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Impact Assessment of Floating and Alternative Feeds (*Wolffia globosa*) for Fish Rearing Technologies in Tripura, India

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HIGHLIGHTS

- Floating feed and Wolffia-based technologies improved aquaculture's social, economic, and environmental outcomes.
- Floating feed increased fish production, efficiency, and livelihoods but faced high costs and supplier dependence.
- Wolffia-based feed offered a sustainable alternative, enhancing profitability, efficiency, and household welfare.
- Major constraints included high feed costs for floating feed and flood-induced feed loss for Wolffia technology.

ARTICLE INFO

Keywords: Aquaculture, Alternative feed, Floating feed, Impact assessment, Duckweed.

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ABSTRACT

The study assessed the social, economic, and environmental impacts of floating feed– and Wolffia-based fish rearing technologies disseminated by the College of Fisheries, CAU (Imphal), Lembucherra, Tripura. An after-only design was employed with 140 respondents: 100 floating feed adopters chosen through simple random sampling and 40 Wolffia adopters through complete enumeration. Impact indicators across social, economic, and environmental domains were developed using Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) criteria, expert-validated, and analysed with the Wilcoxon Signed-Rank Test, paired t-tests, and Spearman's correlation. Floating feed adoption improved production (+16.75 kg cycle^{-1}), net returns (+Rs. 6,644.26), and feed efficiency [Apparent feed conversion ratio (AFCR) –0.23], raising the Economic Impact Score from 32.93 to 40.23 (p = 0.000). Social participation, awareness, and income increased, while the Environmental Impact Score fell from 23.996 to 19.146, reflecting improved water quality. Wolffia adoption also enhanced production (+18.48 kg cycle^{-1}), returns (+Rs. 4,804.35), and AFCR (–0.25), contributing to livelihoods, nutrition, and climate-resilient aquaculture. Major constraints included high floating feed price, supplier dependence, flood-induced losses, and weak extension support. Overall, both technologies boosted aquaculture productivity, profitability, and sustainability, highlighting the need for technical services, training, and institutional support.

INTRODUCTION

India, like many developing countries, faces challenges of food insecurity, unemployment, migration, and malnutrition, exacerbated by population growth (Noor et al., 2018). Like many regions of India, fisheries contribute to Tripura's economy by ensuring income, employment, and nutritional security significantly (Das, 2012). The state records the fastest growth in fish production among the Northeastern states (Debnath, 2011). In 2010, culture fisheries accounted for 97.01% of total production (DoF, 2011). Presently,

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38,594.69 hectare (ha) of water are available, of which 30,715.93 ha are under culture fisheries and 7,878.76 ha under capture fisheries. Pisciculture occupies 29,390.62 ha, including seed production (DES, Govt. of Tripura, 2024). In 2009–10, production was 37,000 tonnes (t) against demand of 41,000 t (DoF, 2011), while recent figures report 85,805.68 t with per capita consumption of 27.73 kg in 2023–24 (DES, Govt. of Tripura, 2024). Despite progress, imports from West Bengal, Andhra Pradesh, and Bangladesh continue.

Aquaculture is crucial for both economic contribution and human nutrition (Sajeev et al., 2023). Feed approaches such as floating feed and Wolffia-based feed play a vital role in enhancing production and profitability. Floating feed reduces wastage and improves water quality (Abdelhamid et al., 2019). Wolffia, with 30–40% protein and rapid growth, offers a low-cost, sustainable feed source. It enhances the growth of species such as *Labeo rohita*, improves water quality by recycling nutrients, and reduces the risk of eutrophication (Nath et al., 2021; Said et al., 2022).

