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SUPPLEMENTATION OF FOUR NON-CONVENTIONAL AQUATIC WEEDS TO THE BASAL DIET OF *CATLA CATLA* AND *CIRRHINUS MRIGALA* FINGERLINGS: EFFECT ON GROWTH, PROTEIN UTILIZATION AND BODY COMPOSITION OF FISH

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Kalita P., Mukhopadhyay P.K., Mukherjee A.K. 2008. Supplementation of four non-conventional aquatic weeds to the basal diet of *Catla catla* and *Cirrhinus mrigala* fingerlings: Effect on growth, protein utilization and body composition of fish. Acta Ichthyol. Piscat. 38 (1): 21–27.

Background. Our previous study has shown that four aquatic weeds viz. Asian watermoss, *Salvinia cucullata*; water spinach *Ipomoea reptans*; water chestnut, *Trapa natans*; and lesser duckweed, *Lemna minor*) from north-east India are important sources of proteins, vitamins and minerals, suitable for incorporation in fish diet. The aim of the present study was to compare the efficacy of these aquatic weeds based formulated diets on growth, feed utilization and nutrient turnover from feed to fish flesh of fingerlings of two species of Indian major carps: catla, *Catla catla* (Hamilton, 1822), and mrigal, *Cirrhinus mrigala* (Bloch, 1795).

Material and Methods. The fingerlings were hand-sorted and distributed in 15 glass aquaria (each having 50 l capacity) at a stocking density of 5 fishes per aquarium. Five formulated diets (containing 26%–28% of crude protein approximately) were prepared and analyzed for proximate composition. The diets were fed to catla and mrigal fingerlings in triplicate treatments at the rate 3% of body weight for 60 days and fish performance in terms of growth, feed utilization and carcass composition was evaluated.

Results. The whole body composition and energy content of *C. catla* fingerlings before and at the end of feeding trials did not differ significantly ($P > 0.05$), however, the proportion of crude lipid content was high when fed with diet F_2 ($P < 0.05$). In case of *C. mrigala,* crude protein, as well as lipid contents, were significantly higher in all the groups of fish at the end of experiment as compared to the initial fish. The hepatic- as well as the muscle tissues of catla and mrigal fingerlings fed the diet F_2 (containing *I. reptans*) displayed high contents of crude protein and vitamin E ($P < 0.01$). Interestingly, although no difference in muscle glycogen level in *C. mrigala* was observed irrespective of the diet fed however, muscle and liver glycogen contents in *Catla catla* fingerlings fed F_2 diet was significantly higher compared to glycogen contents of these tissues of initial fish or fish fed with control diet.

Conclusions. Presently reported study suggests that *I. reptans*, being a rich source of nutrients, is suitable for incorporation in fish diet for *C. catla* and *C. mrigala* fingerlings.

Keywords: *Catla catla, Cirrhinus mrigala*, fish feed, gross energy, Indian major carp, *Ipomoea reptans*

INTRODUCTION

Aquaculture is a powerful livelihood for a large section of economically under-privileged population in India. Cyprinids form the major component of aquaculture production in the country and contribute as much as 87% of the total aquaculture production of 1768 million tons (Anonymous 1998). The two cyprinid species, *Catla catla* (catla) and *Cirrhinus mrigala* (mrigal), non-predatory Indian major carps, are predominantly accepted in the Eastern and North Eastern parts of India both in terms of consumer preference and amenability to culture in different ecosystems (Ayyappan and Jena 1998).

Feed is considered as the most critical input for augmenting fish production. The fish accept a wide variety of agricultural by-products in the form of pelleted or dough feed. Several studies have been carried out on the development of formulated feed for the species under controlled culture system (Mohanty et al. 1995, Mukhopadhyay and

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Ray 1999, Mukhopadhyay and Ray 2001, Khan et al. 2004, Biswas et al. 2006). In almost all these studies, ingredients, such as fishmeal, soybean meal, and ground-nut oil cake were liberally used. All these materials are becoming prohibitively costly for their continued use in aquafeeds in the foreseeable future. This has necessitated search for alternative sources available locally in the country. In this context use of certain potential aquatic weeds offer excellent scope as these nutrient-laden materials are naturally grown in the entire North Eastern region of the country without much agronomic care (Kalita et al. 2007). Certain aquatic macrophytes have been used as feed components, in the past, based on laboratory trials (Ray and Das 1992, 1995). These have been shown to contain substantial amount of protein and minerals (Edwards 1987) and were considered suitable for incorporation as a feedstuff for conversion into protein sources of high biological value.

