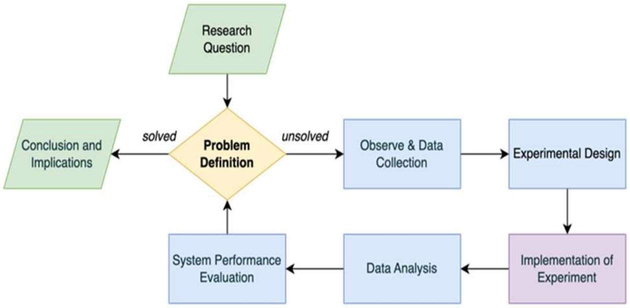

Fig 1. Research Methodology Flow

The experimental phase involved a controlled comparison of two treatment groups, each containing 50 juvenile catfish, one utilizing the Smart Feeder and the other subjected to manual feeding protocols. Both groups were housed in identical environmental conditions to isolate the effects of the Smart Feeder intervention [17]. The evaluation measured parameters such as survival rates, growth increments, and the precision of the feeding and probiotic treatments over seven days. Technical components of the Smart Feeder included the NodeMCU ESP8266 microcontroller, an ultrasonic sensor for feed detection, a servo motor for feed dispensing, and a water pump for probiotic delivery [18]. Additionally, the system features an ESP32-CAM for visual monitoring, with operational data stored in a Firebase cloud database accessible via the dedicated Android application [19].

Evaluation focused on system accuracy and its impacts on fish health and growth. Timing accuracy for feed and probiotic delivery was assessed, maintaining a maximum deviation limit of 10 seconds, indicating good operational compliance. Results showed that the Smart Feeder cohort had 43 out of 50 fish survive and grow from 7–8 cm to 10–11 cm, whereas the control group had only 29 survivors and minimal growth [20], [21]. Quantitative comparisons of both experimental groups, bolstered by qualitative user experience evaluations, demonstrated a robust performance of the Smart Feeder system, underlining its promise for enhancing efficiency in small-scale catfish aquaculture [22].

IV. RESULTS AND ANALYSIS

A. SMART FEEDER HARDWARE IMPLEMENTATION

The fundamental architecture of the proposed IoT-enabled Smart Feeder is deliberately optimized to meet the particular requirements of catfish aquaculture using 80-liter containers. Centralized control is facilitated by a NodeMCU ESP8266 microcontroller, which manages all system operations. The servo motor meticulously regulates feed distribution, while a specialized water pump dispenses probiotics as necessary. Feed inventory levels are consistently monitored with an HC-SR04 ultrasonic sensor, guaranteeing prompt replenishment and uninterrupted operations. The incorporation of an RTC DS3231 module ensures precise scheduling for both feeding and probiotic medication, hence ensuring compliance with appropriate aquaculture standards. All functioning components are integrated within a compact housing intended for direct installation on the culture bucket. This compact management framework is designed for easy installation atop culture buckets, operating efficiently at a low voltage of 3.3 V, making it ideal for urban or residential aquaculture applications [23]. This system offers an affordable and robust technology intervention for small-scale catfish farmers, answering essential needs in precision aquaculture management.

Fig 2. Hardware implementation

B. SOFTWARE AND MOBILE APPLICATION

The functioning of the IoT-enabled Smart Feeder for catfish aquaculture, utilizing 80-liter containers, is primarily regulated by the NodeMCU ESP8266 microcontroller, which manages all system functions. The servo motor meticulously regulates feed dispensing, guaranteeing precise supply intervals and volumes. The incorporation of a water pump enables the automated delivery of probiotics, while the HC-SR04 ultrasonic sensor consistently tracks feed inventory levels. The RTC DS3231 module facilitates temporal control, ensuring the punctual dispensing of both feed and probiotics in accordance with established timetables. All components are integrated within a small shell intended for positioning atop the culture container. The system functions effectively at around 3.3 volts, maximizing energy efficiency and making it particularly appropriate for compact aquaculture applications. The mobile application provides users with virtual access to feeding schedules and application log data, allowing further adjustments as necessary to optimize fish growth [18]. The rising demand for sustainable and effective home-based aquaculture solutions signifies a pivotal progress in the sector.

