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Effect of Different Levels of Dietary Carbohydrate on the Growth Performance and Nutrient Utilization of Blue Gourami, *Trichogaster trichopterus*

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Abstract

This study evaluated the effects of graded dietary carbohydrate (CHO) levels on the growth performance and nutrient utilisation of blue gourami (*Trichogaster trichopterus*) fingerlings. Juvenile fish with an initial average weight of 1.76 ± 0.01 g were randomly stocked at a density of 10 fish per tank in triplicate in indoor fibre-reinforced tanks (500 L capacity) filled with 100 L of water. Six semi-purified diets were formulated to contain graded CHO levels (T1-20%, T2-25%, T3-30%, T4-35%, T5-40%, and T6-45%) while maintaining constant levels of crude protein (35%) and lipid (8%). The feeding trial was conducted over a period of 60 days. At the conclusion of the trial, fish fed the diet containing 40% CHO exhibited significantly ($p < 0.05$) superior growth performance, as evidenced by higher weight gain (WG), specific growth rate (SGR), protein efficiency ratio (PER), and protein retention efficiency (PRE), along with a significantly lower feed conversion ratio (FCR), compared to other dietary treatments. Whole-body proximate composition analysis revealed significant ($p < 0.05$) differences among treatments. The highest crude protein content (16.40%) was recorded in fish fed the 20% CHO diet (T1), whereas the lowest (15.31%) was observed in fish receiving the 45% CHO diet (T6). Conversely, total lipid content was highest in the T6 group (5.29%) and lowest in T1 (4.27%). Ash content peaked in T1 (3.22%) and was lowest in T6 (2.84%). Whole-body carbohydrate content increased with dietary CHO levels, with the highest value recorded in T6 (1.55%) and the lowest in T1 (1.12%). These findings suggest that a diet containing 40% carbohydrates is adequate to support optimal growth and nutrient utilisation in blue gourami, *T. trichopterus* fingerlings.

Keywords: Blue gourami, carbohydrate, growth performance, nutrient utilisation, *Trichogaster trichopterus*

Introduction

Feed expenses account for approximately 50% of variable costs in standard aquaculture production systems and over 60% of total production costs are attributed to feed (Khalasi et al., 2025; Routroy et al., 2025). This economic load highlights the importance of developing nutritionally balanced, sustainable, and cost-effective aquafeeds to enhance profitability and optimize the cost-to-benefit ratio. A key step toward this goal involves understanding the nutritional requirements of cultured species, particularly in terms of dietary nutrient optimization (Prakash et al., 2023). Among dietary components, carbohydrates are considered the most cost-effective energy source and play a significant role in reducing feed costs (Stone, 2003; Singha, Sahu, Sardar, Shamna, & Kumar, 2024). Unlike proteins and lipids, carbohydrates are generally less expensive and more abundant, making them an attractive option for providing energy in aquafeeds (Wilson, 1994; Hemre, Mommsen, & Krogdahl, 2002). Tropical freshwater fish, such as carp and other Cyprinidae species with omnivorous feeding habits, exhibit relatively high efficiency in carbohydrate utilisation compared to carnivorous species (Kumar, Sahu, Pal,

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Choudhury, & Mukherjee, 2006; Kamalam, Medale, & Panserat, 2017). Optimum CHO inclusion in the diet can spare dietary protein from catabolism for energy purposes, thereby enhancing protein retention for tissue growth while simultaneously reducing nitrogenous waste output, which benefits environmental sustainability and water quality management (Krogdahl, Hemre, & Mommsen, 2005; Prakash et al., 2023).

The blue gourami (*T. trichopterus*), a popular ornamental and food freshwater species, holds significant commercial and ecological importance, especially in Southeast Asia and India (Mohanta, Subramanian, & Korikanthimath, 2013; Talwar & Jhingran, 1991). This air-breathing, omnivorous fish, classified under the family Osphronemidae, possesses a specialised labyrinth organ above the gills that enables atmospheric oxygen uptake (Degani & Meerson, 2024). This adaptation allows them to survive in hypoxic environments, contributing to its resilience and adaptability across diverse aquatic habitats. The species can thrive in environments with low dissolved oxygen, fluctuating temperatures, and varied pH levels (Mohanta et al., 2013; FAO, 2024).

Despite its popularity among aquarists and its potential for small-scale aquaculture ventures, limited scientific data regarding the dietary nutrient requirements of *T. trichopterus* are available. Mohanta et al. (2013) reported that this species requires 35% protein and 8% lipid for improved growth and nutrient utilisation. Most existing nutritional studies on ornamental fish primarily focus on colour enhancement, disease resistance, or breeding performance rather than growth optimization through macronutrient balancing (Sales & Janssens, 2003; Lim et al., 2008). Furthermore, understanding carbohydrate tolerance and the optimum level of utilisation is crucial because ornamental species often exhibit different metabolic responses compared to conventional food fish (Steinberg, 2022).