The present study was undertaken to assess the comparative efficacy of four selected aquatic weeds (Asian watermoss, *Salvinia cucullata*; water spinach *Ipomoea reptans*; water chestnut, *Trapa natans*; and lesser duckweed, *Lemna minor*)—based formulated diets on the growth performance, feed utilization and nutrient turnover from feed to fish flesh of catla and mrigal fingerlings.

MATERIALS AND METHODS

Experimental design. The experiment was conducted in 15 glass aquaria each having 50 L of water with 5 fish (*C. catla* fingerlings average weight 41.2 ± 2.1 g, n = 5, average length 15.0 ± 1.2 cm and *C. mrigala* average weight 43.2 ± 1.7 g, n = 5, average length 15.6 ± 1.0 cm) per aquarium. The fingerlings were procured from a local fish farm and acclimatized to the laboratory condition for 48 h prior to the commencement of the experiment. Five fishes were used for analysis of initial whole body proximate composition. The fingerlings were randomly distributed at the rate of 5 fish per aquarium with three replications for each diet treatment. Aeration was continuously provided from air compressors through air stones daily and about 50% of water from each aquarium was replaced with clean stored tap water. The aquaria were maintained indoor under natural photoperiod conditions. The experimental fish were fed twice daily at 0930 h and 1700 h at a fixed feeding rate of 3% of the total biomass for a period of 60 days and during this period, water temperature was recorded everyday and it ranged from 26 to 30°C. Fish were weighed and length measured at fortnightly intervals and feeding quantity was readjusted accordingly. Left over feed, if any, was removed by siphoning 2 h post feeding. At the end of the experiment 4 fishes from each aquaria were used for analysis of whole body composition.

Experimental diet preparation and chemical analyses. The ingredient composition of the experimental diets and proximate composition including the gross energy and protein / energy ratio are presented in Table 1. For the purpose of feed preparations raw ingredients including the four aquatic weeds viz. *S. cucullata*, *I. reptans*, *T. natans*, and *L. minor* were dried at room temperature, ground to powder, sieved, and then weighed. The ingredients were heated to about 70ºC and then cooled to room temperature. Weighed amounts were then mixed thoroughly using a commercial blender cum mixer followed by mixing with vitamin- mineral premix.

Measured volume of lukewarm water was mixed to these feed mixtures and dough form was prepared for each. These were then put to hand pelletizer fitted with a 2-mm die. The pellets (spaghetti type) of all five formulated feeds (F_1 through F_4 and C) were sun dried and stored in airtight containers in refrigerator for use during feeding trial. The diets were analyzed for proximate composition (%) following the procedures of AOAC (Anonymous 1990). The crude protein was determined by Kjeldahl method using boric acid to trap the released ammonia. Total lipid was analyzed gravimetrically using Soxhlet apparatus (petroleum ether extraction, boiling point 60–80ºC). Ash content was determined by incinerating the dried samples in a muffle furnace. Crude fibre content was estimated using the Fibertech system (Fibro Plus, Model Kelvat FES2). The carbohydrate (NFE) content of feed was determined as the weight difference using moisture, crude protein and lipid and ash content data (Carrel et al. 1956). Gross energy was determined by using an adiabatic bomb calorimeter (IKA C-7000) using benzoic acid as a standard. For whole body analyses exactly similar procedures were followed.

Sample collection. At the end of 60 days feeding trial, fish were weighed and their growth performance and nutrient utilization were determined in terms of feed conversion ratio (FCR), protein efficiency ratio (PER), specific growth rate (SGR), protein retention efficiency (PRE), and energy retention (ER) according to Castell and Tiews (1980). Average food consumption (AFC) was standardized by calculating it in relation to the metabolic weight of the fish as described previously by Elliott (1979) and modified by Jobling (1993).

Analysis of fish tissue. Fishes were sacrificed (12 h after the last feeding) under cold conditions; liver and muscle tissues were dissected out from fish as quickly as possible and stored at –20°C to analyze glycogen, total protein and lipid and vitamin E contents of liver and muscle tissues.

