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Effects of different ration levels on survival, moulting and food conversion in two freshwater prawns

R PONNUCHAMY, S RAVICHANDRA REDDY and KATRE SHAKUNTALA
Department of Zoology, Bangalore University, Jnana Bharathi, Bangalore 560 056, India

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Abstract. Effects of different daily rations of the oligochaete worm *Tubifex tubifex* on survival, moulting and food conversion of *Macrobrachium lanchesteri* (Palaemonidae) and *Caridina weberi* (Atyidae) have been described. Moulting is a metabolic necessity for either species and occurs even at the expense of organic reserves of starving prawns. The geometric derivation of the growth-feeding rate relations in *M. lanchesteri* indicated that, 88, 162 and 204 mg live food/g live prawn/dav represent the maintenance, optimum and maximum feeding rates respectively. The corresponding values for *C. weberi* were 96, 236 and 396 mg. Food availability has a marked influence on the food partitioning and biochemical composition of either species.

Keywords. Ration levels; survival; moulting; conversion efficiency; *Macrobrachium lanchesteri*; *Caridina weberi*.

1. Introduction

Decapod crustaceans of the sub-order Natantia (prawns and shrimps) form a major aquatic resource for human utilization. During the last decade considerable interest has been evinced in India for developing prawn fisheries (Verghese 1978; Jhingran 1982). For successful culture of any species of prawns, the size of the daily meal to be offered is to be established. While the influence of ration levels (size of meal) on the bioenergetics of feeding and growth of fishes have been widely studied (Brett *et al* 1969; Gerking 1971; Brett and Shelbourn 1975; Reddy and Katre 1979), there is a need to extend similar studies in decapod crustaceans (see Katre and Reddy 1976; Sedgwick 1979). In this paper, effects of different ration levels on the survival, moulting, food intake, conversion and yield of two Natantians, *Macrobrachium lanchesteri* and *Caridina weberi* are described.

2. Material and methods

2.1 *Maintenance and feeding of prawns*

M. lanchesteri (de Man) and *C. weberi* (de Man) were collected from freshwater habitats of Bangalore (77°33 E-12°55 N) and maintained in separate stocking tanks containing 20 l freshwater and fed on an *ad libitum* food of oligochaete worms. After acclimatization to the laboratory conditions for a week, the prawns were starved for 3 days to ensure evacuation of their guts. Active intermoult individuals identified by the method of Peebles (1977), were selected from this stock and maintained in groups of 4 (*M. lanchesteri*: live body weight 408±35 mg) or 8 (*C. weberi*: live body weight 123±7 mg) in separate aquaria (size: 38 × 38 × 25 cm) containing 15 l freshwater. Throughout the experimental period, a daily photoperiod cycle of 10L:14D (L=0800-1800 hr. D=1800-0800 hr) was maintained and the water temperature was 23.2±1.6°C.

Tubifex tubifex (Muller) which are known to constitute a rich source of nutrition for freshwater prawns (Subrahmanyam 1980; Ponnuchamy *et al* 1981a), were used as food in the present experiment. The different ration levels offered, calculated as percentages of the initial live body weight of the prawns were 0, 1, 3, 6, 12, 15, 20 and 25 for *M. lanchesteri* and 0, 3, 6, 12, 24, 30, 35 and 40 for *C. weberi.* Four replicates were maintained for each feeding level. Feeding and collection of uningested food was undertaken daily between 1000 hr and 1200 hr. During the 60-day experimental period, water was aerated continuously. Since no qualitative analyses of the faecal matter was undertaken, fortnightly collection of faecal matter by filtration provided adequate quantitative data on the production of faeces by the experimental prawns.

