

Effects of Dietary Fish Oil Levels on Growth Performance and Nutrient Utilization in Larval Glass Catfish, *Kryptopterus lois* (Bleeker, 1851)

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ABSTRACT

The glass catfish, *Kryptopterus lois* (Bleeker, 1851), is economically important; however, its larval nutritional requirements remain poorly understood. This study evaluated the effects of dietary lipid levels on growth, feed utilization, survival, and whole-body composition of *K. lois* larvae. Eleven-day-old post-hatchlings with an initial body weight of 0.01 ± 0.00 g and total length of 0.47 ± 0.01 cm were reared for 60 days in net cages at 50 fish per cage, with three replicates per treatment. Four isoproteic diets containing 42.86% crude protein and 5%, 10%, 15%, or 20% lipid were compared with a commercial diet. Larvae were fed to apparent satiation four times daily. Growth performance and feed utilization improved as dietary lipid increased to 15%, whereas the 20% lipid diet provided no additional benefit. Survival exceeded 96% in all treatments and was not significantly affected by treatment. Second-order polynomial regression estimated optimal dietary lipid levels of 14.40% based on specific growth rate and 15.36% based on feed conversion ratio. Whole-body crude protein was highest in fish fed the 15% lipid diet and was comparable to that of fish fed the commercial diet. Whole-body lipid content was higher in fish fed 15%, 20%, and commercial diets than in those fed the 5% and 10% lipid diets, whereas moisture and ash were unaffected. In conclusion, these findings indicate that approximately 15% dietary supports favorable growth performance and feed utilization in *K. lois* larvae. Further studies using isoenergetic diets are needed to confirm the dietary lipid requirement of this species.

Keywords: Body composition, Larvae, Lipid requirement, Nutritional needs

INTRODUCTION

The glass catfish, *Kryptopterus lois* (Bleeker, 1851), is a freshwater species distributed in Sumatra and Borneo and is locally important in inland fisheries as a food fish. It is commonly consumed fresh or processed into smoked or salted products and has particular socioeconomic importance in Riau Province, Indonesia (Froese and Pauly, 2026). In addition to its importance as a food source, *K. lois* plays a vital role in supporting

the livelihoods of small-scale fishers in rural communities (Muchtar and Rosyadi, 2020). Furthermore, the species holds commercial potential as an ornamental fish and contributes to the conservation of native fish biodiversity in public water bodies, including lakes and reservoirs (Rosyadi *et al.*, 2025).

The growing demand for *K. lois* has driven intensive capture fisheries, raising significant concerns about overexploitation, population

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depletion, and the risk of local extinction. To ensure the species' long-term sustainability, aquaculture development represents a promising and ecologically responsible alternative. Aquaculture may reduce pressure on wild populations while promoting increased yields and consistent product quality (Rosyadi *et al.*, 2025). Despite its significant economic potential, knowledge of the nutritional requirements of *K. lais*, particularly during the larval stage, remains limited. Our previous study demonstrated that a diet containing 42.86% crude protein supports optimal growth performance in *K. lais* larvae (Rosyadi *et al.*, 2025). However, specific information on the dietary lipid requirements of this species remains unavailable. As highlighted by Toledo-Solis *et al.* (2020), defining the nutritional requirements of newly cultured fish species is a fundamental step in feed formulation and provides a basis for developing more efficient and targeted diets.

Lipids are essential components of fish diets, serving as a major energy source and supplying fatty acids, phospholipids, and sterols that support physiological processes, the maintenance of biological structures, and cell membrane integrity (Lee *et al.*, 2021). Dietary lipid supplementation may also improve protein utilization through a protein-sparing effect and reduce nitrogen excretion (Harmantepe *et al.*, 2014). In catfish, dietary lipid sources can influence growth performance, tissue fatty-acid composition, and lipid-metabolism-related gene expression (Lamkom *et al.*, 2017). Dietary phospholipid supplementation has also been shown to affect physiological and biochemical responses in pangasiid catfish, although these effects may vary according to species and life stage (Torsabo *et al.*, 2025).

