Design and performance of an automatic fish feeder with an adjustable spreader system

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Abstract: This study aimed to improve the feeding process in aquaculture fish farming by designing and implementing an automatic feed spreader system that can adjust the feeding amount and schedule according to the fish species and age. The research methodology included functional analysis, prototyping, and testing to evaluate the performance of the prototype. The results showed that the mass sensor on the scales had high accuracy and precision with an error of 0.61 and a deviation of 0.11, respectively. The analysis of dropping and distributing feed showed a direct proportionality between feed mass, filling time and dropping time (R^2 was above 0.94). Moreover, the time of spreading the feed was directly proportional to the amount of feed given (R^2 was 0.94). The electric motor for throwing activity was regulated using an inverter with a linear relationship between the motor speed and inverter frequency. Additionally, the maximum throw distance was directly proportional to the motor's rotational speed. In conclusion, this study presents a successful design and implementation of an automatic feed spreader system with reliable and accurate performance. The system's features, including adjusting the feeding amount and schedule, can provide significant benefits to the aquaculture industry.

Keywords: aquaculture, feed spreader, automatic feeder, pond.

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1 Introduction

Aquaculture feed plays a critical role in fish growth and health (Hasan, 2001; Sushma and Sharma, 2021). The nutritional value of feed is determined by its composition, with protein, fat, minerals, and water being the main components (Obeng et al., 2015). However, in most animal production systems, feed takes the largest part of the costs (Kenis et al., 2014). Proper feeding is one of the factors supporting the success of fish farming (Elfitasari and Albert, 2017; Kasda et al., 2021). Fish only absorb about 25% of the feed given, while the remaining 75% settles as waste in the waters (Diarta et al., 2022). Waste from feed will be mineralized by bacteria into ammonia. Ammonia accumulation can contaminate the cultivation medium and can even cause death (Pratiwi et al., 2020; Nadarajan and Sukumaran, 2021). Feeding must be accurately dosed to avoid excessive feed waste, which can lead to pollution and poisoning. In addition, feeding rates should be carefully adjusted to avoid overfeeding or underfeeding, which can impact fish growth and survival rates. Previous studies have shown that proper feeding can significantly improve fish growth, with optimal feed dosages ranging from 3-5% of the fish's body mass per day (Putri and Aliyas, 2019). Therefore,

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developing an effective and efficient feeding system is crucial to maintaining high yields in aquaculture.

Previous studies have explored the development of various feeding tools for aquaculture, each with its own set of advantages and limitations. Some of the tools include a simple feed demand feeder (Mohapatra et al., 2009), a propeller-driven feed spreader that does not require electrical energy for propulsion (Prem and Tewari, 2020), an automatic fish feeder with a timer programmed using a microcontroller or programmable logic control (PLC) (Noor et al., 2012; Dada et al., 2018; Babu and Mahesh, 2019; Hendri et al., 2019), IoT based solar powered automated fish feeding system (Faiz et al., 2022), and prototypes equipped with integrated mechanical and electrical systems for feed dispensing (Wei et al., 2017; Yusoff et al., 2018). These tools represent significant progress in aquaculture feeding technology, however there is still room for improvement to increase their effectiveness and efficiency.

In this study, the design of an automatic feed spreader system was equipped with a scheduling system and a precise amount of feed, enabling accurate adjustments according to fish species and age. It was also equipped with a feed storage system before the feed was stocked using a feed spreader. The system that had been designed and built was expected to help facilitate the work of fish farmers in feeding fish which so far was still manual with doses that use estimates.

2 Materials and methods

2.1 Materials

This research was conducted from June to August 2022 at the Research Center for Appropriate Technology, Subang, West Java, Indonesia (S 6° 34' 16.6224", E 107° 45' 34.8876"). The materials used to construct and test the fish feed spreader system were chosen based on the functional and structural analysis. Materials were chosen based on properties such as strength, toughness, stiffness, corrosion resistance, availability, and cost. Most of the material used to build the prototype was SS 314 which has a yield strength of 215 MPa, a Modulus of elasticity of 200 GPa and was resistant to corrosion (Cavallo, 2023). In the performance tests, catfish feed was used and prepared according to standard feed equipment procedures. The feed spreader system consists of several parts, including a 304 stainless steel storage container with a capacity of 20 kg, measuring 50 cm in height and 40 cm in diameter, and with a thickness of 2 mm. The scales used in the system have a maximum capacity of 1000 grams and are made of acrylic material, equipped with an HX711 load cell mass sensor. The feed spreader itself is made of 304 stainless steels with a thickness of 1.2 mm and is equipped with an electric motor rated at 220 Volt / 50 Hz, 120 Watt. This type of electric motor specification was chosen because it is able to move the feed spreader well, was easily available in the general market, was affordable and could be used on a household electricity scale. The catfish species was chosen for the feeding experiments, and commercial-type feed was used throughout.