2.2 *Moult record*

Daily, while removing the uningested food, the moults produced by the experimental prawns were collected. After blotting the adhering water, the moults were weighed and dried overnight in a hot air oven (90°C) to record the dry weight. Moulting frequency, total moult weight and mean moult weight of the prawns were calculated as follows:

$$\text{Average moulting frequency (days)} = \frac{\text{Experimental duration} \times \text{Number of prawns}}{\text{Number of moults produced}}$$

Total moult weight = Pooled dry weight (mg) of all the exuviae produced per prawn during the entire experimental period.

Mean moult weight = Moult dry weight expressed as percentage of the initial dry body weight of the prawn.

2.3 *Parameters of feeding and conversion*

Food intake, assimilation efficiency and gross and net conversion efficiencies (K_1 and K_2: %) were calculated following the procedures detailed by Katre and Reddy (1976) and Ponnuchamy *et al* (1981b). The production of new tissues (= conversion) was calculated by adding the exuvial weight to the gain in total weight of the prawn and the actual growth was calculated by subtracting the exuvial weight from the gain in total weight and expressed as "yield". The gross and net yield efficiencies were calculated as follows:

$$\text{Gross yield efficiency } (Y_1, \%) = \frac{\text{Total weight gain} - \text{exuvial weight}}{\text{Food consumed}} \times 100$$

$$\text{Net yield efficiency } (Y_2, \%) = \frac{\text{Total weight gain} - \text{exuvial weight}}{\text{Food assimilated}} \times 100$$

Since the duration of the experiment was fairly long, the feeding and conversion rates are calculated on the basis of mean body weights (=mean of initial and final body weight) of the animals and represented as mg dry/g live prawn/day. The data was statistically compared by the students 't' test (Fisher 1950).

2.4 *Biochemical parameters*

Biochemical constituents of initial and experimental prawns were estimated in dried samples. The water content was calculated as the difference between live and dry weights of the material. Carbohydrate was determined by estimating the glycogen content following the phenol-sulphuric acid method (Dubois *et al* 1956). Fat was estimated by extracting a known amount of the material (35 to 45 mg) in 2:1 chloroform-methanol mixture, using a Soxhlet apparatus. Each extraction was run for 20 hr, as suggested by the Association of Official Agricultural Chemists (1950). Ash was estimated by incinerating a known amount of material (35 to 45 mg) in a Muffle furnace at 560°C for 5 hr (Paine 1964). The percent protein value including undetermined chitin content was derived by subtracting the determined percent values of fat, carbohydrate and ash from 100 and expressed as "crude protein".

3. Results and discussion

3.1 *Survival*

M. lanchesteri and *C. weberi* showed 100% survival at 6% ration level and beyond. While total mortality of starved *M. lanchesteri* occurred within 53 days, starved *C. weberi* indicated only 15.6% mortality during the experimental period. A lower survival (18.7%) was observed for *M. lanchesteri* receiving 1% ration level, as compared to 3% ration level (85%). However, *C. weberi* receiving 3% ration level showed a higher survival (93.7%).

3.2 *Moult production and moulting frequency*

At lower feeding levels, the moulting frequency of the prawns was low. Reeve (1969) also reported that in *Palaemon serratus* lower feeding levels interfere seriously with the fine control mechanism of moulting, producing widely different intermoult periods. However, as compared to that of *P. lamarrei* (Katre and Reddy 1976), the intermoult durations of *M. lanchesteri* observed presently are higher. While there were no marked differences in the mean moult weight of *M. lanchesteri* in relation to ration level (table 1), Katre and Reddy (1976) have cited a decrease in the per moult weight with increase in ration levels of *P. lamarrei*. Consequent to frequent moulting with increase in ration level, the total moult weight of *M. lanchesteri* increased markedly. Observations on the intermoult durations and total moult weights of *C. weberi* in relation to ration level indicated similar changes as observed for *M. lanchesteri*. However, the mean moult weight of *C. weberi* increased with increases in ration level.

