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Journal of Zoological Research
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REVIEW

Review on Using of Macro Algae (seaweeds) in Fish Nutrition

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ARTICLE INFO

Article history
Received: 24 June 2020
Accepted: 17 July 2020
Published Online: 30 July 2020

Keywords:
Feed ingredients
Common feed ingredients
Seaweeds
Macro algae
Fish nutrition
feed cost

ABSTRACT

Currently, the search is on for alternative sources of feed ingredients, the main reasons being the increasing cost and uncertainty about the continuous supply of common feed ingredients especially fishmeal and soybean meal. The importance of macro algae or seaweeds as a potential substitute protein source for fish nutrition cultured has been documented in recent years. Macro algae are receiving consideration for their essential amino acid content and high protein value, trace metals and vitamins in fish nutrition. In addition, macro algae or seaweeds could be a potential low cost source of protein for fishes. Furthermore, the economic comparison of feed cost revealed that the increase in the level of dried and fresh seaweeds in alternative feeding treatments, and commercial diets used for fish growth have decreased which led to a significant decrease in the cost of feed. From the results of previous studies, using of macro algae (seaweeds) in fish diets may improves growth performance, feed efficiency, physiological activity, carcass quality, disease resistance and reduced stress response. This review describes effects of using of macro algae (seaweeds) in diets on growth performance of fish.

1. Introduction

Aquafeed accounts for about 50-80 percent of aquaculture production cost and therefore, its use has to be carefully considered and managed. Nutritionally balanced fish diets generally contain fish meal, soybean meal, wheat bran and yellow corn. Currently, the search is on for alternative sources of feed ingredients, the main reasons being the increasing cost and uncertainty about the continuous supply of common feed ingredients. The importance of macro algae or seaweeds as a potential substitute protein source for fish nutrition cultured has been documented in recent years [1]. The annual global aquaculture production of macro algae or seaweeds was 145 tonnes (including; brown, green and red seaweeds and different aquatic plants) in 2007 [2]. Global production has been dominated by marine macro algae or seaweeds, grown in both marine water and brackish water. Macro algae are receiving consideration for their essential amino acid content and high protein value, trace metals and vitamins in fish nutrition [1]. In addition, macro algae or seaweeds could be a potential low cost source of protein for fishes [3]. Furthermore, the economic comparison of feed cost revealed that the increase in the level of dried and fresh seaweeds in alternative feeding treatments, and commercial diets used for fish growth have decreased which led to a significant

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DOI: https://doi.org/10.30564/jzr.v2i2.2054

decrease in the cost of feed.

Macro algae (seaweeds) are plantlike organisms that generally live attached to rocks or other solid substrata in coastal areas. Seaweeds belong to three different groups, empirically distinguished on the basis of thallus color: green algae (phylum; Chlorophyta, classes; Chlorophyceae, Bryopsidophyceae, Prasinophyceae, Dasycladophyceae and Ulvophyceae), brown algae (phylum; Heterokontophyta (also known as the Ochrophyta) class; Phaeophyceae) and red algae (phylum; Rhodophyta). About 8000 species of macro algae (seaweeds) along the world's coast live and they may extend as deep as 270 m [4]. A total of 350 species of red seaweeds, 90 species of brown seaweeds and 25 species of green seaweeds are found in the world sea area that are commercially important because of their protein, amino acids and mineral contents [5].

The aim of this review was, to evaluate the overall effects of using of macro algae (seaweeds) in fish diets on growth rates, survival rate, feed efficiency, body chemical composition and blood indices of fishes.

2. Importance of Macro Algae (Seaweeds) in Fish Nutrition

Marine macro algae (seaweeds) have been used for healthy feed supplement providing necessary amino acids, fatty acids, beneficial polysaccharides, antioxidants, minerals and vitamins [7,8]. They prefer as food by herbivorous fishes since their stomach have low pH levels and specialize guts required for the digestion of plant materials [9]. Moreover, they improve the immune system, antiviral, antimicrobial, improved gut function and stress resistance serves as an alternative for fish meal, and they would help to take the pressure off wild fish stocks [10]. There is limited evidence that herbivorous and omnivorous fish were more effective at digesting and utilizing seaweed in diet.

