



Dietary inclusion of the brown seaweed *Sargassum ilicifolium* meal in diets for the endemic Iranian cichlid *Iranocichla hormuzensis*: effects on growth performance, feed utilization and whole-body composition

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Abstract

The Iranian cichlid, *Iranocichla hormuzensis* Coad, 1982, is an endemic cichlid of Southern Iran with potential value as a native ornamental and aquaculture species. This study evaluated the effects of dietary inclusion of dried meal of the brown seaweed *Sargassum ilicifolium*, collected from the Chabahar coastal area of the Gulf of Oman, on growth performance, feed utilization, somatic indices and whole-body composition of *I. hormuzensis*. Fish with an initial mean body weight of approximately 51 g were fed for 56 days with four experimental diets containing 0%, 5%, 10% or 15% *S. ilicifolium* meal. The diets were formulated to provide approximately similar crude-protein concentrations. Fish receiving the 5% seaweed diet showed the highest numerical final body weight, weight gain, relative weight gain, survival and protein efficiency ratio and the lowest numerical feed conversion ratio. However, according to the reported statistical results, differences among treatments in growth performance, survival and feed-utilization indices were not statistically significant ($p>0.05$). Hepatosomatic, viscerosomatic and gonadosomatic indices were also not significantly affected by dietary seaweed inclusion. Whole-body moisture, crude protein and crude lipid contents did not differ significantly among treatments, whereas a significant difference was reported for whole-body ash content. Overall, low-level inclusion of *S. ilicifolium* meal, particularly at 5%, appeared to be well tolerated by *I. hormuzensis* under the experimental conditions and produced the most favourable numerical growth response. However, the absence of statistically significant differences in most production variables does not support a definitive growth-promoting effect. The findings are consistent with the broader evidence that responses to dietary macroalgae are strongly dependent on fish species, seaweed species, inclusion level and diet formulation. Further experiments using clearly independent replicate tanks, digestibility measurements and characterization of mineral, contaminant and bioactive-compound profiles are required to establish the nutritional and functional value of *S. ilicifolium* for this endemic cichlid.

Keywords: *Iranocichla hormuzensis*, *Sargassum ilicifolium*, Brown seaweed, Macroalgae, Dietary inclusion, Growth performance, Feed conversion ratio, Whole-Body composition, Ornamental fish, Aquaculture

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Introduction

The development of sustainable aquaculture increasingly depends on the identification of locally available feed ingredients that can contribute nutritional or functional value without compromising fish performance. Marine macroalgae have attracted considerable attention because they contain minerals, carbohydrates, dietary fiber, pigments, polyphenols and bioactive polysaccharides. However, the nutritional value of whole seaweed meals is highly variable and depends on species, geographical origin, season, environmental conditions, harvesting procedures and processing methods. Consequently, responses to macroalgae in aquafeeds are strongly species- and dose-dependent.

Recent evidence supports the use of macroalgae primarily as functional or complementary feed ingredients rather than as straightforward substitutes for conventional protein sources. A 2026 meta-analysis based on 138 publications found that dietary seaweed generally improved specific growth rate but that responses were highly heterogeneous. Fish species and trophic level, seaweed species, inclusion rate, the protein source being replaced and the mode of incorporation all contributed to variation among studies. Inclusion levels below 5% were associated with more favorable responses, whereas higher inclusion levels were increasingly likely to impair growth or feed efficiency.

Brown seaweeds are of particular interest because they contain compounds such as fucoidan, alginate and

phlorotannins, which may contribute antioxidant, immunomodulatory or other biological activities. At the same time, whole brown-seaweed meals may contain substantial amounts of ash, fiber and structural polysaccharides and comparatively low levels of protein. Increasing dietary inclusion may therefore alter nutrient density and digestibility even when crude protein and energy are approximately balanced.

The Iranian cichlid, *Iranocichla hormuzensis* (Coad, 1982), is an endemic cichlid of southern Iran. The species occurs in drainage systems around the Strait of Hormuz and is adapted to warm freshwater and brackish environments. Natural stomach-content studies indicate that algae, including diatoms, and detrital material are important components of its natural food resources. Keivany and Daneshvar (2016), based on 432 guts examined over a 13-month period, classified the species as omnivorous and reported that males tended to have more herbivorous feeding habits than females. These characteristics provide a biological rationale for investigating plant- and algal-derived dietary ingredients in this species.