The College of Fisheries, CAU (Imphal), Lembucherra, has promoted these technologies to meet rising demand. Floating feed was standardised using rice bran, mustard oil cake, corn, wheat, and fish meal to ensure floatability, nutrition, and cost efficiency. Adoption has extended to ICAR, the Department of Fisheries, Tripura, KVKs, and institutions in Assam, Arunachal Pradesh, and Mizoram. Production requires feed mills, ingredients, labour, and electricity (Saha et al., 2020). Floating feed is applied in fertilised ponds or tanks at an apparent feed conversion ratio (AFCR) of 1.8–2.2, with a six-month culture period and stocking density of 15,000 ha^{-1}. Feeding is adjusted from 3-4% of biomass twice daily, reducing to 0.5–1.0% in cloudy weather and winter (Das et al., 2016). The College also developed Wolffia-based fry rearing for Rohu (*Labeo rohita*) fingerlings in 2020 and disseminated it from 2020 to 2023. Live Wolffia (*W. globosa*), rich in protein, low in fibre, and highly digestible, addresses both feed cost and water quality challenges (Seephua et al., 2025). Experimental trials showed higher survival, growth, and fingerling quality in Rohu fry fed with Wolffia compared with artificial feed (Yadav et al., 2025).

Impact assessment of floating and Wolffia-based feeds is essential to evaluate their effectiveness, efficiency, and sustainability. These technologies enhance growth, survival, productivity, and profitability while minimising feed wastage and mitigating environmental stress. Assessment also considers scalability, economic viability, and farmer adaptability, supporting broader dissemination (Das et al., 2014).

Against this backdrop, this study aims to assess the social, economic, and environmental impacts of floating feed and Wolffia-based fish rearing technologies disseminated by the College of Fisheries, CAU (Imphal), Lembucherra, Tripura and to understand the related challenges to farming communities in continuing to use the technologies.

METHODOLOGY

The study was conducted in Tripura during 2024–2025. Tripura, located in the north eastern region of India, covers a territorial area of 10,492 km² between 22°56'–24°32' N latitudes and 90°09'–92°10' E longitudes. Floating feed and Wolffia-based fish rearing technologies have been disseminated by the College of Fisheries, CAU (Imphal), Lembucherra, in different districts of Tripura. For the study, districts were selected based on farmer adoption of these technologies, with the highest adoption recorded in West Tripura, followed by Sepahijala, North Tripura, Dhalai, and South Tripura (DoF, 2023). In total, 238 farmers were identified as adopters of floating feed-based technology and 40 as Wolffia adopters. Wolffia-based technology adoption was found to be lower because a farmer needs an extra pond to produce Wolffia for harvesting Wolffia on a continuous basis. Most of the fish farmers in the region are smallholders possessing a single pond of a smaller size. They cannot afford the water area to produce Wolffia continuously, which reduces the adoption of Wolffia-based fish rearing technology by the fish farmers in the region. Owing to their small number, all Wolffia farmers were included through complete enumeration, while 100 floating feed farmers were selected using simple random sampling from 238 identified farmers. Thus, the final sample comprised 140 respondents.

An *ex-post facto* research design was used, as the technologies were already adopted by farmers. Specifically, an after-only design was applied, which relies on post-adoption data to assess effects without prior manipulation (Reed et al., 2021). Impact indicators covering social, economic, and environmental domains (Garlock et al., 2024) were developed using the Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) criteria (Doran, 1981). Preliminary focused group discussions (FGDs) generated indicators, which were validated through expert consultation using a Google Forms survey. Thirty-two experts, including scientists, extension personnel, and officials, rated indicators on a five-point Likert scale (1 = not relevant to 5 = highly relevant). Qualitative feedback helped refine, merge, or drop indicators, ensuring contextual relevance. From the literature review and field consultations, 139 indicators were initially identified. Experts rated them on a five-point Likert scale, while qualitative feedback helped refine, merge, or remove items. Items were computed, and items scoring less than 3.5 of the weighted mean score were eliminated. The final set comprised 81 indicators: for floating feed, 16 social, 16 economic, and 10 environmental; for Wolffia feed, 14 social, 14 economic, and 10 environmental. These validated indicators provided a reliable framework for a comprehensive assessment of the technologies' social, economic, and environmental impacts. The impact assessment was done in an After-only design with perceived responses of the farmers before and after adoption of the technology on a five-point Likert scale (1 = very low to 5 = very high) on the combinations of positive and negative selected and validated indicators for floating and Wolffia-based technologies as mentioned above.