Determination of Vitamin E (α-tocopherol) contents of hepatic and muscle tissues of *C. catla* and *C. mrigala* was done by extracting the total lipid material of tissue (Folch et al. 1957) followed by extraction of α-tocopherol from total lipid and then the extracted α-tocopherol was quantified by the procedure of Baker and Frank (1968).

Isolation and estimation of glycogen content of liver and muscle tissues were done as described by Plummer (1996). The tissue sample (liver or muscle) of 2 g was briefly homogenized in 10% w/v (weight/volume) TCA (Trichloro acetic acid) and centrifuged at 10 000 × g for 15 min at 4ºC, the supernatant was transferred to another tube and the sediment was re-homogenized with 5% (w/v) TCA and the process was repeated. The two supernatants were combined and 45% ethanol was added to make up the volume to 50 mL. After mixing them well it was left

Table 1

Ingredient proportions and proximate composition (% DM) of formulated diets for *Catla catla* and *Cirrhinus mrigala* fingerlings; the values for proximate composition represent mean ± standard deviation of five determinations

Components/composition	Formulated Diets				
	F1	F2	F3	F4	Control
	Ingredients proportion [%]				
Mustard oil cake	45	45	50	45	45
Silk worm pupae	10	10	10	10	8
Rice bran	23	33	15	33	45
Salvinia cuculata	20	—	—	—	—
Ipomoea reptans	—	10	—	—	—
Trapa natans	—	—	23	—	—
Lemna minor	—	—	—	10	—
Vitamin mineral premix*	2	2	2	2	2
	Proximate composition [%]				
Dry matter	78.9 ± 0.9	81.1 ± 0.8	91.6 ± 0.9	91.1 ± 0.7	97.7 ± 1.1
Crude protein	26.5 ± 1.7	27.5 ± 1.1	27.7 ± 1.4	28.1 ± 1.4	28.2 ± 1.6
Crude lipid (ether extract)	7.8 ± 1.4	7.0 ± 1.5	8.1 ± 2.5	7.9 ± 4.4	8.0 ± 2.6
Ash	10.4 ± 0.8	7.2 ± 1.6	6.5 ± 1.5	8.2 ± 1.3	6.4 ± 1.5
Crude fibre	10.4 ± 0.8	7.4 ± 1.1	7.6 ± 0.9	7.7 ± 1.2	7.5 ± 1.6
Nitrogen free extract	43.2 ± 2.5	39.2 ± 3.4	48.2 ± 4	47.4 ± 2.3	54.0 ± 2.1
Total carbohydrate (NFE + crude fibre)	53.6 ± 1.6	46.6 ± 1.7	55.8 ± 1.9	55.1 ± 1.7	61.5 ± 1.2
	Energy values				
Gross energy [kcal/100 g]	398.6 ± 1.8	360.6 ± 1.6	399.4 ± 3.4	399.1 ± 2.8	424.2 ± 3.8
P/E [mg protein/kcal]	66.5 ± 1.8	76.3 ± 1.1	69.4 ± 2.3	70.4 ± 2	66.5 ± 3.1

*Vitamin premix (mg or IU/g premix): retinol palmitate, 500 000 IU; thiamin, 5; riboflavin, 5; niacin, 25; folic acid, 1; pyridoxine, 5; cyanocobalamine, 5; ascorbic acid, 10; cholecalciferol, 50 000 IU; a -tocoferol, 2.5; menadione, 2; inositol, 25; pantothenic acid, 10; choline chloride, 100; biotin, 0.25.

in the refrigerator overnight for precipitation, and the next day the precipitate was isolated by centrifugation, dried at room temperature and then used for glycogen isolation and quantification.

Total lipid from tissue samples was isolated by the method of Folch et al. (1957).

Statistical analysis. The effects of dietary treatments on the measured response variables were studied with the help of two-way analysis of variance (ANOVA) by using the software Systat-10 because two factors are being tested simultaneously i.e., diet and fish species. A probability level of $P < 0.05$ was considered statistically significant.

RESULTS

Table 1 presents the proximate composition of the diets. Total protein content of the diets ranged between 26.0% and 28.0% on moisture free basis. Statistical analysis showed that proximate composition and energy values of these diets did not differ significantly ($P > 0.05$) whereas crude lipid content and P/E (protein/energy) value of the diets displayed some variations. Diet F_2 (containing *I. reptans as* ingredient) was characterized to possess least amount of lipid and highest P/E value as compared to three other formulated diets and control ($P < 0.01$).

