ORIGINAL RESEARCH ARTICLE

Aquafarm automation system

Satyanarayana Chanagala[1,*], Romala Sesha Syamala Srinivas[1], George Chellin Jeya Chandra[2], Manda Kavitha[3], Kanduri Madhusudhana Rao[4]

[1] *Magni5, Hyderabad 500073, India*

[2] *School of Computing Science and Engineering, VIT-BHOPAL University, Bhopal 466114, India*

[3] *Electronics and Communications, MNR College of Engineering and Technology, Sangareddy 502294, India*

[4] *Electronics and Communications, KKR & KSR Institute of Technology and Science, Guntur 500017, India*

*** Corresponding author:** Satyanarayana Chanagala, scorppytek_satya@yahoo.com

ABSTRACT

This paper deals with the design of an automated system to increase the yield of shrimp farming in the country. There are three factors involved in designing an aqua form automation system (AFAS). The first factor is to get the maximum egg to postlarva conversion. The second factor is to make the farming environment contamination-free, and the third factor is to conserve electrical energy, which is the need of the hour for the economy. Several experiments have been conducted to make the system robust, foolproof, and ready for commercial usage. This system has reduced manpower while giving leverage to the consumer in terms of investment.

Keywords: automation; IoT; hatchery; solid state relay; shrimp; temperature sensor

1. Introduction

Presently, about 2.70 lakh hectares of brackish water area are under shrimp forming with a seed requirement of about 20–25 billion postlarvae, which is being met by about 270 commercial shrimp hatcheries having installed capacity of 11.4 billion postlarvae. It is estimated that by 2030 AD, the area under shrimp forming may nearly double, leading to a demand of 50 billion postlarvae annually. Hence, there is enormous scope for the establishment of commercial shrimp hatcheries in the country.

The quality of the seed plays a very important role in shrimp seed production or hatchery technology, as the shrimps do not mature and spawn under captive conditions. The quality of the seed plays a very important role in shrimp seed production or hatchery technology, as the shrimps do not mature and spawn under captive conditions. The early larval forms being purely marine, very much need the marine environment for growth and survival. Hatchery technology, therefore, aims to provide the larvae with a conducive environment with stable water quality and a proper quantity of quality feed.

The Central Institute of Brackish Water Aquaculture (CIBA), Chennai has developed a package of practices for shrimp hatchery technology. Based on production capacities, shrimp hatcheries are classified as backyard, medium, and large-scale hatcheries.

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In the present work, an embedded and IoT-based automation system is designed to monitor and control the temperature of the water in tanks, which plays a major role in the conversion of eggs to post-larva.

2. Literature survey

Abdel-Latif et al.[1] have discussed shrimp farming undertaken in some countries and focused on disease outbreaks that led to the collapse of the entire industry.

Khanjani et al.[2] have emphasized increasing the yield through microbial-based approaches such as Biofloc technology (BFT), synbiotics, and aquamimicry. They have also highlighted the increase in production costs and skilled staff with this technique.

Some authors[3] have observed that microbial aggregates, mainly formed by bacteria, may present nutritional deficiencies in their contribution, in particular essential amino acids and polyunsaturated fatty acids of the ω-3 family, fundamental for the development of shrimp.

Ferreira et al.[4] have discussed some eco-based systems of farming based on low-input sustainable aquaculture. The ecosystem approach to aquaculture focuses on low-input-based technology matching the local conditions, ensuring sustainable, economically viable, and socially acceptable methods.

In this work, the authors[5] aimed to evaluate three different strategies for rearing *L.vannamei*in a biofloc system: heterotrophic, chemoautotrophic, and mature biofloc systems relative to the effects of water quality, waterbacterial community, biofloc composition, and yield.

The authors[6] here discussed ways to increase marine shrimp production based on their feed. They have also narrated how shrimp larval survival and their disease resistance capability are affected by an unbalanced live feed that contains low nutritional compositions. Further, the authors have highlighted that brine shrimp *Artemia* can be collected in nature and stored as cysts until needed.

Nursery system production-increasing methods are discussed here[7]. The various aspects like control over early disease outbreaks, limited water exchange, improved feed management, control over the culture medium, and improved shrimp health before transfer to the grow-out phase are focused on.

The focal point of this work[8] is on synbiotics, a combination of prebiotics and probiotics. The mechanisms of how synbiotics work as growth and immunity promoters are discussed.

The concept of aquamimicry[9,10] is highlighted in this paper. It uses fermented rice bran to activate natural zooplankton, with the sole provision of fermented soybeans as feed for shrimp. This combination completely replaces the need to buy or create pellets and is referred to as "aquamimicry fermented soybeans" (AFSY). AFSY has been successful in the extensive and semi-intensive farming of black tiger shrimp and whiteleg shrimp.

