Indian Journal of Experimental Biology
Vol 42, December 2004, pp. 1239-1244

Conversion efficiency and nutrient digestibility of certain seaweed diets by laboratory reared *Labeo rohita* (Hamilton)

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Received 4 December 2003; revised 21 September 2004

Impact of three different types of seaweed diets on growth, feed utilization and nutrient digestibility of *L. rohita* was studied for 120 days. The seaweed diet fed fishes, especially *Ulva* based diet showed comparatively higher growth and weight increment. Good food conversion ratio, food assimilation efficiency, protein efficiency ratio and better nutrient digestibility were recorded for seaweed diet fed fishes. The results suggests the suitability of utilizing seaweeds, *Ulva fasciata, Spyridia insignis* and *Sargassum wightii* as partial substitute for fishmeal in formulated diets of *L. rohita*.

Keywords: Seaweed diets, Indian major carp, *Labeo rohita*, Growth, Feed utilization, Nutrient digestibility

Semi-intensive and intensive culture of fish is mainly dependent on a supply of supplementary feeds, which ensures the rapid growth of fish from juvenile to market or edible size with higher survival rate. For augmenting protein content in supplementary feeds, fishmeal is being used the world over, which in turn results in higher cost and scarcity of fishmeal[1]. Therefore, fish nutritionists have been trying to replace fishmeal partially or completely with other protein sources to bring down the cost of feeds. In this regard, several workers have assessed the suitability of different plant protein sources[2] and seaweeds/marine algae are one among them[3-7]. Certain species of marine algae are even superior to meat, egg, fish and cereals and many of them possess all the essential amino acids which are not available in other land and fresh water plant proteins[8].

The present study has been undertaken to assess the suitability of three different species of marine algae viz. *Ulva fasciata* (Division: Chlorophyta, Class: Chlorophyceae, Order: Ulvales, Family: Ulvaceae), *Spyridia insignis* (Division: Rhodophyta, Class: Rhodophyceae, Order: Ceramiales, Family: Cerameaceae) and *Sargassum wightii* (Division: Phaeophyta, Class: Phaeophyceae, Order: Fucales, Family: Sargassaceae) as partial substitutes for fishmeal in formulated diets of *Labeo rohita*.

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Materials and Methods

Fish — Fingerlings of *L. rohita* procured from Government hatchery of Fisheries Department of Kerala were used. They were stocked in large holding tanks for acclimatisation for two weeks. These holding tanks had provision for water exchange and the temperature remained 27°±1°C and oxygen near air saturation. During the acclimatisation period, the fingerlings were offered a formulated feed of 30% protein.

Diets — For the present study, three types of seaweed diets and a control diet were prepared following Hardy's square method[9]. The proximate composition of all the dried, powdered ingredients was analysed according to AOAC procedures[10] (Table 1). Seaweed diets were prepared by partially replacing fishmeal with seaweed powders; all other ingredients were same as those of control diet. The control diet (CL-Diet) was a standard fish meal based diet. In *Ulva* diet (UL-Diet) fishmeal was replaced by *U. fasciata*, *Spyridia* diet (SP-Diet) with *S. insignis* and *Sargassum* diet (SA-Diet) with *S. wightii* respectively (Table 2). Appropriate quantities of finely powdered ingredients were weighed and mixed thoroughly by adding water. The dough thus prepared was steam cooked for 30 min in a pressure cooker. The cooled dough was fortified with vitamin and mineral mix (1%) and was pelletized using a hand pelletizer. The extruded pellets were dried overnight in a hot air oven at 60°C. Proximate analyses of diets were carried out using standard methods[10] (Table 2).

Experimental procedure—The feeding experiments were conducted in 12 large drainable outdoor cement cisterns of 4.5 × 4.5 × 1.5 m capacity each in a completely randomised design. There were three replications for each treatment. To each of these cisterns, samples of 20 fingerlings each (1.99 ± 0.10 to 2.05 ± 0.13 g live weight and 5.39 ± 0.08 to 5.46 ± 0.08 cm length), segregated from the acclimatisation tank were transferred after measuring the length and weight. To each treatment, the fish were fed at 10% of their body weight daily, which was split into two equal rations, fed at 0800 and 1800hrs.

(i) Water quality monitoring: Water samples were collected fortnightly at 0730 hrs prior to daily feeding from all the experimental cisterns and analysed [11] for different parameters viz., temperature, *p*H, dissolved oxygen concentration, total alkalinity and productivity. Half of the water in all the cisterns was changed with fresh water every fortnight.

