Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci. (October–December 2012) 82(4):489–496
DOI 10.1007/s40011-012-0060-y

RESEARCH ARTICLE

Dietary Protein Requirement of Giant Snakehead, *Channa marulius* (Ham., 1822) Fry and Impact on Growth Indices

Sudhir Raizada · Prem Prakash Srivastava · Piyush Punia · Kailash Chandra Yadav · Vikash Sahu · Shipra Chowdhary · Joykrushna Jena

Received: 9 April 2012 / Revised: 5 June 2012 / Accepted: 12 July 2012 / Published online: 31 July 2012

Abstract Six semi-purified diets (energy 17.97–18.47 kJ g^{-1}) containing protein levels of 300 g kg^{-1}(diet-A), 360 g kg^{-1}(diet-B), 420 g kg^{-1}(diet-C), 480 g kg^{-1}(diet-D), 540 g kg^{-1} (diet-E) and 600 g kg^{-1}(diet-F) were estimated for the protein requirement of *Channa marulius* fry (length 4.11 ± 0.59 cm) in a completely randomized experiment design in triplicate set. The fry were reared in 18 FRP tanks at a stocking density of 40 fry m^3 and fed @ 8–5 % bw. The diets A, B, C and D showed significantly ($p < 0.05$) low survival levels of 46.6, 46.6, 46.6 and 53.3 in comparison to diets E (88.3 %) and F (85.0 %) after 28th day of rearing. The net biomass, SGR and per day weight gain were found significantly ($p < 0.05$) higher and FCR low with diets E and F in comparison to diets A, B, C and D. The proximate analysis of carcass showed that the fish fed diets E and F had significantly ($p < 0.5$) higher deposition of protein and lipids in the tissue. The study revealed that the protein requirement of *C. marulius* fry is around 540–600 g kg^{-1} and the fry could be reared to fingerling size on formulated diets.

Keywords *Channa marulius* · Protein requirement · Survival · Growth

Introduction

Giant snakehead, *Channa marulius* (Hamilton) belonging to family Channidae is one of the important food, ornamental and game fish of India, Pakistan, China, Thailand and Cambodia [1]. They are found in rivers, canals, lakes, swamps, marshes and rice fields [2] and grow to a maximum length of 183 cm [3] and weight of 30 kg [4]. The snakeheads are in great demand as food fish due to their appealing flavor [5], fewer muscular spines, medicinal importance [6–11] and air-breathing nature [9] that facilitates high density culture and easy transport in live condition to the markets. However, due to environmental degradation and absence of aquaculture technology, the population of this species has declined tremendously during last 3–4 decades in natural waters and there is a need to sustain their population through aquaculture.

The snakehead (striped snakehead: *C. striatus*) culture is widely popular in Thailand and on limited scale in India, Philippines and Taiwan [9, 12–15]; by and large very little work has been carried out on culture of *C. marulius* due to poor understanding of breeding and larval rearing requirements that could facilitate mass seed availability under captive conditions. The species has been observed to breed in almost all type of aquatic systems including rivers, reservoirs, rice-fields, ponds and small cement tanks and their seed in large quantities can be procured in the form of eggs (floating eggs), yolk-sac larvae, fry and fingerlings from such water bodies. The major problem associated with snakehead culture is its predatory and cannibalistic habit that starts from the larval stage [16] and continues till adult stage consuming prey fish more than half to two-third of its length [9, 16–18].

Several studies have demonstrated that although cannibalistic aggression in fishes is difficult to be stopped, even after feeding the fish to satiation level but it can be reduced by increasing natural food availability [19–22] or by weaning the fish to accept formulated feed [17, 18, 22, 23]. Successful larval rearing of snakehead, therefore, depends more on the

S. Raizada (✉) · P. P. Srivastava · P. Punia · K. C. Yadav · V. Sahu · S. Chowdhary · J. Jena
National Bureau of Fish Genetic Resources, Canal Ring Road, Telibagh, Lucknow 226 002, Uttar Pradesh, India
e-mail: sudhirraizada@hotmail.com

understanding of dietary requirements at the first-feeding and during growth. Therefore, the aim of the present study was to evaluate the dietary protein requirement of giant snakehead fry so that a nutritionally-balanced diet could be developed for raising fingerling in captivity which could provide stocking material for culture in ponds to meet need-based diversified aquaculture commodity in India.

Material and Methods

Procurement of Test Fish

The early fry of *C. marulius* were procured from the farm facilities of NBFGR, Lucknow, India where they bred naturally in May 2011. The fry were washed thoroughly and disinfected with formalin (15 mg L^{-1}) and reared initially in two fibre reinforce plastic (FRP) tanks of 1,125 L (size 1.5 × 1.0 × 0.75 m) for 30 days. The fry were initially given zooplankton as the main food for 3 days followed by a combination of zooplankton and egg custard for next 7 days, subsequently zooplankton was withdrawn from their diet. The fry were then acclimatized to synthetic diet 'D' (protein 480 g kg^{-1}) for 5 days prior to start the experiment.

