Asian Fisheries Science 8(1995):55-62.
Asian Fisheries Society, Manila, Philippines
https://doi.org/10.33997/j.afs.1995.8.1.005

Effect of Varying Dietary Lipid Levels on Growth, Feed Conversion, Nutrient Retention and Carcass Composition of Fingerling Catfish, *Heteropneustes fossilis*

M. FAROOQ ANWAR and A.K. JAFRI

Fish Nutrition Research Laboratory
Department of Zoology
Aligarh Muslim University
Aligarh - 202002 (U.P.) India

Abstract

Casein-gelatin based purified diets (40% CP, 18 kJ·g^{-1} GE) with graded levels (3,5,7,9,11 and 13%) of lipid were fed to fingerling *Heteropneustes fossilis* to investigate changes in growth, feed conversion, nutrient retention and carcass composition. Fish stocked in triplicate sets of 15 fish each, in 70 l flow-through (1.0-1.5 l·min^{-1}) type polyvinyl circular troughs, were fed diets at the rate of 4% body weight·day^{-1}. Over the six-week growth trial, maximum gain in live weight (194%), specific growth rate (2.57%), protein efficiency ratio (1.76) and best feed gain ratio (1.44) were noted in fish at 7% lipid intake.

Moisture, crude protein, fat and gross energy contents of carcass were significantly ($P<0.05$) affected by diet. Although carcass protein and percent protein retention increased up to 7% dietary lipid level, dry matter, crude fat, gross energy and percent GE retention registered a constant increase with dietary lipid levels. The tendency of fat deposition at each incremental dietary lipid level was found to be more pronounced in viscera than in muscle. The hepatosomatic index was not correlated to dietary lipid levels. It was concluded that *H. fossilis* requires a level of 7% lipid as an energy source in 40% CP diet, with 18.2±0.21 kJ·g^{-1} of gross energy and a carbohydrate-to-lipid ratio of about 5 for maximum utilization and growth.

Introduction

Use of lipid as an energy source and nutrient to spare protein, for optimizing production, has been attempted in diets formulated for various fish species (Watanabe 1982; Sargent et al. 1989; De Silva et al. 1991). In most practical fish rations, lipid level is generally kept low to prevent excessive accumulation of visceral adipose tissue and to avoid problems associated with feed manufacturing (Reinitz and Hitzel 1980). The influence of varying dietary lipid levels on growth and body composition of fish has been reported by several workers (Stickney and Andrews 1972; Lee and Putnam 1973; Gatlin and Stickney 1982; Stickney and Hardy 1989; Ellis and Reigh 1991; Hanley 1991).

Heteropneustes fossilis (Bloch), a fish of high market value found in India and in other South Asian countries, is cultured extensively. Aquaculture of this catfish on a scientific basis is of recent origin and significant improvements have been made in the culture techniques, and yields of about 4,510 kg $ha^{-1}year^{-1}$ have been achieved under semi-intensive culture conditions, using feed mixture consisting of trash fish and rice bran. In intensive culture operations, yields of 35,000 $kg \cdot ha^{-1}$ in seven months have been reported (Thakur 1991). Although the air breathing nature of *H. fossilis* permits high stocking density, provision of complete diets based on nutritional requirements of the species can further enhance its rate of production. Earlier work on the nutrition of this species was confined mainly to observations on feed acceptability (Niamat and Jafri 1984) and protein requirements (Akand et al. 1989).

The present study examines the effect of varying levels of dietary lipid on growth, feed conversion, nutrient retention and carcass composition of fingerling *H. fossilis*.

Materials and Methods

H. fossilis (7-9 cm) were obtained from a local fish market and acclimated to a purified diet (Halver 1989) in the laboratory for two weeks. Iso-nitrogenous (40% CP), casein-gelatin based experimental diets (Table 1) were prepared with graded levels (3,5,7,9,11 and 13%) of lipid containing a mixture of 2:1 corn and codliver oil. A crude protein level of 40% is the known requirement of the species (Niamat 1985). The estimated gross energy and P/E ratio in the diets ranged from 18.0 to 18.4 $kJ \cdot g^{-1}$ and 21.3 to 21.7 mg kJ^{-1}, respectively. Mineral and vitamin premixes, and the method of preparation of the experimental diets were according to Halver (1989).