The feasibility of maintaining *I. hormuzensis* under captive conditions has also been investigated in Iran. Dadgar *et al.* reported successful adaptation of wild-caught Iranian cichlids to aquarium conditions, supporting the feasibility of maintaining the species under controlled culture conditions and its potential as a native ornamental fish (Dadgar *et al.*, 2015).

This previous work provides an important background for developing nutritional protocols for captive *I. hormuzensis*.

Nutritional research on *I. hormuzensis* remains limited. One later study evaluated *Azolla filiculoides* as a plant-protein ingredient in diets for the species. Hafezieh *et al.* (2020) replaced 15–60% of dietary protein sources with Azolla powder for eight weeks. Growth was not significantly impaired by the tested replacements, while 45% replacement produced the highest numerical weight increase and higher replacement levels adversely affected growth and survival. This study demonstrates that plant-derived aquatic biomass can be incorporated into diets for *I. hormuzensis*, but it does not address the nutritional or functional value of marine macroalgae.

Sargassum ilicifolium is a brown macroalga occurring along the Iranian coastline of the Persian Gulf and Gulf of Oman. Previous Iranian research has examined its chemical composition and dietary applications. Hafezieh *et al.* (2017), including the present author among the co-authors, investigated the proximate and chemical composition of *S. ilicifolium* collected from 18 stations along the coast of Sistan and Baluchestan. Samples from Tis Beach near Chabahar contained approximately 9.18% protein on a dry-weight basis, together with substantial carbohydrate, mineral and bioactive components, illustrating the nutritional variability of this biomass.

Other studies have evaluated *S. ilicifolium* in aquafeeds. Zamannejad *et al.* (2016) investigated 5%, 7.5% and 10% inclusion in rainbow-trout diets and reported significant effects on several growth and feed-utilization variables at lower inclusion levels. Hafezieh *et al.* (2017) evaluated 5–15% replacement of protein sources with *S. ilicifolium* meal in white-leg shrimp diets and reported significant effects on muscle cholesterol but not body lipid content. More recently, Zeynali *et al.* (2020) investigated replacement of fishmeal with *S. ilicifolium* meal in juvenile Asian seabass and assessed growth, innate immunity and immune-gene expression.

More recent work has also emphasized the distinction between whole seaweed meal and isolated bioactive fractions. Pourazad *et al.* (2024) reported that sulfated polysaccharides extracted from *S. ilicifolium* at 2–4 g kg⁻¹ diet improved antioxidant and immune-related responses in juvenile *Litopenaeus vannamei* without impairing growth. These results suggest that functional effects of *S. ilicifolium* may be associated with specific bioactive fractions and should not automatically be attributed to whole-seaweed meal.

A recent study in *Catla catla* further demonstrated species-specific responses to whole *S. ilicifolium* meal. Fish were fed 3%, 5% or 7% seaweed for 60 days, and the 7% treatment produced the highest growth and improved several physiological responses. This contrasts with other studies in which higher seaweed inclusion reduced performance

and reinforces the importance of species, basal diet and inclusion level when interpreting seaweed-feeding studies.

Importantly, the biochemical composition of *S. ilicifolium* collected from Chabahar is not constant. Kowsari Sedgh and Fakhrian (2023) demonstrated significant changes in protein, ash, carbohydrate, moisture and astaxanthin concentrations before and after the monsoon in Chabahar Bay. Therefore, the composition reported for the seaweed used in the present study should be regarded as characteristic of the particular biomass and collection conditions rather than as a universal composition for the species.

To the best of the authors' knowledge, published literature has not previously evaluated whole *S. ilicifolium* meal as a dietary ingredient in *I. hormuzensis*. The closest studies concern either *I. hormuzensis* fed another aquatic plant ingredient, such as *Azolla*, or *S. ilicifolium* used in diets for other fish and shrimp species. The present study therefore addresses a specific species–ingredient combination that remains poorly documented.

