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Aquaculture

**OPTIMUM DIETARY CARBOHYDRATE REQUIREMENT OF ROHU,  
*LABEO ROHITA* (HAMILTON), FINGERLINGS****OPTYMALNY UDZIAŁ WĘGLOWODANÓW W PASZY DLA  
PALCZAKÓW ROHU, *LABEO ROHITA* (HAMILTON)**

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A laboratory feeding trial was conducted for 80 days using rohu, *Labeo rohita*, fingerlings ( $5.67 \pm 0.25$  g) to evaluate the optimum dietary carbohydrate level. Five semipurified diets containing 30, 35, 40, 45, and 50% carbohydrate (diets D1 to D5) were formulated and fed to triplicate groups of fish. All the diets were isonitrogenous (35% protein) and almost isocaloric. Fish performance in terms of average live weight gain (%), *SGR* (%/day) and FCR was best with 40% carbohydrate level. Significantly ( $P < 0.05$ ) poor growth of fish also was noticed in the groups reared on diets with 30 and 35% levels of dietary carbohydrate, however, no significant difference in *PER* and *ANPU* (%) was obtained with diets D2 and D3. Although no significant difference in apparent protein digestibility was recorded up to 45% dietary carbohydrate level, lipid, ash, dry matter, and energy digestibilities were found to be significantly ( $P < 0.05$ ) higher for the diets D2 and D3. These two dietary treatments also resulted in higher deposition of protein and lipid and lower moisture and ash contents in the fish muscle. Amylolytic and proteolytic enzyme activities also were estimated to be higher in the groups of fish fed 35% and 40% carbohydrate diets. The study indicated that a minimum level of 40% dietary carbohydrate is required (protein content being 35%) for optimum growth, feed conversion and nutrient utilisation in rohu, *Labeo rohita*, fingerlings.

## INTRODUCTION

Carbohydrates are considered the least expensive form of dietary energy for animals, but their utilisation by fish varies and remains somewhat obscure (Bowen 1987; Wilson

1994). Warm water fishes are able to utilise much higher levels of dietary carbohydrate than cold water or marine fishes (Wilson 1994) and carnivorous fishes are illadapted to digest carbohydrates compared to herbivorous/omnivorous fishes (Bergot 1979; Hofer and Sturbauer 1985; Kim and Kaushik 1992). From a practical point of view, incorporation of substantial levels of carbohydrate is inevitable in fish diets. Moreover, it is well known that carps can better utilise carbohydrate than trout and carbohydrate can compete successfully with lipid as an energy source (Dąbrowski 1986). It is therefore, important to provide the appropriate level of carbohydrate in diet of fish. If carbohydrates are not provided, other nutrients such as proteins and lipids will be catabolised for energy and to provide metabolic intermediates for the synthesis of other biologically important compounds (Wilson 1994). Although a number of studies have been conducted on the carbohydrate requirements of fishes most of them are confined to the carnivorous fishes (Singh and Nose 1967; Bergot 1979; Pascaul 1989; Lim 1991; Ellis and Reigh 1991; Nematipour et al. 1992; Bague et al. 1994; Jantrarotai et al. 1994). Reports on the dietary carbohydrate requirement of Indian major carps are however, scanty. The present study was therefore, conducted to assess the optimum level of carbohydrate in the diet of rohu, *Labeo rohita*, fingerlings, the most important species among the Indian major carps.

## MATERIAL AND METHODS

### Diet preparation

Apart from three principal ingredients (fish meal, mustard oil cake, and rice bran), casein, potato starch, and cellulose powder also were used to formulate five isonitrogenous (35% protein) diets (diets D1 to D5) with variable dietary carbohydrate levels (30 to 50% with 5% increment) (Table 1). Dietary ingredients, after procuring from their individual sources, were dried, finely pulverised and sieved to obtain uniform particle size (less than 400  $\mu\text{m}$  diameter). Requisite quantities of the ingredients with respect to each diet were subsequently mixed thoroughly with a small quantity of lukewarm water to form a thick dough, using carboxymethylcellulose (CMC) as a binder. A readymade vitamin-mineral mixture (Vitaminetes forte, Roche India Ltd.) was added to all the diet mixtures before pelletization. To each of the formulated diets chromic oxide ( $\text{Cr}_2\text{O}_3$ ) was added at 1% level as the digestibility marker for digestibility estimations. The dough was steamed in an autoclave for 10 minutes and then passed through a semi-automatic pelletizer to obtain pellets of about 1.5 mm diameter. The pellets were dried in an oven overnight at 60°C. The pellets were then packed in air-tight plastic bags and stored in a deep freeze until used.