Table 2 shows the growth responses and associated nutritional indices of both catla- and mrigala fingerlings fed the five experimental diets (F_1 through F_4 and C) for 60 days. The fishes readily accepted all the formulated diets as it was evident from the observation of average food consumption in fish, which did not differ significantly ($P > 0.05$) among the different groups of fish. Except PER, SGR, and PRE, the other growth parameters in terms of feed conversion ratio (FCR), increase in length (IL), and gain in body weight (BWG) were significantly higher in catla and mrigal fingerlings fed *I. reptans*-based diet (F_2), as compared to the other diets.

The carcass composition of experimental *C. catla* and *C. mrigala* fingerlings before and at the end of 60 days of feeding is shown in Table 3. It was observed that except crude lipid content, the other tested components and gross energy content of *C. catla* fingerlings before and post feeding trial did not differ significantly ($P > 0.05$) irrespective of the supplied feed, but the proportion of crude lipid was higher in those fishes fed with the diet F_2 as compared to other feeds ($P < 0.05$). In case of *C. mrigala*, crude protein as well as crude lipid contents were enhanced significantly ($P < 0.05$) post feeding the F_2 and control diets (Table 3).

Table 4 displays some biochemical composition of liver and muscle tissues of *C. catla* and *C. mrigala* fingerlings fed with different aquatic weeds-based formulated and control diets for 60 days. Both catla and mrigal fingerlings fed the diet F_2 displayed high content of crude protein and vitamin E in their hepatic as well in the muscle tissues ($P < 0.01$). The crude lipid content of muscle

Table 2

Growth performance and feed utilization by *Catla catla* and *Cirrhinus mrigala* fed different experimental diets (F_1 to F_4 and control) for 60 days; values are mean ± standard deviation of triplicate groups of fish, with 5 fish/group (n = 5); values for each experiment in the same row followed by different superscripts are significantly different ($P < 0.05$)

Experimental diets	Parameters							
	FCR	PER	PRE	SGR	SWG	IL	AFC	PS
				C. catla				
F1	6.4 ± 1.0[a]	0.3 ± 0.2[a]	0.04 ± 0.01[a]	0.3 ± 0.3[a]	117.05 ± 1.6[a]	107.31 ± 1.5[a]	0.04 ± 0.03[a]	98.1 ± 2.0[a]
F2	2.5 ± 0.6[b]	0.7 ± 0.5[a]	0.18 ± 0.1[a]	0.7 ± 0.5[a]	151.60 ± 2.6[b]	115.79 ± 1.5[b]	0.04 ± 0.01[a]	99.2 ± 1.8[a]
F3	4.4 ± 1.2[a]	0.4 ± 0.3[a]	0.09 ± 0.01[a]	0.3 ± 0.3[a]	108.05 ± 0.9[a]	104.55 ± 1.1[a]	0.04 ± 0.02[a]	95.8 ± 1.6[a]
F4	3.3 ± 1.0[b]	0.5 ± 0.3[a]	0.13 ± 0.02[a]	0.5 ± 0.1[a]	136.47 ± 1.5[a]	106.87 ± 1.6[a]	0.05 ± 0.02[a]	98.0 ± 1.3[a]
Control	3.0 ± 0.8[b]	0.3 ± 0.1[a]	0.10 ± 0.05[a]	0.7 ± 0.2[a]	147.05 ± 1.4[b]	113.66 ± 1.5[b]	0.05 ± 0.02[a]	98.5 ± 2.0[a]
				C. mrigala				
F1	5.0 ± 0.4[a]	0.4 ± 0.3[a]	0.2 ± 0.2[a]	0.3 ± 0.2[a]	127.1 ± 3.6[a]	107.2 ± 2.6[a]	0.11 ± 0.05[a]	98.0 ± 1.9[a]
F2	2.2 ± 0.4[b]	0.9 ± 0.4[a]	0.4 ± 0.2[a]	0.8 ± 0.2[a]	157.1 ± 2.7[b]	114.0 ± 2.5[a]	0.1 ± 0.04[a]	99.1 ± 1.4[a]
F3	4.8 ± 0.6[a]	0.4 ± 0.3[a]	0.2 ± 0.2[a]	0.4 ± 0.2[a]	123.8 ± 2.7[a]	107.2 ± 2.5[a]	0.11 ± 0.1[a]	96.2 ± 2.5[a]
F4	3.2 ± 0.4[a]	0.7 ± 0.4[a]	0.3 ± 0.2[a]	0.6 ± 0.3[a]	143.5 ± 2.7[a]	108.1 ± 3.6[a]	0.1 ± 0.06[a]	98.2 ± 1.5[a]
Control	2.7 ± 0.5[b]	0.7 ± 0.4[a]	0.3 ± 0.1[a]	0.6 ± 0.3[a]	146.2 ± 2.4[b]	111.2 ± 3.0[a]	0.1 ± 0.01[a]	98.7 ± 2.0[a]

