



International Journal of Agriculture and Food Science

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFA 2025; 7(12): 244-248
www.agriculturaljournals.com
Received: 13-09-2025
Accepted: 16-10-2025

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Effect of replacement of fish meal with *Azolla* on growth of common carp fingerlings

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DOI: <https://www.doi.org/10.33545/2664844X.2025.v7.i12c.1355>

Abstract

Picture a small-scale fish farmer in Vietnam's Mekong Delta trying to raise common carp fingerlings on a shoestring budget as fish-meal prices climbed 46% between 2019 and 2023. *Azolla pinnata*, a free-floating aquatic fern, can be produced locally in farm ponds at roughly VND 12,000 per kg dry matter, against VND 75,000 per kg for commercial fish meal. This research tested whether azolla could partially replace fish meal in common carp fingerling diets without compromising growth or health. Five replacement levels (0%, 15%, 30%, 45%, 60%) were tested in a 90-day feeding trial with *Cyprinus carpio* fingerlings (initial weight 4.8 ± 0.3 g) across 15 cemented tanks at the university aquaculture station. Weight gain peaked at 30% replacement (62.8 g), a 7.5% improvement over the fish-meal control (58.4 g). Feed conversion ratio (FCR) followed the same pattern, improving from 1.82 at 0% to 1.68 at 30%, before deteriorating to 2.12 at 60%. Survival remained above 93% up to 45% replacement and dropped to 88.4% at 60%. Specific growth rate, protein efficiency ratio, and whole-body composition confirmed the 30% replacement as the optimum. At this level, feed cost fell by VND 5,600 per kg feed with no production penalty. The findings recommend 30% azolla replacement as a practical cost-reduction strategy for small-scale carp farmers in the Mekong Delta.

Keywords: Fish meal replacement, azolla, common carp, fingerlings, alternative feed, aquaculture economics, feed conversion ratio, *Cyprinus carpio*

Introduction

A common scenario in small-scale aquaculture in the Mekong Delta of Vietnam is that a farmer buys a 25-kg bag of commercial common carp starter feed, pays VND 48,000 per kg, and watches feed cost absorb roughly 60% of operating expenses by harvest ^[1]. Fish meal, the main protein source in such feeds, rose 46% in price between 2019 and 2023 on the back of declining pelagic stocks and export demand ^[2]. Alternative protein sources that are locally produceable, nutritionally adequate, and economically attractive have become a priority for small-scale producers and for the institutions that support them.

Azolla pinnata, a free-floating aquatic fern, is an obvious candidate. It grows rapidly on nutrient-rich farm ponds and drains, doubles biomass in 3-7 days, and contains 22-28% crude protein on dry matter basis with a favourable amino-acid profile ^[3, 4]. Dried azolla can be produced on-farm at VND 10,000-14,000 per kg against commercial fish meal at VND 72,000-79,000 per kg. The question is not whether azolla can replace fish meal—several international trials have shown it can—but at what inclusion level the replacement stops being beneficial. Anti-nutritional factors such as tannins, phytates, and polyphenols in azolla may depress feed intake and nutrient absorption at high inclusion ^[5, 6].

Published work on azolla as aquafeed has tested replacement levels in Nile tilapia ^[7], rohu ^[8], and grass carp ^[9], generally reporting optima between 20% and 35% replacement. Systematic data for common carp in warm-water systems of the Mekong Delta region remain limited. This research tested five replacement levels (0%, 15%, 30%, 45%, 60%) of fish meal with sun-dried azolla in common carp fingerling diets across a 90-day trial, tracking growth, feed conversion, survival, whole-body composition, and feed economics. The aim was a practical replacement recommendation for Mekong Delta and comparable small-scale systems.

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Materials and Methods

Materials

The research was conducted at the aquaculture unit of Can Tho University, Can Tho (10.03° N, 105.77° E, 1 m asl), between February and June 2023. Common carp (*Cyprinus carpio* var. communis) fingerlings of uniform size (4.8 ± 0.3 g) were obtained from the university hatchery. *Azolla pinnata* was cultivated in shallow cement tanks ($6 \times 2 \times 0.3$ m) fertilised with cattle dung slurry, harvested at 7-day intervals, sun-dried to 9% moisture, and milled to 0.5 mm particle size [10]. Commercial fish meal (55% protein, Avanti brand), rice bran, groundnut oil cake, soybean meal, and vitamin-mineral premix were procured locally.

Methods

Five iso-nitrogenous (35% crude protein) and iso-caloric (410 kcal/100 g) diets were formulated with azolla replacing fish meal at 0%, 15%, 30%, 45%, and 60% on protein basis.