2.2 The design criteria

The purpose of the automatic fish feed spreader system in general was to make it easier for farmers to feed the fish automatically at predetermined times. To get the design of an automatic feed spreader system that suits their needs, several features must be considered, with the design criteria consisting of:

The automatic feed spreader system has a feed storage container that functions to accommodate the feed for several days with the capacity of 20 kg per batch.

The automatic feed spreader system has a weighing scale to allocate feed with a maximum capacity of 1000 grams.

The automatic feed spreader system is equipped with a spreader disc with a diameter of 20 cm and three fins for throwing.

The feed spreader system is driven using a 220 Volt/50 Hz electric motor with low power. Automatic feed spreader system can be disassembled. The automatic feed spreader system is easy to move. The automatic feed spreader system can be used on various types of ponds.

Based on the design criteria, a functional analysis was performed to describe the main functions and sub-functions, then derived to the required components was selected to build the device, as state by Sagita et al. (2021) . The results of the functional analysis of the feeding system are shown in Table 1.

Table 1 Functional analysis of the automatic feed spreader system

Main Function	Sub Function	Component
Spread fish feed automatically based on time settings and a certain number of doses	Feed storage container with a capacity of 20 kg per process	304 stainless steel plate in the form of a tube measuring 50 cm high and 40 cm in diameter.
	Scales with a maximum capacity of 1000 grams	Made of acrylic, with a 1 kg loadcell sensor
	20 cm diameter spreader discs and three throwing fins.	Constructed by using Stainless steel 304 materials
	Spreader system drive	Electric motor 220 Volt, 120-Watt

The automatic feed spreader system has several important parts. The parts of the device consist of a frame, feed storage container, scales, spreader disc, throwing fins, drive motor, and feed storage container. The spreader disc is designed with a diameter of 20 cm and three throwing fins were designed. A schematic of the disc and fin system is shown in Figure 1.

