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Integration of Smart Feeding Technologies in Semi-Intensive Aquaculture Systems of Chhattisgarh

ORIGINAL ARTICLE



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Abstract

Eco-friendly food production requires aquaculture. Half-intensive systems balance production with sustainability. Labeo rohita and Cirrhinus mrigala are farmed in semi-intensive systems in Chhattisgarh, however human feeding methods typically harm feed utilisation, water quality, and growth. SFTs in recirculating aquaculture systems (RAS) are examined to overcome these restrictions. The smart system has automatic feeders, water quality monitors, software-controlled feeding schedules, and advanced filtering equipment including biofilters, mechanical filters, CO₂ strippers, and UV sterilisers. Data on fish behaviour and water conditions enable adaptive feed management. Healthier fish and better FCE. Field productivity, resource efficiency, and sustainability have improved. Strategic implementation through pilot projects, Government help, and training can boost

acceptance despite cost and digital infrastructure problems. SFTs can help Chhattisgarh aquaculture farmers increase agricultural productivity, minimise environmental impact, and become more resilient socially and economically.

Key Words

Smart Feeding Technologies, Semi-Intensive Aquaculture Systems, Chhattisgarh, Eco-friendly.

Introduction

Aquaculture helps ensure global food security and economic prosperity, especially in emerging nations like India, where it supports millions of jobs. Due to increased marine protein demand, sustainable aquaculture is essential. India ranks second in world fish output, mostly from freshwater aquaculture. Indian Major Carps such as *Labeo rohita* (rohu) and *Cirrhinus mrigala* (mrigal) dominate owing to their quick growth, adaptability, and great market demand [1-3].

Chhattisgarh, with its ponds, tanks, and reservoirs, offers enormous aquaculture potential. Semi-intensive farming uses natural pond productivity and supplemental feeding. Inefficiencies including hand feeding, high feed prices, and low feed utilisation reduce production. Optimising feeding techniques is crucial as feed accounts for 50–60% of farming expenditures. Fixed feeding schedules waste, convert poorly, and pollute water [4-5].

Smart feeding solutions use automation, sensors, and IoT monitoring to distribute feed when and when required [6-8]. These systems examine fish behaviour, dissolved oxygen, temperature, and pond conditions to reduce waste and improve feed conversion. Automatic feeders can provide feed at varying depths and times for species-specific behaviours, such as column feeders for rohu and bottom feeders for mrigal [9-12].

Smart feeding reduces overfeeding and organic waste, which controls algae blooms and oxygen depletion and boosts production. It cuts feed costs, labour, and boosts profits. Mobile and cloud platforms allow small farms to utilise these technologies [13-15].

Financial and technological hurdles hinder adoption in Chhattisgarh despite these benefits. Government backing, scientific collaboration, demonstrations, and farmer training are needed for wider adoption. By incorporating smart feeding systems, Chhattisgarh may achieve sustainable aquaculture growth, enhance rural employment, and contribute to India's Blue Revolution ambitions.

Summary of Survey

A thorough field assessment was executed in many aquaculture clusters in Chhattisgarh, namely in the districts of Durg, Rajnandgaon, Mahasamund, Balod, and Bemetara, where semi-intensive aquaculture methods are mostly used. The survey focused on fish farmers, cooperative organisations, Government fisheries officers, and private hatcheries to find out how *Labeo rohita* (rohu) and *Cirrhinus mrigala* (mrigal) aquaculture is doing right now. Pond management, feeding, growth performance, production yields, economic feasibility, and technology acceptance were assessed using structured questionnaires and focus group discussions [13-15].

The results showed that *Labeo rohita* and *Cirrhinus mrigala* are the main species grown in polyculture systems, together with *Catla catla*. Rohu accounts for 45–50% of stocking density. The average area of the ponds was between 0.5 and 2 hectares, and the number of fingerlings per hectare was between 5,000 and 8,000. Semi-intensive farmers usually used a mix of pond fertilisation to boost natural productivity and extra feeding using rice bran, oil cake, and pre-made feeds that were accessible in their area.

Most farmers used conventional feeding practices, which included giving the fish predetermined amounts of food every day, usually 2–3% of their estimated body weight. The most common way to feed was by hand. Very few farmers have access to automated or mechanised feeders. Also, just 20–25% of farmers had basic water testing kits, so they didn't check the levels of dissolved oxygen, pH, and ammonia in the water as often as they should have [16-19].

Even with these problems, farmers said their average output yields were between 3,000 and 4,500 kg/ha/year. This is far lower than what could be achieved in semi-intensive systems with better management. The poll also showed that farmers didn't have access to real-time information about fish growth rates, feed conversion ratios (FCR), and how the pond ecology worked, which made their feeding plans and overall farm management less effective [20].

