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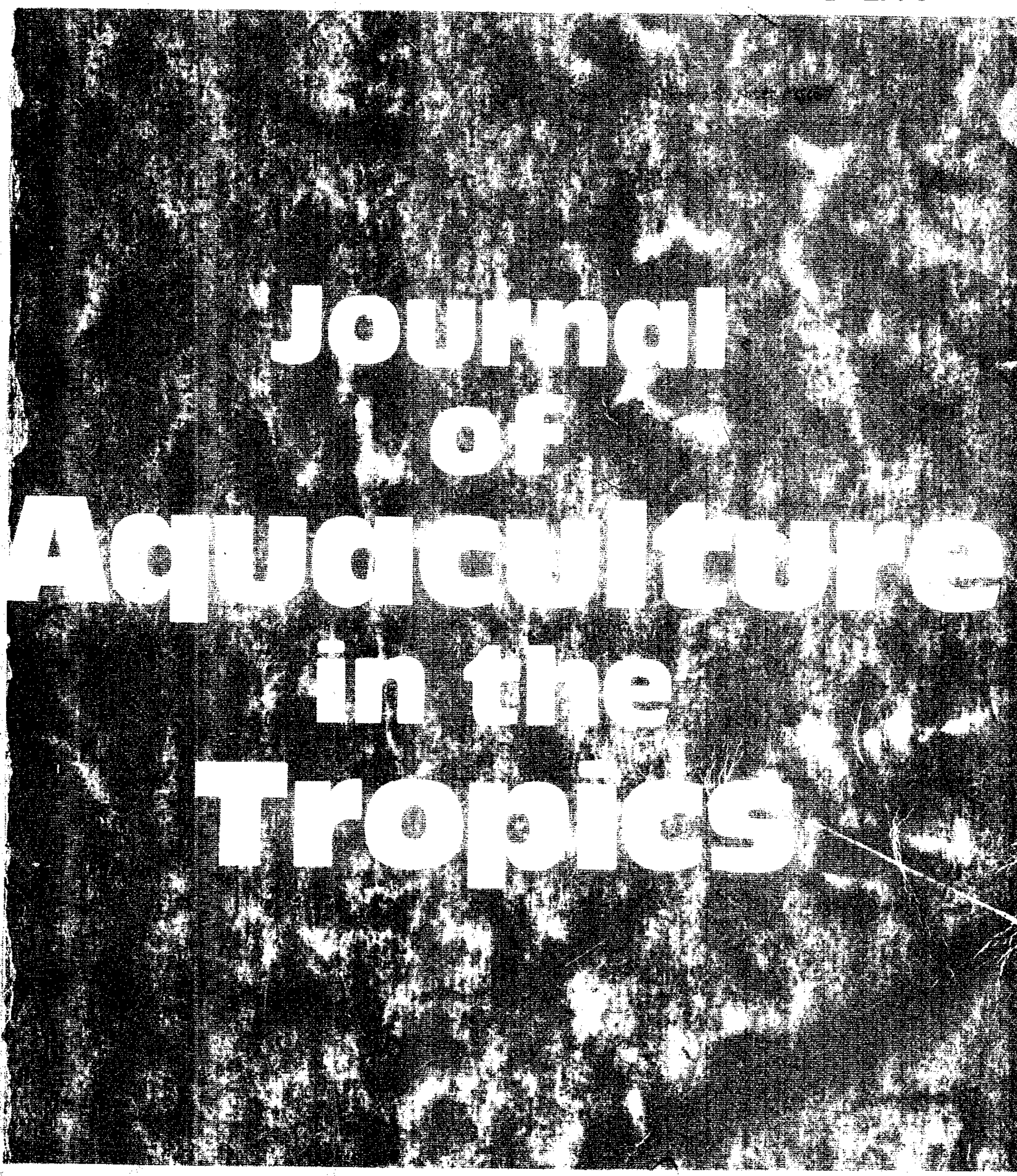

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A.A. BALKEMA

EVALUATION OF DIFFERENT CARBOHYDRATES IN THE DIET OF THE PRAWN *PENAEUS INDICUS*

S. AHAMAD ALI

Central Marine Fisheries Research Institute, Cochin, India
Present address: Central Institute of Brackishwater Aquaculture (CIBA), 141, Marshals Road, Madras 600 008, India