(ii) Sampling and growth studies: The duration of feeding experiment was 120 days. The specimens were sampled once in every 15 days and a minimum of 5 fish were collected from each cistern and length

Table 1 — Proximate composition (%) of feed ingredients (dry weight basis)

Feed ingredients	Proximate composition (%)					
	Moisture	Crude protein	Crude fat	Crude fibre	NFE	Ash
Rice bran	8.85	7.35	1.74	11.32	56.61	14.13
Tapioca flour	5.67	2.80	1.68	1.79	85.27	2.79
Groundnut oil cake	10.74	45.75	6.07	3.98	25.68	7.78
Fish meal	7.40	51.34	6.12	10.32	1.27	23.55
Ulva powder	7.11	8.75	1.95	3.08	61.47	17.70
Spyridia powder	4.87	14.45	1.20	6.02	53.26	20.20
Sargassum powder	8.77	10.95	2.15	10.78	40.35	27.00

Table 2 — Proportion of ingredients and proximate composition of the diet

Feed Ingredients	Percentage composition (g)			
	CL-Diet	UL-Diet	SP-Diet	SA-Diet
Rice bran	9.83 (0.72)	5.95 (0.44)	3.74 (0.28)	5.12 (0.38)
Tapioca flour	9.83 (0.28)	5.95 (0.17)	3.74 (0.11)	5.12 (0.14)
Groundnut oil cake	40.17 (18.38)	29.37 (13.44)	30.84 (14.11)	29.92 (13.69)
Fishmeal	40.17 (20.62)	29.37 (15.08)	30.84 (15.83)	29.92 (15.36)
Ulva powder	–	29.37 (2.57)	–	–
Spyridia powder	–	–	30.84 (4.46)	–
Sargassum powder	–	–	–	29.92 (3.28)
Vitamin-mineral mix	1.00	1.00	1.00	1.00
Total	100.00 (40.00)	100.01 (31.70)	100.00 (34.79)	100.00 (32.85)

Figures in parenthesis indicate the protein percentage contributed by each feed ingredient

Parameters	Proximate composition (%) of diets [Values are Mean ± SD]			
Moisture	6.39 ± 0.28	8.80 ± 0.32	8.09 ± 0.25	7.09 ± 0.19
Crude protein	38.81 ± 0.85	31.12 ± 0.77	33.56 ± 0.59	32.08 ± 0.72
Crude lipid	5.20 ± 0.19	4.32 ± 0.23	4.38 ± 0.17	4.46 ± 0.25
Nitrogen free extract	28.50 ± 0.98	35.16 ± 0.84	28.90 ± 0.72	30.03 ± 0.91
Crude fibre	7.00 ± 0.09	5.80 ± 0.12	6.79 ± 0.18	8.04 ± 0.23
Ash	14.10 ± 0.73	14.80 ± 0.68	18.28 ± 0.55	18.30 ± 0.66

and weight was recorded for studying growth. Specific growth rate (SGR) [12] was calculated as,

$$SGR = \frac{\log e\, W_2 - \log e\, W_1}{T_2 - T_1} \times 100$$

where W_1 is the weight (g) of fish at time T_1 and W_2 is the weight at time T_2.

(iii) Feed utilization and nutrient digestibility: To study the feed utilisation [12] of *L. rohita*, short term experiments were conducted in laboratory in fibre glass tanks of 100 litre capacity employing 5 fish from each treatment for 30 days. There were three replicates for each treatment. The weighed feed was supplied to fish in Petri dish, at 10% of their body weight. The unconsumed feed, if any, was siphoned out 6 hr after feeding. Likewise, faecal matter was also siphoned out the next day prior to the next feeding. The unconsumed feed and faecal matter was oven dried at 60°C, weighed and kept in a desiccator for proximate analysis. According to Halver's procedures[12], feed conversion ratio, feed conversion efficiency, assimilation efficiency, protein efficiency ratio and nutrient digestibility were calculated.

Food conversion ratio (FCR) = Dry weight of food consumed (g)/Production (g)

Food conversion efficiency (FCE) % = Production (g) / Food consumed (g) × 100

Food assimilation efficiency (FAE)% = Assimilation (g) / Food consumed (g) × 100

Protein efficiency ratio (PER) = Production (g) / Protein intake (g).

Apparent protein digestibility (APD) % = Protein in feed- Protein in excreta / Protein in feed ×100

Apparent fat digestibility (AFD) % = Lipid in feed- Lipid in excreta/Lipid in feed ×100

Apparent carbohydrate digestibility (ACD)%= Carbohydrate in feed- Carbohydrate in excreta / Carbohydrate in feed ×100

(iv) Statistical analysis: One way ANOVA[13] was carried out to find significant difference in the final mean percentage increase in length and weight, feed utilization and nutrient digestibility by *L.rohita* between treatments and control. Multiple range test [14] was applied to find out significant difference between various treatment means and control mean for the observed parameters.