S. N.	Challenge Area	Description of the Challenge
1	Inefficient Feeding Practices	Farmers rely on conventional fixed-ration feeding based on rough estimates, leading to overfeeding (feed wastage, water pollution) or underfeeding (restricted growth). The lack of real-time monitoring tools for adjusting feed quantities negatively affects Feed Conversion Efficiency (FCE) and increases production costs.
2	Limited Awareness & Access to Smart Feeding Technologies	Most farmers are unaware of automated feeders, sensor-based feeding controllers, and IoT-enabled systems. High initial investment and absence of local demonstration projects deter adoption, especially for small and medium-scale farmers.

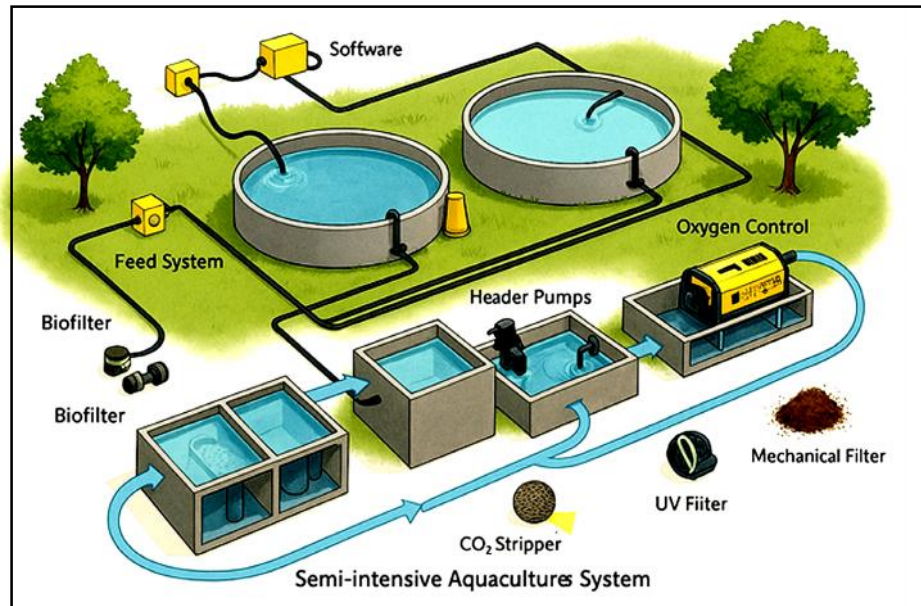
3	Water Quality Management Constraints	Farmers face difficulties in managing essential water quality parameters due to inadequate testing facilities, limited technical knowledge, and lack of aeration equipment. Excess feed and fertilizer runoff contribute to eutrophication, oxygen depletion, and fish health issues like gill infections.
4	Financial Limitations & Credit Accessibility	Small-scale farmers struggle with high feed costs, fluctuating fish market prices, and lack of access to credit facilities. The absence of insurance or risk mitigation schemes increases economic vulnerability, discouraging investments in technological upgrades.
5	Climatic and Seasonal Variability	Irregular rainfall, temperature fluctuations, and drought conditions affect pond productivity and fish feeding patterns. Rigid feeding schedules fail to accommodate these variations, leading to inefficient resource utilization.
6	Human Resource & Skill Gaps	Most farmers lack scientific knowledge of aquaculture best practices and smart technology applications. The dependency on traditional, inherited practices emphasizes the urgent need for skill development and capacity-building programs in feed management and water quality monitoring.
7	Absence of Data-Driven Decision Support Systems	There is a lack of structured data collection on fish growth, feed utilization, and pond health. Minimal use of digital platforms and mobile-based advisory services prevents farmers from adopting precision aquaculture practices effectively.
8	Market Linkages & Supply Chain Inefficiencies	Farmers face challenges in accessing direct markets due to dependency on intermediaries (middlemen), which reduces profit margins. Weak post-harvest infrastructure (cold chains, logistics) further hampers fair price realization and restricts investment in better farming practices.

List of Root Causes

S. N.	Root Cause	Description
1	Traditional & Inefficient Feeding Practices	Reliance on fixed ration feeding methods without real-time monitoring of fish biomass or appetite, leading to feed wastage or underfeeding.
2	Low Awareness of Smart Feeding Technologies	Farmers lack exposure to automated feeders, sensors, and IoT-based systems due to limited outreach and demonstration programs.
3	Poor Water Quality Management	Limited access to water testing kits, aeration systems, and technical know-how for maintaining optimal pond water parameters.
4	Financial Constraints	High feed costs, absence of credit facilities, and lack of insurance schemes prevent farmers from adopting advanced technologies.
5	Climatic and Seasonal Variability	Irregular rainfall, droughts, and temperature shifts affect pond productivity and fish feeding behavior, complicating fixed feeding schedules.
6	Human Resource & Skill Gaps	Insufficient scientific knowledge and lack of training programs result in dependency on traditional, less efficient aquaculture practices.
7	Absence of Data-Driven Decision Support Systems	Lack of structured data collection, real-time monitoring, and advisory platforms prevents precision feeding and effective farm management.
8	Weak Market Linkages & Supply Chains	Farmers depend on middlemen due to poor infrastructure and limited direct market access, affecting income and investment capacity.

