

Development of top-dressing automation technology for sustainable shrimp aquaculture in India

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Abstract

Globally, the shrimp farming industry faces increasing challenges and pressure to reduce the broken shrimps and maintain a healthier pond environment. Shrimps lack an adaptive immune system to combat invading pathogens due to an imbalance in beneficial gut microbiota. The use of top-dressing agents like probiotics and pond optimizers is an alternative strategy to improve the innate immune system leading to produce disease-free shrimp in international markets. The cost of top-dressing agents is accounted for 20% of the production cost and therefore, the development of top-dressing automation technology is important to maintain and improve the financial and environmental viability of shrimp sustainable farming. This perspective described several sensor-based aquaculture technologies for on-farm management systems but sustainability in the aquaculture industry is not yet achieved in practice. The present technology is a new invention to reduce labor and production costs required for reducing bacterial and organic loads in Biofloc shrimp cultures. Aquaculture automation system disperses the top-dressing agents to the shrimp ponds based on the signals received from microbial and environmental sensors. Continuous monitoring of shrimp growth, mortality, immune responses, diseases, and pond water quality parameters will fetch larger profits with additional savings on labor and production costs for sustainable shrimp aquaculture in India.

Keywords Shrimp · Probiotics · Automation · Disease control · Top-dressing · Immunity

1 Introduction

Shrimp farming is one of the most profitable and fastest-growing sectors in the aquaculture industry. The total global production of shrimp in 2017 was 4,267,500 metric tons of which Asian countries accounted for about 80.1% of production [1]. The Pacific white shrimp (*Litopenaeus vannamei*) is the most commercially important shrimp species in the world [2]. India is endowed with a long coastline and has a scope for large exploitation of marine wealth. In India, an estimated brackish water area suitable for shrimp culture is 11.91 lakh ha of which around 1.356 lakh ha area is currently under shrimp farming. *L. vannamei* is a benefited shrimp production in India. It is approved by the Coastal Aquaculture Authority of India in the States of Andhra Pradesh, Tamil Nadu, Maharashtra, Gujarat, Orissa, Goa, and Union Territories of Diu and Pondicherry. Andhra Pradesh has 974 km of coastline and 175,000 ha of brackish water. It produces more than half of the country's farmed shrimp. Shrimp exports in India are increased by 16.21% (4,34,484 metric tons) during 2016–17. The Garret ranking and Rank Based Quotient analyses projected severe constraints in the shrimp aquaculture sector in India due to COVID-19 related lockdown [3]. However, a wide gap between the demand and supply increases

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global shrimp markets and overexploitation from coastal water [4]. About 76% of all farmed shrimp production is coming from the aquaculture sector. Value chain industries (aqua-feeds, equipment, chemicals, investments, and marketing, etc.) are also contributed to the farmed shrimp-related economic growth. The fragmented market and global shrimp supply chains can be affected by the production of post-larvae shrimp by hatcheries [5].

Organic, traditional, and wastewater aquaculture methods are directly complementing the concepts of sustainability of shrimp culture [6]. Current environmental problems that plague the aquaculture industry are accomplished by organic aquaculture [7, 8]. Traditional aquaculture is effective in most rice-growing and fish-eating countries in Asia [9, 10]. The purposes of recycling organic wastewater for shrimp production and environmental protection are achieved with the wastewater aquaculture method [11]. Shrimp grow-out technology continues to be most extensive to semi-intensive and its efficiency should be improved through innovation and standardization of procedures. The grow-out shrimp are critically affected by overall operation success, risk of diseases, feeding control ratio, mortality, and low salinity [12]. Nurseries provide an opportunity for acclimation during the grow-out season. The sustainability of shrimp culture in the Biofloc system is very successful in practice [13–16]. However, increased energy costs, advanced technical skills, constant monitoring, and further research necessary to acclimatize Biofloc production. Various viral, bacterial and fungal diseases are also important challenges globally facing in Biofloc shrimp production worldwide [17, 18].