Therefore, the present study investigated the effects of varying dietary carbohydrate levels on the growth performance, nutrient utilisation, and whole-body proximate composition of *T. trichopterus* fingerlings. By optimizing carbohydrate inclusion levels, this research aims to contribute to the formulation of nutritionally balanced, cost-effective, and environmentally sustainable feeds specifically tailored for blue gourami, an important and widely preferred tropical ornamental fish. These findings are expected to aid aquarists, ornamental fish farmers, and small-scale aquaculture enterprises in enhancing productivity while minimizing production costs and maintaining optimum water quality in culture systems.

Materials and Methods

Four 500 L capacity flow-through fiber-reinforced plastic (FRP) tanks with continuous aeration were used to acclimate 1,000 uniformly sized blue gourami, *T. trichopterus* fingerlings (average weight 1.5 g), to laboratory conditions in the Fisheries Wet Laboratory (ICAR-Research Complex for Goa, Goa, India) over the course of 15 days. The fingerlings were procured from the local market in Panaji, Goa, India. During the acclimation period, the fish were fed a commercial diet to apparent satiation. Continuous aeration system was maintained in all tanks throughout the acclimation period.

In this experiment, six semi-purified experimental diets (Table 1) were prepared with varied carbohydrate levels of T1: 20%, T2: 25%, T3: 30%, T4: 35%, T5: 40%, and T6: 45%, while maintaining dietary protein and lipid levels at 35% and 8%, respectively, based on the nutritional requirement of this species as suggested by Mohanta et al. (2013). The dietary energy levels of the experimental diets ranged from 4.04 to 4.07 kcal/g diet.

The acclimated blue gourami fingerlings (average body weight 1.76 g) were placed in triplicate groups in 18 FRP tanks (10 fish/tank) for every feeding treatment. The experiment was carried out in indoor FRP tanks with a capacity of 500 L containing 100 L of water. The natural light cycle for the experiment was 12 hours of light and 12 hours of darkness. Seasoned groundwater was used for fish rearing. The fish were fed continuously to apparent satiation for 60 days. Uneaten feed and excreta were removed daily from each tank prior to feeding. Water quality parameters were maintained within the optimal range for fish rearing, as recommended by Mohanta et al. (2013). Fish from each tank were batch weighed every 15 days to ascertain their weight and visually assess their general health condition.

The proximate composition of feed samples and fish was determined following the standardized procedures of AOAC International (1995). Moisture content was estimated by weighing feed samples in petri dishes and drying them in a hot air oven at

100 ± 2 °C for 16 hours until a constant weight was obtained. Dry matter (DM) was calculated by subtracting the moisture percentage from 100. Crude protein (CP) content was estimated using the micro-Kjeldahl method, in which samples were digested in sulfuric acid and the resulting nitrogen content was measured through distillation and titration, followed by multiplication with a conversion factor of 6.25. Ether extract (EE) was quantified using petroleum ether (boiling range 40–60 °C) in a Soxhlet apparatus over a period of 10–12 hours. Total lipid content was determined gravimetrically following solvent extraction and evaporation. Ash content was measured by incinerating the samples in a muffle furnace at 650 °C until complete ashing. Crude fibre (CF) content was determined using the acid and alkaline digestion methods. Digestible energy (DE) was calculated based on the method described by Halver (1976). Detailed compositional values are presented in Table 2.

$$\text{Digestible energy (kcal/g)} = [4 \times CP + 9 \times EE + 4 \times NFE]$$

The growth and nutritional parameters of *T. trichopterus* were calculated using the following formula:

$$\text{Weight gain (WG; g)} = \text{Final weight (g)} - \text{Initial weight (g)}$$

$$\text{Specific growth rate (SGR; \%/day)} = \frac{\ln(\text{final weight; g}) - \ln(\text{initial weight; g})}{\text{Experiemental period (days)}} \times 100$$

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Feed intake (dry weight; g)}}{\text{Net weight gain (wet weight; g)}}$$

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Net weight gain (wet weight; g)}}{\text{Protein intake (dry weight; g)}}$$

$$\text{Protein retention efficiency (PRE)} = \frac{\text{Net weight gain (wet weight; g)}}{\text{Total protein intake (dry weight; g)}} \times 100$$

The effect of varying dietary carbohydrate levels on growth performance, feed intake, and selected physiological and metabolic parameters were evaluated using SPSS version 25.0. Statistical analyses included one-way ANOVA, contrast analysis, and Duncan's multiple range test to determine significant differences among treatment groups, with significance set at $p < 0.05$. Results are presented as mean ± standard error of the mean (SEM).

Results and Discussion

The proximate composition of the experimental diets used in the carbohydrate requirement study of *T. trichopterus* is presented in Table 2. The crude protein content of the diets ranged from 34.56% to 35.87%, while ether extract levels varied between 7.69% and 8.11%. Total ash content ranged from 5.20% to 5.98%, and crude fibre content ranged from 2.89% to 3.24%. The nitrogen-free extract (NFE) content increased with higher dietary carbohydrate inclusion, ranging between 47.04% and 49.23%. The digestible energy (DE) contents of the diets remained relatively consistent, ranging from 4.04 to 4.07 kcal/g.