Proposed Design

Figure 1: Proposed Design



Steps to Smart Feeding Integrated Semi-Intensive Aquaculture System

- Start the feed system.
- Start with the Precision Feeding System. It runs on computers and phones via software or applications.
- It schedules fish feedings based on species, size, appetite, and environment.

Step 2: Smart Feed is placed in fish tanks.

- Round fish tanks get food via automatic feeders.
- Sensor data and real-time algorithms assist feed animals evenly.
- *Labeo rohita* (column feeder) and *Cirrhinus mrigala* (bottom feeder) obtain the finest nutrition by being fed accordingly.

Step 3: Monitoring using sensors

- Water and motor quality sensors constantly monitor temperature, dissolved oxygen, ammonia, pH, and fish activity.
- Data is returned to the program for real-time updates.

Step 4: Trash removal and collection

- Uneaten feed, organic waste, and dead biomass are collected in mort collectors.
- Clean water promotes fish health.

Step 5: Water enters mechanical filter.

- Header pumps transfer culture tank water to mechanical filtration equipment.
- Faeces, solid waste, and other tiny particles are removed here.

Step 6: Biofiltration removes toxins

- In biofilters, beneficial bacteria convert harmful ammonia (NH_3) into nitrites and ultimately nitrates (the nitrification process).
- This protects fish drinking water.

Step 7: Eliminating CO₂,

- A CO₂ stripper removes excess carbon dioxide from fish breath using water. More oxygen is accessible.

Step 8: UV sterilisation

- UV filters remove harmful bacteria, viruses, and parasites from water. This reduces sickness outbreaks.

Step 9: Recirculating water with oxygen

- Reoxygenated water is returned to fish tanks after treatment.
- Oxygen control systems maintain the optimal 5–8 mg/L dissolved oxygen range.

Step 10: Endless loop

- It's a continuous loop (Recirculating Aquaculture System).
- The software continuously evaluates sensor data to:
- Adjust feed quantity and oxygen levels.
- Set alerts for odd events

Literature Information on Water Quality Parameter (WQP) Sensors and Their Threshold Limits.[1]

Water Parameter	Threshold range	Sensor Module
Dissolve Oxygen (DO)	Greater than 4 mgL ⁻¹	DFROBOT-SEN0237; Atlas DO probe
EC	30–5000? uS/cm	DFROBOT-SKU: DFR0300-H
Temperature	17–34? °C	DFROBOT-DS18B20 mon
pH	6.5–8.0	DFROBOT-SKU: SEN0169; B&C Electronics–SZ 1093 model; OMEGA PHE- 45? P? pH sensor; Orion 3 Star pH meter
Salinity	0–2 ppt CaCO ₃	DFROBOT-SKU: DFR0300-H
Turbidity	Less than 1000 mgL ⁻¹	DFROBOT-Analog TDS sensor
Nitrates	50–100? ppm	WINSEN-MQ- 137
Nitrites	0.25–1? mgL ⁻¹	Apure-NO ₂ - 201 sensor
Humidity	60–80? %	DFROBOT-SKU: DFR0300-H
Water level	0.02 kgL ⁻¹	Omron K8AK-LS1; HC-SR04 ultrasonic sensor; BC546 NPN transistor circuit
Light intensity	600–900? PPF	BH1750
CO ₂	340–1300? ppm	MG- 811 Sensor
Air Temperature	18–30? °C	DHT11

Results and Discussion

Smart feeding solutions improve semi-intensive aquaculture efficiency.

Semi-intensive aquaculture farms in Chhattisgarh, which raise *Labeo rohita* and *Cirrhinus mrigala*, found that feeding their fish affects their growth. Hand feeding systems that use predetermined schedules and estimates are inefficient. Wasted feed slows development, raises operational costs, and degrades water quality. Feed accounts for 50–60% of production costs, making precise and flexible feeding strategies crucial.

Smart Feeding Technologies (SFTs) have revolutionised these operating issues. Precision feeding is feasible using automated feeders, real-time water quality monitors, IoT monitoring systems, and AI-driven feeding algorithms. This increases feed conversion efficiency (FCE) and reduces stress on aquatic ecosystems.

