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Design and implementation of automatic fish feeder (AFF) using microcontroller powered by solar cell: A Contribution to the fish farmers

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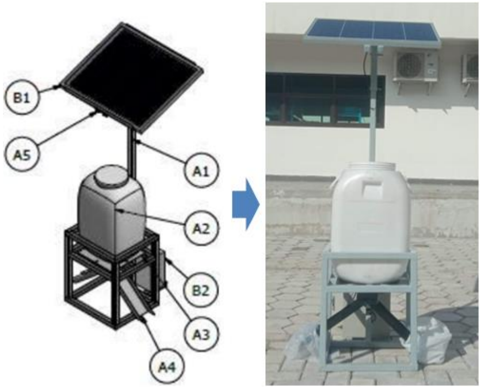

Highlights:

- Automatic fish feeder (AFF) has been successfully designed and implemented for tilapia and goldfish farmers.
- AFF is able to supply a certain amount of feed, three times a day.
- Feed conversion ratio (*FCR*) decreased from 1.44 to 1.44 and feed efficiency (*FE*) increased from 69.4% to 86.8%.

Abstract

This study aims to design and test an automatic fish feeder (AFF) controlled by a microcontroller with an electricity supply from a solar cell. To build a reliable and accurate system, input data is collected for design, followed by system development, feasibility analysis, and performance testing. The test results show that AFF works according to the settings of the microcontroller, where the servo motor can open and close the feed channel periodically, three times a day. The feeding schedule is set at 07.00, 12.00, and 16.00. In addition, fundamental indicators including feed conversion ratio (*FCR*) and feed efficiency (*FE*) are showing positive results. Through the application of AFF which replaces manual feeding, the *FCR* is obtained at 1.15 from the initial value of 1.44. Meanwhile, *FE* increased from 69.4% to 86.8%. Technically, AFF is suitable for use by tilapia and carp farmers.

Keywords: Fish feeding, Solar cell, Microcontroller, Arduino

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1. Introduction

In the last decade, tilapia and carp have become the interest of many farmers in Indonesia because of their characteristics and high market demand [1]–[3]. To increase production intensively, a good feeding system is a key to success in aquaculture practices [4]–[6]. Physiologically, the amount and quality of feed affect the fish growth [7]. The implementation of modern feed equipment at least provides advantages in terms of time and amount of feed according to fish weight [8]–[10]. In Cijambe District, Subang Regency, West Java, tilapia and carp farmers still practice conventional farming, where the feed is spread directly into the pond as shown in **Figure 1**. Conventional feeding requires a lot of time and schedule uncertainty. As a result, problems arise in the fish growth and size. On the other hand, too much feed causes high production costs [11]. Yeoh [12] reported that growth and feed conversion can be achieved through the right frequency of feeding and that is difficult to achieve by conventional farmers [13], [14]. Automatic fish feeders (AFF) have been successfully practiced in the modern fishing industry

Figure 1.
Conventional fish feeding

as well as in aquariums [15]. However, it depends on the availability of electricity. Meanwhile, many aquaculture ponds do not yet have access to electricity.

Today, there are two types of fish feeders, namely fixed fish feeders and mobile fish feeders [16]. The fixed fish feeder is used in single ponds and the mobile fish feeder is suitable for multi ponds. Based on previous research, most AFFs cannot easily control the amount of feed released [17]. Lack of feed causes stunted fish growth and has the potential to eat each other. On the other hand, excessive feed causes pond quality to decline rapidly and increases production costs. Therefore, our present study aims to design and implement AFF using a microcontroller powered by a solar cell [18] that works with a combination of mechanical and electrical systems. As is known, the combination of sensors, controls and actuators in engineering implementation has become a necessity since the industrial revolution 4.0 [19]. AFF which is powered by solar energy and a wireless battery supply is very suitable for fish ponds that are not covered by electricity [20]. AFF is assembled from solar panels, a solar charger controller (SCC), a Watt meter, a step-down, and a battery. The electricity generated by the solar panels is read by a wattmeter. Before being supplied to the battery, the electric voltage from the solar cell is regulated by the SCC. Furthermore, feeding is controlled by Arduino. A real-time clock (RTC) is used as a timer to take the feed out. Liquid crystal display (LCD) is used to display data. Finally, the servo motor is used for the feed valve opening and closing system.