The objective of the present study was to evaluate the effects of dietary inclusion of *S. ilicifolium* meal at 5%, 10% and 15% on growth performance, feed utilization, somatic indices and whole-body composition of *I. hormuzensis*. The study was designed to identify an inclusion level that could be tolerated by this endemic Iranian cichlid and to provide baseline information for future nutritional and functional-feed research.

Materials and methods

Experimental period and seaweed preparation

The feeding experiment lasted 56 days.

Fresh *Sargassum ilicifolium* was collected from the coastal area of Chabahar, Sistan and Baluchestan Province, Iran. The collected biomass was washed with seawater and subsequently with freshwater to remove sediment and attached materials. The seaweed was sun-dried and ground into a fine meal before incorporation into the experimental diets. The proximate composition of the seaweed meal was determined using standard analytical procedures (Table 1).

Table 1: Proximate composition of *Sargassum ilicifolium* meal.

Component	Value
Dry matter (%)	91.0
Crude protein (% DM)	9.8
Ash (% DM)	41.6
Neutral detergent fibre (% DM)	26.4
Acid detergent fibre (% DM)	12.1
Crude fibre (% DM)	8.4

The seaweed contained relatively low crude protein and high ash, characteristics that are relevant when increasing the proportion of whole seaweed meal in a complete diet. These values are also broadly consistent with the variability reported for Iranian *S. ilicifolium* biomass (Hafezieh *et al.*, 2017; Siddik *et al.*, 2023).

Experimental diets

Four experimental diets were prepared containing 0% (control), 5%, 10% and 15% *S. ilicifolium* meal. Diets were formulated to provide approximately

comparable crude-protein concentrations. The ingredients were mixed, oil was incorporated, and approximately 40% boiled distilled water was added to facilitate pelleting.

The diets were mechanically pelleted, dried in a cabinet dryer and stored at -20°C until use (Table 2).

Table 2: Proximate composition and calculated energy content of the experimental diets.

Parameter	Control	5% S	10% S	15% S
Moisture (%)	7.08	7.14	7.00	7.09
Crude protein (% DM)	33.22	33.16	33.13	32.09
Ash (% DM)	8.11	8.45	8.56	8.82
NFE (% DM)	20.57	20.31	20.80	21.21
Calculated energy (kcal kg^{-1})	3555	3560	3562	3564

The diets should therefore be described as approximately isonitrogenous, rather than strictly isonitrogenous. The approximately 1.1 percentage-point difference in crude protein between the control and 15% treatment should also be considered when interpreting growth responses. The complete formulation of the diets, including percentages of all ingredients and the source and type of oil, should be provided in the final journal version.

Fish and experimental design

A total of 180 *I. hormuzensis* with an initial mean body weight of approximately 51 g were obtained from a private ornamental-fish production facility. Fish were selected to obtain a relatively homogeneous size distribution and randomly allocated to the experimental treatments.

Four dietary treatments were evaluated:

- Control: 0% *S. ilicifolium*
- 5% S: 5% *S. ilicifolium*
- 10% S: 10% *S. ilicifolium*
- 15% S: 15% *S. ilicifolium*

Fish were fed to apparent satiation three times daily at approximately 09:00, 14:00 and 17:00. Feed consumption was recorded daily.

Experimental-unit verification

The original experimental record describes three concrete tanks while also indicating four dietary treatments with three replicates. These descriptions are incompatible. The total number of fish (180) is consistent with four treatments $\times$ three replicates $\times$ 15 fish per replicate. However, the exact number and arrangement of independent experimental units must be confirmed from the original records before submission.

Water quality

Approximately 30% of the water was exchanged daily. Temperature, dissolved oxygen, pH, nitrite, nitrate and phosphate were monitored throughout the experiment. Tanks were cleaned periodically and refilled with fresh water (Table 3).

Table 3: Water-quality parameters during the feeding trial.