Growth performance and nutrient utilisation parameters of blue gourami fingerlings fed diets containing different carbohydrate levels are summarized in Table 3. Initial body weights were statistically insignificant among treatment groups ($p > 0.05$). However, final body weight, weight gain (WG), specific growth rate (SGR), protein efficiency ratio (PER), and protein retention efficiency (PRE) were significantly ($p < 0.05$) influenced by dietary carbohydrate levels ($p < 0.001$).

At the end of the feeding trial, fish fed the diet containing 40% carbohydrate (T5) exhibited significantly ($p < 0.05$) higher final body weight (7.19 ± 0.02 g), weight gain (5.44 ± 0.09/ g), SGR (2.36 ± 0.02% day^{-1}), PER (1.71 ± 0.01), and PRE (29.67 ± 0.08%), along with a significantly ($p < 0.05$) lower feed conversion ratio (FCR) (1.69 ± 0.04), compared to the other treatment groups ($p < 0.05$). Although fish fed the 45% carbohydrate diet (T6) also demonstrated improved growth performance compared to the lower carbohydrate groups, their performance was slightly lower to that of fish fed the 40% carbohydrate diet.

The whole-body proximate composition of blue gourami fingerlings at the end of the feeding trial is presented in Table 4. Moisture content decreased with increasing dietary carbohydrate levels, ranging from 74.92% (T1) to 72.19% (T6). In contrast, whole-body lipid content increased progressively from 4.27% (T1) to 5.29% (T6). Crude protein content showed a slight declining trend, decreasing from

16.40% (T1) to 15.31% (T6). Total ash content decreased marginally across treatments, while total carbohydrate content increased slightly with increasing dietary carbohydrate inclusion levels.

Overall, the significant ($p < 0.05$) results indicated that a dietary carbohydrate level of 40% optimally supports growth performance, feed efficiency, and protein utilisation in *T. trichopterus* fingerlings under the given experimental conditions.

This study investigated the effects of varying dietary carbohydrate levels on the growth performance and nutrient utilisation of blue gourami (*T. trichopterus*) fingerlings. In aquafeeds, carbohydrates are an essential energy source that, when properly managed, can enhance protein utilization and reduce feed costs (Singha et al., 2024). The study aimed to determine the optimum dietary carbohydrate inclusion level for this species by formulating six semi-purified meals with increasing carbohydrate concentrations (from 20% to 45%) while maintaining constant protein and lipid levels according to the nutritional requirements previously reported by Mohanta et al. (2013). Key growth metrics and whole-body composition were evaluated throughout the 60-day feeding study in order to gauge the physiological reaction to these dietary modifications.

Among the experimental diets, the 40% carbohydrate diet resulted in the highest weight gain (WG), specific growth rate (SGR), and protein efficiency ratio (PER), along with the lowest feed conversion ratio (FCR). The results showed that dietary carbohydrate levels had a significant impact on the growth performance, feed utilization efficiency, and whole-body composition of *T. trichopterus* fingerlings. These findings highlight the importance of optimizing dietary carbohydrate levels in aquafeed formulations for omnivorous species such as blue gourami.

Carbohydrates are inexpensive and readily accessible energy source that can effectively spare proteins from being utilised for energy metabolism, thereby allowing greater protein utilisation for tissue repair and growth (Singh, Kesharwani, & Keservani, 2017). In the present study, diets containing 40% carbohydrate maximized growth and nutritional efficiency of blue gourami, suggesting a relatively high capacity for carbohydrate absorption comparable to that reported in juvenile bluegill fish and giant gourami (Giri, 2017; Sari, Ekasari,

Table 1. Ingredient composition (% dry matter) of the experimental diets used for carbohydrate requirement study of blue gourami, *Trichogaster trichopterus*

Parameters	Treatments*					
	T1	T2	T3	T4	T5	T6
Casein	32.0	32.0	32.0	32.0	32.0	32.0
Gelatine	8.0	8.0	8.0	8.0	8.0	8.0
Dextrin	6.0	7.5	9.0	10.5	12.0	13.5
Corn starch	14.0	17.5	21.0	24.5	28.0	31.5
CMC[1]	2.0	2.0	2.0	2.0	2.0	2.0
Vit-Min mix[2]	5.0	5.0	5.0	5.0	5.0	5.0
Vegetable oil	4.0	4.0	4.0	4.0	4.0	4.0
Cod liver oil	4.0	4.0	4.0	4.0	4.0	4.0
α-Cellulose	25.0	20.0	15.0	10.0	5.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

*T1: 20% CHO (carbohydrate), T2: 25% CHO, T3: 30% CHO, T4: 35% CHO, T5: 40% CHO, T6: 45% CHO