The capacity of fish to utilize dietary lipids is inherently limited. Excessive lipid inclusion may suppress feed intake, impair growth performance, increase body lipid deposition, and negatively affect carcass quality (Mongile *et al.*, 2014; Bonvini *et al.*, 2015; Liao *et al.*, 2016). Considering the critical role of lipids in fish nutrition, their relatively high cost, and the need for species-specific nutritional information for emerging aquaculture candidates, the current study was designed to assess the effects of varying dietary lipid levels on growth performance,

nutrient utilization, survival, and whole-body composition in larval *K. lais*.

MATERIALS AND METHODS

Experimental diets

Four diets were prepared to contain 42.86% crude protein (isoproteic), following Rosyadi *et al.* (2025), with graded lipid levels of 5%, 10%, 15%, and 20%. A commercial diet (CD) was employed as a control. The composition and proximate analysis of the experimental diets are summarized in Table 1. Fish meal and shrimp by-product meal were used as protein sources, whereas fish oil served as the exclusive lipid source. All dry ingredients, including fish meal, soybean meal, shrimp by-product meal, wheat flour, as well as vitamin and mineral premixes, were thoroughly blended according to the predetermined formulations. Fish oil was then incorporated, followed by water equivalent to 50% of the total dry ingredient weight (w/w), to obtain a homogeneous moist paste (Hadi *et al.*, 2024). The physical properties of the final paste were evaluated by observing the consistency and ensuring it adhered to the intended texture for ease of feeding. To preserve feed quality, the prepared diets were stored at -20 °C and allowed to thaw at room temperature for about 15 min before being administered to the fish (Suharman *et al.*, 2026).

Experimental setup and water management

The larvae of *K. lais* were reared in concrete ponds (3×1.5×1 m) equipped with net cages measuring 30×30×45 cm, with each cage housing 50 larvae. A total of 15 net cages were installed in the pond. To prevent exposure to direct sunlight and rainfall, the pond was covered with a paranet. The system was equipped with aeration devices to ensure the maintenance of optimal dissolved oxygen levels, thereby supporting the larvae's growth and development. Every 10 days, 30% of the pond water was exchanged by draining the outlet, a process that facilitated the removal of waste, including fecal matter and uneaten feed. Subsequently, fresh water from a reservoir tank was introduced to replenish the water volume.

Table 1. Ingredients and proximate composition of the experimental diets during the 60-day feeding trial.

Ingredient	Dietary lipid level (% dry matter)				CD ^a
	5	10	15	20	
Fish meal	37.00	37.00	37.00	38.00	-
Shrimp by-product meal	25.00	25.00	25.00	25.00	-
Soybean meal	19.00	19.00	19.00	17.00	-
Wheat flour	14.50	11.00	6.00	2.50	-
Fish oil	0.50	4.00	9.00	13.50	-
Vitamin mix ^b	2.00	2.00	2.00	2.00	-
Mineral mix ^c	2.00	2.00	2.00	2.00	-
Proximate analysis					
Crude protein	43.09±0.19 ^b	42.82±0.10 ^b	42.84±0.12 ^b	43.05±0.10 ^b	40.64±0.11 ^a
Lipid	5.38±0.19 ^a	10.27±0.15 ^c	15.46±0.13 ^d	19.75±0.65 ^e	6.30±0.08 ^b
Ash	10.28±0.04 ^a	10.27±0.08 ^a	10.23±0.08 ^a	10.30±0.04 ^a	10.18±0.04 ^a
Crude fiber	1.89±0.05 ^b	1.90±0.06 ^b	1.88±0.08 ^b	1.81±0.05 ^b	1.59±0.10 ^a
NFE ^d	39.38±0.01 ^d	34.84±0.01 ^c	29.61±0.18 ^b	25.10±0.64 ^a	41.30±0.08 ^c
GE (kcal·100 ⁻¹ g) ^e	454.17±0.78 ^a	480.42±0.74 ^b	509.40±0.11 ^c	533.41±3.07 ^d	456.65±0.51 ^a
DE (kcal·100 ⁻¹ g) ^f	340.63±0.59 ^a	360.32±0.56 ^b	382.05±0.08 ^c	400.06±2.31 ^d	342.49±0.38 ^a
Ratio DE/P (kcal·g ⁻¹) ^g	7.91±0.05 ^a	8.42±0.03 ^b	8.92±0.02 ^c	9.29±0.07 ^d	8.43±0.03 ^b

