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DESIGN AND OPTIMISATION OF A TIME-CONTROLLED FEEDING MACHINE FOR SHRIMP FARMING

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The shrimp farming industry at a global scale has experienced noteworthy growth over time; however, it is important to note that conventional farming methods in Thailand are currently encountering various obstacles, including low yields, high production costs, and risks associated with diseases. This research explores the development and implementation of a time-controlled, mobile automatic shrimp feeding machine aimed at optimising feed distribution and enhancing the overall efficiency of shrimp farming operations. The designed system utilises an Arduino-based microcontroller to automate and precisely control feeding schedules, ensuring the delivery of an optimal amount of feed based on the shrimp's weight and developmental stage. Through rigorous performance assessments conducted within a sizable 15 × 20 meter shrimp pond, the results demonstrated that the automatic feeding machine achieved a feed distribution coverage of 83% of the pond area, significantly higher than the 65.33% coverage achieved through manual feeding. The machine's mobility further ensures even feed dispersion throughout the pond, addressing the limitations of stationary feeders. Additionally, the automation of feeding processes significantly reduces the manual labour required, thus increasing operational efficiency and reducing the potential for human error associated with traditional feeding practices.

Keywords: shrimp farming efficiency; automatic feeding system; feed distribution; shrimp feed management

Shrimp, a widely favoured type of seafood across the globe, has experienced a significant surge in global farmed production over the years. Beginning with a modest output of less than 9000 metric tons back in 1970, the industry has witnessed a remarkable growth to reach a staggering 3.5 million metric tons by 2009, as reported by Asche et al. (2012) and Cao et al. (2011). This growth trend continued, with production figures climbing to approximately 4 million metric tons by 2018, showcasing a steady annual increase of 3–5% according to the Food and Agriculture Organisation (FAO, 2019).

In Thailand, the main products of Thai aquaculture are farmed shrimp, fish, and molluscs, with shrimp being the largest contributor to total yields. Farmed shrimp is the main product, making up 40% of total yields, followed by fish at 38% and molluscs at 22% (Sampantamit et al., 2020). Shrimp is also one of the leading economic animals in terms of export value among aquatic species. Major markets for Thai shrimp exports include Japan, Europe, and the United States (Geetha et al., 2020).

However, shrimp farmers in Thailand currently face various challenges such as pesticide residue in shrimp, low yield, high production costs, and the risk of shrimp diseases during cultivation. The majority of shrimp farmers still adhere to traditional methods, emphasising low investment,

extensive shrimp farming, and a lack of technology adoption (Szuster, 2006). Under traditional farming systems, shrimp yield can range from 200 to 250 kg per 1,600 m², which is relatively low compared to modern practices. However, with effective management, yields can increase significantly, potentially reaching up to 1,000 kg per 1,600 m² (Chirdchoo and Cheunta, 2019).

The success of shrimp farming relies on several key factors, with efficient feeding practices and effective environmental management of shrimp habitats being crucial components. One critical aspect is the careful distribution of food to the shrimp, as this directly impacts their growth and development (Al Eissa et al., 2022). Overfeeding should be carefully prevented at all costs, as it has the potential to cause negative impacts on the air quality and oxygen levels within the shrimp farming environment (Srinivas et al., 2023). Managing shrimp feeding according to their age is paramount for shrimp farming. Due to the short and straight intestines of shrimp, frequent feeding sessions are necessary, along with the widespread distribution of food within ponds. Usually, farmers adhere to a feeding plan of 3–4 times daily (Rahayani and Gunawan, 2018; Reis et al., 2020).

Adequate feeding plays a crucial role in the success of shrimp farming, as the balance between providing enough

food and avoiding excessive feeding is essential to ensure optimal shrimp growth and maintain overall pond health (Emerenciano et al., 2022; Nunes et al., 2022). When shrimp are not provided with sufficient feed, their growth rate is significantly slowed down, leading to an extended period required for reaching maturity. This inadequate feeding also results in a poor feed conversion ratio (FCR) and ultimately leads to lower yields in shrimp production. However, excessive feeding presents its own set of challenges by increasing production costs through feed wastage. Additionally, overfeeding causes uneaten feed to accumulate in the pond, which in turn contributes to the deterioration of water quality. Furthermore, excessive feeding promotes the growth of harmful bacteria in the pond environment, increasing the risk of diseases among the shrimp population. Ultimately, both inadequate and excessive feeding practices can have long-term detrimental impacts on shrimp health and survival rates, stressing the critical importance of proper feeding management in shrimp farming operations (Arditya et al., 2021; Ghosh et al., 2018; Jesús et al., 2022; Khasani et al., 2022).