Table 1

Ingredient composition (% dry weight) of the diets

Ingredients	Diets				
	D1	D2	D3	D4	D5
Fish meal	41.00	43.00	37.00	24.00	20.00
Mustard oilcake	26.00	26.00	29.00	25.00	21.00
Rice bran	12.00	19.00	27.00	24.00	14.00
Casein	2.00	—	—	10.00	15.00
Potato starch	—	—	—	10.00	23.00
Cellulose*	12.00	5.00	—	—	—
Premix**	1.00	1.00	1.00	1.00	1.00
Chromic oxide	1.00	1.00	1.00	1.00	1.00
Binder***	5.00	5.00	5.00	5.00	5.00

\* Cellulose powder was used as filler in diet

\*\* Vitamin-mineral mixture (Vitaminets forte, Roche India Ltd., Mumbai)

\*\*\* Carboxymethylcellulose

### Experimental design

The experiment was conducted for 80 days in flow-through 75 dm<sup>3</sup> circular fibre-glass tanks with continuous aeration. Rohu, *Labeo rohita* fingerlings were obtained from a local fish seed dealer and acclimated to the laboratory conditions for 15 days prior to the commencement of the experiment and fed with a 1 : 1 mixture of rice bran and mustard oil cake. Rohu fingerlings (mean weight 5.76 ± 0.25 g) were randomly distributed at the rate of 10 fish per tank with three replicates for each dietary treatment. The experimental fish were fed twice daily at 9.00 hours and at 15.00 hours, feeding rate being 5% of total body weight. Rohu fingerlings were exposed to their respective diets continuously for three hours during each feeding and thereafter the uneaten feed were taken out and stored separately for calculating the feed conversion ratio. The amount of feed was adjusted every 10 days after weighing each group of fish. The digestibility study was conducted separately in a static water system for 20 days. The faecal samples released by the fish were collected by pipetting following the method described by Spyridakis et al. (1989), separately from each aquarium. The pooled faecal samples were kept in a hot air oven for drying at 60°C and subsequently were analysed for digestibility estimations. At the termination of the feeding experiment, all the fish were weighed individually, lengths were measured and used for analysis of muscle composition. The range of water quality parameters were: temperature 27.0–31.5°C, pH 7.4–7.9, dissolved oxygen 6.8–7.2 mg/dm<sup>3</sup>.

### Chemical analyses

Feed ingredients, experimental diets, faecal samples, and fish muscle (initial and final) were analysed for proximate composition (%) following the procedures outlined by AOAC (Helrich 1990). The water quality parameters were monitored following the methods described by Stirling (1985).

Fish from each experimental set were dissected on ice in a tray, both prior to commencement and at termination of the experiment and the desired tissues (intestine and hepatopancreas) were taken out to estimate the digestive enzyme activities.  $\alpha$ -Amylase was quantitatively determined following the method suggested by Bernfeld (1955). Protease activity was measured according the method of Moore and Stein (1948) using bovine serum albumin (BSA) as the substrate. Chromic oxide in the diets as well as in the faecal samples was estimated spectrophotometrically following the method of Bolin et al. (1952).

### Data collection

The following indices were calculated:

$$\text{Live weight gain} = \frac{\text{Final body weight} - \text{Initial body weight}}{\text{Initial body weight}} \times 100 (\%)$$

$$\text{Specific growth rate (SGR)} = \frac{l_n \text{ Final body weight} - l_n \text{ Initial body weight}}{\text{Days of trial}} \times 100 (\%/day)$$

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Dry weight consumed}}{\text{Wet weight gain of fish}}$$

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Wet weight gain of fish}}{\text{Protein intake}}$$

$$\text{Apparent net protein utilisation (ANPU)} = \frac{\text{Net increase in carcass protein}}{\text{Protein consumed}} \times 100 (\%)$$

Apparent digestibility (*AD*) of the nutrients was calculated according to the formula of Cho et al. (1982) as follows:

$$AD (\%) \text{ of nutrients} = 100 - 100 \left[ \frac{\% \text{ marker in diet}}{\% \text{ marker in faeces}} \times \frac{\% \text{ nutrient of faeces}}{\% \text{ nutrient of diets}} \right]$$

### Statistical analysis

Analysis of variance (ANOVA) followed by Duncan's multiple range test (Duncan 1955) was employed to find out which treatment differed significantly from the other with respect to growth, muscle composition, nutrient digestibility, profiles of digestive enzymes and general performance of the fish.