Macro algal polysaccharides play vital role in feeding process since they have direct impact on the efficiency of nutrient assimilation in fish gut since polysaccharide can affect digestibility [11]. Alginate extracted from Ascophyllum nodosum etimulated lysozyme activity of Salmo salar [12]. Besides the nutritional value, seaweed contain bioactive compounds which exhibited antimicrobial, antiviral, antioxidative, anti-inflammatory, and neuroprotective so improved the immune response and stress resistance and act as scavenger to reactive oxygen species "ROS" [13]. Fucoidan from Sargassum wightii increased immunological parameters such as phagocytic activity, total leucocyte count and respiratory burst activity of Pangasianodon hypophthalmus [14].

Inclusion of agar from red seaweed enhanced the survival rate of *Aeromonas hydrophila*. Interestingly, seaweed act as the major market for astaxanthin so act as pigmentation source in aquaculture [15]. Astaxanthin, a carotenoid equipped with two asymmetric carbon located at the 3 and 3′ position of the benzenoid rings on either end of the molecule. In 1987, the United States Food and Drug Administration approved the use of astaxanthin as a feed additive for aquaculture and subsequently in 1999 astaxanthin where be approved as a nutraceutical. It was the most important carotenoid in rainbow trouts and salmons [16].

3. Chemical Composition of Macro Algae (seaweeds)

The protein content of macro algae or seaweeds varies with different species and seasonal period. In general, the protein content of brown seaweeds is low (3 - 5% of the dry weight (DW)) compared to that of the red or green seaweeds (10 - 47% DW). The content of crude protein, crud lipid, fiber and ash in green seaweeds meals from 7 - 29%, 0.5 - 4%, 3 - 6% and from 13 - 36%, respectively [17, 18]. Macro algae contain low amounts of lipids (1 to 3%), medium/high amounts of proteins (10 to 47%) and high amounts of carbohydrates (up to 60%) with a variable content of mineral ash (7–38%) [19]. The high carbohydrate content includes a large variety of easily-soluble polysaccharides, such as mannitol, laminarin, fucoidan or alginate in brown types; mannans, starch and sulphated galactans in red types and Ulvan in green types [20]. Other non carbohydrate products obtained from macro algae include proteins, lipids, terpenoids, and phenols and minerals such as phosphorus, potash and iodine useful for animal nutrition and human [21]. Chemical composition of some macro algae (seaweeds) are shown in Table 1.

Table 1. Chemical composition of some macro algae or seaweed (moisture (M), crude protein (CP), ether extract (EE), crude fiber (CF) and nitrogen free extract (NFE)) (%, on dry matter basis)

Species	M	CP	EE	CF	Ash	NFE	References
Green algae							
M. genuflexa	88.57	17.63	1.71	--	36.83	43.83	[22]
M. genuflexa	88.80	11.78	1.48	--	53.58	33.16	[22]
E. intestinalis	85.19	15.81	1.35	--	48.48	34.35	[22]
E. flaxusa	77.83	25.64	2.16	4.59	28.75	38.86	[23]
E. flaxusa	78.60	25.03	1.74	4.61	30.19	38.43	[24]
U. lactuca	--	20.33	3.21	9.87	17.98	48.34	[25]

DOI: https://doi.org/10.30564/jzr.v2i2.2054

U. fasciata	76.10	27	0.57	9.81	20.06	42.56	[24]
U. fasciata	88.77	20.66	2.44	--	45.09	31.82	[22]
C. glomerata	89.57	8.81	3.09	--	21.42	66.67	[22]
C. laetevirens	90.44	14.63	3.64	--	12.82	68.92	[22]
Red algae							
P. capillacea	--	18.92	2.74	12.02	20.95	44.99	[25]
H. cornuta	87.31	11.69	3.61	--	38.79	45.91	[22]
G. corticata	94.58	16.41	2.14	--	15.93	65.52	[22]
G. corticata	84.08	11.72	1.71	--	10.32	76.26	[22]

Notes: M., Mougeotia; E., Enteromorpha; U., Ulva; C., Cladophora; P., Petrocladia; H., Hypnea; G., Gracilaria.

4. Effect of Using of Macro Algae or Seaweeds in Diets on Growth Performance of Fish

Recently, there are many researches have been carried out on the use of seaweeds as ingredient for aquafeed for different fish species. For example but not limited to.