The main source of electricity for AFF is supplied by a controlled solar panel, where the degree of inclination of the solar panel can be adjusted according to the sunlight. This tilt adjustment increases the power output of the solar panel. Battery charging is controlled by the solar charger controller (SCC). When overcharging occurs, the current is immediately cut off to protect the battery [21]. The feeding automation process uses Arduino Uno which has an Atmega328 microcontroller and a 555 timer [22]. AFF with a microcontroller can control feeding up to 24 cycles every day, depending on the timer set, and can be reset [23].

2. Methods

2.1. Needs Assessment

The needs assessment process is carried out to identify the needs of the farmers. We conducted observations, literature studies, and interviews. Based on observations and interviews, fish farmers need fish feeders with the following criteria:
(1) capable of dispensing feed automatically at a predetermined time,
(2) being able to provide fish feed according to the weight of the fish, and
(3) using solar panels so that they do not depend on the availability of the electricity network.

2.2. Design and Manufacturing

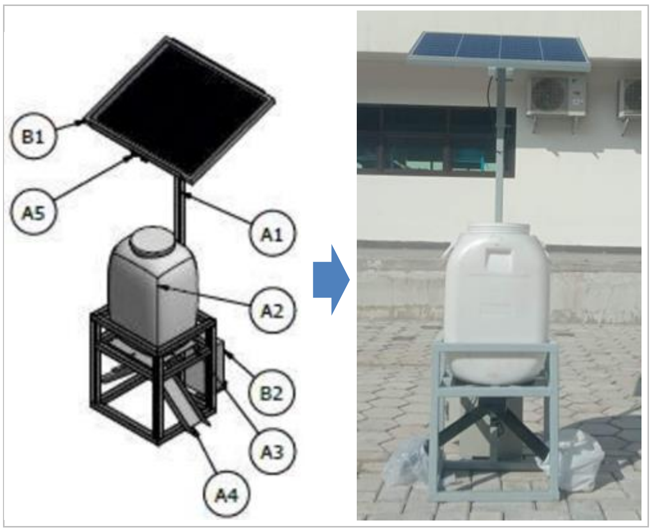

Figure 2.
The design of an automatic fish feeder (AFF)

The AFF design was carried out using Autodesk Inventor 2021. The design phase begins with identifying the product's functions and working principles. The second stage is embodiment design which includes layout, form scale, assembly analysis, and function optimization. The third stage is detailed design which consists of component inspection, material selection, performance, and cost optimization [18]. The AFF design is presented in **Figure 2** and the specifications for each component are given in **Table 1**, respectively.

Table 1. Component Specification of AFF

No	Component	Specification
A1	Main frame	Hollow steel, 1615 x 445 x 380 mm
A2	Fish feed containers	Plastic, 60L
A3	Funnel plate	Steel plate, 300 x 300 x 0.8 mm
A4	Distribution plate	Steel plate, 642 x 150 x 0.8 mm
A5	Solar panel holder	Hollow steel and elbow, 600 x 569 x 438 mm
B1	Solar panel	50 WP
B2	Panel box	Steel plate, 250 x 250 x 120 mm

The AFF main frame manufacturing process includes preparation, measurement processes, material cutting, drilling, and welding. As presented in Figure 2 (right), the AFF main frame is made with a height of 1615 mm, a length of 445 mm and a width of 380 mm. The funnel plate has a top diameter of 150 mm, a bottom diameter of 100 mm and a funnel height of 50 mm with an overall length of 300 mm and a width of 300 mm. The output channel has two feed outlets measuring 642 mm in length and 569 mm in width with a slope of 40°. Solar panel holder with a combination of angle iron and hollow iron. AFF size details are presented in Table 1.