3. Proposed method

Most of the research discussed above emphasizes feed-related work to increase the yield of shrimp. However, work related to hatching the eggs is not taken up by the researchers exhaustively. In the existing methods, the shrimp culture is carried indoors using tanks, where each tank holds one thousand two hundred liters of water. One million eggs are put in each tank. Apart from the salinity of the water, temperature is a vital parameter that decides the conversion of the egg into the post-larva stage. Temperatures beyond the optimal limit influence fish health by increasing the metabolic rate and oxygen consumption, which in turn can lead to the death of the species or may affect growth. To maintain the temperature according to the requirements of the breeding type, we have to develop a system to monitor the temperature and automatically turn on/off the heater according to the required set points. By maintaining the temperature accordingly, the growth of the breeds will be uniform, which in turn leads to good yielding. Studies have revealed the fact that the temperature of the water must be precisely maintained between 32.50 °C and 330 °C. When the temperature is precisely maintained within this range, the conversion of the eggs to post-larva is 99%. The temperature either above or below this range would reduce the conversion to less than 70%. In the present conventional method, the temperature is monitored manually, and if the temperature is outside the range, then heating rods are activated. However, owing to human limitations, the temperature can deviate, resulting in a reduction in the yield.

Further, when the temperature goes well below the range, the heaters must be switched on for a longer duration, which may consume high power, leading to high electricity bills. This is the chief concern of the hatcheries.

Also, as the monitoring is done manually using traditional thermometers, there are fairly good chances of contamination of the water in the tanks, which may result in a decrease in the yield. Specifically, when a deceased person monitors the temperature of the water in the tanks, there are high chances of water contamination. The AFAS device will overcome this.

Therefore, there is a need to automate the above operations. As per the inputs taken from the hatchery owners, there is an immediate requirement for the same. Hence, initially, a prototype is designed and tested under various conditions, and based on the results, obtained modifications are incorporated to make the automated system ready for installation in the hatcheries. There was no prior product in this regard, and even to date, there is no competitor for the same.

4. Description of the device

Arduino-Uno platform is used with an embedded C programming environment. Espressif ESP-WROOM 32U controller is used with solid state relay, temperature sensor (DS18B20), and a 7-segment display.

ESP32-WROOM-32U are powerful, generic Wi-Fi + Bluetooth® + Bluetooth LE MCU modules that can be used for a wide variety of applications, starting from low-power sensor networks to the most challenging tasks, such as voice encoding and decoding and music streaming. It is a 38-pin, 32-bit controller with a clock frequency range of 40 MHz to 80 MHz and a 3.3 V DC requirement. It has a low-power coprocessor that can be used instead of the CPU to save power while performing trivial tasks that do not require much computing power, such as monitoring peripherals. It comes with a rich set of peripherals, ranging from SD card interface, capacitive touch sensors, high-speed SPI, Ethernet, I2S, I2C, and UART.

Wi-Fi and Bluetooth low energy ensure that a variety of applications can be aimed. Wi-Fi allows a large range and direct connection to the Internet through a Wi-Fi router. While Bluetooth allows the user to connect to the phone or transmit low-energy beacons for its identification. The sleep current of the ESP32 chip is less than 5 µA, and this makes it appropriate for battery-powered and wearable electronics applications. The module supports a data rate of up to 150 Mbps and 20 dBm output power at the antenna to ensure alarger range. Thus, the module offers industry-required specifications. Further, it has 32 GPIO pins, which gives greater space for the designer.

The internal memory includes 448 KB of ROM for booting and core functions, 520 KB of on-chip SRAM for data and instructions, and 8 KB of SRAM in RTC, which is called RTC FAST Memory and can be used for data storage. It is accessed by the main CPU during RTC Boot from the deep-sleep mode, and 8 KB of SRAM in RTC, which is called RTC SLOW Memory that can be accessed by the co-processor during the Deep-sleep mode. It also has 1 Kbit of eFuse, out of which 256 bits are used for the system in terms of MAC address and chip configuration, and the remaining 768 bits are reserved for customer applications, including flashencryption and chip ID.

The DS18B20 temperature sensor-comes as one wire which is used as a data line and GND to communicate with the Arduino. Every individual DS18B20 temperature sensor has a unique 64-bit serial code. This allows the user to connect multiple sensors to the same data wire. Hence, one can detect temperature from multiple sensors using one Arduino digital pin. The DS18B20 temperature sensor is also available in a waterproof version.

Solid State Relay (SSR) is the heart of the designed automated system. It is a three-phase relay that is controlled by a 4 V DC voltage connecting the 3.3 KW heating rod to 440 V AC voltage. Each phase has a maximum current carrying capacity of 8 Amperes current. However, the present design uses 5.5 Amperes current per phase, and thus a total current of 16.5 Amperes is used by the heating rod. This is one device that requires proper maintenance. A proper selection of heat sinks decides the durability of the system. **Figure 1** shows the device ready for the commercial application.