## RESULTS

## Proximate composition of the diets

The proximate composition of the experimental diets (diets D1 to D5) is presented in Table 2. The protein content of the diets ranged from 34.06 to 37.03%. The dry matter and lipid contents of the experimental diets were also within a close range, being 95.87 to 96.94% and 5.34 to 6.88%, respectively. The total carbohydrate level increased gradually and was estimated as 30.91, 36.50, 40.15, 45.91, and 50.11% in diets D1, D2, D3, D4, and D5, respectively. Both the crude fibre and ash contents were recorded highest in diet D3, being 13.10% and 10.37, respectively. All the diets were almost isocaloric, energy content ranging between 3.94 and 4.48 kcal/g.

Table 2

Proximate composition of the diets (on dry matter basis)

Proximate composition (%)	Diets				
	D1	D2	D3	D4	D5
Dry matter	96.83	96.21	95.87	96.76	96.94
Protein	37.03	36.81	35.74	35.11	34.06
Lipid	6.24	6.83	6.88	6.17	5.34
Ash	10.65	11.57	13.10	9.57	7.43
Crude fibre	6.20	8.33	10.37	8.90	5.65
NFE*	24.71	28.17	29.78	37.01	44.46
Total carbohydrate	30.91	36.50	40.15	45.91	50.11
Protein energy (kcal/g)	2.09	2.08	2.01	1.98	1.92
Non-protein energy (kcal/g)	1.85	2.14	2.30	2.46	2.56
P/E ratio (mg protein/kcal)	93.98	87.22	82.92	79.07	76.02
Gross energy (kcal/g)	3.94	4.22	4.31	4.44	4.48

\*Nitrogen free extract

## Fish growth

The performance of rohu fingerlings fed diets D1 to D5 with varying carbohydrate levels is given in Table 3. The average weight and length of the fish increased considerably from the initial values (5.67 g and 7.34 cm, respectively) in all the dietary treatments. However, the highest attainment in fish body weight, percentage live weight gain and *SGR* was recorded in the group of fish fed 40% carbohydrate diet. The fish did not perform better with the diets containing higher levels of carbohydrate beyond 40%. The weight gain and *SGR* of the fish fed diets D1 and D5 containing 30% and 50% carbohydrate did not differ significantly. There was also no significant difference ( $P < 0.05$ ) in percent live weight gain and *SGR* of the fish fed diets D2 and D4, containing 35% and 45% carbohydrate.

*PER* was recorded highest with 35% carbohydrate (diet D2) which was not significantly different from that obtained with diet D3, containing 40% carbohydrate (Table 3).

*PER* value was lowest with diet D5 (50% carbohydrate) which was not significantly different from the value obtained with diet D4, containing 45% carbohydrate. Apparent net protein utilisation (*ANPU*) was highest for diet D3 while lowest with diet D5 (Table 3). The *FCR* was better for the fish fed diet D3 (40% carbohydrate). The *FCR* values for diets D1 and D4 did not differ significantly ( $P < 0.05$ ). The *FCR* was poor with diets containing higher levels (45% and 50%) of carbohydrate. There was no mortality of fish fed diets D2 and D3 having 35% and 40% carbohydrate. In the other groups (D1, D4 and D5) survival of fish ranged between 90 and 95%.

Table 3

Performance of *Labeo rohita* fingerlings fed experimental diets for 80 days ( $\bar{x} \pm SD$ )