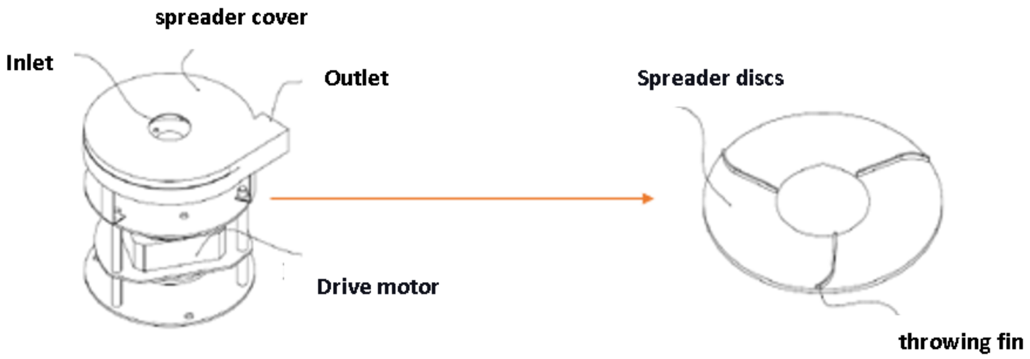

Figure 1 Schematic system of the spreader disc and throwing fins

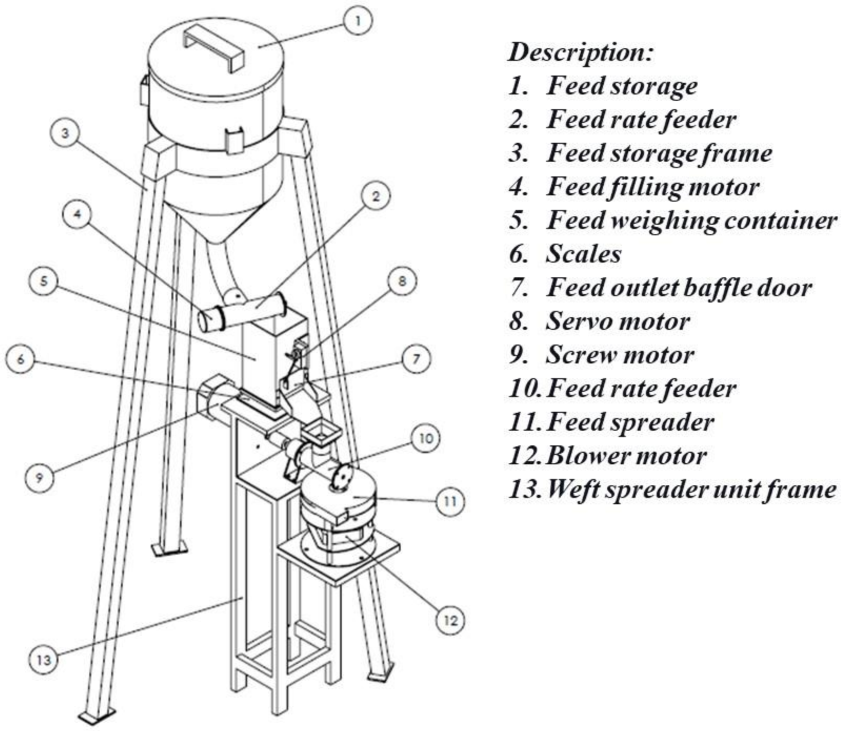

Figure 2 Design drawings of an automatic feed spreader system

This automatic feed spreader system can be adjusted by scheduling time and the number of feeding doses. The system is built and placed on a support framework. There is a feed storage container at the top of the system, a feed storage with a capacity of 20 kg, and a cylindrical reservoir with a height of 50 cm and a diameter of 40 cm. Then the feed goes to the scales, box-shaped scales made of acrylic with a capacity of 1000 grams. At this weighing stage, the feed dose can be adjusted according to the age of the fish. Feed that has been measured according to the desired dose will enter the feed spreader plate with a diameter of 20 cm and spread the feed a certain distance. The design and detailed parts of the automatic feed spreader system as a whole can be seen in Figure 2, while the material for fabricating the automatic feed spreader system is presented in Table 2.

Table 2 Materials for fabricating automatic feed spreader systems

No	Component Name	Specification
1	Feed storage	Capacity 20 kg, stainless steel 304 material
2	Feed holder	Height: 1730 mm, mild steel material
3	Feeder cover	Ø2 inch, stainless steel material
4	Feeder thread	Stainless steel material
5	Feed filling motor	40-watt, AC 220 V
6	Scales	Capacity 1000 gr, acrylic material
7	Feed throw plate	Diameter 80 mm, aluminum casting material
8	Throw cover	Stainless steel 304 material
9	Blower motor	70-watt, AC 220 V
10	Drive motor mount	Stainless steel 304 material

2.3 Performance evaluation

2.3.1 Preparation of the performance test of the automatic feed spreader system

The following is a block diagram for the performance test preparation for the automatic feed spreader system. The fish commercial feed used was obtained from a local store in Subang, West Java, and has a moisture content of 12%. The feed is stored in a storage container to then be entered on the scales and spread out.

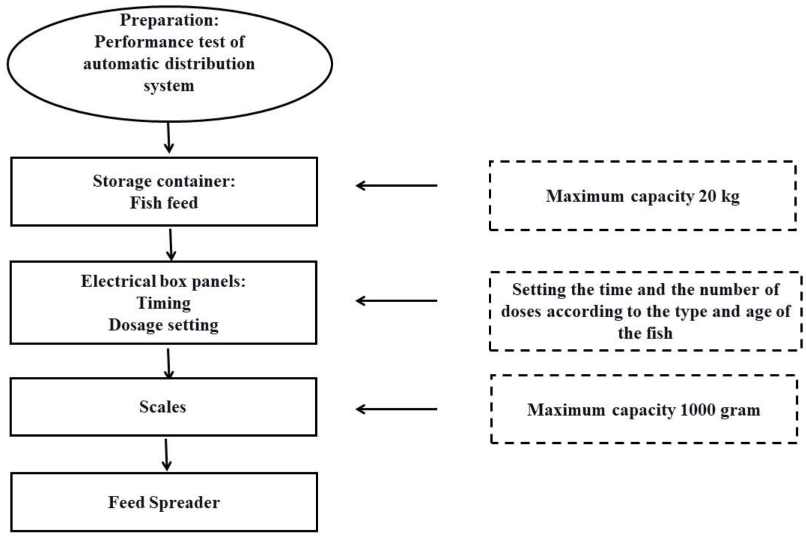

Figure 3 Block diagram of the preparation for the performance test of the automatic feed spreader system

2.3.2 Analysis of the static characteristics of the mass sensor on the scales

The static analysis of the mass sensor is using the HX711 load cell, 10 times data collection, the analysis includes accuracy and precision. The accuracy of the weight sensor is obtained by comparing the readings of the mass sensor with a standard digital scale measuring instrument type SJ-5001HS with an accuracy of 1 gram.

2.3.3 Analysis of the spreader system

In the spreader system that has been designed, an analysis of the performance of dropping and distribution of feed can be carried out, as well as an analysis of the speed of the electric motor for throwing activity.

2.3.4 Statistical analysis

The analysis used in this research was descriptive statistical analysis and Pearson correlation analysis to obtain the correlation coefficient between some parameter measured.