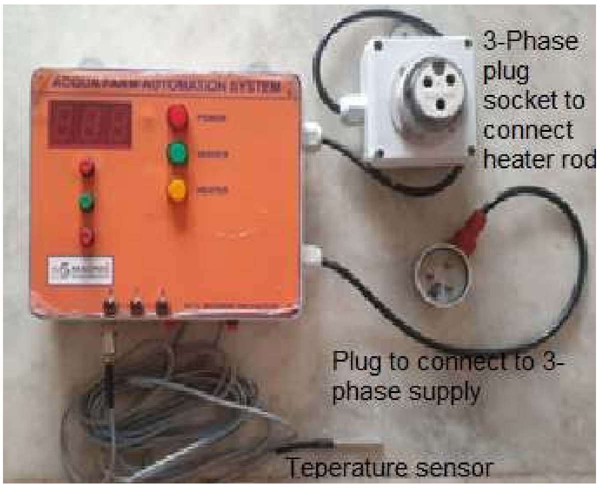

Figure 1. Designed automation system.

Figure 2 shows the installation of the device in the real-time environment of hatcheries in the Andhrapradesh state of India. **Figure 3** gives a closer view of the installed device.

Figure 2. Automation devices installed in the hatcheries.

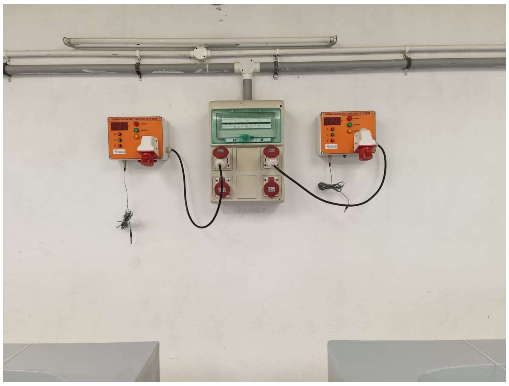

Figure 3. A closer view of the installed device.

Figure 4 shows the way hatcheries located at different locations can be controlled from a remote office location. Hatcheries have n number of sheds, in each shed there are 10–15 tanks and every tank is installed with one automation device. The data that has the on /off status of the heater and the tank temperature are transferred to the centralized server. One can monitor all the tanks' temperatures from a single place, thus reducing many expenses and making a more profitable business.

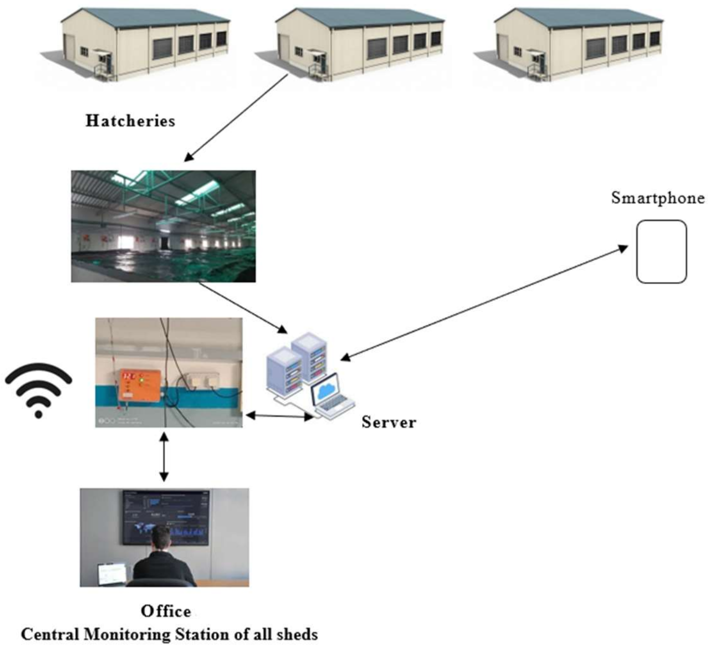

Figure 4. Monitoring and controlling the devices from a remote location.

5. Challenges

A few challenges have been encountered during the design phase. As the system employs a 3-phase 3 KW heating rod, the system is facilitated with a three-phase connectivity to the mains of the hatchery. In contrast, the controller used in the system requires a DC voltage between 3.3 V DC and 6 V DC. A single-phase step-down transformer with an appropriate rectifier circuit with filters and a regulator is used.

The second challenge is about the temperature sensor. The DS18B20 temperature sensor is used in the present work. Since the sensor has to detect the temperature of the water. However, the sensor can't be directly dipped into the water, and hence an alternate path has been explored. A metal capsule with dimensions of 50 mm and a diameter of 5 mm is used, and the sensor is inserted into the capsule. The capsule is filled with silicone gel for further protection. A Teflon-insulated cable is used to take out the connection from the sensor, and the other end of the cable is connected to the three-pin metal connector which can be connected to the main system. However, this has resulted in an accuracy deviation of 0.1 ℃ which is accepted by the Hatchery owners.

