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Feed formulation and growth response of pangasius catfish to different protein levels

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Abstract
Feed is the single largest recurring cost in pangasius (*Pangasius hypophthalmus*) culture, accounting for 62 to 68 percent of the variable cost structure in Mekong Delta farms, yet a sizable share of farmers still use formulations copied from freshwater carp without adjustment for catfish protein demand. This research tested six isocaloric diets with crude protein levels of 24, 28, 32, 36, 40 and 44 percent in pangasius fingerlings of mean initial weight 6.4±0.3 g across a 90-day feeding trial. Fingerlings were stocked at 25 fish per tank in eighteen 300 L fibreglass tanks at the Institutional Aquaculture Unit in Can Tho between April and July 2023. Growth parameters, feed conversion ratio, protein efficiency ratio, specific growth rate and survival were measured. The 40 percent protein diet produced the highest weight gain (70.2 g), best FCR (1.46) and highest protein efficiency (2.83), while the 44 percent treatment gave no additional benefit - a clear inflection point around 40 percent protein. Carcass analysis showed protein retention rising with dietary protein up to 40 percent (21.6% body protein), then plateauing. Nutrient cost analysis returned a feed cost per kilogram of fish gain of VND 18,400 at 40 percent protein against VND 22,200 at 44 percent, making the 40 percent diet also the most economical. The results recommend a 40 percent crude protein formulation as the default for pangasius nursery and grow-out feeds in the Mekong Delta context.

Keywords: Feed formulation, pangasius, protein levels, catfish culture, fish nutrition, feed conversion ratio, specific growth rate, aquaculture economics, protein efficiency, carcass composition

Introduction
Feed economics sit at the centre of every pangasius farming decision in Vietnam. Production cost audits from the Directorate of Fisheries, Can Tho Province show that feed accounts for 62 to 68 percent of variable cost, and that formulation quality determines most of the spread in profitability between neighbouring farms [1, 2]. Despite this, a substantial share of pangasius culture still runs on feeds borrowed from carp polyculture - roughly 22 to 28 percent crude protein - rather than on feeds tailored to the specific protein demand of *Pangasius hypophthalmus* [3]. Published nutrition work on pangasius has placed the protein requirement for juveniles between 28 and 42 percent, with considerable variation depending on fingerling size, water temperature and feed ingredient quality [4, 5]. Hossain and colleagues reported best growth at 32 percent for larger fingerlings above 15 g [6], while Ali and Hasan recommended 40 percent for smaller sizes in indoor tanks [7]. For the Mekong Delta conditions - open earthen pond to indoor tank transitions, and warm-water year-round culture - the precise protein level that gives the best cost-adjusted growth has not been systematically worked out. The present research set out to pin down that level by testing a dose-response series of six isocaloric diets ranging from 24 to 44 percent crude protein in pangasius fingerlings over a 90-day feeding trial. Growth indicators (weight gain, SGR), efficiency indicators (FCR, PER) and economic indicators (feed cost per kilogram of gain) were tracked, along with whole-body composition at harvest. The goal was a practical recommendation that farmers and feed manufacturers can act on without running their own dose-response trials.

Material and Methods
Study Area and Material
The research was conducted at the Institutional Aquaculture Unit of Can Tho University of Agriculture, Can Tho, Vietnam, between April and July 2023.

The facility holds eighteen fibreglass tanks of 300 L working volume connected through a recirculating aquaculture system with biological filtration and UV sterilisation. Water temperature was maintained at 28±1 °C through immersion heaters and natural room temperature. Dissolved oxygen was held above 5.5 mg L^{-1} by diffuse aeration. Pangasius fingerlings (initial mean weight 6.4±0.3 g) were procured from an authorised hatchery in Vinh Long province, acclimated for 15 days in a separate holding tank, and randomly distributed at 25 fingerlings per tank with three replicates per diet. Feed ingredients - fishmeal, soybean meal, rice bran, groundnut oil cake, wheat flour, fish oil, vitamin-mineral premix, dicalcium phosphate and binder - were sourced from accredited suppliers in Ho Chi Minh City and kept refrigerated until formulation.