Parameter	Mean value
Temperature (°C)	27.0
Dissolved oxygen (mg L ⁻¹)	7.9
pH	7.6
Nitrite, NO ₂ ⁻ (mg L ⁻¹)	0.6
Nitrate, NO ₃ ⁻ (mg L ⁻¹)	3.7
Phosphate, PO ₄ ³⁻ (mg L ⁻¹)	0.5

Proximate analysis

The proximate composition of the seaweed meal, experimental diets and whole fish was determined according to standard AOAC (2019) procedures. Dry matter was determined gravimetrically, Weight gain (WG, g) was calculated as:

WG = final body weight – initial body weight

Relative weight gain (RWG, %) was calculated as:

$RWG = [(final\ body\ weight - initial\ body\ weight) / initial\ body\ weight] \times 100$

Specific growth rate (SGR, % day⁻¹) was calculated as:

$SGR = [\ln(final\ body\ weight) - \ln(initial\ body\ weight)] / days \times 100$

Feed conversion ratio (FCR) was calculated as:

FCR = feed intake / weight gain

Protein efficiency ratio (PER) was calculated as:

PER = weight gain / protein intake

Survival was calculated as the percentage of fish remaining alive at the end of the experiment.

Somatic indices and whole-body composition

At the end of the feeding trial, 15 fish from each dietary treatment were

crude protein by the Kjeldahl method, ash following incineration and crude lipid by Soxhlet extraction. The specific analytical method numbers should be added to the final manuscript if they are available in the original laboratory records.

Growth and feed-utilization indices

Growth performance was evaluated using initial body weight, final body weight, weight gain, relative weight gain, specific growth rate and survival.

randomly selected for chemical analysis. Liver, viscera and gonads were removed and weighed. The following indices were calculated:

Hepatosomatic index (HSI, %) = liver weight / body weight $\times 100$

Viscerosomatic index (VSI, %) = viscera weight / body weight $\times 100$

Gonadosomatic index (GSI, %) = gonad weight / body weight $\times 100$

Whole-body moisture, crude protein, crude lipid and ash were determined

using standard proximate-analysis procedures.

Statistical analysis

The original study used one-way analysis of variance (ANOVA), followed by Duncan's multiple-range test at a significance level of 5%. However, the statistical unit requires clarification before publication. If individual fish were treated as independent observations while fish were housed in shared tanks or compartments, pseudoreplication may have occurred. For growth and feed-utilization variables, the independent tank or compartment receiving a dietary treatment should normally constitute the experimental unit. Fish sampled within a tank should generally be treated as subsamples unless the experimental design specifically justifies individual-fish replication. Accordingly, the original statistical analysis should be reconstructed from the raw data using the actual experimental-unit structure before submission.

Results

Growth performance, feed utilization and survival

All experimental diets were consumed by *I. hormuzensis* during the 56-day feeding period. Fish fed the 5% *S. ilicifolium* diet showed the highest numerical final body weight and weight gain, followed by the control treatment, whereas fish receiving 10% and 15% seaweed showed lower numerical growth.

Mean body weight increased from 50.9 to 117.4 g in the control treatment, from 51.1 to 119.2 g in the 5% treatment, from 51.2 to 104.8 g in the 10% treatment and from 51.0 to 100.5 g in the 15% treatment. Using the standard equations, the relative weight gains calculated from the reported initial and final weights were approximately 130.6%, 133.3%, 104.7% and 97.1% for the control, 5%, 10% and 15% treatments, respectively.

Similarly, the recalculated SGR values were approximately 1.49, 1.51, 1.28 and 1.21% day⁻¹, respectively (Table 4).

Table 4: Growth performance and feed utilization of *Iranocichla hormuzensis* fed diets containing different levels of *S. ilicifolium*.

Parameter	Control	5% S	10% S	15% S
Initial body weight (g)	50.9	51.1	51.2	51.0
Final body weight (g)	117.4	119.2	104.8	100.5
Weight gain (g)	66.5	68.0	53.6	49.5
Relative weight gain (%)†	130.6	133.3	104.7	97.1
SGR (% day ⁻¹)†	1.49	1.51	1.28	1.21
Survival (%)	91.9	97.5	94.4	93.9
FCR	2.3	2.0	2.4	2.5
PER	3.5	3.7	3.4	3.0

† Recalculated from the reported initial and final body weights using standard equations.

