Zoological Studies **43**(2): 267-275 (2004)

Zoological Studies

Biochemical Profile of *Heliodiaptomus viduus, Sinodiaptomus* (*Rhinediaptomus*) *indicus*, and *Mesocyclops aspericornis* and their Dietary Evaluation for Postlarvae of *Macrobrachium rosenbergii*

Safiullah Aman[1] and Kareem Altaff*

[1]*Department of Zoology, The New College, Chennai - 600 014, India*

(Accepted January 24, 2004)

Safiullah Aman and Kareem Altaff (2004) Biochemical profile of *Heliodiaptomus viduus*, *Sinodiaptomus* (*Rhinediaptomus*) *indicus*, and *Mesocyclops aspericornis* and their dietary evaluation for postlarvae of *Macrobrachium rosenbergii*. *Zoological Studies* **43**(2): 267-275. The biochemical profiles of a calanoid, *Sinodiaptomus* (*Rhinediaptomus*) *indicus*, and a cyclopoid, *Mesocyclops aspericornis*, from a natural pond were studied for a period of 1 yr. In *S*. (*R*.) *indicus*, moisture, protein, lipid, carbohydrate, ash, and amino acid contents were 81.1%, 68.1%, 8.9%, 19.11%, 3.2%, and 56.2%, respectively; while in *M*. *aspericornis*, the values of these parameters were 82.4%, 69.0%, 12.4%, 13.97%, 4.5%, and 62.9%, respectively. Fatty acid content was higher in *M*. *aspericornis* (102.38%) than in *S*. (*R*.) *indicus* (42.87%). Variations were observed with regard to biochemical components in different seasons. The biochemical profile of *S*. (*R*.) *indicus* and *M*. *aspericornis* cultured in medium fertilized with an equal mixture of yeast (Y), poultry waste (PW), cotton seed cake (CSC), gingly cake (GIN), and ground nut cake (GNC), was comparable with that of copepods from natural sources. Higher values of the biochemical profile, survival, and growth were recorded in postlarvae of *M*. *rosenbergii* fed on a mixture of *S*. (*R*.) *indicus* and *M*. *aspericornis* than those fed on individual copepods or on *Artemia nauplii*. The amino acid content of postlarvae of *M*. *rosenbergii* fed on *M*. *aspericornis* was higher (71.83%) than that of postlarvae fed on *S*. (*R*.) *indicus* (46.15%) and a mixture of *M*. *aspericornis* and *S*. (*R*.) *indicus* (34.48%). The nutritional importance of copepods in aquaculture is discussed.
http://www.sinica.edu.tw/zool/zoolstud/43.2/267.pdf

Key words: Freshwater copepods, Live food, Feeding experiments.

Copepods constitute an important component of the food chain in aquatic systems. The nutritional quality of copepods is accepted to be highly satisfactory for larvae of prawn and finfish species. Biochemical studies have shown that copepods are rich in proteins, lipids, essential amino acids (EAAs), and essential fatty acids (EFAs) which can provide enhanced reproduction of broodstock, augmented growth, immune stimulation, and color enhancement in prawns and fishes (Watanabe et al. 1983, Altaff and Chandran 1989, Safiullah 2001).

Copepods show wide occurrence from wild sources throughout the year (Rajendran 1973, Dharani 1998). However, fluctuations in quality and quantity and drawbacks of collecting methods are major problems for their commercial utilization. In view of the growing needs for the production of large quantities of larval shrimp/fish for aquacultural practices, the culture of copepods has been attempted (Stöttrup et al. 1986, Vilela 1992, Tawfiq et al. 1997, Zehra 2000). Copepods constitute important live food in the rearing of larvae of fishes (Hussain and Higuchi 1980, Kraul et al. 1991, Toledo et al. 1997, Doi et al. 1997). Many authors have reported the utilization of copepods from wild and cultured sources for higher yields of prawns in ponds (Anderson et al. 1987, D'Abramo and Sheen 1991, Collins 1999). Studies on the comparative biochemistry of different copepods and

*To whom correspondence and reprints requests should be addressed. Present address: Department of Chemistry, The New College, Chennai - 600014, India. E-mail:kaltaff@rediffmail.com

their utilization as food for the freshwater prawn, *M. rosenbergii*, postlarvae is limited. Therefore, the current study focused on variations in the biochemical composition of laboratory-cultured copepods and copepods from natural sources during different seasons as well as the biochemical composition of *M. rosenbergii* postlarvae fed on these copepods.

MATERIALS AND METHODS

Collection and identification of copepods from wild sources

Copepods were collected from Nanganallur Pond, Chennai, from Jan. to Dec. 1998, using a plankton net (150-µm mesh size) by towing at a depth of 1 m. Collections were made between 06:00 and 07:00, and samples were transported to a wet laboratory. Copepods were sorted from the sample with the help of a 200~500 µm mesh filter and were maintained in concrete tanks. Identification was carried out following the taxonomic descriptions of Edmondson (1959), Rajendran (1973), Rangareddy (1994), and Dussart and Defaye (1995).