The Wilcoxon Signed-Rank Test was applied to ordinal data to capture perceptual changes in social and environmental impacts, while the paired t-test assessed parametric economic variables, including feed cost, production, returns, and feed conversion ratio. Constraints were grouped into technological, economic, social, and extension domains, rated on a five-point severity scale (Most severe = 5 to Least severe = 1). These were ranked using weighted mean scores, and their relationships with impact scores were analysed through Spearman's rank correlation coefficient.

RESULTS

Impact of floating feed-based fish rearing technology

Table 1 shows that the Wilcoxon Signed-Rank Test, to evaluate the impact of floating feed-based fish rearing technology. The technology had a significant positive social impact ($p < .001$), enhancing participation, awareness, income, consumption, and education, while improving efficiency through reduced labour requirements. Gains were also noted in knowledge, training, extension access, and social status. Economically, despite higher perceived market risks from feed costs, the impact score rose from 26.54 to 39.39, reflecting improved livelihoods and sustainability. Production, returns, fish weight, feed handling, and efficiency increased, while wastage, mortality, and market distance declined. Overall, the Economic Impact Score improved from 2.93 to 40.23 ($p < .001$), confirming significant benefits. The Environmental Impact Score decreased from 23.996 to 19.146 ($p < .001$), indicating better pond conditions. Improvements included higher water clarity and dissolved oxygen, alongside reduced algal blooms, odour, disease incidence, leftover feed, sediment buildup, and wastage. Soil texture, however, showed no change.

Table 1. Social, economic and environmental Impact of floating feed-based fish rearing technology

Parameters	Before	After	p-value	Impact
Social Impact				
Farmer group participation	1.43	2.43	0.000	+ve
Labour need	2.43	1.43	0.000	+ve
Household income	1.43	2.43	0.000	+ve
Prophylaxis use	1.00	1.43	0.000	+ve
Fish consumption	2.43	3.43	0.000	+ve
Training effectiveness	1.43	2.43	0.000	+ve
Aquaculture dependence	1.43	2.43	0.000	+ve
Education investment	1.43	2.43	0.000	+ve
Peer knowledge-sharing	1.43	2.43	0.000	+ve
Market risk	2.43	3.43	0.000	-ve
Social status	1.43	2.43	0.000	+ve
Ease of use satisfaction	2.43	3.43	0.000	+ve
Knowledge on feed management	1.43	2.43	0.000	+ve
Extension access	2.00	3.43	0.000	+ve
Farm sustainability perception	2.43	3.43	0.000	+ve
Overall	*26.54*	*39.39*	*0.000*	*+ve*
Economic Impact				
Feed cost/cycle	2.44	3.39	0.000	-ve
Fish production	2.21	2.72	0.000	+ve
Total return	2.13	3.18	0.000	+ve
Avg. fish weight	1.98	2.41	0.000	+ve
Feed wastage	2.80	1.74	0.000	+ve
Market distance	2.89	1.90	0.000	+ve
Feed storage/handling	2.38	3.48	0.000	+ve
Fish mortality	2.72	1.87	0.000	+ve
Feed enterprises	2.52	3.39	0.000	+ve
Profitability perception	2.43	3.43	0.000	+ve
Feed price variation	2.26	3.33	0.000	-ve
Market dependency	2.30	3.34	0.000	-ve
Farmer knowledge transfer	1.43	2.48	0.000	+ve
Feed availability	2.44	3.57	0.000	+ve
Overall	*32.93*	*40.23*	*0.000*	*+ve*
Environmental impact				
Water clarity	2.41	3.43	0.000	+ve
Dissolved Oxygen	2.41	3.49	0.000	+ve
Algal bloom	2.59	1.61	0.000	+ve
Water odour	2.61	1.57	0.000	+ve
Fish disease	2.57	1.57	0.000	+ve
Disease treatment	2.00	1.00	0.000	+ve
Leftover feed	2.02	1.02	0.000	+ve
Soil texture	2.60	2.60	1.000	Neutral
Sediment buildup	2.41	1.43	0.000	+ve
Feed wastage	2.38	1.43	0.000	+ve
Overall	*23.99*	*19.15*	*0.000*	*+ve*