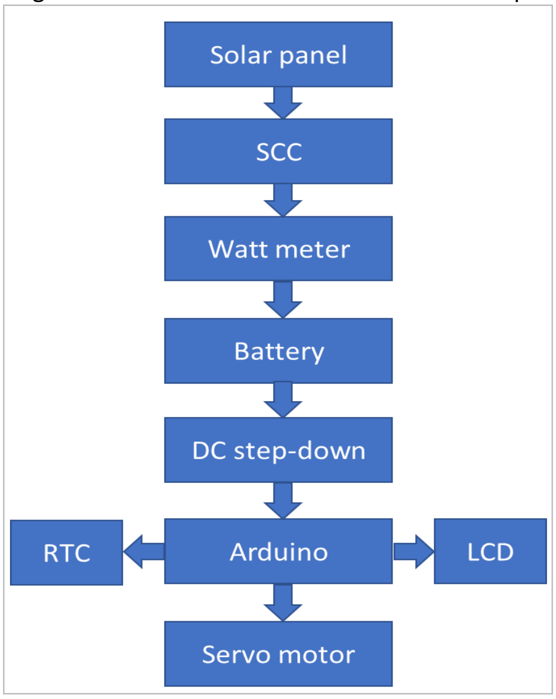

Figure 3. The bloc diagram of automatic fish feeder (AFF)

Furthermore, a block diagram is made to simplify the process of electrical installation or wiring on the AFF, as shown in Figure 3. In this work, Arduino is the most important component for AFF. This is hardware that can be programmed to automatically activate the motor at a predetermined time [19]. AFF is built by assembling solar panels on a frame and installing a Watt meter, and SCC to regulate the voltage to the battery. DC step-down on Arduino serves to lower the voltage so that overvoltage does not occur on the controller and drive system. The control components consist of RTC, LCD, and servo motors for scheduling the feed out and output of the drive system. The block diagram of the designed AFF is presented in Figure 3. Meanwhile, the electricity source and controller circuits are shown in Figure 4a and Figure 4b, respectively.

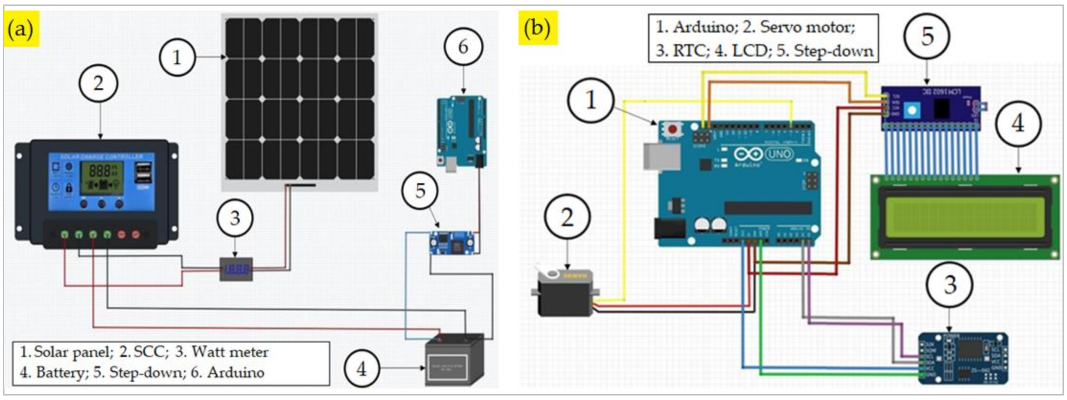

Figure 4. Wiring diagram: (a) electricity source, and (b) controller

3. Results and Discussion

3.1. Performance Test

The test results show that the servo motor works to open and close the feed channel properly. The servo motor opens and closes for one second with three rotation periods of 180°, so certain feed can be supplied three times a day at 07.00, 12.00, and 16.00. The results of further observations, the battery capacity with a voltage of 12 volts and a current of 7 Ah can be used for 16 hours. Based on observations, when charging the battery from 07.00 to 18.00, it produces 2.5 Wh to 17.7 Wh with an average output of 0.40 A and an average power of 5.2 Watt. The results of the AFF test are presented in **Table 2**.