[1]CMC, Carboxymethylcellulose; [2]Vitamin and Mineral mixture, commercial grade vitamin and mineral mixture (M/S Supplevite-M, Sarabhai Zydus, Vadodara, India) contains (quantities/kg mixture): Vitamin A, 20,00,000 IU; Vitamin D3, 4,00,000; Vitamin B2, 0.4 g; Vitamin E, 250 IU; Vitamin K, 0.2 g; Calcium pantothenate, 0.5 g; Nicotinamide, 2.0 g; Vitamin B12, 2.4 mg; Choline chloride, 30 g; Calcium, 150 g; Manganese, 5.5 g; Iodine, 0.2 g; Iron, 1.5 g; Zinc, 3 g; Copper, 0.4 g; Cobalt, 0.09 g

Table 2. Proximate composition (% dry weight basis) of the experimental diets used for carbohydrate requirement study of blue gourami, *Trichogaster trichopterus*

Parameters	Treatments*					
	T1	T2	T3	T4	T5	T6
Crude protein	35.87	35.21	34.70	35.17	34.56	35.28
Ether extract	8.11	8.03	7.98	8.06	7.69	8.08
Total ash	5.86	5.36	5.20	5.80	5.38	5.98
Crude fibre	3.12	2.89	2.97	3.24	3.14	2.97
NFE[1]	47.04	48.51	49.15	47.73	49.23	47.69
DE[2] (kcal/g)	4.05	4.07	4.07	4.04	4.04	4.05

*T1: 20% CHO (carbohydrate), T2: 25% CHO, T3: 30% CHO, T4: 35% CHO, T5: 40% CHO, T6: 45% CHO
[1]NFE, nitrogen free extract = [100 – (crude protein + crude lipid + crude fibre + ash)]; [2]DE, Digestible energy (kcal/g) = [4 × CP + 9 × EE + 4 × NFE] (Halver, 1976)

Table 3: Effect of different levels of carbohydrate on the growth and nutrient utilization of blue gourami, *Trichogaster trichopterus*

Parameters	Treatments*						*p*-value
	T1	T2	T3	T4	T5	T6	
In. wt[1] (g)	1.78±0.01	1.76±0.01	1.77±0.01	1.76±0.01	1.75±0.01	1.75±0.01	0.658
Fn. Wt[2] (g)	4.27±0.05[f]	4.48±0.02[e]	4.76±0.06[d]	5.68±0.04[c]	7.19±0.02[a]	6.86±0.05[b]	<0.001
WG[3] (g)	2.49±0.12[f]	2.72±0.08[e]	2.98±0.06[d]	3.92±0.11[c]	5.44±0.09[a]	5.11±0.14[b]	<0.001
FCR[4]	1.98±0.07[a]	1.93±0.05[b]	1.89±0.08[b]	1.82±0.02[c]	1.69±0.04[e]	1.75±0.08[d]	<0.001
SGR[5]	1.46±0.05[f]	1.55±0.06[e]	1.64±0.03[d]	1.95±0.05[c]	2.36±0.02[a]	2.28±0.04[b]	<0.001
PER[6]	1.41±0.09[e]	1.46±0.02[d]	1.52±0.04[c]	1.56±0.06[c]	1.71±0.01[a]	1.62±0.04[b]	<0.001
PRE[7]	23.22±0.08[f]	24.50±0.09[e]	25.86±0.11[d]	26.91±0.05[c]	29.67±0.08[a]	27.99±0.06[b]	<0.001
Survival (%)	100.00	100.00	100.00	100.00	100.00	100.00	<0.001

Data are expressed as mean ± SE, n = 3; the mean values of the same superscript in the same column are not significantly different ($p < 0.05$)
*T1: 20% CHO (carbohydrate), T2: 25% CHO, T3: 30% CHO, T4: 35% CHO, T5: 40% CHO, T6: 45% CHO
[1]In. wt, Initial weight; [2]Fn. Wt; Final weight; [3]WG, Weight gain; [4]FCR, Feed conversion ratio; [5]SGR, Specific growth rate; [6]PER, Protein efficiency ratio; [7]PRE, Protein retention efficiency

Nasrullah, Suprayudi, & Alimuddin, 2022). Similarly, Zhang, Zhou, and Cheng (2009) reported enhanced growth performance and feed efficiency in juvenile spotted Babylon (*Babylonia areolata*) fed diets containing up to 40% carbohydrate. Ali and Jauncey (2004) also observed that common carp (*Cyprinus carpio*) efficiently utilise dietary carbohydrates, with optimum inclusion levels ranging from 30% to 40%.