Starvation and lower ration levels seem to retard moulting to a certain extent in both the species of prawns. This is in conformity with the observations of Katre and Reddy (1976) for *P. lamarrei* and other crustaceans (Pyle 1943; Costlow and Bookhout 1953, 1957). Even starved individuals of *P. lamarrei* were known to exhibit regular moulting, though they were shown to decrease in their final body weights (Katre and Reddy 1976). Interestingly, Lasker (1966) reported that, despite the presence of food, the shrimp *Euphausia pacifica* did not exhibit growth but underwent moulting with a final decrease in the body weight. This indicates that moulting is a metabolic necessity in these natantians and that it continues even at the expense of the organic

Table 1. Influence of ration levels on the moult production and moulting frequency of the two natantians.

Ration level (%)	Moults produced (number)	Moulting frequency (days)	Total moult weight (mg)	Mean moult weight (%)
Macrobrachium lanchesteri				
0	0.25±0.00	–	2.31±0.00	10.32±0.46
1	0.62±0.12	–	7.68±0.00	12.59±1.25
3	0.62±0.12	–	4.52±1.89	8.90±1.23
6	0.83±0.24	–	6.30±3.28	9.89±1.43
12	1.75±0.25	34.76±4.09	11.43±1.43	8.60±1.36
15	1.67±0.24	35.50±6.35	12.99±4.71	9.63±1.04
20	1.94±0.26	30.92±3.76	17.81±4.36	9.67±1.46
25	1.88±0.38	27.90±6.10	13.06±3.80	10.37±1.76
Caridina weberi				
0	0.97±0.09	–	2.02±0.78	8.78±0.69
3	1.00±0.01	–	2.99±0.65	10.10±0.94
6	2.62±0.35	23.27±3.21	8.76±2.17	11.23±1.17
12	3.17±0.54	18.75±2.76	10.40±1.66	12.07±0.51
24	3.80±1.02	16.00±2.89	14.24±2.67	13.00±1.26
30	3.90±0.64	15.77±2.77	17.08±3.02	14.78±1.06
35	4.05±0.20	14.60±0.70	15.92±1.57	14.29±1.24
40	4.35±0.60	13.90±1.21	17.29±1.02	14.57±0.68

reserves of the animal. In contrast to this, Roberts (1957) reported that, starvation inhibited moulting in the crab *Pachygrapsus grassipes*.

3.3 *Food offered and food ingested*

Table 2 indicates different ration levels offered, the food ingested by and the growth of *M. lanchesteri*. The food offered was consumed up to a ration level of 6%. Beyond this level, food ingested was less than the food offered. However, with increase in the food offered beyond 6%, there were increases in the food ingested reaching a maximum of 18% at the highest ration level (25%).

Table 3 indicates the food offered, food ingested by and the growth of *C. weberi*. Food was fully ingested upto a ration level of 12%, beyond which the food ingested was lower than that offered. However, as in *M. lanchesteri*, with further increases in ration level offered, there were increases in the food ingested reaching a maximum of 32.5% of the animal's initial body weight.

The differences in feeding rates of *M. lanchesteri* at 15% ration level and above were significant ($P > 0.05$) indicating that, 15% is the maximum that this prawn can ingest under the present experimental conditions. In *C. weberi* the differences in feeding rates beyond 32% ration level were insignificant ($P > 0.9$). This indicates that *C. weberi* accepts a maximum of 32% of food under the experimental conditions which is nearly twice that accepted by *M. lanchesteri*. Smaller body size and correlated higher metabolic rate may be the factors governing the higher rates of feeding in *C. weberi*.

Table 2. Influence of ration levels on the body weight, food intake and growth of *Macrobrachium lanchesteri*.