The 5% treatment therefore produced the highest numerical growth response. However, the original statistical analysis

reported no significant differences among treatments for the principal growth variables ($p>0.05$).

Consequently, the data do not demonstrate a statistically confirmed growth-promoting effect of 5% *S. ilicifolium*.

Survival was numerically highest in the 5% treatment (97.5%), followed by the 10% (94.4%), 15% (93.9%) and control (91.9%) treatments. According to the original analysis, these differences were not statistically significant. The 5% diet also produced the numerically lowest FCR (2.0) and highest PER (3.7), whereas the 15% diet produced the highest FCR (2.5) and lowest PER (3.0).

These differences were reported as statistically non-significant.

Somatic indices

The HSI, VSI and GSI were not significantly affected by dietary treatment ($p>0.05$). The lowest numerical HSI and VSI occurred in fish receiving the 5% diet. GSI increased numerically with increasing seaweed inclusion, from 1.2% in the control to 1.9%, 2.2% and 2.3% in the 5%, 10% and 15% treatments, respectively. These differences were nevertheless reported as non-significant (Table 5).

Table 5: Somatic indices of *Iranocichla hormuzensis* at the end of the feeding trial.

Index (%)	Control	5% S	10% S	15% S
HSI	1.8	1.3	1.6	1.5
GSI	1.2	1.9	2.2	2.3
VSI	6.4	5.2	6.4	6.7

Whole-body composition

Dietary inclusion of *S. ilicifolium* did not significantly affect whole-body moisture, crude protein or crude lipid. Whole-body crude protein was numerically highest in the 10% treatment and lowest in the 15% treatment. Crude lipid was numerically lower in all seaweed treatments than in

the control. A difference among treatments was reported for whole-body ash, with the highest numerical value occurring in the 15% treatment. The original significance letters and exact *P*-values should be regenerated from the raw statistical output before submission (Table 6).

Table 6: Whole-body proximate composition of *Iranocichla hormuzensis* (% wet weight).

Component	Control	5% S	10% S	15% S
Moisture	69.2	71.4	70.0	71.9
Crude protein	10.8	10.6	11.2	9.1
Crude lipid	8.5	7.0	7.2	7.2
Ash	11.5	11.0	11.6	12.8

Discussion

The principal finding of the present study was that whole *S. ilicifolium* meal was apparently tolerated by *I. hormuzensis* at dietary inclusion levels

of 5–15% over 56 days. The 5% treatment generated the highest numerical final weight, weight gain, relative growth, survival and PER and the lowest numerical FCR. However, the

reported statistical analysis did not identify significant differences among treatments for most growth and feed-utilization variables. The scientifically appropriate interpretation is therefore that 5% produced the most favourable numerical response rather than demonstrating a statistically confirmed growth-promoting effect.

This distinction is particularly important in view of the recent meta-analysis of dietary seaweed inclusion in fish diets. Weththasinghe *et al.* (2026) found substantial heterogeneity among studies and identified fish species, trophic level, seaweed species, inclusion level, the protein source replaced and the mode of incorporation as contributors to variation. The authors found more favourable responses at lower inclusion levels, whereas higher inclusion levels were increasingly associated with impaired growth or feed efficiency. The numerical pattern observed in the present experiment—better performance at 5% followed by lower performance at 10–15%—is therefore biologically plausible, but the present study does not provide sufficient statistical evidence to establish a dose-response relationship.

The feeding ecology of *I. hormuzensis* provides an additional biological rationale for investigating algal ingredients. Natural feeding studies have shown that algae and detrital material form important components of its food resources, and males in particular may show more herbivorous feeding characteristics. The species may therefore have greater physiological capacity to utilize plant-

and algal-derived dietary material than strictly carnivorous ornamental fishes.

The previous work of Dadgar *et al.* (2015) demonstrated that *I. hormuzensis* can adapt to aquarium conditions and can be maintained under controlled culture conditions. This is relevant to the present study because the practical development of a nutritional protocol for an endemic ornamental species requires not only an appropriate feed ingredient but also reliable captive husbandry.