Parameters	Diets (carbohydrate content)				
	D1 (30%)	D2 (35%)	D3 (40%)	D4 (45%)	D5 (50%)
Final body length (cm)*	11.94 $\pm$ 0.32 <sup>a</sup>	13.26 $\pm$ 0.45 <sup>b</sup>	13.37 $\pm$ 0.40 <sup>b</sup>	13.16 $\pm$ 0.42 <sup>b</sup>	11.69 $\pm$ 0.38 <sup>a</sup>
Final body weight (g)**	16.28 $\pm$ 0.55 <sup>a</sup>	20.85 $\pm$ 0.74 <sup>b</sup>	21.96 $\pm$ 0.82 <sup>c</sup>	20.47 $\pm$ 0.80 <sup>b</sup>	15.74 $\pm$ 0.64 <sup>a</sup>
Avg. live wt. gain (%)	187.1 <sup>a</sup>	267.7 <sup>b</sup>	283.3 <sup>c</sup>	261.0 <sup>b</sup>	177.6 <sup>a</sup>
<i>SGR</i> (%/day)	1.31 <sup>a</sup>	1.62 <sup>b</sup>	1.69 <sup>c</sup>	1.60 <sup>b</sup>	1.27 <sup>a</sup>
<i>PER</i>	1.81 <sup>bc</sup>	1.86 <sup>c</sup>	1.85 <sup>c</sup>	1.76 <sup>ab</sup>	1.68 <sup>a</sup>
<i>FCR</i>	1.96 <sup>c</sup>	1.74 <sup>b</sup>	1.67 <sup>a</sup>	2.08 <sup>c</sup>	2.43 <sup>d</sup>
<i>ANPU</i> (%)	27.83 <sup>c</sup>	28.94 <sup>cd</sup>	29.21 <sup>d</sup>	25.78 <sup>b</sup>	23.16 <sup>a</sup>
Survival rate	95%	100%	100%	95%	90%

\* Initial body length = 7.34  $\pm$  0.22 cm

\*\* Initial body weight = 5.67  $\pm$  0.25 g

Values having the same superscripts in the same row are not significantly different ( $P < 0.05$ )

#### Apparent nutrient digestibility

The results pertaining to the digestibility of nutrients and energy from all the five experimental diets are presented in Table 4. Although apparent protein digestibility (*APD*) was highest for diet D3 (40% carbohydrate), there was not significant ( $P < 0.05$ ) difference in protein digestibility for diets D1, D2, and D4. The *APD* was lowest from diet D5, containing 50% carbohydrate. The lipid digestibility was highest for diet D3 which was not significantly ( $P < 0.05$ ) different from that for diets D2 and D4. Diet D5 (50% carbohydrate) showed poor lipid digestibility by the fish in comparison to other dietary treatments. The dry matter and gross energy digestibilities also indicated a similar trend as noticed in the case of lipid digestibility. Ash digestibility was highest for diet D3 (40% carbohydrate). There was not significant difference ( $P < 0.05$ ) in ash digestibility for diets D2 and D4, containing 35% and 45% carbohydrate, respectively. These values were however, significantly lower than that obtained for diet D3.

Table 4

Apparent digestibility (%) of nutrients from the experimental diets in *Labeo rohita* fingerlings ( $\bar{x} \pm \text{SD}$ )

Digestibility (%)	Diets (carbohydrate content)				
	D1 (30%)	D2 (35%)	D3 (40%)	D4 (45%)	D5 (50%)
Protein	84.61 $\pm$ 0.45 <sup>b</sup>	85.44 $\pm$ 0.55 <sup>b</sup>	85.76 $\pm$ 0.62 <sup>b</sup>	84.74 $\pm$ 0.48 <sup>b</sup>	82.59 $\pm$ 0.42 <sup>a</sup>
Lipid	74.23 $\pm$ 0.40 <sup>b</sup>	77.87 $\pm$ 0.45 <sup>c</sup>	78.05 $\pm$ 0.48 <sup>b</sup>	77.56 $\pm$ 0.85 <sup>c</sup>	68.84 $\pm$ 0.38 <sup>a</sup>
Ash	44.54 $\pm$ 0.24 <sup>b</sup>	46.53 $\pm$ 0.28 <sup>c</sup>	48.27 $\pm$ 0.25 <sup>d</sup>	46.37 $\pm$ 0.23 <sup>c</sup>	40.16 $\pm$ 0.20 <sup>a</sup>
Dry matter	64.79 $\pm$ 0.32 <sup>b</sup>	68.12 $\pm$ 0.41 <sup>c</sup>	68.52 $\pm$ 0.62 <sup>c</sup>	67.84 $\pm$ 0.38 <sup>c</sup>	61.32 $\pm$ 0.25 <sup>a</sup>
Gross energy	68.35 $\pm$ 0.65 <sup>b</sup>	71.96 $\pm$ 0.72 <sup>c</sup>	72.81 $\pm$ 0.75 <sup>c</sup>	71.75 $\pm$ 0.68 <sup>c</sup>	61.27 $\pm$ 0.55 <sup>a</sup>