ABSTRACT

The dietary characteristics of seven different carbohydrates—glucose, fructose, galactose, maltose, sucrose, glycogen, and starch—were evaluated for the prawn *Penaeus indicus*, through formulation of purified diets. All the carbohydrates tested showed excellent apparent digestibility of above 85% at 30% level in the diet. But the growth of prawns fed with diets having glucose, fructose, galactose, sucrose, and glycogen was lower than the growth recorded by the diet having zero carbohydrate. Similarly, food conversion ratio (FCR) was inferior in the case of diets having monosaccharides. On the other hand, the diets with maltose and starch produced significantly ($p < 0.01$) superior growth and FCR compared to all the other diets. While the FCR of the diet having sucrose was superior to that of the diets having monosaccharides, it was inferior to that of the diets with maltose, starch, and glycogen. However, the FCR of the diet with glycogen was comparable to the FCR of maltose and starch diets. The survival of prawns fed with all the diets was above 60%, except of those fed with glycogen diet, which was only 29.2%. Among the mixed carbohydrate combinations evaluated, the diet having sucrose-maltose-starch mixture (1:1:1 ratio) was the best and was significantly superior ($p < 0.01$) to the other combinations. Cellulose was found to be necessary in the diet even at the cost of dietary energy. The FCR and survival progressively improved with increase in cellulose level up to 10%, after which any further increase lowered the performance of the diet.

Besides being an important source of energy components in the diet, carbohydrates play a significant role in glycogen storage, chitin synthesis, and the formation of steroids and fatty acids in prawns. Although the digestion and the presence of digestive enzymes of carbohydrates are demonstrated in prawns (Kooiman, 1964; Dall, 1964; Tyagi and Prakash, 1967; Karunakaran and Dhage, 1977), the capacity to use different carbohydrates seems to vary from species to species. In some penaeid prawns it has been demonstrated that disaccharides and polysaccharides are more efficiently utilized than monosaccharides. However, differences existed in these findings. In this study, seven different carbohydrates were selected and evaluated individually and also in combinations for understanding their dietary characteristics for the Indian white prawn *Penaeus indicus* so as to be able to recommend suitable carbohydrates for the prawn. The effect of cel-

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lulose in diet on the growth and FCR of the prawn was also investigated in the study.

MATERIALS AND METHODS

Glucose, fructose, galactose (monosaccharides), maltose, sucrose (disaccharides), and glycogen and starch (polysaccharides) were selected for evaluation in the diet of *P. indicus*. Eight purified diets were formulated, each containing one of the selected carbohydrates at 30% level. The ingredient composition of these diets, which are designated CE_1, CE_2, CE_3, CE_4, CE_5, CE_6, CE_7, and CE_0 (having no carbohydrate), is given in Table 1. In the second experiment, seven diets (CE_8 to CE_{14}) were formulated comprising seven combinations of carbohydrates—glucose-glycogen, glucose-starch, glucose-maltose, glucose-sucrose, glucose-sucrose-starch, glucose-maltose-starch, and sucrose-maltose-starch—with the objective of studying the effect of mixed carbohydrate in diet on growth, FCR, and survival of prawn. The details of composition of these diets are

Table 1. Ingredient composition of the diets CE_0 to CE_7

Ingredients	Diet							
	CE_0	CE_1	CE_2	CE_3	CE_4	CE_5	CE_6	CE_7
Albumen (egg)	70.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cod-liver oil	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Glucose	—	30.0	—	—	—	—	—	—
Fructose	—	—	30.0	—	—	—	—	—
Galactose	—	—	—	30.0	—	—	—	—
Sucrose	—	—	—	—	30.0	—	—	—
Maltose	—	—	—	—	—	30.0	—	—
Starch	—	—	—	—	—	—	30.0	—
Glycogen	—	—	—	—	—	—	—	30.0
Cholesterol	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Glucosamine HCl	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Vitamin mix*	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Mineral mix**	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Cellulose	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
Cr_2O_3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium alginate	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Crude protein %	55.0	31.5	31.5	31.5	31.5	31.5	31.5	31.5
Lipid %	7.2	6.7	6.7	6.6	6.7	6.7	6.7	6.7
Carbohydrate	2.6	32.1	33.2	34.6	33.8	33.9	33.4	33.4
Digestible energy (kcal/100 g)	386.7	371.3	375.8	381.6	378.3	376.7	376.7	375.7

*Vitamin mixture: 100 g of diet contained ascorbic acid 2.0 g, choline chloride 0.12 g, cyanocobalamine 0.00008 g, folic acid 0.08 g, nicotinic acid 0.04 g, pantothenic acid (calcium salt) 0.06 g, para aminobenzoic acid 0.01 g, pyridoxine hydrochloride 0.012 g, riboflavin 0.008 g, thiamine hydrochloride 0.004 g, biotin 0.00004 g, β-carotene 0.0096 g, inositol 0.2 g, menadione 0.004 g, and α-tocopherol 0.029 g.

