LABORATORY STUDIES ON FEEDING AND WATER EXCHANGE IN THE CULTURE OF *PENAEUS INDICUS* H. MILNE EDWARDS

DISSERTATION SUBMITTED BY

Kum. ANI S.

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भाकृअप
ICAR

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CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
COCHIN-682 031

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CERTIFICATE

This is to certify that this Dissertation is a bonafide record of work carried out by Kumari **Ani S.** under my supervision and that no part thereof has been presented before for any other degree.

Dr. A. NOBLE
PRINCIPAL SCIENTIST
CENTRAL MARINE FISHERIES
RESEARCH INSTITUTE
COCHIN.

Countersigned by:

Dr.P.S.B.R.JAMES
DIRECTOR
CENTRAL MARINE FISHERIES
RESEARCH INSTITUTE
COCHIN.

CONTENTS

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PREFACE

Aquaculture has emerged as one of the most promising industries in the world with considerable growth potential and is expected to contribute around a quarter of the global fishery harvest by the year 2000. The demand of fish products in the world is increasing at a rate of over 8% annually (Alagh 1991).

Of all the aquacultural products, the shrimps are the most important by virtue of their high value and persistent demand. World production of cultured shrimp may attain one million tonnes per year by the turn of the century and from India the expected production is 50,000 tonnes. In this context, it is imperative that India also should intensify its efforts in shrimp farming.

Since intensive aquaculture systems are characterised by high stocking densities, natural food supply alone cannot support the biomass. Hence quality artificial feed that compensates for any inadequacies in food available in the pond is a must to augment production. Now pelletised feeds are, therefore being widely used. However, with the anxiety of increasing production, large quantities of it are dumped into the culture systems. Over-feeding results in the build up of anaerobic conditions which generate toxic gases and this along with toxic metabolites changes the pond environment and causes stress on culture organisms. The stress weakens the individuals and results in mortality. Thus problems in water quality become the bottleneck in successful culture.

Water exchange is an effective means to resolve the water quality problems. Nevertheless, in India with regard to replacement, no specific recipe is available. Levels of water replacement depend on stocking density, water quality and feeding scheme. Unfortunately water exchange in improving water quality has not been verified in our culture systems. Much research is badly needed to develop quantitative relationships among water exchange rates, water quality and feeding rates.

The aim of the present study is to develop a feeding regime which would stimulate maxmimum growth with efficient food conversion in juvenile P. indicus fed on artificial diet. Under varied feeding and water exchange rates, laboratory experiments were designed to establish absolute food requirements and replacement of water.

I am grateful to my supervising teacher Dr.A. Noble, Principal Scientist, CMFRI for his guidance throughout my work and critically going through the write up. I express my gratitude to Dr. P.S.B.R. James, Director of the Institute for providing me with the required facilities during the course of the study. I am thankful to Mr. T.V.Sathianandan and Mr. K. Balan, Scientists at CMFRI for helping me with the statistical aspects. I express my gratitude to Dr.Manpal Kaur, Scientist at CMFRI for the help. I am thankful to Mr. P.M. Aboobaker, Technical Officer, Mr. A. Nandakumar, Technical Assistant and Mr. V.A.Kuttappan, Supporting Staff for their assistance. I am grateful to Mr.B.C.Mohapatra, Senior Research Fellow for his help during this work. I take this opportunity

to thank all my classmates, senior and junior scholars for their help and encouragement.

Finally I wish to express my gratitude to the Indian Council of Agricultural Research for awarding me Junior Research Fellowship during which period this work was done.

INTRODUCTION

Shrimp is considered as the "pink gold" by virtue of its universal appeal, persistent demand among the wealthier nations of the world (Sakthivel, 1987). The high market demand, their attractive export value and the rather stagnating situation in capture have led to production through culture. India's domination as the leading shrimp exporter to Japan and USA had been dismantled due to the rapid growth of cultured shrimp by major competitors (Kant 1991). The Marine Products Export Development Authority had fixed a target of exporting over Rs.1500 crores worth of marine products by the end of the 8th plan period, 80% of which is projected to be contributed by prawns (Sing and Sampth 1992).

In India, the prawn culture practices had been oriented towards wild, traditional extensive farming in the pokkali fields of Kerala and bheries of West Bengal, with very low production of around 500-600 kg/ha in 2 crops per annum. To upgrade the production, future emphasis should be on semi-intesive and intesive scientific farming. Production rates in scientific prawn farming is scaling new heights with the introduction of high energy feed and resorting to high stocking densities previously unimaginable. Taiwan has shown to the world the techno-economic viability of shrimp farming by semi-intensive farming to produce up to 20 tonnes ha/year. Apart from farmers, several private companies in India have entered into prawn farming in a big way in many parts in recent years and a production of 9 tonnes/ha/yr is already achieved (Das 1991). To promote and establish a viable and throbbing intensive shrimp farming, the major constraints still to be overcome are feeding and water quality management.

Penaeus indicus (Indian white prawn) and *P. monodon* (Jumbo tiger prawn) are the two species brought under culture in India, and the former has been identified as a favourable candidate for intensive farming. In extensive culture operations, the stock of the prawn mainly depends on natural food. In contrast, in intensive systems the natural food available is not sufficient to support good growth. Hence such systems, yielding tens of thousands of kg/ha/yr have to be wholly dependent upon additional high quality nutritionally balanced feeds, deriving little, if any, benefit from natural food webs (Clifford 1985). Recently pelleted feeds containing 30-40% protein have been widely used by many farmers in India.

The amount of fish that can be produced in a pond is dependent upon how much additional feeding is possible while allowing water quality to be maintained sufficient for fish growth. Ration is considered to be a driving force and any restriction to it results in the lower metabolic rate (Brett 1979), accompanied by the decrease in the oxygen demand and depression in the growth rate of fishes (Andrews *et al.* 1973). Over-feeding is also not beneficial as the unconsumed food cannot be recovered, thus reducing the conversion efficiency, at the same time adding to pollution of water. In intensive aquaculture systems since about 60% of the operation cost goes to feed (Shang 1981), feeding should be optimised to get maximum results. Hence a precise knowledge of the relationship between food requirement and body weight for a particular species and diet would be essential to avoid both overfeeding and restricted growth through rations below optimum.

It has been found that fish production increases linearly with feeding rates (Tucker et al. 1979, Cole and Boyd 1986). But the ultimate limit on feeding rate and fish production is set by water quality. Feeding rates have been correlated to water quality parameters in freshwater systems (Burtz and Vens-Cappell 1981), but little work has been reported on the assessment of feed's biochemical reactivity in sea water systems and their impact on water quality (Chieng et al. 1989).

Water quality for aquaculture is defined "as the degree of excellence that a given water possesses for the propagation of desirable aquatic orgaisms" (Fast 1983). Impact that the feed makes into the system is the main source of water quality variability, over riding photosynthetic effects. The utilization of feed by fish and microorganisms increases the ammonium level in the water through excretion and decomposition, reduces the concentration of total suspended solids (TSS), increases nitrite and nitrate concentrations through nitrification (Milstein 1990). Increased respiration lowers the pH. Decomposing uneaten food decreases the oxygen and increases the biochemical oxygen demand (BOD). All these, stress the pond environment. Individuals weakened under stress are susceptible to parasites and disease causing organisms which become ubiquitous in highly intense systems where excessive organic loading provides favourable conditions for their growth (Saclauso 1989).

Water quality parameters that directly relate to the animals and their environment are ammonia, dissolved oxygen, pH, nitrite, nitrate and suspended solids. BOD does't directly relate to the well being of the cultured animal, but it offers some significant advantages as a parameter to assess a feeds potential impact on water quality (Chieng et al. 1989).

Among the potentially life-endangering substances accumulating in the culture water, ammonia is of primary importance. Ammonia accumulation occurs in culture water from two sources, the ammonification of untaken food by heterotrophic bacteria and transamination and deamination of catabolic products of organic nitrogen ingested and assimilated by cultured animal (Armstrong 1979). In an aqueous solution, ammonia is present in ionized (NH_4^+) and more toxic, easily diffusable and highly soluble in lipid unionized (NH_3) forms; the proportion of these varying with pH (Trussell 1972). Ammonia is a major growth inhibitor in intensive aquaculture systems. Spotte (1970) recommends that the total measurable ammonia should be less than 0.1 mg/l. By bacterial action ammonia is oxidised to nitrite and then nitrate by nitrifying nitrosomonas and nitrobacter bacteria.

Nitrite, an intermediate product in the nitrification of ammonia to nitrate and bacterial denitrification of nitrate to nitrogen is highly toxic to culture organisms. The toxicity of nitrite increases with a decrease in pH. Like nitrite, nitrate also accumulates in the culture systems by bacterial nitrification of ammonia. The actual level at which nitrate becomes toxic to aquatic animals is largely unknown (Stickney 1979) and according to Spotte (1970) it may not be directly toxic. But accumulation of nitrate causes undesirable pH decrease. With the accumulation of excessive amounts of waste and metabolites, demand for dissolved oxygen increases and the pH decreases. Low or high pH values may affect the growth and survival of the animal.

A water body in nature is sure to have suspended solids. But these in excess lead to sediment accumulation in ponds and clogging of gills in culture animals and hamper production. At the same time its absence, for it works as a biological filter, adversely affects the performance of a pond. Wickins (1981) suggests its level not to exceed 15 mg dry weight per litre.

BOD is a measure of oxygen consumed over time by microfauna and flora in a water body. BOD increases with increasing feeding rates and the decomposing uneaten food utilizing oxygen and creating oxygen tension decreases survival (Boyd 1986).

The water quality problems caused by excessive feed are currently resolved by water exchange. The process of water exchange has 2 effects: supply oxygen rich water and flush out water laden with wastes. The water exchange according to Pillai (1990) and Kongkeo(1990) is also required to accelerate and synchronise the moulting cycle of the stock.

The importance of water exchange in water quality has been demonstrated by Daniels and Boyd (1989). Wajsbrot *et al.* (1989) reported that at higher water exchange rates, the steady state level of ammonia-N would be lower. In the intensive shrimp production systems of *P. japonicus* in Japan the water exchange rate may exceed 300% per day where the feeding rate is up to 40 gm twice per day (Shigueno 1985). While our extensive farms are tide fed, the semi-intensive and intensive systems are pump fed with no scientific basis.

Eventhough excess metabolites may have detrimental effects upon the cultured species, in controlled amounts they can be beneficial to the growth of the cultured organism (Millemana 1990). Therefore, an optimum water replacement rate that will bring the toxic metabolites to the permissible level would be desirable. Since cost of pumping is high, working out an optimum water replacement will ensure considerable savings.

The present investigation was, therefore undertaken to study different feeding and water exchange rates on water quality and growth performance of the Indian white prawn. For want of out door facilities, the experiments were conducted in laboratory conditions with the hope, that it would serve as a guide for such work in fields.

MATERIALS & METHODS

1. Collection and transportation of prawns:

Prawns of 50-60 mm size (1.1 - 1.4 gm weight) were collected from the brackish water canals of Puduvypu by cast nets. The salinity, dissolved oxygen and pH of the water at the site of collection were found out to determine the quality of the medium to be used in the laboratory. The animals were transported to the laboratory in 10 litre capacity polythene bags with 3 litres of water.

2. Acclimation and Laboratory set up:

Animals were acclimatised to laboratory conditions for 7 days by maintaining them in a fibreglass tank of 2 tonne capacity with filtered and well aerated sea water of salinity 15.0 ± 1%$_0$, pH 7.5 ± 0.5, dissolved oxygen 5.6 ± 0.5 mg/l and temperature 27.0 ± 1.0°C. To reduce the concentration of metabolites a biological filter was used. The organisms were fed twice a day with pelleted feed containing 32% protein. Every day the faecal matter and left out feed were siphoned out and 40% of the water replaced with fresh medium.

For experiment, fibreglass tanks of 40 litre capacity containing 30 litres of water with facility for continuous aeration and drainage were used. The tanks were covered with velon screen to prevent the animals from jumping out. Prawns were maintained at 12 L : 12 D photoperiod cycle.

The base values of nitrate, nitrite, ammonia, pH and total suspended solids (TSS) of the medium were determined using standard methods.

3. Standardisation:

The experiments were done in duplicates of 6 days duration. There were 2 sets of it, first with 10% feeding and 10, 30 and 50% replacement of water and the second with 30% replacement of water with 10, 30 and 50% feeding levels.

Ten animals, their length and weight noted down individually were released into each tank and kept for 24 hours to recover from stress if any. During this period they were starved to avoid contamination of the medium by release of metabolites. Specified quantity of water was replaced daily and the prawns were fed twice a day, 40% in the morning and 60% in the evening. Water samples in the morning were analysed for ammonia. The ammonia values were plotted in graph sheet (Fig.1) and best fit drawn. The values at the cross points which represent the experimental condition with 10% feeding and 30% replacement were then plotted on a semi-log paper (Fig.2). From the graph it was observed that the ammonia values increase from 1st to 4th day and then become more or less same thereafter. Thus the 4th day value was taken for further standardisation. At all feeding levels the ammonia values came down to the base near 75% replacement. This value was hence taken as the upper limit. Keeping 30% in the middle, 4 levels of replacement viz. 13.5, 24, 42 and 75% were obtained from the log table of APHA

Regression equation and correlation coefficient given in **Fig. 1.**

i : 30% replacement with 10%, 30% and 50% feeding levels.

Days	**Regression equation**	**Correlation coefficient (r)**
2	$y = 0.5873 + 0.0090x$	0.873
3	$y = 0.6788 + 0.0080x$	0.880
4	$y = 0.7545 + 0.0060x$	0.857
5	$y = 0.7143 + 0.0072x$	0.881
6	$y = 0.8198 + 0.0053x$	0.883
7	$y = 0.7923 + 0.0063x$	0.883

(y = Ammonia values, x = levels of feeding)

ii : 10% feeding with 10%, 30% and 50% replacement of water.

Days	**Regression equation**	**Correlation coefficient (r)**
2	$y = 0.9660 - 0.0160x$	-1.000
3	$y = 1.2380 - 0.0121x$	-0.981
4	$y = 1.3484 - 0.0121x$	-0.926
5	$y = 1.3250 - 0.0112x$	-0.883
6	$y = 1.3640 - 0.0122x$	-0.914
7	$y = 1.3830 - 0.0128x$	-0.927

(y = Ammonia values and x = levels of replacement)

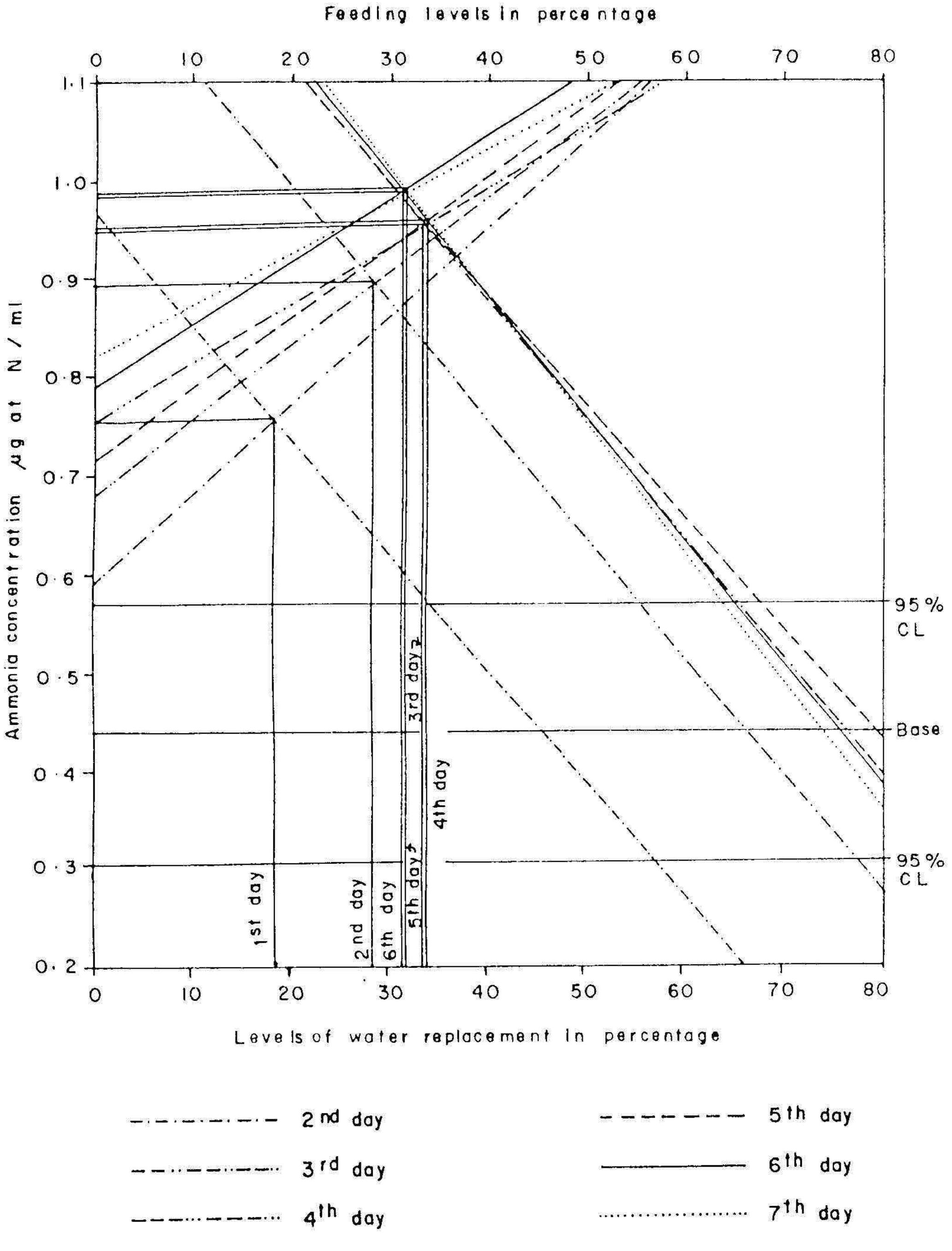

Fig. 1. Standardisation of the experiment based on ammonia values, declining lines denoting 10% feeding at 10, 30 & 50% replacement of water and ascending lines denoting 30% replacement with 10, 30 & 50% feeding.