Experiment Design

Feed trial was conducted in triplicate set with six variable diets in 18 FRP tanks of 1,125 litre (size 1.5 × 1.0 × 0.75 m) kept under an open shade at the NBFGR farm facility during July 2011. The tanks were filled with 500 L bore well water and covered with green house netting (75 % light cutting). Twenty fry (mean length 4.11 ± 0.59 cm) of test fish were stocked in each of the 18 designated tanks. The average initial biomass of stocked fry of each of the tank was recorded before placing them in the tank which did not differ significantly ($p > 0.01$) among six treatments. Feed was given once a day (11.00 a.m.) initially @ 8 % of bw for first 10 days and then corrected to 5 % of bw for rest of the period. The tanks were cleaned on every third day through siphoning when all the debris was removed and 50 % tank water was replaced with fresh chlorine-free bore well water.

Preparation and Application of Test Diets

Six semi-purified test diets A, B, C, D, E, and F containing 300, 360, 420, 480, 540 and 600 g kg^{-1} protein levels were prepared using casein as a protein supplement. The other feed ingredients mixed in the various diets are given in Table 1. The feed ingredients after proper mixing were steamed in a pressure cooker for 10 min and after cooling divided into four blocks and stored in a deep freezer (−20 °C) in a sealed polythene bag. One by one these feed blocks were taken out from the deep freezer, kept under normal cooling (temperature around 5–6 °C) condition in a refrigerator and gradually used for feeding the fish. The feed was graded to small particle size with the help of a hand held metal grater and spread in circular fine meshed plastic tray (diam 22 cm) hanged in the water.

Collection of Survival and Growth data

Mortality was counted every day in the morning and evening and the dead fish were removed at the earliest. Cannibalism was estimated from the difference between initial number of fish stocked and sum of survivors plus dead fish removed. All the fishes were removed on 28th day, measured for length and weight and five samples from each of the replicates was packed in sealed polythene sackets and kept in deep freezer (−20 °C) for proximate analysis of carcass.

Proximate Analysis

Proximate composition of diets and fish carcasses was analyzed following methods of AOAC [24]. All samples were analyzed in triplicate. Dry matter was calculated by drying in an oven at 105 °C for 24 h; crude protein (N X 6.25) by the Kjeldahl method after an acid digestion method and crude lipid by ether extraction after acid hydrolyses. Nitrogen free extract was estimated by subtraction method.

Water Quality

Water samples for the analysis of temperature, pH, total alkalinity, dissolved oxygen, and free carbon dioxide were tested on every third day. The temperature was measured with a centigrade thermometer, pH with digital electronic meter (Eutec), total alkalinity, dissolved oxygen and free carbon dioxide by titration methods following the standard methods [25].

Data collection

All the surviving samples of fishes were measured for total length (L) and weight (W) at the end of the experiment. Survival rates (S), net biomass, specific growth rates (SGR), per day weight gain, feed conversion ratio (FCR) and length-weight relationship (W) were calculated using the following formulae:

$$S = 100 \times (n_t/n_0)$$

where, S is survival rate (%), n_t is the number of fishes survived at time t and n_0 is the number of fishes at the commencement of the experiment.

Table 1 Composition of experimental diets and proximate composition

Ingredient	Feed ingredients used in different test feeds (g kg^{-1})					
	Diet A	Diet B	Diet C	Diet D	Diet E	Diet F
Casein[1]	300.0	360.0	420.0	480.0	540.0	600.0
Starch[2]	434.0	374.0	314.0	254.0	194.0	134.0
Cellulose[3]	180.5	180.5	180.5	180.5	180.5	180.5
Cod liver oil[4]	45.0	45.0	45.0	45.0	45.0	45.0
Ascorbate[5]	0.50	0.50	0.50	0.50	0.50	0.50
CMC[6]	20.0	20.0	20.0	20.0	20.0	20.0
VM + MM[7]	20.0	20.0	20.0	20.0	20.0	20.0
GE. (kg^{-1})	4,279	4,303	4,327	4,351	4,375	4,399
KJ g^{-1}	17.95	18.07	18.17	18.27	18.37	18.47
Proximate Composition						
Protein	294.3*	349.0*	402.9*	475.7*	528.6*	586.6**
NFE	597.6**	551.6*	487.0*	426.0*	361.3*	307.6*
Lipid	44.0*	43.3*	41.6**	42.2**	44.5*	43.4*
Moisture	50.2	46.0	65.4	52.3	62.5	54.5
GE kg^{-1}	4,279	4,303	4,327	4,351	4,375	4,399
KJ g^{-1}	17.97	18.07	18.17	18.27	18.37	18.47

