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Design and Build an Automatic Feeding System for Catfish Farming based-on Internet of Things (IoT)

Mukhlis Surito Fajri[1], Asrizal[1,*], Harman Amir[2], Mairizwan[3]

Department of Physics, Universitas Negeri Padang, Padang 25131, Indonesia

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Corresponding Author
*Author Name: Mukhlis Surito Fajri
Email: mukhlissuritofajri@gmail.com

Abstract: Fish farming represents a sector aimed at boosting the national economy. The Ministry of Marine Affairs and Fisheries has prioritized programs to support the growth of catfish farming.. However, there are still obstacles experienced by cultivators such as irregularities in feeding time and uneven distribution of feed. Therefore, a solution is needed in the form of designing an efficient system in providing fish feed. The system is developed using ESP32 microcontroller, servo motor, stepper motor, loadcell, and connected to the website for remote control. The system utilizes a motor, load cell, and is integrated with a website for remote operation. This research employs an engineering approach, focusing on system design and testing. The findings indicate that the system achieves an average feed weight measurement accuracy of 98.31%, demonstrating reliable performance in both laboratory and field-scale tests. This system is expected to increase efficiency, practicality, and effectiveness in catfish farming, as well as providing real-time information about feed and feeding schedules.

Keywords: Automatic feed, Catfish farming, IoT, Load cell, Sensor.

1. Introduction

Empowerment is the act of enabling individuals to gain strength and improve their quality of life [1]. Fish farming is a sector that has been developed to enhance the national economy [2]. The Ministry of Marine Affairs and Fisheries prioritizes programs to support catfish farming development, highlighting the significant potential of fish farming in Indonesia, particularly in catfish cultivation [3]. Catfish is the most popular freshwater fish among the community due to its easy cultivation and affordable price, which is why many beginner catfish farmers choose it as their main commodity [4]. Catfish contains high nutritional content and is very useful, including calories, fat, protein, sodium, vitamins and other nutritional content. Catfish farming has become a profitable business sector in Indonesia [5]. Catfish cultivation has been developed conventionally in cultivation, pond making, water treatment, seed and feed enlargement catfish[6]. Conventional cultivation has required large costs and a long time, while the catfish

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produced is not abundant[7]. The increasing public need for catfish consumption makes it difficult for catfish farmers to meet these needs [8].

Land and water resources are increasingly limited, so that cultivation technology is environmentally friendly and water-saving [9]. Some things that must be considered in fish farming are by providing scheduled fish feed, fish pond maintenance such as monitoring the water temperature in the pond, and pond cleanliness [10]. Feed is a crucial component that plays a significant role in supporting the growth and survival of catfish [11]. Feeding fish is one of the most important things because if the fish forget to feed it, it can cause fish growth to be inhibited. Feeding activities are currently still carried out using manual stocking techniques [12]. In the first initial study, research on the design of feeding fish has been carried out before. Previous research conducted by Marisal (2020) regarding the design of automatic fish feeding equipment using accelerometer sensors and load cell sensors [13]. The tool was created based on the known fish satiety variable from the accelerometer sensor output.

The tool can detect the weight of the remaining feed in the tube using a load cell sensor. A load cell sensor is a transducer, an electronic component that converts physical quantities, such as pressure from a load, into electrical signals [14][15]. The second preliminary study on automatic fish feeding was conducted by Supriadi (2019), who designed an automatic fish feeding scheduling and monitoring system based on the Internet of Things (IoT). However, the shortcomings of this tool include the inaccurate display of the amount of feed based on the fish's weight and age, uneven distribution of feed, and the absence of a marker when the feed in the container runs out [10].

The third preliminary study on automatic fish feeding design was conducted by Baihaqi (2020), who developed a study titled "Automatic Fish Feeding System for Tilapia Based on the Internet of Things (IoT)" [16]. The Internet of Things (IoT) refers to the connection of various physical devices and objects worldwide via the internet [17][18]. With the growth of practical and online technologies, there has been extensive research on Android-based control systems utilizing IoT [19]. This research aimed to create an application and design a tool for scheduling and monitoring fish feed, along with the output of feed conditions. Additional information provided includes the feeding status and the condition of the dispensed feed.