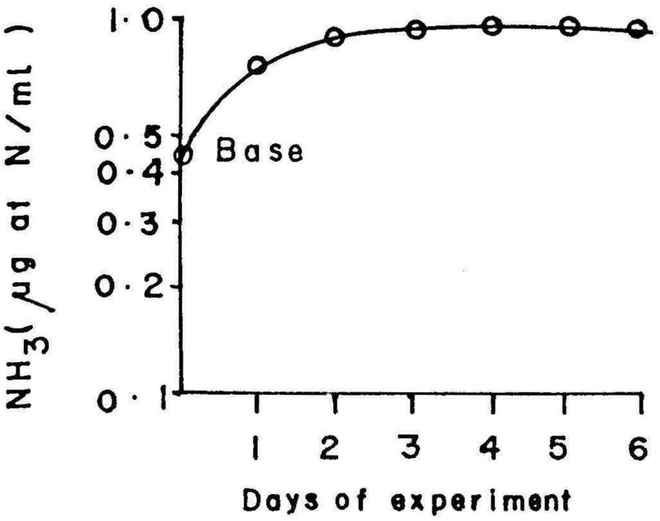

Fig. 2: Standard curve.

(1975). Placing 10% feeding in the middle, 5 feeding levels such as 2 4, 8, 16 and 32% were selected on a geometric scale.

4. Experiment :

Experiments on water replacements at the above levels were conducted in 4 sets, each of 24 days duration, against the 5 feeding rates (Fig.3). The experimental set up was the "2 factor completely randomised design" given in Snedecor and Cochran (1973).

Cutting off aeration for about 20 minutes, suspended matter in the water was allowed to settle and specified quantity of water from bottom siphoned out daily. The left-over feed was collected on bolting silk, washed in distilled water to remove salt and dried in pre-weighed petridishes at 90°C for 24 hours.

Throughout the experiment the temperature ranged between 26-28°C and the salinity was maintained at 15%$_0$ as suggested by Venkataramiah et al. (1975). The sea water was filtered through bolting silk and mixed with fresh water for appropriate salinity.

Water samples for analysis were drawn from the quantity removed from the tank was diluted by adding fresh medium in the proportion given below to equalise it to the medium in the tank after replacement.

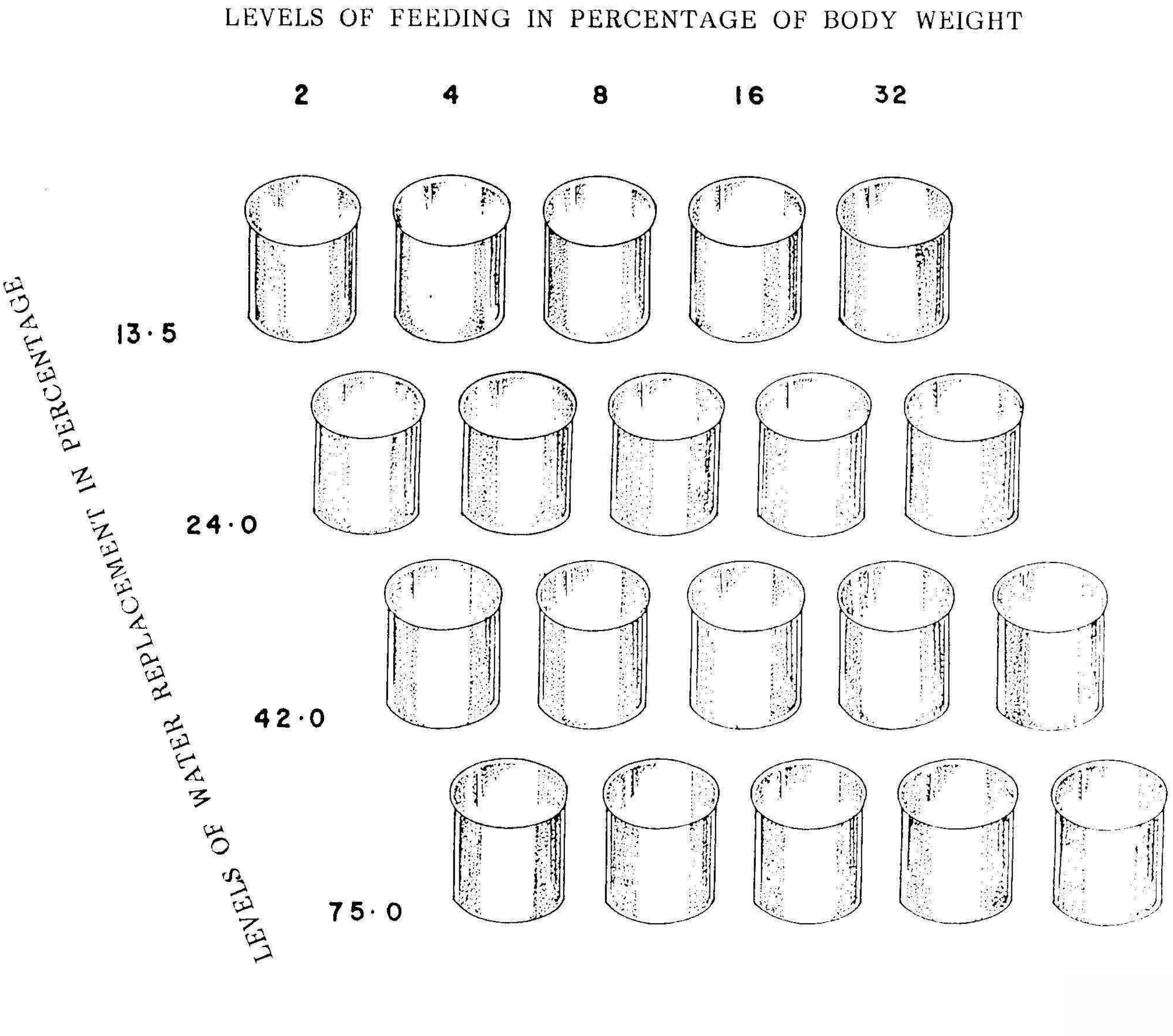

Fig. 3: Experimental set up.

Replacement	Medium in litres		Total in litres
	Fresh	Removed	
13.5%	0.27	1.73	2.00
24.0%	0.48	1.52	2.00
42.0%	0.84	1.16	2.00
75.0%	1.50	0.50	2.00

The water thus made up on alternate days was analysed within one hour for ammonia, nitrite, nitrate, pH and TSS. BOD was determined once in 4 days.

Ammonia was determined by phenol-sodium hypochlorite method (Solarzano 1969), nitrite by Strickland and Parsons (1972), nitrate by spectrophotometric method (Mullin and Riley 1955), oxygen by Winkler method and salinity by argentometric method (both by Strickland and Parsons 1972) and the TSS as per the methodology given in APHA (1980). The BOD assays were conducted in 300 ml BOD bottles at 20°C with procedures and equipment described in APHA (1980). pH was determined by an Elico pH meter of 0.01 accuracy.

Close monitoring of length and weight gain was carried out to study the biological parameters such as food conversion ratio (FCR), protein efficiency ratio (PER), gross conversion efficiency (K_1%), specific growth rate and condition factor.

a) Absolute growth = Final weight (W_2) - Initial weight (W_1)

b) Absolute growth rate = $\dfrac{W_2 - W_1}{t_2 - t_1 \text{ (Time period)}}$

c) Specific growth rate = $\dfrac{\text{Log}_e\ W_2 - \text{Log}_e\ W_1}{t_2 - t_1} \times 100$

d) Food consumed = Food given - Food uneaten

e) Percentage consumption = $\dfrac{\text{Food consumed} \times 100}{\text{Food given}}$

f) Food conversion ratio (FCR) = $\dfrac{\text{Food consumed}}{\text{Absolute growth} \times \text{Harvested number}}$

g) Protein efficiency ratio (PER) = $\dfrac{\text{Live weight gain}}{\text{Protein consumed}}$

h) Gross conversion efficiency (K_1%) = $\dfrac{\text{Increase in wet weight} \times 100}{\text{Food consumed}}$

i) Relative condition factor was found out by using the formula $K_n = W/\bar{W}$ Where 'W' is the observed weight and $\bar{W}$ is the expected weight. The expected weight was calculated using the length-weight relationship $W = {}^{-}6.0438\ L^{3.4584}$ after Lalitha Devi (1986).

j) The specific growth rate was plotted against each ration at 4 different replacements using the method followed by Brett et al. (1969) and parameters of ration size were obtained. Smooth curves constructed with these data are given in Fig. 18. The point at which the curve flattens is taken as the maximum ration which stimulates maximum growth. A tangent to the curve from the origin gives the optimum or most efficient ration which provides for greatest growth with least intake. Extension of the relationship to cut the abcissa gives the maintenance ration that keeps the animals without weight change.

5. Statistical analysis:

Results were subjected to ANOVA and tested for significance at 1% and 5% levels after Snedecor and Cochran (1973) and effects of treatments on different hydrological and biological parameters were compared. To determine the best growth rate, pairwise comparisons at different feeding and replacements were done using Students 't' test.

RESULTS

1. Ammonia:

The concentration of ammonia observed on alternate days at the 5 feeding levels and different water replacements is given in Fig. 4. At 2 and 4% feeding levels against 13.5% replacement it reached the maximum by 6 - 8 days and then declined up to the 10th/12th day. Then it again increased till 22nd day and further declined. At 8, 16 and 32% feeding, the ammonia showed the same trend at 13.5% replacement. However, the concentration was high at high feeding levels. In these 3 cases, the ammonia level increased up to 8 - 10 days and then declined sharply at 12th from where it again increased by the 16th. It remained high for few days before showing a further decrease at 8 and 16% feeding but at 32% it again showed an up and down trend. The ammonia concentrations exhibited high fluctuations at 13.5% replacement at all feeding levels and it approached a steady state towards higher replacements. At 75% replacement even at 32% feeding, the ammonia level remained steady without much variation. Average values of ammonia with standard error plotted against different feeding levels at the 4 water replacements show a gradual increase from 2 to 32% feeding (Fig.5).

Statistical analysis (Table I) showed that both feeding and water replacement had highly significant effect on ammonia. Combined effect of feeding and water replacement was also highly significant.

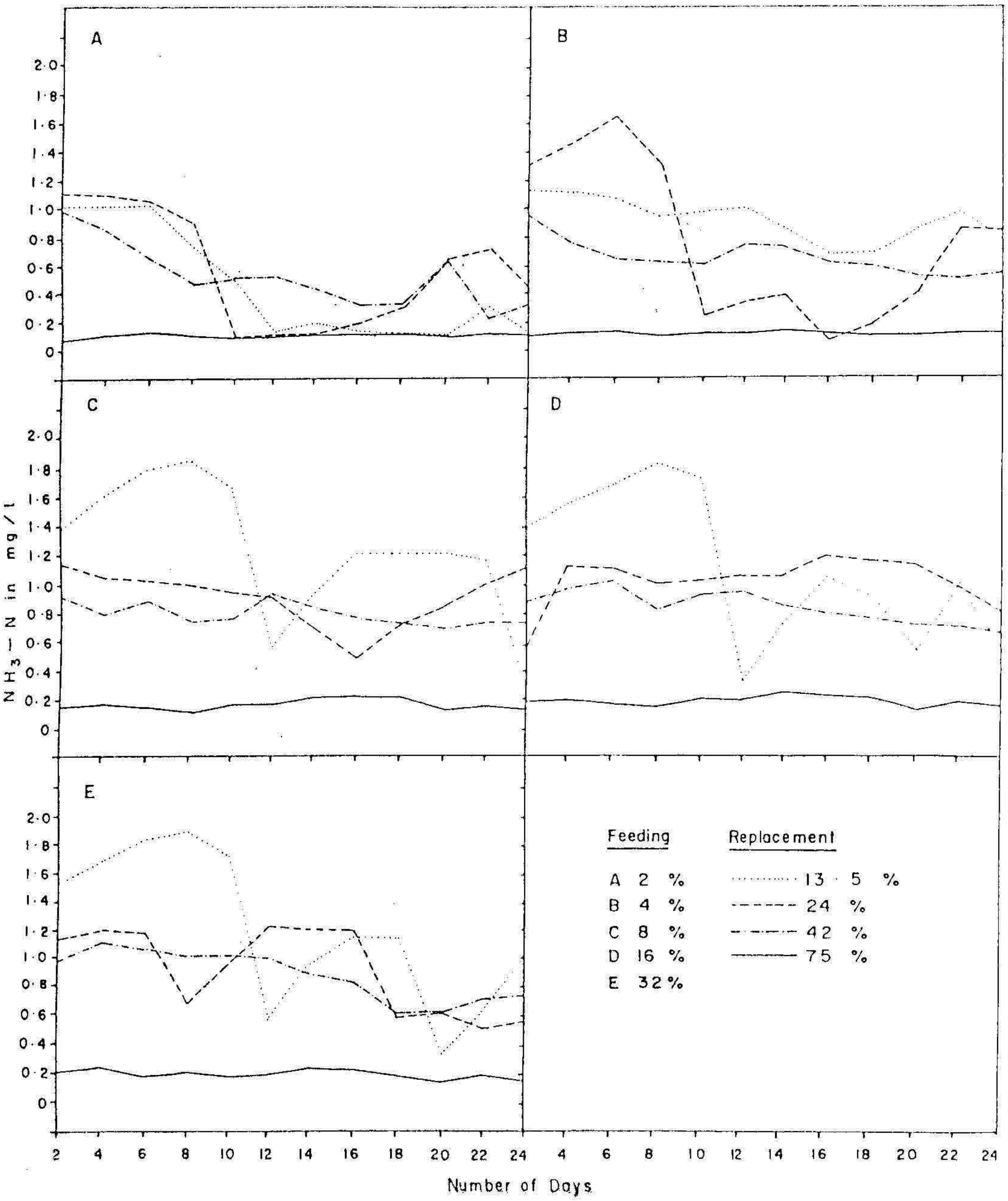

Fig. 4: Fluctuations in ammonia at different feeding levels and replacement of water.