Culture of copepods

Mass culture of copepods was achieved using different organic ingredients like yeast (Y), cotton seed cake (CSC), gingly cake (GIN), ground nut cake (GNC), and poultry waste (PW) in equal proportions prepared at 250 ppm. This medium was added to 500 L of aerated, filtered fresh water. Laboratory-reared copepods of *M. aspericornis* and *S.* (*R.*) *indicus* were separately inoculated (25 individuals L^{-1}) on the 3rd day and then harvested after 13 d. A continuous culture was maintained by fertilizing the culture tanks for 45 d.

Feeding experiments

Macrobrachium rosenbergii postlarvae were individually reared with *S.* (*R.*) *indicus* and *M. aspericornis* separately and with their combination in equal weight from a wild source as test feed and with *Artemia nauplii* (GSL strain) as the control feed. Triplicate experiments were conducted for 45 d in circular concrete tanks of 50-L capacity (45 x 40 cm), and 300 acclimatized healthy postlarvae were randomly introduced into each tank. The total length and weight of postlarvae were measured.

Formalin-treated (5 ppm) control and test feed was given 3 times a day (08:00, 14:00, and 20:00) at the rate of 10% body weight of *M. rosenbergii* postlarvae. During the experimental period, the parameters of pH, salinity, and temperature were recorded, and 50% of the water was exchanged daily.

Biochemical analysis

Copepods from cultured and natural sources as well as pre- and post-experimental *M. rosenbergii* postlarvae were weighed, and the moisture content was determined (AOAC 1995). Lyophilized samples were analyzed for protein by estimating the nitrogen content by the micro-Kjeldahl method (Hawk 1954). The amino acid composition was determined using an automatic analyzer (Shimatzu, high performance liquid chromatography LC 4A) using a single column and a sodium buffer system (Yamamoto et al. 1994). The lipid content was estimated following the modified procedure of Bligh and Dyer (1959). Methyl esters of fatty acid mixtures were quantified using gas chromatography (Hewlett Packard model 5890) following AOAC (1995) procedures. The carbohydrate content was determined by phenol sulfuric acid reagent (Dubois et al. 1956), and the ash content was determined at 550°C (AOAC 1995).

Statistical analysis

Data on the biochemical composition of wild and laboratory-cultured copepods as well as experimental animals were analyzed statistically using one-way of analysis of variance (ANOVA) and Duncan's multiple range (DMR) test (Snedecor and Cochran 1980).

RESULTS

Copepods of Nanganallur Pond include *Heliodiaptomus viduus*, *S.* (*R.*) *indicus*, and *M. aspericornis*, and the results indicated that the latter 2 species were more dominant than the former species. The biochemical composition of *M. aspericornis* and *S.* (*R.*) *indicus* from Jan.~Dec. 1998 showed variations (Figs. 1, 2). The protein content was found to be highest in the cyclopoid during the months of Aug., Sept. Oct., and Feb. (71.5%~74.7%), low concentrations of protein were recorded during January (62.36% ± 1.69%)

and June (62.65% ± 5.86%), and moderate levels were observed during other months 68.27% ~69.0%). ANOVA showed that recorded protein values significantly differed during Oct. and Apr. compared to other months ($p < 0.05$). Lipid contents were low (7.5%~8.83%) in the cyclopoid during Apr., May, Aug., Nov., and Dec. (Fig. 1). The highest lipid levels (17.33%~20.76%) were recorded during Jan., June, and July, whereas moderate levels were recorded during Feb., Mar., and Oct. (9.47%~11.32%). However, one-way ANOVA showed that these values did not significantly differ ($p > 0.05$). Nitrogen free-extract levels were low (2.65%~4.12%) during Aug. to Oct. and high (13.01%~18.65%) in Dec., Apr., and May, but during other months they were moderate (7.40% ~11.16%). ANOVA also indicated that the nitrogen free-extract values were significant ($p < 0.05$). The ash content was lowest (1.40%) in May, and highest (8.10%) in Oct. Overall, ANOVA for ash levels was significant. Values for fiber and moisture did not significantly differ.

Protein values of *S*. (*R*.) *indicus* were low in Jan. (63.03% ± 2.51%), high in Sept. (71.11% ± 5.71%), and moderate during other months (66.47%~69.96%) (Fig. 2). However, these values

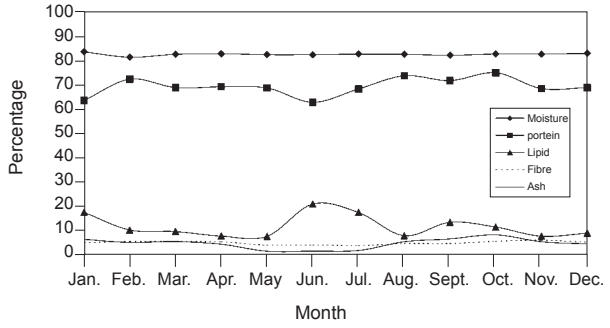

Fig. 1. Seasonal variations in biochemical composition of *M. aspericornis* during 1998.