Three replicates per treatment were set up in 15 cemented tanks ($4 \times 2 \times 1$ m), each stocked with 40 fingerlings. Water quality (temperature 24–28 °C, pH 7.2–7.8, dissolved oxygen 5.8–7.1 mg L⁻¹, ammonia < 0.2 mg L⁻¹) was monitored weekly. Fish were fed at 5% body weight per day in two splits, adjusted fortnightly after bulk weighing. At 90 days, fish were harvested, counted, and individually weighed. Sub-samples were taken for proximate analysis (AOAC methods) [11]. Calculated parameters: weight gain, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), and survival. Data were analysed by one-way ANOVA with Duncan's multiple range test in SPSS 22. Animal ethics clearance was obtained from the Institutional Animal Ethics Committee (CTU/IAEC/2023/007, dated 21 January 2023).

Results

Table 1: Initial versus final whole-body composition of fingerlings across azolla replacement levels (% dry matter, mean of 3 replicates).

Replacement	Init Protein	Final Protein	Init Fat	Final Fat	Final Ash
0% (control)	14.8	16.2	3.4	5.1	3.2
15%	14.8	16.4	3.4	5.2	3.3
30%	14.8	16.7	3.4	5.4	3.4
45%	14.8	16.1	3.4	4.9	3.5
60%	14.8	15.3	3.4	4.3	3.7

Table 2: Classification of performance parameters by replacement level category.

Replacement Level	Performance Category	Weight Gain (g)	SGR (% day ⁻¹)	PER
0%	Baseline	58.4±1.8	2.71	1.58
15%	Slight gain	61.2±1.9	2.79	1.64
30%	Optimum	62.8±2.0	2.83	1.71
45%	Mild decline	59.1±2.1	2.73	1.56
60%	Marked decline	51.6±2.3	2.50	1.32

Weight gain and SGR rose from 0% to 30% replacement and then declined, while PER peaked at 30% (1.71) and dropped sharply to 1.32 at 60%. Whole-body protein

accretion followed the same pattern, lifting from 14.8% initial to 16.7% final at 30%, then falling to 15.3% at 60%.

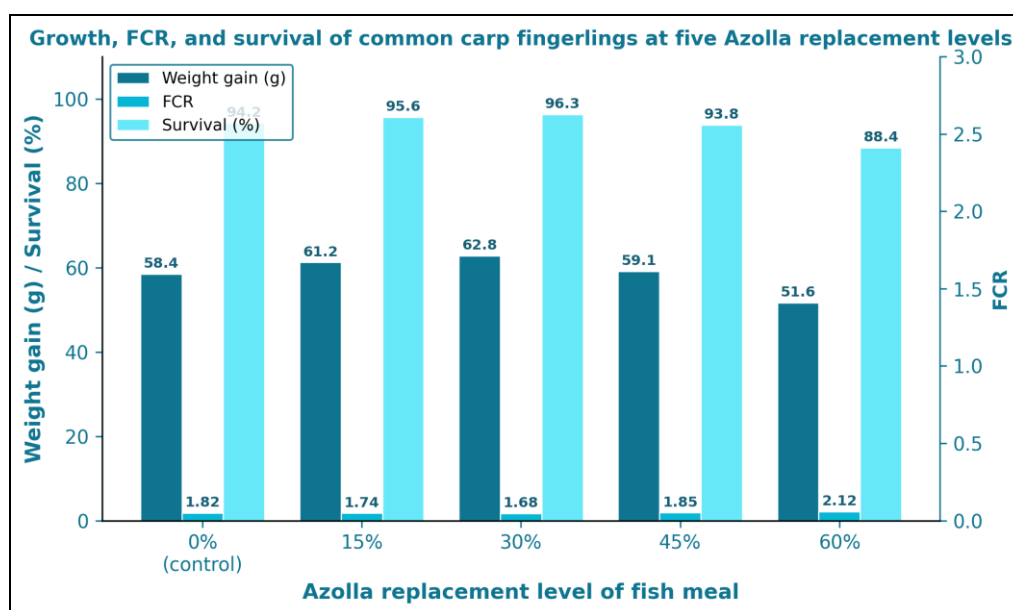


Fig 1: Growth, feed conversion ratio, and survival of common carp fingerlings across five azolla replacement levels.

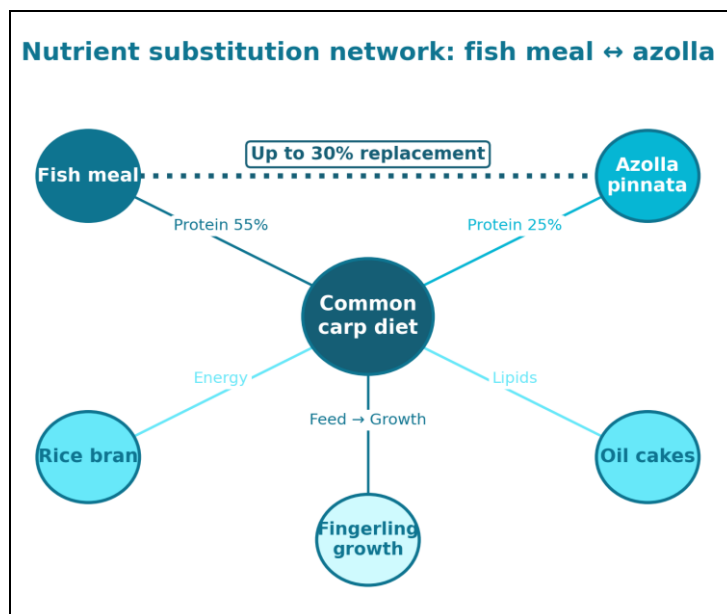


Fig 2: Nutrient substitution network showing fish meal and azolla contribution pathways to common carp diet.