[1] HiMedia, Mumbai Lot No: 0000042681

[2] HiMedia, Mumbai, Lot No: 0000028340

[3] Cellulose (HiMedia, Mumbai, Lot No: 0000040304

[4] Cod Liver Oil, Manufacturer Universal Medicare Pvt. Ltd., Mumbai Batch No. R0109 J

[5] L-Ascorbate-2 triphosphate Ca salt-HiMedia, Mumbai, Lot No. 000000517

[6] HiMedia, Mumbai, Lot No. 0000042121

[7] Each kg of Vitamin and mineral mixture named('Agrimin Forte) contains Vit. A 700000 IU, Vit. D_3 70000 IU, Vit. E 250 mg, Nicotinamide 1,000 mg, Co 150 mg, Cu 1,200 mg, I 325 mg, Fe 1,500 mg, Mg 6,000 mg, Mn 1,500 mg, K 100 mg, Se 10 mg, Na 5.9 mg, S 0.72 %, Zn 9,600 mg, Ca 25.5 %, P 12.75 % Manufacturer Brindavan Phosphates Pvt. Ltd, 48 N, Doddaballpur Ind. Area, Doddaballapur-561 203, India and marketed by Virbac Animal Health India Pvt. Ltd., Andheri-Kurla Road, Andheri, Mumbai-400 059, India. Batch No. BFA-611 September 2010

*Values are significantly different at 95 % confidence limit for two replicates of each diet

**Values are significantly different at 99 % confidence limit for two replicates of each diet

$$NB = GB - IB$$

where, NB is net biomass (g) of all the surviving fishes, GB is measured gross biomass (g) of all the surviving fishes at the time of final harvesting and IB is the measured initial biomass (g) of all the stocked fishes.

$$SGR = 100(\ln Wt - \ln W_0)/(t_2 - t_1)$$

where, SGR is specific growth rate; *Wt* is the total weight at time t_2, W_0 is initial weight at the time t_1.

$$FCR = TF/NB$$

where, FCR is food conversion ratio, TF is total quantity of given feed (g), NB is net biomass (g).

$$W = a\,L^b$$

where, W is assumed weight of fish, 'a' and 'b' are constant and 'L' is length of fish.

$$PDWG = NB/t.$$

where, PDWG is per day weight gain, NB net biomass and 't' number of days.

Data Analysis

Analysis of variance was used to determine the significance levels between different production attributes by SPSS version 16.0 software. Student's *t* test was performed to analyze significance levels for diets. Regression graphs were plotted for comparing the length-weight relationship at final harvesting and 'Y' (simple linear regression) and 'R^2' (corelation) were recorded using M.S. Excel (Version 2007) and 'W' was calculated by the formula ($W = aL^b$) in M.S. Excel spread sheet. The data are expressed as mean ± standard deviation. Significant levels were considered at $p < 0.05$ and $p < 0.01$ and means were compared using Duncan multiple range test.

Results and Discussion

A significantly ($p < 0.05$) higher survival of 88.3 and 85.0 % respectively in diets E (protein 540 g kg^{-1}) and F (protein 600 g kg^{-1}) in the present study in comparison to diets A (protein 300 g kg^{-1}), B (protein 360 g kg^{-1}), C (protein 420 g kg^{-1}) and D (protein 480 g kg^{-1}) revealed that the protein requirement of *C. marulius* is quiet high at fry stage (length 4.11 ± 0.59 cm) (Table 2). This was well corroborated with the work of Mohanty and Samantaray [26] who obtained highest growth performances (survival was not defined by the authors) in *C. striata* fry fed formulated diet (made from natural ingredients) containing 550 g kg^{-1} protein (energy 4,320 kcal kg^{-1}) fed at the rate of 10 % bw day^{-1}. Though highly significant variations ($p < 0.05$) in the survival rates between diets A–D with that of diets E and F were observed, the average length and weight were insignificant ($p > 0.05$) with all the six diets pointing the poor survivals in diets A–D may be due to higher rate of cannibalism or cannibalism attempts that might have caused injury and subsequent mortality. It is well known that snakeheads observed great amount of cannibalism at all stages of life and it is one of the major reasons of low survival during their culture [16]. In the process of cannibalism although shooters are able to prey on fish measuring 2/3 in length [17] or 63–80 % [18] to predator size in case of *C. striatus*, no information as to predator–prey ratio is available for *C. marulius* though the species is known to grow larger in size, more predatory and cannibalistic in nature in comparison to earlier species. *C. striatus* in the process of cannibalism ingested comparatively smaller numbers (≥10 %) of prey and a large number of them die due to injury, shock and spread of diseases [23]. This phenomenon was observed in the present study also whereby hardly 15–20 % of the populations were found missing in the tanks and rest were collected in dead condition showing signs of injury in different parts of the body, more prominently on the caudal fin, which was eaten up either in toto or in part.