Recent advancements in research and technology have led to the development of automated feeding systems tailored specifically for shrimp farming, aimed at supplanting manual labour with automated processes. These systems not only increase the amount of feed but also decrease the time needed for feeding (Reis et al., 2021). Noteworthy research contributions in this area involve the development of an automated feeding system by Irwan et al. (2020). This system can be controlled using buttons or smartphones and incorporates an Arduino-based microcontroller board along with a DC motor for spreading feed up. Furthermore, Novianda et al. (2020) and Arditia et al. (2021) used Arduino UNO and RTC Module for feeding controlled by time, while Rahayani and Gunawan (2018) created a mobile application for remotely controlling feeding machines. Wardhany et al. (2020) introduced a feeding schedule based on age through a mobile application, and Chirdchoo and Cheunta (2019)

proposed an algorithm for detecting shrimp feed using 2D histogram and colour analysis to adjust feed quantities based on the remaining feed in the tray. In a comparative analysis, Inayathullah et al. (2021) showed that automatic feeding machines resulted in increased shrimp growth rates, enhanced health, decreased disease risks, reduced feed and labour costs, and higher profits for farmers.

Recent advancements suggest that automated feeding systems can significantly enhance feeding precision and efficiency. However, ensuring the even distribution of feed within shrimp ponds remains a persistent challenge. This study addresses this gap by developing a prototype of a time-controlled feeding machine designed to optimise feed distribution. The objective of this research is to evaluate the performance of the proposed feeding machine in achieving uniform feed distribution

and to assess its impact on shrimp growth and pond health. This study aims to contribute to the development of more efficient and sustainable shrimp farming practices.

Material and Methods

Design and components of the automatic shrimp feeding machine

The design of the automatic shrimp feeding machine on a sliding ramp, as illustrated in Fig. 1(a), comprises a food tank measuring 30 cm in width, length, and height, capable of holding 10 kg of pellet shrimp feed. It includes a steel frame to secure the food tank to the machine's base for added durability. Beneath the tank, there is a flap valve for food release, driven by wind force through a food dispenser barrel, adjustable in shooting angle. The mobile component of the feeding

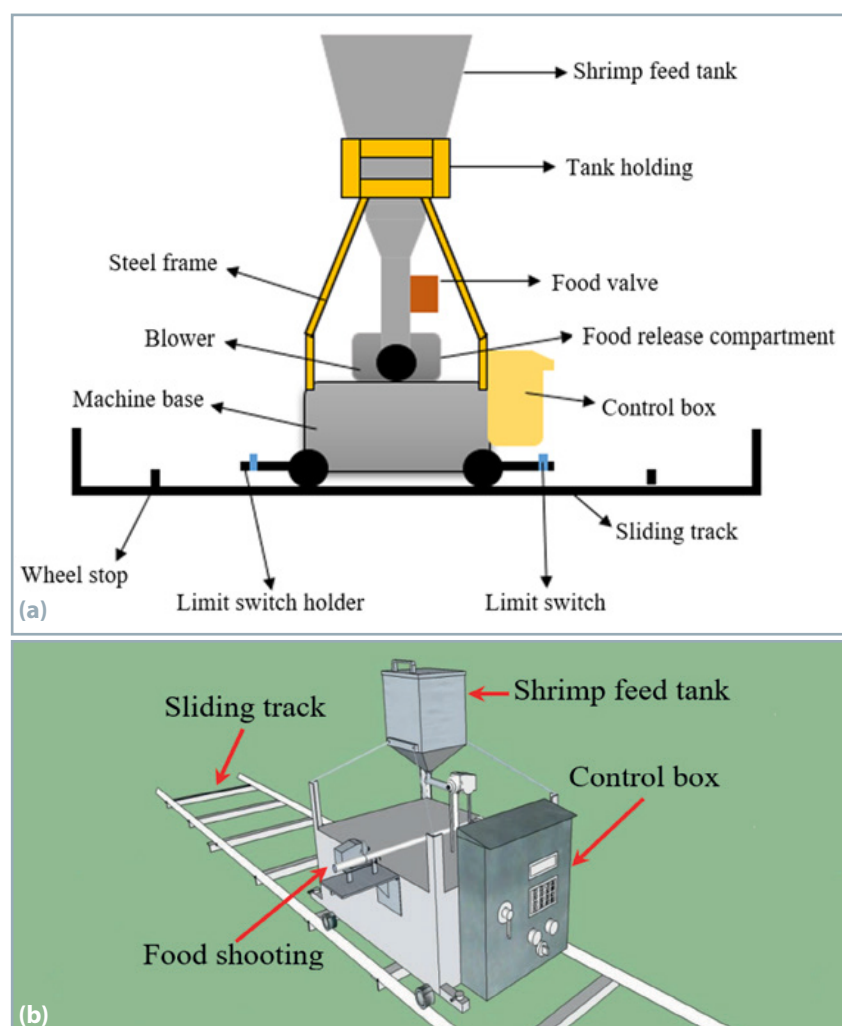


Fig. 1 Design of automatic feeder for shrimp pond

machine operates on the sliding ramp, equipped with stopper points at both ends to trigger a switch, causing the machine to slide back in the opposite direction. All operations are controlled by a control box. In Fig. 1(b), the main structure of the automatic shrimp feeding machine on a sliding ramp is depicted, consisting of the shrimp food tank, feeding system, sliding ramp system, and control cabinet.