Note: ^a CD (Commercial diet); ^b (Rosyadi *et al.*, 2025); ^c (Rosyadi *et al.*, 2025); ^d (Rosyadi *et al.*, 2025); ^e Gross energy (GE) (Chandan *et al.*, 2021); ^f Digestible energy (DE) (Hepher, 1988); ^g Energy-to-protein ratio (DE/P) (Hepher, 1988); The data are presented as mean±SD, and different superscript letters within the same row indicate significant differences between treatments (p<0.05).

Fish trial and feeding experiment

The experimental fish used were obtained from semi-artificial spawning at a fish hatchery facility, Faculty of Agriculture, Universitas Islam Riau, Pekanbaru. Three days post-hatching, *K. lais* larvae were fed finely chopped *Tubifex* sp. as a live feed during the first 10 days. Weaning onto formulated diets commenced on day 11. A total of 750 healthy larvae of uniform size were randomly stocked into 15 net cages (30×30×45 cm), with each cage containing 50 individuals with an initial body weight of 0.01±0.00 g and total length of 0.47±0.01 cm. Fish in three cages receiving the same diet were considered as one experimental treatment. The experimental diets were administered to larvae at four daily feedings (08:00 a.m., 12:00 p.m., 04:00 p.m., and 08:00 p.m.) until apparent satiation throughout the 60-day trial (Rosyadi *et al.*, 2025). Before each feeding, a 10-g portion of

the prepared diet was weighed and then offered gradually in small portions under direct observation until the larvae no longer showed an active feeding response. Uneaten feed remaining after the feeding response ceased was collected by siphoning and subsequently reweighed to estimate the amount of unconsumed feed. For feed-utilization calculations, feed intake was determined as the amount of diet offered minus the amount of uneaten feed recovered and was expressed on a dry-matter basis. The water added during diet preparation (50% of the dry ingredient weight) was excluded from the dry feed mass. To minimize feed loss through the net-cage mesh, feed was dispensed slowly near the center of each cage, and additional portions were offered only after the preceding portion had been consumed. Nevertheless, small, unquantified losses through the cage mesh could not be completely excluded; therefore, feed-utilization indices were interpreted as apparent estimates.

Sampling and proximate composition analysis

Prior to the experiment, 50 fish were randomly selected to determine their initial body weight and total length. The fish in each net cage were weighed at 10-day intervals to monitor body weight gain. After 60 days of feeding, all fish were fasted for 24 h, after which body weight, total length, and the number of fish in each cage were recorded. For whole-body proximate composition, 30 fish were collected from each treatment by pooling fish from the three replicate cages to obtain sufficient sample material. The pooled fish were homogenized, and each proximate component was determined in triplicate. These triplicate measurements were analytical replicates and were not independent biological replicates.

Proximate analyses were performed following standard AOAC (2022) procedures. Moisture content was determined by drying samples at 105 °C for 24 h in a Binder oven. Crude protein content was measured using the Kjeldahl method, lipid content was determined by Soxhlet extraction, and ash content was quantified by incinerating samples at 550 °C for 6 h. Growth and nutrient utilization parameters were determined according to the following equations:

WG (Weight gain, g)

$$= \text{final body weight (FBW)} - \text{initial body weight (IBW)}$$

SGR (Specific growth rate, %/day)

$$= [(\ln \text{FBW} - \ln \text{IBW}) / \text{days}] \times 100$$

PER (Protein efficiency ratio)

$$= \text{wet WG (g)} / \text{protein intake (g)}$$

LER (Lipid efficiency ratio)

$$= \text{wet WG (g)} / \text{lipid intake (g)}$$

DFI (Daily feed intake, %BW/day)

$$= 100 \times \text{total feed given per fish (g)} / [(\text{IBW} + \text{FBW} + \text{weight of dead fish}) / 2 \times \text{feeding days}]$$

