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Comparative Assessment of Feeding Regimens on the Performance of Composite Fish Culture in Tribal Villages of Tripura

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ABSTRACT

This study evaluated three feeding strategies in composite fish culture (CFC) systems in tribal villages of Tripura to enhance aquaculture productivity. Fifteen farmer ponds (0.08 ha each) were utilized with three treatments in five replicates: conventional feed (CF: rice polish and mustard oil cake 1:1), floating pelleted feed (FPF), and combination feeding (COM: CF and FPF). Indian major carps were stocked at 10,000 fingerlings/ha with species composition of *Catla catla* (40%), *Labeo rohita* (30%), and *Cirrhinus mrigala* (30%). Feeding rates were progressively reduced from 5% of fish biomass in initial two months to 1% in final two months over a 10-month culture period. Fish production was significantly higher ($P<0.05$) in COM treatment (4.2±0.12 MT/ha) followed by FPF (3.8±0.08 MT/ha) and CF (3.2±0.06 MT/ha). Feed conversion ratio was most efficient in COM (2.1±0.05) compared to FPF (2.4±0.06) and CF (3.1±0.08). Economic analysis revealed highest net profit in COM treatment (¹ 4,49,000±18,750 per hectare) with benefit-cost ratio of 2.6±0.07. The combination feeding strategy demonstrated superior performance by optimizing feed utilization efficiency while maintaining cost-effectiveness. These findings suggest that alternating feeding regimen can significantly enhance fish productivity in tribal aquaculture systems, providing a sustainable approach for livelihood improvement in northeastern India.

KEYWORDS: Composite fish culture, Economic analysis, Feeding strategies, Fish production, Tribal aquaculture

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INTRODUCTION

Aquaculture is a key contributor to food security and livelihoods in India's northeastern states, with Tripura showing significant progress (Debnath, 2024). Fish production in the state rose from 19,840 MT in 2004–05 to 85,805 MT in 2023–24—an increase of approximately 332.5% (Fisheries Statistics of Tripura). Despite this growth, productivity remains at 2.8 MT/ha, below the national average of 3.0 MT/ha (Jayasankar, 2018), highlighting the need for technological interventions to boost efficiency.

The tribal areas under the Tripura Tribal Areas Autonomous District Council (TTAADC) face particular challenges in aquaculture development, with productivity levels ranging from 1.0 to 1.5 MT/ha/year due to inadequate fisheries resource management and subsistence-level farming practices. These communities often lack access to scientific pond management techniques, appropriate feed management strategies, and modern aquaculture technologies (Debnath et al., 2017). The persistent gap between potential and actual production necessitates targeted interventions to enhance productivity through improved feeding strategies.

Feed represents the most critical input in intensive aquaculture systems, typically accounting for 50-60% of total operational costs (O'Keefe and Campabadal, 2022). The feeding strategy adopted significantly influences fish growth performance, survival rates, and overall production efficiency (De Silva and Gunasekera, 1991; Das et al., 2020; Das et al., 2021). The incorporation of appropriate feed additives has emerged as a crucial factor in optimizing fish performance and aquaculture profitability (Singh et al., 2024). In traditional aquaculture practices prevalent in tribal areas, farmers predominantly rely on locally available feed ingredients such as rice polish and mustard oil cake, which, while cost-effective, often result in suboptimal growth performance due to nutritional inadequacies and poor feed conversion efficiency.

Commercial floating pelleted feeds have gained recognition for their superior nutritional profile and improved feed utilization efficiency compared to conventional feed ingredients (Yaqoob et al., 2010). These feeds offer advantages including reduced wastage, better feed conversion ratios, and enhanced growth rates. However, their higher cost often limits adoption among small-scale farmers. The development of cost-effective feeding strategies that combine the economic advantages of conventional feeds with the technical benefits of commercial pellets could provide a viable solution for enhancing aquaculture productivity in resource-constrained environments.