3 Result and discussion

3.1 Prototype of automatic feed spreader system

A prototype of the automatic feed spreader system has been successfully made based on the design criteria. This device has been able to accommodate as much as 20 kg of feed and the rationing scales can accommodate up to a maximum of 1000 grams. The prototype construction consists of a feed storage container, scales, a spreader, and an electrical panel. The system required 120 W electric power. The prototype is visually described in Figure 4. Overall dimensions are 2100 × 1000 × 650 mm.

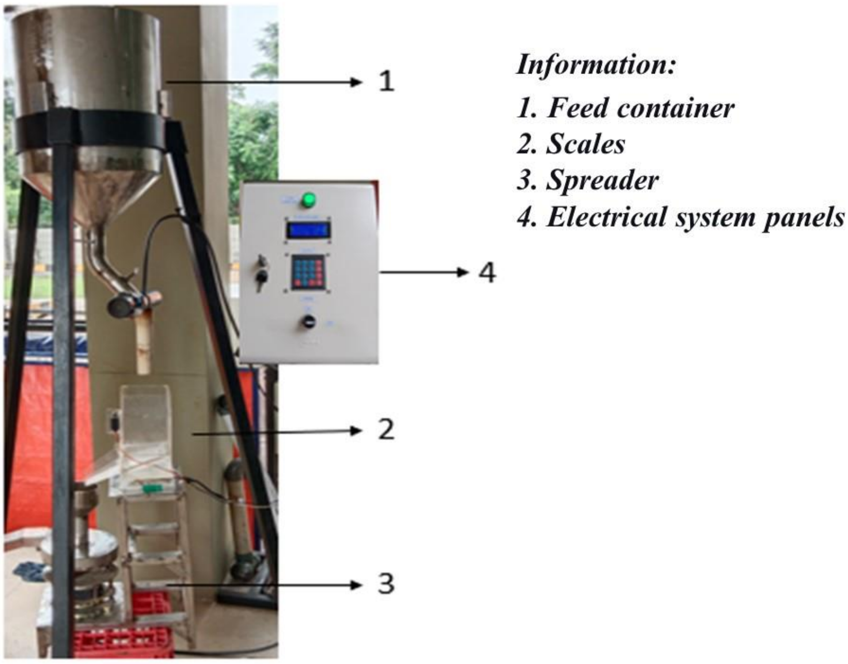

Figure 4 The prototype of automatic feed spreader system

Table 3 Comparison of mass sensor readings with standard measuring instruments

No	Loadcell sensor HX711 (g)	Digital scales type SJ-5001HS (g)	Error (g)
1	25.4	26.0	0.6
2	83.3	84.0	0.7
3	103.0	103.6	0.6
4	140.0	140.5	0.5
5	165.2	165.7	0.5
6	284.3	284.8	0.5
7	376.2	377.0	0.8
8	448.0	448.7	0.7
9	478.0	478.5	0.5
10	508.2	508.9	0.7
	Average error		0.61
	Standard deviation		0.11

The feed distribution system continues to be developed to reduce the risk of feed gathering at one point in the pond. The spreader was equipped with a rotating disk and 3 fins, this serves to regulate the throw mechanically.

3.2 Static analysis of weight sensors on scales

In Table 3 it can be seen that the mass sensor readings have a little different reading value when compared to standard measuring instruments. The average value of the percentage error in weight measurement is 0.5%. The average error of sensor is 0.61 g with a deviation of 0.11 g, so to improve accuracy, a correction is needed for the difference in reading the value. In similar research related to the implementation of mass sensors for digital scales (Fitzgerald et al., 2015), the result is that the designed mass sensor has an error percentage of 0.11%.

Corrections are made by correlating sensor readings with actual mass values. Previous paper (Islam and Mukhopadhyay, 2019) reported that many sensors show response non-linearity with different measurement parameters. Some sensors show linear results in a certain range. Figure 5 shows the correlation results of the mass sensor readings with a standard digital scale measuring instrument.