Similar patterns have been reported in other omnivorous fish species, including Nile tilapia (*Oreochromis niloticus*) and pearl spot (*Etroplus suratensis*), which exhibit improved growth and energy utilisation when dietary carbohydrate levels are maintained between 30–40% (National Research Council [NRC], 2011). Similarly, *Mugil cephalus* has shown efficient carbohydrate metabolism, with recommended dietary carbohydrate levels ranging between 35% and 45% to maximize growth and feed utilisation (Venou, Alexis, Fountoulaki, & Haralabous, 2006). In carnivorous species such as largemouth bass (*Micropterus salmoides*), Amoah et al. (2008) also reported improved growth, feed utilization, and digestive enzyme activity when moderate levels of dietary carbohydrate were included in the diet.

The superior performance observed at the 40% dietary carbohydrate level may be attributed to the omnivorous feeding habit and physiological adaptatability of *T. trichopterus*. Gourami species are known to consume soft aquatic weeds like Hydrilla, Lemna, and Azolla, and one of the species is utilised for the biological control of aquatic weeds (Nair & Sajina, 2021). This feeding behaviour may be one of the reasons for the relatively higher carbohydrate utilisation capacity of this species. Furthermore, the ability of the blue gourami, an air-breathing species with a labyrinth organ, to withstand a variety of climatic circumstances may also be related to its metabolic flexibility, which includes effective use of carbohydrates (Degani & Meerson, 2024). Further emphasizing their function in encouraging protein sparing and growth enhancement, the relatively low dietary lipid content (8%) maintained across all experimental diets ensured that carbohydrates acted as the primary non-protein energy source (Alami-Durante et al., 2019; Singha et al., 2024).

The growth performance results were corroborated by the whole-body proximate composition data. Fingerlings fed the 40% carbohydrate diet exhibited improved nutritional assimilation and deposition, which resulted in excellent crude protein and fat retention. An inverse relationship was observed between the whole-body moisture and lipid content (Du et al., 2005). A compensatory shift in nutrient deposition with increasing dietary energy levels was also suggested by the inverse relationship between the crude protein and total lipid content in the fish body, which is consistent with the findings of Al Hafedh (2001) in Nile tilapia (*O. niloticus*). Lower dietary carbohydrate levels appeared to compromise growth performance, possibly due to inadequate energy provision, leading to increased protein catabolism to meet metabolic energy demands, a phenomenon also reported in other fish species (Kamalam et al., 2017).

Notably, the findings of the study provide important new insights into the dietary energy needs and carbohydrate metabolism of blue gourami. These findings provide a workable answer for small-scale fish farmers as well as the ornamental aquaculture businesses, since there has only been limited studies that focused on the nutritional requirements of this ornamental species. It is feasible for formulating economical, nutritionally balanced diets that improve fish growth, lower production costs, and lessen environmental effects by reducing nitrogen excretion by maximizing carbohydrate inclusion (Sulaiman, Kamarudin, Romano, & Syukri, 2020).

The improved performance observed at the 40% inclusion level in blue gourami (*T. trichopterus*) fingerlings may be attributed to an optimal balance between nutrient availability and digestive capacity. At moderate dietary inclusion levels, nutrients are utilised more efficiently due to better digestibility and reduced metabolic burden, thereby enhancing growth performance and feed conversion efficiency. Similar findings have been reported in other teleost species, where moderate dietary inclusion of test

Table 4. Proximate composition (% wet weight) of whole-body *Trichogaster trichopterus* fed graded dietary carbohydrate levels for the period of 60 days

Parameters	Treatments*						*p*-value
	T1	T2	T3	T4	T5	T6	
Moisture	$74.92^{a} \pm 0.16$	$74.46^{a} \pm 0.09$	$73.75^{b} \pm 0.11$	$73.26^{bc} \pm 0.04$	$72.76^{cd} \pm 0.19$	$72.19^{d} \pm 0.06$	<0.001
Crude protein	$16.40^{a} \pm 0.24$	$16.19^{bc} \pm 0.14$	$15.97^{bcd} \pm 0.16$	$15.86^{cd} \pm 0.08$	$15.69^{cd} \pm 0.19$	$15.31^{d} \pm 0.18$	<0.001
Total lipid	$4.27^{d} \pm 0.07$	$4.38^{d} \pm 0.09$	$4.61^{bc} \pm 0.15$	$4.70^{bc} \pm 0.12$	$4.85^{b} \pm 0.09$	$5.29^{a} \pm 0.06$	<0.001
Total ash	$3.22^{a} \pm 0.08$	$3.13^{ab} \pm 0.05$	$3.05^{b} \pm 0.09$	$2.98^{bc} \pm 0.11$	$2.92^{bc} \pm 0.16$	$2.84^{c} \pm 0.12$	<0.001
Total carbohydrate	$1.12^{c} \pm 0.25$	$1.29^{b} \pm 0.21$	$1.36^{ab} \pm 0.14$	$1.45^{a} \pm 0.17$	$1.53^{a} \pm 0.27$	$1.55^{a} \pm 0.13$	<0.001

Data are expressed as mean ± SE, n = 3; the mean values of the same superscript in the same column are not significantly different ($p < 0.05$)

*T1: 20% CHO (carbohydrate), T2: 25% CHO, T3: 30% CHO, T4: 35% CHO, T5: 40% CHO, T6: 45% CHO ingredients supported superior growth compared to lower or higher levels (NRC, 2011). Conversely, lower inclusion levels may not provide sufficient quantities of key nutrients required for optimal growth. The same trends have been documented in ornamental and freshwater species, where intermediate dietary levels maximise protein utilisation and energy allocation toward somatic growth rather than maintenance (De Silva & Anderson, 1995; Hardy, 2010). Therefore, the superior growth at 40% inclusion likely reflects an optimal dietary threshold that supports efficient nutrient assimilation and physiological functioning in blue gourami fingerlings.