Recent research has demonstrated that different fish species respond variably to floating and sinking feeds based on their feeding habits and ecological niches within the pond ecosystem (Hussain et al., 2017). Specifically, surface feeders such as *C. catla* benefit more from floating feeds, while bottom feeders like *C. mrigala* show better performance with sinking feeds. This species-specific response to different feed types suggests that combination feeding strategies might optimize overall system productivity by catering to the diverse feeding requirements of different species in composite culture systems.

The present investigation was designed to evaluate the comparative efficacy of three feeding strategies: conventional feed, floating pelleted feed, and a combination approach involving use of both feed types. The study aimed to determine the optimal feeding strategy for enhancing fish production while maintaining economic viability in tribal aquaculture systems of Tripura.

MATERIALS AND METHODS

The study was conducted in Lembucherra village, located under the jurisdiction of Tripura Tribal Areas Autonomous District Council (TTAADC), Tripura, India. The experimental site was selected based on its representativeness of typical tribal aquaculture practices and the availability of willing participant farmers. The study was implemented under the Schedule Tribe Component (STC) program to ensure direct benefit to the tribal community. A total of fifteen earthen ponds, each measuring 0.08 ha with depths ranging from 1.0 to 1.5 m, were utilized for the experiment. The ponds were randomly allocated to three treatments with five replicates each: Treatment 1 (T1) - Conventional feed (CF), Treatment 2 (T2) - Floating pelleted feed (FPF), and Treatment 3 (T3) - Combination feeding (COM). The experiment was conducted over a 10-month period from June to March. Pond preparation followed standard protocols as described by Ayyappan et al (2019). Ponds were drained completely and lime was applied at 250 kg/ha for pH adjustment and soil conditioning. After 15 days, ponds were filled with water and organic manure (cattle manure) was applied at 2,500 kg/ha to enhance natural productivity. Ponds were allowed to develop natural plankton populations for two weeks before fish stocking.

Indian major carp fingerlings were procured from the ICAR-RC NEH Tripura Centre fish farm. The species composition followed standard composite fish culture practices: *C. catla* (40%), *Labeo rohita* (30%), and *C. mrigala* (30%). Fingerlings with average weights of 8.5±0.5g, 6.5±0.4g, and 4.4±0.3g for catla, rohu, and mrigal respectively were stocked at a density of 10,000 fingerlings/ha. Fingerlings were transported to experimental sites in oxygenated plastic bags and subsequently acclimatized for 30 minutes to equilibrate water temperature before being released into their respective ponds.

Conventional Feed was prepared by mixing rice polish and mustard oil cake in equal proportions (1:1 by weight) with water to form semi-solid dough. The proximate composition showed crude protein content of 24.8±0.5%. Commercial floating pellets (Make: ABIS India, 3mm diameter) procured from local market in Tripura, with crude protein content of 24.6±0.4%. The pellets maintained buoyancy for 45-60 minutes. Combination Feeding was practiced by alternating daily feeding schedule where conventional feed was provided on odd days and floating pelleted feed on even days.

The feeding schedule was designed with progressively decreasing rates based on fish biomass:

- Months 1-2: 5% of fish biomass daily
- Months 3-4: 4% of fish biomass daily
- Months 5-6: 3% of fish biomass daily
- Months 7-8: 2% of fish biomass daily
- Months 9-10: 1% of fish biomass daily

Fish biomass was reassessed bi-monthly by sampling 20-30 individuals of each species using cast nets from each pond. Based on these sampling assessments, feeding rates were adjusted according to the estimated total biomass. For feeding calculations between sampling periods, survival rates were conservatively estimated at 90% after the first two months and 80% after four months (Ayyappan et al., 2019). Water quality parameters were monitored monthly following standard methods (APHA, 1998). Water temperature was measured using a mercury thermometer, pH was determined using a digital pH meter (Eutech Instruments PCSTestr 35, Singapore), and dissolved oxygen was measured using a portable dissolved oxygen meter (Lutron PDO-519, Taiwan). Total alkalinity was determined through titration with standardized sulfuric acid, and ammonia-nitrogen concentrations were analyzed using the indophenol blue colorimetric method.