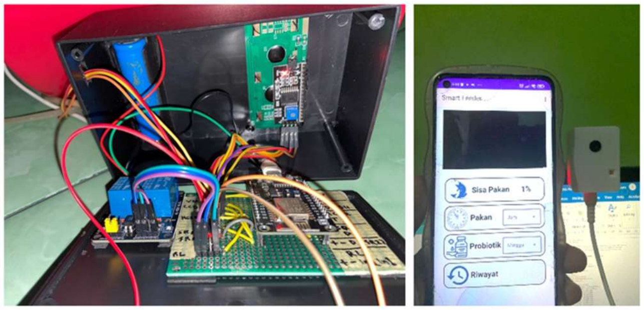

Fig 3. Hardware and mobile application synchronization

C. SYSTEM INTEGRATION AND COMMUNICATION MECHANISMS

The integration of hardware and software components is accomplished by creating a Wi-Fi connection between the NodeMCU ESP8266 and a Firebase real-time database. All data exchanges, encompassing sensor outputs and user commands, are encoded in JSON format and delivered using HTTP or HTTPS protocols. Scheduled user actions are safely retained in Firebase until accessed by the NodeMCU, which thereafter performs essential tasks such as feeding or probiotic administration with exact timing [24]. Empirical communication evaluations demonstrate that data synchronization transpires within milliseconds, ensuring swift command execution and remarkable operational precision.

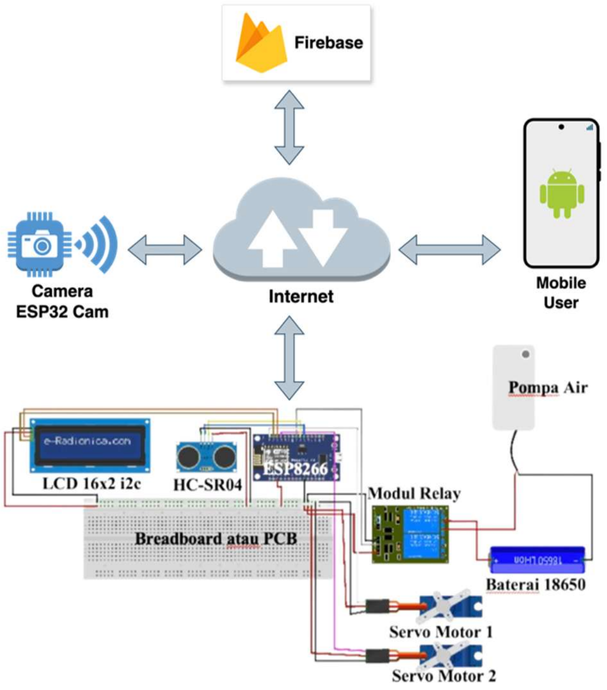

Fig 4. System integration and communication mechanisms

D. HARDWARE AND SOFTWARE TESTING

A thorough assessment of the Smart Feeder's hardware and software was performed to ascertain its operational efficacy in facilitating catfish farming within 80-liter containment units. A black-box testing methodology was utilized, concentrating on the validation of essential system functionalities as experienced by end users, rather than examining the internal mechanisms that support such functions. The evaluation indicated that all fundamental subsystems operated dependably. The embedded real-time camera facilitated ongoing situational monitoring, and the ultrasonic sensor ensured precise measurement of residual feed. The user interface features, including the “About” and “Exit Application” functions, exhibited immediate responsiveness. The application consistently recorded a comprehensive log of feed and probiotic administration events, complete with exact timestamps. The system's hardware components, including the servo motor, water pump, and ESP32-CAM, demonstrated strong interoperability with the software architecture, which includes the Android application and Firebase backend. The results demonstrate that the Smart Feeder platform functions in alignment with its designated design objectives, confirming its appropriateness for practical application in aquaculture settings.