FCR (Feed conversion ratio)

$$= \text{total dry weight of diet fed (g)} / \text{wet WG (g)}$$

CF (Condition factor, %)

$$= 100 \times [\text{BW (g)} / \text{body length}^3 \text{ (cm)}]$$

SR (Survival rate, %)

$$= [\text{number of final fish} / \text{number of initial fish}] \times 100$$

Statistical analysis

For growth performance, feed-utilization indices, condition factor, and survival, the replicate cage was considered the experimental unit ($n = 3$ cages per treatment), and data are expressed as mean $\pm$ SD. Statistical analyses were performed using SPSS version 21.0 (IBM, Chicago, IL, USA). Normality of residuals and homogeneity of variances were assessed using the Shapiro–Wilk and Levene's tests, respectively. Data were analyzed by one-way analysis of variance (ANOVA), followed by Duncan's multiple range test when significant differences were detected ($p < 0.05$). Second-order polynomial regression was used to estimate the optimal dietary lipid level based on SGR and FCR. Only the four graded experimental diets (5%, 10%, 15%, and 20% lipid) were included in the regression analysis, while the commercial reference diet was excluded.

RESULTS

The experimental diets contained similar crude protein concentrations but progressively higher lipid and energy levels as dietary fish oil inclusion increased (Table 1). Lipid content increased from 5.38% to 19.75%, whereas NFE decreased from 39.38% to 25.10%. The commercial diet differed from the experimental diets in crude protein, lipid, crude fiber, NFE, and several calculated energy variables.

Growth performance of *K. lais* larvae across all treatments exhibited a consistent and stable trend during the first 10 days of the experimental period. However, after this period, significant differences in body weight gain and total length increase were observed among treatments (Figures 1a and 1c). At the end of the experiment L15 and CD showed the highest body weight and length (Figures 1b and 1d).

Weight gain (WG), specific growth rate (SGR), protein efficiency ratio (PER), lipid efficiency ratio (LER), and feed conversion ratio (FCR) in fish fed the 15% lipid diet were comparable to those in fish fed the commercial diet and were better than those in fish fed 5%, 10%, and 20% lipid diets as shown in Table 2. The lipid efficiency ratio (LER) showed a different trend, with the highest value observed in the commercial diet group. Among the lipid supplanted groups, the LER values followed the order L5>L10, L20>L15. However, daily feed intake (DFI), condition factor (CF), and survival rate (SR) were not significantly different among groups.

Second-order polynomial regression analyses of SGR and FCR estimated optimal dietary lipid level of 14.40% and 15.36%, respectively

(Figure 2). Overall, these results indicate that dietary lipid levels of approximately 14–15% may support optimal growth performance and feed utilization efficiency in *K. lais* larvae.

Whole-body proximate composition of *K. lais* larvae fed diets with different lipid levels is shown in Table 3. The 15% lipid diet resulted in the highest crude protein content ($18.53 \pm 0.06\%$), which did not differ significantly from that of the commercial diet. Whole-body crude lipid content increased with dietary lipid level. Fish fed the commercial diet had the highest numerical lipid content ($7.42 \pm 0.06\%$), although this value did not differ significantly from those of fish fed the 15% ($7.18 \pm 0.27\%$) and 20% lipid diets ($7.37 \pm 0.06\%$). No significant differences were observed in ash content among treatments, which values averaging