Fish growth was monitored bi-monthly by sampling 10 specimens of each species from each pond using cast nets. Fish were measured for total length to the nearest 0.1 cm and weighed to the nearest 0.1 g before being returned to their respective ponds following a prophylactic dip treatment in potassium permanganate solution (10 ppm for 3-5 minutes) to prevent stress-related infections. Final harvest was conducted after 10 months using drag nets, and all fish were counted, measured, and weighed individually.

Growth parameters were calculated using the following formulas:

- Weight gain (g) = Final weight - Initial weight
- Daily weight gain (g) = Weight gain / Culture period (days)
- Specific growth rate (SGR, % per day) = [(ln Final weight - ln Initial weight) / Culture period] × 100
- Feed conversion ratio (FCR) = Total feed consumed (dry weight) / Total weight gain
- Survival rate (%) = (Number of fish harvested / Number of fish stocked) × 100

Economic analysis was conducted considering all input costs, including pond preparation, fingerlings, feed, labour, and miscellaneous expenses. Feed costs were calculated based on market prices: rice polish ₹ 15/kg, mustard oil cake ₹ 20/kg, and floating pelleted feed ₹ 30/kg. Fish were valued at wholesale price of ₹ 175/kg. Net profit, benefit-cost ratio, and return on investment were calculated for each treatment.

Prior to statistical analysis, data normality was assessed using the Shapiro-Wilk test, and homogeneity of variance was evaluated using Levene's test. Data were analyzed using one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test for mean separation when significant differences were detected. Results are presented as mean ± standard error, and statistical significance was determined at $P<0.05$ level. All statistical analyses were performed using SPSS version 21.0.

RESULTS AND DISCUSSION

Water quality parameters

Water quality parameters remained within acceptable ranges for carp culture throughout the experimental period (Table 1). Temperature ranged from 14.4°C during winter months to 32.8°C during summer months. Dissolved oxygen levels showed variations among treatments, with higher values recorded in FPF treatment (5.8±0.2 mg/L) compared to CF treatment (5.2±0.3 mg/L). pH remained alkaline throughout the study period, ranging from 7.2 to 8.4. Total alkalinity ranged from 68.5±3.2 to 71.2±2.8 mg/L across treatments. Ammonia-nitrogen concentrations were lowest in FPF treatment (0.62±0.03 mg/L) and highest in CF treatment (0.78±0.04 mg/L), with COM treatment showing intermediate values (0.68±0.05 mg/L).

Table 1. Water quality parameters (mean ± SE) in different treatments during the study period

Parameter	T1 (CF)	T2 (FPF)	T3 (COM)
Temperature (°C)	27.6±1.2	27.8±1.1	27.4±1.3
Dissolved oxygen (mg/L)	5.2±0.3^{b}	5.8±0.2^{a}	5.6±0.3^{a}
pH	7.8±0.2	7.9±0.1	7.7±0.2
Total alkalinity (mg/L)	68.5±3.2	71.2±2.8	69.8±3.5
Ammonia-N (mg/L)	0.78±0.04^{a}	0.62±0.03^{b}	0.68±0.05^{ab}

Values bearing different superscripts (a,b) in the same row differ significantly (P<0.05)

Fish growth performance

Significant differences in fish growth performance were observed among treatments across all three species (Table 2). *C. catla* achieved the highest final weights in COM treatment (892±15.2g), followed by FPF treatment (845±12.8g) and CF treatment (678±11.4g). Daily weight gain for catla followed the same pattern, with COM treatment recording 2.92±0.05g, FPF treatment 2.76±0.04g, and CF treatment 2.21±0.04g. *L. rohita* demonstrated similar treatment responses, with final weights of 595±10.2g in COM treatment, 562±9.8g in FPF treatment, and 485±8.6g in CF treatment. Daily weight gain for rohu was highest in COM treatment (1.94±0.03g), followed by FPF treatment (1.83±0.03g) and CF treatment (1.58±0.03g). *C. mrigala* showed distinct performance patterns compared to the other species. The highest final weight was recorded in COM treatment (485±9.4g), while CF and FPF treatments showed similar performance with 425±8.2g and 398±7.8g respectively. Daily weight gain for mrigal was 1.58±0.03g in COM treatment, 1.39±0.03g in CF treatment, and 1.30±0.03g in FPF treatment.