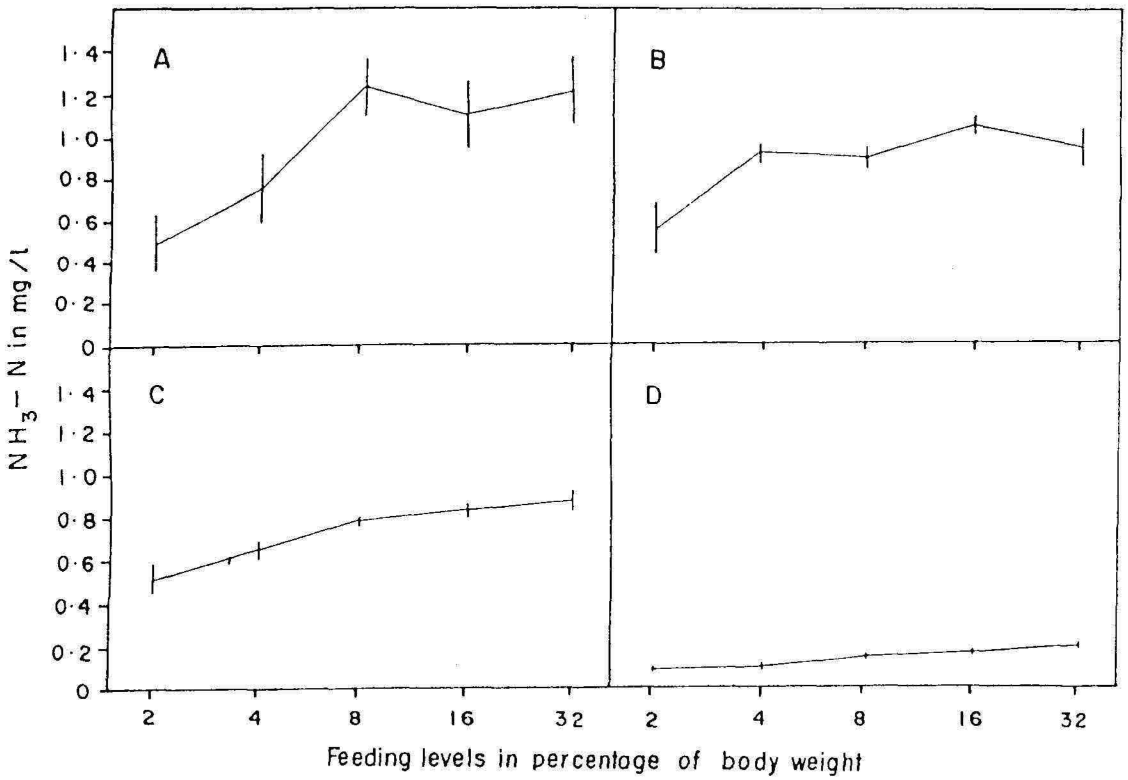

Fig. 5: Mean values with standard error of ammonia at different levels of feeding and replacements. A-13.5%, B-24%, C-42% and and D-75% replacement of water.

Table - I. **Ammonia (NH_3)**

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	5.186	1.296	14.9306	$P < 0.01$
Water replacements	3	23.417	7.806	89.8971	$P < 0.01$
Interaction	12	2.519	0.212	2.4372	$P < 0.01$
Error	220	19.102	0.087		

Table - II. **Nitrite (NO_2)**

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	0.021	0.005	0.9337	$P > 0.05$
Water replacements	3	3.403	1.134	198.6986	$P < 0.01$
Interaction	12	0.110	0.009	1.6044	$P > 0.05$
Error	220	1.256	0.006		

2. Nitrite:

Fig. 6 shows the trend of nitrite at different feeding and replacement rates. At 13.5 and 24% replacements the nitrite at all the 5 feeding levels was almost the same. On the whole, it averaged around 0.3 mg/l. At 42% replacement except at 2 and 4% feeding levels, the values were below 0.1 mg/l. At 8% feeding the values which were initially below 1 gradually increased and reached 0.211 mg/l on the 12th day. Subsequently it declined and registered values below 0.1 mg/l. Though the values showed similar trend at 16% feeding, the values remained totally below 0.1 mg/l thoughout. But at 32% feeding it increased to a level of 0.139 mg/l on the 8th day and declined on the 10th day to 0.09 mg/l and continued at this level during the rest of the period. At 75% replacement, at 2, 4, 8 and 16% feeding it was almost the same at a mean value around 0.04 mg/l. At 32% feeding eventhough it was slightly above 0.05, it was lower than the values at other replacements. Irrespective of the feeding levels, the nitrite values remained much below at 75% replacement at all feeding levels (Fig.7).

Statistical analysis (Table II) showed significant variation in nitrite concentration between replacements, but not at all significant between feeding levels. Their interaction was also found not significant.

3. Nitrate:

The nitrate at all feeding levels against 13.5% replacement had the same trend of an increase from the initial to a peak on 8th day,

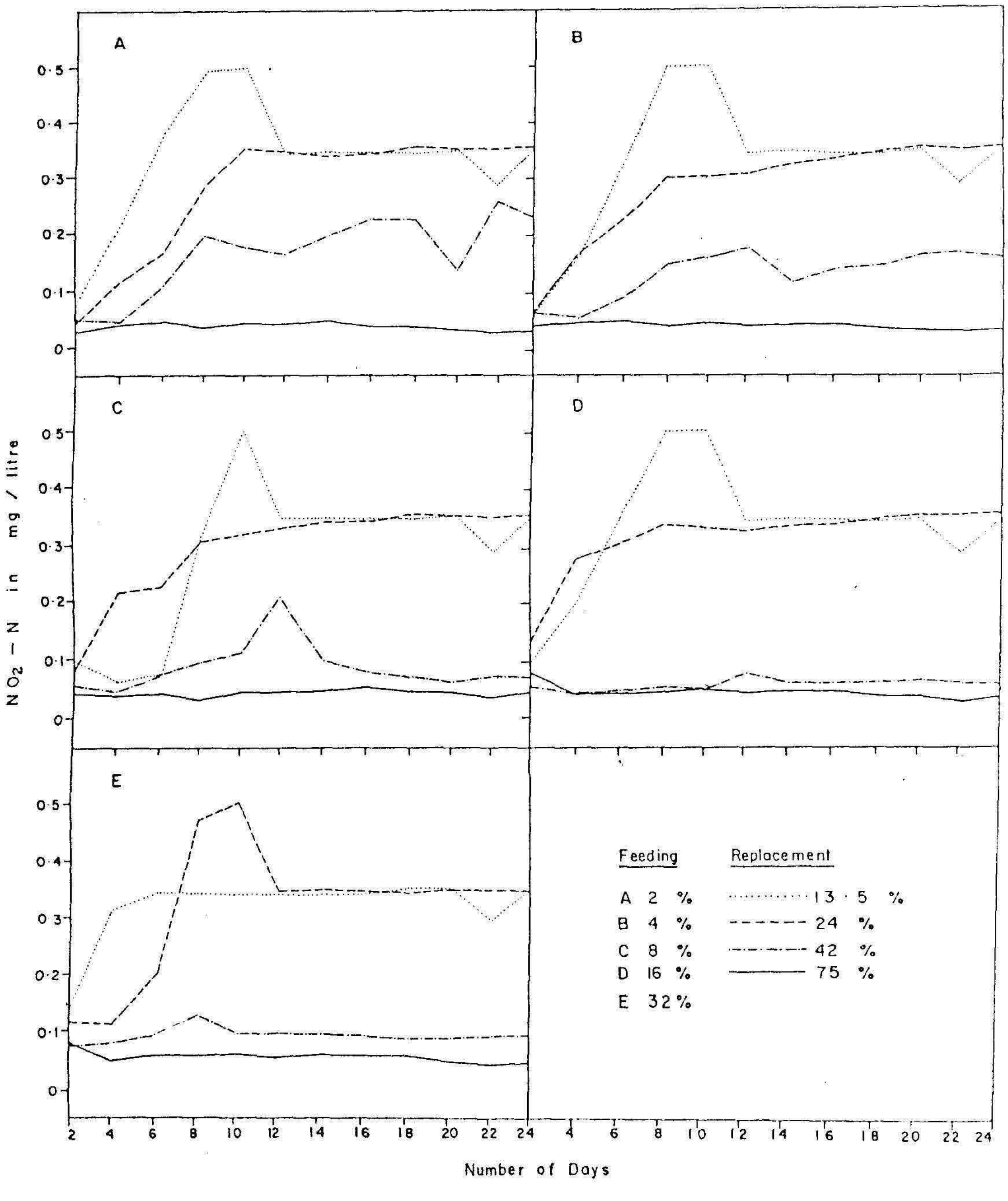

Fig. 6: Fluctuations of nitrite at different feeding levels and replacement of water

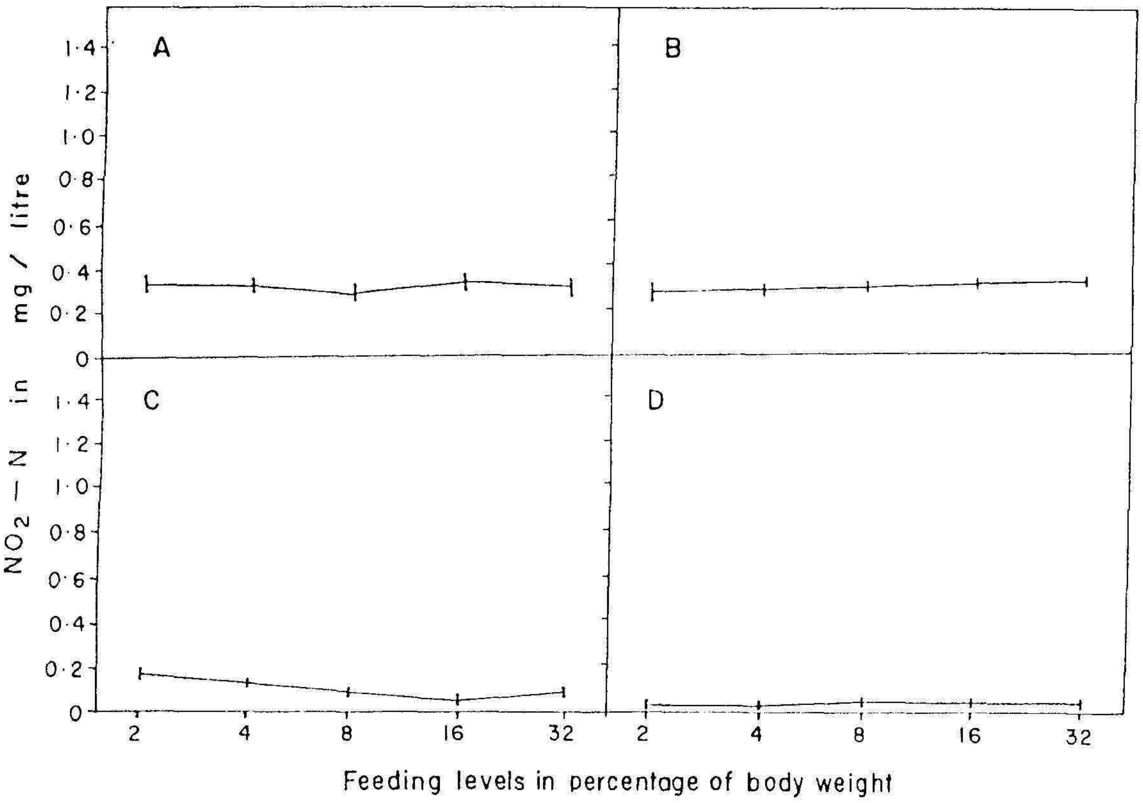

Fig. 7: Mean values with standard error of nitrite at different levels of feeding and replacements. A-13.5%, B-24%, C-42% and D-75% replacement of water.

fall on 12th day and a subsequent levelling (Fig.8). At 24% replacement at all the 5 feeding levels, there was a sudden increase from the initial on the 4th day and a subsequent steadying if not a gradual inclination along with the levelling. At 42% also, the values were almost steady but 75% replacement showed fluctuations at all feeding levels indicating the lowest on 12th day. The nitrate concentration at all feeding levels (Fig.9) decreased as the replacement increased.

Statistically (Table III) the variation in nitrate concentration was highly significant between replacements. But between feeding levels it was not at all significant. Likewise, the interaction was also not significant.

4. H^+ concentration:

The data indicated that there was a gradual decrease in pH from the 1st day to the last day of the experiment at all the five feeding levels (Fig.10). However, this decrease was more at lower replaements, against higher feeding levels. The pH at 32% feeding and 13.5% replacement decreased to 7.58 on the 24th day. At 75% replacement the pH at all the feeding levels was above 8.

The pH decreased as the feeding level increased, and increased as replacement increased (Fig.11). In both cases, the variation was highly significant (Table IV). Their interaction was also highly significant.

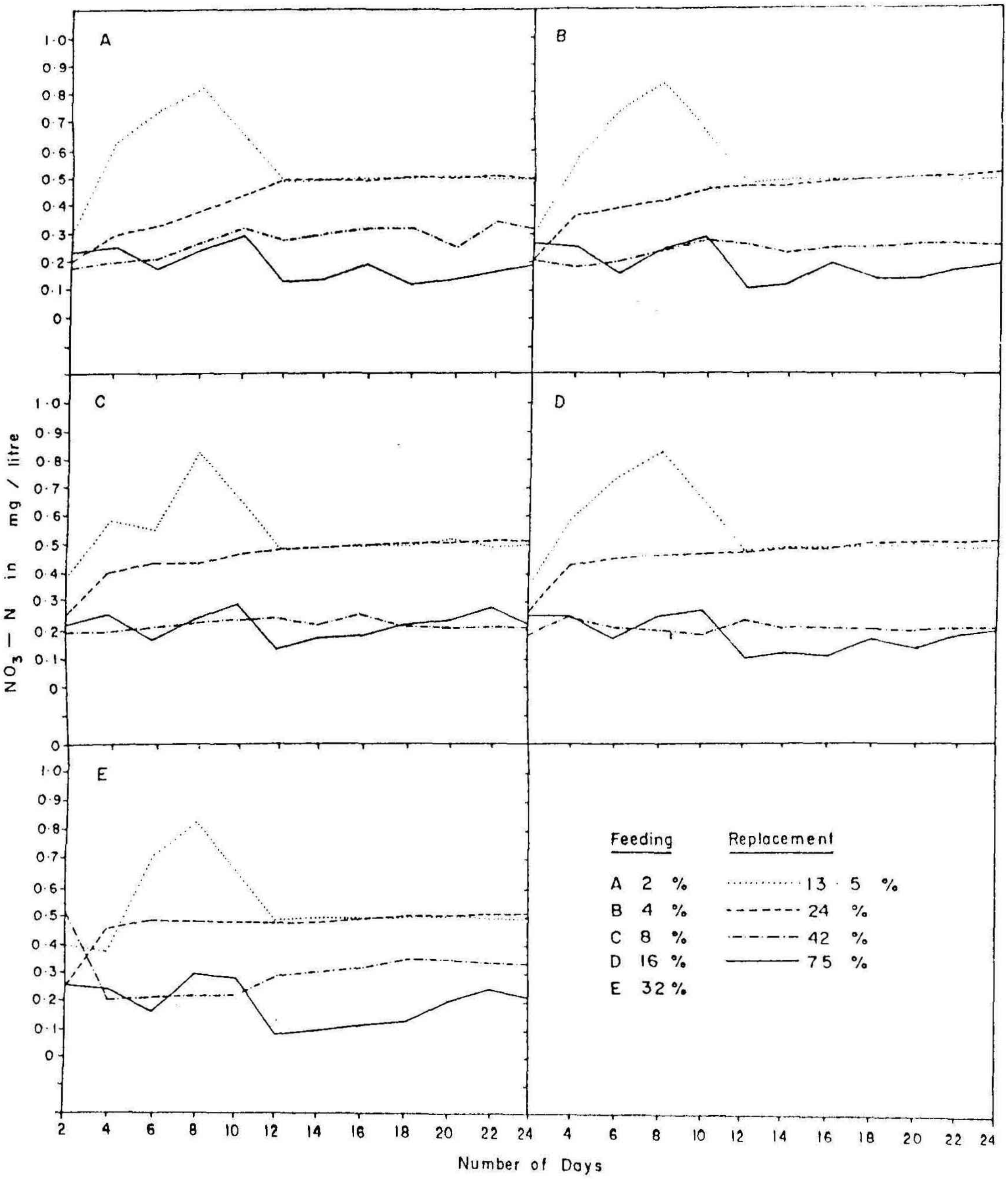

Fig. 8: Fluctuations in nitrate at different feeding levels and replacement of water.