In the endeavour to engineer a time-controlled feeding apparatus, the formulation can be articulated through the following mathematical expressions.

$$\text{sliding ramp distance} = \text{pond distance} - 1 \text{ (m)} \quad (1)$$

Equation 1 computes the distance the sliding ramp will traverse towards the shrimp pond, deducting 1 m from the total ramp distance to account for the final stopping point at the pond's end.

$$\text{feeding time} = \frac{\text{feed quantity in the tank}}{\text{feeding machine rate}} \text{ (s)} \quad (2)$$

Equation 2 calculates the time required for feeding by dividing the feed quantity in the tank by the feeding rate of the machine, resulting in the total time needed for complete feeding from the tank.

$$\text{number of feeding halts} = \frac{\text{sliding ramp distance}}{\text{feeding halt distance}} + 1 \quad (3)$$

Equation 3 determines the number of times the sliding ramp halts for feeding by dividing the sliding ramp distance by the feeding halt distance and adding 1 to include the initial halt.

$$\text{feed quantity per feeding} = \frac{\text{feed quantity in the tank}}{\text{number of feeding halts}} \text{ (kg per feeding)} \quad (4)$$

Equation 4 calculates the amount of feed provided per feeding session by dividing the feed quantity in the tank by

the number of feeding halts, resulting in the feed quantity dispensed per feeding session.

$$\text{feeding time per feeding} = \frac{\text{feed quantity per feeding}}{\text{feeding machine rate}} \quad (5)$$

Equation 5 computes the time required for each feeding session by dividing the feed quantity per feeding by the feeding rate of the machine, indicating the time spent for each individual feeding session.

Testing the uniformity of feed distribution

To evaluate the uniformity of feed distribution, a systematic testing procedure was implemented. The methodology involved the following steps.

1. The setup and preparation involved installing the feeding machine in a shrimp pond measuring 15 × 20 m. A grid of collection points was established across the pond, with uniform spacing of 1 m, resulting in a total of 300 collection points.
2. The feed was dispensed by programming the feeding machine to release a predefined amount of feed at specific intervals throughout the day. Standard pelletised shrimp feed was used in the experiment to ensure consistency.
3. Collection trays were placed at each grid point to capture the dispensed feed. After each feeding session, the feed collected in each tray was carefully gathered and weighed using a precision digital scale, with strain gauges employed to ensure accurate measurement of the feed mass.
4. The weight of the feed collected at each grid point was meticulously recorded for each trial. Multiple trials were conducted over several days to ensure the reliability and reproducibility of the results.
5. The recorded data were analysed to determine the distribution pattern of the feed across the pond. A histogram was created to visualise and assess the uniformity of feed distribution.

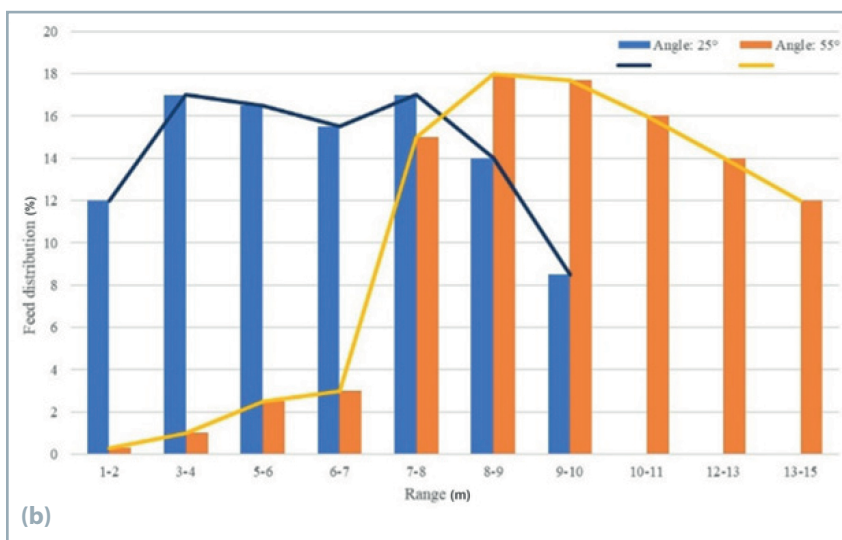


Fig. 2 (a) Experimental trials to determine the optimal angle; (b) Distribution of shrimp feed within a 15 m range angles of 25° and 55°