Values having the same superscripts in the same row are not significantly different ( $P < 0.05$ )

### Fish muscle composition

The moisture and ash content in the fish muscle decreased as compared to the initial values whereas, the protein and fat levels increased with all the dietary treatments (Table 5). Moisture and ash contents in the muscle were lower with the increasing amount of lipid in the muscle of the fish fed diets D2, D3 and D4, containing 35%, 40%, and 45% carbohydrate, respectively. Though all the fish were fed isonitrogenous diets, maximum amount of muscle protein was recorded in the group of fish fed diets D2 and D3. Increase in dietary carbohydrate level beyond 40% (diets D4 and D5) reduced the muscle protein content. Fish fed diet containing low (30%) carbohydrate level (diet D1) also resulted in lower deposition of protein in fish muscle, though it was significantly ( $P < 0.05$ ) higher than that obtained with diet D5 (50% carbohydrate).

Table 5

Proximate muscle composition (on wet-weight basis) of *Labeo rohita* fingerlings fed experimental diets ( $\bar{x} \pm \text{SD}$ )

Muscle composition (%)	Initial value	Final values				
		Diets (carbohydrate content)				
		D1 (30%)	D2 (35%)	D3 (40%)	D4 (45%)	D5 (50%)
Moisture	81.93 $\pm$ 0.55	76.11 $\pm$ 0.48 <sup>b</sup>	74.64 $\pm$ 0.48 <sup>a</sup>	74.25 $\pm$ 0.50 <sup>a</sup>	76.81 $\pm$ 0.45 <sup>a</sup>	76.87 $\pm$ 0.52 <sup>b</sup>
Protein	11.08 $\pm$ 0.25	15.29 $\pm$ 0.28 <sup>b</sup>	16.43 $\pm$ 0.13 <sup>cd</sup>	16.57 $\pm$ 0.13 <sup>d</sup>	16.24 $\pm$ 0.12 <sup>c</sup>	14.77 $\pm$ 0.28 <sup>a</sup>
Lipid	2.73 $\pm$ 0.08	4.18 $\pm$ 0.12 <sup>a</sup>	4.32 $\pm$ 0.14 <sup>b</sup>	4.35 $\pm$ 0.10 <sup>b</sup>	4.27 $\pm$ 0.12 <sup>b</sup>	3.97 $\pm$ 0.09 <sup>d</sup>
Ash	1.71 $\pm$ 0.09	1.42 $\pm$ 0.07 <sup>a</sup>	1.28 $\pm$ 0.05 <sup>a</sup>	1.25 $\pm$ 0.06 <sup>a</sup>	1.31 $\pm$ 0.05 <sup>a</sup>	1.55 $\pm$ 0.07 <sup>b</sup>

Values having the same superscripts in the same row are not significantly different ( $P < 0.05$ )

### Profiles of digestive enzymes

Both the protease and  $\alpha$ -amylase activities were higher in hepatopancreas than those in the intestine, and the enzyme activities (both hepatopancreatic and intestinal) increased considerably from the respective initial values in all the dietary treatments (Table 6). Both

hepatopancreatic and intestinal  $\alpha$ -amylase activities were estimated higher in the fish fed diets D2, D3, and D4. Further increase in carbohydrate level in the diet (diet D5) did not show any increase in  $\alpha$ -amylase activity. Both  $\alpha$ -amylase and protease activities were significantly ( $P < 0.05$ ) lower in the fish fed diet D1, containing 30% carbohydrate (Table 6). Hepatopancreatic protease activity was higher in fish fed diets D3 and D2 which did not differ significantly from each other. Higher levels of carbohydrate in the diet resulted low proteolytic activity in hepatopancreas and intestine as was recorded in fish fed diet D5, containing 50% carbohydrate. No significant difference ( $P < 0.05$ ) in intestinal protease activity was noted among the fish fed diets D2, D3, and D4, containing 35, 40 and 45% carbohydrate, respectively (Table 6).