Results

The water quality parameters in the experimental cisterns were within the optimum range for growth of *L. rohita* irrespective of the diets supplied. The water temperature ranged from 27° to 30.5°C and *p*H within the alkaline range (7.2 to 8.1). The dissolved oxygen concentration varied from 6.85 to 11.21mg / l and the total alkalinity from 35 to 70 ppm. The productivity values were found to be within the range of 2.52 to 12.12 mg C /m^3 /day in different cisterns.

At the end of experimental period, since there was no significant difference in final average weight of fishes among the replicates ($P<0.01$) average growth was calculated pooling the three values. The highest specific growth rate (1.65%) was recorded for UL-Diet followed by SA-Diet (1.61%), SP-Diet (1.56%) and CL-Diet (1.55%) respectively (Table 3).

Table 3 — Results of feeding trials of *L. rohita* fed with different experimental diets

[Values are mean ± SD]

Parameters	CL-Diet	UL-Diet	SP-Diet	SA-Diet
Initial length (cm)	5.42 ± 0.31	5.46 ± 0.08	5.39 ± 0.29	5.39 ± 0.08
Initial weight (g)	1.99 ± 0.10	1.98 ± 0.09	2.05 ± 0.13	2.01 ± 0.11
Final length	10.94 ± 0.08	11.44 ± 0.39	11.06 ± 0.10	11.29 ± 0.25
Final weight	12.80 ± 0.59	14.28 ± 0.16	13.30 ± 0.22	13.88 ± 0.15
Net weight gain (g)	10.81	12.30	11.25	11.87
Increasing rate of body weight	6.46 ± 0.21	7.10 ± 0.19	6.49 ± 0.28	6.97 ± 0.34
Mean percentage increase in weight (F ratio 24.8483 *)	542.92 ^{a}± 29.41	621.31 ^{c}± 8.16	549.12 ^{a} ± 10.80	591.33 ^{b} ± 7.36
Specific Growth Rate (SGR) (%)	1.55	1.65	1.56	1.61
Survival (%)	82	90	92	94

* indicates significance ($p<0.01$).

a, b, c — Mean values with same superscript do not differ significantly (Duncan's multiple range test).

Table 4 — Feed utilisation of *L. rohita* fed with different experimental diets

(Values are mean ± SD)

Parameters	Treatments			
	CL-Diet	UL-Diet	SP-Diet	SA-Diet
Initial weight (g) [W_1]	5.33 ± 0.64	5.32 ± 0.69	5.32 ± 0.82	5.34 ± 0.72
Final weight (g) [W_2]	7.07 ± 0.59	7.68 ± 0.62	7.12 ± 0.23	7.54 ± 0.29
Production (g) [$P = W_2-W_1$]	1.74 ± 0.03	2.36 ± 0.42	1.80 ± 0.38	2.20 ± 0.14
Feed consumption (g) [C]	4.97 ± 0.47	5.12 ± 0.5	5.03 ± 0.6	5.09 ± 0.59
Faecal output (g) [F]	1.59 ± 0.03	1.56 ± 0.08	1.61 ± 0.07	1.55 ± 0.05
Relative growth rate [P/W_1]	0.33 ± 0.01	0.44 ± 0.01	0.34 ± 0.01	0.41 ± 0.01
Assimilation (g) [A = C-F]	3.37 ± 0.57	3.56 ± 0.43	3.42 ± 0.34	3.54 ± 0.27
Metabolism (g) [R = A-P]	1.64 ± 0.08	1.20 ± 0.07	1.62 ± 0.12	1.34 ± 0.09
Food conversion ratio [FCR = C/P]	2.86 ± 0.79^a	2.17 ± 0.43^a	2.79 ± 0.39^a	2.31 ± 0.25^a
Food conversion efficiency (%) [FCE = P/C × 100] (F ratio 7.7229)*	35.01 ± 2.85^a	46.09 ± 4.56^b	35.79 ± 1.29^a	43.22 ± 3.99^b
Food assimilation efficiency (%) [FAE = A/C ×× 100]	68.00 ± 1.88^a	69.53 ± 2.09^a	67.99 ± 1.86^a	69.54 ± 2.86^a
Protein efficiency ratio (PER = *P*/ Protein intake) (F ratio 118.7429)*	0.90 ± 0.04^a	1.48 ± 0.03^d	1.07 ± 0.03^b	1.35 ± 0.06^c
Apparent protein digestibility (%) [APD]	90.06 ± 2.72^a	92.28 ± 5.96^a	88.88 ± 3.69^a	91.74 ± 3.70^a
Apparent fat digestibility (%) [AFD]	50.12 ± 3.01^a	52.54 ± 4.82^a	51.92 ± 3.82^a	52.08 ± 5.06^a
Apparent carbohydrate digestibility (%) [ACD]	50.86 ± 2.83^a	52.84 ± 3.92^a	52.08 ± 2.85^a	52.24 ± 2.90^a

* indicates significance (P<0.01).

a, b, c, d —Mean values with same superscript do not differ significantly (Duncan's multiple range test).