Based on the shortcomings and limitations of previous research, where the information provided has not been in accordance with expectations, there is no marker when the feed in the container is out or not, unstable feeding, and the tool designed is not internet-based, the author is interested in raising the title of the research, namely "Design and Build an Automatic Feeding System for Catfish Cultivation Based on Internet of Things (IoT)". This automatic fish feeding is designed by using ESP32 as a microcontroller center, a stepper motor to rotate the feed container so that the feed is evenly distributed, a servo motor, a load cell to measure the weight of the feed, and connected to the website. The design of catfish feeding equipment made using internet of things technology with a website can help and make it easier for users to manage and carry out the work of the tool.

The use of internet of things (IoT) technology using websites is expected to be able to provide information on many fish feeds available in the shelter containers. Users can also adjust the weight of the fish feed that is distributed, set the time of feeding fish connected to the user's smartphone/Personal Computer (PC), and use a spreader container that can spread the feed evenly. These characteristics will be an added value to the design of this tool so that users will be efficient, practical, and effective.

2. Materials and Method

2.1. System Design

The designed system consists of several electronic components. The system design will be connected to the internet and can be controlled using a website via a smartphone/PC. The geometric arrangement of the block diagram of the system can be seen in Figure 1.

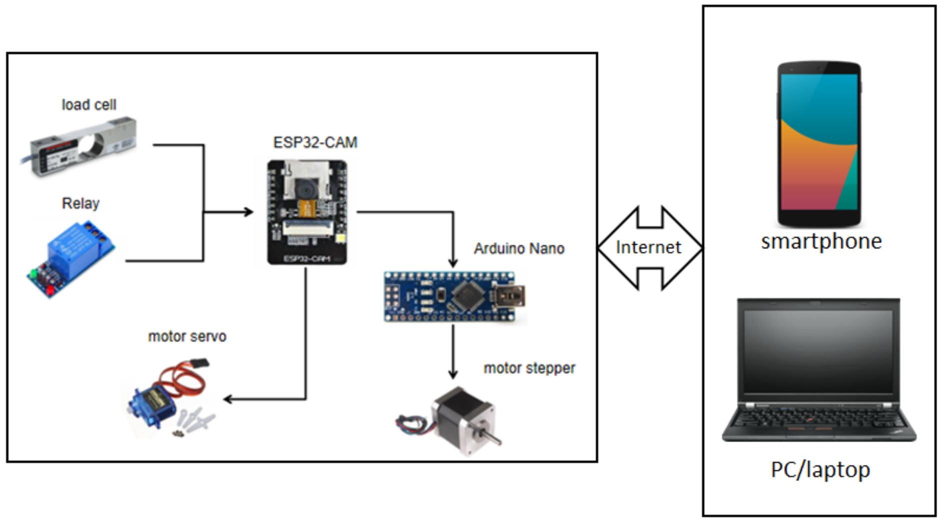


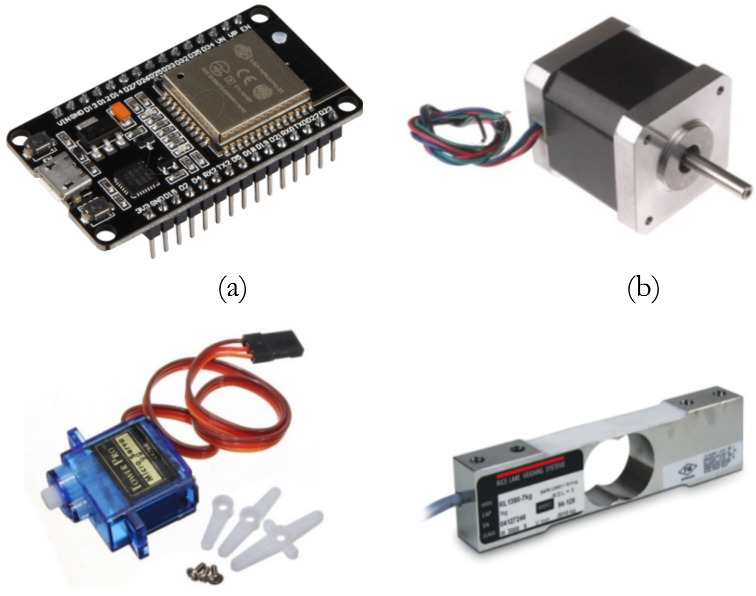
Figure 1. System Diagram Block

From Figure 1, it can be observed that power serves as the source of voltage, with the ESP32 acting as the control center for the entire system. The load cell is used to measure the weight of the feed. Relays as time delay and voltage reduction switches to protect motors or other components from overvoltage or short circuits. The servo motor as the output will rotate to dispense the feed, and the stepper motor to rotate the feed container so that the feed is evenly distributed. The designed system will be connected to the internet. Smartphone/PC is used to monitor the system. From a smartphone/PC, users can set the weight of the feed to be removed and the time the system works, display the result of the weight of the feed removed from the container, and notifications or markers when the tool is finished working and also when the feed runs out in the container.

ESP32 is a ESP8266 development microcontroller which is a popular Wifi module. This module is already equipped with WiFi and bluetooth, so it is ideal for IoT applications, smart home devices and others [20]. The ESP32 uses a 32-bit RISC Tensilica Xtensa LX106 chip which includes digital signal processing features and an FPU (Floating Point Unit). The ESP32 has a clock speed of 240MHz and an SRAM of 520KB.