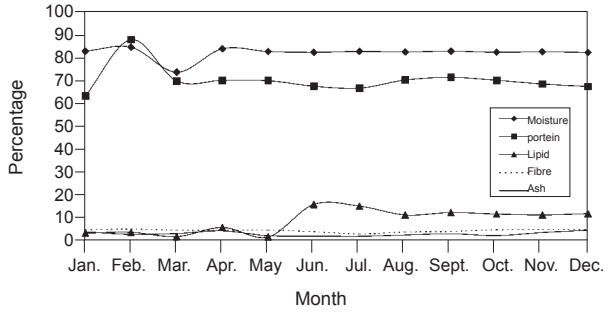

Fig. 2. Seasonal variations in biochemical composition of *S.*(*R.*) *indicus* during 1998.

did not significantly differ ($p > 0.05$%). Moderate lipid levels (11.36% ± 4.38%) were observed from Aug. to Dec., whereas during June and July, higher lipid levels (15.95% ± 4.54% and 15.19% ± 0.97%, respectively) were recorded. The low levels of lipids (1.80%~5.94%) during Jan. to May significantly differed from values in other months ($p < 0.05$). The nitrogen free-extract levels during Jan. to May (15.16%~24.54%) were double those of June to Dec. (9.15%~13.12%). ANOVA also indicated that the nitrogen free extract during June to Dec. did not significantly differ, but values were significant in the remaining months at the $p < 0.05$ level. Both the ash (2.18%~2.33%) and fiber contents (3.94%~4.10%) were low during May, June, and July, but higher levels of ash (3.73%~4.70%) and fiber (5.0%~5.1%) were recorded during Nov. and Dec. (Fig. 2). *M. aspericornis* contained a higher amino acid proportion as protein (62.88%) and AA% as dry matter (43.66%) than *S*. (*R*.) *indicus*, in which AA% as protein and AA% as dry matter were 56.21% and 39.43%, respectively (Table 1). Similarly, the fatty acid content was higher (102.38 mg g^{-1}) in *M. aspericornis* compared to *S*. (*R*.) *indicus* (42.87 mg.g^{-1}) (Table 2). The levels of tridecanoic acid, palmitic acid, stearic acid, arachidonic acid, cis linoleic acid, and arachidonic acid were also higher in *M. aspericornis* than in *S*. (*R*.) *indicus*. However, levels of capric acid and oleic acid were higher in *S*. (*R*.) *indicus* (at 13.55 and 2.68 mg g^{-1}, respectively).

A higher biomass of copepods was obtained after 21 d of culture. The maximum populations of *M. aspericornis* and *S*. (*R*.) *indicus* recorded were 625 and 250 individuals (ind.) L^{-1}, respectively. Cultured *S*. (*R*.) *indicus* contained 65.14% ± 0.98% of protein, 6.47% ± 0.51% of lipids, and 23.14% ± 1.97% of carbohydrates; in the case of *M. aspericornis*, the protein, lipid, carbohydrate, and ash contents were found to be 64.48% ± 1.21%, 6.27% ± 1.25%, 24.70% ± 0.7%, and 2.91% ± 1.23%, respectively (Table 3). *M. aspericornis* showed a quantitatively higher amino acid content than the calanoid *S*. (*R*.) *indicus*. The AA% as dry matter and AA% as protein of *M. aspericornis* were almost 3 times higher (26.01% and 45.34%) than those of *S*. (*R*.) *indicus* (9.87% and 17.22%), respectively (Table 1). The levels of methionine, arginine, and lysine were found to be higher in *M. aspericornis* (0.936%, 2.28%, and 1.95%) than in *S*. (*R*.) *indicus* (0.19%, 0.65%, and 0.67%), respectively.

Postlarvae of *M. rosenbergii* fed with a mixture of cyclopoids and calanoids showed signifi-

cantly higher total growth (198.41 ± 8.84 mg) than those fed with other feeding regimes (79.08~92.49 mg) (Fig. 3). ANOVA and DMR tests indicated that the rate of survival of postlarvae of *M. rosenbergii* fed with a mixture of cyclopoids and calanoids was significantly higher than that of postlarvae fed on *Artemia* nauplii and cyclopoids (Fig. 4).

The results indicated that *M. rosenbergii* postlarvae fed with a mixture of cyclopoids and calanoids showed significantly higher protein content (78.52% ± 2.55%) than those fed on cyclopoids and calanoids individually (58.25%~62.47%) (Fig. 5). Lipid content was low in experimental animals (6.29%~9.34%) compared with their initial value (13.92% ± 2.61%; Fig. 5) and no significant difference in lipid levels was noted. The carbohydrate content of postlarvae was lowest (7.45% ± 2.72%) with the mixed calanoid and cyclopoid diet compared to those fed with individual diets (24.10% ~30.90%). However, no significant difference was observed between the carbohydrate levels of postlarvae fed on individual or mixed diets of cyclopoids and calanoids. The moisture and ash contents ranged between 75.52% and 76.78%, and 4.57% and 4.77%, respectively, and one-way ANOVA indicated that these values were not significant ($p > 0.05$).

M. rosenbergii postlarvae fed on cyclopoids achieved a higher amino acid content (41.12 AA% as dry matter and 71.83 AA% as protein) than those fed with other food types (Table 4). *M. rosenbergii* postlarvae fed calanoids solely or in combination with cyclopoids showed less AA% as dry matter and protein. Although values of AA% as dry matter of postlarvae fed on these diets were similar (28.79% and 28.16% for calanoids and mixed diets, respectively), values of AA% as protein showed marked differences (46.16% and 34.49%). *M. rosenbergii* postlarvae fed on *S.* (*R.*) *indicus* alone showed a reduced amino acid composition (32.21%) compared to the initial protein level (54.34%).