Khalafalla and El-Hais [25] studied the effect of red algae (*Pterocladia capillacea*) and green algae (*Ulva lactuca*) at three levels (0.0, 2.5 and 5%) on blood indices, growth rates, feed efficiency and carcass composition of *Oreochromis niloticus* fingerlings. The results showed that, no significant effect were obtained for liver enzymes activity and serum total protein, globulin and albumin. Values of the growth rates and feed efficiency were significantly higher with Nile tilapia fed on diets (2.5 and 5%) for both red and green algae supplementation. Fish fed diet (5%) of green algae (*Ulva lactuca*) had acceptable growth rates compared to other diets. Nile tilapia fed supplemented diets had insignificant effect with slight increases and decreases for carcass lipids and protein. Also, Garcia-Casal *et al*. [26] reported that the better growth and nutrient utilization were using 5% *U. rigida* dietary supplementation for Nile tilapia (*Oreochromis niloticus*). In addition, Guroy *et al*. [27] observed that the weight gain value was higher for *Oreochromis niloticus* fed on diets supplemented with different levels of *Ulva* meal (5 to 10%). The incorporation 5% of green seaweed (*Ulva lactuca*) in Nile tilapia (*Oreochromis niloticus*) feeds promoted growth, diet utilization, immune response [28]. Siddik *et al*. [29] found that, Nile tilapia (*Oreochromis niloticus*) fed alternative 1 day commercial diet and 1 consecutive day dried or fresh seaweeds (*Enteromorpha sp*.) showed similar feed efficiency to fish feed the commercial diet. These results revealed that seaweeds can be used 1 day after using 1 day commercial diet without affecting feed efficiency of Nile tilapia.

Saleh [23] studied the effect of use fresh macro algae or seaweeds (*Enteromorpha flaxuse*) with or without artificial diet on growth rates, survival percentage and feed efficiency of hybrid red tilapia juvenile. Red tilapia juvenile were fed on three feeds (artificial feed only, fresh macro algae only and 50% artificial feed with 50% fresh macro algae. The highest final weight and specific growth rate of fish were recorded with fed on artificial feed alone and fresh algae alone. But, fish fed on artificial feed alone led to higher final length, total weight gain and daily growth rate. The best feed conversion ratio was recorded with red tilapia fed on artificial feed alone. Red tilapia juvenile were not acceptance of feeding on fresh algae with feeding on artificial feed, this may be the reason for the lower growth in this treatment. Survival percentage was within the range 86–90%, with insignificant differences among treatments. Also, El-Tawil [30] reported that the specific growth rate improved significantly with increasing green seaweeds (*Ulva sp.*) level in the diet up to 15% of red tilapia (*Oreochromis sp.*). And increasing green seaweeds (*Ulva sp.*) level beyond 15% had insignificant differences on growth. Supplementation of *Ulva sp.* to the prepared red tilapia (*Oreochromis sp.*) diet had a positive effect on feed conversion ratio except red tilapia fed the diet containing 25% *Ulva sp.* level with the poorest feed conversion ratio value [30]. Moreover, Costa *et al*. [31] observed that the dried and fresh brown seaweed can be used as a feed to substitute commercial diets for fish juveniles such as red tilapia (*Oreochromis sp.*), spotted scat (*Scatophagus argus*) and giant gourami (*Osphronemus goramy*).

In the other studies, Yousif *et al*. [32] showed that, rabbitfish (*Siganus canaliculatus*) were fed a diet with addition of a known weight of fresh green algae (*Enteromorpha sp.*) placed in plastic baskets at the bottom of the rearing tanks was the best in feed conversion ratio than the other treatments. Moreover, Abdel-Aziz and Ragab [24] who reported that, the green seaweed (*Ulva* and *Enteromorpha*) exhibited a positive effect on growth parameters of rabbitfish (*Siganus rivulatus*) fry and reduce of the feed cost as half of the feeding rate with artificial diet, but replacement of artificial diet with fresh seaweeds had negative consequences on growth parameters of *Siganus rivulatus* fry. Moreover, Shude *et al*. [33] indicated that incorporation of dried seaweeds (*Gracilaria lemaneiformis*) in rabbitfish (*Siganus canaliculatus*) juvenile diet is feasible. In addition, Xu *et al*. [34] recommend a level of less than 33% dried (*Gracilaria lemaneiformis*) in the *Siganus canaliculatus* diet.