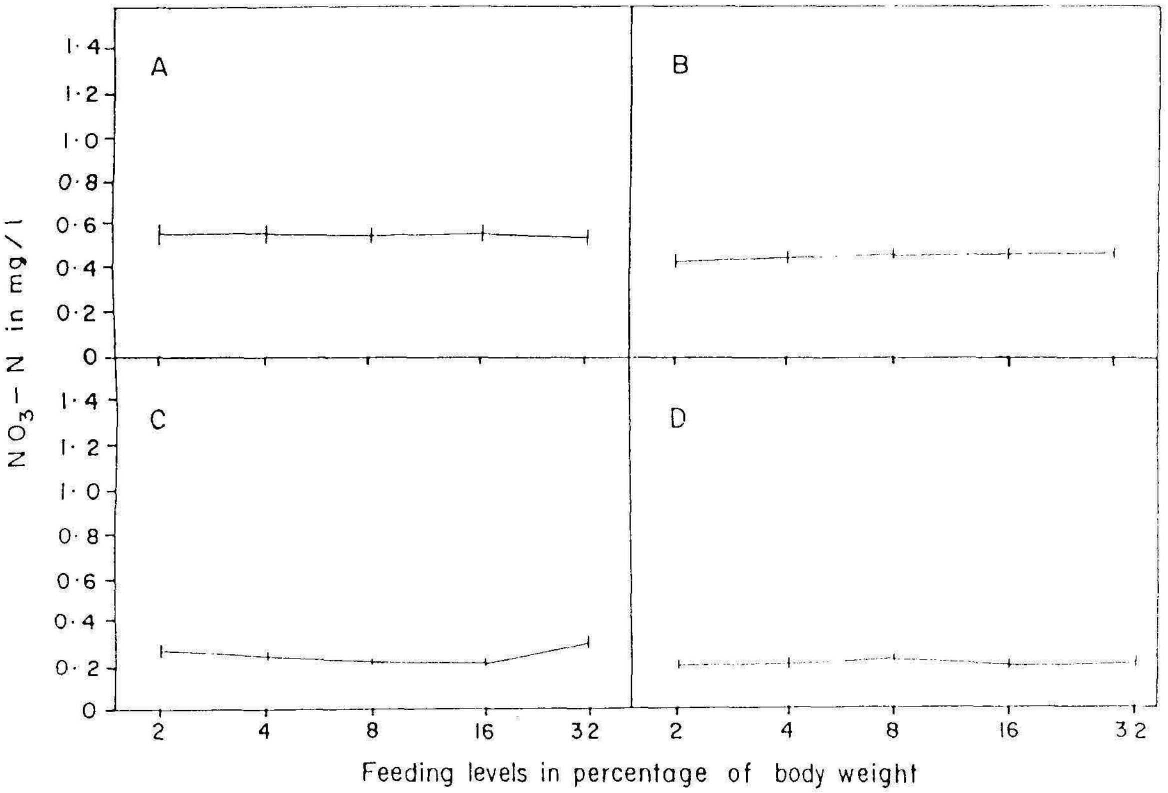

Fig. 9: Mean values with standard error of nitrate at different levels of feeding and replacements. A-13.5%, B-24%, C-42% and D-75% replacement of water.

Table - III. Nitrate (NO_3)

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	0.018	0.005	0.6208	$P > 0.05$
Water replacements	3	5.086	1.695	228.3073	$P < 0.01$
Interaction	12	0.091	0.008	1.0196	$P > 0.05$
Error	220	1.634	0.007		

Table - IV. H^+ concentration (pH)

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	0.918	0.230	27.4997	$P < 0.01$
Water replacements	3	1.728	0.576	69.0080	$P < 0.01$
Interaction	12	0.417	0.035	4.1665	$P < 0.01$
Error	220	1.836	0.008		

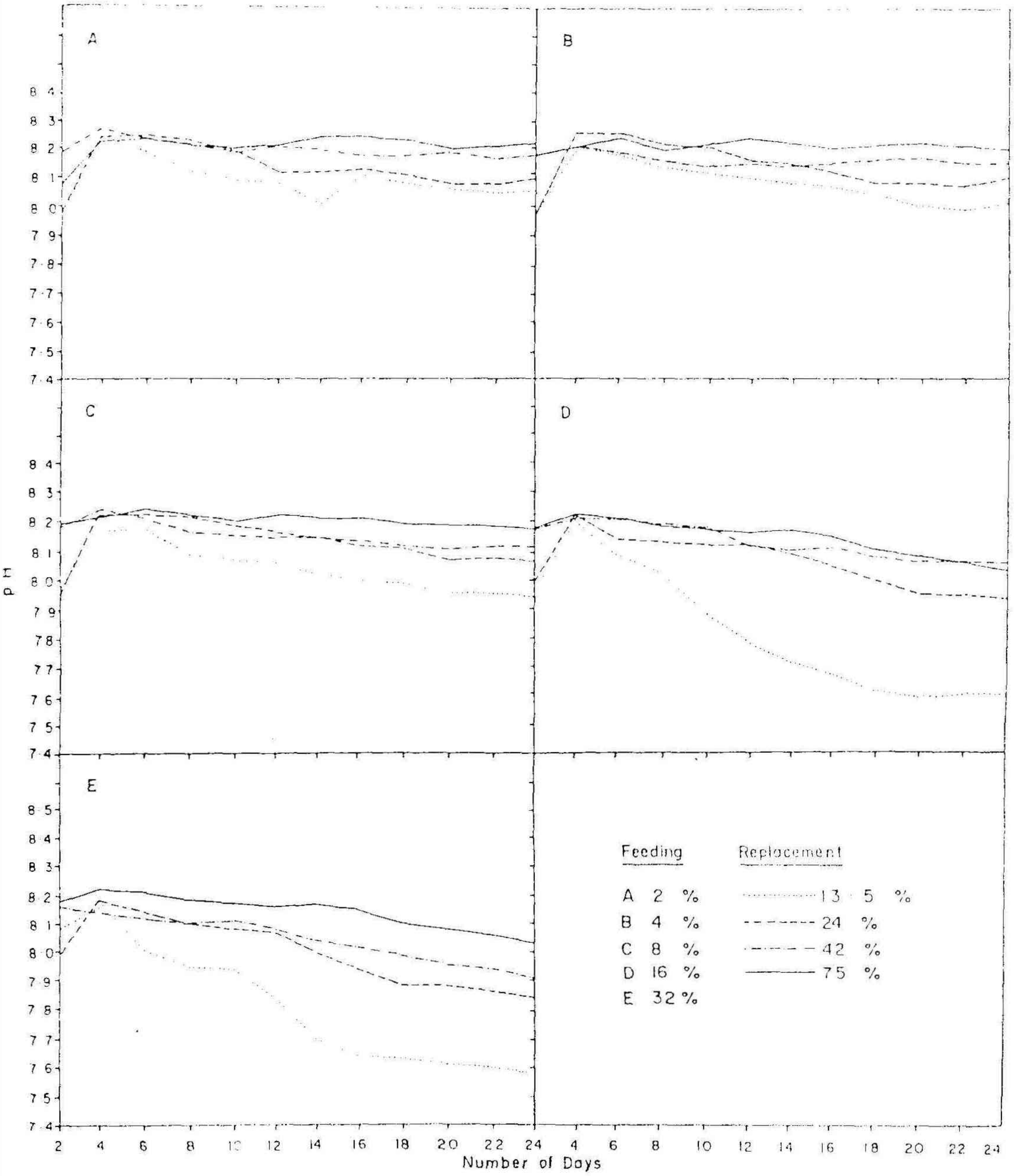

Fig. 10: Fluctuations in pH at different feeding levels and replacement of water.

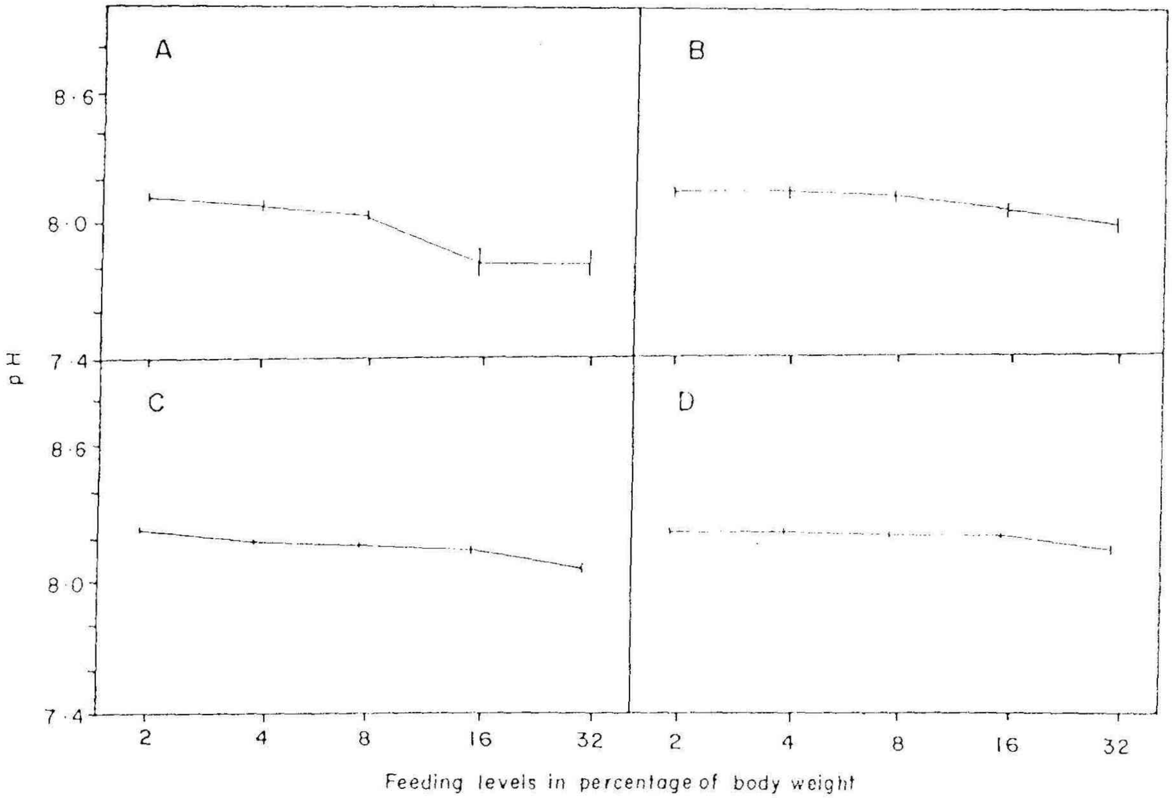

Fig.

Fig. 11: Mean values with standard error of pH at different levels of feeding and replacements. A-13.5%, B-24%, C-42% and D-75% replacement of water.

5. Total suspended solids:

As seen in Fig. 12, the TSS showed higher concentration at higher feeding levels. It was very high at 32% feeding against 13.5% replacement and was more than double than that at 16% feeding. TSS concentration at 2, 4, and 8% feeding was below the permissible level of 15 mg/l at all replacements. But at 32% feeding even at higher replacements its concentration was near to the permissible level.

The TSS thus increased towards higher feeding levels and decreased towards higher replacements, the variation in both cases was highly significant (Table V). Their interaction was also highly significant.

6. Biochemical oxygen demand:

BOD (Fig.13) showed the same trend as that of TSS. With the advancement of days it also increased at all feeding levels. But at 2, 4, and 8% feeding, towards higher replacements the variation was less and it almost attained a steady level at 75% replacement. But at 16 and 32% feeding, the BOD level went above 10 mg/l at all replacements except 75%. At 75% replacement while it was well below 5 mg/l at 16% feeding, it was near to 10 mg/l at 32% feeding.

The ANOVA(Table VI) showed that BOD was highly significant between feeding and replacements. But their interaction was not significant.

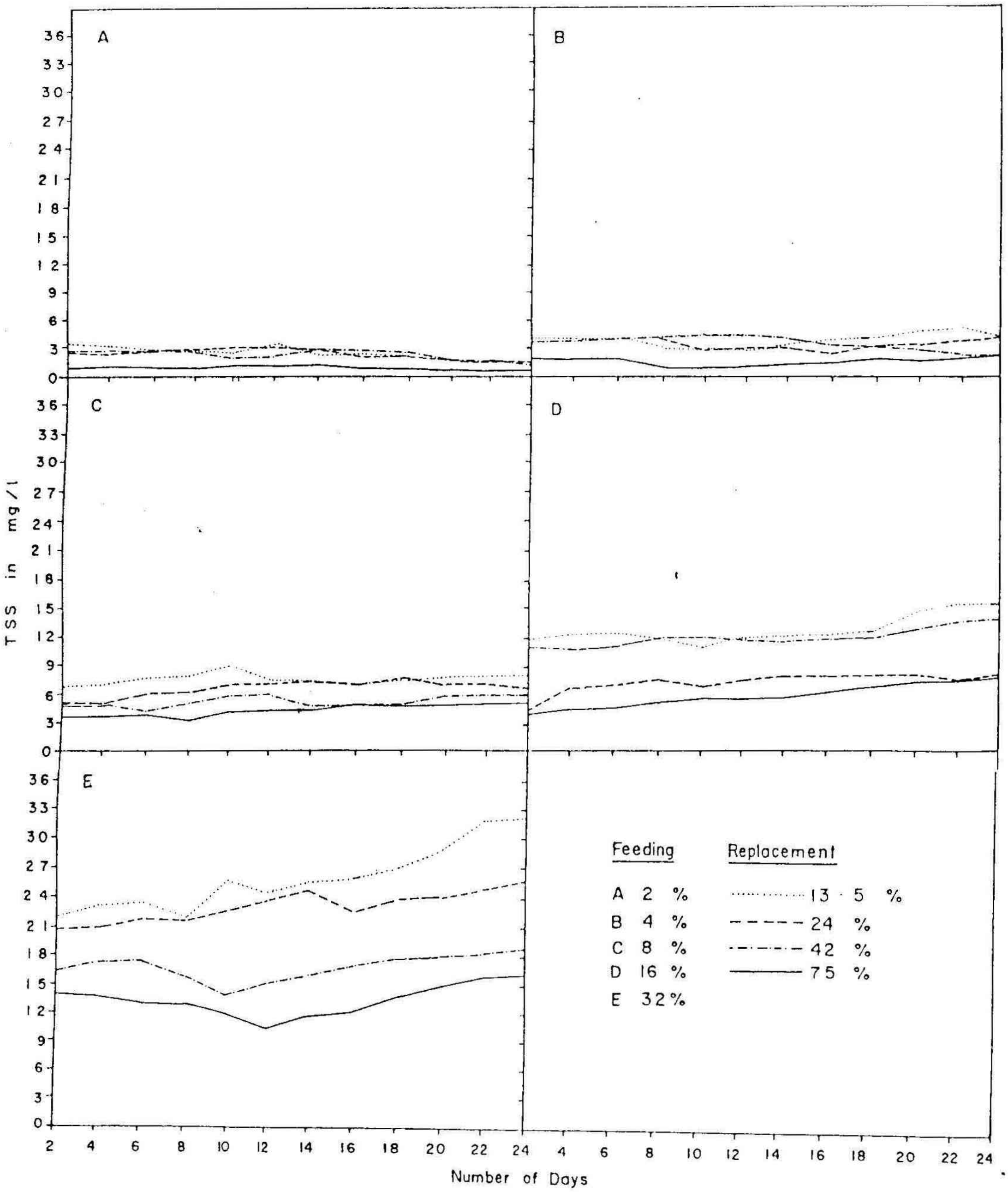

Fig. 12: Fluctuations in TSS at different feeding levels and replacement of water.

Table - V. Total suspended solids (TSS)

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	9944.342	2486.085	1633.2962	$P < 0.01$
Water replacements	3	1051.968	350.656	230.3722	$P < 0.01$
Interaction	12	712.061	59.338	38.9839	$P < 0.01$
Error	220	334.868	1.522		

Table - VI. Biochemical oxygen demand (BOD)

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	1304.711	326.178	83.7501	$P < 0.01$
Water replacements	3	415.868	138.623	35.5931	$P < 0.01$
Interaction	12	41.518	3.460	0.8884	$P > 0.05$
Error	220	389.465	3.895		

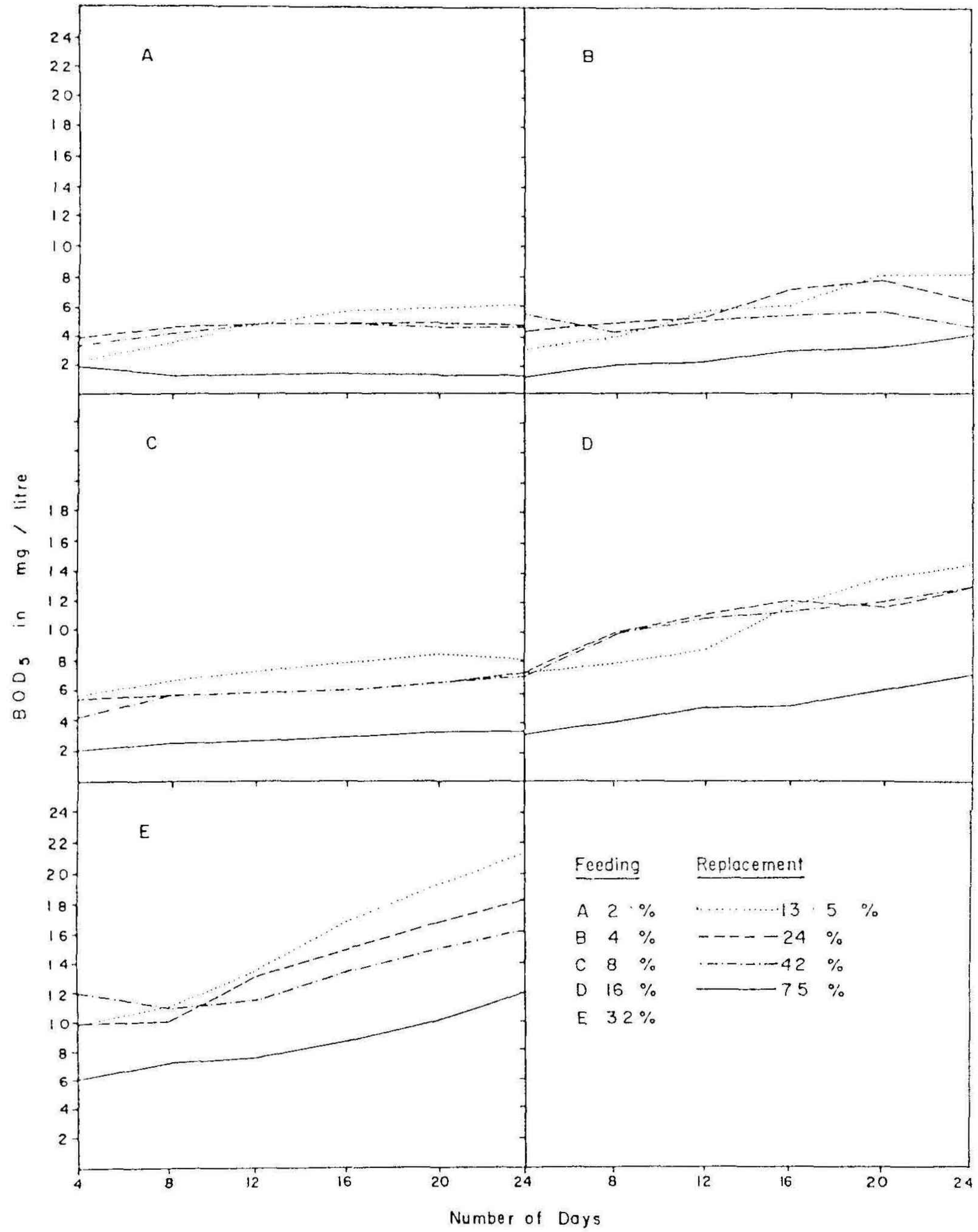

Fig. 13: Fluctuations in BOD at different feeding and replacements.