DISCUSSION

Inland aquatic systems harbor rich micro- and macrofauna. Most of the microorganisms can be considered as live food for larval forms of commercially important freshwater fishes and prawns.

Table 1. Amino acid composition (% as dry matter and % as protein) A/E and EAAI of live food organisms from wild and cultured sources (g 100 g^{-1} of crude protein)

	Wild source				Cultured source			
	Sinodiaptomus (*R.*) *indicus*		*Mesocyclops aspericornis*		*S.* (*R.*) *indicus*		*M. aspericornis*	
Amino acid	AA % dry matter	AA % as protein	AA % dry matter	AA % as protein	AA % dry matter	AA % as protein	AA % dry matter	AA % as protein
Arg	1.39	1.98	3.94	5.68	0.65	1.13	2.28	3.98
His	0.54	0.76	0.55	0.80	0.14	0.24	0.38	0.66
Ilu	2.04	2.90	2.08	2.99	0.48	0.84	1.25	2.17
Leu	3.23	4.61	3.16	4.55	0.74	1.29	2.08	3.62
Lys	3.13	4.46	3.45	4.96	0.67	1.17	1.05	3.40
Met	1.29	1.84	1.32	1.90	0.19	0.33	0.94	1.63
Phe	1.86	2.65	1.65	2.37	0.55	0.96	1.13	1.96
Thr	1.83	2.61	2.23	3.22	0.51	0.89	1.31	2.28
Val	2.93	4.17	2.97	4.27	0.73	1.27	1.85	3.22
Total EAA	18.23	25.99	21.34	30.74	4.66	8.13	13.15	22.92
Ala	3.77	5.37	4.48	6.45	0.10	1.58	2.40	4.19
Asp	2.87	4.09	3.00	4.32	0.81	1.42	2.00	3.48
Glu	7.34	10.47	7.10	10.10	1.53	2.66	4.00	6.98
Gly	2.45	3.49	2.57	3.70	0.62	1.09	1.51	2.63
Ser	1.59	2.26	2.17	3.12	0.49	0.85	1.24	2.17
Tyr	3.19	4.55	3.09	4.44	0.86	1.49	1.71	2.98
Total EAA	21.21	30.23	22.31	32.14	4.40	9.09	12.86	22.42
Total	39.43	56.22	43.66	62.88	9.88	17.22	26.01	45.35
EAAI	-	-	-	-	-	-	-	-

Although these organisms are locally available, very few investigations have attempted to determine their nutritional quality and culture aspects due to the ready availability of *Artemia* cysts. The present study reveals the occurrence of 3 species of copepods, *M. aspericornis*, *S.* (*R.*) *indicus*, and *H. viduus*. However, the density of zooplankton in these ponds was found to be identical with that of other tropical ponds (Battish 1992, Venkataraman 1992). Results of biochemical profiles of monthly samples of calanoids indicate variations in all components except moisture and fiber contents. The lipid content of cyclopoids was high (17.33% ~20.77%) during Jan. and July 1998 and low (7.51%~8.83%) during Apr., May, Aug., and Nov. 1998. These results differ from those of Shamsudin (1994) who recorded a high lipid content in Sept. and a low content during the monsoon. The lower lipid content may be due to high caloric expenditures during spring and winter to maintain body temperature. The most important element of a viable diet is protein, and the biological value of dietary protein depends on its EAA composition (Kanazawa and Teshima 1981). Levels of phenylalanine of *S.* (*R.*) *indicus* (2.65%) and *M. aspericornis* (2.37%) may be sufficient for protein synthesis and other physiological functions, a finding which supports results of an earlier study by Nose (1979).

Fatty acids play a vital role in maintaining structural and functional integrity of fish/prawn cell membranes. Zooplankton contain high levels of arachidonic acid which help in the growth and survival of larvae as documented by Bell et al. (1995) and Sargent et al. (1995). The cislinolic acid content of *M. aspericornis* was found to be high. Chanmugam et al. (1983) also reported high linoleic acid contents in freshwater species. Fatty acid analysis indicated that *M. aspericornis* has higher total saturated (61.24 mg g^{-1}) and unsaturated fatty acid (41.15 mg g^{-1}) contents than does *S.* (*R.*) *indicus*. Fatty acids like heptadecanoic acid, caprylic acid, and capric acid were not recorded in *M. aspericornis*, while *S.* (*R.*) *indicus* lacked arachidonic and behenic acids.

The maximum population of *S.* (*R.*) *indicus* recorded was 250 ind. L^{-1} in medium containing an

Table 2. Fatty acid composition of live food organisms from a wild source (mg g^{-1} of lipid)

Fatty acid	*Sinodiaptomus* (*R.*) *indicus*	*Mesocyclops aspericornis*
Saturated		
Hepatonic acid (7:0)	-	-
Caprylic acid (8:0)	-	-
Nonanoic acid (9:0)	-	1.64
Capric acid (10:0)	13.55	-
Undecanoic acid (11:0)	0.05	5.43
Lauric acid (12:0)	0.32	0.15
Tridecanoic acid (13:0)	0.32	14.46
Myresticacid (14:0)	0.74	7.00
Pentadecanoic acid (15:0)	0.03	0.09
Palmitic acid (16:0)	20.91	19.51
Heptadecanoic acid (17:0)	0.22	-
Stearic acid (18:0)	0.16	2.77
Nondecanoic acid (19:0)	-	-
Arachidonic acid (20:0)	3.74	10.09
Heneiocosanoic acid (21:0)	-	-
Behenic acid (22:0)	-	0.11
Tricosanoic acid (23:0)	-	-
Lignoceric acid (21:0)	-	-
Total	40.04	61.25
Unsaturated		
Palmitoleic acid (16:1)	-	-
Oleic acid (18:1 n-9)	2.68	2.42
Cis linoleic acid (18:2 n-6)	0.15	4.18
Linolenic acid (18:3 n-3)	-	-
Arachidonic acid (20:4 n-3)	-	34.55
Total	2.83	41.15
Total (saturated + unsaturated)	42.87	102.40

