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Growth Response, Feed Utilization and Nutrient Retention in *Catla catla* (Ham.) Fry fed Varying Levels of Dietary Carbohydrate

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Abstract

Isonitrogenous (40% CP) diets with varying levels of carbohydrate (8, 16, 24, 32, 40 and 48%) were fed to *Catla catla* fry (0.28 ± 0.02 g) in a 6-week growth trial conducted in 70-l flow-through indoor circular troughs. Triplicate groups of 30 fish/trough were fed the experimental diets 6 days a week, twice daily at 0800 and 1600 h, at a total rate of 10% and 6% of their body weight for the first four and last two weeks, respectively. Live weight gain (%) was significantly affected by carbohydrate intake, attaining a maximum (339%) at 40% dietary carbohydrate intake. The relationship of dietary carbohydrate intake (up to 40%) with specific growth rate (SGR), protein efficiency ratio (PER), and protein and/or energy retention was linear and positive. However, the relationship of dietary carbohydrate intake to feed conversion ratio (FCR) was negative. Dietary carbohydrate significantly ($P<0.05$) affected carcass moisture, lipid and/or gross energy content while crude protein and ash remained unaffected ($P>0.05$).

Introduction

Carbohydrate is an inexpensive and immediate source of energy in fish diets and serves as a precursor for the various intermediary metabolic functions. The inclusion of carbohydrate in fish diets improves the pelleting quality of feed. However, carbohydrate utilization with respect to digestibility and metabolism remains unclear in many fish species (Jauncey 1982; NAS-NRC 1993). Carps have been reported to tolerate relatively higher levels of carbohydrate in the diet (Shimeno 1982; Viola and Arieli 1983). This also holds true for channel catfish, red sea bream, tilapia, and European eel (Garling and Wilson 1977; Furuichi and Yone 1980; Anderson *et al.* 1984; Degani and Levanon 1987). Jauncey (1982) has pointed out that carps, despite their high levels of carbohydrate utilization, show greater disparities in their levels of carbohydrate utilization. However, because of the low cost of dietary carbohydrate, particularly when compared to protein and fat, inclusion of this nutrient in diets may prove profitable in many fish species. The presence of carbohydrate in fish diets has a protein-sparing effect similar to that of lipid (Wilson 1994).

Basic nutritional studies on Indian major carps are relatively few (Sen *et al.* 1978; De Silva and Gunasekera 1991; Ravi and Devaraj 1991), and more information on carbohydrate nutrition/utilization is needed. Among Indian major carps, *Catla catla* is the fastest growing fish, attaining a marketable size of over 900 g in a year (Jhingran and Pullin 1988). Previous studies on the nutrition of this fish remained confined to protein and amino acid requirements (Khan and Jafri 1991; Ravi and Devaraj 1991). This study reports on growth response, feed utilization and nutrient retention in *C. catla* fry fed varying levels of dietary carbohydrate.

Materials and Methods

Experimental diets

Six isonitrogenous diets (40% CP) were formulated using bread-flour (whole-wheat) as a source of carbohydrate (Table 1). Diets were formulated to provide 30% CP from a casein-gelatin mixture and fish meal, with the remaining 10% CP being derived from interchanging defatted soybean and bread flour. The vitamin and mineral premixes were according to Halver (1976). Experimental diets were analyzed for dry matter, crude protein, total lipid and ash using standard AOAC (1984) methods. Crude fiber was quantified as loss on ignition of fat-free dried residue remaining after digestion of sample with standard solution of 1.25% sulphuric acid and 1.25% sodium hydroxide. Nitrogen-free extract was calculated by difference (Table 1). Gross energy (GE) in

Table 1. Ingredient and proximate composition of experimental diets.

Ingredients (g/100 g, diet)	Dietary carbohydrate levels (%)					
	8	16	24	32	40	48
Basal premix[1]	45.10	45.10	45.10	45.10	45.10	45.10
Soybean meal[2]	18.12	15.84	13.15	11.30	8.98	6.69
Bread flour[3]	8.00	16.00	24.00	32.00	40.00	48.00
μ-cellulose	28.78	23.06	17.35	11.60	5.92	0.21
Nutrients (% dry matter)[4]						
Crude protein	40.10	40.00	40.00	40.00	40.00	40.00
Lipid	5.60	5.65	5.66	5.70	5.64	5.60
Ash	7.24	7.33	7.40	7.32	7.36	7.33
Fibre	35.70	28.90	23.45	16.90	10.50	4.60
NFE[5]	11.36	18.12	23.49	29.98	36.50	42.48
Gross energy[6]	3.53	3.74	3.95	4.15	4.36	4.56