Commercially formulated high-energy feeds have been used for sustainable shrimp aquaculture in the prevention control of shrimp diseases and environmental crises [19]. In addition to the nutrients provided in the feed, farmers frequently top-dress their feed with vitamins, minerals, immune-stimulants, probiotics, and pond optimizers [20, 21]. Top-dressing agents are perceived by the farmers to be feed attractants and growth promoters [22, 23]. These agents have typically increased feed costs by US\$39/ton in small-scale shrimp farming [24]. These agents can prevent the disease rather than the treatment of the disease in static or low water exchange systems. Farmers always aim to minimize overfeeding and usage of top-dressing agents to gain reasonable profits. There are several methods to be used for top-dressing applications. A traditional method requires constant hand labor for multiple top-dressing applications, which deteriorates the water and soil quality of the ponds. A mixture of feed and probiotics, adding probiotics in the feed ingredients and manual spraying top-dressing agents after feeding are traditional practices with the help of skilled laborers. A regular mild stirring of the pond bottom using iron chains to suspend the organic matter, followed by the addition of carbon sources can promote beneficial in-situ bacterial populations in culture ponds.

This practice results accumulation of an excess of ammonia and nitrite in the ponds. It can be solved by the addition of ammonia-oxidizing bacteria or nitrifying bacteria into the culture system upon the ammonia levels. Consequently, on-farm management gains major importance in the long-term sustainability of the aquaculture sector [25–28]. Therefore, there are no proper top-dressing automation methods for continuous monitoring and evaluation of shrimp growth and pond conditions. In this perspective, new top-dressing automation technology is suggested to reduce labor and production costs required for reducing bacterial and organic loads for sustainable shrimp aquaculture in India.

2 Materials and methods

The PRISMA criteria were used in a methodical approach to this systematic review [29]. The information related to sensor-based automation methods and on-farm management was searched from the NCBI-PubMed databank and Google Scholars in February 2021. The following search parameters and MeSH terms “probiotics”, “sensor”, “Biofloc”, “aquaculture”, “pond water”, “automation”, and “shrimp”. The inclusion criteria were the following: top-dressing agent, aquaculture automation system, on-farm management system, sustainable shrimp aquaculture, sensor-based automation, and pond water quality published in a peer-reviewed article and full-text publication. The exclusion criteria were the following: manual aquaculture methods, probiotics, shrimp production, and shrimp diseases. Most of the examined papers were published between 2000 and 2021. A total of 70 publications were evaluated for this systematic perspective by two independent experts. Online books were used for the definitions of aquaculture terms.

The regulatory concerns in environmental and economic sustainability issues affect shrimp farming in India [4]. A complex set of factors require multiple inputs and diverse perspectives in sustainable shrimp farming. Aqua-feeds, organic loads, chemical pollution, salinization of water, shrimp infections, and market failure are the nature of the environmental impacts associated with sustainable shrimp farming [30, 31]. These issues have also interacted with grow-out methods of shrimp aquaculture. Besides, biological community structures including bacteria, fungi, zooplankton, and phytoplankton have shown indirect effects on sustainable shrimp farming [32, 33]. White spot syndrome virus, infectious hypodermal and hematopoietic necrosis virus, monodon baculovirus, hepatopancreatic

parvovirus, infectious myonecrosis virus, yellow head virus, and Taura syndrome virus are common viral diseases in shrimp aquaculture. Necrotizing hepatopancreatitis bacterium, acute hepatopancreatic necrosis disease, and enterocytozoon hepatopenaei are other microbial diseases affecting the growth of shrimp production. The PCR-based diagnoses of immune-response and probiotic competency-related genes are very important to know the health status of shrimp during the culture period (Table 1). Therefore, intensive production systems and sustainable practices that reduce the impact on local water quality and shrimp diseases can improve shrimp production in India.

3 On-farm management systems

Several on-farm management systems have been developed for sustainable shrimp aquaculture worldwide. An agricultural drip irrigation system for continuous water flow and a permanent supply of live food has been used for *L. vannamei* culture ponds [34]. TEMA software has been developed as a consultant for controlling pond water quality, productivity, and feeding [35]. A real-time automatic monitoring system has been used for continuous monitoring of pond water parameters [36]. ARM7 controller system has been modified for automatic detection and control of temperature, pH, and dissolved oxygen in aquaculture ponds [37]. The solar-powered automatic shrimp feeding system has been initiated to utilize a 10-hour timer to be set in intervals preferred by the user [38]. Auto Switch Aqua Feeder 1 has been designed for automation of feeding administration and substantially reducing the labor cost [39]. It helps to increase the shrimp growth rate and make shrimp healthier by living in high water quality. Aqua monitoring system using wireless sensor networks and IAR-Kick has been proto-typed to monitor and control an aquaculture system for semi-literate farmers to take suitable actions based on pond environmental information [40]. A patented prototype has been invented for a possible solution to automate and simplify the rearing of shrimps in the laboratory and the commercial ponds [41]. Hence, advances in automatic controlling systems and feeding algorithms support us to integrate environmental and microbial sensors for real-time monitoring of probiotics efficiency, pond water quality, and immune performance in shrimp farming.