Table 3. Biochemical compositions of live food organisms from wild and cultured sources

Live food organisms	Wild source		Cultured source	
Biochemical composition	*Sinodiaptomus* (*R.*) *indicus*	*Mesocyclops aspericornis*	*S.* (*R.*) *indicus*	*M. aspericornis*
Moisture (% wet weight)	83.23 ± 1.23	82.36 ± 0.00	80.97 ± 2.90	81.16 ± 2.00
Protein (%)	68.17 ± 0.82	71.01 ± 1.07	65.19 ± 0.98	64.49 ± 1.21
Lipid (%)	10.76 ± 1.72	11.82 ± 0.59	6.47 ± 0.51	6.20 ± 1.25
Carbohydrate (%)	19.11 ± 0.54	13.97 ± 0.90	23.14 ± 1.97	24.70 ± 0.70
Ash (%)	3.01 ± 0.91	4.70 ± 0.91	3.54 ± 1.30	2.91 ± 1.23

equal mixture of Y: PW: CSC: GIN: GNC at 250 ppm; a similar density was recorded by Dharani (1998). Similarly, *M. aspericornis* (625 ind. L^{-1}) was also recorded in this medium. Zehra (2000) found oil cake-fertilized medium to be suitable for raising maximum populations of *M. aspericornis*.

The calanoids and cyclopoids of both laboratory-cultured and wild sources showed similar biochemical compositions. Likewise, earlier reports on biochemical compositions of copepods support the present findings (Watanabe et al. 1983, Altaff and Chandran 1989, Dong et al. 1993). The levels of some of the EAAs such as methionine and histidine were low in copepods (0.33% and 0.24%, respectively), similar results to those reported by Sorgeloss and Lavens (1996).

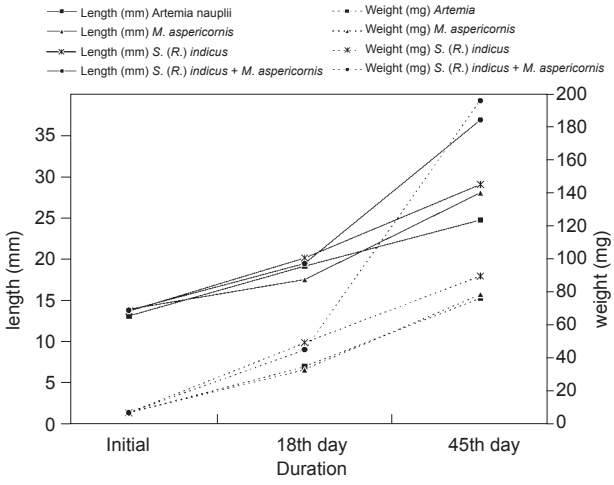

Fig. 3. Length and weight of *M. rosenbergii* post larvae fed on wild live food organisms.

M. aspericornis and *S.* (*R.*) *indicus* met the requirements of *M. rosenbergii* larvae with regard to fatty acid content as live food organisms; in particular, palmitic acid in both *M. aspericornis* (19.50 mg g^{-1}) and *S.* (*R.*) *indicus* (20.01 mg g^{-1}) was utilized by *M. rosenbergii* larvae to synthesize saturated and unsaturated fatty acids as reported by Kanazawa et al. (1979) and Kattner et al. (1981).

Feeding experiments with *M. rosenbergii* larvae using a mixture of *S.* (*R.*) *indicus* and *M. aspericornis* showed better survival and growth than with individual copepods or even with *Artemia* nauplii. This may have been due to the higher levels of required EFAs (n - 3 and n - 6 families) in the mixed *M. aspericornis* and *S.* (*R.*) *indicus* diet as documented by earlier studies (Fujita 1979, Coyle et al. 1996, Tidwell et al. 1997). *Artemia* nauplii-fed on animals showed lower growth (79.08 ± 1.34 mg) than those fed on other food types (Fig. 3),

Table 4. Amino acid composition (% as dry matter and % as protein) of *M. rosenbergii* postlarvae fed on live food organisms from wild and cultured sources (g 100 g^{-1} of crude protein)