FCR = feed conversion ratio; PER = protein efficiency ratio PRE = protein retention efficiency; SGR = specific growth rate; BWG = body weight gain [%]; IL = increase in length [%]; AFC = average food consumption [mg · $g^{-0.75}$ body weight · d^{-1}]; PS = percent survival.

Table 3

Whole body composition (% fresh wet weight basis) and energy content [kJ] of *Catla catla* and *Cirrhinus mrigala* fingerlings fed with different diets for 60 days; each value represents mean ± standard deviation of five determinations; values in the same row within each experiment followed by different superscripts are significantly different ($P < 0.05$)

Experimental diets	Parameters					
	Crude protein [%]	Crude lipid [%]	Ash [%]	Crude fibre [%]	Nitrogen-free extract	Gross energy [kJ]
			C. catla			
Initial fish	50.3 ± 4.2	3.1 ± 0.7	2.2 ± 1.2	2.2 ± 1.2	34.3 ± 11.6	16.3 ± 1.3
F1	51.2 ± 4.2[a]	3.5 ± 0.9[a]	2.8 ± 1.3[a]	2.8 ± 1.3[a]	33.4 ± 9.1[a]	17.2 ± 1.2[a]
F2	55.1 ± 3.5[a]	5.3 ± 0.9[b]	2.5 ± 1.1[a]	2.5 ± 1.1[a]	26.0 ± 8.5[a]	16.7 ± 0.8[a]
F3	52.7 ± 6.5[a]	4.5 ± 0.5[a]	3.1 ± 1.7[a]	3.1 ± 1.7[a]	28.8 ± 7.0[a]	17.2 ± 0.9[a]
F4	54.2 ± 8.8[a]	4.0 ± 0.5[a]	3.5 ± 1.3[a]	3.5 ± 1.3[a]	28.0 ± 9.2[a]	17.2 ± 1.2[a]
Control	53.1 ± 5.8[a]	5.1 ± 0.8[b]	3.3 ± 1.7[a]	3.3 ± 1.7[a]	28.0 ± 9.4[a]	17.2 ± 1.3[a]
			C. mrigala			
Initial fish	50.1 ± 0.6	5.3 ± 0.7	2.5 ± 0.6	2.5 ± 0.6	29.7 ± 2.0	16.3 ± 0.1
F1	54.3 ± 0.7[a]	5.8 ± 0.7[a]	3.0 ± 0.9[a]	3.0 ± 0.9[a]	26.8 ± 1.7[a]	17.2 ± 0.2[a]
F2	60.8 ± 0.6[b]	7.4 ± 0.7[b]	2.8 ± 0.7[a]	2.8 ± 0.7[a]	16.2 ± 1.6[b]	16.7 ± 0.2[a]
F3	54.7 ± 1.0[a]	6.1 ± 0.8[a]	3.5 ± 0.8[a]	3.5 ± 0.8[a]	22.3 ± 2.9[a]	17.2 ± 0.2[a]
F4	57.1 ± 0.7[a]	6.0 ± 0.8[a]	4.0 ± 1.6[a]	4.0 ± 1.6[a]	20.0 ± 1.6[b]	17.2 ± 0.4[a]
Control	58.6 ± 1.5[b]	6.9 ± 0.8[b]	4.2 ± 1.6[a]	4.2 ± 1.6[a]	18.3 ± 1.3[b]	17.2 ± 0.4[a]

and hepatic tissues of catla and muscle tissue of mrigal fingerlings did not vary significantly ($P > 0.05$). The highest hepatic lipid content was displayed by groups of fish fed on diets F_2 and F_3. The muscle glycogen level was significantly enhanced in those *Catla catla* fed F_2 diet (Table 4). Identically, liver glycogen content in both catla and mrigal fish was significantly increased ($P < 0.01$) post feeding the F_2 diet.