Table 6

Intestinal (i) and hepatopancreatic (h) enzyme activity in *Labeo rohita* fingerlings fed experimental diets ( $\bar{x} \pm SD$ )

Enzyme activity		Initial value	Final values				
			Diets (carbohydrate content)				
			D1 (30%)	D2 (35%)	D3 (40%)	D4 (45%)	D5 (50%)
$\alpha$ -Amylase *	i	5.47 $\pm$ 0.06	7.83 $\pm$ 0.08 <sup>a</sup>	9.06 $\pm$ 0.19 <sup>bc</sup>	9.28 $\pm$ 0.12 <sup>c</sup>	9.35 $\pm$ 0.15 <sup>c</sup>	8.78 $\pm$ 0.10 <sup>b</sup>
	h	7.42 $\pm$ 0.09	12.61 $\pm$ 0.12 <sup>a</sup>	14.85 $\pm$ 0.38 <sup>bc</sup>	15.24 $\pm$ 0.15 <sup>c</sup>	15.30 $\pm$ 0.24 <sup>c</sup>	14.65 $\pm$ 0.12 <sup>b</sup>
Protease **	i	28.24 $\pm$ 0.42	33.64 $\pm$ 0.54 <sup>b</sup>	36.02 $\pm$ 0.65 <sup>c</sup>	36.17 $\pm$ 0.58 <sup>c</sup>	35.85 $\pm$ 0.56 <sup>c</sup>	31.94 $\pm$ 0.50 <sup>a</sup>
	h	31.12 $\pm$ 0.45	40.35 $\pm$ 0.88 <sup>b</sup>	42.27 $\pm$ 0.60 <sup>cd</sup>	42.45 $\pm$ 0.55 <sup>d</sup>	41.73 $\pm$ 0.75 <sup>bc</sup>	38.57 $\pm$ 0.52 <sup>a</sup>

\*  $\alpha$ -Amylase activity = mg of maltose liberated/hour/mg of protein

\*\* Protease activity =  $\mu$ g of glycine liberated/hour/mg of protein

Values having the same superscripts in the same row are not significantly different ( $P < 0.05$ )

## DISCUSSION

### Fish growth

The level of dietary carbohydrate which resulted in best performance of *L. rohita* fingerlings in terms of percent weight gain, *SGR*, *FCR*, and *PER*, was found to be approximately 40%. A similar dose-response for dietary carbohydrate (approximately 40%) has been reported for other warmwater fishes such as, tilapia, *Oreochromis* sp. (cf. Luquet 1991), milkfish, *Chanos chanos* (cf. Lim 1991) and common carp, *Cyprinus carpio* (cf. Satoh 1991).

Final weight gain, percent live weight gains, and *SGR* all increased proportionately with increasing dietary carbohydrate up to a level of 40% (diet D3) and thereafter decreased with further increase in dietary carbohydrate (45% and 50% in diets D4 and D5, respectively). Better growth of Nile tilapia, *Oreochromis niloticus* (cf. Teshima and Kanazawa 1986), catla, *Catla catla* (cf. Seenappa and Devaraj 1995), and rainbow trout, *Oncorhynchus mykiss* (cf. Bergot 1979) was reported due to an increase in carbohydrate

level in diets containing proper protein and lipid levels. Poor/reduced growth of fish fed lower carbohydrate diets during the present study agrees with the findings of Bergot (1979) and Jantrarotai et al. (1994) in rainbow trout and hybrid *Clarias* catfish, respectively. Moreover, higher levels of inclusion of cellulose as filler in the low carbohydrate diets (diets D1 and D2) may have resulted poor fish growth (Beamish and Medland 1986).

Fish fed higher (45 and 50%) carbohydrate diets (diets D4 and D5) also had poor growth. Similar observations also have been made in red sea bream (Furuichi and Yone 1971), plaice (Cowey et al. 1975), yellowtail (Shimeno et al. 1979) and rainbow trout (Phillips et al. 1948; Buhler and Halver 1961; Hilton and Atkinson 1982). Incorporation of high levels of starch in the diets of trout has been reported to adversely affect the availability of non-protein energy (Kaushik and Medale 1994) which leads ultimately to poor fish growth. Jantrarotai et al. (1994) also observed a significant decrease in energy retention in hybrid *Clarias* catfish when fed a diet containing higher (54%) level carbohydrate. Garling and Wilson (1977) reported that either less carbohydrate or more carbohydrate in the diets reduced the weight gain and protein retention of channel catfish.