It has been demonstrated in several of the studies that application of formulated diets had improved survival greatly in fishes that observed great amount of cannibalism [23, 27–31]. However, it is also more important that formulated feed should meet the nutritional requirement of fish in general. The poor survival with isocaloric diets A, B and C containing protein levels of 300, 360 and 420 g kg^{-1} respectively, has revealed that nutritionally deficient diets tend to aggravate cannibalism as feed applied to all the treatments was in uniform quantity and was totally consumed everyday within a short span of time. The higher size of minimum length and weight of fishes in all the treatments at the time of termination of experiment with that of initial length and weight also confirmed that the feed was accepted in all the treatments, however, it is the

Table 2 Growth parameters of *Channa marulius* fed with different protein levels in the diet

Parameter	Feed A	Feed B	Feed C	Feed D	Feed E	Feed F
Initial no.	60	60	60	60	60	60
Survival (%)	46.6^{b}	46.6^{b}	46.6^{b}	53.3^{b}	88.3^{a}	85.0^{a}
Initial avg. length (cm)	4.11 ± 0.59^{a}	4.11 ± 0.59^{a}	4.11 ± 0.59^{a}	4.11 ± 0.59^{a}	4.11 ± 0.59^{a}	4.11 ± 0.59^{a}
Final avg. length (cm)*	6.34 ± 0.76^{a}	6.40 ± 0.79^{a}	6.50 ± 0.89^{a}	6.40 ± 0.90^{a}	6.23 ± 0.61^{a}	6.49 ± 0.6^{a}
Initial av. weight (g)	0.78^{a}	0.82^{a}	0.83^{a}	0.86^{a}	0.80^{a}	0.81^{a}
Final average weight (g)*	1.62 ± 0.57^{a}	1.68 ± 0.69^{a}	1.89 ± 0.74^{a}	1.71 ± 0.70^{a}	1.51 ± 0.46^{a}	1.72 ± 0.53^{a}
Initial biomass (g)*#	47.5^{a}	49.0^{a}	50.5^{a}	49.5^{a}	48.5^{a}	49.5^{a}
Gross biomass (g)*	46.4^{c}	47.2^{c}	53.0^{c}	62.8^{bc}	80.5^{ab}	88.6^{a}
Net biomass (g d^{-1})*	-1.1^{c}	-1.8^{c}	2.5^{c}	14.5^{bc}	33.0^{ab}	39.1^{a}
SGR % d^{-1}*	-0.0805^{c}	-0.0661^{c}	0.0748^{c}	0.3627^{bc}	0.771^{ab}	0.875^{a}
Weight gain per day (g)*	-0.01^{c}	-0.021^{c}	0.02^{c}	0.17^{bc}	0.39^{ab}	0.46^{a}
FCR*	2.37^{cd}	2.48^{d}	2.09^{c}	1.87^{b}	1.35^{a}	1.26^{a}
'y' values**	$0.0709x - 2.8474$	$0.0883x - 3.9726$	$0.0795x - 3.2779$	$0.0785x - 3.2300$	$0.0745x - 3.1314$	$0.0780x - 3.3771$
'w' values**	$0.0062{*}L^{3.0000}$	$0.0057{*}L^{3.000}$	$0.0066{*}L^{3.000}$	$0.0064{*}L^{3.000}$	$0.0061{*}L^{3.000}$	$0.0063{*}L^{3.000}$
'R^2' values**	0.878	0.940	0.951	0.943	0.939	0.853

Mean values within same rows and with different superscripts are significantly different at ($p < 0.05$) and ($p < 0.01$)

*n Values of all the surviving fishes

**$n = 28$ fishes

quality of feed which in the instant case is the level of protein that mattered for low and higher survival in different treatments (Table 2). It is better explained in case of diets E and F as the survival is better in these diets. It reveals that optimum dietary protein levels reduce the tendency of cannibalism. Qin and Fast [32] also have reported that when snakeheads begin feeding on formulated feed, the progressive size variation as fish grows does not necessarily provoke cannibalism when an adequate amount of suitable food is available.

The tanks showing higher rate of mortality also found to have greater size variations both in length and weight (Table 2 and Figs. 1, 2, 3, 4, 5, 6) that could have been occurred due to cannibalism in these tanks. Qin and Fast [23] and Qin et al. [33] observed that *C. striatus* in all treatments of feed application rates was found to cannibalize most small individuals and all treatments had a few large individuals at the end. This situation did not arise in the present study due to short-term experiment; however, greater differences in minimum and maximum size were observed in treatments showing poor survival provided with diets of low levels of protein. The wide range in initial size distribution enabled large individuals to cannibalize small ones and hence resulting into low survival.