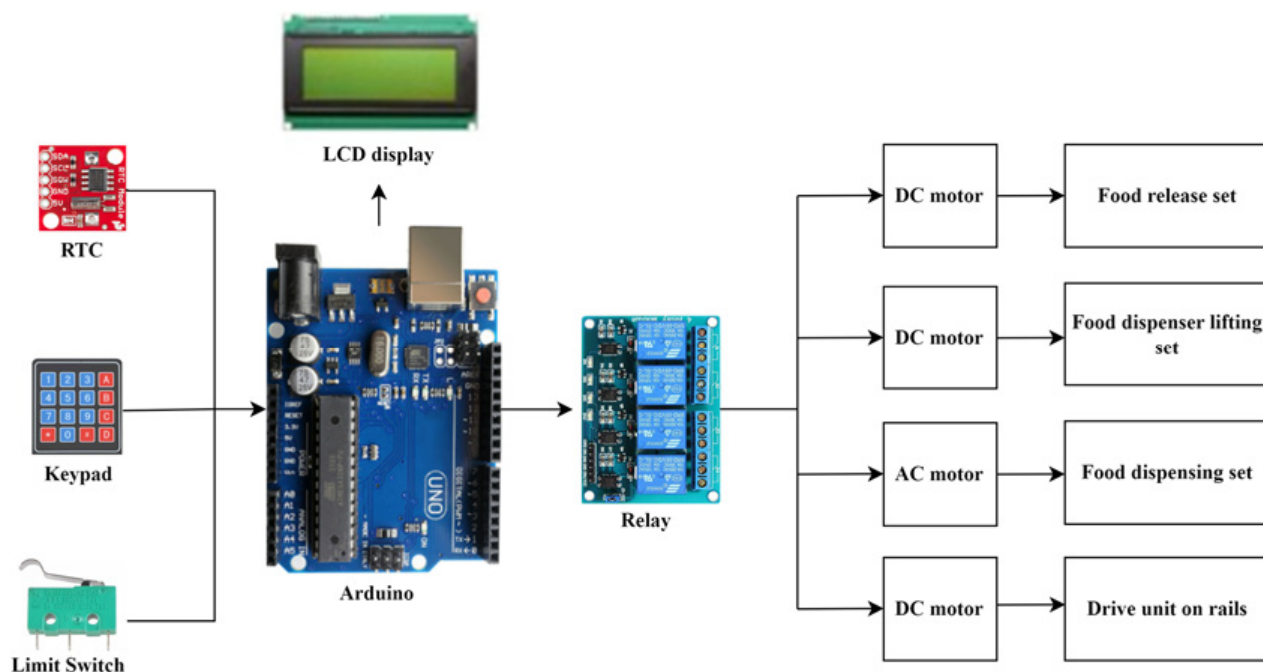


Fig. 3 Block diagram of automated shrimp feeding system

Experimental trials were conducted using an airflow of 7.5 m per second, generated by a blower, to determine the optimal angle for achieving the most uniform distribution of shrimp feed, as depicted in Fig. 2(a). The uniformity of feed distribution was thoroughly assessed, providing valuable data on the performance of the feeding machine. Figure 2(b) shows the distribution of shrimp feed within a 15 m range angles of 25° and 55°. The x-axis represents the range of feed weights collected at each grid point, while the y-axis shows the frequency of grid points within each feed weight range.

These angles effectively covered the feed distribution within the 0–15 m range, with an observed efficiency of 83%.

Automated system for controlling shrimp feeding

The automated shrimp feeding control system is depicted in Fig. 3. The system comprises essential components, including the Arduino microcontroller board, RTC module, keypad, limit switch sensor, LCD, electric motor relay for feed control, feed dispenser relay set, and rail drive relay set. Each component plays a crucial role in the overall functionality

Table 1 Detail description of feeding machine components

Component	Model	Technical specifications	Operating parameter
Arduino Microcontroller Board	Arduino Uno R3	microcontroller: ATmega328P operating voltage: 5V	- manages the opening and closing of the feed container - oversees feeding schedule and machine propulsion
RTC Module	DS1307 RTC Module	power supply: 3.3–5 V interface: I2C	- regulates feeding schedules with precise timekeeping - provides real-time clock functionality to the system
Keypad	4x4 Matrix Keypad	number of keys: 16 operating voltage: 3.3–5 V	- facilitates the input of parameter values for system control - allows users to set and adjust feeding schedules and other parameters
LCD	HD44780 16x2 LCD	display size: 16 characters x 2 lines operating voltage: 5 V	- displays system status and parameters - provides user feedback for system operation
Electric Motor Relay	SRD-05VDC-SL-C	coil voltage: 5 V DC contact rating: 10 A at 250 V AC/30 V DC configuration: SPDT	- interfaces with the electric motor - ensures accurate feed release timing
DC motor	–	rated voltage: 12 V DC	- controls the food release set - controls the lifting of the feed dispenser - controls the unit on rails
AC motor	–	rated voltage: 220 V AC	controls the food dispensing set

of the feeding machine. The detailed description of these components, including their manufacturers, technical specifications, and operating parameters, is shown in Table 1.