Table 2. Social, Economic, and Environmental Impact of Wolffia-Based Fish Rearing Technology

Parameters	Before	After	p-value	Impact
Social score				
Farmer group participation	1.48	2.43	0.000	+ve
Household fish consumption	1.52	2.45	0.000	+ve
Labour requirement	1.48	1.48	1.000	Neutral
Prophylaxis treatment applied	1.48	2.48	0.000	+ve
Household income	1.48	2.48	0.000	+ve
Training effectiveness	2.48	3.48	0.000	+ve
Satisfaction with Wolffia feed	2.48	3.48	0.000	+ve
Risk of market fluctuations	2.00	2.00	1.000	Neutral
Social status	1.48	2.48	0.000	+ve
Commercial feed dependency	1.48	1.52	0.835	Neutral
Education investment	1.48	2.00	0.001	+ve
Farmer-to-farmer knowledge	2.48	3.48	0.000	+ve
Access to extension services	1.48	2.00	0.001	+ve
Farm sustainability perception	1.48	2.48	0.000	+ve
Overall	*24.26*	*34.26*	*0.000*	*+ve*
Economic score				
Feed used	1.70	2.48	0.000	+ve
Feed cost	2.00	2.00	1.000	Neutral
Fish production	1.30	2.00	0.000	+ve
Return	1.22	2.13	0.000	+ve
Avg. fish weight	1.22	2.22	0.000	+ve
Feed wastage	2.61	2.04	0.000	+ve
Storage loss (monsoon)	2.00	2.61	0.000	+ve
Shift to Wolffia feed	1.48	2.61	0.000	+ve
Fish mortality	2.26	1.52	0.000	+ve
Feed the enterprise's need	2.00	2.00	1.000	Neutral
Feed price variation	2.00	2.00	1.000	Neutral
Market dependency	1.48	1.48	1.000	Neutral
Yield improvement perception	1.22	1.87	0.001	+ve
Overall	*22.48*	*26.30*	*0.003*	*+ve*
Environmental score				
Water clarity	1.48	2.48	0.000	+ve
Dissolved oxygen	2.48	3.48	0.000	+ve
Algal bloom presence	2.48	1.48	0.000	+ve
Water odour	2.00	1.48	0.001	+ve
Fish disease occurrence	2.52	1.52	0.000	+ve
Disease treatment applied	2.52	1.52	0.000	+ve
Leftover feed in the pond	1.48	1.00	0.001	+ve
Soil texture change	1.48	1.48	1.000	Neutral
Sediment buildup from the feed	2.00	1.00	0.000	+ve
Feed wastage	1.48	1.48	1.000	Neutral
Overall	*19.91*	*16.91*	*0.000*	*+ve*

Impact of Wolffia feed-based fish rearing technology

Table 2 shows that the impact of Wolffia-based fish rearing reveals significant gains across social, economic, and environmental dimensions. Socially, the Overall Score rose from 24.26 to 34.26 ($p < .001$), with improvements in participation, income, consumption, training, satisfaction, extension access, social status, and education, while labour, market risk, and feed dependency remained unchanged. Economically, the score increased from 22.48 to 26.30 ($p < 0.003$), driven by higher production, returns, fish weight, and lower mortality and wastage, though feed cost, market dependency, and storage loss persisted. Environmentally, the score declined from 19.91 to 16.91 ($p < .001$), reflecting better pond health through improved water clarity and dissolved oxygen and reduced algal blooms, odour, disease, and sediment, with no change in soil texture or feed wastage. Overall, Wolffia technology strengthened livelihoods, pond ecology, and farmer confidence.

Comparative economic performance of Wolffia and floating feed technologies

Paired t-test results (Table 3) showed significant improvements ($p < .001$) in economic performance for both floating feed and Wolffia technologies separately. In floating feed, feed cost rose by Rs. 2,206.56 per cycle (6-month cycle), yet fish production (+16.75 kg) and returns (+Rs. 6,644.26) increased, with AFCR improving by 0.23, reflecting higher efficiency. Similarly, Wolffia adoption led to higher feed use (+11.21 kg), increased production (+18.48 kg), and greater returns (+Rs. 4,804.35), with AFCR improving by 0.25. Overall, both technologies enhanced efficiency, productivity, and profitability despite higher input costs.