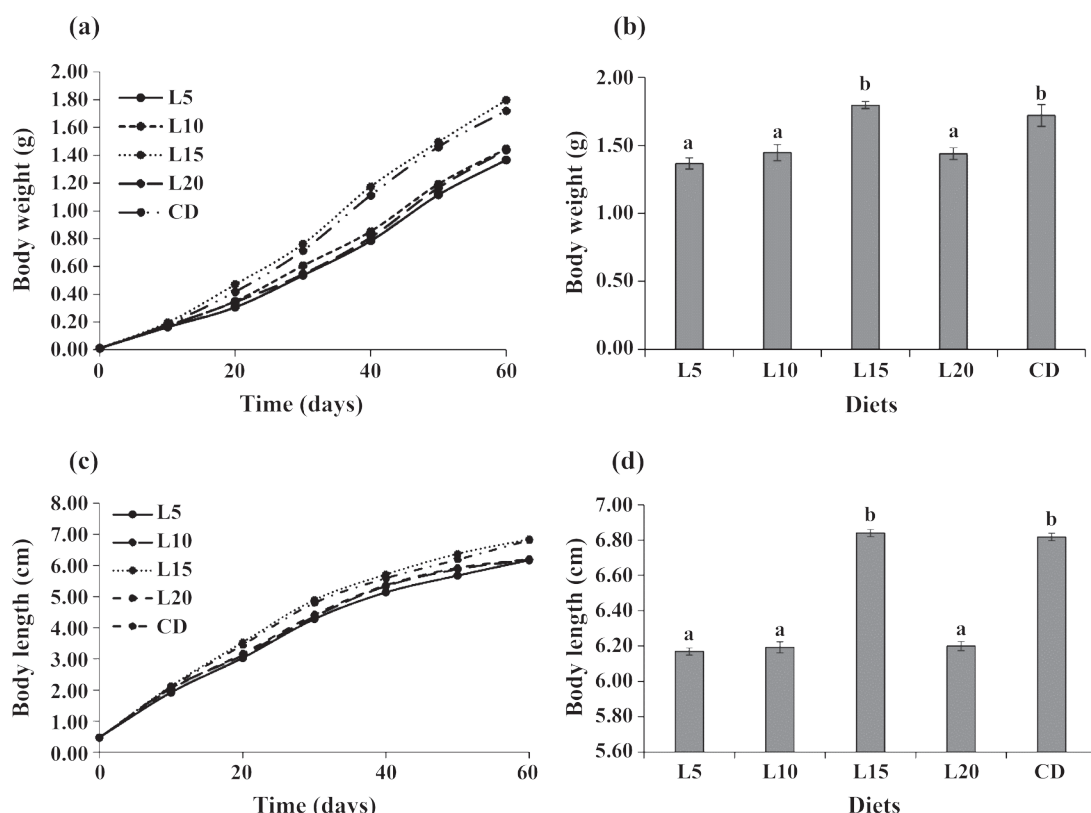


Figure 1. Growth performance of *Kryptopterus lais* larvae fed diets containing 5–20% lipid (L5–L20) or a commercial diet (CD): (a) body weight over the 60-day experimental period; (b) weight measured on day 60; (c) total length over the 60-day experimental period; (d) body length measured on day 60. Different superscripts above the bars indicate significant differences among treatment means ($p < 0.05$).

Table 2. Growth performance, feed utilization, condition factor, and survival rates of *Kryptopterus lais* larvae fed diets containing 5%, 10%, 15%, or 20% lipid or a commercial diet (CD) for 60 days.

Indices	Lipid level (%)				CD
	5	10	15	20	
WG (g)	1.36±0.04 ^a	1.43±0.07 ^a	1.79±0.03 ^b	1.43±0.04 ^a	1.71±0.08 ^b
SGR (%·day ⁻¹)	7.89±0.19 ^a	8.09±0.27 ^a	8.50±0.13 ^b	8.12±0.05 ^a	8.58±0.08 ^b
PER	1.45±0.02 ^a	1.58±0.08 ^b	1.68±0.08 ^c	1.65±0.01 ^b	1.88±0.07 ^c
LER	11.66±0.14 ^c	6.58±0.33 ^b	5.14±0.22 ^a	5.60±0.02 ^b	12.15±0.43 ^d
DFI (%·day ⁻¹)	6.95±1.85	7.87±2.23	8.28±2.09	8.12±1.10	6.89±1.99
FCR	1.58±0.01 ^c	1.47±0.06 ^b	1.25±0.04 ^a	1.40±0.00 ^b	1.30±0.05 ^a
CF (%)	0.58±0.02	0.61±0.02	0.56±0.01	0.60±0.02	0.55±0.03
SR (%)	96.67±2.31	98.67±1.15	98.00±2.00	98.00±2.00	97.33±3.06

Note: Values are presented as mean±SD (n = 3). Different superscript letters within the same row indicate significant differences between treatments (p<0.05); WG = Weight gain; SGR = Specific growth rate; PER = Protein efficiency ratio; LER = Lipid efficiency ratio; DFI = Daily feed intake; FCR = Feed conversion ratio; CF = Condition factor; SR = Survival rate

Table 3. Whole-body proximate composition of *Kryptopterus lais* larvae fed diets containing 5%, 10%, 15%, or 20% lipid or a commercial diet (CD) for 60 days.