Ration level (%)	Initial dry body weight (mg)	Final dry body weight (mg)	Food offered (mg dry food/g live prawm/day)	Growth (mg dry weight/ prawn/day)
0	93.46±9.19	34.71±6.80	–	−1.70±0.35
1	91.11±5.61	39.98±9.35	1.93±0.12	1.40±0.17
3	94.87±2.63	63.46±7.17	5.28±0.17	0.55±0.11
6	93.22±8.50	80.21±8.04	10.34±0.20	0.22±0.07
12 (10.8)	83.75±4.60	103.92±9.82	19.80±0.73 (17.91±0.86)	+0.34±0.14
15 (12.5)	94.96±6.38	139.30±8.87	25.32±1.33 (21.18±2.81)	0.74±0.11
20 (13.8)	92.10±7.15	116.68±5.57	27.27±0.27 (18.88±2.66)	0.41±0.17
25 (18)	84.63±6.96	101.94±9.79	34.46±0.35 (24.76±3.56)	0.30±0.20

The numbers in the parentheses represent the amounts of food ingested by the prawn at each ration level.

Table 3. Influence of ration levels on the body weight, food intake and growth of *Caridina weberi*.

Ration level (%)	Initial dry body weight (mg)	Final dry body weight (mg)	Food offered (mg dry food/g live prawn/day)	Growth (mg dry weight/ prawn/day)
0	27.47±1.00	10.43±0.53	–	−0.30±0.02
3	29.27±1.29	19.04±0.91	5.21±0.12	0.17±0.03
6	29.24±1.58	27.49±1.75	10.20±0.13	0.03±0.01
12	27.11±1.29	29.96±4.71	20.53±0.17	+0.05±0.02
24 (21.2)	28.71±1.57	35.25±1.09	41.14±3.51 (36.29±3.52)	0.11±0.03
30 (24.5)	29.56±2.25	41.52±3.53	49.23±0.14 (40.23±1.74)	0.20±0.09
35 (32.5)	27.67±1.44	42.82±2.95	55.93±1.17 (51.98±2.76)	0.25±0.03
40 (32.4)	27.41±0.60	42.86±1.88	64.01±0.30 (51.95±4.54)	0.26±0.04

The numbers in the parentheses represent the amounts of food ingested by the prawn at each ration level.

3.4 *Metabolism and growth*

A daily ration level of 6% body weight was insufficient for the growth of *M. lanchesteri* (table 2). At higher feeding levels, considerable growth occurred, the maximum being 0.74±0.11 mg at 15% ration level. This ration level is interestingly equivalent to the *ad libitum* ration level determined for these prawns held at the ideal population density levels (Ponnuchamy 1981). In *P. lamarrei*, maximum growth was recorded at a ration level of 10% (Katre and Reddy 1976). At higher ration level, inspite of higher food consumption (table 2) the growth of *M. lanchesteri* decreased, perhaps due to decreased assimilability of the prawns (see Monokov 1972).

A daily ration level of 6% was also insufficient for the growth of *C. weberi* (table 3). At higher feeding levels, considerable growth ensured, reaching a maximum of 0.26±0.04 mg at the highest ration level offered (40%). However, increases in growth almost approached an asymptote, beyond a ration level of 30%. Inspite of differences in their optimum ration levels, both the species indicated growth only beyond the ration level of 12%. This indicates that both the species expend considerable energy for their maintenance.

Physiologically useful energy in excess of metabolic requirements of animals, is available for deposition as body tissue during growth, fat depot and/or for synthesis during the reproductive process. The geometric derivations (*cf* Thomson 1941) of the growth-feeding rate relations for *M. lanchesteri* indicated that 88, 162 and 204 mg food/g live prawn/day represent the maintenance, optimum and maximum feeding rates of the prawn respectively (figure 1). While these values are higher than those reported for *P. lamarrei* (Katre and Reddy 1976), the maximum feeding rate of *M. lanchesteri* (126.7 mg) is lower than that of *P. lamarrei* (179.5 mg). The differences may be due to the differences in the size of the two species of prawns.