The third challenge is about the selection of SSR. During the initial phase of designing the system, a hit-and-trial method is adopted. Many times SSRs are burnedout, which results in several brainstorming. Finally, the SSR with the current rating of 8 Amperes/Phase exhibited good performance.

After making the device, it is kept under an aging period of 72 h. Observations reveal that 3% to 4% of transformers have shown problems in the form of overheating. Efforts are on to identify the faults in the transformer.

6. Algorithm

Figure 5 shows the algorithm that explains the operation of the automation device. This is a completely IoT-automated device used to control the temperature of an aquatic tank using the set point given manually or by updating on the APP or portal side.

Among the various physical factors influencing the aquatic environment is temperature, it plays a critical role in the lives of aquatic cold-body animals in which a variable body temperature changes as a function of the temperature of the environment. Hence, the temperature is considered a biotic factor. The physiological processes of the creature, such as food consumption, digestion, and immunity, are influenced by water temperature. For the yield to be maximum, the temperature of the water in the tank must be maintained within the range of 32.5 ℃ and 33 ℃.

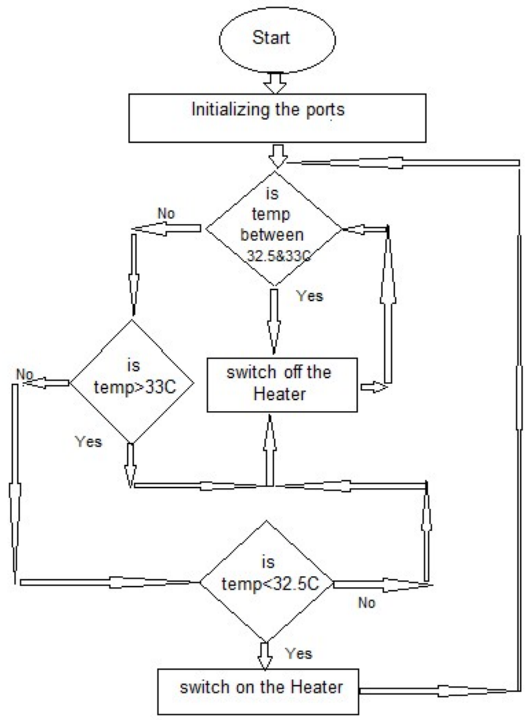

Figure 5. Flow chart of the process.

7. Performance improvement

Experimental results at the hatcheries have provided real-time data that aligns with the projections anticipated. **Table 1** shows the improvement in performance with the designed system.

Table 1. Performance improvement.

Sr.No.	Parameter	Without the automation device	With the automation device	Performance improvement
1.	Energy consumed/Tank/1 day duration	30 units	15 units	50%
2.	Personnel required for 12 tanks	Three persons are required	One	33%
3.	Contamination	Fair chances of contamination (manual operation)	Contamination free (no manual operation)	On average 10% more yield in one cycle of 21 days

The time required to raise the temperature of the water in the tank by 1 °C from the room temperature of 28 °C is 2 h. Therefore, the energy consumed is 6 units. With manual monitoring and control of the tank due to human limitations, temperatures often drop two to three degrees from 32.5 °C. Further, with manual operation for an average of 10 h, the heater is made on for 24 h duration. This would consume energy of 30 units.

With the automated system, this waste of electrical energy is mitigated. Observations have shown that 5 h of switching on the heater satisfy the requirement. This would require 15 units of energy.

Further, in the manual process, thermometers are used to monitor the temperature of water, which can be carriers of harmful bacteria from one tank to another. Also, if the personnel working in the hatchery is infected, the same may be carried to the tanks. All these may lead to a reduction in the yield. Observations have revealed an average reduction of 15% yield over one cycle, which spans 21 days.

8. Conclusion and future development

The designed automation system for the hatcheries has given satisfactory results. Positive feedback is received from the hatcheries spread across the Andhra Pradesh state of India. A 50% savings in electrical energy, a 33% reduction in the personnel requirement, and a contamination-free environment increased the yield by 10%, which increased the profit margins.

As per the requests from the hatchery owners, work has started to integrate PH and salinity sensors to monitor the quality of the water.

Author contributions

Conceptualization, SC and RSSS; methodology, SC; software, RSSS; validation, SC, RSSS and MK; formal analysis, SC; investigation, SC and RSSS; resources, GCJC; data curation, KMR; writing—original draft preparation, SC; writing—review and editing, SC; visualization, KMR; supervision, SC; project administration, KMR; funding acquisition, RSSS. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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