Although acceptability of feed was recognized as stated above, significant differences ($p < 0.05$) existed amongst treatments in case of net biomass production, SGR, weight gain per day and FCR. The feeds A and B, however, showed negative values for net biomass production, SGR and per day weight gain due to higher rate of mortality/cannibalism and low protein levels in these diets. These values were, however, significantly higher in diets C ($p > 0.05$) and D ($p < 0.05$) which were also likely to happen due to reasons stated above. However, no significant ($p < 0.05$) change in net biomass, SGR and weight gain per day was observed in diets E and F provided with higher protein levels in the present study that indicated that the fish may efficiently consume protein up to 600 g kg^{-1} and protein level of 540 g kg^{-1} would be economical for its culture (Table 2). This finding was partly favoured in respect that protein level of 540 g kg^{-1} in diet performed best and economical but protein level of 600 g kg^{-1} also showed more or less similar growth in fishes which was in contrast to the findings of Mohanty and Samantaray [26], who observed depressed growth at protein levels higher than 550 g kg^{-1} in *C. striatus*. Similar observations have

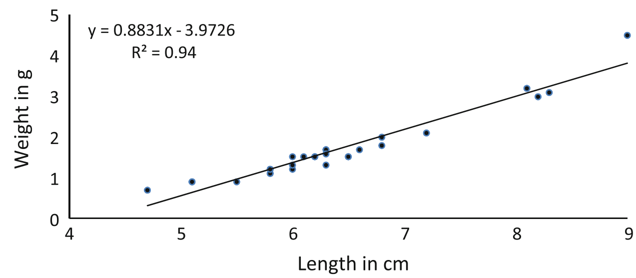

Fig. 2 Length-weight relationship of *C. marulius* fed diet B

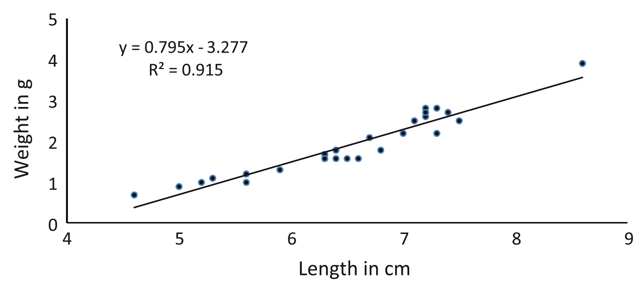

Fig. 3 Length-weight relationship of C. marulius fed diet C

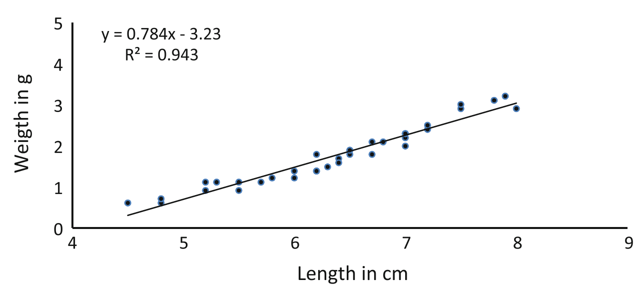

Fig. 4 Length-weight relationship of *C. marulius* fed diet D

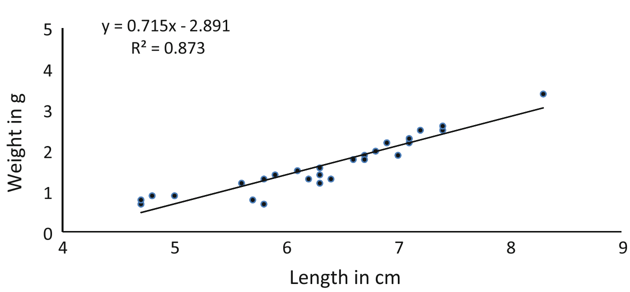

Fig. 1 Length-weight relationship of *C. marulius* fed diet A

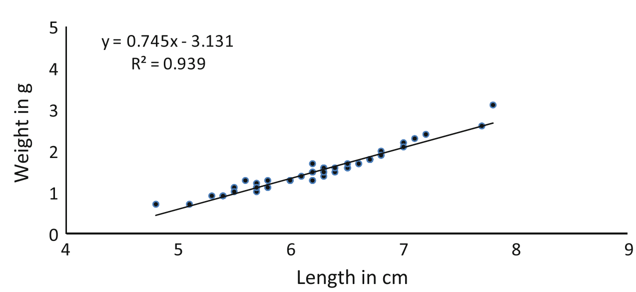

Fig. 5 Length-weight relationship of *C. marulius* fed diet E

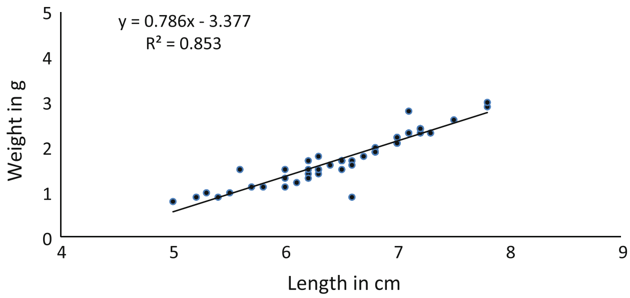

Fig. 6 Length-weight relationship of *C. marulius* fed on diet E

also been made in case of juvenile *C. striata* [34], *C. micropeltes* [35], *Chanos chanos* [36], *Epinephelus tauvina* [37], *Cyprinus carpio* [38], *Ictalurus punctatus* [39] and *Sarotherodon mossambicus* [40].