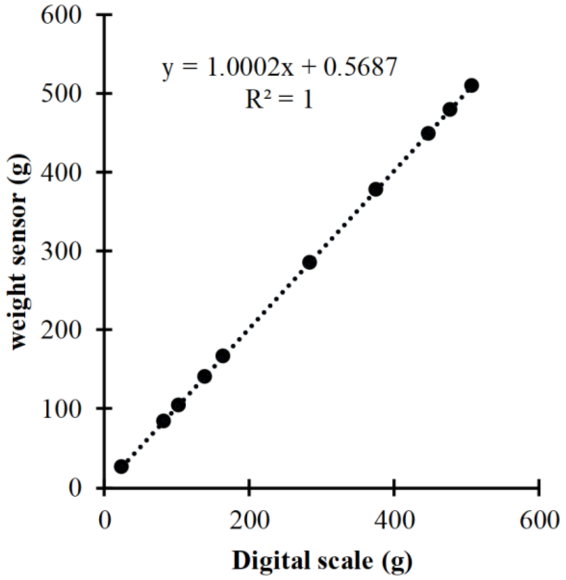

Figure 5 Comparison of mass sensor values with a digital scale measuring instrument

From Figure 5, there are differences in measurement readings between the sensor and the standard measuring instrument, these differences are then compared to obtain a calibration correction equation. Based on the calculation results, the correction equation is 1.0002x+0.5687 can be used to calibrate the mass sensor measurement with an R^2 value high (1). Based on (Pramono et al., 2022), the measurement of the mass of the load by the loadcell is the same as the measurement of digital scales with the specifications of the loadcell used having an accuracy of ±1%.

3.3 Analysis of dropping performance and feed distribution

The first performance observed was the length of feed filling time based on the specified feed mass target. This is important to determine the length of time the feed fill screw is in operation.

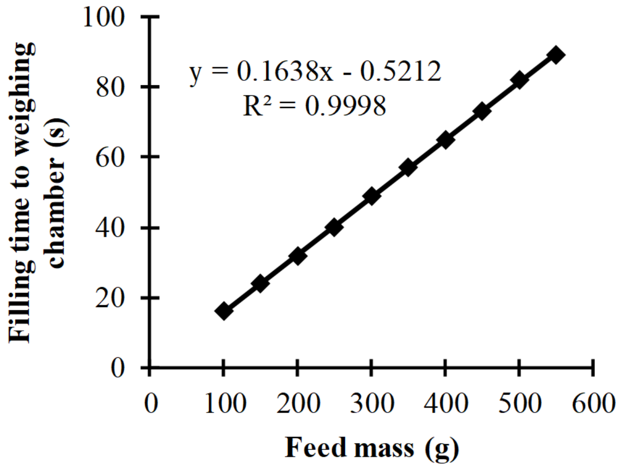

Figure 6 The correlation result of feed filling performance

Based on Figure 6, it can be seen that the increase in feed mass is directly proportional to the filling time which is indicated by a linear line with the R^2 value of 0.9998. Pearson correlation analysis also found a large correlation value between feed mass and feed filling time close to 1. Based on research (Fasoyin et al., 2021), there was a correlation between the amount of feed spread per unit of time. Analysis of variance at $p \leq 0.05$ showed that the length of time for feeding had a significant effect on the amount of feed removed (Fasoyin et al., 2021). Thus, filling time can be used as a reference in determining how much feed will be fed to fish at a time. This is important because the loading of feed into the scale is based on the operating time of the screw feeder connected to the fish feed hopper.

The next test was determining the time of dropping the feed from the scales to the distributor. This is important because the dropping process is carried out after the feed is on the scales. The length of time required to fill the feed into the distributor is presented in Figure 7.

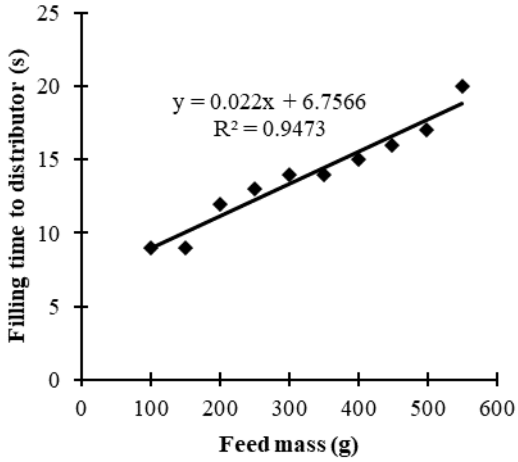

Figure 7 Determination of the time for dropping feed from the scales to the distributor