4 Sensor-based on-farm management systems

Commercial microbial and aquaculture sensors have been developed for online measurements of microbial growth and pond water quality parameters (Table 2). These aquaculture sensors are highly expensive but stable in hard environmental conditions for a long period of applications. Comparative analysis of sensor specifications indicated that environmental sensors available in Atlas Scientific are economically more suitable with desired quality for online applications in shrimp aquaculture. Ammonia sensor available in YSI Inc. is a low-cost one and appropriate to shrimp aquaculture applications. BACMON has been developed as a microbial sensor to detect the bacterial load in water continuously using automated batch sampling technology [42]. Hach's has been developed a combination sensor for ammonium and nitrate and UVAS plus the reagent-free determination of the organic load in the ponds. Hach's SC200 Universal Controller is the most versatile controller on the market and provides compatibility with the broadest range of sensors. AQ1 Sound Feeding System SF200 with complex filtering algorithms has been developed to analyze shrimp feeding sounds in aquaculture ponds using a hydrophone. AQ1 Adaptive© Feeding Algorithm has been implemented to control feed output to match the feed intensity precisely and eliminate feed waste using environmental sensors. FluoRAS sensor has been developed to monitor the accumulation of organic matter for optimizing recirculating aquaculture systems [43]. The online bacteria sensor has been developed based on 3D image recognition with algorithms considering 59 quantified image parameters for monitoring water quality [42]. A turbidity sensor has been designed based on the Beer–Lambert law for water quality monitoring in aquaculture ponds [44]. Low-cost environmental sensors have been designed, calibrated, and deployed to ensure their suitability for monitoring the water quality and fish behavior in aquaculture tanks during the feeding process [45]. The availability of environmental and microbial sensors and the deployment of wireless sensor networks could promote on-farm top-dressing practices [46].

Table 1 Details of PCR and RT-PCR primers for studying probiotics competency, biofilm-forming efficiency, Biofloc microbiota, and shrimp diseases

Target specifications	Primer	Primer sequence
Microbiota		
Bacteria	1114-F	CGGCAACGAGCGCAACCC
	1275-R	CCATTGTAGCACGTGTGTAGCC
Methanogens	McrA-F	TTCGGTGGATCDCARAGRGC
	McrA-R	GBARGTCGWAWCCGTAAGTCC
	Probe	ARGCACCKAACAMCATGGACACWGT
Lactobacillus	lacto-F	GAGGCAGCAGTAGGGAATCTTC
	lacto-R	GGCCAGTTACTACCTCTATCTTCTTC
Immune-response and probiotic competency related genes		
F ₁ F ₀ -ATPase β -subunit	MGB-lacto	ATGGAGCAACGCCGC
	atpD-F	GCCAACCTGGTTCGATGTG
	atpD-R	ACCACGTCGTCGATCTTACC
Bile salt hydrolase	bsh-F	ATGGGCGGACTAGGATTACC
	bsh-R	TGCCACTCTGTCTGCATC
Mucin binding protein	mub-F	GTAGTTACTCAGTGACGATCAATG
	mub-R	TAATTGTAAAGGTATAATCGGAGG
Mucus adhesion-promoting protein	mapA-F	TGGATTCTGCTTGAGGTAAG
	mapA-R	GACTAGTAATAACGCGACCG
Glyceraldehyde-3-phosphate dehydrogenase	Gadph-bac-F	ACTGAATTAGTTGCTATCTTAGAC
Nisin biosynthesis protein	nisB-F	GGGAGAGTTGCCGATGTTGT
	nisB-R	TAAAGCCACTCGTTAAAGGGCAAT
18 S rRNA (Shrimp)	18 S ShrRNA-F	GAGACGGCTACCACATCTAAG
	18 S ShrRNA-R	ATACGCTAGTGGAGCTGGA
β -Actin (Shrimp)	LvActin-F	CCACGAGACCACCTACAAC
	LvActin-B	AGCGAGGGCAGTGATTTC
Shrimp disease-coding genes		
White spot syndrome virus	WSSV-F	ATCATGGCTGCTTCACAGAC
	WSSV-R	GGCTGGAGAGGACAAGACAT
Infectious hypodermal and hematopoietic necrosis virus	IHHNV-F	TCCAACACTTAGTCAAACCAA
	IHHNV-R	TGTCTGCTACGATGATTATCCA
Monodon baculovirus	MBV-F	CGATTCCATATCGGCCGAATA
	MBV-R	TTGGCATGCACTCCCTGAGAT
Hepatopancreatic parvovirus	HPV-F	GCATTACAAGAGCCAAGCAG
	HPV-R	ACACTCAGCCTCTACCTTGT
Infectious myonecrosis virus	IMNV-F	CGACGCTGCTAACCATACAA
	IMNV-R	ACTCGGCTGTTGATCAAGT
Yellowhead virus	YHV-F	CCGCTAATTTCAAAACTACG
	YHV-R	AAGGTGTATGTCGAGGAAGT
Taura syndrome virus	TSV-F	AAGTAGACAGCCGCGCTT
	TSV-R	TCAATGAGAGCTTGGTCC
Necrotizing hepatopancreatitis bacterium	NHPB-F	CGTTGGAGGTTCTCCTTCAGT
	NHPB-R	GCCATGAGGACCTGACATCATC
Acute hepatopancreatic necrosis disease	AHPND-F	ATGAGTAACAATATAAAACATGAAAC
	AHPND-R	ACGATTTGACGTTCCCAA
Enterocytozoon hepatopenaei	EHP-F	CAGCAGGCGGAAAATTGTCCA
	EHP-R	AAGAGATATTGTATTGCGCTTGCTG