[1]Basal premix: Casein, 19.04 (84% CP); gelatin, 4.56 (87.6% CP); fish meal, 14.50 (69% CP; 11% ash; 10% lipid); corn oil, 4.00; vitamin premix, 1.00; mineral premix, 1.00 and carboxymethyl cellulose, 1.00 g.
[2]Soybean meal : (49% CP; 7.75% ash; 0.88% lipid).
[3]Bread flour : (14% CP; 4.55% ash; 88.35% carbohydrate; 0.12% lipid).
[4]Based on 3-5 determinations.
[5] Nitrogen-free extract.
[6]Based on deterimined values on bomb calorimeter. GE contributed by μ-cellulose and carboxymethyl cellulose was subtracted, so GE from ingredients are more truly represented.

diet and fish samples was quantified by direct calorimetry on a Gallankamp ballistic bomb calorimeter. The GE in the experimental diets ranged from 3.53 to 4.56 kcal•g^{-1}.

For the preparation of experimental diets, quantities of air-dry ingredients were thoroughly mixed in a Hobart electric mixer and blended with water (75 -80°C) to obtain a bread dough-like consistency. For the preparation of dry crumbles, the above material was extruded through a Hobart extruder fitted with 1-mm die. The strands were spread over the receiving tray and placed in a hot air oven at 60°C. The diet, upon complete drying (8% moisture), was crumbled and sieved through 18/30 mm screens and stored in sealed bags at 4° C until feeding.

Feeding trial

Hatchery-bred *C. catla* (0.28±0.02 g) were sorted out from a previously acclimated fish lot maintained on a casein-gelatin-based H-440 semi-purified diet (Halver 1976) in a wet laboratory, and randomly stocked in triplicate groups of 30 fish each in 70-l high-density polyvinyl flow-through (1–1.5 l/min underground freshwater) indoor circular troughs (water volume=55 l).

Fish were fed the experimental diets six days a week, twice daily at 0800 and 1600 h, at a total rate of 10% and 6% of their body weight (dry to wet basis) for the first four and last two weeks, respectively. The feeding ration and feeding frequency was carefully chosen after a preliminary feeding trial conducted at the laboratory to ensure maximum feed consumption with relatively almost no feed wastage. Initial and subsequent weekly weight gains (g) were recorded on a sensitive top loading balance (Precisa 120 A), after the fish were anesthetized with tricanemetane sulfonate (MS 222) solution (1:10,000). Scrubbing and cleaning of troughs were carried out at the time of the weekly measurements. Based on the daily measurements, average water temperature and dissolved oxygen over the experimental period were 28±1° C and 6.8±0.22 ppm, respectively. The experimental trial was conducted under natural photoperiod (light:dark) in the months of August and September 1994.

Growth and body composition

Live weight gain (%), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were calculated using standard definitions (Hardy 1989). At the end of the feeding trial, fish were randomly sacrificed with an overdose of MS-222 solution, and placed in a deep freezer (-20°C) for the assessment of initial and final body composition, using methods similar to those employed for the analyses of experimental diets. Protein and energy retention efficiencies (%) were calculated using the method of Kim and Kaushik (1992).

Statistical methods

Comparison among different treatment means or between initial and final values of the same dietary treatment were made by one-way analysis of variance (ANOVA) and Duncan's Multiple Range Test at 0.05% probability level (Sokal and Rholf 1981; Duncan 1955). Correlation coefficient (r) was calculated to establish the relationship of dietary carbohydrate intake to growth, body constituents and nutrient retention efficiencies.

Results

Table 2 depicts the growth and feed efficiency of *C. catla* fry fed different levels of dietary carbohydrate over a 6-week growth trial. The maximum (339%) live weight gain in body weight, SGR (3.52%), FCR (2.35), and PER (1.13) were observed at 40% dietary carbohydrate intake, beyond which these parameters declined. A strong linear and positive relationship ($r=0.99$; $P<0.05$) was similarly found between 40% dietary carbohydrate intake and live weight gain (%), SGR (%) and PER. On the other hand, FCR showed a linear negative ($r=-0.99$; $P<0.05$) relationship up to the above level of carbohydrate intake. Survival rate was over 94% and had no effect on the dietary regimen.