Monthly growth assessments revealed that growth rates were highest during the initial four months across all treatments. The combination feeding strategy maintained consistently higher growth rates throughout the ten-month culture period, with the most pronounced differences observed during months three through six.

Table 2. Fish growth performance parameters

Species	T1 (CF)	T2 (FPF)	T3 (COM)
Catla catla			
Final weight (g)	678±11.4^{c}	845±12.8^{b}	892±15.2^{a}
Weight gain (g)	669±11.2^{c}	836±12.6^{b}	883±15.0^{a}
Daily weight gain (g)	2.21±0.04^{c}	2.76±0.04^{b}	2.92±0.05^{a}
Labeo rohita			
Final weight (g)	485±8.6^{c}	562±9.8^{b}	595±10.2^{a}
Weight gain (g)	478±8.4^{c}	555±9.6^{b}	588±10.0^{a}
Daily weight gain (g)	1.58±0.03^{c}	1.83±0.03^{b}	1.94±0.03^{a}
Cirrhinus mrigala			
Final weight (g)	425±8.2^{a}	398±7.8^{a}	485±9.4^{b}
Weight gain (g)	420±8.1^{a}	393±7.7^{a}	480±9.3^{b}
Daily weight gain (g)	1.39±0.03^{a}	1.30±0.03^{a}	1.58±0.03^{b}

Values bearing different superscripts (a,b, c) in the same row differ significantly (P<0.05)

Fish production and survival

Total fish production varied significantly among treatments (Table 3). The combination feeding strategy achieved the highest production (4.2±0.12 MT/ha), followed by floating pelleted feed (3.8±0.08 MT/ha) and conventional feed (3.2±0.06 MT/ha). Survival rates were consistently higher in FPF and COM treatments compared to CF treatment.

Table 3. Fish production and survival parameters (mean ± SE) by treatment

Parameter	T1 (CF)	T2 (FPF)	T3 (COM)
Total production (MT/ha)	$3.2±0.06^{c}$	$3.8±0.08^{b}$	$4.2±0.12^{a}$
Survival rate (%)	$74.2±1.8^{b}$	$81.6±1.4^{a}$	$83.8±1.2^{a}$
Species-wise production (kg/ha)			
Catla catla	$1,286±28^{c}$	$1,642±32^{b}$	$1,785±38^{a}$
Labeo rohita	$875±18^{c}$	$1,028±21^{b}$	$1,158±25^{a}$
Cirrhinus mrigala	$1,065±24^{a}$	$998±22^{a}$	$1,257±28^{b}$
Feed conversion ratio	$3.1±0.08^{a}$	$2.4±0.06^{b}$	$2.1±0.05^{c}$

Values bearing different superscripts (a,b, c) in the same row differ significantly (P<0.05)

Economic analysis

Economic evaluation revealed significant differences in profitability among treatments (Table 4). The COM treatment achieved the highest net profit of ₹ 4,49,000±18,750 per hectare, followed by FPF treatment at ₹ 3,17,400±18,300 per hectare and CF treatment at ₹ 2,87,400±14,330 per hectare. Total production costs were lowest for CF treatment (₹ 2,72,600±5,630 per hectare), intermediate for COM treatment (₹ 2,86,000±6,250 per hectare), and highest for FPF treatment (₹ 3,47,600±8,000 per hectare). The benefit-cost ratio was highest in COM treatment (2.6±0.07), followed by CF treatment (2.1±0.05) and FPF treatment (1.9±0.05). Return on investment showed similar rankings with COM treatment achieving 157±6.5%, CF treatment 105±5.3%, and FPF treatment 91±5.3%. Feed costs constituted the largest component of variable costs across all treatments, representing 63.7% in CF treatment, 78.7% in FPF treatment, and 73.3% in COM treatment of total variable costs.