Besides, the slightly reduced growth observed at the 45% inclusion level compared to 40% can be attributed to physiological and nutritional constraints associated with higher dietary inclusion. Fish generally exhibit a dose-dependent growth response, where performance increases up to an optimum dietary level and declines thereafter (Radhakrishnan et al., 2020). Beyond this optimum, excess dietary nutrient may not be efficiently utilised for somatic growth, leading to increased amino acid catabolism and energy loss through deamination processes (Luthada-Raswiswi, Mukaratirwa, & O'Brien, 2021).

At higher inclusion levels, particularly with nonconventional or plant-derived ingredients, the presence of anti-nutritional factors and complex carbohydrates can reduce digestibility and interfere with nutrient absorption (Samtiya, Aluko, & Dhewa, 2020). These compounds can also impair digestive enzyme activity, thereby limiting protein hydrolysis and nutrient availability for growth (Liang et al., 2022). Furthermore, excessive inclusion levels can disrupt the dietary protein-to-energy balance, resulting in inefficient nutrient utilisation and increased metabolic demand (Serra, Pastorelli, Tedesco, Turin, & Guerrini, 2024). Therefore, the marginal decline in growth at 45% inclusion suggests that this level may exceed the optimal dietary threshold for blue gourami fingerlings, leading to reduced feed utilisation efficiency and suboptimal growth performance.

The present study is a basic study on determination of the optimum dietary carbohydrate level of blue gourami. However, more research is required to look at the long-term impacts, reproductive performance, histological changes, digestive enzyme function, and the interactions of carbohydrates with other dietary elements like fibre and certain amino acids in *T. trichopterus*. In addition, gaining a deeper understanding of the physiological and molecular mechanisms that govern the digestion and metabolism of carbohydrates would contribute to the development of improved feed formulation techniques for this species and other comparable ornamental fish species.

The current study concludes that for blue gourami fingerlings, a dietary carbohydrate content of 40% is optimal for fostering better growth performance, nutrient utilisation, and effective feed conversion. Development of a more economically feasible and environmentally sustainable aquafeed for this commercially significant ornamental fish species can be greatly aided by this understanding of dietary carbohydrate utilisation.

The present study demonstrates that dietary carbohydrate levels play a critical role in optimising growth performance, nutrient utilisation, and whole-body composition in *T. trichopterus* fingerlings. A 40% carbohydrate diet considerably increased the nutrient profile and improved weight gain, specific growth rate, protein efficiency ratio, and feed conversion ratio among the studied levels of the fish. These results support the adaptation of blue gourami to diets high in carbohydrates and are consistent with findings of the previous research on the utilisation of carbohydrates in omnivorous freshwater species. In order to create species-specific diets that meet the nutritional requirements of blue gourami and thereby enabling their sustainable production in ornamental aquaculture systems, this study offers useful baseline data. For thorough dietary optimization of this species, more research may include interactions with other macro-nutrients and long-term feeding effects.

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Ethics approval

This study followed the guidelines set forth by the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA) established by the government of India. These guidelines are designed to safeguard the well-being and care of fish involved in laboratory research for biomedical investigations and product evaluation.

References

Alami-Durante, H., Cluzeaud, M., Bazin, D., Schrama, J. W., Saravanan, S., & Geurden, I. (2019). Muscle growth mechanisms in response to isoenergetic changes in dietary non-protein energy source at low and high protein levels in juvenile rainbow trout. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, *230*, 91–99. https://doi.org/10.1016/j.cbpa.2019.01.009

Al Hafedh, Y. S. (2001). Effects of dietary protein on growth and body composition of Nile tilapia, *Oreochromis niloticus* L. *Aquaculture Research*, *30*(5), 385-–393. https://doi.org/10.1046/j.1365-2109.1999.00343.x

Ali, M. Z., & Jauncey, K. (2004). Optimal dietary carbohydrate to lipid ratio in African catfish *Clarias gariepinus* (Burchell 1822). *Aquaculture International*, *12*, 169–180. https://doi.org/10.1023/B:AQUI.0000032065.28059.5b

Amoah, A., Coyle, S. D., Webster, C. D., Durborow, R. M., Bright, L. A., & Tidwell, J. H. (2008). Effects of graded levels of carbohydrate on growth and survival of largemouth bass, *Micropterus salmoides*. *Journal of the World Aquaculture Society*, *39*(3), 397–405. https://doi.org/10.1111/j.1749-7345.2008.00168.x

AOAC International. (1995). *Official methods of analysis of the association of official analytical chemistry* (16th ed.).