DISCUSSION

The present study documents the growth response of catla and mrigal fingerlings fed with the four aquatic weeds based formulated diets. Our result showed that both catla and mrigal fish fed on different diets differed significantly with respect to growth response showing superiority of F_2 diet (containing *I. reptans*) as compared to the other three diets. The results of our previous study have shown that the aquatic weed *I. reptans* contains a significantly higher amounts of vitamins, mineral ions and proteins, and tolerable amounts of anti-nutrients (e.g., trypsin inhibitory activity, tannins, phytate and calcium oxalate) compared to other three aquatic weeds (Kalita et al. 2007). These properties of *I. reptans* might be responsible for overall best growth performance of catla and mrigal fish post feeding the F_2 (*I. reptans* based) diet.

Since in the present study, the gross energy content of the formulated diets did not vary significantly ($P > 0.05$)

Table 4

Some biochemical composition of liver and muscle tissues of *Catla catla* and *Cirrhinus mrigala* (n = 5) fed with different formulated diets for 60 days; values are mean ± standard deviation of triplicate group of fish, with 5 fish/group; values in the same row within each experiment followed by different superscripts are significantly different ($P < 0.05$)

		Glycogen [μg · g^{-1} tissue]	Crude Protein [%]	Crude Lipid [%]	Vitamin E [μg · g^{-1} tissue]
		C. catla			
Initial fish	Hepatic tissue	21.3 ± 0.9	16.1 ± 0.7	1.2 ± 0.7	8.7 ± 0.5
F1		25.2 ± 0.7^{a}	18.2 ± 1.0^{a}	2.4 ± 0.9^{b}	18.1 ± 0.9^{b}
F2		35.3 ± 0.8^{b}	24.1 ± 0.6^{b}	3.5 ± 0.7^{b}	25.5 ± 0.9$^{b, c}$
F3		33.2 ± 0.7^{b}	20.4 ± 1.1^{a}	3.3 ± 1.6^{b}	23.2 ± 1.6$^{b, c}$
F4		31.2 ± 0.9^{a}	21.1 ± 0.5^{a}	2.1 ± 0.6^{b}	12.1 ± 1.0^{b}
Control		34.2 ± 1.0^{b}	23.2 ± 2.2^{b}	3.0 ± 0.1^{b}	21.1 ± 0.8^{b}
Initial fish	Muscle tissue	1.0 ± 0.3	9.2 ± 0.3	0.8 ± 0.5	0.4 ± 0.3
F1		1.8 ± 0.3^{a}	10.2 ± 0.4^{a}	1.0 ± 0.5^{a}	0.7 ± 0.5^{a}
F2		3.1 ± 0.4^{b}	13.2 ± 0.5^{b}	2.1 ± 0.5^{a}	2.4 ± 0.5^{b}
F3		2.1 ± 0.4^{a}	11.2 ± 0.6^{a}	1.5 ± 0.6^{a}	1.5 ± 0.8^{a}
F4		1.2 ± 0.5^{a}	11.0 ± 0.4^{a}	1.7 ± 0.3^{a}	0.8 ± 0.7^{a}
Control		2.5 ± 0.4^{b}	12.3 ± 0.3^{b}	1.4 ± 0.9^{a}	1.0 ± 0.5^{a}
		C. mrigala			
Initial fish	Hepatic tissue	27.1 ± 1.4	20.1 ± 3.3	1.8 ± 0.5	12.3 ± 2.3
F1		31.2 ± 3.2^{a}	22.2 ± 3.7^{a}	3.1 ± 0.5^{b}	22.1 ± 2.5^{b}
F2		41.1 ± 2.9^{b}	28.4 ± 1.3^{b}	4.3 ± 0.5^{b,c}	30.4 ± 3.0^{c}
F3		38.3 ± 5.1^{a}	23.3 ± 3.6^{a}	3.8 ± 1.0^{b,c}	28.2 ± 2.7^{c}
F4		35.4 ± 3.5^{a}	25.4 ± 2.6^{a}	2.4 ± 0.5^{a}	16.2 ± 2.6^{a}
Control		40.1 ± 3.0^{b}	27.1 ± 3.4^{b}	3.4 ± 1.1^{b}	25.4 ± 2.6^{b}
Initial fish	Muscle tissue	1.4 ± 0.8	13.2 ± 2.5	1.4 ± 1.2	0.8 ± 0.9
F1		2.4 ± 1.6^{a}	14.3 ± 2.6^{a}	1.6 ± 1.1^{a}	1.1 ± 1.3^{a}
F2		3.7 ± 1.2^{a}	17.1 ± 1.9^{a}	3.7 ± 1.3^{a}	3.1 ± 1.0^{b}
F3		2.7 ± 1.0^{a}	15.1 ± 2.5^{a}	2.6 ± 0.7^{a}	2.7 ± 1.4^{b}
F4		1.7 ± 1.2^{a}	14.6 ± 2.0^{a}	2.8 ± 0.9^{a}	2.1 ± 1.0^{b}
Control		2.9 ± 0.9^{a}	16.3 ± 2.1^{a}	2.1 ± 0.7^{a}	2.5 ± 1.8^{b}