The Arduino board oversees various operations, such as managing the opening and closing of the feed container, controlling the lifting of the feed dispenser, feeding the shrimp, and propelling the feeding machine. It interfaces with the electric motor through relays, while the RTC module regulates feeding schedules, and the keypad facilitates the input of parameter values for system control.

Results and Discussion

Development of an automatic shrimp feeding machine

The development of the automatic shrimp feeding machine on a sliding rail is illustrated in Fig. 4(a). This system includes a shrimp feed container, a feed dispenser lifting unit, a shrimp feed shooter unit, and a control cabinet. Figure 4(b) shows the shrimp feed tank container, which can hold up to 10 kg of pellet shrimp feed. Figure 4(c) illustrates the feed dispenser lifting unit, which uses a DC motor to adjust the angle as required. The automatic shrimp feeding control parameters can be set using a keypad, including the parameters such as the pond size, feed quantity in the container, and the number of feedings per day. These parameters are then processed by a microcontroller to manage the feeding operations accordingly.

Performance testing of the automatic shrimp feeding machine

The performance of the time-controlled automatic shrimp feeding machine was rigorously evaluated in a 15 × 20 m shrimp pond. The experimental setup involved a detailed procedure designed to measure the key performance metrics, including feeding time, feed distribution coverage, and feed remaining after each feeding session.

Feeding time analysis

The feeding time, which is the duration required for the feeding machine to complete each cycle, was closely

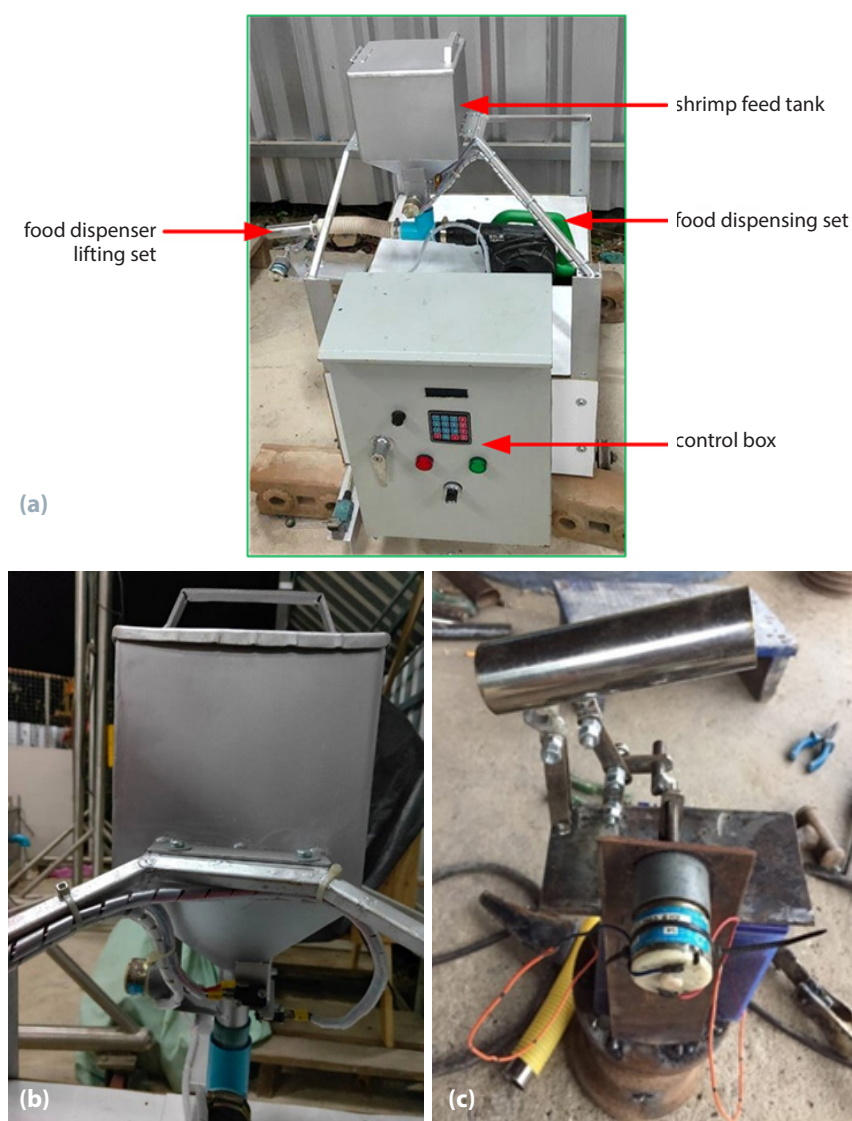


Fig. 4 (a) Automatic shrimp feeding machine; (b) Shrimp feed tank; (c) Feed dispenser lifting unit