Table 2. Performance Test

No.	Component	Function	Test method	Evident/photograpic view
1	SCC	Regulating the electricity generated from solar panels	Turn ON	
2	Watt Meter	Read the electricity generated by solar panels and battery capacity	Turn ON	
3	RTC	Time sensor to adjust the actuator	Turn ON	
4	LCD	Reads the time generated by the RTC	Turn ON	
5	Arduino	Sends signals to RTC, LCD, and servo motors according to a predetermined program	Turn ON	

3.2. Feasibility Analysis

Efficient conversion of fish feed is very important for farmers because feed is a major component of the total production cost [24], [25]. The AFF assessment criteria is carried out by calculating the feed supplied in the pond (Day Feed Amount/DFA) which is calculated by Eq. (1) [26].

$$DFA = W \times N \times SR \times R \tag{1}$$

Where *W* is the average weight of fish (grams), *N* is the number of fish, *SR* is the prediction of fish survival (%), and *R* is the amount of feed (gram). As it is known that accuracy in feeding can minimize costs in fish farming [27]–[29]. Then the technical feasibility of AFF is assessed by the feed conversion ratio (*FCR*) and feed efficiency (*FE*) calculated by Eq. (2) and Eq. (3) [30].

$$FCR = \frac{F}{(Wt + D) - Wo} \tag{2}$$

$$FE = \frac{Wt + D - Wo}{F} \times 100 \tag{3}$$

Where, *F* is the amount of feed consumed, *Wt* is the weight of the fish at the end of the study, *D* is the number of dead fish, *Wo* is the weight of the fish at the start of the study, and *FE* is Feed Efficiency. The smaller the *FCR* value means the better the feed efficiency level. Conversely, the greater the *FCR*, the worse the *FE*. Feed efficiency is obtained from the comparison between fish weight gain and the amount of feed consumed by fish during rearing time. The greater the feed efficiency value, the more efficient it is [31]–[33].

AFF feasibility analysis was carried out based on two main parameters, namely *FCR* and *FE* according to Eqs. (2) and (3). Based on observational data, the average fish weight (*W*) is 25 grams, the number of fish (*N*) is 4,000, the prediction of fish survival (*SR*) is 90% and the feed given (*R*) is 8%, then, based on the Eq. (1) obtained *DFA* of 7.2 Kg per day and *FCR* 1.152. *FCR* values close to 1 indicate better feed management. Then, the *FE* value was obtained at 86.8%. Prior to the application of AFF, the FCR and FE values were obtained at 1.44 and 69.4%, respectively. The higher the *FE* (close to 100%) means more efficient feeding.

4. Conclusion

In this project, AFF was successfully developed and applied to selected fish farmers. Based on performance tests, AFF can function properly, where it is able to supply feed in a predetermined amount and schedule. The electricity generated from the solar panels is sufficient for charging the battery as a power supply for the entire system. Technically, AFF is suitable for use by tilapia and carp farmers. In addition, fundamental indicators including FCR and FE are showing positive results. Through the application of AFF which replaces manual feeding, the feed conversion ratio (FCR) is obtained at 1.15 from the initial value of 1.44. Meanwhile, feed efficiency (FE) increased from 69.4% to 86.8%. In conclusion, AFF is very promising to be applied in pond areas where electricity is not available. With reported performance, AFF implementation can reduce production costs and improve farmers' welfare.

Authors' Declaration

Authors' contributions and responsibilities - The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation, and discussion of results. The authors read and approved the final manuscript.

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Availability of data and materials - All data are available from the authors.

Competing interests - The authors declare no competing interest.

Additional information – No additional information from the authors.

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