The present findings also complement the study of Hafezieh *et al.* (2020), who evaluated *Azolla filiculoides* as a plant-protein ingredient in *I. hormuzensis*. Their results indicated that considerable replacement of conventional protein sources was possible without significant adverse effects on growth at some inclusion levels, although excessive replacement impaired growth and survival. The common feature of the two studies is that aquatic plant or algal biomass can be incorporated into diets for *I. hormuzensis*, while the optimal level depends on the characteristics of the biomass and the basal diet.

The relatively high ash content of the seaweed meal used in the present experiment is an important nutritional consideration. The *S. ilicifolium* meal contained 41.6% ash on a dry-matter basis, while the complete diets showed a progressive increase in ash from 8.11% in the control to 8.82% in the 15% treatment. Increasing whole-seaweed inclusion therefore changes not only the fibre and carbohydrate fractions but also the mineral contribution of the diet.

The lower numerical growth observed at 10% and 15% inclusion may have several possible explanations. Increased dietary fibre and structural polysaccharides may reduce nutrient digestibility, while the high mineral fraction may dilute energy-yielding nutrients. Brown seaweeds also contain secondary metabolites and complex polysaccharides that may exert functional effects but can influence nutrient utilization depending on concentration and processing.

This interpretation is consistent with the broader literature. Zamannejad *et al.* (2016) reported significant growth and feed-utilization responses in rainbow trout receiving 5% and 7.5% *S. ilicifolium*, while higher inclusion was less favourable. In contrast, Zeynali *et al.* (2020) investigated *S. ilicifolium* as a replacement for fishmeal in Asian seabass and demonstrated that responses also involve immune parameters and gene expression, illustrating that seaweed may have functional effects that are not captured by growth measurements alone.

More recently, Naseer *et al.* (2025) reported positive growth, haematological and digestive-enzyme responses in *Catla catla* at 7% *S. ilicifolium*. This result differs from the numerical decline observed above 5% in the present study and illustrates why inclusion recommendations cannot simply be transferred from one fish species to another.

The distinction between whole seaweed and isolated bioactive compounds is also important. Pourazad

et al. (2024) found that sulfated polysaccharides extracted from *S. ilicifolium* at 2–4 g kg⁻¹ diet enhanced antioxidant and immune-related responses in juvenile white-leg shrimp without significantly altering growth. Such results support the possibility that some of the biological value of *S. ilicifolium* is associated with specific polysaccharide fractions. However, those findings cannot be directly extrapolated to the whole seaweed meal used here because whole meal contains substantial amounts of ash, fibre and other components.

The previous work of Hafezieh *et al.* (2017), including the present author, is particularly relevant to interpretation of the seaweed used in this experiment. Analysis of *S. ilicifolium* collected from multiple stations along the Sistan and Baluchestan coast demonstrated geographical variation in protein, carbohydrate, mineral and other biochemical characteristics. Thus, the 9.8% crude-protein and 41.6% ash values measured in the present experiment should not be treated as fixed species-level values for *S. ilicifolium*.

Seasonal variability provides an additional reason for caution. Kowsari Sedgh and Fakhrian (2023) documented significant changes in protein, ash, carbohydrate, moisture and astaxanthin concentrations in *S. ilicifolium* from Chabahar Bay before and after the monsoon. Consequently, future nutritional experiments should report the exact collection date, location, environmental conditions and

processing procedure of the seaweed biomass.

The lack of significant differences in HSI and VSI suggests that the tested dietary levels did not cause major changes in liver or visceral mass under the experimental conditions. The numerical reduction in HSI at 5% could indicate altered lipid deposition, but HSI alone cannot establish a change in hepatic lipid metabolism. Histological examination and biochemical measurements would be necessary to determine whether seaweed inclusion affects hepatic lipid accumulation or liver health.

GSI increased numerically with increasing seaweed inclusion, although the difference was not statistically significant. Because *I. hormuzensis* is a species of interest for captive propagation, future nutritional experiments should control for sex, maturity stage and reproductive season. Variation in gonadal development may otherwise obscure dietary effects.