7. Consumption:

The prawns were observed to consume the entire feed given at 2 and 4% levels of feeding. At feeding levels above these, left over food was seen. At 8% level about 1/4 of the food given remained uneaten. However, the consumption rate in the animals showed an increase from 8% to 32% (Fig.14). The percentage consumption of the provided food, on the other hand, showed a decreasing trend towards higher feeding levels (Fig.15). At 16% and 32% feeding the consumption of the animals increased with increase in replacements.

Statistically (Table VII) the consumption was highly significant between feeding levels but not significant between replacements.

8. Growth rate per day:

The data indicated an increase in growth rate per day with corresponding increase in ration size from 2 to 16% feeding and thereafter at 32% it decreased at all levels of replacement except 13.5% where it kept increasing (Fig.16). The difference in growth rate from 2 to 8% feeding was comparatively high. Although the consumption was more at 16 and 32% feeding, the growth at lower replacements has not appreciably increased in comparison to that at 8% feeding. But at 75% replacement and 16 and 32% feeding the growth was high. The variation in growth rate between replacements was minimum at 2 and 4% feeding. At 8% feeding, the growth rate increased as the replacement increased from 13.5 to 42%. Further increase in replacement didn't seem to have

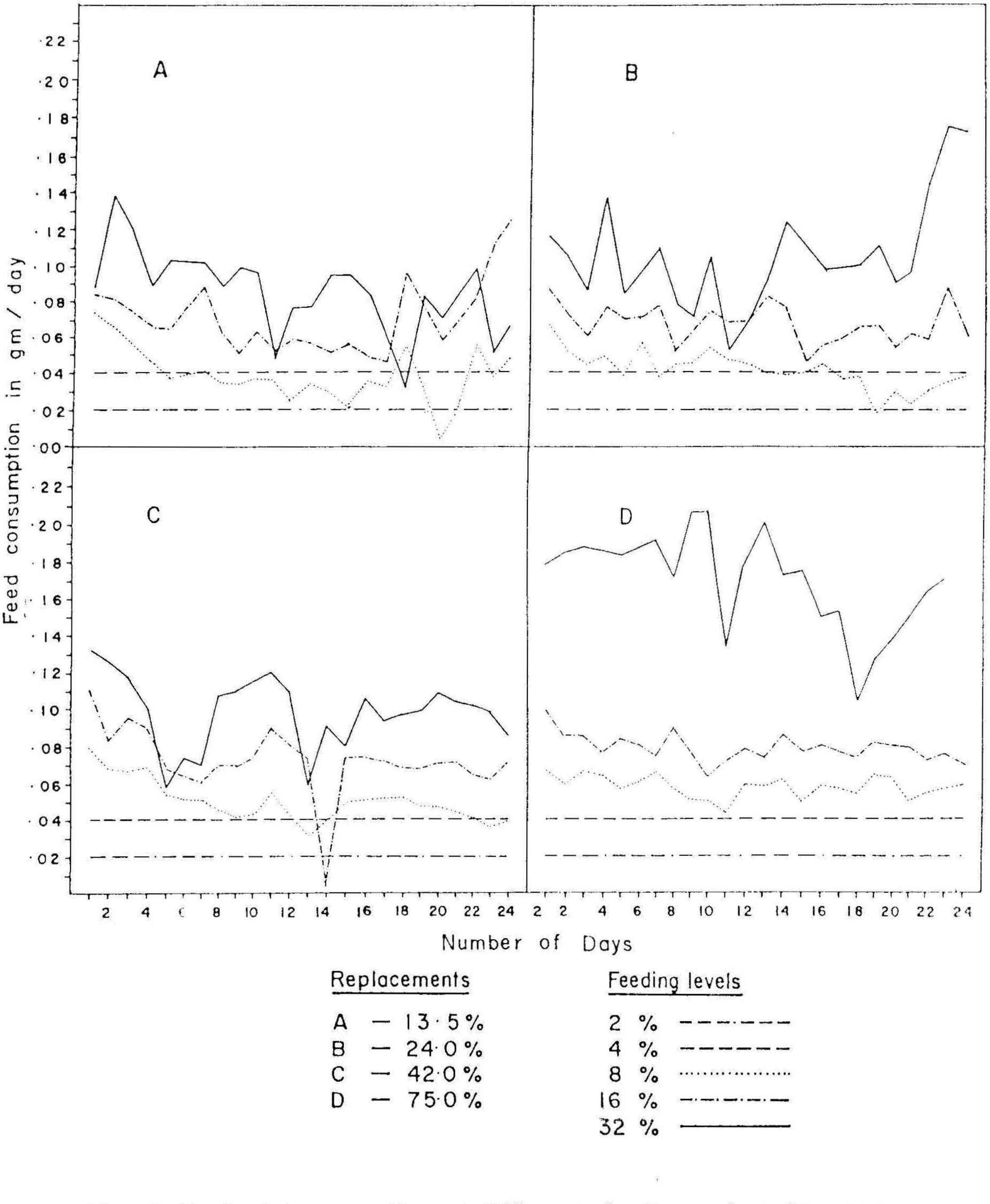

Fig. 14: Daily food consumption at different feeding and replacements.

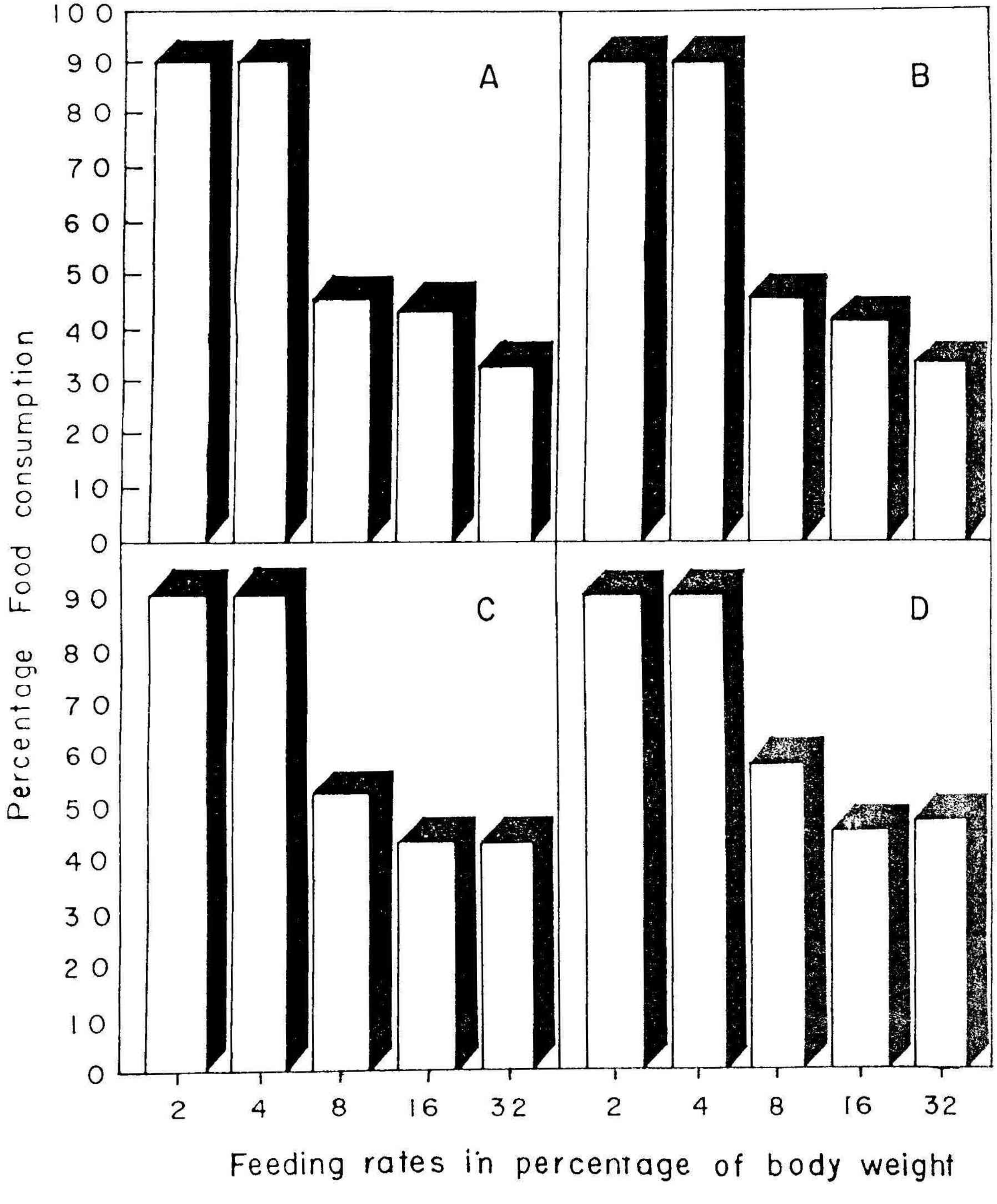

Fig. 15: Percentage food consumption at different feeding and replacements, A-13.5%, B-24%, C-42% and D-75% replacements of water.

Table - VII. **Percentage consumption**

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Signi-ficance
Between:					
Feeding levels	4	10223.22	2555.805	230.71	$P < 0.01$
Water replacements	3	106.12	35.372	3.19	$P > 0.05$
Error	12	132.93	11.078		

Table - VIII. **Growth rate per day**

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Signi-ficance
Between:					
Feeding levels	4	2536.07	634.016	48.83	$P < 0.01$
Water replacements	3	282.52	94.174	7.25	$P < 0.01$
Error	12	155.81	12.984		

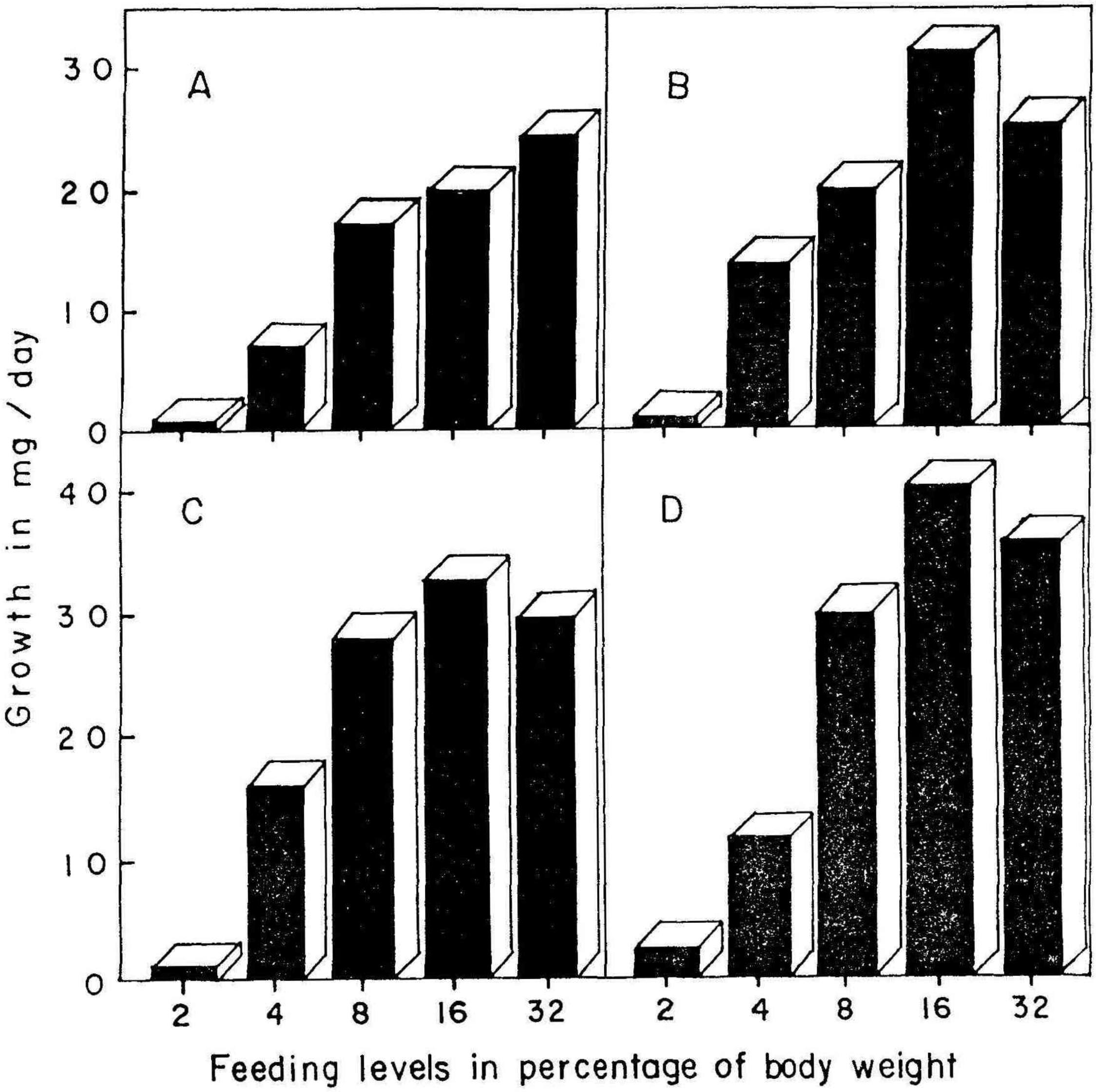

Fig. 16: Growth of P. indicus at different feeding levels and replacements, A-13.5%, B-24%, C-42% and D-75%, replacement of water.

any marked effect. But at 16% feeding the growth showed an increasing trend towards 75% replacement, whereas at 32% feeding eventhough the growth was higher than 8% feeding the difference between replacements was not that much. The maximum growth rate (40.12 mg/d) was at 16% feeding and 75% replacement. Even at 32% feeding it was 35.67 mg/d at 75% replacement. In the case of 8% feeding the growth rate at 42 and 75% replacement was 27.83 and 29.70 mg/d respectively indicating not much difference between them.

Statistically the growth was highly significant between feeding and replacement rates (Table VIII). The 't' test also showed best growth at 16% feeding and 75% replacement.

9. Specific growth rate:

In weekly observations, specific growth rate showed negative values at 2% feeding levels (Fig.17). But it increased at 4% feeding and obtained positive values. This increase continued up to 16% feeding but declined at 32%. The average shown in the figure, at 16 and 32% feeding especially against 13.5 and 75% replacements appears to be almost the same. In the case of 2 and 4% feeding the variation between replacements was marginal. But at 8 and 16% feeding marked variations existed between replacements. At 32% feeding the values were mostly higher than at 8%.