Amino acid	Initial		Cyclopoid (*M. aspericornis*)		Calanoid (*S.* (*R.*) *indicus*)		Copepods (*M. aspericornis* + *S.* (*R.*) *indicus*)	
	AA % dry matter	AA % as protein	AA % dry matter	AA % as protein	AA % dry matter	AA % as protein	AA % dry matter	AA % as protein
Arg	2.35	3.95	2.65	4.63	1.91	3.07	1.64	2.01
His	0.49	0.83	0.53	0.92	0.44	0.7	0.56	0.69
Ilu	1.57	2.64	1.76	3.08	1.08	1.73	0.92	1.19
Leu	2.68	4.51	2.77	4.84	2.29	3.68	1.86	2.28
Lys	2.44	4.1	4	7	3.36	5.39	3.51	4.3
Met	1.14	1.92	1.57	2.73	1.16	1.87	0.74	0.91
Phe	1.52	2.55	2.4	4.2	1.33	2.14	1.59	1.95
Thr	1.51	2.55	1.63	2.84	1.26	2.02	1.17	1.44
Val	1.97	3.32	2.35	4.11	1.57	2.52	1.16	1.43
Total EAA	15.67	26.37	19.66	34.35	14.4	23.12	13.15	16.2
Ala	2.36	4.27	3.15	5.5	2.41	3.87	2.51	3.08
Asp	3.05	5.14	3.55	6.22	2.36	3.79	2.28	2.79
Glu	5.6	9.43	6.38	7.14	4.32	6.92	4.13	5.1
Gly	2.27	3.82	3.21	5.61	2.74	4.38	2.81	3.44
Ser	1.6	2.7	1.77	3.09	1.48	2.37	1.36	1.67
Tyr	1.53	2.57	3.4	5.94	1.07	1.72	1.85	2.27
Total NEAA	16.41	27.93	21.46	33.5	14.38	23.05	14.94	18.35
Total	32.08	54.3	41.12	67.85	28.78	46.17	28.09	34.55

which is in accordance with results of an earlier study by Kitajima (1978). Decreased growth of postlarvae may be due to the reduced nutritional value of *Artemia* nauplii to *M. rosenbergii* larvae. The mixture of cyclopoids and calanoids supplies all required nutrients, as evidenced by their biochemical and amino acid contents. Many earlier investigations also recorded higher survival and weight gain in postlarvae of *M. rosenbergii* when fed on zooplankton from a wild source than an artificial diet (Brown et al. 1992, Collins 1999, Paulraj and Altaff 1999). Rearing of early larvae of groupers with copepodid nauplii as food showed improved growth and survival (Doi et al. 1997). Further, Toledo et al. (1999) indicated that *Epinephelus coioides* showed a higher preference for copepod nauplii than for rotifers. Higher survival and faster growth of larvae of *E. coioides* were reported when they were fed on nauplii of

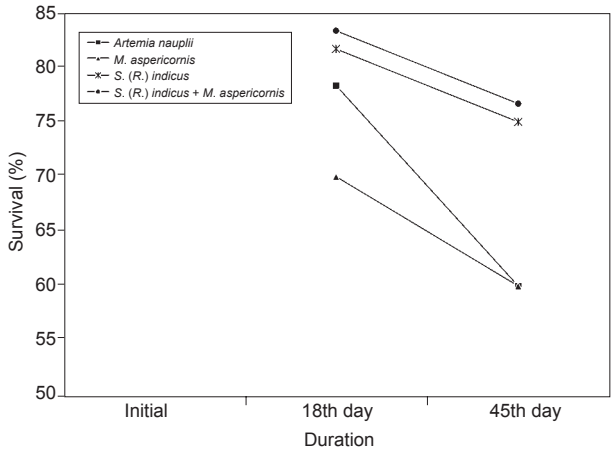

Fig. 4. Survival of of *M. rosenbergii* post larvae fed on wild live food organisms.

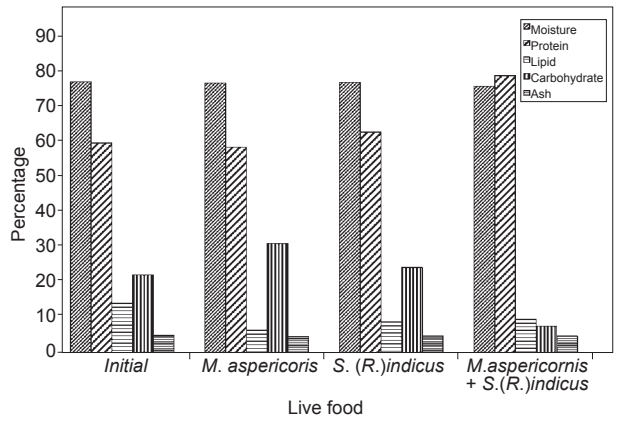

Fig. 5. Biochemical composition of *M. rosenbergii* post larvae fed on wild live food organisms.

calanoid copepods such as *Pseudodiaptomus annandalei* and *Acartia testuidensis* along with rotifers (Toledo et al. 1999).

Furthermore, these copepods feed on algae, which contain large amounts of free amino acids, and it is believed that amino acid release could be responsible for trypsin stimulation in postlarvae (Admiral et al. 1986). Although higher AA% as protein (71.83%) was recorded in *M. rosenbergii* which fed on *M. aspericornis*, the weight gain was less in postlarvae (81.34 ± 1.99 mg). This may have been due to the excess free amino acids causing a depressive effect leading to a reduction in weight of the animal as reported by Ravi and Devaraj (1991) in *Catla catla*.

Lower levels of lysine and arginine in *S.* (*R.*) *indicus* (3.36% and 1.07%) than in *M. aspericornis* may have been responsible for the reduction in survival rate of *M. rosenbergii* fed on *M. aspericornis* collected from a wild source; similar observations were also reported by Keembiychetty and Galtin (1992). A reduction in growth rate with increasing levels of methionine in *M. aspericornis* indicates a depressive effect of excess free methionine, which was also reported earlier (Ravi and Devraj 1991).