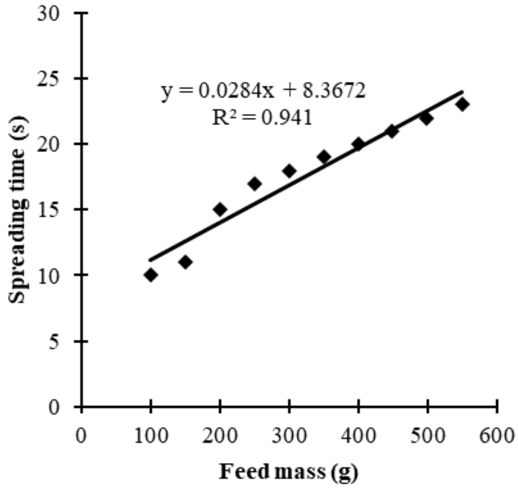

Figure 8 Feed distribution time to ponds based on feed mass

Based on Figure 7, it can be seen that the time for dropping feed from the scales to the distributor is directly proportional to the mass of the feed on the scales. The higher the feed mass, the longer the time needed to drop the feed. From these results, it was found that there was a high correlation (0.9473) between feed mass and dropping time. Thus, the valve opening time on the feed scale can be determined based on time with a linear equation as shown in Figure 7. Previous research (Busaeri et al., 2019) explained that there is a linear correlation between the amount of feed, feed size, and dropping time, this can be seen in the experiment that the time needed for feed size 2 mm with an amount of 2 kg is

1 minute, while for feed size 4 mm with an amount of 4 kg is 1, 2 minutes.

The next test is the evaluation of the time to spread the feed to the pond based on the mass of the feed given. The test results are presented in Figure 8.

Figure 8 shows the relationship between the mass of feed dispensed and the time it takes to spread the feed to the pond until it runs out. It was found that the time of spreading the feed is directly proportional to the amount of feed given which is indicated by a linear line with the value of R^2 0.941 and a correlation coefficient of 0.97. This value is very high so that the linear equation obtained can be used as a reference as the basis for the length of time the blower is turned on when the feed tool is in operation. Precise blower working time can reduce the energy consumption of the feed equipment so that the use of electrical energy is efficient. The same thing was also stated that there is a linear correlation between the amount of feed, feed size, and energy consumption (Busaeri et al., 2019). This can be seen in the experiment that the time required for feed size 2 mm with an amount of 2 kg is 0.085 Wh, while for feed size 4 mm with an amount of 4 kg is 0.097 Wh.

3.4 Analysis of the speed of the electric motor against throwing activity

In testing the speed of an electric motor, the digital instrument Lutron DT 2234 B tachometer is used to measure the rotational speed of the motor. This is done to determine the effect of motor rotational speed on the feed throw distance. The rotational speed of the motor is regulated using an inverter, where the frequency of the inverter is set from a value of 10 to 60 Hz. The relationship between inverter frequency and motor speed is presented in Figure 9.

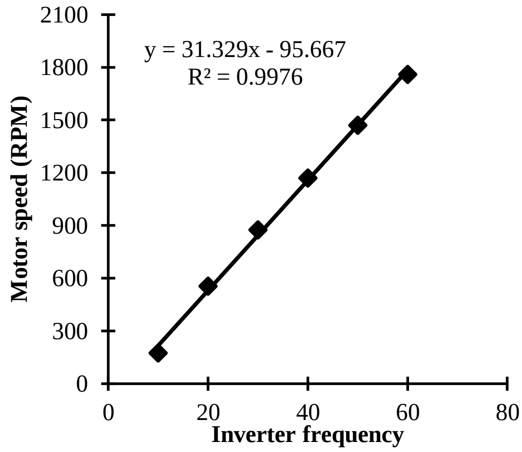

Figure 9 The relationship between inverter frequency and motor speed

In Figure 9, it can be seen that increasing the frequency of the inverter increases the motor speed between 175 to 1760 rpm. The relationship between the two is linear with an R^2 value close to one (0.9976). Thus, the rotational speed of the electric motor can be determined with precision based on a given inverter frequency value. Previous research (Nugraha et al., 2020) reported that the speed of the motor rotation was set from (0 to 700 rpm) this is also linearly proportional to the resulting throwing distance.

Furthermore, the speed of the electric motor was used as a basis for evaluating the maximum distance of throwing feed over the fishpond. The relationship between the motor rotational speed and the maximum feed throw distance can be seen in Figure 10.

Based on Figure 10, it was found that the rotational speed of the motor affected the maximum throw distance from the feed. The relationship between the two was found to be linear with a correlation coefficient of 0.98 and R^2 of 0.9692. (Nugraha et al., 2020) reported that the rotational speed of the motor (0 to 700 rpm) affected the throw distance of 0 to 15 meters. (Novianda et al., 2020) evaluated the maximum distance of throwing feed over the shrimp pond, which was at a pond with width of 400 m^2. The system could throw feed with a minimum distance of 1 meter up to a maximum distance of 7 meters. Based on Figure 10, it shows that the results of this test are important because the feed tool is expected to be applied in each type of pond with a different area. With these results, the target distance for throwing feed over the fishpond can be determined based on the rotational speed of the motor, so that the feed can be properly distributed throughout the pond area according to the area of the pond used for fish farming.