Figure 2 represents the quantitative relations of the feeding rates to the food absorbed, metabolised for body functions and converted into new body substance in *M. lanchesteri*. From the estimated maintenance ration (figure 1), the level of specific dynamic action (SDA : of Brody 1968) or calorigenic effect (Kleiber 1961) could be derived. SDA represents the energy requirements of the animal for digestion, assimilation, transportation, biochemical treatment and incorporation (Beamish 1974). An increase in the SDA from 2.5 mg at the optimum level to 6.5 mg at the maximum

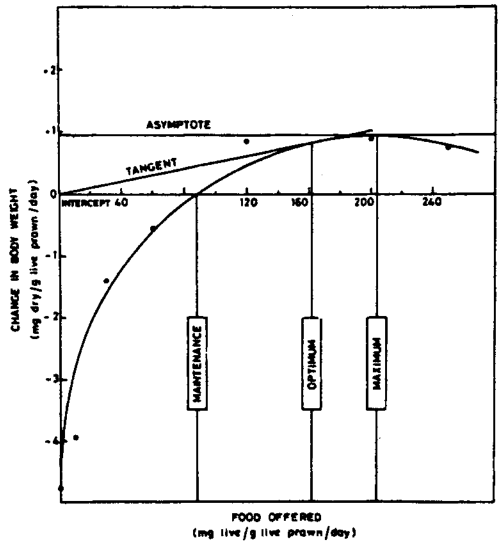

Figure 1. Geometric derivations of maintenance, optimum and maximum feeding rates for *Macrobrachium lanchesteri*.

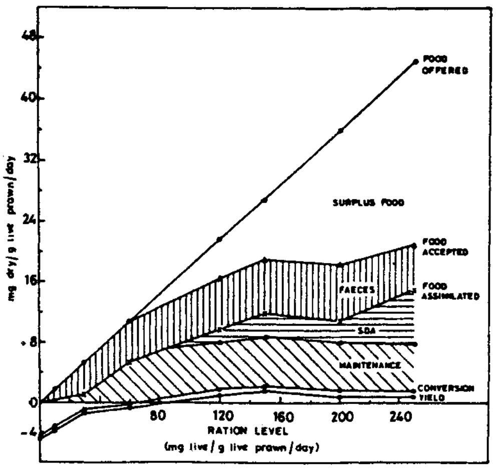

Figure 2. Quantitative partitioning of food in *Macrobrachium lanchesteri*.

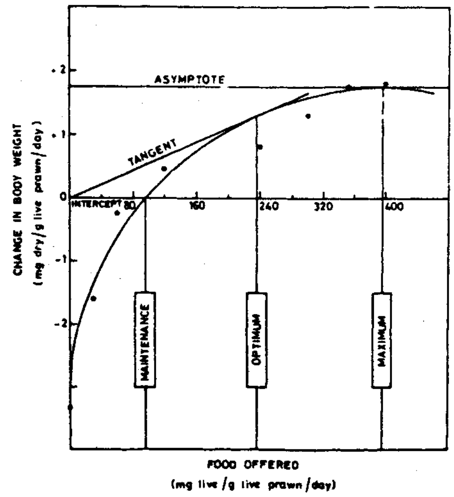

Figure 3. Geometric derivations of maintenance, optimum and maximum feeding rates for *Caridina weberi*.

ration level is evident. Higher SDA for individuals fed near maximum rations have also been reported for *P. lamarrei* (Katre and Reddy 1976).

From the geometric derivations of the growth-feeding rate relations for *C. weberi* (figure 3), it is evident that 96, 236 and 396 mg/g live prawn/day represent the maintenance, optimum and maximum feeding rates respectively. The observed value of 282.3 mg is rather low as compared to the geometrically-derived maximum.

The quantitative relationships between the feeding rates and energy budget of *C. weberi* are represented in figure 4. The SDA increased from 11 mg at optimum ration level to 17 mg at the maximum ration level indicating the considerable energy cost of converting food into body substance at the higher ration levels. Higher values of maintenance, optimum and maximum feeding rates were observed in *C. weberi* as compared to *M. lanchesteri*. Comparatively higher SDA was also observed for *C. weberi* than for *M. lanchesteri*.