The specific growth rate plotted against each ration level at 4 different replacements is given in Fig. 18. The maintenance, optimum

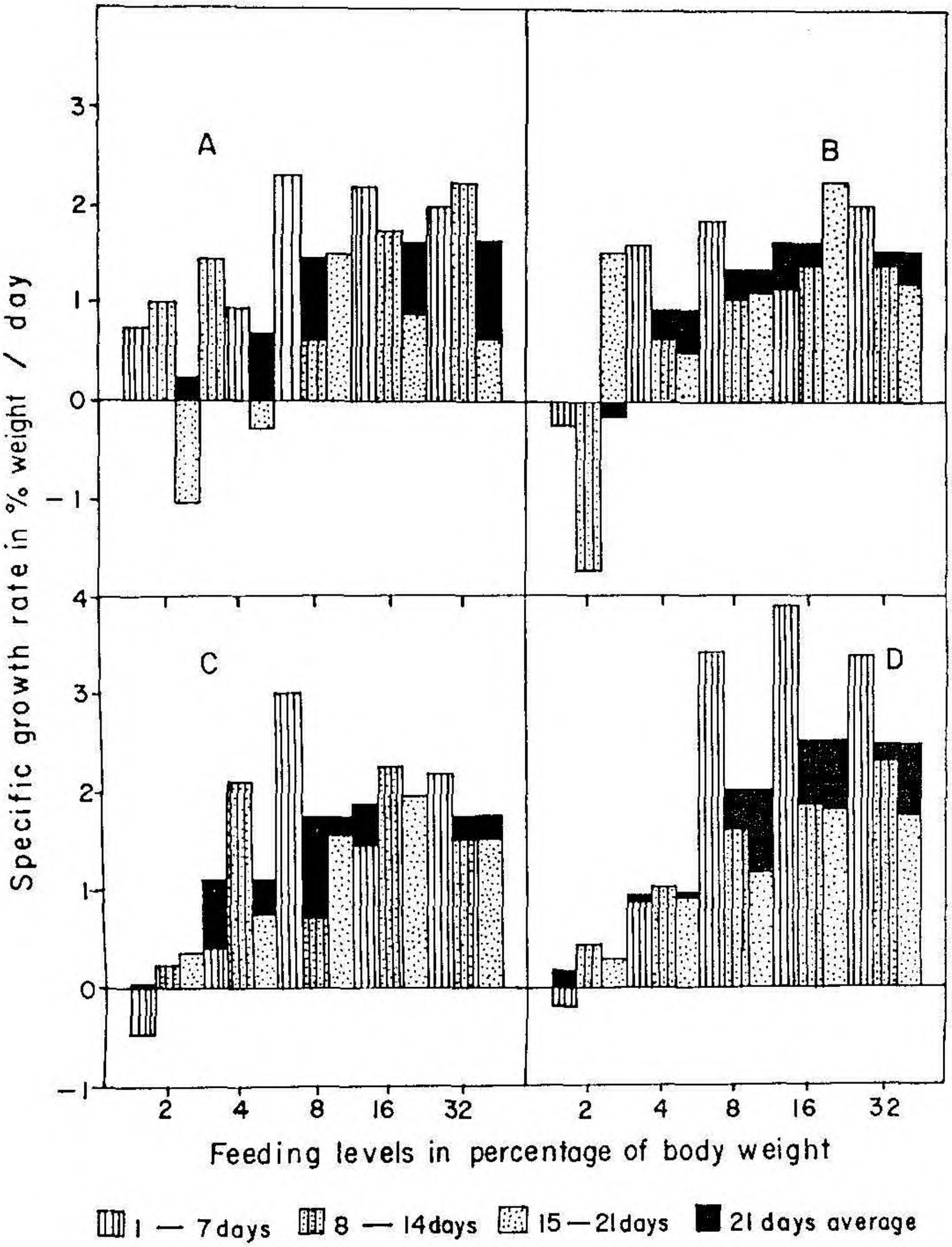

Fig. 17: Specific growth rate of P. indicus at different feeding levels and replacements. A-13.5%, B-24%, C-42% and D-75% replacement of water.

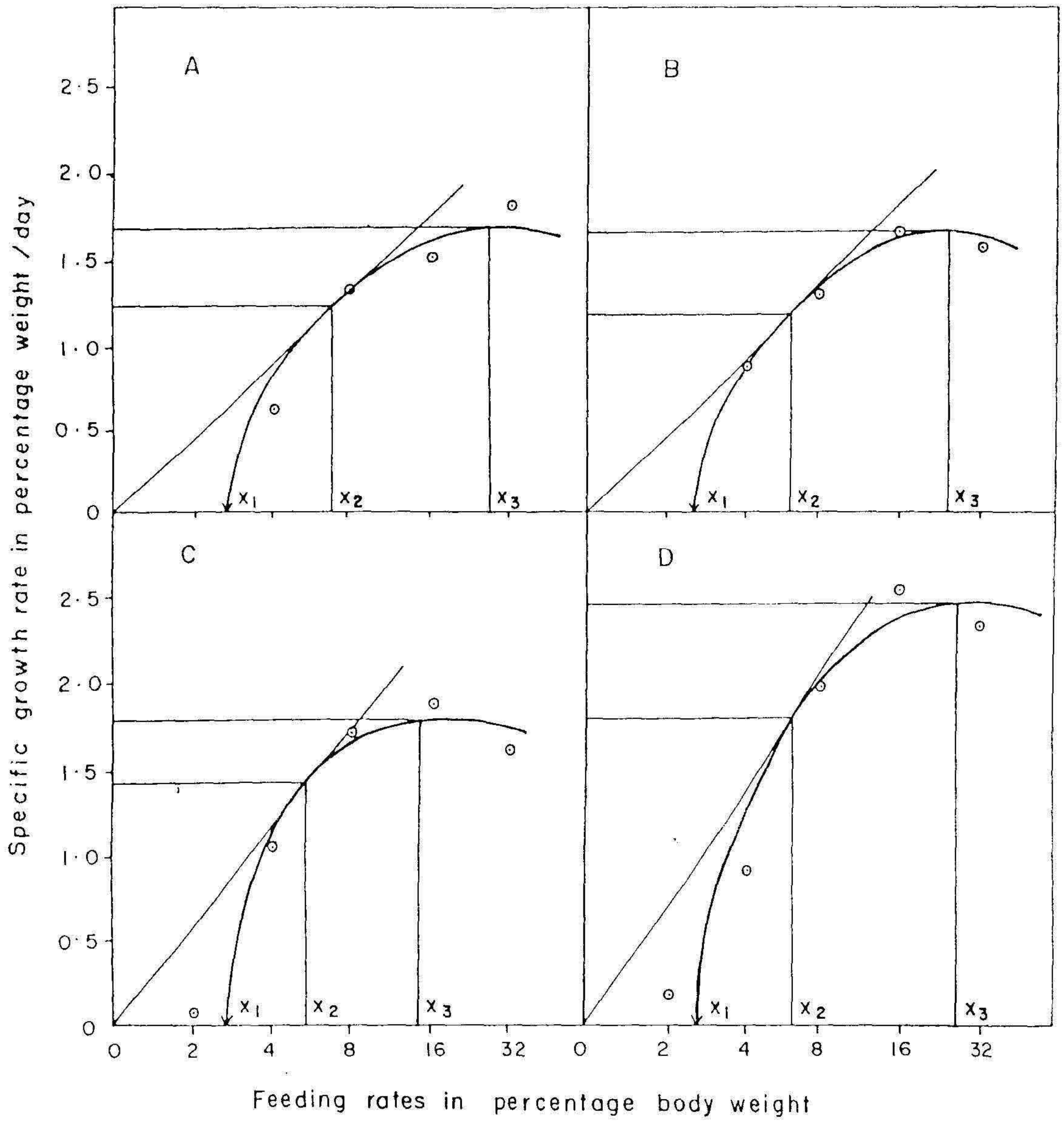

Fig. 18: Curve of specific growth against feeding and water replacement. A-13.5%, B-24%, C-42% and D-75% replacement of water and X_1, X_2, X_3 are respectively maintenance, optimum and maximum food rations.

and maximum rations at each replacements are given under:

Rations (in % of body weight)	Replacements			
	13.5%	24%	42%	75%
Maintenance	2.65	2.50	2.70	2.65
Optimum	7.00	6.10	5.65	6.35
Maximum	27.50	24.00	14.30	26.00

10. Food conversion ratio:

FCR at 2% feeding was high at all replacements. At 4%,it suddenly declined and reached the minimum at 8% but again increased at 16 and 32%. The minimum FCR was obtained at 8% feeding against 42% replacement (2.76) and 75% replacement (2.74). At 16 and 32% feeding the FCR values were around 3 or above at all replacements (Fig.19).

Statistical analysis showed highly significant variation between the feeding levels (Table IX). On the contrary, increase in replacements did not have any significant effect.

11. Protein efficiency ratio:

The PER increased from 2% feeding up to 8% and then declined at all replacements (Fig.20).

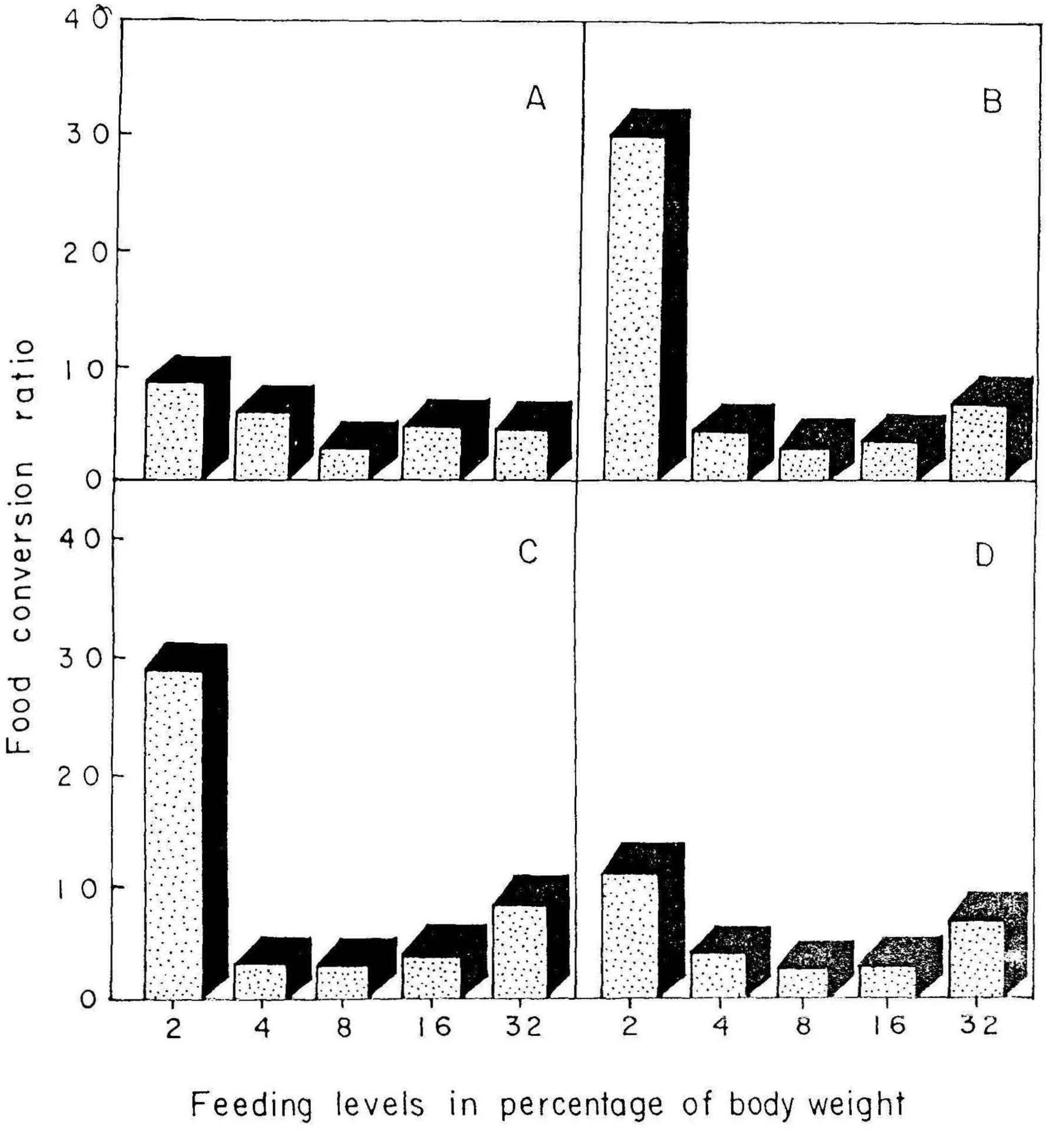

Fig. 19: Food conversion ratio at different levels of feeding and replacement. A-13.5%, B-24%, C-42% and D-75% replacement of water.

Table - IX. **Feed conversion ratio (FCR)**

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	800.21	200.053	7.19	P <0.01
Water replacements	3	82.86	27.621	0.99	P >0.05
Error	12	333.95	27.829		

Table - X. **Protein efficiency ratio (PER)**

ANALYSIS OF VARIANCE

(2 way ANOVA

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	1.90	0.474	23.95	P <0.01
Water replacements	3	0.03	0.010	0.51	P >0.05
Error	12	0.24	0.020		

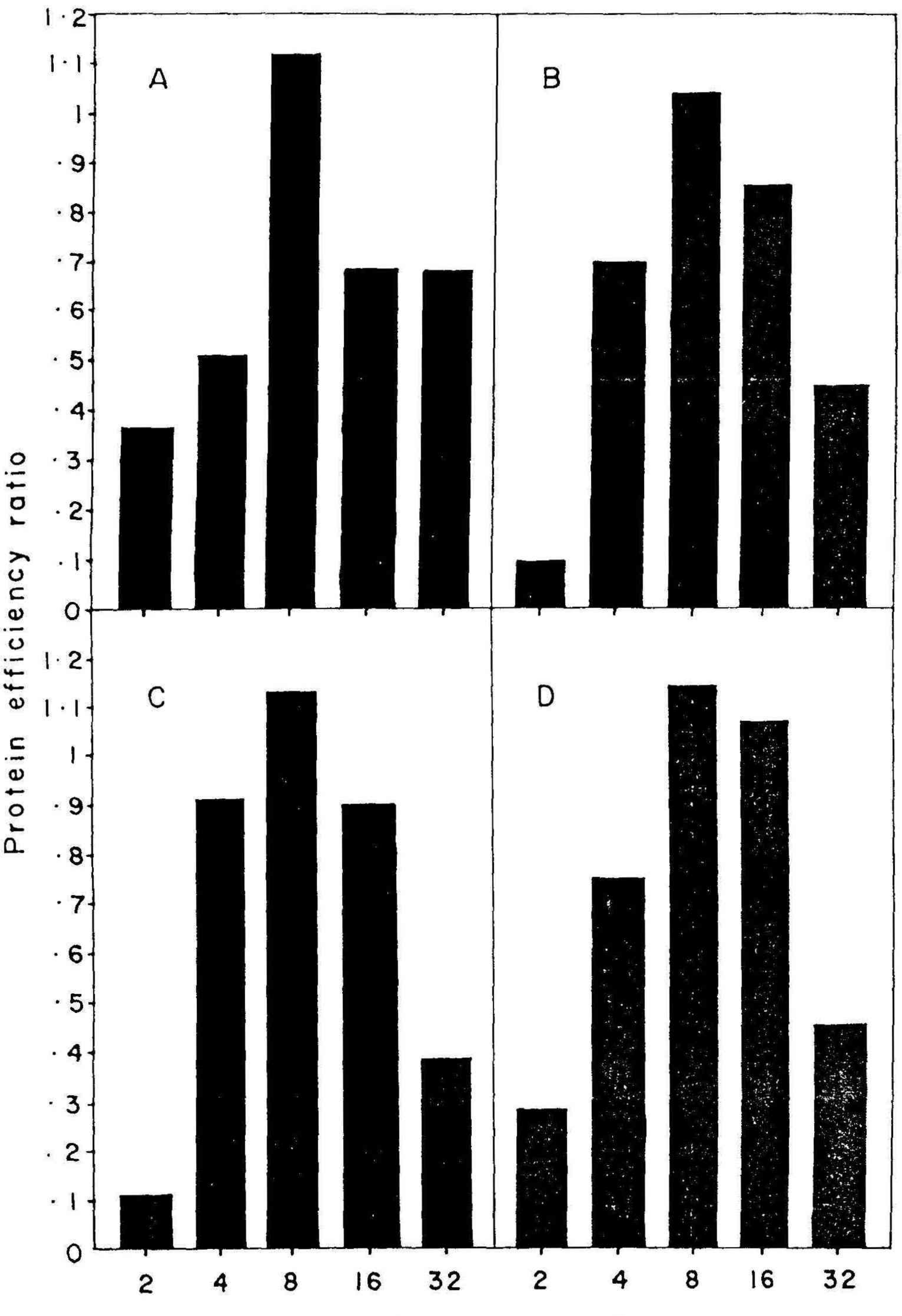

Fig. 20: Protein efficiency ratio at different levels of feeding and replacements. A-13.5%, B-24%, c-42% and D-75% replacement of water.