Analysis of the biochemical composition of copepods (from cultured and wild sources) and results of feeding experiments suggest that copepods can serve as good live food for postlarvae of *M. rosenbergii*. If these copepods are used instead of prepared feed (egg custard/artificial pellet feed) in *M. rosenbergii* hatcheries from the postlarvae stage (PL 1) to the stocking stage (PL 15~12), then seed quality can be improved.

Acknowledgments: The authors are thankful to the management of The New College, Chennai, India for providing research facilities. The authors are grateful to Dr. Rocha, Univ. of Sao Paulo, Brazil and Dr. Ohno, Tokyo Univ. of Fisheries, Japan for their helpful comments on the manuscript.

REFERENCES

Admiral W, H Peletier, RWPM Lanne. 1986. Nitrogen metabolism of marine planktonic diatoms: excretion, assimilation and cellular pools of free amino acids in seven species with different cell size. J. Exp. Mar. Biol. Ecol. **98:** 241-263.

Altaff K, MR Chandran. 1989. Sex-related biochemical investigation of the diaptomid *Heliodiaptomus viduus* (Gurney) (Crustacea: Copepoda). Proc. Indian Sci. Acad. (Animal

Sci.). **98:** 175-179.
Anderson RK, PL Parker, AL Lawrence. 1987. A C^{13}/C^{14} tracer study of the utilization of present feed by a commercial important shrimp *Penaeus vannamei* in a pond growout system. J. World Aquacult. Soc. **18:** 149-155.
AOAC. 1995. Official methods of analysis. 16th ed. Washington DC: Association of Official Analytical Chemists
Battish SK. 1992. Freshwater zooplankton of India. New Delhi: Oxford and IBH Publishing Co., pp. 127-173.
Bell JG, JD Carfell, DR Tocher, FM Macponald, JR Sargent. 1995. Effect of different dietary arachidonic acid: docosahexaenoic acid ratios or phospholipid, fatty acid composition and prostogland production in juvenile turbot (*Scophthalamus maximum*). Fish. Physiol. Biochem. **14:** 139-151.
Bligh EG, WJ Dyer. 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol. **37:** 911-917.
Brown MF, ET Wetzel, A Spacie, P Konopka. 1992. Evaluation of naturally-occurring organisms as food for juvenile crayfish *Procambarus clarki*. J. World Aquacult. Soc. **23:** 211-216.
Chanmugam P, J Donovan, CJ Wheeler, DH Hwang. 1983. Differences in the lipid composition of freshwater prawn (*M. rosenbergii*) and marine shrimp. J. Food Sci. **48:** 1440-1441.
Collins PA. 1999. Role of natural productivity and artificial feed in the growth of freshwater prawn *Macrobrachium borellii* (Nobili, 1896) cultured in enclosures. J. Aquacult. Trop. **14:** 47-56.
Coyle S, T Najeeullah, J Tidwell. 1996. Evaluation of naturally occurring organisms, distiller's by-products and prepared diets as food for juvenile freshwater prawn *Marcobrachium rosenbergii*. J. Appl. Aquacult. **6:** 57-66.
D'Abramo LR, SS Sheen. 1991. Nutritional requirements, feed formulations and feeding practices of the freshwater prawn *Marcobrachium rosenbergii*. Rev. Fish. Sci. **2:** 1-21.
Dharani G. 1998. Reproductive biology and culture of the freshwater plankton *Sinodiaptomus* (*Rhinediaptomus*) *indicus* (Kiefer) (Calanoida: Copepoda). Ph.D. thesis, University of Madras. 141 pp.
Doi M, J Toledo, MSN Golez, M De Los Santos, A Ohno. 1997. Preliminary investigation of feeding performance of larvae of early red-spotted grouper, *Epinephelus coioides*, reared with mixed zooplankton. Hydrobiologia **358:** 259-263.
Dong FM, RW Hardy, FH Norman, FT Barrows, BA Rasco, WT Fairgrieve, IP Forster. 1993. Chemical composition and protein digestibility of poultry by-product meals for salmonid diets. Aquaculture **108:** 149-158.
Dubois M, KA Gilles, JK Hamilton, PA Rebers, F Smith. 1956. Colorimetric method for determination of sugars and related substances. J. Anal. Chem. **28:** 350-356.
Dussart BH, D Defaye. 1995. Introduction to the Copepoda. City, Country: SPB Acad. Publ. Netherlands, pp. 1-253.
Edmondson WT. 1959. Freshwater biology. 2nd ed. New York: J Wiley, 1248 pp.
Fujita S. 1979. Culture of red sea bream, *Pagrus major* and its food. *In* E Stryezynska Jurewicz, T Backiel, E Jaspers, G Personae, eds. Cultivation of fish fry and its live food. Broaden, Belgium: European Marine Society Special Publ. No. 4. Ems, pp. 183-197.
Hawk BP 1954. Practical physiological chemistry. 13th ed. New York: McGraw Hill, 545 pp.
Hussain NA, M Higuchi. 1980. Larval rearing and development of the brown spotted grouper, *Epinephelus tauvina* (Forskål). Aquaculture **19:** 339-350.
Kanazawa A, S Teshima. 1981. Essential amino acids in prawn. Nippon Susisan Gakkaishi **47:** 1375-1377.
Kanazawa A, S Teshima, K Ono. 1979. Relationship between essential fatty acid requirements of aquatic animals and the capacity for bioconversion of linoleic acid to highly unsaturated fatty acid. Comp. Biochem. Physiol. **633:** 295-298.
Kattner G, M Krause, J Trahms. 1981. Lipid composition of some typical North Sea copepods. Mar. Ecol. Prog. Ser. **4:** 69-74.
Keembiychetty CN, DM Galtin. 1992. Dietary lysine requirements of juvenile hybrid striped bass (*Morone chrysops x M. saxatilis*). Aquaculture **104:** 271-277.
Kitajima C. 1978. Acquisition of fertilized eggs and mass culture of juveniles red sea bream, *Pagrus major*. Japan: SPI. Report of the Nagasaki Prefecture Institute of Fisheries **5:** 92 pp
Kraul S, H Ako, K Brittain, A Ogasawara, R Centrell, T Nagao. 1991. Comparison of copepods and enriched *Artemia* as feeds for larvae Mahimahi, *Coryphaena hippurus*. European Aquaculture Society Special Publication no. 15.
Nose T. 1979. Summary report on the requirement of essential amino acids for carp. *In* JE Halver, L Tews, eds. Finfish nutrition and fish feed technology I. Berlin: Heeneman, pp. 145-156.
Paulraj A, K Altaff. 1999. Survival and growth of post larvae of *Marcobrachium rosenbergii* (de Man) in different feeding regimes. Pak. J. Sci. Ind. Res. **42:** 192-196.
Rajendran M. 1973. A guide to the study of freshwater calanoids. J. Madurai Kamaraj Univ. **Supplement 1:** 1-86.
Rangareddy Y. 1994. Copepoda: Calanoida: Diaptomidae. *In* Y Rangareddy, HJF Dumont, eds. Guides to the identification of the Macroinvertebrates of the continental waters of the world. The Netherland, SPB Publications, pp. 1-221.
Ravi J, KV Devaraj. 1991. Quantitative essential amino acid requirements for growth of *Catla catla* (Hamilton). Aquaculture **96:** 281-291.
Safiullah A. 2001. Biochemical and nutritional evaluation and culture of freshwater live food organisms for aquahatcheries. Ph.D. thesis, University of Madras, 103 pp.
Sargent JR, JG Bill, MV Bell, RJ Handerson, DR Tocher. 1995. Requirement criteria for essential fatty acids. J. Appl. Ichthyol. **11:** 183-198.
Shamsudin L. 1994. Food value of indigenous zooplankton species collected from various coastal waters of South China Sea for aquaculture. Third Asian Fisheries Forum. Manila, the Philippines: Asian Fisheries Society, pp. 752-755.
Snedecor GW, WG Cochran. 1980. Statistical methods. 7th ed. Ames., IA: Iowa State Univ. Press, 507 pp.
Sorgeloos P, P Lavens. 1996. Manual on the production and use of live food for aquaculture. Fisheries Technical Paper. Vol. 361. Rome: Food and Agriculture Organization of the United Nations, pp. 49-78.
Stottrup JG, K Richardson, E Kirkegaard, NJ Pihl. 1986. The cultivation of *Acartia tonsa* (Dana) for use as live food source for marine fish larvae. Aquaculture **58:** 87-96.
Tawfiq S, A Rezq, AB Yule, SK Feng. 1997. Ingestion, fecundity, growth rates and culture of harpacticoid copepod, *Tisbe furcata* in the laboratory. Hydrobiologia **347:** 109-118.