Fish from the acclimated lot were stocked in triplicate groups of 15 fish each, in 70-l high density polyvinyl circular troughs supplied with ground water in a flow-through (1.0-1.5 $l \cdot min^{-1}$) system. The fish were fed the experimental diets in the form of a moist cake, 6 d a week, at a rate of 4% body weight d^{-1}, divided into two meals, at 0800 and 1600 h. The growth trial lasted six weeks. Any uneaten feed was siphoned through a filter screen, weighed and the amount of remaining food determined. A natural photoperiod was maintained throughout the trial. The water temperature and dissolved oxygen during the trial were 29 ± 1 °C and 6.2 ± 1 ppm, respectively.

Carcass composition was determined at the beginning of the experiment, in triplicate samples of three fish each taken out from the acclimated lot, and an equal number of fish sacrificed at the end of the feeding trial. Standard techniques (AOAC 1984) were used to determine the proximate composition of carcass and the experimental diets. Crude protein (N x 6.25) was determined by the Kjeldahl method, and crude fat was quantified through soxhlet exhaustive extraction technique using petroleum ether (40-60°C BP) as the solvent. A 2-5 g dried sample was incinerated (600°C) in a muffle furnace for 2 h for the estimation of ash. Crude fiber was determined through acid-alkali digestion method. N-free extract (NFE) was calculated by the difference.

Gross energy was estimated by direct calorimetry using a Gallenkemp ballistic bomb calorimeter.

Table 1. Ingredients and nutrient composition of experimental diets.

	Diets					
	I	II	III	IV	V	VI
Ingredients (g·100^{-1} g as-fed)						
Vitamin-free casein[1]	37.0	37.0	37.0	37.0	37.0	37.0
Gelatin[2]	10.0	10.0	10.0	10.0	10.0	10.0
Dextrin white	41.7	36.4	31.0	25.7	20.4	15.0
Oil	3.0	5.0	7.0	9.0	11.0	13.0
Mineral mix[3]	4.0	4.0	4.0	4.0	4.0	4.0
Vitamin mix[3]	1.0	1.0	1.0	1.0	1.0	1.0
∝cellulose	1.3	4.6	8.0	11.3	14.6	18.0
Carboxymethyl cellulose	2.0	2.0	2.0	2.0	2.0	2.0
Nutrient (g·100^{-1} g, dry weight)						
Crude protein	39.5	39.8	38.9	39.1	39.4	38.5
Lipid (ether extract)	3.2	5.1	7.4	9.3	11.6	13.3
N- free extract	47.7	42.5	36.5	31.3	25.8	20.5
Ash	3.9	3.6	3.6	3.5	3.5	3.4
Crude fiber	3.4	6.9	12.1	13.6	17.9	21.8
Gross energy (kJ·g^{-1})[4]	18.4	18.3	18.2	18.2	18.2	18.0

[1]ICN Pharmaceuticals, Cleveland, Ohio
[2]Loba Chemie, Bombay
[3]Halver 1989
[4]GE contributed in the diets by ∝ cellulose and CMC was subtracted so that GE levels from ingredients are more truly represented.

Growth rate, feed conversion, protein efficiency ratio and nutrient retention (%) were calculated using definitions as proposed by Hardy (1989) and Hanley (1991). Statistical evaluation, through one-way analysis of variance (Snedecor and Cochran 1967) and Duncan's multiple range test (Duncan 1955), was done to test the differences between treatment means.

Results

The response of *H. fossilis* fingerling to varying levels of dietary lipid are summarized in Table 2. Over the six-week growth trial, significant differences ($P<0.05$) were observed in the percent live weight gain of the fish at different levels of dietary lipid intake (Fig. 1). Fish receiving 7% dietary lipid shared the maximum gain in weight (194%) while those reared on diets of higher lipid content (9-13%) showed reduced weight gain. The highest specific growth rate (SGR %) was also noted at 7% dietary lipid inclusion. Significant differences ($P<0.05$) were observed in feed:gain ratio (FCR) among the test groups, the best FCR being at 7% dietary lipid. Protein efficiency ratio (PER) was also the maximum at this level. FCR and PER in fish at higher dietary lipid levels (9-13%) indicated no significant differences ($P>0.05$). Percent protein retention revealed significant differences ($P<0.05$) over the initial, up to 7% dietary lipid intake, beyond this level the differences in protein retention (%) were not significant ($P>0.05$).