The 'W' values were found to follow Fulton's cube law with all the diet treatments indicating well being of the fish and was better than the adult natural stock [41, 42]. The 'R^2' values (0.853–0.943) were also comparable with the natural population [43] that also confirmed satisfactory growth on all experimental artificial feeds (Table 2). These facts illustrate that the cause of mortality in fish in different treatments is not because of poor feed acceptability, instead it is the quality of feed that mattered for higher survival and growth.

Protein efficiency studies on snakehead body tissue have been performed in good number of cases both from capture and culture stocks [11, 26, 44–46], however, there is dearth of such literature on *C. marulius*. Barring the study of Zuraini et al. [11], the level of protein in body tissues in case of *C. striatus* has been reported to be 230 g kg^{-1} [11] to 449.0 g kg^{-1} [45] in natural stocks whereas in experimental culture, protein level as high up to 713 g kg^{-1} has been reported when fish fed dietary protein level 450 g kg^{-1} along with a lipid level of 65 g kg^{-1} [44]. The latter, therefore support the present findings in which protein levels in body carcass of *C. marulius* was recorded from 560.9 to 666.3 g kg^{-1} (Table 3) when *C. marulius* was fed semi-purified diets containing dietary protein levels of 300 g kg^{-1} (energy 17.97 kJ g^{-1}) to 600 g kg^{-1} (18.47 kJ g^{-1}). The availability of protein in body carcass greatly depends on species, size, age, season, protein quality, dietary level of energy, water quality and presence of natural food and culture management [45, 47].

Protein efficiency in *C. marulius* was found almost directly proportional to the dietary protein levels as all treatments had significantly ($p < 0.05$) different carcass protein with highest protein in diet F (Table 3). These results were similar to the work of Aliyu-Paiko et al. [44] and Mohanty and Samantray [26]. Higher amount of carcass protein in comparison to the dietary protein in all the treatments revealed that this fish has high sparing capacity of metabolizable NFE to protein [44]. This also fits well in case of lipid levels with diets E and F, where carcass lipid levels were found significantly ($p < 0.05$) higher than the dietary lipid levels (Table 3). According to Gam et al. [45], carcass protein level depends on availability of natural food in water in case of *C. striatus* and found highest during rainy season when quantity of natural food is at maximum. The reason of higher deposition of carcass protein in the fish in the present study and that of findings of Aliyu-Paiko et al. [44] therefore, may be due to feeding higher amount of dietary protein in the present instance. The moisture content was also found significantly ($p < 0.05$) low with diet F in comparison to other diets. The average values of water quality was found in normal range having temperature 28.3 ± 1.15 °C, pH 7.5 ± 0.07, total alkalinity 138.4 ± 2.06 mg L^{-1} and DO 6.84 ± 0.27 mg L^{-1} respectively whereas, free CO_2 was absent in all the tanks.

Conclusion

On the basis of survival, growth and protein efficiency indices recorded in the present study, the dietary protein requirement of *C. marulius* fry was assessed to be around 54–60 g kg^{-1} at energy value of 18.4 kJ g^{-1} when fed @ 8–5 % of bw day^{-1}. It was also evaluated that this fish has

Table 3 Proximate composition of the carcass of *C. marulius* fed on different diets

Parameter	Initial	Diet A	Diet B	Diet C	Diet D	Diet E	Diet F
Protein (A) (g kg^{-1})	651.5^{a}	560.9^{d}	576.9 ^{cd}	583.3^{c}	627.6^{b}	586.6^{b}	666.3^{a}
NFE (B) (g kg^{-1})	123.0^{a}	114.0^{bc}	102.2^{d}	117.0^{ab}	111.3^{bc}	108.2 ^{cd}	108.1d^{c}
Lipids (C) (g kg^{-1})	54.4^{c}	43.0^{d}	44.6^{d}	34.6^{f}	38.5^{e}	58.6^{b}	66.8^{a}
Moisture (%)	72.04^{d}	80.30^{c}	81.77^{bc}	84.26^{a}	82.78^{ab}	81.95^{bc}	72.04^{e}
Dry matter (%)	27.95	19.70	18.23	15.74	17.22	18.045	27.96
Total (A + B + C) (DM basis) (g kg^{-1})	828.9	718.0	723.8	734.9	777.4	798.1	841.2
GE kg^{-1}	393.19	338.36	342.15	341.94	363.10	381.82	404.98
KJ g^{-1}	16.51	14.21	14.37	14.36	15.25	16.03	17.00

Values in a row are significantly different at 95 % confidence limit high sparing capacity of utilizing metabolizable NFE in protein and lipid replacement. However, this needs to be confirmed with natural feed ingredients in future studies.