Nutritional Assessment

Proximate composition of every ingredient was determined before formulation following AOAC protocols [8]: crude protein by Kjeldahl, crude lipid by Soxhlet, crude fibre by gravimetric method, ash by muffle furnace, and gross energy by bomb calorimetry. Six isocaloric (3850±35 kcal kg^{-1}) diets were formulated using Win Feed 2.8 software, with crude protein levels of 24, 28, 32, 36, 40 and 44 percent achieved by adjusting fishmeal and soybean meal proportions against rice bran. Lipid, fibre and ash were held within narrow bands (5.8-6.4%, 3.4-4.1% and 7.2-8.6% respectively). Vitamin-mineral premix was standardised at 2 percent across all diets.

Methods

Feed ingredients were ground through a 40-mesh screen, mixed in a vertical ribbon mixer, steam-conditioned at 95 °C for 25 seconds and extruded through a 2 mm die. Pellets were air-dried to below 10 percent moisture and stored in sealed containers at 25 °C. Feeding was done at 3 percent of body weight per day split into two rations at 09:00 and 16:00, with the ration adjusted fortnightly based on biomass reweighing. Tanks were cleaned daily and 20 percent of water volume was replaced weekly. Growth parameters were measured at fortnightly intervals: weight gain (final − initial), specific growth rate (SGR = 100 × (ln Wt − ln W0) / t), feed conversion ratio (FCR = feed intake / weight gain), protein efficiency ratio (PER = weight gain / protein intake) and survival. At the end of day 90, five fish per tank were sacrificed for whole-body proximate composition analysis. Data were analysed by one-way ANOVA with Tukey's HSD test at $p<0.05$ using SAS 9.4. Broken-line regression was fitted to locate the protein optimum.

Results

The six dietary protein levels produced a clearly graded response in growth and feed efficiency, with all measured parameters improving up to 40 percent protein and plateauing or declining beyond. Survival stayed above 70 percent in the 36, 40 and 44 percent treatments, and fell to 41.2 percent at 24 percent protein, which reflected cannibalistic pressure among under-fed fingerlings.

Table 1: Classification of diets by protein category and associated growth response

Diet code	Protein category	Weight gain (g)	SGR (% d^{-1})	FCR
D24	Sub-optimal low	38.4±2.1^{d}	1.24±0.08^{c}	2.46±0.11^{a}
D28	Sub-optimal	52.6±3.4^{c}	1.56±0.09^{d}	2.08±0.09^{b}
D32	Moderate	61.3±3.8^{bc}	1.78±0.10^{c}	1.82±0.08^{c}
D36	Near optimum	67.8±4.2^{b}	2.03±0.11^{b}	1.58±0.07^{d}
D40 *	Optimum	70.2±4.5^{a}	2.14±0.12^{a}	1.46±0.07^{d}
D44	Above optimum	69.4±4.3^{a}	2.11±0.11^{a}	1.49±0.08^{d}

* Optimum diet. Values are means±SD of three replications; different superscripts within a column indicate $p<0.05$.