Table 2 Commercial aquaculture sensors and their specifications

Parameters	YSI Inc.		Xylem Inc.		IN SITU Inc.		ATLAS Scientific	
	Model	Range	Model	Range	Model	Range	Model	Range
Temperature	006560	1–50 °C	4060R	1–40 °C	0063490	1–50 °C	V 1.2	1–99 °C
pH	577602	0–14	6589FR	0–14	0060000	0–14	V4.2	0–14
ORP	006565	±300 mV	SensoLyt®SEA	±2000 mV	0063470	±1400 mV	V 2.2	±2000 mV
Conductivity	599827	0–100 mS/cm	4119ASW	0–75 mS/cm	0063460	0–350 mS/cm	V 3.7	0.07–50 mS/cm
DO	006562	0–50 mg/L	FDO 700 IQ	0–20 mg/L	RDO®Blue	0–60 mg/L	V 4.6	0–100 mg/L
Turbidity	626901	0–4000 FNU	WQ 730	0–1000 FTU	0063480	0–4000 FNU	–	–
Ammonia	626906	0–200 mg/L	Tru Lab 1320	0.02–17,000 mg/L	0033700	0–10,000 mg/L	–	–
Nitrate	608090	0–10 mg/L	YSI MultiLab 4010-2	0.4–62000 mg/L	0033710	0–40,000 mg/L as N	–	–
Chlorophyll	599102-01	0–100 µg/L	YSI 6025	0–400 µg/L	0038900	0–1000 µg/L	–	–
BGA	626210	0–100 RFU	YSI 6031	0–100 RFU	0038930	0–100 RFU	–	–

5 Top-dressing automation technology

Top-dressing agents (probiotics, ammonia-oxidizers, pond optimizers, etc.) can prevent the disease rather than the treatment of the disease and pond water quality until the culture period. Generally, top-dressing agents are very expensive to the production cost and have been applied to aquaculture ponds manually by a simple hand-throwing method. The automatic top-dressing system is a part of the on-farm management system in addition to automating feeding technology. It can automatically disperse top-dressing agents to the shrimp ponds based on the signals received from environmental and microbial sensors. It can automatically operate a solenoid valve to dispense the probiotics and pond optimizers from separate top-dressing tanks for managing pond water quality and making a favorable environment for healthier shrimp growth. It also operates an aerator to dispense air in the pond based on the concentration of dissolved oxygen.