Carcass composition, visceral fat content and hepatosomatic index (HSI) of the different groups of fish are given in Table 3. Carcass moisture, protein, fat

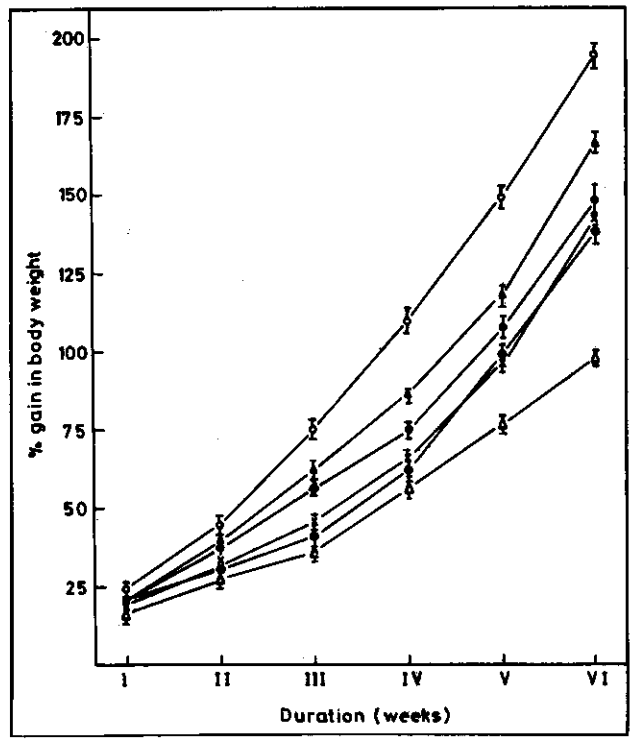

Fig. 1. Weekly weight gain of *H. fossilis* fed varying levels (Δ 3%; ▲ 5%; O 7%; ● 9%; X 11% and ⊙ 13%) of dietary lipid.

Table 2. Results of feeding varying dietary lipid levels to fingerling *H. fossilis*.

	Dietary lipid levels					
	3%	5%	7%	9%	11%	13%
Initial mean wet weight (g)	3.12^{a} ±0.07	3.19^{a} ±0.07	3.11^{a} ±0.09	3.16^{a} ±0.06	3.21^{a} ±0.12	3.33^{a} ±0.06
Final mean wet weight (g)	6.17^{d} ±0.18	8.49^{b} ±0.20	9.14^{a} ±0.17	7.85^{c} ±0.15	7.76^{c} ±0.36	7.91^{c} ±0.14
Percent gain in live weight	97.49^{e} ±1.61	166.15^{b} ±2.65	194.14^{a} ±3.59	148.28^{c} ±4.24	141.43^{d} ±2.15	137.80^{de} ±3.19
Specific growth rate (%)	1.62^{e} ±0.02	2.33^{b} ±0.02	2.57^{a} ±0.03	2.17^{c} ±0.04	2.10^{d} ±0.02	2.06^{de} ±0.03
Feed: gain ratio	2.33^{a} ±0.02	1.56^{c} ±0.02	1.44^{d} ±0.01	1.71^{b} ±0.01	1.70^{b} ±0.01	1.73^{b} ±0.03
Protein efficiency ratio	1.09^{d} ±0.01	1.61^{b} ±0.02	1.76^{a} ±0.01	1.49^{c} ±0.01	1.49^{c} ±0.01	1.50^{bc} ±0.02
Protein retention (%)	17.41^{d} ±0.23	32.79^{c} ±0.68	38.57^{a} ±0.89	35.13^{bc} ±0.29	37.78^{ab} ±1.99	34.66^{bc} ±2.04
Gross energy retention (%)	12.09^{e} ±0.43	22.22^{de} ±0.63	25.61^{cd} ±1.35	23.96^{bc} ±0.37	27.44^{ab} ±1.11	27.11^{a} ±1.57
Percent survival	96	100	100	100	98	98

Percent gain in live weight = 100 x $(BW_f\text{-}BW_i)/BW_i$, where Bw_i and Bw_f are the average initial and final body weight (g) of fish, respectively; SGR (%) = 100 ($\log_e$ final weight (g) - $\log_e$ initial weight (g)/time (days); FCR = dry weight of food offered (g)/wet weight gain (g); PER = weight gain (g)/protein fed (g, dry-weight basis); apparent nutrient retention (%) = 100 x (carcass nutrient content at the end of the experiment) - (carcass nutrient content at start of the experiment)/nutrient intake during experiment; results are mean of triplicate runs; ± SEM; value in each row with the same superscript are not significantly ($P<0.05$) different.

Table 3. Carcass composition, gross energy and visceral lipid content of fingerling *H. fossilis* fed varying dietary lipid levels.