Similarly, highest feed consumption, good food conversion ratio, highest food conversion efficiency, food assimilation efficiency and protein efficiency ratio were recorded for UL-Diet compared with other seaweed diets and control diet (Table 4). Apparent digestibility of nutrients showed only slight variations among the experimental diets and control diet. A higher value of protein digestibility was recorded for UL-Diet and lower value for SP-Diet. Digestibility of fat and carbohydrate was higher in UL-Diet and lower in CL-Diet respectively (Table 4)

ANOVA results of the experimental data revealed significant differences (P<0.01) between different treatments for parameters such as final percentage increase in length, weight, food conversion efficiency and protein efficiency ratio. Duncan's multiple range test showed that mean percentage increase in weight (F ratio 24.8483) and protein efficiency ratio (F ratio 118.7429) of all treatments differed significantly from each other. But, for the parameters such as food conversion ratio, food assimilation efficiency, digestibility of nutrients etc., the differences were not significant.

Discussion

In the present study, *L. rohita* recorded very good response in terms of growth and feed utilization to seaweed diets. Better food utilisation has been reported for carps when fed with plant meal based diets[15-16]. Patnaik *et al.*[16] reported that, plant meal based feeds appear to be better utilised than animal based diets for carps owing to their herbivorous feeding habit. Growth and digestibility studies regarding sea weed based diets for fishes are very meagre in India, although some outstanding and promising works were carried out in foreign laboratories[3-7]. Penaflorida and Golez[4] studied the effects of two sea weeds, *Kappaphycus alvarezii* and *Gracilaria heteroclada* as binders in shrimp diets and found that the algae incorporated diets gave good growth with no adverse effect on survival of juvenile shrimps. Floreto *et al.*[5] found that the sea weed *Undaria pinnatifida* showed highest growth rate in white sea urchin *Tripneustes gratilla* and abalone *Haliotis discus*. Palatzidis *et al.*[6] tested the efficacies of three green sea weeds in the culture of sea hare, *Aplysia juliana* and found that *Enteromorpha intestinalis* produced fastest growth rate. Davies *et al.*[7] conducted feeding trials to assess the nutritional value of *Porphyra purpurea* for thick lipped grey mullet *Chelon labrosus* and opined that partial substitution of nutritionally superior fishmeal with sea weed proved to be cost effective. In India, studies of Chitra[17] showed that fishmeal mixed with the marine algal powder *S. wightii* gave better growth and weight increment of *Oreochromis mossambicus*. Bindu[18] and Sobha *et al.*[19] assessed the nutritional value of *U. fasciata* as a feed ingredient for *L. rohita* and *O. mossambicus* and found that *U. fasciata* can be better used as a feed supplement to aquaculture practices. Bindu *et al.*[20] in another work reported that seaweed based diets increase the total and specific activities of digestive enzymes in grass carp, *Ctenopharyngodon idella*, encompassing a direct relationship with the food conversion and assimilation. According to Olin *et al.*[3] and Floreto *et al.*[5] in USA and Thailand, sea weeds and sea weed based diets are the most widely used grow-out feed for abalone culture, because they support good growth, survival and has a minimal impact on water quality. Olin *et al.*[3], also observed that the incorporation of the marine algae in formulated diets increased the water stability of pellets because of the nature of the phytochemicals and stabilisers present in them. Moreover, marine algae contain essential amino acids and other growth promoting substances[8], and they are reported to be having the capacity of texturising well and can be used as a binder for different feed ingredients[3-7] in formulated diets. The higher food consumption and production of *L. rohita* to seaweed diets may be due to their high water stability and lower disintegration, which are limiting factors in carp culture, as carps are slow feeders. Comparatively, higher digestibility of nutrients from plant sources than animal proteins for carps has been reported[1, 2, 15, 16]. In the present study also digestibility values of nutrients were found to be slightly higher in seaweed diets than the fishmeal based control diet.

From the observations of present study, it can be concluded that *L. rohita* grows well with the pelleted feed containing seaweeds *U. fasciata*, *S. insignis* and *S. wightii* and they can efficiently utilize the nutrients from these weeds in addition to other aquatic macrophytes tried so far. Superior and statistically significant data is indicative of the possibility of utilizing these seaweeds as an alternate/substitute for fishmeal to *L. rohita*, hence they can be better recommended as a diet ingredient for cost effective carp culture practices.

Acknowledgement

M S Bindu is thankful to CSIR, New Delhi for the Senior Research Fellowship.

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