**Mineral mixture: 100 g of diet contained calcium lactate 2.72 g, potassium dihydrogen orthophosphate 0.79 g, magnesium sulphate 3.02 g, manganese chloride 0.004 g, and ferrous chloride 0.015 g.

given in Table 2. In another experiment, eight more diets were formulated having 0, 1, 3, 5, 8, 10, 15, and 20% of cellulose replacing an equivalent amount of carbohydrate in order to evaluate the role of cellulose as roughage (fibre) in diet. The composition of these diets (CE_{15} to CE_{22}) is given in Table 3.

The diets were prepared by mixing ingredients that were individually powdered (in electrical grinder) and sieved (through 250 μm sieve). Water was added (30 ml for 100 g dry diet) to the diet mixture and homogenized into a dough. It was steamed for 10 min. and pelletized using a laboratory model hand pelletizer having 3 mm diameter die. The pellets were dried in an electrical oven at 60°C for 12 hr. The dry pellets were gently crushed to obtain pellets 2 to 3 mm long. Diets were fed to early juveniles of *P. indicus* with an average initial length and dry weight of about 30 mm and 0.04 g respectively in a 30-day feeding experiment in which eight animals were held in 10 l capacity circular tanks in triplicate. The prawns were offered weighed quantity (20% of body weight) of feed twice a day in the morning and evening. Faeces were collected carefully with a pipette, washed gently with distilled water, and dried at 60°C for digestibility studies. The water used in these feeding experiments had a salinity of 16.5 ± 1.0‰, dissolved oxygen 4.0 ml/l, temperature 28.0 ± 0.5°C, and pH 8.0 ± 0.2. Carbohydrate in diets and faeces was determined by spectrophotometric method using anthrone reagent. Chromium oxide was analysed by the method of McGinnis and Kasting (1964). While the protein was estimated by Kjeldahl method and lipid by chloroform-methanol (2:1) extraction, digestible energy was computed using the energy equivalents of nutrients. At the end of the feeding experiment, the prawns

Table 2. Ingredient composition of the diets CE_8 to CE_{14}

Ingredient	Diet						
	CE_8	CE_9	CE_{10}	CE_{11}	CE_{12}	CE_{13}	CE_{14}
Albumen (egg)	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cod-liver oil	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Glucose	15.0	15.0	15.0	15.0	10.0	10.0	—
Sucrose	—	—	15.0	—	10.0	—	10.0
Maltose	—	—	—	15.0	—	10.0	10.0
Starch	—	15.0	—	—	10.0	10.0	10.0
Glycogen	15.0	—	—	—	—	—	—
Cholesterol	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Glucosamine HCl	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Vitamin mix*	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Mineral mix*	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Cellulose	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Sodium alginate	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Crude protein %	31.5	31.5	31.5	31.5	31.5	31.5	31.5
Lipid %	6.8	6.7	6.7	6.7	6.6	6.7	6.6
Carbohydrate	33.1	32.8	32.9	33.6	33.4	33.2	32.8
Digestible energy (kcal/100 g)	376.4	374.2	374.6	377.5	375.7	375.8	373.3

*Vitamin mixture and mineral mixture are the same as those used in diets CE_0 to CE_7 (Table 1).

Table 3. Ingredient composition of the diets CE_{15} to CE_{22}

Ingredients	Diet							
	CE_{15}	CE_{16}	CE_{17}	CE_{18}	CE_{19}	CE_{20}	CE_{21}	CE_{22}
Protein mix*	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cod-liver oil	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Carbohydrate mix**	40.0	39.0	37.0	35.0	32.0	30.0	25.0	20.0
Cholesterol	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Glucosamine HCl	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Vitamin mix***	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Mineral mix***	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Cellulose	0.0	1.0	3.0	5.0	8.0	10.0	15.0	20.0
Sodium alginate	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Crude protein %	34.8	34.8	34.9	34.9	34.8	34.8	34.8	34.8
Lipid %	6.5	6.5	6.5	6.4	6.4	6.4	6.5	6.6
Carbohydrate %	40.4	39.5	37.3	35.4	32.3	30.4	25.4	20.3
Digestible energy (kcal/100 g)	421.9	418.3	409.8	401.1	387.8	380.0	360.4	340.5