Tidwell JH, G Schulmeister, C Manl, S Coyle. 1997. Growth, survival and biochemical composition of freshwater prawns *Marcobrachium rosenbergii* fed natural food organisms under controlled conditions. J. World Aquacult. Soc. **28:** 123-132.

Toledo JD, SN Golez, M Doi, A Ohno. 1997. Food selection of early grouper, *Epinephelus coioides*, larvae reared by the semiintensive method. Suisanzoshoku **45:** 327-337.

Toledo JD, SN Golez, M Doi, A Ohno. 1999. Use of copepod nauplii during early feeding stage of grouper *Epinephelus coioides*. Fisheries Sci. **65:** 390-397.

Venkataraman K. 1992. Biogas slurry for *Daphnia* culture. Proc. Zool. Soc. Calcutta **45:** 205-208.

Vilela MH. 1992. Mass culture and nutritional quality of the marine copepod *Tigriopus brevicornis* (Muller). Biol. Inst. Nac. Invert. Pescas. Lesboa **17:** 49-63.

Watanabe T, C Kitajima, S Fujita. 1983. Nutritional value of live organisms used in Japan for mass propagation of fish: a review. Aquaculture **34:** 115-143.

Yamamoto T, PA Marcouli, T Unuma, T Akiama. 1994. Utilization of malt protein flour in fingerling rainbow trout diets. J. Fish. Sci. **60:** 455-460.

Zehra A. 2000. Breeding biology and culture of the freshwater cyclopoid *Mesocyclops aspericornis* (Daday, 1906). Ph.D. thesis, University of Madras, 162 pp.