The body composition and nutrient retention efficiencies were markedly affected by the level of dietary carbohydrate intake in fish (Tables 3 and 4). With the increase in dietary carbohydrate from 8 to 48%, whole body dry matter, lipid and gross energy content in fish increased ($P<0.05$) over the initial values. Moisture content was found to decrease significantly ($P<0.05$) with the increase in dietary carbohydrate intake up to 48% level in the diet. Crude protein and ash contents were not influenced ($P>0.05$) by high carbohydrate levels in the diet.

Protein and energy retention efficiency values increased up to 40% dietary carbohydrate intake. Beyond this level, a significant ($P<0.05$) reduction resulted (Table 4).

Table 2. Growth, conversion efficiencies and survival (%) in *C. catla* fry fed varying levels of dietary carbohydrate*.

Diets	Mean final body weight (g)	Weight gain[1] (%)	SGR[2] (%)	FCR[3]	PER[4]	Survival (%)
8	0.67[a]	139[a]	2.10[a]	3.50[a]	0.78[a]	94
16	0.86[b]	201[b]	2.60[b]	2.80[d]	0.90[b]	96
24	0.95[c]	240[c]	2.90[c]	2.60[b]	0.95[b]	96
32	1.10[d]	292[d]	3.25[d]	2.44[a]	1.03[b]	98
40	1.23[e]	339[e]	3.52[e]	2.35[a]	1.13[c]	96
48	0.96[c]	241[c]	2.92[c]	2.70[c]	0.94[b]	96
Pooled s.e.	0.57	57.71	0.54	0.43	0.38	
ANOVA *P*	0.05	0.05	0.05	0.05	0.05	

*Results are mean of triplicate runs. Values with different superscripts within each column are significantly different ($P < 0.05$).

[1]100 X Mean live weight gain (g) / mean initial body weight (g).

[2]100 X *ln* Mean final body weight (g) – *ln* mean initial body weight (g) / duration.

[3]Dry feed intake (g) / mean live weight gain (g).

[4]Mean live weight gain (g) / protein intake (g, dry weight basis).

Table 3. Whole body composition of *C. catla* fry fed varying levels of dietary carbohydrate*.

Diets	Moisture**	Crude Protein	Lipid	Ash	Energy** ($kcal \cdot g^{-1}$)
Initial	83.14	12.30	1.50	2.92	5.03
8	82.10[e]	13.86	2.19[a]	1.66	5.52[a]
16	81.94[e]	13.89	2.36[b]	1.58	5.68[b]
24	80.17[d]	13.93	2.83[c]	1.93	5.77[c]
32	79.22[c]	13.86	3.58[d]	1.81	5.85[d]
40	78.19[b]	13.90	4.26[e]	1.88	5.98[e]
48	77.74[a]	13.84	4.49[f]	1.96	6.02[e]
Pooled s.e.	0.77	0.44	0.65	0.38	0.32
ANOVA *P*	0.05	0.05	0.05	0.05	0.05
r	-0.98	0.60	0.99	-0.38	0.98

*Results are mean of triplicate runs (% wet weight basis). Values with different superscripts within each column are significantly different ($P<0.05$).
**Dry matter basis.

Table 4. Nutrient retention efficiencies (%) in *C. catla* fry fed varying levels of dietary carbohydrate*.

Diets	Nutrient retention efficiency (%)	
	Protein	Energy
8	18.17[a]	28.98[a]
16	22.32[b]	31.33[b]
24	26.45[c]	38.89[c]
32	31.08[d]	45.89[d]
40	38.77[e]	49.80[e]
48	33.44[d]	47.77[d]
Pooled s.e.	2.33	3.18
ANOVA *P*	0.05	0.05

*Results are mean of triplicate runs. Values with different superscripts within each column are significantly different ($P<0.05$).

Discussion

In general, fish have no true carbohydrate requirement, but the incorporation of certain levels of carbohydrate in the diet influences the growth and conversion efficiencies of fish (NAS-NRC 1993). This is evident in the present study. An increase in dietary carbohydrate from 8 to 40% corresponded to 3.53 to 4.36 $kcal \cdot g^{-1}$ (GE), improved growth and conversion efficiencies. These findings seem to conform to the observation of Sen *et al.* (1978) on spawn, fry, and fingerling of common carp and to that of Swamy (1988) on fry and fingerling of *Cirrhinus mrigala*. Similar observations have been made on common carp, red sea bream, and yellowtail (Furuichi and Yone 1980). An earlier study found that *Labeo rohita* fingerlings can grow well on diets containing 30% dietary carbohydrate (Erfanullah and Jafri 1993).