The fish production achieved in this study (3.2-4.2 MT/ha) represents a substantial improvement over existing productivity levels in tribal areas of Tripura (1.0-1.5 MT/ha/year). The combination feeding strategy resulted in 31.3% higher production compared to conventional feeding and 10.5% higher than exclusive use of floating pelleted feed. These findings align with Hussain et al. (2017), who reported 19-23% yield increases when tribal farmers adopted floating pelleted feeds over traditional local feeding practices in Arunachal Pradesh. Their three-year study in East Siang District compared floating pelleted feed against local practices involving rice bran, mustard oil cake, and kitchen waste, closely paralleling our conventional feed approach. Hussain et al. achieved an average 21.4% production improvement across study years. The present study extends these findings, demonstrating that our combination feeding strategy achieved superior results with 31.3% higher production than conventional feeding, suggesting that alternating feeding protocols provide additional benefits beyond exclusive use of either feed type.

Table 4. Economic analysis of different feeding strategies

Cost components	T1 (CF)	T2 (FPF)	T3 (COM)
Variable costs (Rs/ha)			
Fingerlings	20,000±0	20,000±0	20,000±0
Feed cost	1,73,600±4,340c	2,73,600±6,840a	2,09,500±5,240b
Labor	20,000±400a	15,000±300c	17,500±350b
Lime and manure	8,500±200	8,500±200	8,500±200
Equipment rental	12,000±240	12,000±240	12,000±240
Harvesting costs	8,500±170	8,500±170	8,500±170
Miscellaneous	10,000±250	10,000±250	10,000±250
Total variable cost	2,72,600±5,630c	3,47,600±8,000a	2,86,000±6,250b
Gross income	5,60,000±11,200c	6,65,000±13,300b	7,35,000±14,700a
Net profit	2,87,400±14,330b	3,17,400±18,300c	4,49,000±18,750a
Return on investment (%)	105±5.3b	91±5.3c	157±6.5a
Benefit-cost ratio	2.1±0.05b	1.9±0.05c	2.6±0.07a

Values bearing different superscripts (a,b, c) in the same row differ significantly (P<0.05)
Fish selling price: ¹ 175/kg based on prevailing wholesale market rates; Rice polish ¹ 15/kg, Mustard oil cake ¹ 20/kg, Floating pellets ¹ 30/kg; Labor costs reflect differential requirements: T1 (¹ 20,000) includes daily feed mixing labor, T2 (¹ 15,000) for standard feeding operations, T3 (¹ 17,500) includes alternate day feed mixing labor; Equipment rental includes cast nets, weighing scales, and feeding implements; Harvesting costs for drag net operations and labor; Miscellaneous costs include fish health management, transportation, water quality monitoring, etc; Fixed costs excluded as experimental ponds were farmer-owned with maintenance performed by participating farmers

The species-specific response was most evident in mrigal, which achieved slightly higher final weights with conventional feed (425±8.2g) compared to floating pelleted feed (398±7.8g), though the difference was not statistically significant (P=0.08). This differential performance among species may relate to the physical characteristics of the feed types and their availability in different water zones. The conventional feed, being a semi-solid dough preparation, settles immediately upon application, making it accessible to bottom-dwelling species for extended periods. In contrast, floating pellets remain at the surface and mid-water column for 45-60 minutes, providing different accessibility patterns for various feeding guilds.