Stepper motors are electromechanical components that can convert electronic pulses into mechanical movements. To move the stepper motor, a stepper motor controller is needed that generates periodic pulses. A servo motor is a type of rotary actuator that operates with a closed-loop feedback system, allowing precise control over the angular position of its output shaft. This device includes a DC motor, a set of gears, a control circuit, and a potentiometer. The gears attached to the motor shaft serve to reduce the rotation speed while increasing the motor's torque. Meanwhile, the potentiometer detects changes in resistance as the motor turns, and it determines the positional limits of the servo motor shaft's rotation.

A load cell is an electronic sensor that transforms pressure or weight into a digital signal. These sensors are essential components in modern digital scales. Inside the load cell, metal elements experience strain when subjected to the load's weight. This strain is then converted into an electrical signal by a strain gauge attached to the load cell [21].



(a) (b)

(c) (d)

Figure 2. (a) ESP32 (b) Motor Stepper (c) Motor Servo (d) Load Cell

2.2. *Data Analysis*

The accuracy of the sensor's measurement in the system is determined by comparing the results displayed on the instrument with those obtained manually using a standard measuring tool, which allows for the calculation of the error percentage. Data processing was also carried out to calculate the accuracy and accuracy value of automatic feeding tools for catfish cultivation based on the internet of thigs (IoT).

3. Results and Discussion

3.1. *Results of System Performance Specifications*

The system is composed of several components, including a single load cell sensor for the fish feeding system. The load cell is used to measure the feed dispensed from the feed holding tube. It calculates the weight based on the principle that a change in position on one side of the load cell occurs when there is a voltage output due to changes in resistance. The load cell sensor circuit is shown in Figure 3.

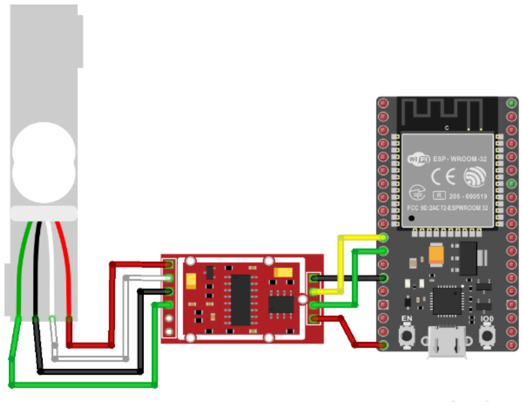


Figure 3. Load Cell Network

From Figure 3, it can be seen that the load cell can be used when connected to the HX711 module and several components connected to the system circuit. The characteristics of a load cell are determined by the load cell's output voltage. The way load cells work is described as a wheat-stone bridge. The load cell has four strain gauges. When there is a compressive force, it will disrupt the balance of the strain gauge. The excitation voltage of the load cell will cause an imbalance in the wheat-stone bridge due to the compressive force on the load cell will be converted into a voltage signal. This change in output voltage will later be converted into object weight information. Load cell characterization was carried out with a standard measuring tool, namely a digital multimeter, so that the load cell characterization value was 127.15. The higher the calibration value, the higher the output voltage, the smaller the calibration value, the lower the load cell output voltage value. The effect of calibration on the output voltage of the load cell is directly proportional.