6 Experimental biofloc system

The total volume of the proposed Biofloc pond is 12,000 L (4 m in diameter and 1.25 m in height) and the working volume is 10,000 L (Figs. 1 and 2). Each pond is made up of tarpaulin material and covered with iron mesh. The aquaculture automation system is based on zero-waste water technology because the water supply is equivalent to discharged water. A pressure pump provides a 100 L water supply from the water sump to an experimental pond at a specific time. At the same time, the sludge pump discharges 100 L of excretory and feed waste products from the pond to 500 L anaerobic digester where those wastes are utilized as feedstock for biogas production. The digester effluent is drained off to the experimental garden for the cultivation of nursery plants. The total volume of the top-dressing tank (plastic) is 50 L and the working volume is 35 L (Fig. 3). It consists of an iron impeller that shaft is connected with an electric gear motor for stirring the top-dressing contents before dispersing to the pond. The outlet of this tank is connected with a solenoid valve for dispensing top-dressing agents. The iron lid of this tank has a provision of an inlet and outlet for filling the top-dressing agents.

7 On-line measurement of water quality

We should follow standard operation procedures for sustainable and eco-friendly Biofloc-based shrimp culture. All the physicochemical parameters should be maintained at an optimal level for better production of shrimp. The aquaculture automation system can continuously monitor the pond water quality in the Biofloc system during the culture period (Fig. 4). It can receive signals from sensors for temperature, pH, conductivity, dissolved oxygen, oxidation-reduction

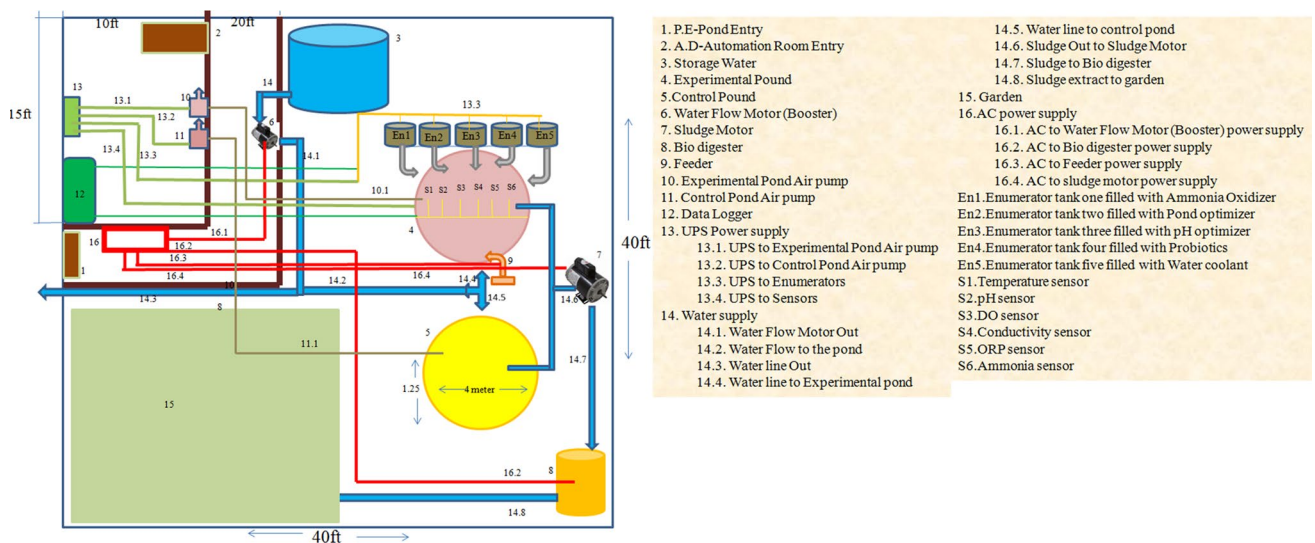


Fig. 1 Schematic representation of aquaculture automation designing for Biofloc production of shrimp