monitored across multiple trials. As shown in Table 2, the average feeding time recorded was 63.50 s, with a standard deviation of 1.75 s. A one-sample *t*-test was conducted to compare the observed feeding time against the expected time, with a calculated *t*-statistic of 0. The resulting *p*-value was 1.00, there is no significant difference between the observed feeding time and the expected time.

Feed distribution coverage

The feed distribution coverage was another critical metric assessed during the experiment. The automated feeding machine achieved an average coverage of 83% of the pond area, significantly higher than the 65.33% coverage achieved through manual

feeding, as illustrated in Table 3. A Chi-Square test for homogeneity was applied to assess the distribution differences between the machine and manual feeding methods, resulting in the χ^2 value of 6.314 and the *p*-value of less than 0.01. This confirmed that the automated feeding method has a different and better distribution coverage compared to manual feeding.

Feed remaining post-distribution

In addition to feed distribution, the amount of feed remaining in the container post-distribution was analysed to assess the accuracy of the feeding machine. The average feed remaining was 94.5 g, with a standard deviation of 1.89 g, as shown in Table 4. An ANOVA test was

Table 2 Feeding time of the feeding machine with 1 kg

Feeding cycle	Expected feeding time (s)	Observed feeding time (s)	Deviation (%)
Cycle 1	63.50	64.00	+0.79
Cycle 2	63.50	62.50	-1.57
Cycle 3	63.50	63.80	+0.47
Cycle 4	63.50	63.20	-0.47
Average	63.50	63.50	0.00
SD	–	1.75	–

SD – standard deviation

Table 3 Feed distribution coverage

Feeding method	Pond area (m ²)	Feed distribution area (m ²)	Percentage of feed distribution (%)
Manual feeding	300	196	65.33
Automated feeding	300	249	83.00

Table 4 Feed remaining post-distribution

Feeding cycle	Initial feed quantity (g)	Feed remaining (g)	Deviation (%)
Cycle 1	1000	95.0	-5.00
Cycle 2	1000	92.5	-7.50
Cycle 3	1000	96.0	-4.00
Cycle 4	1000	94.5	-5.50
Average	1000	94.5	-5.50
SD	–	1.89	–

SD – standard deviation

conducted to determine if there were significant differences in the amount of feed remaining across different feeding sessions. The results indicated no significant variance ($F = 1.32$, $p = 0.26$). These results reinforce the consistency and reliability of the feeding machine, showing no significant variance in its performance across different feeding cycles.

The results of our study demonstrate the significant improvements in feeding efficiency and accuracy achieved by the time-controlled automatic shrimp feeding machine compared to traditional manual methods. The machine's ability to consistently cover 83% of the pond area, while minimising feed waste and reducing manual labour, underscores its potential to enhance shrimp farming operations. These findings align with previous research that highlights the benefits of automated feeding systems in aquaculture.

For instance, studies by Reis et al. (2020) and Irwan et al. (2020) have shown that automated feeding systems can significantly increase feed distribution uniformity and reduce labour costs. Reis et al. (2021) further demonstrated that automated systems not only improve the precision of feed delivery but also contribute to better growth rates and health outcomes for shrimp, similar to the results observed in our study. The consistent performance of our machine, with a standard deviation of only 1.75 s in feeding time, also echoes the findings of Wardhany et al. (2020), who reported on the reliability of automated systems in maintaining consistent feeding schedules and quantities.

Moreover, the accuracy of feed distribution achieved by our system, measured at 83%, surpasses the distribution rates

reported in several other studies. For example, Chirdchoo and Cheunta (2019) reported feed coverage rates of around 70% with other automated systems, indicating that our design offers a more effective solution for uniform feed spread. The reduction in feed waste observed in our trials is consistent with the work of Emerenciano et al. (2022), who emphasised the importance of precise feed management in reducing environmental impact and improving overall farm efficiency.

Conclusion

This research introduces an innovative approach to enhance the efficiency of shrimp farming by introducing a time-controlled automatic shrimp feeding machine. Shrimp farming plays a crucial role; however, it encounters obstacles like low yields, high production costs, and disease risks, often exacerbated by conventional farming methods and limited technology adoption. The proposed machine aims to tackle these challenges by ensuring even feed distribution in shrimp ponds, thus supporting healthier shrimp growth and minimising disease risks.