The time data displayed on the smartphone/PC screen is obtained by entering time commands such as time, day, month, and year on the menu on the website. There is a program command to get the appropriate time, namely by using the Date Time command. The Date Time command can display the actual time information. The time data on the device will run once the device is connected to the internet. A servo is a drive motor used to open and close the feed availability tube closing valve. The servos needed in this system amount to one servo. The circuit of the servo motor can be seen in Figure 4.

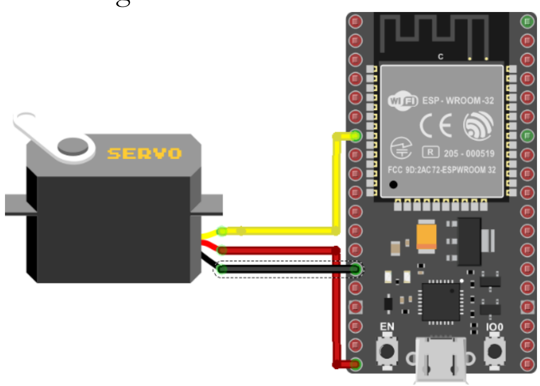


Figure 4. Servo Motor Range

In Figure 4 there is a single servo connected to the ESP32. The servo has three pins, each of which consists of a ground pin, a VCC pin, and a data or control signal pin. For the VCC pin is connected on the 5 V pin as input. The ground pin is connected on the ESP32 ground pin, while the control signal pin is connected on pin 32. The servo movement will move according to the angle input through the program into the ESP32 using the Arduino IDE software. From the measurement results, the reading angle value is the same as the programmed angle. The servo rotates 45 degrees in each direction. The output voltage when the servo motor is open is less than when the servo motor returns to the starting position.

The stepper motor is utilized to rotate the spreader container, ensuring that the feed is distributed evenly. It rotates according to the angle value input in the program. The motor's rotation performance is controlled by the TB6600 driver. Unlike conventional motors, the stepper motor moves based on digital pulses rather than continuous voltage. In the study, five data points were recorded at an angular speed of 210 rpm, demonstrating that both the stepper motor and the TB6600 driver perform effectively. The display on the PC or smartphone shows input and output data, accessible via a website. The webpage for the automatic fish feeding system can be accessed by entering the link https://pakan-ikan-otomatis.vercel.app/ into a search engine. The PC display is shown in Figure 5.