Acknowledgments The first and third authors are thankful to Uttar Pradesh Council of Agricultural Research, Lucknow for funding the part of this work. The facilities provided by the Director, NBFGR, Lucknow for carrying out this work is also greatly acknowledged.

References

1. Parameswaran S, Kamal MY (1988) Synopsis of biological data on the giant murrel, *Channa marulius* and the spotted *Channa punctatus*. India Bulletin, 53, P 77, CIFRI, Barrackpore
2. Kilambi RV (1986) Age, growth and reproductive strategy of the snakehead, *Ophiocephalus striatus* Bloch from Sri Lanka. J Fish Biol 29:13–22
3. Shrestha TK (1990) Resource ecology of the Himalayan waters. Curriculum Development Centre, Tribhuvan University, Kathmandu
4. Talwar PK, Jhingran AG (1991) Inland fishes of India and adjacent countries, vol 2, A.A. Balkema, Rotterdam
5. Hossain MK, Latifa GA, Rahman MM (2008) Observation on induced breeding of snakehead murrel, *Channa striatus* (Bloch 1793). Int J Sustain Crop Prod 3:65–68
6. Mat Jais AM, McCulloh R, Croft K (1994) Fatty acid and amino acid composition in haruan as a potential role in wound healing. Gen Pharmacol 25:947–950
7. Mat Jais AM, Dambisya YM, Lee TL (1997) Antinociceptive activity of *Channa striatus* (haruan) extracts in mice. J Ethnopharmacol 57:125–130
8. Somchit MN, Solihah MH, Israf DA, Ahmad Z, Arifah AK, Mat Jais AM (2004) Anti-inflammatory activity of *Channa striatus*, *Channa micropeltes* and *Channa lucius* extracts: chronic inflammatory modulation. J Orient Pharm Exp Med 4(2):91–94
9. Wee KL (1982) The biology and culture of snakeheads. In: Muir JF, Roberts RJ (eds) Recent advances in aquaculture. Westview Press, Boulder, Colorado, pp 180–211
10. Zakaria ZA, Somchit MN, Sulaiman MR, Mat Jais AM (2004) Preliminary investigation on the antinociceptive activity of haruan (*Channa striatus*) fillet extract with various solvent system. Pak J Biol Sci 7(10):1706–1710
11. Zuraini A, Somchit MN, Solihah MH, Goh YM et al (2006) Fatty acid and amino acid composition of three local Malaysian *Channa* spp. Fish Food Chem 97(4):674–678
12. Chacko PI (1947) Culture of murrel fish *Ophiocephalus marulius* (Ham.) in irrigation wells. J Bombay Nat Hist Soc 47(2):392–393
13. Chacko PI, Kurian GK (1947) On the culture of *Ophiocephalus marulius* Hamilton, in the Coimbatore and Salem districts, Madras. Proc Indian Sci Congr 34(3):180
14. Chen LC (1990) Snakehead culture. In: aquaculture in Taiwan. Blackwell, Boston, pp 39–42
15. Wee KL (1981) Snakehead (*Channa striatus*) farming in Thailand. NACA/WP/81/3 Nov 1981
16. Ng PKL, Lim KKP (1990) Snakeheads (Pisces: Channidae): Natural history, biology and economic importance. In: Ming CL, Ng PKL (eds) Essays in Zoology. Papers commemorating the 40th anniversary of the Department of Zoology, National University of Singapore, pp 127–152
17. Diana JS, Chang WYB, Ottey DR, Chuapoehuk W (1985) Production systems for commonly cultured freshwater fishes of Southeast Asia. In: international program report, number 7, Great Lake and Marine Water Center, University of Michigan, Ann Arbor, Michigan, USA, pp 75–79
18. Qin J, Fast Arlo W (1996) Size and feed dependent cannibalism with juvenile snakehead *Channa striatus*. Aquaculture 114: 313–320
19. Fox LR (1975) Cannibalism in natural populations. Annu Rev Ecol Syst 6:87–106
20. Hecht T, Pienaar AG (1993) A review of cannibalism and its implication in fish larviculture. J World Aquacult Soc 24: 246–261
21. Polis GA (1981) The evolution and dynamics of intraspecific predation. Annu Rev Ecol Syst 12:225–251
22. Qin J, Fast AW (1997) Food selection and growth of young snakehead *Channa striatus*. J Appl Ichthyol 13:21–25
23. Qin J, Fast Arlo W (1996) Effects of feed application rates on growth, survival, and feed conversion of juvenile snakehead *Channa striatus*. J World Aquacult Soc 27(1):52–56
24. AOAC (Association of Official Analytical Chemists) (1990) In: Helrich K (ed) Official methods of analysis of the association of official analytical Chemists, 15th edn. Association of Official Analytical Chemists, Arlington, Virginia, p 1298
25. APHA (1985) Standard Methods for the examination of water and wastewater. edition, 16th edn. American Public Health Association, Washington
26. Mohanty SS, Samantaray K (1996) Effect of varying levels of dietary protein on the growth performance and feed conversion efficiency of snakehead *Channa striata* fry. Aquacult Nutr 2: 89–94
27. Hoelzer GA (1992) The ecology and evolution of partial-clutch cannibalism by parental Cortez damselfish. Oikos 65:113–120
28. Kvarnemo C, Svensson O, Forsgren E (1998) Parental behavior in relation to food availability in the common goby. Anim Behav 56:1285–1290
29. Andrea Manica (2004) Parental fish change their cannibalistic behavior in response to the cost-to-benefit ratio of parental care. Anim Behav 67:1015–1021
30. Rohwer S (1978) Parental cannibalism of offspring and egg raiding as a courtship strategy. Am Nat 112:429–440
31. Sargent RC (1992) Ecology of filial cannibalism in fish: theoretical perspectives. In: Elgar MA, Crespi BJ (eds) Cannibalism: ecology and evolution among diverse Taxa. Oxford University Press, Oxford, pp 38–62
32. Qin JF, Fast AW (1998) Effects of temperature, size and density on culture performance of snakehead, *Channa striatus* (Bloch), fed formulated feed. Aquacult Res 29(4):299–303
33. Qin J, Fast Arlo W, DeAnda D, Weidenbach Ronald P (1997) Growth and survival of larval snakehead (*Channa striatus*) fed different diets. Aquaculture 48:105–113
34. Wee KL (1986) A preliminary study on the dietary protein requirements of juvenile snakehead. In: Proceedings of International Conference Dev Managet Trop Living Aqua Resources, Serdang, Malaysia. 2–5 Aug 1983, pp 131–136
35. Wee KL, Tacon AGJ (1982) A preliminary study on the dietary protein requirement of juvenile snakehead. Bull Jpn Soc Sci Fish 48:1463–1468
36. Lim C, Sukhawongs S, Pascual FP (1979) A preliminary study on the protein requirement of *Chanos chanos* (Forskal) fry in a controlled environment. Aquaculture 17:195–201
37. Teng SK, Chua TE, Lim PE (1978) Preliminary observation on the dietary protein requirement of estuary grouper, *Epinephelus salmoides* Maxwell, cultured in floating net cages. Aquaculture 15:257–289
38. Ogino C, Saito K (1970) Protein nutrition in fish. I. The utilization of dietary protein by young carp. Bull Jpn Soc Sci Fish 36:250–254
39. Prather EB, Lovell RT (1973) Responses of intensively fed channel catfish to diets containing various protein energy ratios. Proc South East Assoc Game Fish Comm 27:455–459