Perceived constraints of using floating feed-based fish farming

The perceived constraints to floating fish feed adoption were identified across four domains: technological, economic, social, and extension-related (Table 4). Technological issues included limited quality testing facilities (Mean = 4.57) and inadequate access to aerators and pumps (Mean = 3.95). Economically, the high cost of feed (Mean = 4.72) was the most severe constraint, along with poor access to credit and subsidies. Social barriers such as resistance to change (Mean = 3.44) and weak farmer networking (Mean = 2.43) were noted, while extension constraints included inadequate dissemination of success stories (Mean = 4.21) and irregular monitoring. Overall, economic and extension constraints were most critical, followed by technological and social factors.

Table 4. Perceived constraints associated with using floating feed-based technology

Constraints	Mean	Rank
Technological		
Lack of access to quality testing facilities	4.573	1
Lack of access to basic technologies	3.950	2
Limited technical knowledge	2.573	3
Poor water quality management	2.311	4
Incompatibility of floating feed with the traditional pond	1.459	5
Complexity in using floating feed	1.163	6
Difficulty in storing feed	1.098	7
Economic		
High cost of floating feed	4.721	1
Limited access to credit or subsidies	4.262	2
Low profitability in small-scale farms	3.623	3
Fluctuating market prices for fish	3.361	4
High wages & labour cost	1.329	5
High transportation cost of feed	1.295	6
Social		
Resistance to change	3.442	1
Poor networking among fish farmers	2.426	2
Illiteracy	2.000	3
Lack of awareness about the floating feed	1.443	4
Mistrust in new feed brands or products	1.409	5
Extension		
Poor dissemination of success stories	4.213	1
Irregular monitoring and feedback mechanisms	3.885	2
Lack of regular training or demonstration programs	3.852	3
Inadequate number of fisheries extension workers	3.786	4
Limited availability of locally relevant training materials	3.131	5

Perceived constraints of using Wolffia feed-based fish rearing

The perceived constraints in adopting Wolffia-based feed technology were observed across technological, economic, social, and extension domains (Table 5). Technologically, flood-induced feed loss (Mean = 4.43), weather dependency, and poor growth

Table 3. Economic performance in Wolffia and floating feed

Parameter	Mean Difference (After-Before)	Std. Deviation	95% Confidence Interval of the Difference		Paired Difference	
			Lower	Upper	t-value	p-value
Wolffia-based fish rearing technology						
Feed used	-11.213	5.29462	-13.503	-8.923	-10.157	.000
Fish production	-18.478	13.26605	-24.215	-12.742	-6.680	.000
Total return	-4804.348	2363.256	-5826.296	-3782.399	-9.750	.000
AFCR	.2547	0.182	0.176	0.333	6.718	.000
Floating feed-based fish rearing						
Feed cost	-2206.558	744.842	-2397.320	-2015.794	-23.137	.000
Fish production	-16.754	12.643	-19.992	-13.516	-10.350	.000
Total return	-6644.262	3110.092	-7440.794	-5847.731	-16.685	.000
AFCR	0.232	0.131	0.199	0.266	13.864	.000

Table 5. Perceived constraints associated with using Wolffia (alternative) feed

Constraints	Mean	Rank
Technological		
Flood-induced feed loss	4.435	1
Weather Dependency	2.652	2
Poor growth of Wolffia due to insufficient nutrients	2.565	3
Contamination by other aquatic weeds (Azolla, Spirogyra, Lemna, etc.)	2.261	4
Lack of storage technique	1.783	5
Unsuited for certain fish species	1.739	6
Complexity of the technology/Difficulty in maintaining	1.565	7
Potential for overfeeding and water quality issues	1.435	8
Technology is not suited to the existing environment	1.304	9
Economic		
Lack of financial support/non-availability of credit	4.174	1
Low profitability in small-scale farms	3.174	2
Dependency on external suppliers	1.435	3
High transportation cost of feed	1.174	4
High wages & labour costs	1.087	5
High cost of Wolffia	1.043	6
Social		
Poor networking among fish farmers	2.739	1
Resistance to change	1.739	2
Lack of awareness among farmers about the Wolffia feed	1.174	3
Illiteracy	1.000	4
Extension		
Lack of regular training or demonstration programs	3.739	1
Poor dissemination of success stories or research findings	3.696	2
Irregular monitoring and feedback mechanisms	3.304	3
Inadequate number of fisheries extension workers	2.261	4
Ineffective communication	1.870	5
Limited availability of locally relevant training materials	1.435	6