*Protein mixture: Albumen, casein, fibrin (blood), and gelatin in the ratio 1:1:1:1.
**Carbohydrate mixture: Sucrose, maltose, and starch in the ratio 1:1:1.
***Vitamin mixture and mineral mixture are the same as those used in diets CE_0 to CE_7 (Table 1).

were dried in an oven at 60°C and the growth in dry weight was calculated using the following relation:

$$\text{Growth in dry wt. (\%)} = \frac{\text{Final average dry wt.} - \text{Initial average dry wt.}}{\text{Initial average dry wt.}} \times 100$$

The digestibility of carbohydrate was determined using the following formula:

$$\text{Digestibility of carbohydrate} = 100 - \frac{\%\ Cr_2O_3 \text{ in diet}}{\%\ Cr_2O_3 \text{ in faeces}} \times \frac{\%\ \text{carbohydrate in faeces}}{\%\ \text{carbohydrate in diet}}$$

The FCR was calculated as follows:

$$\text{FCR} = \frac{\text{Average wt. of food consumed in dry wt.}}{\text{Average gain in live wt.}}$$

The data obtained in the feeding experiments were subjected to analysis of variance following Snedecor and Cochran (1973). The means were compared by calculating the least significant difference.

RESULTS AND DISCUSSION

The results of evaluation of individual carbohydrates are depicted in Fig. 1. Among the different carbohydrates tested, the diets having glucose, fructose, galactose, sucrose, and glycogen showed poor growth which was lower than the growth recorded by the diet having no carbohydrate. On the other hand, the diets con-