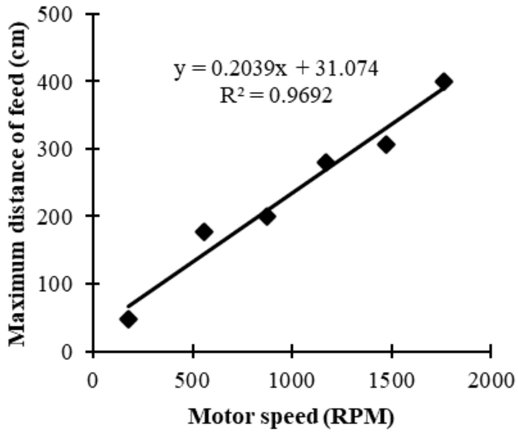

Figure 10 Motor rotation speed with the maximum throw distance

4 Conclusion

The study successfully developed a prototype automatic feed spreader system that can hold up to 20 kg of feed and can distribute feed evenly in the pond. The prototype consists of a feed storage container, scales, a spreader, and an electrical panel. The prototype requires 120-watt electric power and has an overall dimension of 2100 × 1000 × 650 mm. The mass sensor has worked satisfactorily in measuring the feed weight precisely. The study found that the average error of sensor was 0.61±0.11 g. The increase in feed mass was found directly proportional to the filling time which was indicated by a linear line with the R^2 value of 0.9998. Also, there was a high correlation (0.973) between feed mass and dropping time. Thus, the valve opening time on the feed scale can be determined based on time with a linear equation. The time of spreading the feed was directly proportional to the amount of feed given which was indicated by a linear line with the value of R^2 0.941 and a correlation coefficient of 0.97. The frequency of the inverter increased the motor speed between 175 to 1760 rpm with an R^2 value close to one (0.9976). Furthermore, the rotational speed of the motor affected the maximum throw distance from the feed with a correlation coefficient of 0.98 and R^2 of 0.9692. The study suggests that the automatic feed spreader system can be improved by correcting the difference in reading value between mass sensor readings and standard measuring instruments to increase the accuracy of the system. The length of time for feeding can be used as a reference to determine how much feed will be fed to fish at a time, and the valve opening time on the feed scale can be determined based on time. Precise blower working time can reduce the energy consumption of the feed equipment, and the rotational speed of the electric motor can be determined with precision based on a given inverter frequency value. This prototype is expected to facilitate the work of fish cultivators in providing feed which has so far been manual with doses based on estimates.

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References

Babu, D. R. S., and G. Mahesh. 2019. Developing fish feeder system using aurdino. *International Journal of Scientific Engineering and Technology Research*, 8(1): 647–651.

Busaeri, N., N. Hiron, A. Andang, and I. Taufiqurrahman. 2019. Design and prototyping the automatic fish feeder machine for low energy. In *Proc. of 2019 International Conf. on Sustainable Engineering and Creative Computing (ICSECC)*, 9–13. Bandung, 20-22 August.

Cavallo, C. 2023. All About 304 Steel (Properties, Strength, and Uses). Available at: https://www.thomasnet.com/articles/metals-metal-products/all-about-304-steel-properties-strength-and-uses/. Accessed: 15 February 2023.

Dada, E. G., N. C. Theophine, and A. L. Adekunle. 2018. Arduino UNO microcontroller based automatic fish feeder. *The Pacific Journal of Science and Technology*, 19(1): 168–174.

Diarta, I. M., I. P. Sujana, and L. K. Merawati. 2022. The effect of efishery and probiotic dosage on growth rate and survival of Tilapia. In *Proceedings 5th International Conference of Sustainable Development (ICSD)*, 234–239. Bali, 17 December 2021.

Elfitasari, T., and A. Albert. 2017. Challenges encountered by small scale fish farmers in assuring fish product sustainability. *Omni-Akuatika*, 13(2):128–136.

Faiz, R., N. Alam, S. R. Islam, S. N. Khan, and M. R. Hoque. 2022. IoT based solar powered automated fish feeding system. *CIGR Journal*, 24(4): 219–229.

Fasoyin, S. A., W. A. Akinfiresoye, L. A. S. Agbetoye, L. A. Olutayo, and O. Adetuyi. 2021. Performance evaluation of a small-scale mechanical fish feeder. *European Journal of Engineering and Technology Research*, 6(5): 168–170.

Fitzgerald, D. W., F. E. Murphy, W. M. Wright, P. M. Whelan, and E. M. Popovici. 2015. Design and development of a smart weighing scale for beehive monitoring. In *2015 26th Irish Signals and Systems Conference (ISSC)*, 1–6. Carlow, Ireland, 24-25 June.

Hasan, M. 2001. Nutrition and feeding for sustainable aquaculture development in the third millennium. In *Technical Proc. of the Conf. on Aquaculture in the Third Millennium*, 193–219. Bangkok, Thailand, 20–25 February.