Indices	Lipid level (%)				CD
	5	10	15	20	
Crude protein	16.80±0.06 ^a	17.04±0.28 ^a	18.53±0.06 ^b	17.10±0.01 ^a	18.39±0.05 ^b
Crude lipid	5.29±0.05 ^a	5.98±0.13 ^b	7.18±0.27 ^c	7.37±0.06 ^c	7.42±0.06 ^c
Ash	4.16±0.04	4.14±0.03	4.13±0.02	4.11±0.02	4.13±0.01
Moisture	67.74±0.02	67.66±0.05	67.72±0.04	67.75±0.03	67.69±0.04

Note: Values are presented as mean±SD. Different superscript letters within the same row indicate significant differences between treatments (p<0.05).

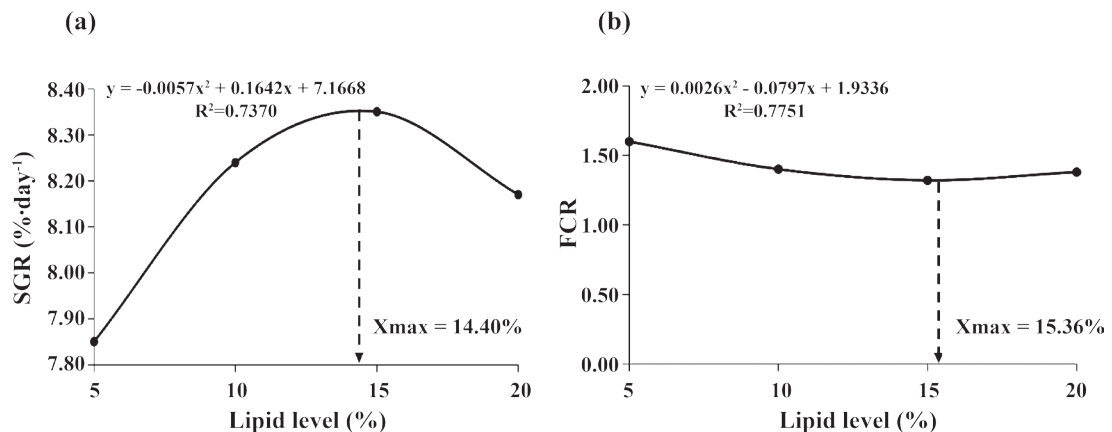


Figure 2. Second-order polynomial regression of (a) specific growth rate (SGR) and (b) feed conversion ratio (FCR) in *Kryptopterus lais* larvae fed diets containing 5–20% lipid for 60-days. The estimated optimal dietary lipid levels were 14.40% for SGR and 15.36% for FCR.

approximately 4.13%. Whole-body moisture content also showed no significant variation, ranging from 67.66% to 67.75%. These findings indicate that increasing dietary lipid levels significantly affected whole-body protein and lipid content, but had no significant effect on ash or moisture content.

Water quality variables, including temperature (27–30 °C), dissolved oxygen (DO; 5.40–6.30 mg·L⁻¹), pH (5.40–6.10), and ammonia concentration (0.01–0.15 mg·L⁻¹), were all maintained within acceptable limits for supporting normal larval development.