The automatic feeding system is equipped with sophisticated features, such as a sliding rail system, a feed dispenser lifting unit, and a control cabinet, all controlled by an Arduino-based microcontroller board. These elements enable precise management of feeding parameters, including pond size and feed quantity, adjustable via a keypad. The mobility of the machine guarantees uniform feed distribution in the pond, enhancing operational efficiency, optimising feeding practices, and reducing

manual labour. The performance evaluation of the machine took place in a shrimp pond measuring 15 m wide and 20 m long, with feeding trials spanning seven days. The findings revealed that the automatic feeding system provided a more consistent and extensive feed distribution in comparison to traditional methods, covering 83% of the pond area versus 65.33% achieved through manual labour. This uniform distribution is vital for sustaining the overall pond ecosystem balance and fostering healthier shrimp growth.

In conclusion, this research offers a holistic solution to the challenges confronted by traditional shrimp farming practices. The introduction of a time-controlled, mobile automatic shrimp feeding machine brings substantial enhancements in feed distribution, operational efficiency, and shrimp well-being, constituting a valuable contribution to the aquaculture sector.

References

- AL EISSA, A. – CHEN, P. – BROWN, P. B. – HUANG, J.-Y. 2022. Effects of feed formula and farming system on the environmental performance of shrimp production chain from a life cycle perspective. In *Journal of Industrial Ecology*, vol. 26, no. 6, pp. 2006–2019. DOI: <https://doi.org/10.1111/jiec.13370>
- ARDITYA, I. – SETYASTUTI, T. A. – ISLAMUDIN, F. – DINATA, I. 2021. Design of automatic feeder for shrimp farming based on internet of things technology. In *International Journal of Mechanical Engineering Technologies and Applications*, vol. 2, no. 2, pp. 145–151. DOI: <https://doi.org/10.21776/MECHTA.2021.002.02.8>
- ASCHE, F. – BENNEAR, L. S. – OGLEND, A. – SMITH, M. D. 2012. US shrimp market integration. In *Marine Resource Economics*, vol. 27, no. 2, pp. 181–192. DOI: <https://doi.org/10.5950/0738-1360-27.2.181>
- CAO, L. – DIANA, J. S. – KEOLEIAN, G. A. – LAI, Q. 2011. Life cycle assessment of Chinese shrimp farming systems targeted for export and domestic sales. In *Environmental Science & Technology*, vol. 45, no. 15, pp. 6531–6538. DOI: <https://pubs.acs.org/doi/10.1021/es104058z>
- CHIRDOCHO, N. – CHEUNTA, W. 2019. Detection of shrimp feed with computer vision. In *Interdisciplinary Research Review*, vol. 14, no. 5, pp. 13–17. DOI: <https://doi.org/10.14456/jtir.2019.43>
- EMERENCIANO, M. G. C. – ROMBENSO, A. N. – VIEIRA, F. D. N. – MARTINS, M. A. – COMAN, G. J. – TRUONG, H. H. – NOBLE, T. H. – SIMON, C. J. 2022. Intensification of penaeid shrimp culture: An applied review of advances in production systems, nutrition and breeding. In *Animals*, vol. 12, no. 3, article no. 236. DOI: <https://doi.org/10.3390/ani12030236>
- FAO. 2019. Farmed shrimp supply stayed low in Asia. Information and Analysis of Markets and Trade of Fisheries and Aquaculture Products. Available at: <https://www.fao.org/in-action/globefish/news-events/news/news-detail/Farmed-shrimp-supply-stayed-low-in-Asia/en>
- GEETHA, R. – RAVISANKAR, T. – PATIL, P. K. – AVUNJE, S. – VINOTH, S. – SAIRAM, C. V. – VIJAYAN, K. K. 2020. Trends, causes, and indices of import rejections in international shrimp trade with special reference to India: A 15-year longitudinal analysis. In *Aquaculture International*, vol. 28, pp. 1341–1369. DOI: <https://doi.org/10.1007/s10499-020-00529-w>
- GHOSH, A. K. – BISWAS, M. – AZAD, M. A. K. – ISLAM, S. S. – HUQ, K. A. – SHAH, M. S. 2018. Effect of restricted feeding on growth performance and feed utilization of freshwater prawn (*Macrobrachium rosenbergii*) in pond aquaculture system. In *Khulna University Studies*, pp. 13–32. DOI: <https://doi.org/10.53808/KUS.2018.15.1and2.1803-L>