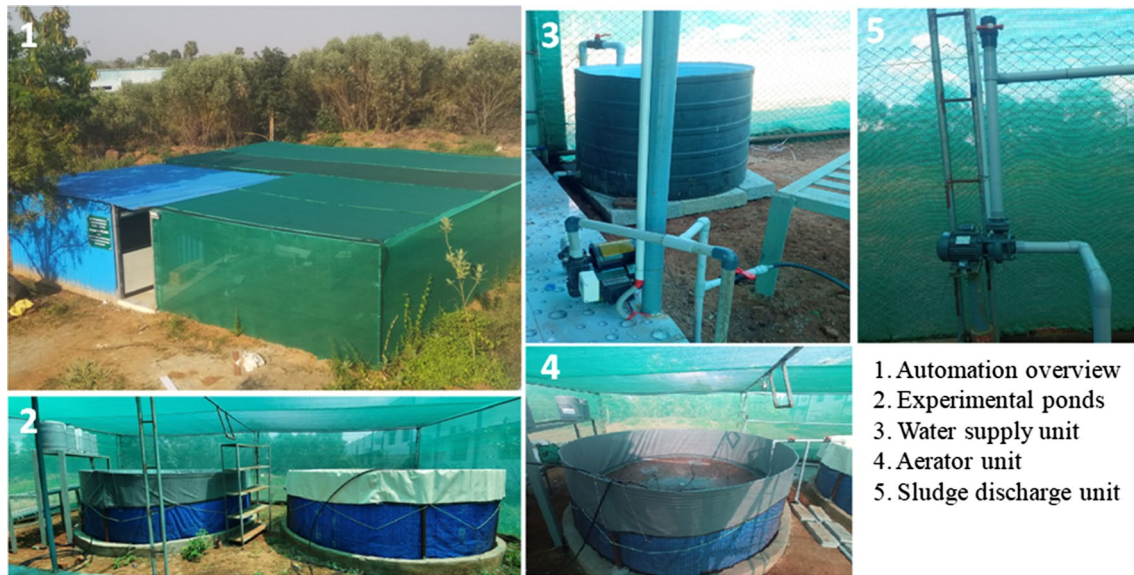


Fig. 2 depicts the overview of experimental aquaculture automation system for Biofloc production of shrimp (Place: Bharathidasan University, Tiruchirappalli, India)



Fig. 3 Top-dressing system with stirring and dispersion units to be used in an aquaculture automation system for Biofloc production of shrimp

potential, and ammonia. Therefore, the relevant online monitoring sensors should be integrated with a controller to execute aquaculture automation systems in the Biofloc shrimp culture [13–16].

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8 Environmental sensors

Temperature is one of the most influential parameters in the pond system, which affects the metabolic rate of a living system, dissolved oxygen, and ammonia during the culture period. The optimum temperature is 28–30 °C for sustainable shrimp aquaculture [47]. The pH is to be maintained in the range between 6.8 and 8.0 due to ammonia–nitrate–nitrogen conversion processes in Biofloc [48]. Probiotic bacteria depend on suspended solids as a substrate for adhesion and as a source of energy from carbon in Biofloc systems [49]. To ensure efficient bacterial activity and a good system to control ammonia, total suspended solids should be maintained in the range of 250–450 ppm and organic load to be 5–15 mg L⁻¹ [50]. Dissolve oxygen should be maintained at 7–8 ppm to ensure the proper functioning of the system due to the