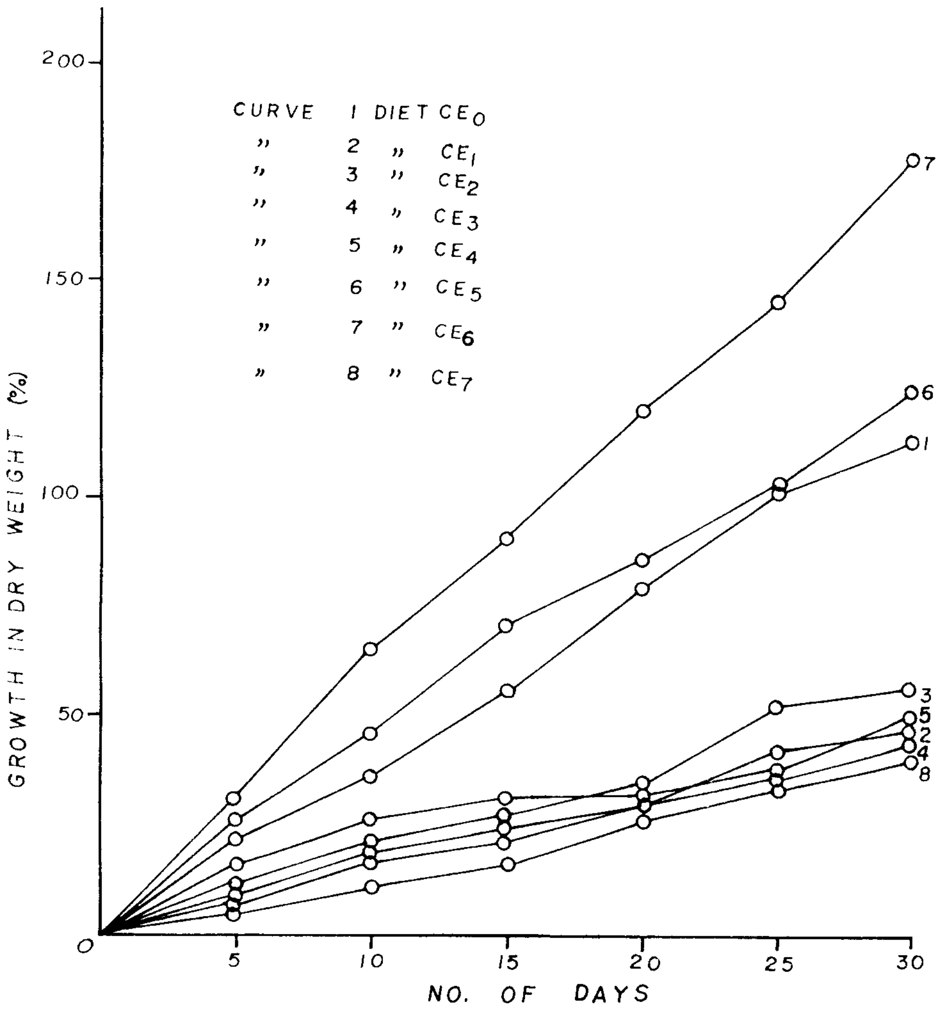

Fig. 1. Growth curves of juvenile *P. indicus* fed with diets CE_0 to CE_7. CE_0 zero carbohydrate, CE_1 glucose, CE_2 fructose, CE_3 galactose, CE_4 sucrose, CE_5 maltose, CE_6 starch, CE_7 glycogen

taining maltose and starch showed significantly ($p < 0.01$) superior growth. The apparent digestibility of all the carbohydrates was above 88% (Fig. 2) and there was no statistical difference among them. The monosaccharides showed distinctly poorer FCR than the di- and polysaccharides (Fig. 2), which were significantly ($p < 0.01$) superior. While the FCR of the diet having sucrose was slightly inferior, the FCRs of diets with maltose, starch, and glycogen were identical. However, the survival of prawns fed with glycogen diet was poor (29.9%), while it was 60%

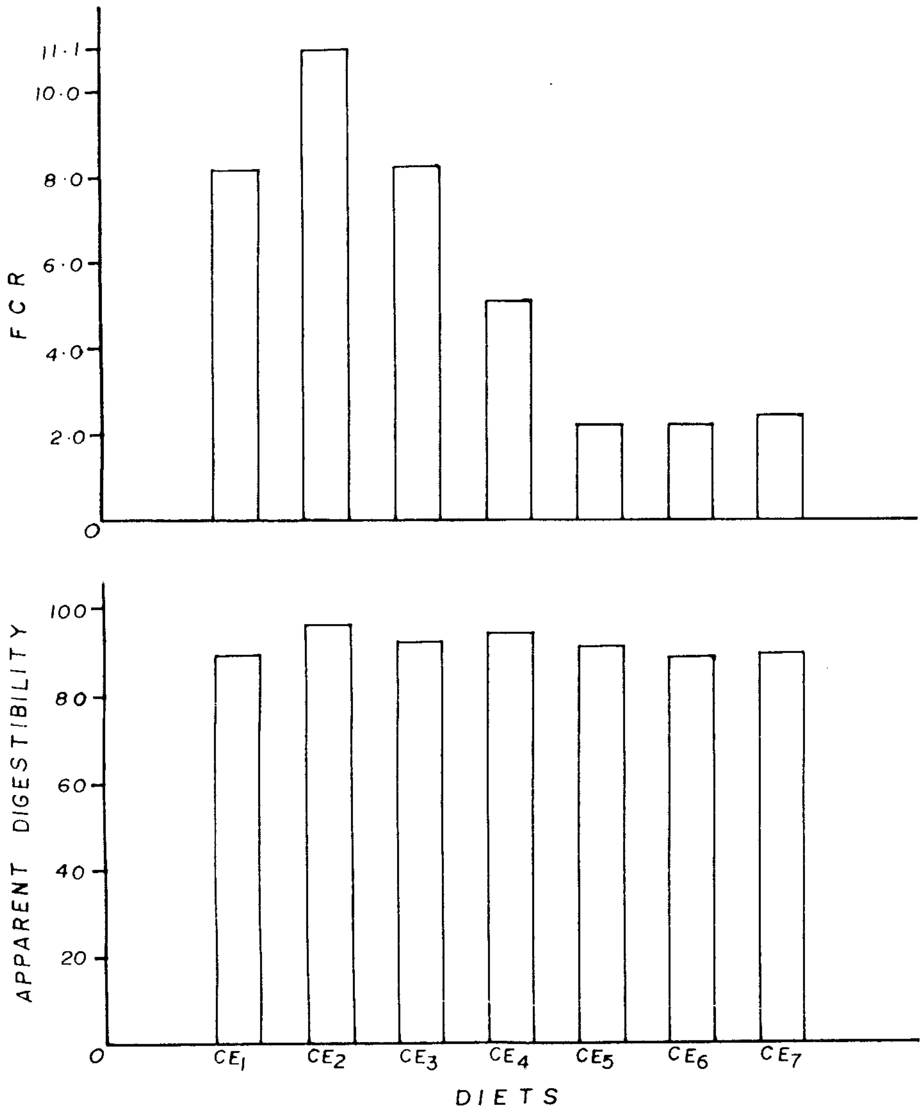

Fig. 2. Evaluation of different carbohydrates in diets CE_0 to CE_7 for juvenile *P. indicus*: (a) apparent digestibility, (b) FCR

in the case of all the other diets. The results have demonstrated that the prawn *P. indicus* utilizes disaccharides and polysaccharides better than monosaccharides and emphasized that carbohydrate in prawn diet is necessary and beneficial.