DISCUSSION

Owing to their highly efficient digestive and metabolic characteristics, lipids in fish diets serve not only as a vital energy source but also play a key role in supporting maximal growth by sparing dietary protein. Given the limited capacity of carnivorous fish to utilize carbohydrates, energy supply can be optimized through appropriate lipid supplementation in formulated diets (Glencross *et al.*, 2017). In the present study, both WG and SGR increased with increasing dietary lipid levels up to 15%, beyond which a significant decline was observed. These results indicate that lipid inclusion levels exceeding 15% do not confer additional growth benefits for *K. lais* larvae. Similar growth response patterns to excessive dietary lipid levels have been reported in a wide range of fish species, including *Hemibagrus wyckioides* (Deng *et al.*, 2021), *Nibea japonica* (Han *et al.*, 2014), *Petenia splendida* (Rodríguez-Estrada *et al.*, 2020), *Oplegnathus punctatus* (Wang *et al.*, 2021), *Gadus chalcogrammus* (Lee *et al.*, 2021), hybrid pufferfish (*Takifugu obscurus* × *T. rubripes*) (Yoo *et al.*, 2022), lumpfish *Cyclopterus lumpus* (Berge *et al.*, 2023), kelabau *Osteochilus melanopleura* (Susanto *et al.*, 2024), yellow catfish *Pelteobagrus fulvidraco* (Fei *et al.*, 2024), and *Epinephelus moara* (Liu *et al.*, 2025), all of which exhibited reduced growth performance when dietary lipid levels exceeded optimal thresholds.

The improved growth observed at 15% dietary lipid may reflect a more favorable balance between dietary protein and non-protein energy. However, metabolic rate, energy expenditure, and

activity-related energy demand were not directly measured in the present study. In addition, because the experimental diets were isoproteic but not isoenergetic, the observed responses may reflect the combined effects of dietary lipid level, energy concentration, and carbohydrate content.

The protein efficiency ratio (PER) increased significantly with increasing dietary lipid levels up to 15%, followed by a clear decline at higher lipid inclusion levels. This finding is consistent with previous studies on various fish species, including striped catfish *Pangasianodon hypophthalmus* (Sivaramakrishnan *et al.*, 2017), Manchurian trout *Brachymystax lenok* (Chang *et al.*, 2017), and kelabau *Osteochilus melanopleura* (Susanto *et al.*, 2024), which demonstrated that appropriate dietary lipid levels can enhance protein utilization efficiency for body protein synthesis. The higher PER observed at 15% dietary lipid suggests improved dietary protein utilization and may be consistent with a protein-sparing effect, although protein retention and nitrogen balance were not directly measured. In contrast, a protein-sparing effect was not observed in several other species fed diets with varying lipid levels, such as *Siganus rivulatus* (Ghanawi *et al.*, 2011), yellowfin seabream *Acanthopagrus latus* (Pang *et al.*, 2024), hybrid pufferfish (Yoo *et al.*, 2022), and *Epinephelus moara* (Liu *et al.*, 2025). These contrasting responses highlight the need for a more comprehensive understanding of optimal dietary lipid integration in feed formulation, particularly for newly cultured fish species.

The lipid efficiency ratio (LER) varied markedly among treatments, with the lowest value observed in fish fed the 15% lipid diet (5.14±0.22). However, because LER is calculated as weight gain relative to lipid intake, its decline with increasing dietary lipid partly reflects the greater amount of lipid consumed and should not be interpreted alone as evidence of impaired physiological lipid utilization. The 20% lipid treatment also produced a significantly higher LER than the 15% treatment. In contrast, studies on other species, such as bay snook *Petenia splendida* (Rodríguez-Estrada *et al.*, 2020) and parrotfish *Oplegnathus fasciatus* (Eom *et al.*, 2024), did not report similar negative effects of increasing dietary lipid levels, suggesting that species-specific responses to dietary lipid inclusion are common.

In terms of feed conversion ratio (FCR), the 15% lipid diet produced the lowest numerical value (1.25 ± 0.04), which was significantly lower than those of the 5%, 10%, and 20% lipid diets but did not differ significantly from that of the commercial diet. These findings underscore the importance of appropriate dietary lipid levels for maximizing feed conversion into fish biomass. Daily feed intake (DFI) remained stable across all treatments, ranging from 6.89% to 8.28%, with no significant differences detected, indicating that variations in dietary lipid levels did not significantly influence feed consumption. Similarly, condition factor (CF) and survival rate (SR) did not differ significantly among treatments, with mean survival exceeding 96% across all groups, suggesting that dietary quality did not adversely affect the survival of *K. lais* larvae. Comparable outcomes have been reported in other species, including pollock *Gadus chalcogrammus* with mean survival rates above 93.9% (Lee *et al.*, 2021), hybrid pufferfish (*Takifugu obscurus* $\times$ *T. rubripes*) with survival exceeding 85% (Yoo *et al.*, 2022), and parrotfish *Oplegnathus fasciatus* with average survival rates above 90.6% (Eom *et al.*, 2024).