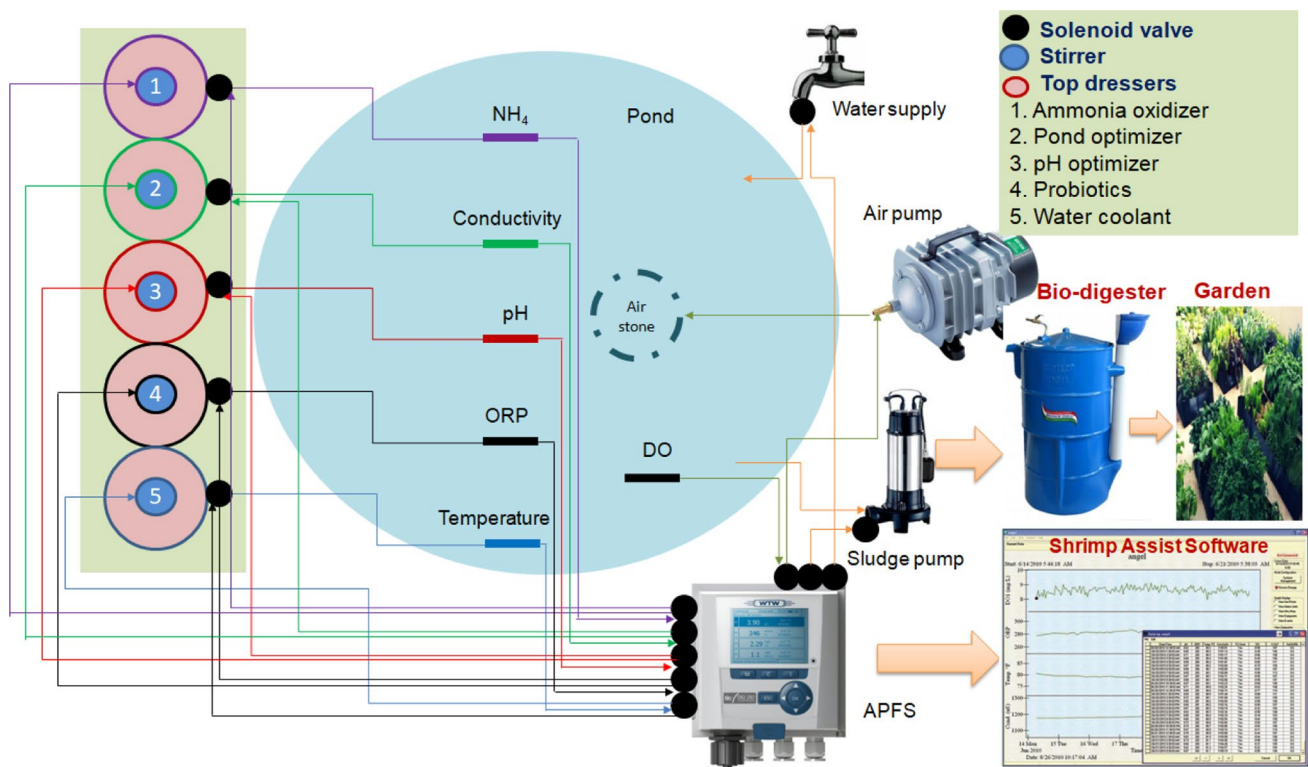


Fig. 4 The proposed model for a top-dressing automation system for Biofloc production of shrimp

oxygen demand of algae and bacteria in the Biofloc system [51]. Oxidation-Reduction Potential (ORP) sensors measure the oxidizing or reducing tendency of pond water and its optimal value to be 650–700 mV. In the optimal Biofloc production of shrimp, it should be maintained for aerobic bacteria (300–800 mV), facultative anaerobes (300 to – 100 mV), and anaerobic bacteria (– 700 to 200 mV) [52–54]. A conductivity sensor monitors the ability of a solution to conduct an electrical current. Conductivity is directly proportional to the concentrations of metal ions in the pond and therefore, it should be maintained as 2.7 dS m⁻¹ in the Biofloc system [55, 56].

The adjustment of the C:N ratio is the important factor for microbial growth in the Biofloc system. The optimum C:N ratio in an aquaculture system is 12–20:1. It has been adjusted by adding carbon sources and/or reducing protein percentage in feed [57]. Ammonium is a potential biomarker of an enzymatic by-product in the key physiological reactions of shrimp and microorganisms. It is considered to be a quality indicator of the Biofloc system. The recommended ammonia concentration in Biofloc culture is less than 1.2 and 6.5 ppm. The concentration of nitrite and nitrate should be in the range of 1 mg L⁻¹ and the range of 0.5–20 mg L⁻¹, respectively [58–62]. Hence, an ammonium sensor is suggested for the measurement of ammonium ions using an aquaculture automation system. It automatically disperses the ammonia-oxidizing bacteria or ammonia-oxidizing chemicals to the bottom of ponds based on ammonia and nitrite levels monitored by a combined ammonia and nitrite sensor.

9 Microbial sensors

Multi-strain probiotic bacteria are commercially procured and formulated in a top-dressing tank containing formulated microbiological media supplements and pond water [63]. Bacterial culture is occasionally stirred by an electric impeller and cultured for 36–48 h at ambient temperature in a semi-continuous mode. Enriched probiotic culture is pumped to the ponds based on the signal receiving from the organic load/bacterial sensor through an automation controller. A top-dressing tank consisting of enriched ammonia-oxidizing archaea/bacteria is formulated in a defined ratio and diluted with pond water containing media ingredients [64–66]. Ammonia-oxidizing cultures are enumerated for 120 h at ambient temperature in a semi-continuous mode and then applied to the pond based on a signal received from the ammonia sensor.