from nutrient deficiency were major issues. Economically, lack of financial support or credit (Mean = 4.17) and low profitability in small-scale farms limited adoption. Socially, weak farmer networking (Mean = 2.74) hindered collaboration, while extension-related challenges included inadequate training, demonstrations, and dissemination of research. Overall, financial insecurity, environmental vulnerability, poor networks, and weak extension support were identified as critical barriers to adoption.

Relationship between constraints and impacts of adopting floating feed and Wolffia-based fish rearing technologies

Spearman's correlation analysis (Table 6) reveals that for floating feed, technical (ρ = -0.676, $p < 0.01$) and extension constraints (ρ = -0.716, $p < 0.01$) significantly reduce effectiveness, while economic factors show no effect (ρ = 0.04, p = 0.757) and social constraints show a weak positive link (ρ = 0.255, $p < 0.05$), possibly due to adaptive practices. For Wolffia, social constraints have a moderate negative impact (ρ = -0.522, p = 0.011), technical barriers are moderately negative but marginal (ρ = -0.399, p = 0.059), while economic and extension factors remain negligible. Overall, technical and extension barriers are critical for floating feed, while social and technical barriers weigh more for Wolffia adoption.

DISCUSSION

This research assesses that floating feed and Wolffia-based fish aquaculture technologies are highly impactful on social, economic, and environmental domains, mirroring trends documented in previous studies. The introduction of floating feed enhanced awareness, involvement, and community actions among farmers, whereas Wolffia-based feed secured social bonding and farmers-to-farmers (F2F) learning. This highlights the capacity of easy and straightforward technology to promote social networks, in agreement with Joffre et al. (2017).

Table 6. Correlation between constraints and impacts of floating feed and Wolffia (alternative) feed

Pair	Spearman's ρ	p-value Sign. at 0.05	Interpretation
TC vs F	-0.676	0.0 *(S)*	Strong negative correlation → As technical constraints increase, the impact of floating feed significantly decreases.
EC vs F	0.04	0.757 *(NS)*	No meaningful relationship
SC vs F	0.255	0.047 *(S)*	Weak but positive correlation → as social constraints increase, impact may slightly increase or vice versa (could be due to contextual factors or farmer adaptation).
ExC vs F	-0.716	0.0 *(S)*	Very strong negative correlation →Higher extension/communication-related constraints are strongly associated with lower impact.
TC vs W	-0.399	0.059 *(S)*	Moderate negative correlation → More technical constraints are associated with reduced impact, but not statistically significant at the 0.05 level.
EC vs W	0.288	0.182 *(NS)*	Weak positive correlation → economic constraints may have a minor influence on impact.
SC vs W	-0.522*	0.011 *(S)*	Moderate negative correlation → higher social constraints significantly reduce the impact of Wolffia feed.
ExC vs W	-0.185	0.397 *(NS)*	Very weak negative correlation → communication issues have little/no relationship with impact score.