E. SCHEDULING ACCURACY TESTING

Upon satisfactory initialization of the device (see Figure 3), we commenced the assessment of the scheduling mechanism's efficacy. Automated feed distribution was set at 30-second intervals to replicate operational automation. The findings, presented in Table 1, reveal that in 3 of 10 trials, the system demonstrated a delay of over five seconds, highlighting significant issues related to scheduling dependability.

TABLE I. RESULTS OF FEED SCHEDULING EXPERIMENT

n-Experiment	Experiment Start	Experiment Log Results	Conclusion
1	May 29, 2025, 19:16:35	May 29, 2025, 19:16:40	Delay of 5 seconds
2	May 29, 2025, 19:16:40	May 29, 2025, 19:17:12	Delay of 2 seconds
3	May 29, 2025, 19:17:12	May 29, 2025, 19:17:45	Delay of 3 seconds
4	May 29, 2025, 19:17:45	May 29, 2025, 19:18:18	Delay of 3 seconds
5	May 29, 2025, 19:18:18	May 29, 2025, 19:18:54	Delay of 6 seconds
6	May 29, 2025, 19:18:54	May 29, 2025, 19:19:31	Delay of 7 seconds
7	May 29, 2025, 19:19:31	May 29, 2025, 19:20:03	Delay of 4 seconds
8	May 29, 2025, 19:20:03	May 29, 2025, 19:20:39	Delay of 6 seconds
9	May 29, 2025, 19:20:39	May 29, 2025, 19:21:12	Delay of 3 seconds
10	May 29, 2025, 19:21:12	May 29, 2025, 19:21:44	Delay of 2 seconds

An evaluation has commenced to examine the scheduling capabilities of probiotic. Automated feed distribution was set at 30-second intervals to replicate genuine operational conditions accurately. Table 2 summarizes that 10 trials were completed, revealing that in three instances, execution delays were above five seconds. These findings highlight the essential need to enhance scheduling performance to guarantee dependable operation.

TABLE II. RESULTS OF PROBIOTIC SCHEDULING EXPERIMENT

n-Experiment	Experiment Start	Experiment Log Results	Conclusion
1	May 29, 2025, 19:22:22	May 29, 2025, 19:22:25	Delay of 3 seconds
2	May 29, 2025, 19:22:25	May 29, 2025, 19:22:59	Delay of 4 seconds
3	May 29, 2025, 19:22:59	May 29, 2025, 19:23:40	Delay of 11 seconds
4	May 29, 2025, 19:23:40	May 29, 2025, 19:24:13	Delay of 3 seconds
5	May 29, 2025, 19:24:13	May 29, 2025, 19:24:47	Delay of 4 seconds
6	May 29, 2025, 19:24:47	May 29, 2025, 19:25:22	Delay of 5 seconds
7	May 29, 2025, 19:25:22	May 29, 2025, 19:25:56	Delay of 4 seconds
8	May 29, 2025, 19:25:56	May 29, 2025, 19:26:35	Delay of 9 seconds

9	May 29, 2025, 19:26:35	May 29, 2025, 19:27:08	Delay of 3 seconds
10	May 29, 2025, 19:27:08	May 29, 2025, 19:27:43	Delay of 5 seconds

Intermittent Wi-Fi access and erratic data syncing with the Firebase server have caused small delays. Nonetheless, the system reliably upholds accurate scheduling capabilities. Experimental findings demonstrate that the NodeMCU ESP8266 microcontroller proficiently regulates the servo motors, guaranteeing prompt distribution of feed and probiotics. These findings demonstrate that the Smart Feeder operates with high accuracy and reliability. Thus, this technology offers a practical option for small-scale, home-based catfish aquaculture, allowing producers to maintain feeding schedules and improve operational efficiency.