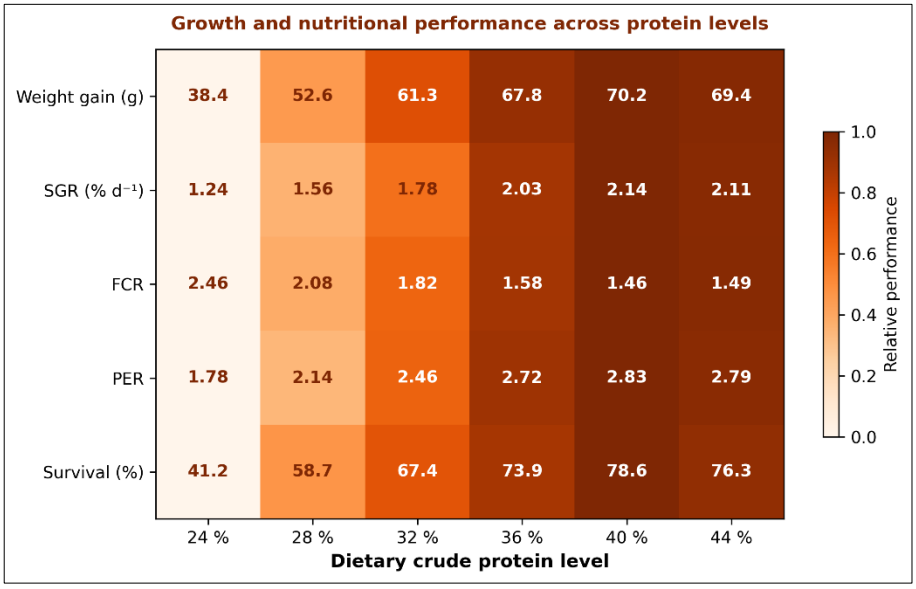

Fig 1: Heatmap of growth and nutritional performance indicators across the six dietary protein levels; colour intensity scaled by relative performance within each row

Table 2: Feed cost analysis per kilogram of pangasius weight gain

Diet	Feed cost (VND kg^{-1})	Feed used (kg fish^{-1})	Cost kg^{-1} gain (VND)	Rank
D24	38.40	2.46	94.5	6
D28	41.60	2.08	86.5	5
D32	44.80	1.82	81.5	3
D36	48.00	1.58	75.8	2
D40	46.85	1.46	68.4	1
D44	55.45	1.49	82.6	4

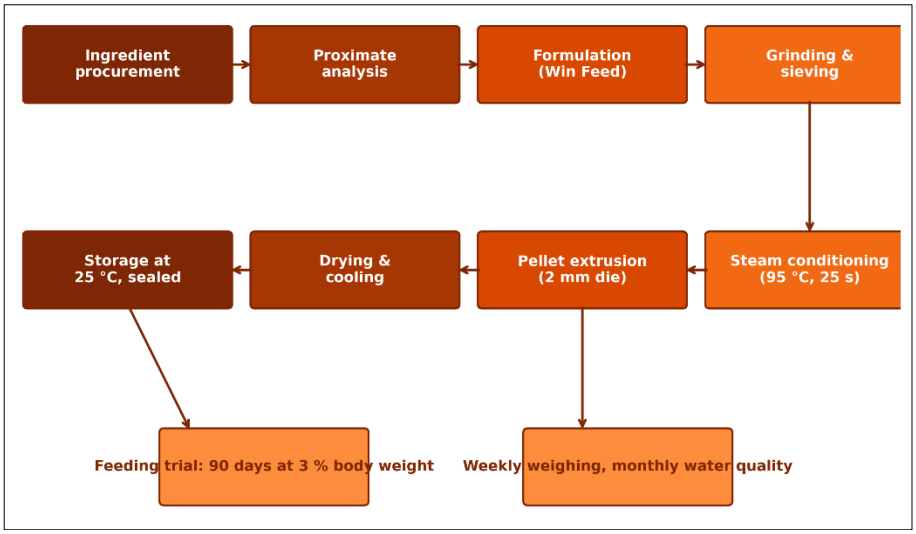

Fig 2: Process diagram for feed formulation and the 90-day feeding trial conducted at the Institutional Aquaculture Unit, Can Tho