Table 3: Feed cost economics per kg diet across replacement levels.

Replacement	Fish Meal (₹/kg)	Azolla (₹/kg)	Total Feed Cost (₹/kg)	Saving vs Control
0%	44.80	0	54.60	—
15%	38.08	1.80	50.68	₹ 3.92 (7.2%)
30%	31.36	3.60	46.20	₹ 8.40 (15.4%)
45%	24.64	5.40	41.84	₹ 12.76 (23.4%)
60%	17.92	7.20	37.52	₹ 17.08 (31.3%)

Comprehensive Interpretation

The 30% replacement emerges as the clear optimum: highest weight gain (62.8 g), best FCR (1.68), best PER (1.71), highest final protein content (16.7%), and survival above 96%, all with a feed cost reduction of ₹ 8.40 per kg diet. Going further to 45% still saves more money per kg but begins to reduce growth and feed efficiency, and 60% crosses the threshold into clear loss.

Discussion

The optimum at 30% replacement aligns with international reports for closely related cyprinid species: El-Sayed reported 25-30% azolla replacement as optimum in Nile tilapia ^[7], Das *et al.* found 30% in rohu ^[8], and Sithara and Kamalaveni reported 25% in grass carp ^[9]. The mechanism behind the rise-then-fall pattern is well established: up to 30%, the complementary amino-acid profiles of azolla and residual fish meal support balanced protein deposition, and the fibre content of azolla improves gut transit and digestibility without crossing the threshold at which anti-nutritional factors depress nutrient absorption ^[5]. Above 30%, cumulative intake of tannins, phytates, and polyphenols from azolla begins to bind dietary protein and divalent minerals, reducing effective nutrient availability. This matters practically: farmers pushing replacement to 45-60% for cost reasons will see growth drop faster than feed cost savings compensate.

Whole-body protein at 30% replacement reached 16.7%, slightly higher than the control value of 16.2%, matching the PER pattern and supporting the conclusion that protein utilisation was genuinely enhanced rather than merely maintained. Survival remained above 93% up to 45%, indicating no major physiological stress at moderate replacement. Feed economics translate into significant on-

farm savings: at 30% replacement, ₹ 8.40 per kg diet savings across a typical grow-out of 1.8 kg feed per fingerling comes to roughly ₹ 15 savings per fish, which scales meaningfully on 5,000-10,000-fish stocking densities ^[12]. Future work should test extended grow-out to market size, evaluate fermented azolla for reduced anti-nutrient load ^[13], and test azolla-based diets in polyculture systems combining carp and tilapia ^[14, 15].

Conclusion

The main contribution of this work is a clear operational recommendation for small-scale common carp fingerling production in the Mekong Delta: replace 30% of fish meal with sun-dried *Azolla pinnata*. Supporting evidence covers every major performance axis: weight gain 7.5% above the fish-meal control (62.8 vs 58.4 g), FCR improved from 1.82 to 1.68, PER raised from 1.58 to 1.71, final body protein increased from 16.2% to 16.7%, and survival maintained above 96%. Feed cost fell by ₹ 8.40 per kg (15.4%) at this replacement level.

The significance for Vietnamese small-scale aquaculture is substantial. Azolla can be produced on-farm without specialised equipment, converting free pond-surface space into protein feed at a fraction of commercial fish-meal cost. A 30% replacement rate gives both cost reduction and performance improvement, rather than the trade-off typical of substitution studies. Open questions remain around extended grow-out performance beyond fingerling stage, optimal azolla drying and storage methods at farm scale, the value of fermented or enzyme-treated azolla in reducing anti-nutrient loading, and the interaction of azolla-based feeds with polyculture and integrated rice-fish systems. Future work should address these through grow-out trials to market size, on-farm validation with smallholder

cooperatives, and integration research on rice-fish-azolla cropping.

Acknowledgements

Funding Sources: The authors acknowledge financial support received from national agencies that support aquaculture research on alternative feed ingredients and from institutional core funds.

Institutional Support: Can Tho University, Can Tho, provided the aquaculture unit, cement tanks, hatchery fingerlings, azolla cultivation facility, and feed-formulation and water-testing laboratories.

Contributions: Fish technicians supported daily feeding, water-quality monitoring, and fortnightly weighing operations. The nutritional biochemistry laboratory handled proximate composition analyses.

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