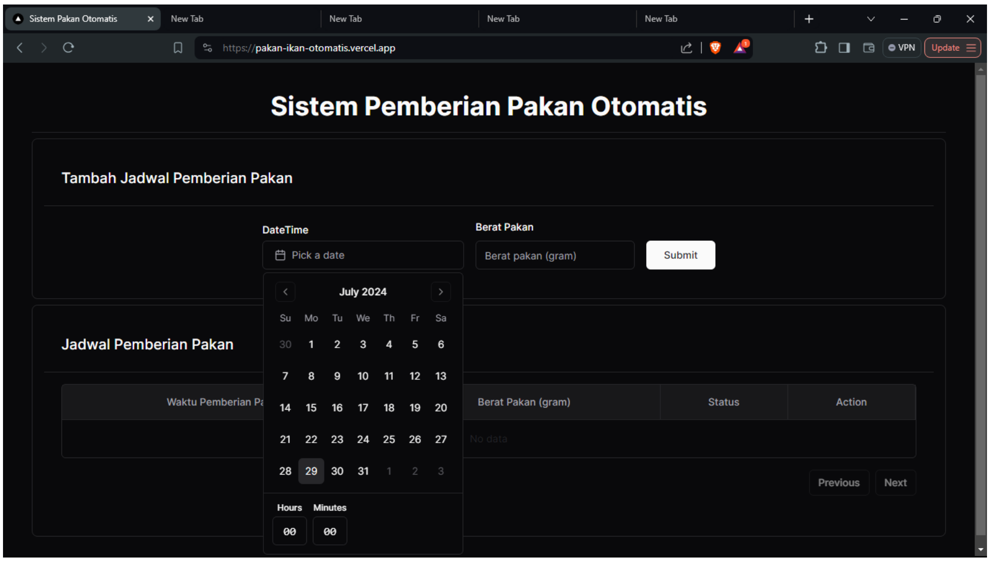


Figure 5. Automatic Feeding System Website Page Display on PC

In Figure 5, it can be explained that the display on the laptop display will be the same as in the picture. The input section has a Date/Time menu where users can set the feeding schedule. There is also a Feed Weight menu to enter the feed weight according to the desired. The output displayed is the working time of the tool and the feed weight reading measured by the load cell on the automatic feeding device. The results of the design of the automatic fish feeding device can be seen in Figure 6.

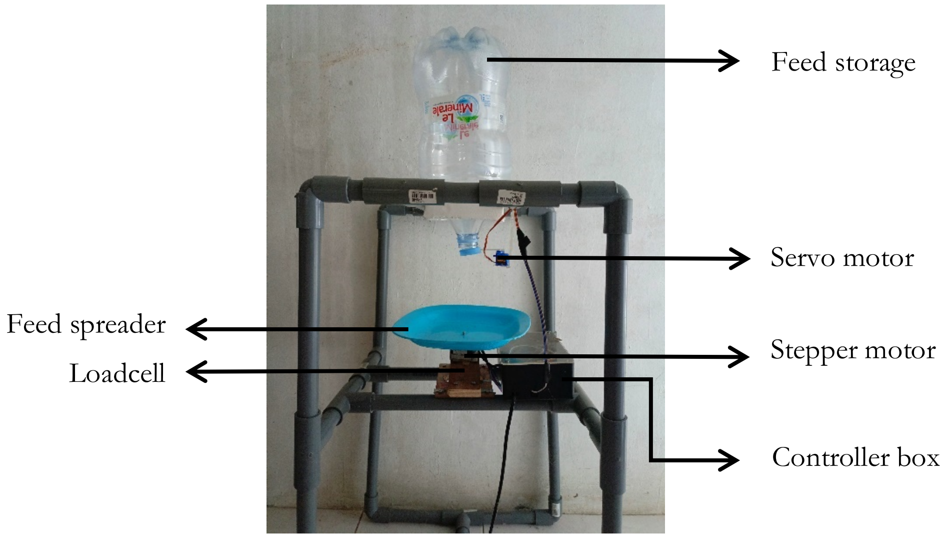


Figure 6. Results of Modeling Automatic Fish Feeding Equipment

3.2. Accuracy and Density of the System in Laboratory Scale Tests

The results of the laboratory-scale test were carried out to determine the comparison of the output value of the system with standard measuring instruments. From the results of the laboratory-scale test, the accuracy and accuracy of the system components were obtained. Laboratory-scale testing is carried out on load cell weight measurement with digital scales, servo motor testing to open and close feed holding tubes, and stepper motor testing to rotate feed sowing discs, as well as working timer testing of automatic feeding devices.

3.2.1. Accuracy of Automatic Fish Feeding Equipment

The accuracy of the tool is determined by comparing the data obtained from system tests with the results from a standard tool. To obtain accuracy data, the weight of the feed is measured. The system's weight measurements are taken using a load cell. Seven different weight variations were tested on the tool, specifically 100 grams, 150 grams, 200 grams, 250 grams, 300 grams, 350 grams, and 400 grams. These measurement results are then compared to those obtained from a standard digital scale. The weight measurement data from the automatic fish feeding device's storage tube is presented in Table 1.

Table 1. Accuracy Data of Weight Variation Measurement on Tools

No	Input (gr)	Tool (gr)	Scales (gr)	Accuracy (%)
1	100	104,67	101,55	96,92
2	150	155,89	150,45	96,38
3	200	204,84	202,30	98,74
4	250	248,28	251,13	98,86
5	300	310,10	303,59	97,85
6	350	351,55	351,19	99,89
7	400	402,76	400,88	99,53
Average accuracy (%)				**98,31**

Based on Table 1, the accuracy of the weight measurement data issued by the instrument holding tube has a fairly good measurement accuracy. Measurements were taken with seven weight variations from 100 grams to 400 grams with a range of 50 grams. In the laboratory-scale test, the accuracy of the system was 98.31%. The measurement results are considered accurate as they have a minimal percentage of error and closely align with the measurements obtained using the standard measuring tools.