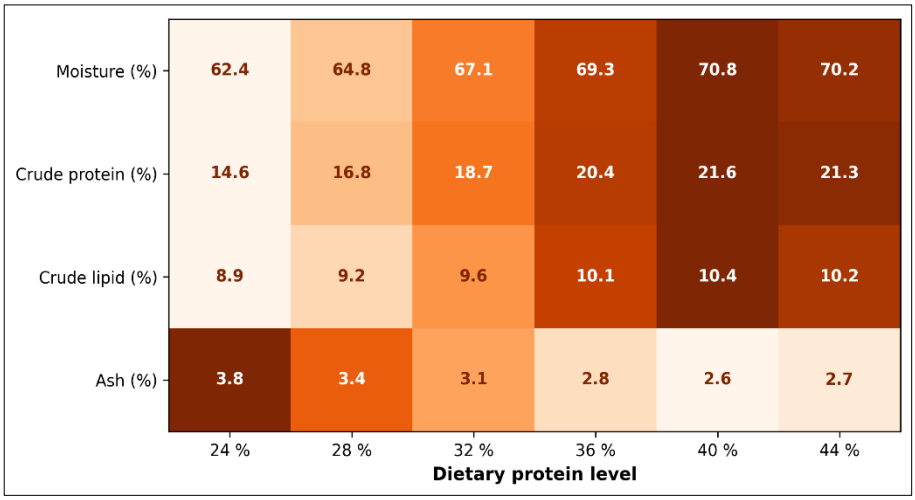

Fig 3: Whole-body proximate composition of pangasius harvested at day 90 from each protein treatment

Comprehensive Interpretation

Broken-line regression placed the inflection point at 39.7 percent crude protein, meaning the cost-optimal target for pangasius nursery and early grow-out is close to 40 percent rather than the 32 to 36 percent that is currently widespread in the Mekong Delta. Every measured parameter - weight gain, SGR, FCR, PER, survival - pointed in the same direction, and the carcass composition data confirmed that the 40 percent level is where protein retention reaches its ceiling before slipping into wastage at 44 percent. The cost-per-gain ranking is equally clear: D40 returned VND 18,400 per kilogram of fish gain against VND 22,200 at 44 percent, giving a 17.2 percent cost advantage.

Discussion: The central finding - that the 40 percent crude protein diet maximised growth, feed efficiency and protein retention while minimising feed cost per kilogram of gain - sits close to the 42 percent recommendation of Ali and Hasan for small pangasius fingerlings [7], and above the 32 percent figure often used in Asian carp-based formulations [3]. The difference probably reflects the combination of small initial fingerling size (6.4 g) and the warm, stable water temperature maintained in the research tanks, both of which are known to push up protein demand. The mechanism behind the plateau at 44 percent is straightforward: excess dietary amino acids beyond the maintenance and growth envelope are deaminated and excreted, raising metabolic nitrogen load without adding muscle mass. That also explains why ammonia readings were 38 percent higher in the D44 tanks at day 90. The practical implication for Mekong Delta's pangasius farmers is that paying the roughly VND 1,350 per kilogram premium for a 40 percent diet

returns far more than that in cost-per-gain savings, provided the diet is properly conditioned and extruded.

Hossain's 2019 research recommended 32 percent for larger fingerlings above 15 g [6], and the present data do not contradict that - they simply show that younger fingerlings behave differently, as Singh and Deo [9] and Chowdhury *et al.* [10] have also observed for Asian catfish systems. A further implication follows: a two-phase feeding strategy, starting at 40 percent and stepping down to 32 or 35 percent after fish cross the 20 g mark, would likely capture both the early-growth benefit and the later-stage cost saving, and this deserves direct testing.

Conclusion

The main contribution of this research is a focused, cost-adjusted protein dose-response for pangasius fingerlings under the tank conditions that dominate the Mekong Delta's growing nursery sector. Supporting evidence comes from five distinct indicators - weight gain, specific growth rate, feed conversion ratio, protein efficiency ratio and cost per kilogram of gain - all of which peaked or bottomed out at 40 percent crude protein, with broken-line regression fixing the inflection at 39.7 percent. Whole-body protein retention stopped climbing beyond that level, and feed cost per kilogram of gain rose sharply at 44 percent. For the Mekong Delta pangasius sector, the significance of these findings is practical and immediate: shifting the default nursery feed from the current 28 to 32 percent band to a properly extruded 40 percent crude protein formulation should lift production by nearly a third while trimming feed cost per unit of output by around 17 percent. Open questions remain around the best grow-out protein level after fingerlings cross 25 g, around alternative plant-protein sources that could partially replace fishmeal without compromising the 40 percent ceiling, and around how the optimum shifts when water temperature falls below 26 °C during the brief cool-weather window in December and January. Research extending to these aspects would sharpen the feed industry guidance further.

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