*FCR*, *PER*, and *ANPU* also were found to be better with an increase in dietary carbohydrate level up to 40%. However, with diets D4 and D5 (45 and 50% carbohydrate), poor *FCR*, *PER*, and *ANPU* were noted. *FCR* was found to correspond to the weight gain of the fish. Similar correlation between weight gain and feed efficiency also was reported in rainbow trout (Bergot 1979). Increasing the energy intake with carbohydrate was reported to improve protein utilisation and *PER* in rainbow trout (Bergot 1979; Kaushik and Olivanteles 1986) and plaice (Cowey et al. 1972). Kim and Kaushik (1992) obtained highest *PER* in rainbow trout fed diet containing 38% gelatinised starch. It also has been reported that the *ANPU* and *PER* depend on the type of energy provided by the dietary ingredients (Ogino and Saito 1970). A reduction in *ANPU* and *PER* values in the fish fed diets D4 and D5 in the present investigation, may be due to the higher amounts of non-protein energy in the diets.

Survival rate of fish was not affected adversely with the dietary carbohydrate levels and in no case was survival rate below 90%. Moreover, no mortality of fish was recorded with 35% and 40% carbohydrate diets.

#### Apparent nutrient digestibility

With constant dietary protein level, apparent protein digestibility (*APD*) was not significantly affected by the increase in dietary carbohydrate level from 20 to 40%. Shimeno (1974) showed that when common carp was fed diets containing 30 to 47% carbohydrate, the digestibility of protein was almost constant at any level of dietary carbohydrate. Kim and Kaushik (1992) and Brauge et al. (1994) also reported that *APD* values were not af-

ected by the level of dietary starch in rainbow trout diets. In the present study, the *APD* values decreased significantly with further rise in dietary carbohydrate level (50%, in diet D5). There also are reports on low *APD* values due to deleterious effects of high carbohydrate level in the diet (Inaba et al. 1963; Kitamikado et al. 1964; Singh and Nose 1967; Page and Andrews 1973; Shimeno et al. 1979; Wee and Tacon 1982).

Digestibility of lipid, dry matter, and energy also did not vary significantly in the fish fed diets containing 35, 40, and 45% carbohydrate. It has been reported that carp can effectively digest and absorb these nutrients regardless of carbohydrate level in the diet (Ogino and Chen 1973; Shimeno 1974). However, the nutrient and energy digestibilities decreased significantly with further increase in dietary carbohydrate level (50%, in diet D5). High dietary carbohydrate levels have been reported to adversely affect the dry matter and energy digestibilities in fish (Inaba et al. 1963; Kitamikado et al. 1964; Kim and Kaushik 1992). A decrease in digestibility of starch as a whole, has been reported in channel catfish with increasing dietary levels of carbohydrate (starch) (Cruz 1975; Sand 1989). Influence of dietary carbohydrate level on the apparent digestibility coefficients also has been reported by Kaushik and Medale (1994) in salmonids.

#### Fish muscle composition

Moisture and ash contents decreased whereas, protein and lipid increased in the fish muscle from the respective initial values in all the dietary treatments during the present investigation. Increase in muscle protein and lipid levels and decrease in moisture content from the initial values in rainbow trout fed varying carbohydrate levels in the diets has been reported by Kim and Kaushik (1992). Protein content in the muscle was recorded highest with 40% carbohydrate diet whereas, the values decreased with further increase in dietary carbohydrate levels (45 and 50%). The protein deposition in fish muscle corresponds to the fish growth and signifies that the growth of fish was due to mainly an increase in muscle protein (Santiago and Reyes 1991). No significant differences in muscle lipid, moisture and ash contents were noticed among the fish fed 35, 40, and 45% carbohydrate diets. Bergot (1979) and Kim and Kaushik (1992) reported that lipid, moisture, and ash contents in rainbow trout were not affected by dietary carbohydrate treatments. Moisture and lipid in fish muscle appeared to be inversely related during the present study which is in agreement with the findings of previous workers (Dąbrowska and Wojno 1977; Atack et al. 1979; Jauncey 1982; Ray and Das 1992; Shearer 1994).