The results of diets with 30% carbohydrate are far superior to those of the diet having no added carbohydrate. Even though the prawns fed with CE_0 diet grew as well as those fed with maltose diet, the FCR of the former was poor, indicating that diets with high protein without adequate carbohydrate are uneconomical. So far as the monosaccharides are concerned the results seen in *P. indicus* in the present study are similar to the findings in other penaeid prawns (Andrews *et al.*, 1972; Sick and Andrews, 1973; Deshimaru and Yone, 1978; Abdel Rahman *et al.*, 1979; Alava and Pascual, 1987). Contrary to the findings of Deshimaru and Yone (1978) in *P. japonicus*, the diet with sucrose did not give good growth in *P. indicus*. Though the growth and survival of prawns fed with the diet having glycogen were very low, the FCR was comparable to that of the diets with maltose and starch, which shows that the prawns did not ingest glycogen diet much, but whatever was ingested was digested well and efficiently utilized. Whether glycogen in the diet influences palatability for prawns is not known. The low survival of prawns fed with glycogen diet in the present study may not be due to glycogen itself.

The excellent digestibility of different carbohydrates clearly demonstrates the presence of the enzymes needed for carbohydrate digestion in *P. indicus*. The poor utilization of monosaccharides by this prawn might be due to similar reasons shown in *P. japonicus* by Abdel Rahman *et al.* (1979) in which it was demonstrated that dietary monosaccharides were rapidly absorbed and serum glucose levels were raised to very high values causing physiological imbalances, whereas the glucose from di- and polysaccharides is absorbed gradually and utilized effectively.

The performance of the diets CE_8 to CE_{14} is depicted in Fig. 3. All the diets having 15% glucose in them (CE_8 to CE_{11}) resulted in poor growth and FCR. Only the combination of glucose-glycogen (diet CE_8) was slightly superior among them. However, when the glucose content was reduced to 10% in diets CE_{12} and CE_{13}, the growth and FCR improved. Glucose-maltose-starch is superior to glucose-sucrose-starch. However, among the different combinations tested, sucrose-maltose-starch mixture (1:1:1) in diet CE_{14} gave significantly ($p < 0.01$) the highest growth and the best FCR ($p < 0.01$). Interestingly, the diets having 10% glucose fared better than those having 15% glucose, whatever may be the other carbohydrates present along with it. This might be because prawns have a tolerance limit for glucose in their diet. Similar observations were also made by Sick and Andrews (1973) in *P. duorarum* and by Abdel Rahman *et al.* (1979) in *P. japonicus*, in which the growth of prawns was very much reduced when the glucose content was raised from 10% to 48%. The diets in which glucose was completely eliminated gave better results. It may be concluded that penaeid prawns prefer di- and polysaccharides as carbohydrate source and a mixture of sucrose-maltose-starch in the ratio 1:1:1 seems to be one of the best combinations in the diet.

The influence of cellulose in diet on growth, FCR, and survival is shown in Fig. 4. The addition of cellulose to the diet did not improve the growth of prawns, but it helped to improve FCR. The FCR was progressively lowered with addition of cellulose and reached a lower value at 10% dietary cellulose. Since the diet contained cellulose at the expense of carbohydrate, the results obtained had