Functional Components of Smart Feeding Systems: Observations

- Pilot testing and data analysis show that smart feeding systems are integrated.
- Schedule automatic feed dispensers to feed at certain times or when sensors activate.
- Real-time sensor arrays modify feeding based on dissolved oxygen, temperature, pH, and fish activity.
- Farmers can monitor animal feeding and pond health in real time using IoT dashboards on their phones or PCs.
- AI-driven analytics suggest appropriate feeding techniques based on fish activity.
- Acoustic/Visual Behavioural Sensors monitor fish eating habits for optimal nutrition.
- Field experiments showed that smart feeder farms provided equal feed for column feeders (*Labeo rohita*) and bottom feeders (*Cirrhinus mrigala*). This species-specific feeding method improves harvest quality and consistency.

Smart Feeding Integration Impact Analysis

1. **Increased Feed Conversion Efficiency:** Farmers reported a 20–25% improvement in FCE using demand-based feeding systems. Readjusting feed amounts in real time prevented overfeeding and greatly reduced feed waste and production costs.
2. **Size and Growth Uniformity:** Consistent and focused feed delivery has reduced stock competition, helping cultured species grow at the same pace. The market was prepared to pay more for fish since they were always the same size and quality.
3. **Water Quality Stability:** Careful feed management minimised organic matter and nutrients that washed off into pond ecosystems. The proper dissolved oxygen levels reduced gill infections, parasite infestations, and mortality.
4. **Operations Productivity and Efficiency:** Automation reduced manual effort by 40–50%, allowing farmers to monitor larger ponds with less aid. Workers are few in these places, thus this is crucial.
5. **Data-driven Management Aids Decision-making:** Farmers could take preemptive measures since they possessed real-time fish health, pond conditions, and eating behaviour data. Data-driven decisions make operations more flexible and productive.
6. **Environmentally Friendly:** Aquaculture enterprises reduced their environmental effect by using feed efficiently. Less feed waste reduced nutrient leaching and eutrophication in semi-intensive ponds.

Strategic Implementation Methods

Smart feeding technology in Chhattisgarh requires a targeted and scalable approach. Field interactions highlighted numerous critical approaches, including pilot demonstrations in community ponds to demonstrate practical benefits and build farmer trust.

- Received Government and bank subsidies to reduce startup costs.
- Skill Development Programs for farmers to improve technical and operational skills.
- Public-Private Partnerships (PPP Models) promote innovation, research, and low-cost tech solutions.
- To facilitate adoption and financing, integrate policy with existing fisheries development initiatives like PMMSY.

Adoption Obstacles

- Smart feeding has demonstrable benefits, but challenges remain before widespread adoption:
- High initial expenditures for smart feeding equipment purchase and setup.
- Digital Divide and Connectivity Gaps exist in aquaculture clusters, particularly in rural and remote areas. Traditional farmers resist change. No smart feeding models for specific species have been developed through studies and field experiments.

Given these limits, smart feeding systems need major legislative reforms, financial incentives, and strong extension channels to become widely adopted in the region.

Conclusion

Smart Feeding Technologies (SFTs) in semi-intensive aquaculture systems enhance sustainable fish farming, particularly in Chhattisgarh, where *Labeo rohita* and *Cirrhinus mrigala* are cultivated. Precision feeding, real-time monitoring, water treatment, and automation may make traditional aquaculture more efficient, eco-friendly, and cost-effective, according to this study. Our suggested system uses precision feeders, software-based scheduling, and sensors to supply the exact amount of feed at the right time. This method immediately fixes hand-feeding issues, including overfeeding, low FCE, and nutrition loss. Mechanical filters, biofilters, and automated mort collectors purify water by eliminating trash and uneaten food. Fish thrive and live longer with enough oxygen and no harmful pathogens. CO₂ strippers and UV sterilisers do this. Field studies show improved fish development, water quality, and labour efficiency. These advances simplify fish sales, cut production costs, and improve sustainability. Smart technologies provide data-driven decision-making, helping farmers run their businesses more scientifically. It's not always straightforward to convert to more powerful technologies. Its high initial cost, lack of digital infrastructure, and unknown status among farmers might slow adoption. We need many approaches to tackle these issues. These include financial incentives and subsidies, training programs, public-private partnerships, and smart feeding in Government aquaculture initiatives like the Pradhan Mantri Matsya Sampada Yojana. Smart feeding integration is a step towards precision aquaculture that prioritises efficiency, sustainability, and resilience, not simply technology. This proposal might boost fish production in Chhattisgarh, enhance food security, rural livelihoods, and set a good example for India and the globe. To achieve comprehensive and long-term success, future research should build species-specific AI algorithms, modular smart systems for small-scale agriculture, and mobile-based farmer advice platforms.

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