De Silva, S. S., & Anderson, T. A. (1995). *Fish nutrition in aquaculture*. Chapman & Hall.

Degani, G., & Meerson, A. (2024). Sex differences in the brain transcriptomes of adult blue gourami fish (*Trichogaster trichopterus*). *Fishes*, *9*(7), Article 287. https://doi.org/10.3390/fishes9070287

Du, Z. Y., Liu, Y. J., Tian, L. X., Wang, J. T., Wang, Y., & Liang, G. Y. (2005). Effect of dietary lipid level on growth, feed utilization and body composition by juvenile grass carp (*Ctenopharyngodon idella*). *Aquaculture Nutrition*, *11*(2), 139–146. https://doi.org/10.1111/j.1365-2095.2004.00333.x

Food and Agriculture Organization of the United Nations. (2024). *The state of world fisheries and aquaculture: Blue transformation in action*. https://doi.org/10.4060/cd0683en

Giri, N. (2017). *The effect of dietary carbohydrate sources and levels on growth in juvenile bluegill (Lepomis macrochirus)* [Master's thesis, Lincoln University]. ProQuest Dissertations and Theses Global.

Halver, J. E. (1976, May 26). *The nutritional requirements of cultivated warm water and cold water fish species*. FAO Technical Conference on Aquaculture, Kyoto, Japan.

Hardy, R. W. (2010). Utilization of plant proteins in fish diets: Effects of global demand and supplies of fishmeal. *Aquaculture Research*, *41*(5), 770–776. https://doi.org/10.1111/j.1365-2109.2009.02349.x

Hemre, G. I., Mommsen, T. P., & Krogdahl, Å. (2002). Carbohydrates in fish nutrition: Effects on growth, glucose metabolism and hepatic enzymes. *Aquaculture Nutrition*, *8*(3), 175–194. https://doi.org/10.1046/j.1365-2095.2002.00200.x

Kamalam, B. S., Medale, F., & Panserat, S. (2017). Utilisation of dietary carbohydrates in farmed fishes: New insights on influencing factors, biological limitations and future strategies. *Aquaculture*, *467*, 3–27. https://doi.org/10.1016/j.aquaculture.2016.02.007

Khalasi, Y., Deo, A. D., Shamna, N., Jayant, M., Sahu, N. P., Suresh, A., Kumari, R., Adakney, S., & Danve, A. (2025). Dietary propylene glycol mitigates cold stress and improves physio-metabolic responses in *Pangasianodon hypophthalmus* (Sauvage, 1878) fingerlings reared at low temperature. *Fish Physiology and Biochemistry*, *51*(2), Article 81. https://doi.org/10.1007/s10695-025-01493-z

Krogdahl, Å., Hemre, G. I., & Mommsen, T. P. (2005). Carbohydrates in fish nutrition: Digestion and absorption in postlarval stages. *Aquaculture Nutrition*, *11*(2), 103–122. https://doi.org/10.1111/j.1365-2095.2004.00327.x

Kumar, S., Sahu, N. P., Pal, A. K., Choudhury, D., & Mukherjee, S. C. (2006). Non-gelatinized corn supplemented with á-amylase at sub-optimum protein level enhances the growth of *Labeo rohita* (Hamilton) fingerlings. *Aquaculture Research*, *37*(3), 284–292. https://doi.org/10.1111/j.1365-2109.2005.01434.x

Liang, Q., Yuan, M., Xu, L., Lio, E., Zhang, F., Mou, H., & Secundo, F. (2022). Application of enzymes as a feed additive in aquaculture. *Marine Life Science & Technology*, *4*(2), 208–221. https://doi.org/10.1007/s42995-022-00128-z

Lim, C., Webster, C. D., & Lee, C. S. (Eds.). (2008). *Alternative protein sources in aquaculture diets*. CRC Press.

Luthada-Raswiswi, R., Mukaratirwa, S., & O'Brien, G. (2021). Animal protein sources as a substitute for fishmeal in aquaculture diets: A systematic review and meta-analysis. *Applied Sciences*, *11*(9), Article 3854. https://doi.org/10.3390/app11093854

Mohanta, K. N., Subramanian, S., & Korikanthimath, V. S. (2013). Effect of dietary protein and lipid levels on growth, nutrient utilization and whole-body composition of blue gourami, *Trichogaster trichopterus* fingerlings. *Journal of Animal Physiology and Animal Nutrition*, *97*(1), 123–136. https://doi.org/10.1111/j.1439-0396.2011.01258.x

Nair, S. M., & Sajina, A. M. (2021). Fish as bio-control agent for microalgae and macrophytes in various aquatic ecosystems. *Biotica Research Today*, *3*(12), 1133–1136.