The increase in PER between feeding was highly significant but not significant between replacements (Table X).

12. Gross conversion efficiency (K_1%):

As seen in Fig. 21, at food rations below 8% the K_1% was low. It was maximum at 8%, and again low at 16 and 32%. The highest value of gross conversion efficiency (36.45) was obtained at 8% feeding and 75% replacement. At 8% feeding and 42% replacement also, it was equally good (36.19). This indicates that there was not much difference between 42 and 85% replacements. At 16% feeding, gross conversion efficiency of 34.19 was obtained at 75% replacement but at all other replacements it was comparatively low. At 32% feeding it was even lower than the values at 4% level.

Statistically the difference in gross conversion efficiency was highly significant between feeding but not significant between replacements (Table XI).

13. Condition factor:

The condition factor of the animals at 2% feeding (Fig.22) decreased from the initial at all replacements. At 4% feeding it went slightly above the initial. At all replacements, the condition factor reached the

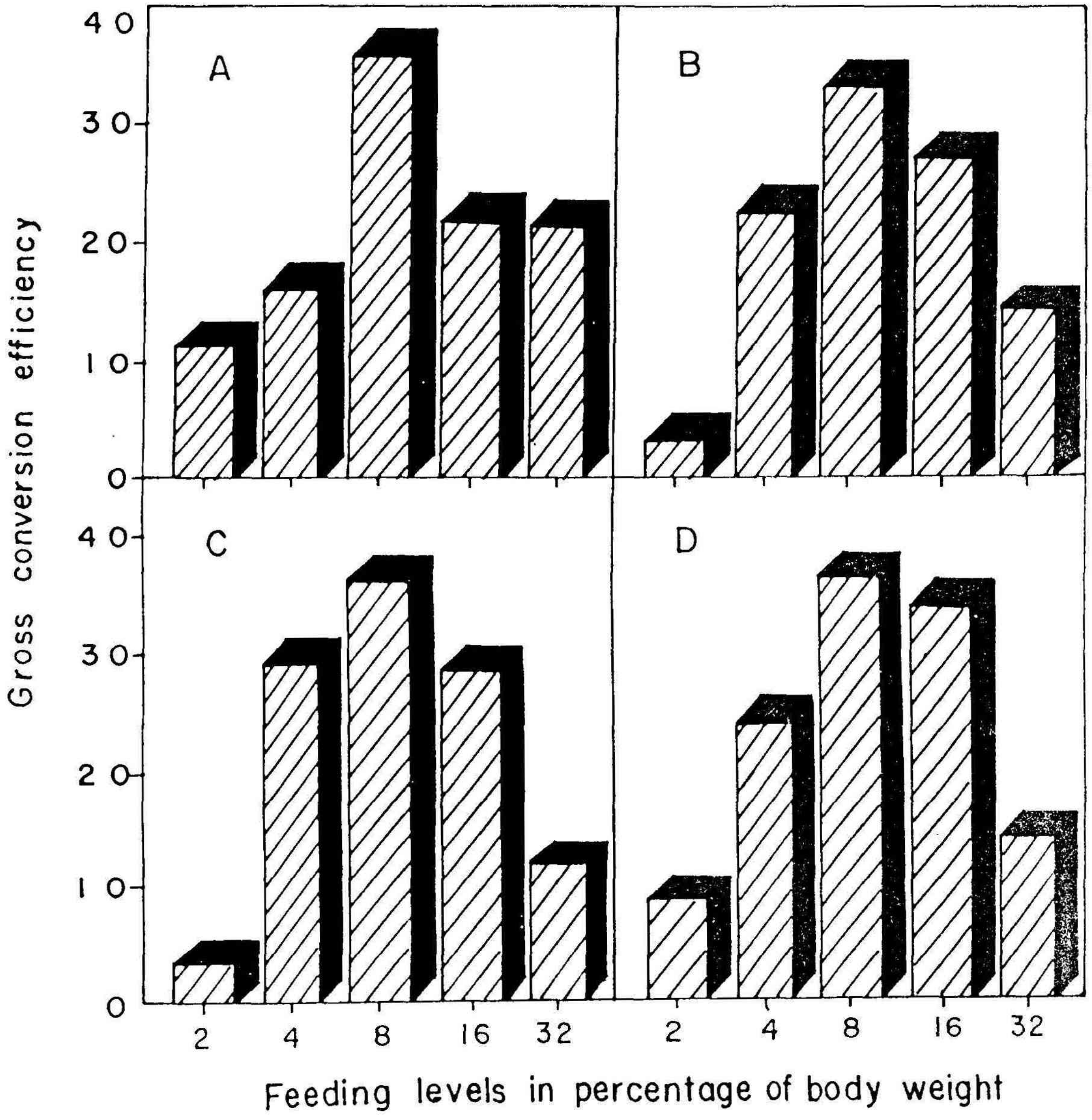

Fig. 21: Gross conversion efficiency at different levels of feeding and replacements. A-13.5%, B-24%, C-42% and D-75% replacement of water.

Table - XI. **Gross Conversion efficiency** (K_1%)

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	1949.66	487.416	24.28	$P < 0.01$
Water replacements	3	31.22	10.408	0.52	$P > 0.05$
Error	12	240.92	20.077		

Table - XII. **Survival**

ANALYSIS OF VARIANCE

(2 way ANOVA)

Source	DF	SS	MSS	F	Significance
Between:					
Feeding levels	4	212.45	53.113	0.51	$P > 0.05$
Water replacements	3	1604.80	534.932	5.17	$P < 0.05$
Error	12	1242.06	103.505		

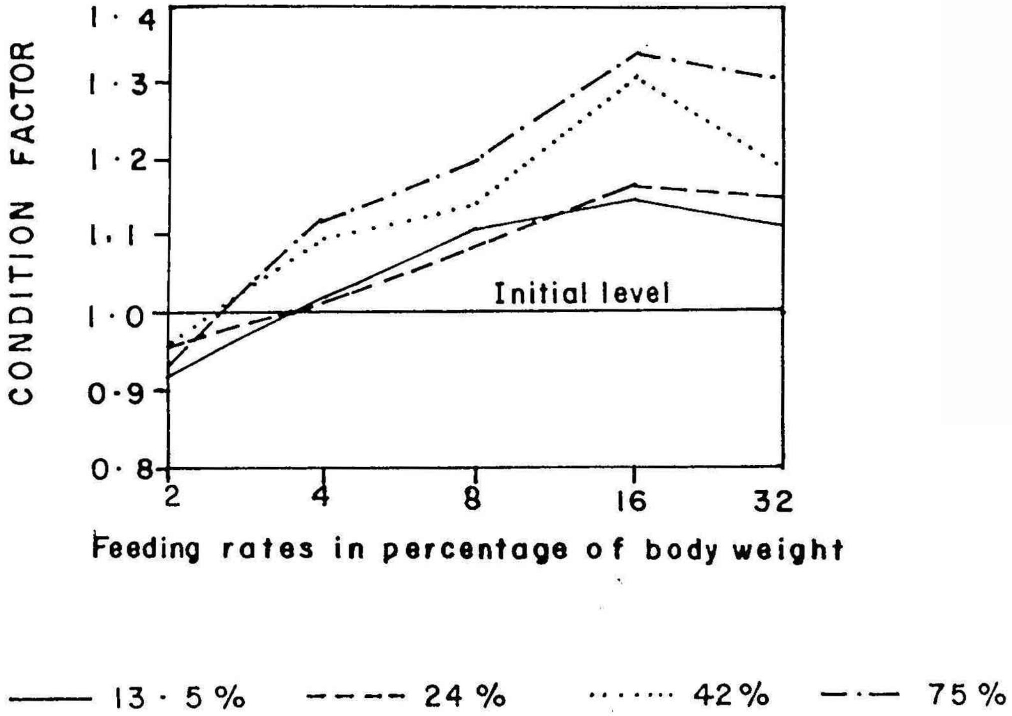

Fig. 22: Condition factor at different feeding and replacements.

peak at 16%, but showed slight decline thereafter. At 8, 16 and 32% feeding levels, the condition factor increased with higher replacements of 42 and 75%.

14. Survival rate:

Fig. 23 shows the survival rates at all the 5 feeding levels at 4 replacements. According to this, the survival rate in general elevated parallelly with increase in replacements at 8, 16 and 32% feeding. At 8 and 16% feeding against 75% replacement it was as high as 90%. At 2% feeding the survival at all replacements was low.

Statistically the survival rate was significant between replacements but not between feeding levels (Table XII).

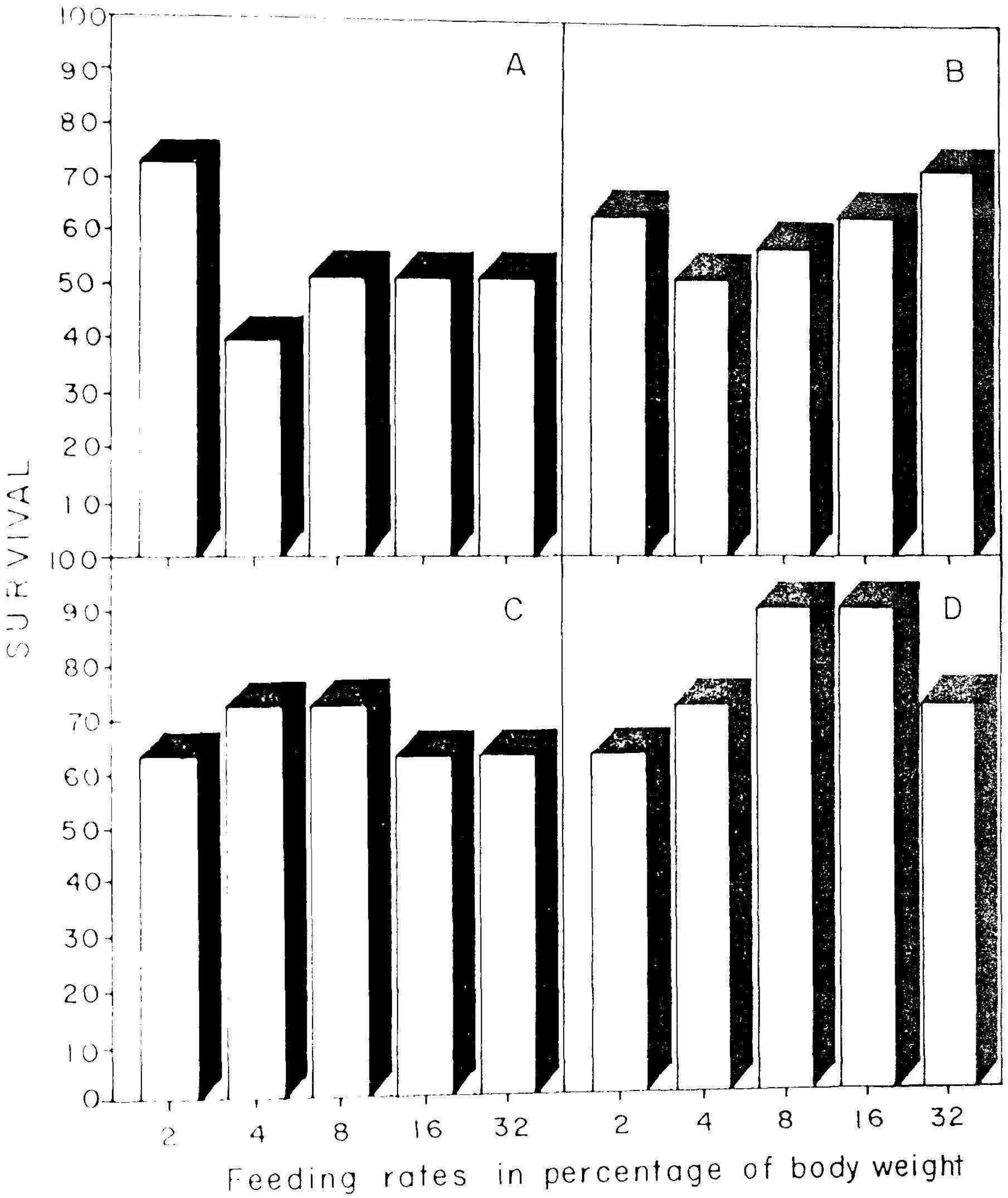

Fig. 23: Survival at different feeding and replacements. A-13.5%, B-24%, C-42% and D-75% replacement of water.

DISCUSSION

In intensive culture of fish, increased feeding rates have been correlated to water quality deterioration by Boyd (1982), Liao and Mayo (1974) and Tucker et al. (1979). Effects of water exchange rate and density on water quality and yield have been, likewise studied by Diana and Fast (1989) and Sampath (1985). But the effects of water exchange rates and feeding levels on water quality and growth seem to have not been done before. No such aspects having done in prawns any where, the study made at present is of high significance in management of shrimp farms.

In intensive culture systems where feed containing high protein is used, ammonia accumulates considerably in the water. Porter et al. (1987) found that in sea-water-grow-out-ponds for Sparus aurata 30% of nitrogen in the feed was released into the water as NH_4-N. According to Millemana (1990), low organic loading rates associated with low feeding levels resulted in low ammonia and nitrite levels. Ammonia accumulation at higher feeding levels has been reported in channel catfish ponds by Cole and Boyd (1986) and Tucker et al. (1979). In the present study also (Fig.5) an increase in ammonia levels with an increase in feeding rates has been observed and these results are in accordance with the above findings.

The reduction in fish growth caused due to continuous exposure to ammonia concentration is widely documented (Brockway 1950, Colt and Tchobanoglous 1978, Kawamoto 1961, Mayer and Krammer 1973 and Robinette 1976). Andrews et al. (1971) observed poor growth of fish in culture tanks due to accumulation of ammonia.

Colt and Tchobanoglous (1978) found significant reduction in growth and survival of channel catfish, Ictalurus punctatus on chronic exposure to ammonia. The 24 hour median lethal concentration (LC_{50}) of ammonia to channel catfish fingerlings according to Robinette (1976) was 2.36 mg/l and concentrations as low as 0.12 mg/l caused significant decrease in growth rate. Wickins (1976) calculated the 3 week EC_{50} (i.e. the concentration that reduced the growth by 50% of that of the controls) as 0.45 ppm NH_3-N ih marine prawns. Also he calculated the 48-h LC_{50} for juvenile P. indicus as 1.28 mg/l NH_3-N (un-ionized ammonia). In the present study the total ammonia (un-ionized and ionized) calculated at 13.5% replacement at 8, 16 and 32% feeding rates were 1.240, 1.106 and 1.205 respectively. These values are much higher than the above level and this may be the reason for the poor growth of the animals.

Ammonia is supposed to affect the growth through reduction in appetite, switch over to urea excretion, and damage to gills. In rainbow trout, Mayer and Krammer (1973) observed that very low levels of ammonia caused hyperplasia of the gill epithelium. In the present study the animals at 13.5% and 24% replacements were affected by bacterial gill disease also causing significant mortality.

According to Borwn (1957) food consumption is probably the most potent factor affecting growth in fishes. The first apparent reaction of fish to high ammonia concentration or that of toxic substances in water is reduced feeding rate or cessation of feeding (Hepher 1988). Shilo and Rimon (1982) observed stoppage of feed intake by the fish with the rise in ammonia. The quantity of food consumed depends on the development of appetite (Brett 1971 and Pandian 1975). Sampath et al. (1991) observed 60% reduction in the food consumption in Oreochromis mossambicus in the highest tested ammonia concentration (14 mg/l). Studying the effect of density on food intake and growth Sampath (1985) concluded that ammonia accumulation under high density culture might be responsible for reduction in food intake and growth in Channa striatus. The results obtained during the present work are in agreement with the above observations. The reduction of appetite due to higher levels of ammonia can be attributed to the lower level of consumption at 13.5 and 24% replacements at 8, 16 and 32% feeding levels (Fig.14).

Ammonia under aerobic conditions is oxidised to nitrite and nitrate. Owing to the slow growth of the nitrifying organisms, the nitrification process cannot respond quickly to shock loads (Colt and Tchobanoglous 1976). This will result initially in an increase in ammonia followed by an increase in nitrite. The decrease in ammonium concentration is related to the onset of nitrification process. In the present work also a rise in NO_2 concentrations coincided with the decline of NH_3 concentrations.