therefore, our result is in accordance with the report of Akand et al. 1991 suggesting determination of the aesthetic quality of a formulated diet by estimating the P/E ratio of the diet rather than by determining the gross energy content of that diet. It has been observed that low feed conversion ratio (FCR) and high growth rate of fish can be achieved if the P/E ratio of diet varies between 19.1 and 23.9 mg protein kJ^{-1} diet (Akand et al. 1991, Samantaray and Mohanty 1997). Therefore, it may be inferred that feed F_2 possessing the highest P/E ratio (18.3 ± 1.1 mg protein kJ^{-1}; mean ± standard deviation) produced better growth response in *C. catla* and *C. mrigala* fingerlings as compared to the other diets. Control diet possessing P/E value of 15.9 ± 3.1 (mean ± s) mg protein kJ^{-1}also displayed good result in terms of fish growth and other nutritional indices. Interestingly, although the P/E values of feeds F_3 and F_4 are higher than that of the control diet, they produced less growth response in all the groups of fish compared to latter diet. A possible explanation of this observed effect might be due to the presence of higher levels of antinutrients in these aquatic weed based diets (Kalita et al. 2007) compared to control diet attributing to the less growth of fish post feeding the F_3 and F_4 feeds.

It has been observed that the crude lipid content of fish increases with the inclusion of F_2 diet in both the groups of fishes. Previous reports have shown that lipid in the fish diet is more favoured as compared to the carbohydrate and perhaps lipid serves as a better source of non-protein energy in carp diet (Mukhopadhyay and Rout 1996). Moreover, fish in general utilize dietary carbohydrates poorly (Furuichi and Yone 1980) because carbohydrate fraction from plant sources is not very digestible whereas lipid component of a feed is almost completely digestible by fish (Siddhuraju and Becker 2001).

Vitamin E acts as natural antioxidant and is essential to protect the fatty acids and other oxidizable components in feed from becoming rancid. The results of our previous study have shown that *I. reptans* (incorporated in diet F_2) contains higher amount of vitamin E compared to other three aquatic weeds (Kalita et al. 2007) and this might be the reason that sufficient amount of vitamin E deposited in the liver and muscle of the fish post feeding the diet fed F_2 meets the requirement of this vitamin for proper growth and development in fish. This result is in consistent with the reports from other laboratories where the dietary supplementation of vitamin E increased the

concentration of α-tocopherol in edible tissues of poultry (Rethwill et al. 1981) and fish (Murata and Yamauchi 1989, Frigg et al. 1990).

Except the glycogen level in the muscle of *C. mrigala*, both the fish groups revealed high glycogen level in their liver as well as in muscle tissues. It is well known that elevation in glycogen level helps the fish as an energy storehouse during prolonged starvation (Collins and Anderson 1995) and glycogen is the stored food materials for animals.

CONCLUSION

Presently reported study suggests that among the different aquatic weeds tested for formulating the fish feed, *I. reptans* because of its superior quality (containing higher amounts of nutrients and lower antinutrients) can be a potential candidate for formulating cost effective and nutrient-rich diet for *C. catla* and *C. mrigala* fingerlings. Further research by employing various processes to either completely eliminate or reduce the anti-nutrients present in this plant for improving the quality of *I. reptans* based diet is in progress. In a nutshell, further commercial exploitation of this aquatic weed for the formulation of nutritionally balanced, low-cost fish diet is highly promising.

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