National Research Council. (2011). *Nutrient requirements of fish and shrimp*. The National Academies Press.

Prakash, P., Swapnil, N., Sheikh, S., Tekam, I., Bhalchandra, N., Madhav, G., & Munilkumar, S. (2023). Nutritional significance of fish in combating malnutrition. *International Journal of Environment and Climate Change*, *13*(11), 249–258. https://doi.org/10.9734/ijecc/2023/v13i113164

Radhakrishnan, G., Shivkumar, Mannur, V. S., Yashwanth, B. S., Pinto, N., Pradeep, A., & Prathik, M. R. (2020). Dietary protein requirement for maintenance, growth, and reproduction in fish: A review. *Journal of Entomology and Zoology Studies, 8*(4), 208–215.

Routroy, S., Prakash, P., Kumar, R., Chandan, N. K., Sahu, B., Nanda, S., Pillai, B. R., & Mohanta, K. N. (2025). Effect of varied levels of dietary protein and lipid on growth response, nutrient utilization, and whole body composition of climbing perch, *Anabas testudineus* (Bloch, 1792) fry. *Aquaculture International*, *33*(1), Article 29. https://doi.org/10.1007/s10499-024-01677-z

Sales, J., & Janssens, G. P. J. (2003). Nutrient requirements of ornamental fish. *Aquatic Living Resources*, *16*(6), 533–540. https://doi.org/10.1016/j.aquliv.2003.06.001

Samtiya, M., Aluko, R. E., & Dhewa, T. (2020). Plant food anti-nutritional factors and their reduction strategies: An overview. *Food Production, Processing and Nutrition*, *2*, Article 6. https://doi.org/10.1186/s43014-020-0020-5

Sari, D. N., Ekasari, J., Nasrullah, H., Suprayudi, M. A., & Alimuddin, A. (2022). High carbohydrate increases amylase, plasma glucose, and gene expression related to glycolysis in giant gourami *Osphronemus goramy. Fish Physiology and Biochemistry*, *48*(6), 1495–1505. https://doi.org/10.1007/s10695-022-01155-4

Serra, V., Pastorelli, G., Tedesco, D. E. A., Turin, L., & Guerrini, A. (2024). Alternative protein sources in aquafeed: Current scenario and future perspectives. *Veterinary and Animal Science, 25*, Article 100381. https://doi.org/10.1016/j.vas.2024.100381

Singh, P., Kesharwani, R. K., & Keservani, R. K. (2017). Protein, carbohydrates, and fats: Energy metabolism. In D. Bagchi (Ed.), *Sustained energy for enhanced human functions and activity* (pp. 103–115). Academic Press. https://doi.org/10.1016/B978-0-12-805413-0.00006-5

Singha, K. P., Sahu, N. P., Sardar, P., Shamna, N., & Kumar, V. (2024). A strategic roadmap for carbohydrate utilization in crustaceans' feed. *Reviews in Aquaculture*, *16*(2), 674–705. https://doi.org/10.1111/raq.12861

Steinberg, C. E. W. (2022). Carbohydrate preference and metabolism— 'Life's little luxury digested'. In *Aquatic animal nutrition: Organic macro-and micro-nutrients* (pp. 393–434). Springer.

Stone, D. A. J. (2003). Dietary carbohydrate utilization by fish. *Reviews in Fisheries Science*, *11*(4), 337–369. https://doi.org/10.1080/10641260390260884

Sulaiman, M. A., Kamarudin, M. S., Romano, N., & Syukri, F. (2020). Effects of increasing dietary carbohydrate level on feed utilisation, body composition, liver glycogen, and intestinal short chain fatty acids of hybrid lemon fin barb (*Barbonymus gonionotus*@& X *Hypsibarbus wetmorei* maleB&). *Aquaculture Reports*, *16*, Article 100250. https://doi.org/10.1016/j.aqrep.2019.100250

Talwar, P. K., & Jhingran, A. G. (1991). *Inland fishes of India and adjacent countries* (Vol. 2). CRC press.

Venou, B., Alexis, M. N., Fountoulaki, E., & Haralabous, J. (2006). Effects of extrusion and inclusion level of soybean meal on diet digestibility, performance and nutrient utilization of gilthead sea bream (*Sparus aurata*). *Aquaculture*, *261*(1), 343–356. https://doi.org/10.1016/j.aquaculture.2006.07.030

Wilson, R. P. (1994). Utilization of dietary carbohydrate by fish. *Aquaculture*, *124*(1–4), 67–80. https://doi.org/10.1016/0044-8486(94)90363-8

Zhang, L. L., Zhou, Q. C., & Cheng, Y. Q. (2009). Effect of dietary carbohydrate level on growth performance of juvenile spotted Babylon (*Babylonia areolata* Link 1807). *Aquaculture*, *295*(3–4), 238–242. https://doi.org/10.1016/j.aquaculture.2009.06.045