Nutrient ($g \cdot 100^{-1}$ g)	Initial	Dietary lipid levels					
		3%	5%	7%	9%	11%	13%
Moisture	77.91^{a}	77.25^{a}	74.38^{b}	73.46^{bc}	72.74^{bd}	70.99^{d}	71.79^{cd}
	±0.99	±0.36	±0.60	±0.98	±0.42	±0.93	±0.95
Crude protein	13.51^{a}	14.76^{d}	17.78^{c}	18.90^{bc}	19.48^{b}	20.44^{a}	19.07^{a}
	±0.64	±0.07	±0.22	±0.37	±0.12	±0.81	±0.88
Crude fat	1.57^{d}	1.77^{d}	2.24^{c}	2.73^{bc}	3.35^{b}	4.32^{a}	4.97^{a}
(ether extract)	±0.09	±0.10	±0.08	±0.30	±0.44	±0.30	±0.54
Ash	1.89^{a}	1.77^{a}	1.78^{a}	1.88^{a}	1.87^{a}	1.88^{a}	1.78^{a}
	±0.12	±0.03	±0.12	±0.07	±0.09	±0.15	±0.16
Nitrogen-free extract	5.11^{a}	4.45^{a}	3.82^{ab}	3.02^{bc}	2.56^{c}	2.37^{c}	2.39^{c}
	±0.53	±0.30	±0.38	±0.32	±0.65	±0.78	±0.37
Gross energy ($kJ \cdot g^{-1}$)*	21.15^{e}	21.65^{e}	22.31^{de}	22.74^{cd}	23.25^{bc}	23.84^{ab}	24.31^{a}
	±0.23	±0.11	±0.22	±0.11	±0.45	±0.31	±0.26
Visceral fat*	6.76^{a}	9.40^{e}	13.99^{e}	18.53^{d}	26.74^{c}	31.87^{b}	35.18^{a}
	±1.06	±0.85	±1.37	±1.70	±1.22	±2.65	±1.66
Hepatosomatic index[1]	0.99^{b}	0.99^{b}	0.97^{b}	1.71^{a}	1.27^{b}	1.15^{b}	1.15^{b}
	±0.07	±0.14	±0.05	±0.25	±0.07	±0.08	±0.09

*Dry weight basis
[1]HSI = (liver weight/body weight) x 100; ± SEM (n=3)
Values in each row with the same superscript are not significantly ($P<0.05$) different.

and gross energy contents of fish revealed significant differences ($P<0.05$) among the test groups. Percentage dry matter increased with dietary lipid intake, whereas moisture content was negatively correlated ($r = -0.84$) to body fat content. Increase in dietary lipid intake, up to 11%, had a positive effect on crude protein. Carcass fat increased with dietary lipid ($r = 0.98$), but levels of lipid intake appeared to have no significant effect ($P>0.05$) on ash content. In contrast, gross energy increased significantly ($P<0.05$) with dietary lipid. A similar effect was evident on percent GE retention (Table 2). The maximum gross energy (27%) was found deposited in fish fed a diet of 13% lipid. Variations in visceral fat content were also significant ($P<0.05$) among the various test groups. Deposition of visceral fat showed a strong correlation ($r = 0.99$) with the dietary lipid level. The maximum amount of visceral fat deposition (35%) occurred in fish fed 13% dietary lipid. The HSI ranged between 0.99 to 1.71 and was not correlated to the dietary lipid levels.

Discussion

Fish in general have the ability to use fat and, to some extent, carbohydrate for energy purposes, sparing protein for growth. In *H. fossilis*, as evident from weight gain and feed conversion values, a level of 7% dietary lipid inclusion seemed essential for optimal growth. Earlier studies on species like channel catfish, *Ictalurus puntatus* (Dupree 1969; Stickney 1984), rainbow trout, *Salmo gairdneri* (Watanabe et al. 1979; Reinitz and Hitzel 1980) and red drum, *Sciaenops ocellatus* (Williams and Robinson 1988; Ellis and Reigh 1991; Serrano et al. 1992) indicated dietary lipid incorporation of 6-11% for optimal growth