The observations on live weight gain (%), SGR (%), FCR and PER values indicate that energy inclusion (through carbohydrate) up to a certain level (4.36 $kcal \cdot g^{-1}$) in the diet increases live weight gain (%), feed efficiency and protein utilization. The performance of the diet at the above level of carbohydrate inclusion reflects a proper nutrient balance in the diet, and greater use of protein for growth purposes. As the diets were isonitrogenous (40% CP) and isolipidic (5.7%), varying only in the energy level supplied through digestible carbohydrate, this clearly suggests that energy supplied through carbohydrate is efficiently utilized by *C. Catla* fry, indicating the protein-sparing effect of digestible carbohydrate in the present experiment. Similar sparing effects of digestible carbohydrate on protein has also been pointed in other fish, including carp (Jauncey 1982; NAS-NRC 1993). The pattern of changes observed in FCR and PER of *C. catla* fry fed increasing levels of energy (through carbohydrate) is also evident in chinook salmon (Buhler and Halver 1961), rainbow trout (Bergot 1979), common carp (Ufodike and Matty 1983), walking catfish fry (Mollah and Alam 1990), and rohu (Erfanullah and Jafri 1993).

The decline in live weight gain (%), SGR (%), FCR and PER with high energy intake through carbohydrate (diets with 48% carbohydrate and 4.56 $kcal \cdot g^{-1}$) incorporation could be attributed to decreased feed consumption owing to high energy density and consequential low protein intake. Since fishes satisfy their daily energy needs, supplying excess dietary energy may fulfill their energy requirements before the necessary amounts of protein or other essential nutrients are met. It should be noted that, at a 48% dietary carbohydrate level, the contribution of protein calories (as GE) is only 46%,which seems insufficient to meet the optimum protein needs of the fish. The depressed growth and overall poor feed efficiencies obtained with the diet containing carbohydrate levels higher than 40% indicate that *C. catla* is unable to handle excessive dietary carbohydrate. The reduced growth at 48% carbohydrate inclusion in the diet may also be attributed to the altered protein to energy ratio (P/E) in the diet. The ratio varied from 92-mg protein/kcal energy (in 40% carbohydrate diet) to 88-mg protein/kcal energy (in 48% carbohydrate diet).

Carcass composition was significantly affected by carbohydrate intake in *C. catla* fry. With the increase in carbohydrate intake from 8 to 48%, dry matter, body lipid and energy content of the fish increased markedly while ash and crude protein remained unaffected. The highest protein and energy retention values occurred in fish at 40% dietary carbohydrate level but further increases in dietary carbohydrate (>40%) resulted in a significant decline in these values.

The strong inverse relationship ($r=-0.99$; $P<0.05$) between moisture content of the fish and dietary carbohydrate level up to 40% clearly indicates that *C. catla* fry efficiently utilized dietary carbohydrate as a ready source of energy in the present experiment. This was seen in the form of increased body weight vis-a-vis fish growth, as well as increased body protein, protein and energy retention.On the other hand, fish fed diets containing increasing levels of dietary carbohydrate (8 to 48%), increased their body lipid and gross energy content, suggesting that absorbed carbohydrate which is not utilized to provide energy can be deposited as lipid in the body. The beneficial effect of dietary carbohydrate up to a level of 40% inclusion in the diet as demonstrated in the present experiment point to the fact that digestible carbohydrate such as bread flour could be successfully incorporated in studying possible protein sparing action in *C. catla*. The above pattern of carcass composition compares favorably with results reported in chinook salmon (Buhler and Halver 1961), rainbow trout (Bergot 1979; 1993; Brauge *et al.* 1994, 1995), common carp, red sea bream, and yellowtail (Furuichi and Yone 1980), mirror carp (Ufodike and Matty 1983), and tilapia (Anderson *et al.* 1984).

The overall low growth and poor feed conversion efficiencies noted in the low carbohydrate (8%) diet could be the result of insufficient non-protein energy source in that diet, necessitating greater utilization of dietary protein for purposes other than growth. Since this diet also contained a high level of indigestible fiber in the form of μ-cellulose, less efficient absorption and reduced availability of other nutrients seems understandable.

In conclusion, the results of the present study indicated that, in *C. catla* fry, 40% carbohydrate in a 40% CP diet, corresponding to an E/P ratio of 92 mg protein/kcal and 4.36 $kcal \cdot g^{-1}$ gross energy, produces maximum growth, the best conversion efficiencies and higher nutrient (protein/energy) retention. Diets containing either low (8%) or high (48%) levels of carbohydrate may reduce growth and conversion efficiencies, and also affect carcass composition and nutrient retention in *C. catla* fry.

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