Whole-body moisture, protein and lipid contents did not differ significantly among treatments. The numerical reduction in body lipid in seaweed-fed fish is nevertheless potentially interesting. Similar changes in carcass composition have been reported in some seaweed-feeding studies, but the present experiment did not measure fatty-acid composition, lipid metabolic enzymes or blood biochemical parameters. Therefore, a mechanistic effect on lipid metabolism should not be inferred.

The reported difference in whole-body ash is biologically plausible given

the high ash content of the seaweed meal. Increasing seaweed inclusion can increase dietary mineral intake and potentially influence mineral deposition in fish tissues. Future studies should therefore measure calcium, phosphorus, sodium, potassium and selected trace elements rather than relying solely on total ash.

A further consideration is feed safety. Marine macroalgae can accumulate potentially undesirable elements such as arsenic, cadmium, lead and mercury, as well as iodine, depending on environmental conditions. This is particularly relevant when wild-collected biomass is intended for repeated commercial use. Contaminant analysis should therefore be incorporated into future studies before recommending *S. ilicifolium* as a commercial feed ingredient.

The experimental design represents an important limitation of the present study. The original description of three tanks is inconsistent with four dietary treatments and three replicates. If individual fish were treated as independent replicates while sharing the same tank, the resulting statistical analysis could suffer from pseudoreplication. This issue should be resolved from the original experimental records before publication and is more important than simply updating the statistical software.

Finally, the present study should be positioned appropriately within the existing literature. Its novelty does not lie in demonstrating that *Sargassum* can be included in fish diets; this has already

been shown in rainbow trout, Asian seabass, *Catla catla* and other species. Its principal novelty is the evaluation of whole *S. ilicifolium* meal in the endemic Iranian cichlid *I. hormuzensis*, a species for which nutritional information remains scarce. The combination of an endemic ornamental cichlid and a locally available Gulf of Oman macroalga provides a relevant species-specific research contribution.

Conclusions

Dietary inclusion of dried *Sargassum ilicifolium* meal at 5–15% was apparently tolerated by the Iranian cichlid *Iranocichla hormuzensis* during the 56-day feeding experiment. Among the tested diets, the 5% inclusion level produced the most favourable numerical values for final body weight, weight gain, survival, FCR and PER. However, the reported statistical analysis did not demonstrate significant differences among treatments for most growth and feed-utilization variables. Accordingly, the present study supports the feasibility and apparent tolerance of low-level *S. ilicifolium* meal inclusion in diets for *I. hormuzensis*, but it does not provide sufficient evidence to claim a statistically significant growth-promoting effect. The numerical decline in performance at 10% and 15% inclusion suggests that increasing whole-seaweed meal beyond approximately 5% may not provide additional production benefits under the present dietary conditions. This interpretation should nevertheless remain preliminary until the original

experimental replication and statistical structure are verified. Future studies should use clearly independent replicate tanks, provide the complete diet formulation, determine apparent digestibility coefficients, characterize amino acids and fatty acids, quantify major and trace minerals, screen for potentially toxic elements, and investigate physiological endpoints such as digestive enzymes, antioxidant status, innate immunity and intestinal morphology.

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Declaration concerning previous presentation

A preliminary version of this study was presented at the 3rd International Congress on Fisheries and Aquatic Research, Istanbul, Türkiye, in 2019, under a closely related title. The present manuscript should be submitted only after confirming that the conference contribution did not constitute a prior peer-reviewed journal publication and after complying with the target journal's policy concerning previously presented conference material.

Data availability

The raw experimental data underlying the reported means, statistical analyses and experimental-unit structure should be retained by the authors and made available to the editor or reviewers if requested.

Conflict of interest

The author declares that no conflict of interest is associated with this study.