10 Automatic controlling system

An autonomous precision farming system is a control unit with the required customization at the hardware and firmware level for automation of top-dressing units in experimental ponds (Fig. 4). It is a user-friendly device that helps the farmers to plan and control the field activities. It monitors different parameters and informs the farmer through a graphical display unit. It also intelligently operates pumps/valves based on the data available from the field and the preloaded programs available in the automation system. The programs can be fed to the controller through the external memory interface. Auto, Manual, and Timer modes are in the controller system. The system integrates all feed-related information, such as the concentration of probiotics and pond optimizers, time of dispersal, and the interval between rations. These operations are automatically determined by the automation system on analyzing the sensor signals from the pond environment. All major units are designed farmer-friendly and assembled with technical experts. The field signals are the aquaculture sensors output that senses the various field parameters. As per the sensed signal thresholds, the autonomous precision farming system executes the control algorithm and generates the corresponding control signals to the field instruments.

11 Sustainability in shrimp aquaculture

The proposed aquaculture technology is a sensor-based automation system that has options to set the frequency and quantity of multi-strain probiotics, pond optimizers, and continuous aeration. It can improve shrimp production and profits, and minimize environmental pollution from shrimp farming. It is also reliable to dispense more viable probiotics to the shrimp gut in the ponds because the commercial probiotics formulation is not ideally viable in the pond environment. It automatically dispenses the top-dressing agents from a radial sample range to allow effective coverage of the “feeding zone” in shrimp farms. It drives productivity by reducing the usage of top-dressing agents, increasing growth, minimizing environmental outputs, maximizing profits with minimal labor, and improving the consistency of size and flesh characteristics at harvest. It should be easy to maintain, long life in small-scale farms, and eliminate feed wastes by minimizing bacterial and organic load in the ponds. Nevertheless, continuous electricity and a relatively high level of technical expertise requirements would be costly to install and operate making them unsuitable for small-scale shrimp farmers.

12 Socio-economic development

Global trends in antimicrobial use, antibiotics resistance, and health of shrimp gut microbiome and emerging diseases are major constraints in the shrimp industry today [67–69]. Moreover, the transfer of complex technical messages is problematic and requires continuous attention and extension as most farmers have relatively limited education [3]. Farmers must be adequately trained on new aquaculture technologies relevant to operations and on-farm top-dressing practices. Technical support should provide to the primary aquaculture societies and build capacity among small-scale farmers to reduce risks and to produce quality shrimp sustainably. The government should urge the researchers to partner in publicly funded research with the commercial probiotics manufacturing sector and aquaculture device manufacturing companies. Aquaculture engineering companies, agriculture, and state cooperative banks should provide financial support or subsidiary to implement that technology in the small-scale shrimp farmers. Aquaculture engineering intervention could be used to promote the development of better top-dressing technologies and allow research results to be more effectively transferred to farmers to improve feed utilization indices and reduce top-dressing costs [70].

13 Conclusions

Top-dressing agents are used for the prevention and control of shrimp diseases and to improve growth yield in Biofloc systems. The cost of probiotics and pond optimizers is restricting the financial and environmental viability of shrimp aquaculture farming. Traditional methods could not help small-scale farmers to achieve sustainable aquaculture in India. Consequently, this perspective highlights the importance of a sensor-based top-dressing automation system for on-farm

aquaculture management in India. The farmer-friendly controller automatically dispenses the top-dressing agents to ponds based on the signals received from each sensor. It gains a great interest in sustainable commercial aquaculture in a long period without any demand for major units. It will be a new aquaculture technology to reduce labor and production costs in Biofloc systems. Continuous monitoring of pond water parameters and microbial activity will reduce the labor and production costs for shrimp farming. Sustainable utilization of automatic aquaculture systems can thus lead to enormous social and economic benefits to the coastal regions of the country. The development of sustainable shrimp culture is possible only with some form of government intervention such as more efficient and environmentally friendly practices and awarding operating licenses. This sensor-based top-dressing automation technology will increase our scientific knowledge to achieving Goal-14 of the 2030 agenda for the development of sustainable aquaculture. Consequently, it will cut the cost of production, enhance the conservation and sustainable use of brackish water, and increase the economic benefits of developing countries in the future.

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Authors' contributions PC: Write, analyze and evaluate data of the manuscript. The author read and approved the final manuscript.

Declarations

Competing interests The authors declare no competing interests.

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