TC= Technological, EC=Economic, SC=Social, ExC=Extension, Impact of Floating Feed= F, Impact of Wolffia= W. Significant = S, Non-Significant = NS

Economic gains were observed in both technologies. Increased fish production, household income, profitability, and enhanced feed conversion ratios were reported by farmers. Results are in line with Belton & Little (2011), who attributed income increases to improved education investment and noted improvements in nutrition through increased consumption of fish (Kawarazaka & Béné, 2011; Munkit et al., 2025). As well, gains in fish yield, mean weight, lowered mortality, and feed utilisation concur with Ng & Romano (2013) to illustrate how efficient feed management contributes to the productivity and sustainability of ponds. Valladão et al. (2018) also showed the importance of feeding management in aquaculture in South American countries. However, the adoption of floating feed had economic issues, such as increased feed price and market dependence, regarding the negativity of commercial feeds (Kumar et al., 2018; Ansah & Frimpong, 2015). Conversely, Wolffia feed remained inexpensive, providing smallholders with a low-input option. Environmental impacts were also greatly enhanced. Both technologies promoted clearer water, increased dissolved oxygen, and minimised sedimentation and algal growth, in favour of Edwards (2015) on sustainable intensification. Minimised wastage of feeds and better pond conditions, in line with Ng & Romano (2013), further emphasise the beneficial ecological impact of these technologies.

In spite of these advantages, the constraint faced by the fish farmers restricted adoption. For floating feed, technological constraints–such as absence of aerators, pumps, quality analysis, and technical information–had a sharp decline in effectiveness ($\rho = -0.676$, $p < 0.01$), which confirms Kumar et al. (2018). Extension gaps came out as the most important challenge ($\rho = -0.716$, $p < 0.01$), indicating the necessity for more intense institutional support (Nirmalkar et al., 2022). These economic factors, like high cost of feeds, limited access to credit, and unstable prices, were noted but did not impact perceived influence considerably ($\rho = 0.04$, $p = 0.757$). Noteably, social constraints showed a weak positive association with influence ($\rho = 0.255$, $p < 0.05$), meaning that farmers who were motivated used networks and resilience practices to adapt to challenges. For Wolffia-based feed, technological limitations like flood-induced losses of feed, environmental sensitivity, and limited growth under conditions of nutrient deficiencies moderately limited adoption ($\rho = -0.399$, $p = 0.059$), as reported by Appenroth et al. (2017). Economic limitations were weak and non-significant ($\rho = 0.288$, $p = 0.182$), highlighting the cost-effectiveness of Wolffia relative to commercial feed.

These results are consistent with Raj et al. (2025), who stated that poor technical support and high input prices constrain the development of improved aquaculture practices. Biswas et al. (2025) & Meinam et al. (2025) also highlighted the importance of stakeholder identification, resource conservation, and sustainable utilisation of water in the development of fisheries. Higher income and better information access were also seen to stimulate demand for upgraded fisheries training (Niangti et al., 2025). In addition, providing the timely delivery of quality seed, feed, and fertilisers by connecting farmers with certified vendors, and the promotion of financial knowledge have been identified as critical to building resource access and planning (Lahiri et al., 2024). Overall, the research shows that there are clear social, economic, and environmental gains of utilising floating feed and Wolffia-based feed. Yet, technology and extension-related constraints have to be addressed by means of precision policy interventions, capacity development, and institutional support in order to ensure optimal adoption, impact, and long-term sustainability, as appreciated by Little et al. (2016) & Munguti et al. (2024) in their study in African countries.

CONCLUSION

The research concludes that floating feed and Wolffia-based fish rearing technologies greatly increase aquaculture productivity, profitability, and sustainability in Tripura. Floating feed enhances market returns, pond water quality, fish growth, and feed efficiency, while Wolffia feed encourages farmer livelihoods, nutrition, and small-scale, climate-smart aquaculture with reduced negative environmental impacts. Social advantages are greater participation, extension service access, knowledge sharing, income, education investment, training effectiveness, and increased income. Major adoption constraints were high feed prices, reliance on off-farm suppliers, flood losses, technical and extension constraints, and poor farmer networking. These need to be addressed through focused interventions like timely training, demonstrations, exposure visits, better storage of feeds, credit facilities, ICT-based advisories, knowledge sharing within the community, and scientific support services like water analysis and feed quality assurance. Subsequent studies should concentrate on trials and long-term evaluations to inform scalable take-up and build resilient aquaculture, livelihoods, and food security in the region.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents during the course of the research.

Conflict of interest: The author declares that there is no conflict of interest related to the publication of this article. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare that during the preparation of this work, thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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