3.2.2. Precision of Automatic Fish Feeding Equipment

The precision of the measurement of the automatic fish feeding device is obtained from repeated measurements on the weight measurement of the equipment. The weight measurement of the equipment was carried out 10 times in each weight variation which was divided into weight variation 1 (250 grams), weight variation 2 (200 grams), and weight variation 3 (150 grams). The following is the density data on the measurement of the weight of the system in Table 2.

Table 2. Data on the Results of Weight Precision Measurement on Equipment

No	Weight 1 (250 gr)	Weight 2 (200 gr)	Weight 3 (150 gr)
1	254,81	209,88	151,14
2	255,89	204,43	155,79
3	252,53	205,87	156,98
4	250,38	201,90	158,46
5	252,21	202,64	152,76
6	252,96	210,13	153,14
7	251,83	208,74	153,64
8	254,45	204,98	153,44
9	255,76	202,44	154,33
10	256,11	204,34	151,22
$\bar{x}$	**253,69**	**205,54**	**154,09**
ΔX	**98,52**	**97,23**	**97,27**

Referring to the data presented in Table 2, the results of the measurement of feed weight precision can be explained that the average precision is 97.27% and is close to precision because it has a small percentage of error.

3.3. Accuracy and Density of the System on Field Scale Tests

The automatic fish feeding device was tested in one of the catfish farming ponds located in Jorong Gunung Sarik, Kuranji District, Padang City. Further observation and testing activities of the tool were carried out from June 15 to June 21, 2024. Further observations were made to observe the state of the pond and the condition of the fish. From the results of further observations, information was obtained on the amount of feed given to catfish, the number of catfish in each pond and the entry and exit of fish in the cultivation area.

Dense dispersal or the number of fish in the pond is ±150 fish. To find out the weight of the fish in the pond, the weight of the fish was measured by taking five fish in the pond as an average weight sample. The measurement of the sample weight is measured using a digital scale. The average weight of catfish samples obtained from weighing was 20.73 grams. The results of the automatic fish feeding device test are in the form of feed weight data released from the holding tube, feeding time, and features displayed on smartphones/PCs. The results of the automatic fish feeding device test are in the form of feed weight data released from the holding tube, feeding time, and features displayed on smartphones/PCs.

3.3.1. Accuracy of Automatic Fish Feeding Equipment

The accuracy of the tool in the field scale test is obtained from the comparison of the measurement data on the system with the measurement data of the standard tool, namely the scale. In obtaining accuracy data, it is done by varying the input value of weight and time on the tool. Data collection was carried out every 30 minutes with different weight variations. The results of testing the system on a field scale can be seen in Table 3.

Table 3. Results of Field Scale Tool Accuracy Testing

No	Feeding time (WIB)	Variation in feed weight (gr)	Tool measurement results (gr)	Scale measurement results (gr)	Accuracy (%)
1	09.00	50	55,13	52,23	94.44
2	09.30	60	64,68	61,66	95,10
3	10.00	70	73,90	72,3	97.78
4	10.30	80	82,24	81,54	99.14
5	11.00	90	93,51	92,87	99.31
6	11.30	100	102,83	101,12	98.31
7	12.00	110	113,25	112,51	99.34
8	12.30	120	122,78	121,33	98.80
9	13.00	130	131,46	131,04	99.68
10	13.30	140	143,67	142,53	99.20
Average accuracy (%)					**98,11**

Table 3 shows the variation in input weight starting from 50 grams-140 grams. Data collection was carried out ten times every 30 minutes. The data obtained showed that the results of the average accuracy test of field-scale equipment were obtained by 98.11%. The results of the average accuracy test of the field scale are not much different from the average accuracy of the tools in the laboratory scale test. The data obtained shows that the tool can work well.

3.3.2. Precision of Automatic Fish Feeding Equipment

The precision test of the tool is carried out by conducting repeated tests on the tool. The testing of the tool is carried out by providing feed at three specific times, namely in the morning at 09.00 WIB, during the day at 14.00 WIB and at night at 19.00 WIB. At the data collection stage, the test of the equipment will be carried out during the day with an ideal dose of 3% of the total weight of the fish. The results of the precision test of field-scale equipment can be seen in Table 4.