Avnimelech et al. (1986) observed that in conventional ponds this decrease will be slow and fluctuating and in circulated drained treatment it will be fastest. In the present study, the treatments in which the feeding levels were 8, 16 and 32%, against 13.5 and 24% replacements can be compared to conventional ponds; characterised by high BOD and denitrification. Ammonia and nitrite in these treatments showed considerable fluctuations. The nitrite at all the 5 feeding levels at 13.5% and 24% replacements (Fig.6) was the same eventhough the ammonia level (Fig.4) was high at 8, 16 and 32% feeding. This may be due to the high level of BOD in these treatments. A higher BOD will result in a reduced nitrification and a temporary accumulation of ammonia. The steady state level of nitrite at higher replacements may be due to the continuous supply of oxygen as stated by Avnimelech et al. (1986). The sudden fall of nitrate after a peak on 7th day at 13.5% replacement (Fig.8) is due to the denitrification process. The nitrate, howbeit will gradually increase towards higher replacements on account of good conditions for oxidation of ammonia to nitrate.

The 3 week EC_{50} for juvenile penaeids was calculated by Wickins (1976) as 6.4 ppm NO_2-N. In the present study the values obtained even at lower replacements were much lower around 0.3 ppm. In rearing the larvae of P. indicus, Sprague (1971) also observed 0.33 ppm NO_2-N as "safe level". But Jayasankar and Muthu (1983) observed it to be only 0.18 ppm for larvae and opined that the juveniles are more tolerant than the larvae. Adults of P. japonicus have, however, been reported by

Mevel and Chamroux (1981) to be very sensitive to nitrite toxicity as 32% mortality occurred at 0.61 mg/l. On the other hand, Armstrong et al. (1976) reported retardation of growth in M. rosenbergii at sub-lethal levels of 1.8 mg/l NO_2-N. According to King and Spotte (1974), in closed seawater systems, the nitrite level shouldn't exceed 0.1 mg/l. In the present investigation at higher replacements the nitrite was well below the above mentioned level.

Finfishes are observed to be more sensitive to nitrite poisoning and it is attributed to the fact that nitrite oxidises the blood pigment haemoglobin to methemoglobin, which cannot bind oxygen for transport; whereas haemocyanin, the blood pigment in prawns, can still bind oxygen in the presence of nitrite (Conant et al. 1933 and Needham 1961). The action of nitrite on oxygen transport may be more serious for the shrimp during ecdysis since oxygen consumption is known to increase significantly at this time (Passano, 1960). In the present study, at lower replacements mortality having occurred only during ecdysis might have been influenced jointly by ammonia and nitrite toxicity.

There is little evidence that nitrate concentrations (25-100 mg NO_3-N/l) likely to be encountered in intensive culture systems are toxic to fish. The growth of P. monodon was not affected by 200 mg NO_3-N/l after 3-4 weeks' exposure (Wickins 1981). Wickins (1976) calculated the 3-4 weeks' EC_{50} for M. rosenbergii as 175 mg NO_3-N/l. In the present study, the maximum concentration of the nitrate obtained was only 0.83 mg/l and it appears to do no harm. But accumulation of nitrate was reported to cause undesirable pH decrease, by replacement of carbonate and bicarbonate ions, as well as nitric acid formation (Honig 1934).

According to Kinne (1976) with excessive amount of food the pH tends to decrease considerably. Wickins (1976) observed 70% and above mortality in 4 inadequately buffered recirculation systems where pH remained low (7.4 - 7.5) for several weeks. In the present study, the pH at 32% feeding against 13.5% replacement averaged 7.813 in a range of 7.58 - 8.18 (Fig.10). This may be caused by the high NO_3 concentration and TSS. Bacteria use suspended matter as substrata and through their respiratory activity lower the pH (Milstein 1990). In the present study the pH increased with higher replacements due to dilution of NO_3 concentration and reduction in TSS by additions of fresh medium.

According to Shilo and Rimon (1982) the suspended particulate matter residing close to the pond bottom is an important source of active ammonification of organic matter and when present in excess are reported to create anaerobic conditions. But Leber and Pruder (1988) concluded that the performance of currently available shrimp feed is greatly improved when shrimp pond effluent is added to the culture water regardless of feed quality. Continuous circulation of water together with resuspension of organic particles induces flocculation of bacteria around organic particles upon which fish can feed (Avnimelech et al. 1989). The TSS at 32% feeding in the current study ranged between 15-32 mg dry weight per litre which is higher than the permissible level (15 mg/l) suggested by

Wickins (1976). In the field conditions where silt and sand would be available and the plankton production is more, higher TSS value can be expected from what is obtained in the laboratory conditions.

The effect of increased feeding levels on BOD has been documented by Costa-Pierce *et al.* (1983) and Smitherman and Boyd (1974). Millemana in 1990 in laboratory experiments with *P.monodon* post larvae observed that at a feed concentration of 500 mg/l, the BOD rose to 21 mg/l at 30% replacement and with 50 mg/l feed the values did not exceed 10 mg/l. But in the present study at 24% replacement, the BOD values rose to 21 mg/l when fed with 150 mg/l feed and 10 mg/l when fed with 40 mg/l feed. The low survival rate obtained in the present study at 13.5% replacement can be attributed to reduction in dissolved oxygen concentration which may increase the toxic effect of ammonia.

Growth of any organism, can be regarded as the positive result of a process tending to increase the body mass due to food intake and decrease due to metabolic expenditure (Huisman 1976). According to Brown (1957) food supply is probably the most important factor affecting the growth in fish. The increase in food ration above the "optimal level" does increase the growth rate, although at a lower conversion efficiency. Higher feeding levels have been observed to depress the growth rate in channel catfish (Andrews 1979) and in *Cyprinus carpio* (Huisman 1976). However, higher growth rates were correlated with increasing feeding levels in juvenile *Homarus americanus* but the *ad libitum* amounts of food didn't promote the highest rates of growth (Bartley et al. 1980).

During deprivation of food, body fat is used mainly by the organism to meet its energy requirements. At maintenance level, instead of body constituents, food is used to meet the energy demand and the growth rate at this ration is defined as zero. According to Kerr (1971) at higher feeding levels, the spontaneous activity increases, resulting in high metabolic energy needs that increase at a greater rate than the energy derived from the increased amount of food available. Thus a larger fraction of energy is dissipated on metabolism. This will explain why in the present study the growth rate did not increase at high feeding levels (Fig.16) eventhough the consumption was very high. A smaller ration requires relatively less post-absorptive processing, at a lower metabolic cost or lower specific dynamic action (SDA) as described by Calow (1977). In the present study a considerable increase in growth rate was observed from 2 to 8% feeding and low consumption.

Many experimental studies have shown that food intake and conversion efficiency strongly depend on environmental factors such as temperature salinity, food, etc. (Brett 1979 and Kinne 1960). Sampath (1985) observed a gradual decrease in the consumption of Channa striatus with increasing density of the stock and decreasing water change frequency. Diana and Fast (1989) observed no significant growth or survival with different water exchange rates eventhough the water quality improved. This may be due to the high stocking density (600 nos/m^3) in the above study. On the otherhand, in the present work, at 16 and 32% feeding levels an increase in growth rate was observed towards higher replacements. At higher water exchanges metabolic expenditure of energy due to stress on account of toxic metabolites is less and the energy from ingested food is directed towards growth.

In the case of juvenile P. merguiensis, Sedgwick (1979) got the maximum ration at 12.5% body weight, optimum at 6.0% and a maintenance ration of about 2.5%. In the present study also, the maintenance ration arrived at all replacements was around 2.5% of body weight (Fig.18). But this was slightly above the lowest feeding level tested. At lower replacements in which the increased metabolic activity due to stress is high, the requirement for optimum and maximum food ration may increase. At 75% replacement, because the water gets somewhat clean the consumption rate increases. But as already stated earlier, due to higher metabolic activity at higher feeding rates more energy has to be expended towards maintenance. Thus the optimum and maximum food ration showed an increase at 75% replacement. According to Brett et al. (1969) the ration level which maximises both growth rate and conversion efficiency is intermediate to the feeding level yielding the most efficient use of food (maximum conversion efficiency) and the feeding level yielding the maximum growth rate. Thus in the present study this ration may be in between 8% feeding which gave maximum conversion efficiency and 16% which gave maximum growth rate.

Gross conversion efficiency describes the increase in wet weight of an organism as a function of the dry weight of feed consumed. The effect of the ration size on the gross conversion efficiency has been well established. In most studies on fishes, it is found to increase with an increase in ration size from near the maintenance level, to a maximum at an intermediate level which may remain largely unchanged or decrease with further increase in ration (Andrews and Stickney 1972, Brett and Shelbourn 1975, Brett et al. 1969, Kerr 1971, Williams and Caldwell 1978 and Wurtsbaugh and Davis 1977a,b). Similar results have been observed in the present study showing an increase from 2% to 8% and then a decline. According to Warren and Davis (1967), the increase in specific dynamic action at high feeding levels decreases the energy available for growth and consequently lowers the conversion efficiency. In the present study also a decrease in food conversion efficiency was found at higher feeding levels (Fig.21). Webb (1978) stated that the food energy assimilated, minus nitrogenous losses after assimilation, is the energy available for metabolism and growth. Metabolism must be satisfied first and it will deplete stored energy available for growth if the ration ingested is low. This would explain why prawns fed with the low ration size in the present study had low food conversion efficiency.

Since true FCR is the ratio between total consumed food and growth, any factor affecting growth and its proportion to maintenance requirement also affects FCR. Cole and Boyd (1986) and Andrews (1979) observed an increase in FCR at higher feeding rates in the case of channel catfish. Sedgwick (1979) also reported an increase in FCR with increase in feeding levels in juvenile P. merguiensis. Niimi and Beamish (1974), who worked with largemouth bass Micropterus salmoides), observed a decrease in FCR with increasing feeding levels until it reached its lowest value at optimum level. When feeding level increased further, FCR too increased gradually. In the present study also similar results have been obtained showing a decrease from 2% to 8% feeding and then an increase towards 32%. The initial decrease in FCR with increasing feeding levels according to Niimi and Beamish (1974), is due to the increased utilization of energy for growth from zero at maintenance, to maximum at optimum level. At higher feeding levels the utilization of energy for growth decreases resulting in an increase in FCR. Venkataramiah et al. (1974) observed excellent food conversion ratios at a feeding level of 20% of body weight in P. aztecus. Nevertheless, in the present study lowest food conversion ratio was obtained at 8% feeding (Fig.19).

The rise in food conversion values at high feeding rates was attributed to high ammonia concentrations (Boyd 1985). The decrease in FCR at 8, 16 and 32% feeding against higher replacements as observed in the present study, may be due to the low ammonia concentrations at these replacements since stress due to undesirable metabolites are low.

The protein efficiency ratio (PER) in the present investigation was found to increase from 2 to 8% feeding and a decline subsequently. This indicates that the protein was most efficiently utilised at the level of 8% feeding.

Chua and Teng (1982) observed an increase in condition factor with an increase in ration size in estuary grouper, Epinephelus salmoides. Similar results have been reported for winter flounder, Pseudopleuronectus americanus by Tyler and Dunn (1976). In both these cases the range of food rations tested was from 2 to 11%. In the present study also a steady increase in condition factor up to 16% feeding has been observed (Fig.22). After that, at 32% it showed a slight decline. The increase in condition factor may be due to the increased utilization of energy for growth at these feeding levels. Since the metabolic activity of the animals is high at high feeding levels, the condition of the animals as given above, is bound to come down. The increase in the condition factor towards higher replacements as observed in the present study may be due to the decreased utilization of energy for maintenance at these replacements, where all the metabolites are found to be below the permissible level. Chua and Teng (1982) observed a reduction in condition factor at 2% ration with time. Similar trend was observed in the present investigation also. Perhaps it may be due to the utilization of fat by the animals to meet the energy requirements at below maintenance level and thus the animals will loose weight.

In P. monodon post larvae, Millemana (1990) observed a decrease in survival towards higher feeding rate. According to this, survival rate of the post larvae is directly influenced by organic content and dissolved O_2 concentration in the culture medium. A combination of the adverse environmental conditions such as high BOD, low DO, high NH_3-N and

NO_2-N can instil stress, resulting decreased survival. Diana and Fast (1989) in their experiments with *Clarias fuscus* observed no significant effect of water exchange rate on survival. In comparison, in the present study, significant effect of water exchange rate on mortality was observed. According to Tucker *et al.* (1979) survival was significantly greater at low feeding levels than at higher treatments. In the present study, the survival was not significant between feeding levels, while it was significant between replacements.

CONCLUSION AND RECOMMENDATIONS

The findings reported here provide an assessment of the relationships among different feeding rates and different water exchanges and their combined effect on water quality. Best growth according to the study can be attained at rations above 8% level. The conversion efficiency on the contrary declines as the feeding level go up. Hence some sacrifice in conversion efficiency would be necessary to take full advantage of growth potential which is high in the case of penaeid prawns. While maximum growth was attained at 16% feeding, the highest gross conversion efficiency happened to be at 8% feeding. As stated earlier, to reduce production cost in aquaculture a feeding level, which maximises both growth rate and conversion efficiency has to be adopted. In the case of P. indicus juveniles, based on this investigation, the desirable feeding level is in between 8 and 16%. An FCR of above 4, low conversion efficiency, decline in growth and high metabolite concentration even at higher replacements; rule out the applicability of high feeding levels above 16%.

Water replacements are meant to reduce accumulation of metabolites in the medium. At lower replacements the most toxic ammonia and nitrite, showed high fluctuations of sudden increase and decrease causing constant stress to the animal. But at higher replacements these metabolites are present in a low concentration at a steady state of level demanding minimum energy for maintenance. The nitrification converting highly toxic ammonia to less harmful nitrate was high at higher replacements. The survival of the animals was high at 75% replacement against 8, 16 and 32% feedings.

At 16% feeding against 75% replacement the concentration of all metabolites stood well below the permissible level resulting in maximum growth. But at 8% feeding the above condition was attained even at 42% replacement. As the desirable feeding level lies in between 8 and 16%, the optimum replacement rate falls between 42 and 75%. Thus from the present study it is revealed in intensive culture systems the adverse effects of density and feeding could be reduced by improving the water quality by high water exchange. Future work to find out levels of exact feeding and water exchange rates may be done in this at closer ranges between 8 and 16% feeding and 42 and 75% replacements. Since the time at disposal was very short this couldn't be done during the current work.

SUMMARY

A study to evaluate the effect of different feeding and replacements on hydrological and biological parameters on growth in the culture of *P. indicus* was carried out. The feeding levels tested were 2, 4, 8, 16 and 32% of body weight and the levels of replacements were 13.5%, 24%, 42 and 75%.

1. An acceleration in ammonia concentration with increase in feeding levels and a decrease towards higher replacements was noticed. At lower replacements ammonia showed high fluctuations but it steadied at higher levels.

2. The nitrite and nitrate concentrations decreased as the replacement increased. Increase in feeding levels was found to have no significant effect on them.

3. The reduction in pH due to accumulation of feed was arrested under high replacements.

4. The TSS went up with higher feeding levels but come down with increasing replacements.

5. BOD also showed the same trend as that of TSS.

6. Prawns consumed all the food at 2% and 4% feeding levels. However the consumption rate ascended at 8-32% feeding. Higher replacements were found to influence the consumption only at 16 and 32% feeding.

7. An increase in growth rate/day with corresponding increas in ration size from 2 to 16% feeding and thereafter at 32% a decrease at all levels of replacement except 13.5% was seen. At 13.5% it kept increasing. The maximum growth rate of 40.12 mg/d was obtained at 16% feeding against 75% replacement.

8. In the case of 8% feeding, no difference in growth rate was found between 42% and 75% replacements.

9. The optimum and maximum feed requirement was found to decrease towards 42% replacement and at 75% replacement it again showed an increase.

10. Food conversion ratio declined from 2% and reached the minimum at 8%, but again increased at 16 and 32% feeding at all replacements.

11. The protein efficiency ratio and gross conversion efficiency at all replacements increased from 2% to 8% feeding and then declined.

12. The condition factor of the animals at 2% feeding decreased from the initial at all replacements. At 4% feeding it went slightly above the initial. The maximum condition factor was obtained at 16% feeding against 75% replacement.

13. The best values for food conversion ratio (2.76 at 42 and 2.74 at 75% replacement), protein efficiency ratio (1.13 at 42 and 1.14 at 75% replacement) and gross conversion efficiency (36.19 at 42 and 36.45 at 75% replacement) were obtained at 8% feeding. At feeding levels below and above 8%, these parameters were found to be not good even at higher replacements.

14. *Maximum relative condition factor was obtained at 16% feeding* against 75% replacement.

15. Survival advanced with elevation in replacements at 8% feeding and above.

16. The desirable feeding is between 8 and 16% and the water replacement between 42 and 75% on the basis of the present study.

17. Further investigation at closer range are suggested to arrive at the exact levels of feeding and replacement for maximum growth.

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