#### Profiles of digestive enzymes

It is reported that the major enzymes required for carbohydrate digestion and metabolism are present in fish (Shimeno 1974; Cowey and, Walton 1989; Wilson 1994). During the present study, both the hepatopancreatic and intestinal  $\alpha$ -amylase activities in-

creased with the increase in dietary carbohydrate level up to 40% and decreased thereafter. The pattern of  $\alpha$ -amylase activity corresponds to growth pattern of the fish reared on different dietary carbohydrate levels. In general, freshwater and warmwater fish appear to digest carbohydrates more effectively than marine and coldwater fish which may be related to the relative amount of amylase activity present in the digestive system of the various species (Wilson 1994). Shimeno et al. (1977) found that amylase activity in the digestive system of carp was about 80 times greater than that of yellowtail. Similarly, Hofer and Sturmhuber (1985) reported that amylase activity in the digestive tract of carp was 10 to 30 times greater than that present in rainbow trout. It is reported that the simpler carbohydrates are readily digested by fish (Bergot 1979; Pieper and Pfeffer 1980). Sufficient secretion of amylase and effective digestion of carbohydrate has also been reported in milkfish (Pascual 1989). However, in spite of higher dietary carbohydrate levels (45 and 50%),  $\alpha$ -amylase activity was estimated lower in the fish fed diets D4 and D5. As has been suggested by Spannhof and Plantikow (1983), low amylase activity in the intestine of the fish fed higher amounts of carbohydrates was not probably due to a decrease in secretion rate but to an adsorption of the amylase to the crude or raw starch present in the diets, thus inhibiting starch hydrolysis. Spannhof and Plantikow (1983), further stated that the transit time of a high-starch diet was about twice as fast as that of a high-protein diet, indicating reduced time for starch hydrolysis in the high-starch diet. Although no significant difference in intestinal protease activity was noted among the fish reared on diets D2, D3 and D4, hepatopancreatic protease activity was recorded highest with 40% carbohydrate diet. Fish reared on this diet also had higher weight gain and higher protein deposition in muscle. Both the protease and  $\alpha$ -amylase activities were estimated higher in hepatopancreas than in the intestine in all dietary treatments.

From the results of the present study it can be concluded that a minimum level of 40% carbohydrate is required in the diet (protein content being 35%) of *Labeo rohita* fingerlings for optimum growth and feed utilisation.

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OPTYMALNY UDZIAŁ WĘGLOWODANÓW W PASZY DLA PALCZAKÓW ROHU,  
*LABEO ROHITA* (HAMILTON)

STRESZCZENIE

Przeprowadzono, trwające 80 dni, laboratoryjne badania żywieniowe palczaków rohu, *Labeo rohita* (Hamilton) (5,67 ± 0,25 g). Celem eksperymentu było ustalenie optymalnego poziomu węglowodanów w paszy. Przygotowano 5 semiocyszczonych pasz zawierających odpowiednio: 30, 35, 40, 45 i 50% węglowodanów (warianty D1 do D5). Każdą z nich podawano trzem grupom ryb. Wszystkie pasze zawierały tę samą ilość azotu (35% białka) i reprezentowały zbliżoną wartość kaloryczną. Najlepsze efekty w zakresie przyrostu żywej masy (%), *SGR* (%/dzień) i *FCR* osiągnięto stosując wariant z 40% udziałem węglowodanów. Statystycznie istotnie ( $P < 0.05$ ) słabszy wzrost zanotowano w grupach żywionych paszą zawierającą 30 i 35% węglowodanów. Nie zaobserwowano jednakże istotnych różnic w *PER* i *ANPU* (%) przy zastosowaniu wariantów D2 i D3. Mimo, że nie zaobserwowano istotnych różnic w strawności białek w paszach zawierających do 45% węglowodanów, to jednak dla lipidów, popiołu, suchej masy i energii trawienia – wielkości były istotnie wyższe ( $P < 0.05$ ) dla pasz D2 i D3 niż dla pozostałych. Te dwie pasze umożliwiły również wyższy poziom odkładania białek i lipidów oraz niższą zawartość wody i popiołu w mięśniach ryb. Ustalono też, że aktywność enzymów amylolitycznych i proteolitycznych była wyższa w grupach ryb żywionych paszami zawierającymi 35 i 40% węglowodanów. Niniejsze badania wskazują, że minimalna zawartość węglowodanów w paszy konieczna dla osiągnięcia optymalnego wzrostu, przyswojenia paszy i wykorzystania substancji odżywczych u palczaków rohu, *Labeo rohita* wynosiła 40% (przy 35% zawartości białka).

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