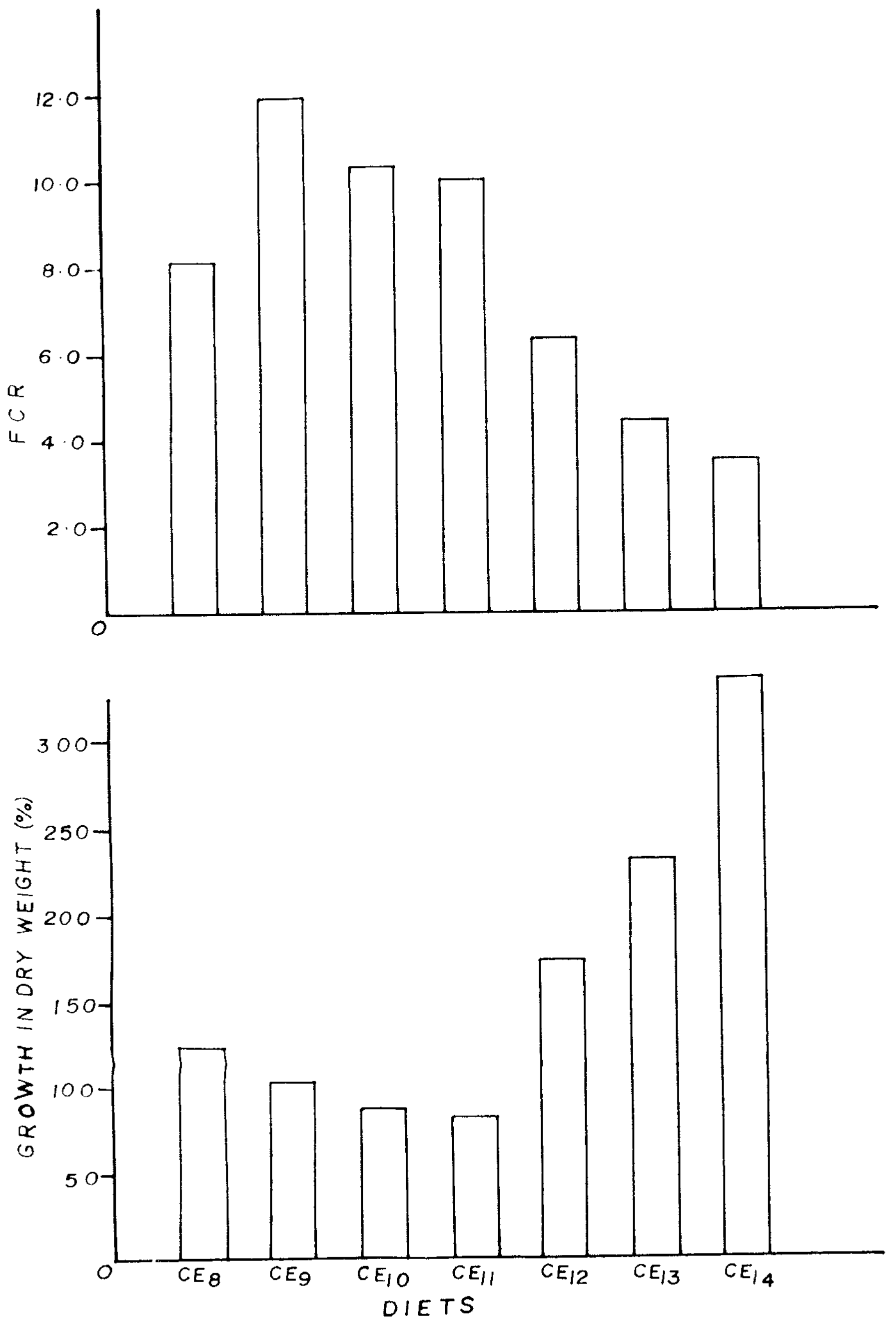

Fig. 3. Evaluation of different combinations of carbohydrates in diets CE_8 to CE_{14} for juvenile *P. indicus*: (a) growth in dry weight, (b) FCR. CE_8 glucose-glycogen, CE_9 glucose-starch, CE_{10} glucose-sucrose, CE_{11} glucose-maltose, CE_{12} glucose-sucrose-starch, CE_{13} glocose-maltose-starch, CE_{14} sucrose-maltose-starch