F. EVALUATION OF CULTIVATION EFFECTIVENESS

A controlled experiment was done to objectively assess the performance of the Smart Feeder system in catfish aquaculture, employing two identical containers, each containing 50 uniformly sized catfish juveniles. The experimental group utilized the Smart Feeder, whereas the control group was subjected to manual feeding. After one week, data demonstrated a significant enhancement in the experimental group, with a survival rate of 86% (43 out of 50 fish) compared to merely 58% (29 out of 50 fish) in the control group. Moreover, the fish in the Smart Feeder group displayed enhanced growth, with average lengths rising from 7–8 cm to 10–11 cm, whereas the control group exhibited negligible growth, attaining just 8–9 cm. These data highlight the significant influence of automated feeding systems on survival and growth rates in catfish aquaculture.

Fig 5. Initial size of catfish

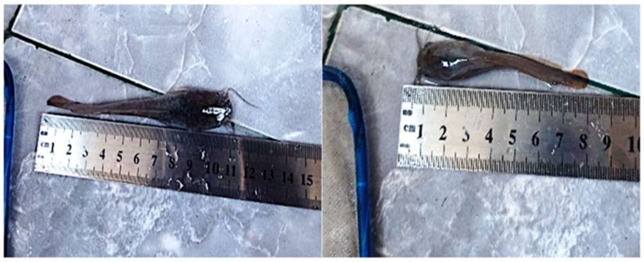

Fig 6. comparison of catfish size after one week

Consult Figure 6. After just one week, a significant difference is evident: the catfish raised with the Smart Feeder (left) display increased size and enhanced overall health relative to those in the control group (right). The findings indicate that the Smart Feeder, via its timed feedings and probiotic addition, markedly improves survival rates, expedites growth, and diminishes occurrences of cannibalism in fish.

G. RESEARCH EXCELLENCE AND INNOVATION

The defining characteristic of this Smart Feeder system is its thorough integration of automatic and scheduled feeding, probiotic delivery, and remote monitoring, all controlled by a specialized mobile application. By removing reliance on external platforms like Blynk, the system facilitates total local control. The incorporation of an activity log markedly improves the effectiveness of overseeing and administering small-scale catfish farming enterprises.

V. CONCLUSION

This study accomplished its main goal of creating and implementing an Internet of Things (IoT)-enabled Smart Feeder system for the automated production of catfish in an 80-liter aquaculture tank. The primary objective was to completely automate the procedures of feed and probiotic administration, facilitating remote monitoring for aquaculture professionals and significantly decreasing human labor and time expenditure. Utilizing diverse sensors and actuators connected through a unified microcontroller platform not only ensures system reliability but also enhances user experience through an intuitive application that simplifies aquaculture operations [25].

The empirical assessment of the system revealed a significant level of reliability, with automated feed and probiotic dispensing occurring as planned in 90% of cases, and response latencies routinely kept under 10 seconds. The seamless integration of hardware and software components enhanced a user experience marked by efficiency and intuitiveness. During a seven-day testing, the Smart Feeder system demonstrated significantly enhanced results: 43 out of 50 fish survived, showing considerable development from an initial length of 7–8 cm to 10–11 cm. Conversely, the manually controlled control group exhibited increased mortality, yielding only 29 survivors and restricted development to 8–9 cm. The findings support the case for broader adoption of advanced aquaculture technologies aiming to improve efficiency, sustainability, and productivity in Indonesian catfish farming [26].

The IoT-based Smart Feeder system effectively accomplished its dual goals of automating essential aquaculture procedures and enabling comprehensive remote monitoring. This innovation optimizes operational processes and provides a dependable, accessible technological solution for small-scale catfish growers, leading to enhanced fish survival and growth. The results underscore the imperative need for the widespread use of sophisticated aquaculture technologies to enhance output, efficiency, and sustainability.

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