40. Jauncey K (1982) The effect of varying dietary protein level on the growth, food conversion, protein utilization and body composition of juvenile tilapia *Sarotherodon mossambicus*. Aquaculture 27:43–54
41. Anish Dua, Kanwaljit Kumar (2006) Age and growth patterns in *Channa marulius* from Harike Wetland (A Ramsar site), Punjab India. J Environ Biol 27(2):377–380
42. Johal MS, Hanel L, Oliva O (1983) Note on the growth of *Ophiocephalus marulius* (Pisces: Ophiocephaliformes). Vest Cs Spolec Zool 47:81–86
43. Devraj M (1973) Biology of the large snakehead, *Ophiocephalus marulius* (Ham.) in Bhavanisagar water. Indian J Fish 20(10): 139–147
44. Aliyu-Paiko M, Hashim R, Shu-Chien AC (2010) Influence of dietary lipid/protein ratio on survival, growth, body indices and digestive lipase activity in snakehead (*Channa striatus*, Bloch 1793) fry reared in re-circulating water system. Aquacult Nutr 16:466–474
45. Gam L-H, Leow C-Y, Baie S (2006) Proteomic analysis of snakehead fish (*Channa striata*) muscle tissue. Malays J Biochem Mol Biol 14:25–32
46. Yang S-T, Lee E-H (1980) Taste compounds of Korean snakehead meat. In: taste compounds of fresh-water fishes. Bull Korean Fish Soc 13(3):115–119
47. NRC (National Research Council) (1993) Nutrient requirements of warm water fishes. National Academy of Sciences, Washington, p 114