References

- AOAC International, 2019.** Official Methods of Analysis of AOAC International. 21st ed. AOAC International, Gaithersburg, MD, USA. ISBN 978-0-935584-89-9.
- Dadgar, S., Khiabani, A., Sharifian, M. and Hosseinzadeh, H., 2015.** Introduction of Iranian cichlid (*Iranocichla hormuzensis*) as an endemic species fish in aquarium. *Aquaculture Development* 8, 83-87. [in Persian]
- Hafezieh, M., Ajdari, D., Ajdehakosh Poor, A. and Hosseini Aghozbeni, H., 2017.** Dietary effects of seaweed *Sargassum ilicifolium* on reducing cholesterol level of white leg shrimp *Litopenaeus vannamei*. *Iranian Journal of Fisheries Sciences*, 16(4), 1248–1256.
- Hafezieh, M., Moradi, Y., Pourkazemi, M., Dadgar, S. and Sharifian, M., 2017.** Determination of proximal and chemical composition of Sistan and Baluchistan Province geographical beaches strain of *Sargassum ilicifolium*. *Iranian Scientific Fisheries Journal*, 25(4), 133–144. <https://doi.org/10.22092/ISFJ.2017.110305>
- Hafezieh, M., Seidgar, M., Ghaedi, A., Mohammadi, M. and Mahdiabkenar, A., 2020.** Using *Azolla filiculoides* powder adopted from Anzali Lagoon as a plant-based protein source in feeding of ornamental fish, *Iranocichla hormuzensis*. *Journal of Animal Environmental Research* 12(1), 331–338.
- Keivany, Y. and Daneshvar, E., 2016.** Contribution to the knowledge of the feeding and growth biology of the Iranian cichlid, *Iranocichla hormuzensis*. *Zoology and Ecology* 26(2), 104–109. <https://doi.org/10.1080/21658005.2016.1163866>
- Kowsari Sedgh, Z. and Fakhrian, M., 2023.** Changes in the biochemical composition of *Sargassum ilicifolium* before and after the monsoon in Chabahar Bay, Gulf of Oman, Iran. *Thalassas* 39, 1–6. <https://doi.org/10.1007/s41208-022-00495-5>
- Naseer, S., Asad, F., Nadeem, A., Zulfiqar, R., Kanwal, I., Jamal, R. and Maqbool, A., 2025.** Evaluation of *Sargassum ilicifolium* as a functional feed additive to improve growth, haematology and disease resistance in *Catla catla*. *Journal of Fish Biology* 107(6), 1868–1878. <https://doi.org/10.1111/jfb.70165>
- Pourazad, M., Bagheri, D., Sotoudeh, E. and Ghasemi, A., 2024.** Effects of dietary sulfated polysaccharides

- extracted from brown macroalgae *Sargassum ilicifolium* on growth indices, antioxidant status, and immune genes expression in white shrimp (*Litopenaeus vannamei*). *Aquaculture Reports* 39, 102387. <https://doi.org/10.1016/j.aqrep.2024.102387>
- Siddik, M.A.B., Francis, P., Rohani, M.F., Azam, M.S., Mock, T.S. and Francis, D.S., 2023.** Seaweed and seaweed-based functional metabolites as potential modulators of growth, immune and antioxidant responses, and gut microbiota in fish. *Antioxidants* 12: 2066. <https://doi.org/10.3390/antiox12122066>
- Weththasinghe, P., Thilakarathne, H.M.T.P., Herath, H.M.U.L. and Jayawardana, B.C., 2026.** Meta-analysis of the effects of seaweed inclusion in fish diets on growth performance. *Aquaculture* 611, 743085. <https://doi.org/10.1016/j.aquaculture.2025.743085>
- Zamannejad, N., Emadi, H. and Hafezieh, M., 2016.** Effects of supplementation of algae (*Sargassum ilicifolium*) on growth, survival and body composition of rainbow trout *Oncorhynchus mykiss*. *Iranian Journal of Fisheries Sciences* 15(1), 194–205. <https://doi.org/10.22092/ijfs.2018.114523>
- Zeynali, M., Nafisi Bahabadi, M., Morshedi, V., Ghasemi, A. and Torfi Mozanzadeh, M.T., 2020.** Replacement of dietary fishmeal with *Sargassum ilicifolium* meal on growth, innate immunity and immune gene mRNA transcript abundance in *Lates calcarifer* juveniles. *Aquaculture Nutrition* 26,1657–1668. <https://doi.org/10.1111/anu.13111>