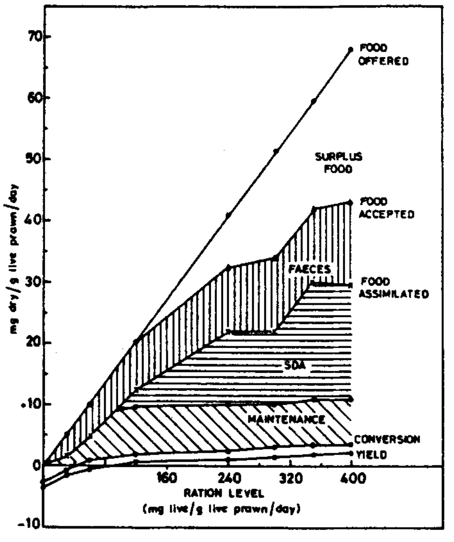

Figure 4. Quantitative partitioning of food in *Caridina weberi*.

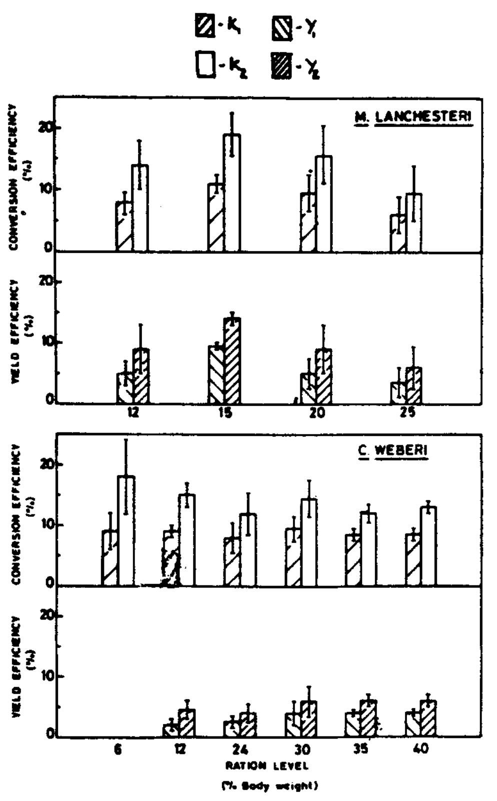

Figure 5. Influence of ration levels on the gross and net conversion/yield efficiencies of the two natantians.

3.5 *Conversion and yield efficiencies*

Figure 5 represents the conversion efficiency and yield efficiency of the two species in relation to different ration levels. Maximum net yield efficiency was observed in *M. lanchesteri* at the ration level of 15% which is equivalent to the maximum ration level accepted. Katre and Reddy (1976) observed a peak conversion efficiency for *P. lamarrei* at the ration level of 10%. However, high net yield efficiency was observed at the higher ration level (30% and above) for *C. weberi.*

Reviewing the studies on feeding in invertebrates, Monokov (1972) reported that under experimental conditions with increase in ration levels and extra feeding, there may be decreases in the assimilability of food which alters the net yield efficiency. In *Penaeus japonicus*, Shigeno *et al* (1972) reported that a high rate of food intake does not always bring out an effective growth rate, thereby leading to lower conversion efficiency. During the present study, while the above was true for *M. lanchesteri, C. weberi* indicated high values of yield efficiency at the higher ration levels. Further, increases in the ration size beyond the highest ration level perhaps results in decreases in the yield efficiency of *C. weberi.*

3.6 *Biochemical composition*

The changes in the biochemical contents of control and experimental *M. lanchesteri* are indicated in table 4. The water content was maximum in starved individuals (88.5%) and is comparable to that reported for *P. lamarrei* (89.1%; Katre and Reddy 1976). Starvation is known to increase the water content of fish also (Phillips *et al* 1960; Pandian and Raghuraman 1972). While the content of ash decreased with increase in the ration level, those of fat, carbohydrate and crude protein (including chitin) did not show significant variation till 6% ration level. However, the biochemical composition of control and experimental prawns receiving a ration level of 12% and above, indicated almost similar values. The differences in all the biochemical constituents were distinct between the prawns receiving the lower (below 6%) and higher levels (above 12%) of ration.