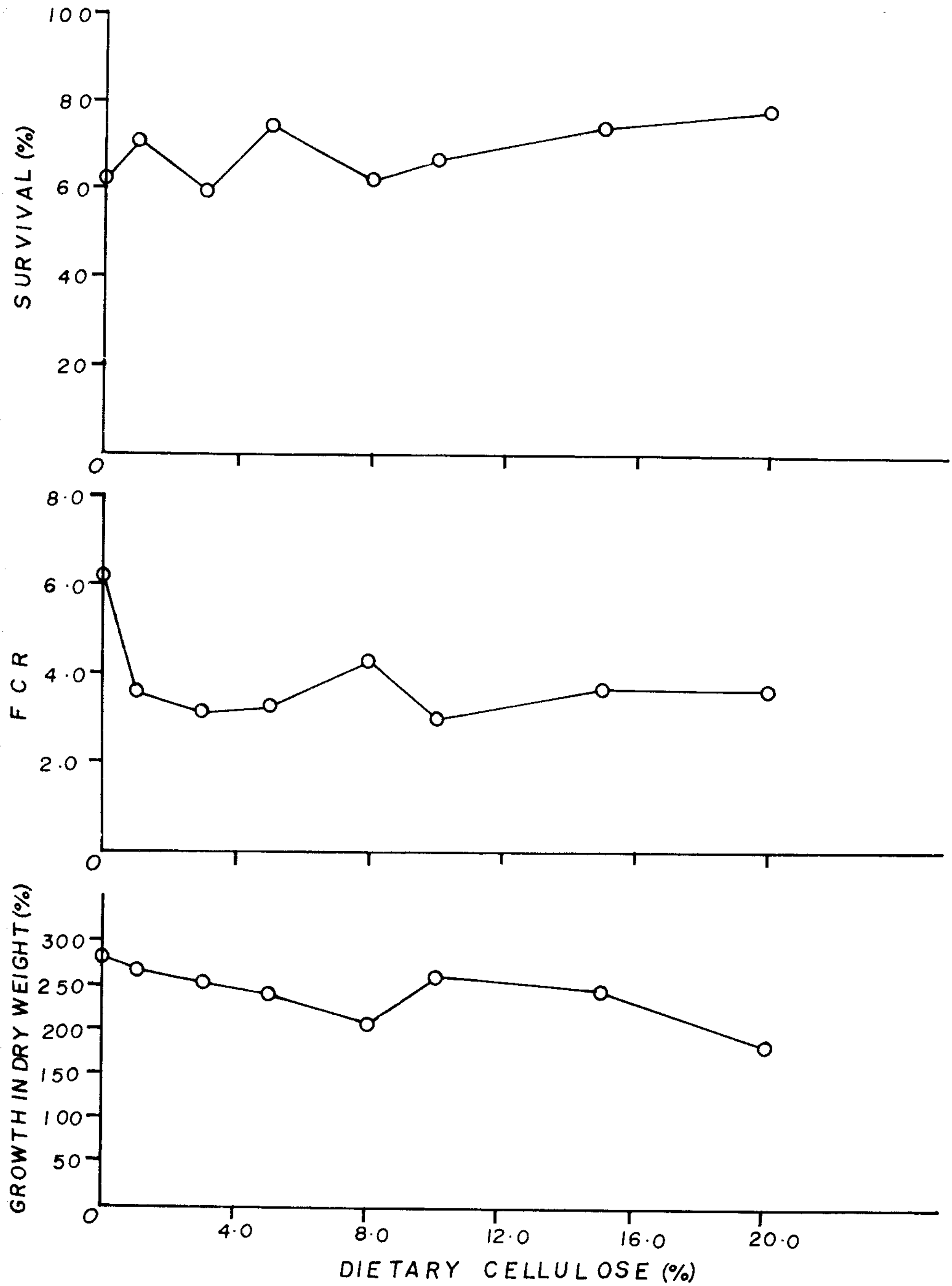

Fig. 4. Influence of cellulose level in diet on (a) growth in dry weight, (b) FCR, and (c) survival of juvenile *P. indicus*

shown that cellulose either was a nutrient or aided in better utilization of other nutrients. The role of dietary cellulose was investigated in other species of prawns (Venkataramaiah *et al.*, 1975; Forster and Gabbott, 1971; Fair *et al.*, 1980) and the results found were similar to those observed in *P. indicus* in the present study. The fact that the growth of prawns is largely unaffected by the addition of cellulose in the diet up to a level of 10% suggests that it is partly assimilated, indicating limited cellulose activity. Though the presence of this enzyme is demonstrated in Caridean prawns *Palaemon serratus* (Forster and Gabbott, 1971) and *Macrobrachium rosenbergi* (Fair *et al.*, 1980), its activity in penaeid prawns is not known. Cellulose level in the diet beyond 10% is not beneficial. The survival of prawns, however, improved with increase in cellulose level of the diet beyond 10%. It may be concluded that dietary cellulose is required for efficient food conversion and better survival. It is recommended that sufficient roughage (cellulose) should be present in practical feeds for prawns with a maximum limit of 10%.

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