In the study of Kotnala *et al*. [35] investigated the growth performance of Indian major carp (*Catla catla*)

DOI: https://doi.org/10.30564/jzr.v2i2.2054

over a period through formulated feeds consisting of three seaweeds, namely *Padina tetrastomatica*, *Chlorodesmis fastigiata* and *Stoechospermum marginatum*. The results demonstrated that seaweeds, such as *P. tetrastomatica* and *C. fastigiata,* could be used in commercially formulated feed to get better growth of the fingerlings of major carps. Also, Diler *et al*. [36] reported that the inclusion of *Ulva rigida* meal at 5 - 15% replacing wheat meal in fish diets improved the growth performance of common carp.

Valente *et al*. [37] studied the inclusion of three seaweeds *Ulva rigida* (UR), *Gracilaria bursapastoris* (GP) and *Gracilaria cornea* (GC) in diets of European sea bass (*Dicentrarchus labrax*) juveniles on the growth performance, feed utilisation and body composition. Six diets were formulated to replace 5% (UR-5, GP-5 and GC-5 diets) and 10% (UR-10, GP-10 and GC-10 diets) fish protein hydrolysate by each of the three seaweeds. The results showed that inclusion of UR and GP up to 10%, can be considered as new ingredients in sea bass diets, as no negative effect on growth rates, feed efficiency and body composition. But, the inclusion of GC should be limited to 5% of the diet. Also, Wassef *et al*. [38] reported that the feeding sea bass at low level (5%) of *Ulva sp.* or *Ptercladia capillacea* meal had the better growth, survival rates and feed efficiency among all the dietary groups. The inclusion of 5% red seaweed (*Pterocladia capillacea*) enhanced some growth performance parameters of European seabass (*Dicentrarchus labrax*) fry, with an increase in body weight, and weight gain [38].

Yildirim *et al*. [2] studied the growth performance of rainbow trout fed with diets containing seaweeds (*Enteromorpha linza* and *Ulva lactuca*). Fishes were fed on three diets containing (0.0 as control group, 10% *Enteromorpha linza* meal and 10% *Ulva lactuca* meal) The results found that a diet with seaweeds (*Enteromorpha linza* and *Ulva lactuca*) inclusion at 10% levels resulted in weaker growth and feed efficiency compared to the control group of rainbow trout. Elmorshedy [39] observed that the final body weight and specific growth rate of gray mullet (*Liza ramada*) were higher significantly with increasing macro algae level (*Ulva sp.*) up to 28% in the gray mullet diet. Patel *et al*. [1] studied the three experimental diets consisting of seaweed *Ulva lactuca* at 10%, 20% and 30% with control diet without seaweed on growth and survival of *Labeo rohita* fry. Fish fed with 10% *Ulva sp.* meal observed an increased survival and growth rates and also a significant increase was found in specific growth rate, feed conversion ratio and protein efficiency ratio.

Ulva rigida low-level dietary incorporation has improved growth, feed efficiency, carcass quality, disease resistance, physiological activity and reduced stress response [37, 40]. Siddik *et al*. [29] found that similar survival rates of Nile tilapia juvenile fed diets with seaweeds and without seaweeds. Also, Rahman and Meyer [41] showed that similar survival rates of Common carp fed diet with seaweeds and without seaweeds.

On the other hand, Siddik *et al*. [29] reported that lowest final body weight and specific growth rate were showed in treatments feeding dried and fresh seaweeds (*Enteromorpha sp.*) as single feeds in Nile tilapia (*Oreochromis niloticus*). Also, the inclusion of 20-30% different macro algae (*Gracilaria cornea*, *Ulva lactuca*, *U. rigida* and *Cystoseira barbata*) in different species of fish meals decreased all growth performance and feed utilization parameters [42].

5. Conclusion

These findings in this review confirm the positive effects reported on promoted growth rates and survival percentage of fishes with the addition of macro algae or seaweeds in fish diets. Using of macro algae (seaweeds) in fish diets may improves growth performance and feed efficiency without adverse effects on liver enzymes activity and blood indices. And *Ulva rigida* low-level dietary incorporation has improved growth, feed efficiency, carcass quality, disease resistance, physiological activity and reduced stress response. Also, using of macro algae in fish diets had positive effect on growth performance and reduces of the feed cost.

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