Table 4. Changes in the biochemical composition of *Macrobrachium lanchesteri.*

Ration level (%)	Water content	Dry matter	Ash	Fat	Carbohydrate	Crude protein including chitin
Control	77.67±2.39	22.33±2.39	13.28±0.42	31.22±1.63	1.56±0.14	53.94
0	88.54±0.66	11.46±0.66	20.94±0.30	19.67±4.25	1.37±0.12	58.02
1	86.92±0.58	13.08±0.58	20.33±0.69	19.39±2.14	1.59±0.27	58.69
3	81.32±2.46	18.68±2.46	15.79±0.07	21.31±1.76	1.81±0.17	61.09
6	79.48±0.52	20.52±0.52	15.31±0.42	21.57±0.90	1.86±0.21	61.26
12	75.08±1.53	24.92±1.53	13.05±1.16	26.72±1.95	1.42±0.18	58.81
15	71.20±1.49	28.80±1.49	13.73±0.54	28.59±3.24	1.36±0.22	56.32
20	75.28±1.76	24.72±1.76	14.07±0.35	34.40±2.16	1.41±0.22	50.12
25	76.65±1.49	23.35±1.49	13.45±0.46	30.07±3.80	1.45±0.06	55.03

While water and dry matter are represented as percent live matter, others are represented as percent dry matter.

Table 5. Changes in the biochemical composition of *Caridina weberi*.

Ration level (%)	Water content	Dry matter	Ash	Fat	Carbohydrate	Crude protein including chitin
Control	77.28±1.67	22.72±1.67	13.53±0.18	31.22±1.63	1.52±0.23	53.73
0	82.05±1.33	17.95±1.33	16.69±0.19	15.79±2.27	1.56±0.09	65.96
3	78.15±0.81	21.85±0.81	14.52±0.80	19.54±1.32	1.51±0.14	64.43
6	75.09±0.45	24.91±0.45	14.35±0.63	19.05±4.43	1.73±0.21	64.87
12	74.45±1.03	25.55±1.03	13.77±0.24	24.85±1.39	1.68±0.22	59.70
24	76.79±0.49	23.29±0.49	12.48±0.62	38.79±1.21	1.68±0.24	45.05
30	76.16±1.15	23.84±1.15	13.10±0.13	39.50±0.09	1.64±0.12	45.76
35	74.57±0.57	25.43±0.57	13.06±0.70	33.97±3.38	2.16±0.36	50.81
40	74.25±0.14	25.75±0.14	13.42±0.90	34.11±4.12	1.76±0.18	50.70

While water and dry matter are represented as percent live matter, others are represented as percent dry matter.

Table 5 indicates the changes in the biochemical constituents of *C. weberi* in relation to different ration levels. As in *M. lanchesteri*, the water content was highest in starved individuals. While the contents of ash decreased with increases in the ration level, that of fat increased. However, the biochemical constituents of prawns receiving higher ration level as well as control prawns showed similar values.

4. Conclusions

From the foregoing account, it is apparent that availability of food has a profound influence on the survival, moulting and food conversion of either species of prawns. While tubificid worms do offer a nutritive source, a poor feed conversion ratio of 34:1 (for *M. lanchesteri*) and 31:1 (for *C. weberi*) at optimal rations, implies that it would be necessary to evolve a nutritionally rich diet, if necessary a compounded one, to obtain better feed conversion ratios.

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