Hendri, H., S. Enggari, M. R. Putra, and L. N. Rani. 2019. Automatic system to fish feeder and water turbidity detector using Arduino Mega. *Journal of Physics: Conference Series*, 1339(1): 012013.

Islam, T., and S. C. Mukhopadhyay. 2019. Linearization of the sensors characteristics : a review. *International Journal on Smart Sensing and Intelligent Systems*, 12(1): 1–21.

Kasda, M., D. P. Kosasih, H. D. Nugraha, and M. Rachman. 2021. Low-cost remote control barge boat to feeder fish. *Journal of Mechanical Engineering Research and Development*, 44(2): 112–121.

Kenis, M., N. Koné, C. A. A. M. Chrysostome, E. Devic, G. K. D. Koko, V. A. Clottey, S. Nacambo, and G. A. Mensah. 2014. Insects used for animal feed in West Africa. *Entomologia*, 2(2): 107-114.

Mohapatra, B. C., B. Sarkar, K. K. Sharma, and D. Majhi. 2009. Development and testing of demand feeder for carp feeding in outdoor culture system. *CIGR Ejournal*, 11: 1352.

Nadarajan, S., and S. Sukumaran. 2021. Chemistry and toxicology behind chemical fertilizers. In *Controlled Release Fertilizers for Sustainable Agriculture*, eds. F. B. Lewu, T. Volova, S. Thomas, and K. R. Rakhimol, ch. 12, 195-229. Cambridge: Academic Press.

Noor, M. Z. H., A. K. Hussian, M. F. Saaid, M. S. A. M. Ali, and M. Zolkapli. 2012. The design and development of automatic fish feeder system using PIC microcontroller. In *2012 IEEE Control and System Graduate Research Colloquium*, 343–347. Shah Alam, Malaysia, 16-17 July.

Novianda, N., F. Liza, and I. Ahmad. 2020. Intelligent system of automatic shrimp feeding. *IOP Conference Series: Materials Science and Engineering*, 854(1): 012046.

Nugraha, M. I., M. Anzullah, and R. S. Saputri. 2020. The design of Litopenaeus Vannamei automatic feeder. *Journal of Physics: Conference Series*, 1528(1): 012004.

Obeng, A. K., R. A. Atuna, and S. Aihoon. 2015. Proximate composition of housefly (Musca domestica) maggots cultured on different substrates as potential feed for Tilapia (Oreochromis niloticus). *International Journal of Multidisciplinary Research and Development*, 2(5): 172–175.

Pramono, E. K., A. Taufan, S. A. Putra, M. A. Karim, A. Haryanto, and S. I. Kuala. 2022. Performance tests of loadcell as real-time moisture content sensor: case study moringa oleifera leaves drying. *IOP Conference Series: Earth and Environmental Science*, 1024(1): 012018.

Pratiwi, R., K. W. Hidayat, and S. Sumitro. 2020. Production performance of catfish (Clarias gariepinus burchell, 1822) cultured with added probiotic Bacillus sp. on Biofloc technology. *Journal of Aquaculture and Fish*

Health, 9(3): 274.

Prem, R., and V. Tewari. 2020. Development of human-powered fish feeding machine for freshwater aquaculture farms of developing countries. *Aquacultural Engineering*, 88: 102028.

Putri, D. U., and A. Aliyas. 2019. Pengaruh pemberian pakan dengan dosis berbeda terhadap pertumbuhan dan kelangsungan hidup benih ikan lele (Clarias sp) dalam media bioflok. *Tolis Ilmiah: Jurnal Penelitian*, 1(2): 92–100.

Sagita, D., A. Rahayuningtyas, and Y. R. Kurniawan. 2021. Design, fabrication and thermal evaluation of lemang (rice bamboo) cooking device integrated with continuous rotating system. *CIGR Journal*, 23(4):13.

Sushma, A. K., and P. Sharma. 2021. Therapeutic and Nutritional aspects of Spirulina in Aquaculture. *Journal of Agriculture and Aquaculture*, 3(1): 1-6.

Wei, H. C., S. M. Salleh, A. M. Ezree, I. Zaman, M. H. Hatta, B. A. M. Zain, S. Mahzan, M. N. A. Rahman, and W. A. W. Mahmud. 2017. Improvement of automatic fish feeder machine design. *Journal of Physics: Conference Series*, 914(1): 012041.

Yusoff, A. H. M., S. M. Salleh, M. E. Abdullah, I. Zaman, M. H. M. Hani, W. A. Siswanto, and W. A. W. Mahmud. 2018. Experimental evaluation of fish feeder machine controller system. *International Journal of Integrated Engineering*, 10(8): 218–222.