- INAYATHULLAH, N. – VIJAYANANAD, P. – SRILAXMI, K. 2021. A comparative study on the shrimp culture practices of *Litopenaeus vannamei* with automatic feeder and boat feeding technique along Karaikal region. In *Journal of Survey in Fisheries Sciences*, vol. 7, no. 3, pp. 101–110. DOI: <https://doi.org/10.17762/sfs.v7i3.102>
- IRWAN – NUGRAHA, M. I. – ANZULLAH, M. – SAPUTRI, R. S. 2020. The design of *Litopenaeus vannamei* automatic feeder. In *Journal of Physics: Conference Series*, vol. 1528, article no. 012004. DOI: <https://doi.org/10.1088/1742-6596/1528/1/012004>
- JESÚS, D. P. – HERNÁNDEZ-VERGARA, M. P. – PÉREZ-ROSTRO, C. I. – FRÍAS-QUINTANA, C. A. 2022. Effect of food restriction on compensatory growth and enzymatic activity of freshwater prawn post larvae (*M. rosenbergii*), during its culture in Biofloc. In *Aquaculture International*, pp. 1–22. DOI: <https://doi.org/10.21203/rs.3.rs-2129435/v1>
- KHASANI, I. – SOPIAN, A. – ANGGRAINI, F. – PAMUNGKAS, W. 2022. Growth, survival rate, and reproductive performance of two superior strains of the giant freshwater prawn (*Macrobrachium rosenbergii*). In *Omni-Akuatika (Journal of Fisheries and Marine Research)*, vol. 18, no. S1, pp. 74–80. DOI: <http://dx.doi.org/10.20884/1.oa.2022.18.S1.983>
- NOVIANDA, N. – LIZA, F. – AHMAD, I. 2020. Intelligent system of automatic shrimp feeding. In *IOP Conference Series: Materials Science and Engineering*, vol. 854, article no. 012046. DOI: <https://doi.org/10.1088/1757-899X/854/1/012046>
- NUNES, A. J. P. – DALEN, L. L. – LEONARDI, G. – BURRI, L. 2022. Developing sustainable, cost-effective and high-performance shrimp feed formulations containing low fish meal levels. In *Aquaculture Reports*, vol. 27, article no. 101422. DOI: <https://doi.org/10.1016/j.aqrep.2022.101422>
- RAHAYANI, R. D. – GUNAWAN, A. 2018. Proposed design of an automatic feeder and aerator systems for shrimps farming. In *International Journal of Materials, Mechanics and Manufacturing*, vol. 6, no. 4, pp. 277–280. DOI: <https://doi.org/10.18178/ijmmm.2018.6.4.391>
- REIS, J. – NOVRIADI, R. – SWANEPOEL, A. – JINGPING, G. – RHODES, M. – DAVIS, D. A. 2020. Optimizing feed automation: Improving timer-feeders and on demand systems in semi-intensive pond culture of shrimp *Litopenaeus vannamei*. In *Aquaculture*, vol. 519, article no. 734759. DOI: <https://doi.org/10.1016/j.aquaculture.2019.734759>
- REIS, J. – WELDON, A. – ITO, P. – STITES, W. – RHODES, M. – DAVIS, D. A. 2021. Automated feeding systems for shrimp: Effects of feeding schedules and passive feedback feeding systems. In *Aquaculture*, vol. 541, article no. 736800. DOI: <https://doi.org/10.1016/j.aquaculture.2021.736800>
- SAMPANTAMIT, T. – HO, L. – LACHAT, C. – SUTUMMAWONG, N. – SORGELOOS, P. – GOETHALS, P. 2020. Aquaculture production and its environmental sustainability in Thailand: Challenges and potential solutions. In *Sustainability*, vol. 12, no. 5, article no. 2010. DOI: <https://doi.org/10.3390/su12052010>
- SRINIVAS, K. S. – ROHINISRI, C. – SUNDARA, N. N. V. V. – KUMAR, S. – ANUSHA, T. – SURYA, B. S. S. 2023. Automatic prawns feeding and monitoring system using internet of things (IoT). In *Journal of Engineering Sciences*, vol. 14, no. 3, 560–564.
- SZUSTER, B. 2006. Coastal shrimp farming in Thailand: Searching for sustainability. In *Environment and livelihoods in tropical coastal zones: Managing agriculture-fishery-aquaculture conflicts*. Wallingford, UK: CAB, pp. 86–98. DOI: <https://doi.org/10.1079/9781845931070.0086>
- WARDHANY, V. A. – YULIANDOKO, H. – SUBONO – AL RASYID, M. U. H. – ASTAWA, I. G. P. 2020. A Mobile application development of automatic shrimp feeder system. In *Proceedings of the International Seminar of Science and Applied Technology (ISSAT 2020)*, pp. 39–45. DOI: <https://doi.org/10.2991/aer.k.201221.008>