The superior performance of the combination feeding strategy may benefit from established principles in aquaculture nutrition. Silva et al. (2016) noted that dietary variation can influence feeding responses in fish systems, while Webster et al. (1992) demonstrated that fish often exhibit improved feeding responses when offered varied diets compared to monotonous feeding regimens. The alternating feeding schedule in the combination treatment potentially provides both sinking and floating feed options, accommodating the diverse habitat preferences of different carp species in the composite culture system. However, the specific behavioral and physiological mechanisms underlying the observed performance differences in this study would require dedicated investigations to establish definitively.

The FCR demonstrated significant improvement with the combination feeding strategy (2.1±0.05) compared to conventional feeding (3.1±0.08). This 32% improvement in FCR indicates more efficient utilization of feed resources, which contributes to the enhanced economic returns observed in this treatment. The improved FCR in combination feeding may be attributed to better feed utilization and reduced wastage. Floating pelleted feeds remain available in the water column for extended periods (45-60 minutes), providing surface and column feeders with better access to nutrients. Conversely, conventional feeds quickly settle to the bottom, making them readily available to benthic feeders. The alternating schedule appears to provide improved feed accessibility for different species while potentially reducing wastage through sedimentation and leaching of nutrients. These findings are consistent with Limbu (2015), who reported that floating feeds resulted in lower FCR compared to sinking feeds due to reduced wastage. The present study suggests that strategic combination of both feed types can achieve better FCR performance than exclusive use of either feed type alone.

The economic analysis reveals that the combination feeding strategy generated the highest net profit (¹ 4,49,000 per hectare) and benefit-cost ratio (2.6) despite higher feed costs compared to conventional feeding. This represents a 56.2% increase in net profit compared to conventional feeding and a 41.5% increase over floating pelleted feed treatment. The superior economic performance results from the substantial increase in fish production that more than compensates for the additional feed costs. The feed cost constituted 63.7% of total variable costs in CF treatment, 78.7% in FPF treatment, and 73.3% in COM treatment. While the combination approach had higher absolute feed costs than conventional feeding, the improved production efficiency resulted in better overall economic returns. The floating pelleted feed strategy, despite achieving higher production than conventional feeding, demonstrated reduced economic advantage due to elevated feed costs relative to the production gains achieved (Posadas, 2005; Kumar et al., 2017). This finding is particularly significant for tribal farmers who often face resource constraints but require improved livelihood outcomes. The return on investment was highest in COM treatment (157%), followed by CF treatment (105%) and FPF treatment (91%), indicating that farmers can expect substantial returns from adopting the combination feeding strategy. The moderate additional investment required for incorporating pelleted feed in the combination approach generates returns within a single culture cycle, making it economically attractive for small-scale tribal farmers.

The observed differences in water quality parameters among treatments provide additional context for the production results. Ammonia-nitrogen concentrations were lowest in FPF treatment (0.62±0.03 mg/L) and highest in CF treatment (0.78±0.04 mg/L), with COM treatment showing intermediate values (0.68±0.05 mg/L). Similarly, dissolved oxygen levels were higher in FPF and COM treatments compared to CF treatment. These water quality differences may reflect variations in feed utilization patterns among the different feeding strategies. Boyd and Tucker (1998) noted that water quality management is fundamental in aquaculture systems, as feed inputs and their subsequent breakdown products influence the pond environment. The maintained water quality parameters within acceptable ranges across all treatments throughout the study period contributed to the successful completion of the experimental trials.

This study demonstrates that the combination feeding strategy produced superior results across key performance indicators in composite fish culture systems. The alternating use of conventional feed and floating pelleted feed achieved the highest fish production (4.2 MT/ha), most efficient feed conversion ratio (2.1), and greatest economic returns (¹ 4,49,000/ha net profit) compared to exclusive use of either feed type. The combination approach resulted in 31.3% higher production than conventional feeding and 56.2% higher net profit. The economic analysis revealed that while feed costs were higher in the combination treatment, the increased production efficiency generated better overall returns with a benefit-cost ratio of 2.6 compared to 2.1 for conventional feeding and 1.9 for floating pelleted feed alone.

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