Table 4. Results of Field Scale Equipment Precision Testing

Day	Time (WIB)	Status	Ideal Feed Dosage (gr)	Feed Dosage Tool (gr)	Standard tool measurement (gr)	Presicion (%)
1	09.00	*On*	93,28	98,76	95,02	96.06
	14.00	*On*	93,28	95,12	95,50	99.60
	19.00	*On*	93,28	94,67	93,33	98.56
2	09.00	*On*	93,28	97,26	94,89	97.50
	14.00	*On*	93,28	95,88	93,88	97.87
	19.00	*On*	93,28	96,76	93,14	96.11
3	09.00	*On*	93,28	96,45	94,17	97.58
	14.00	*On*	93,28	98,35	95,67	97.20
	19.00	*On*	93,28	94,77	93,80	98.97
4	09.00	*On*	93,28	95,29	93,28	97.85
	14.00	*On*	93,28	95,43	94,45	98.96
	19.00	*On*	93,28	95,76	94,21	98.35
Average Precision (%)						**97,88**

Based on Table 4, field scale testing is carried out by comparing the weight of feed issued by the system with a standard measuring instrument, namely a scale. The measurement results indicate that the weight of the feed output by the appliance is greater or much greater than the input. The results of the calculation of the average accuracy value of the feed weight issued by the system in the field scale test have a precision value that is not too different from the results of the laboratory scale test. The average precision value obtained was 97.88%.

The automatic fish feeding system based on IoT has several significant advantages. One of its primary strengths is its high accuracy and precision, with an average accuracy of 98.31% in laboratory testing and 98.11% in field testing, as well as an average precision of 97.27% in the laboratory and 97.88% in the field. These results demonstrate the system's ability to provide reliable and consistent measurements. Additionally, the integration of Internet of Things (IoT) technology enables remote control and monitoring through a web-based interface, making it easier for users to access real-time information about feed levels, feeding schedules, and system status. The system's fully automated process minimizes the need for manual labor and ensures timely feeding. Users can also easily customize parameters such as feeding schedules and feed quantities through an intuitive web interface, providing flexibility tailored to farming needs. Furthermore, the use of a stepper motor ensures even feed distribution, promoting uniform fish growth and preventing overfeeding or underfeeding in specific areas of the pond.

However, the system also has several limitations that need to be addressed. One of the main drawbacks is its dependency on an internet connection. The system can only function if connected to a stable WiFi network, limiting its usability in remote areas with poor internet infrastructure. Additionally, electronic components such as the ESP32 microcontroller, servo motors, and load cells are vulnerable to damage caused by humidity or water exposure, requiring extra protection for outdoor applications. The system's functionality is also limited to feeding and does not include monitoring other essential parameters like water quality (e.g., pH, temperature, or ammonia levels), which are critical for successful fish farming. Moreover, the limited capacity of the load cell poses a risk of damage or inaccurate readings if the feed weight exceeds the sensor's capacity. Finally, the relatively high initial installation cost and the need for technical expertise in assembling and maintaining the system may be a barrier for some users.

4. Conclusion

According to the research that has been conducted,, including the design of the system and the results of the data obtained, it can be concluded that an automatic feeding tool for catfish cultivation based on the Internet of Things (IoT) has been successfully developed. The system uses a loadcell sensor to measure the weight of feed that has been characterized by a standard measuring device, a digital scale. The system is programmed using the ESP32 microcontroller as a control center and IoT device. System control is carried out using a webserver that is integrated with IoT. The system performance specifications have shown that the system is running well. Testing of this system is carried out on a laboratory scale and a field scale. In the laboratory scale test, an average accuracy value of 98.31% and an average precision of 97.27% were obtained. Field testing of the system was carried out in a catfish cultivation pond located at Jorong Gunung Sarik, Kuranji District, Padang City, on June 15 – June 21, 2024. The results of the system test on a field scale have an average accuracy of 98.11% and the precision of the system is 97.88%. Based on these results, it can be concluded that the automatic feeding system for catfish farming based on the internet of things can work well and accurately because it has a small percentage of system errors.

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