and best feed conversion. Hanley (1991) concluded that diets with low and medium lipid levels (5-9%), containing 29-34 mg CP·kJ^{-1} digestible energy, are adequate to meet the requirements for protein and energy in Nile tilapia, *Oreochromis niloticus*. Reduced growth and poor feed conversion, as noticed in *H. fossilis* with higher levels (9-13%) of dietary lipid, was also observed in the catfish, *Clarias batrachus* (Anwar and Jafri, in press), channel catfish (Dupree 1969; Andrews et al. 1978; Santha and Gatlin 1991) and red drum (Williams and Robinson 1988). The reduction in growth of *H. fossilis* at higher lipid levels may be attributed to reduced lipid assimilation or imbalances in protein/fat ratio. Berge and Storebakken (1991) and De Silva et al. (1991) noted no increment in growth of halibut and red tilapia, respectively, when lipid was included in the diet beyond optimal protein:lipid ratio, at a given protein level. Similarly, reduced growth, protein deposition (%) and poor feed conversion in *H. fossilis* at high (48%) dietary carbohydrate intake (diet I) could be related to low levels of carbohydrate tolerance, and this observation is in agreement with the findings of Ellis and Reigh (1991) and Serrano et al. (1992) on red drum. In *H. fossilis*, a dietary carbohydrate-to-lipid ratio of about 5 (diet III) was found most effective in achieving maximum weight gain and protein deposition. Garling and Wilson (1977) reported maximum weight gain in channel catfish at a comparable carbohydrate-to-lipid ratio in the diet.

Carcass composition of fish showed that both crude protein content and protein deposition (%) increased significantly ($P<0.05$) with dietary lipid levels up to 7%, and thereafter changes in crude protein content were not so prominent, but protein retention (%) decreased with increase in dietary lipid. This observation is similar to the findings of Hanley (1991) who noted reduced protein gain in Nile tilapia on high lipid diets. Addition of extra lipid, to conserve protein, appeared to be of limited use beyond 7% dietary lipid inclusion. The lipid content of diets is generally considered to be the most important factor influencing carcass fat in fish (Buckley and Groves 1979). Increased dietary lipid intake in *H. fossilis* resulted in higher body fat content, as has been reported for several other fish species (Lee and Putnam 1973; Garling and Wilson 1977; Reinitz and Hitzel 1980; Zeitler et al. 1984; Ellis and Reigh 1991; Serrano et al. 1992). Williams and Robinson (1988) noted an increase in wholebody lipid of red drum to 23% with dietary lipid increment to 11% only. The changes in body fat content of *H. fossilis* showed an inverse relationship to moisture percentage, similar to that reported in tilapia (Viola et al. 1988; De Silva et al. 1991). Despite reduction in body weight gains at higher levels of lipid (9-13%), the body gross energy content increased with dietary lipid increments. Bromley (1980) attributed this phenomenon in turbot, *Scophthalmus maximus*, to the method adopted in measuring growth through live weight gain, maintaining that a unit of protein energy desposition in the body is accompanied by weight increase of about eight times that associated with the deposition of a similar quantity of energy as lipid.

Compared to muscle lipid, deposition of visceral fat in *H. fossilis*, particularly around the intestine, was greater at each incremental lipid level in the diet. Viola et al. (1988) noted an accumulation of visceral fat amounting to about 40% of total body fat in tilapia. No definite pattern of changes in hepatosomatic

index (HSI) has been reported in different fish species with respect to varying dietary lipid levels. In *H. fossilis*, groups reared on diets of 7-13% lipid showed higher values of HSI, but these changes were not consistent. De Silva et al. (1991), on the other hand, observed that HSI increased in red tilapia with dietary lipid intake. In contrast, Millikin (1983), and Berge and Storebakken (1991) found no change in HSI with respect to dietary protein and lipid concentration.

On the basis of growth rate, feed conversion and nutrient retention, it may be concluded that *H. fossilis* needs 7% lipid, as an energy source in a 40% CP diet with 18.2±0.21 $kJ \cdot g^{-1}$ gross energy and a carbohydrate-to-lipid ratio of around 5, for maximum utilization and growth. Feeding these fish with a diet beyond 9% lipid inclusion should be avoided, as it had little effect in enhancing further growth and protein deposition.

Acknowledgments

The authors are indebted to the Chairman, Department of Zoology, Aligarh Muslim University, Aligarh, India, for providing the laboratory facilities; and to Professor John E. Halver, School of Fisheries, HF-15, University of Washington, Seattle, USA, for his valuable suggestions. Financial assistance rendered by the Far Eastern Regional Research Office of the United States Department of Agriculture, and the Indian Council of Agricultural Research, New Delhi, is gratefully acknowledged.

This study forms part of the research (Grant no. FG-IN-645) financed by the United States Department of Agriculture, Office of International Cooperation and Development, Special Foreign Currency Research Program.

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Manuscript received 8 July 1993; accepted 3 February 1995.