The present study indicates that a dietary lipid level of approximately 15% provides favorable benefits for growth performance and feed utilization efficiency in *K. lais* larvae. Second-order polynomial regression estimated optimal dietary lipid levels of 14.40% based on SGR and 15.36% based on FCR. Comparable results have been reported in other fish species, such as longsnout catfish *Leiocassis longirostris*, which exhibited optimal performance at a dietary lipid level of 14.3% (Pei *et al.*, 2004). In contrast, several other fish species, including *Siganus rivulatus* 8.5% (Ghanawi *et al.*, 2011), *Nibea japonica* 8.22% (Han *et al.*, 2014), *Psetta maxima* 13% (Sevgili *et al.*, 2014), *Pangasianodon hypophthalmus* 10.1% (Sivaramakrishnan *et al.*, 2017), *Oplegnathus punctatus* 12.83% (Wang *et al.*, 2021), hybrid pufferfish 10% (Yoo *et al.*, 2022), and yellowfin seabream *Acanthopagrus latus* 12.83% (Pang *et al.*, 2024)—have been shown to require lower dietary lipid levels. Conversely, studies on bay snook

Petenia splendida, South American catfish *Pseudoplatystoma* sp., and East Asian catfish *Silurus asotus* reported higher optimal dietary lipid requirements for enhanced growth, at 16.2%, 16.0%, and 17.0%, respectively (Arslan *et al.*, 2012; Kim *et al.*, 2012; Rodríguez-Estrada *et al.*, 2020).

Numerous studies have examined the relationship between dietary lipid levels and whole-body lipid deposition (Shapawi *et al.*, 2014; Huang *et al.*, 2022; Shen *et al.*, 2022; Pang *et al.*, 2024). Consistent with these reports, our results showed that increasing dietary lipid levels significantly affected whole-body crude lipid content. Whole-body lipid content increased from the 5% to the 15% lipid treatment. The commercial diet produced the highest numerical value ($7.42 \pm 0.06\%$), although this value did not differ significantly from those of fish fed the 15% ($7.18 \pm 0.27\%$) and 20% lipid diets ($7.37 \pm 0.06\%$). Similar patterns have been reported in hybrid pufferfish (Yoo *et al.*, 2022), *Petenia splendida* (Rodríguez-Estrada *et al.*, 2020), and *Hemibagrus wyckioides* (Deng *et al.*, 2021). The highest whole-body crude protein content was observed in fish fed the 15% lipid diet ($18.53 \pm 0.06\%$), and this value did not differ significantly from that of fish fed the commercial diet. This result indicates that dietary treatment affected whole-body protein content, although protein synthesis was not directly measured.

Ash and moisture contents remained relatively stable across treatments, suggesting that variations in dietary lipid levels did not substantially affect mineral composition or body water content. Collectively, these findings indicate that a dietary lipid level of approximately 15% supports favorable growth performance and feed conversion in *K. lais* larvae. However, whole-body lipid content at this level did not differ significantly from that observed in fish fed the 20% lipid or commercial diet. Because the experimental diets were isoproteic but not isoenergetic, further studies using isoenergetic diets and direct measurements of nutrient retention are needed to confirm the dietary lipid requirement and possible protein-sparing effect in this species.

CONCLUSIONS

Based on the present findings, a dietary lipid level of approximately 15% supports favorable growth performance and feed utilization in larval *K. lais*. Increasing dietary lipid above this level provided no additional growth benefit and was associated with reduced feed utilization efficiency. Further studies using isoenergetic diets are needed to confirm the dietary lipid requirement of this species.

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