Bangladesh J. Fish. Res., 4(1), 2000: 27-34

Feeding metabolism in an Indian major carp (*Catla catla* Lin.) fed on different protein diets

S. C.Chakraborty*, M. A. Kafi, M. H. Rashid[1] and A. K. Sarker[2]
Department of Fisheries Technology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
[1]Department of Biochemistry, Bangladesh Agricultural University, Mymensingh
[2]Department of Chemistry, Bangladesh Agricultural University, Mymensingh
**Corresponding author*

Abstract
Feeding metabolism in an Indian major carp, *Catla catla* fingerlings of 10.8±0.56g was investigated in a flow-through water recirculating system. The metabolic energy loss in resting metabolism and feeding metabolism were determined by the indirect method of oxygen consumption followed by multiplication by suitable oxycalorific coefficient. This was done in four metabolic chambers of a respirometer system. Ten fish fingerlings of mean total weight of 109.5, 110.4 and 112.8g/chambers respectively each in two experimental runs of three treatments a, b and c were used. The mean resting metabolic rate during unfed condition showed no significant variation in different treatments. The fish in three treatments a, b and c fed on diets containing 28, 33 and 38% crude protein had significantly different ($p<0.05$) post-fed SDA magnitude of 497.7, 638.7 and 735.5 mgO_2/chamber/day having an equivalent energy loss of 12.68, 14.68 and 15.86 KJ respectively. The SDA co-efficient in three treatments a, b and c were 14.95, 19.00 and 22.36% respectively whereas, respiratory energy - 'R' as % of mean total ingested energy in three treatments were 26.93, 31.17 and 34.74% respectively showing a significant increase ($p<0.05$) with increase of protein.

Key words: Feeding metabolism, protein diets, *Catla catla.*

Introduction

The metabolic heat energy loss associated with the digestion and transformation of ingested food into metabolisable is known as specific dynamic action (SDA). SDA can represent a major component of respiratory energy budget. To determine the food ration and growth performance of fish, it is necessary to know the specific dynamic action which may range from 4 to 45% of the ingested energy and generally approaching 30% of the gross energy ingested. In poikilotherms SDA has been observed as a post-prandial increase in the rate of oxygen consumption expressed as mgO_2 (then converted into KJ or Kcal). Following food ingestion the oxygen consumption rate in fish increases and then gradually declines back to its resting level (Jobling 1980). The principal component of SDA effect - the total magnitude, the peak increased level and the duration (Jobling 1980). The "magnitude" is the sum of excess metabolic heat production expressed as mgO_2 (or expressed into Kcal) induced by the ingested meal, integrated from the time

metabolism first rises to the peak value and falls back to the base is determined by plotting the curve of increased oxygen consumption after feeding against time until it subsides to the prefeeding rates (resting rate) and then intergrating the area beneath the curve. SDA is expressed as a percentage of the total caloric value of the food ingested (Hill 1976) in metabolic term of SDA coefficient (Smith *et al.* 1978). Whereas, SDA duration is the time during which the oxygen consumption by the fed fish is above resting metabolism.

Estimation of the metabolic expenditure associated with feeding are usually obtained from laboratory experiments using different types of respirometer where the motor activity of fish inside the respirometer (metabolism chamber) chambers may be controlled as much as possible (Chakraborty *et al.* 1992b). The increased oxygen consumption for a fed fish with a defined ration in the chambers may be measured accurately over a defined period of time. The SDA magnitude is dependent on so many factors among which the quantitative and qulitative aspects of dietary protein is important. The SDA coefficient of a particular fish in response to particular diet is very important in fish culture where they must be taken into consideration when constructing energy budgets involved in feeding and growth during holding on growing period.

Till to date, there have been no reported work on post-fed oxygen consumption (specific dynamic action -SDA) in Indian major carp, *Catla catla*. The aim of the study was to investigate the feeding metabolism - SDA in an Indian major carp, *Catla catla* fed on different protein diets.

Materials and methods

Healthy fingerlings of Indian major carp, *Catla catla* (10-12g) from a single stock was collected in August 1996 from local fish farm. Acclimation of the fingerlings was made for 15 days in large plastic pool with continuous aeration at 28 ± 1^{0}C.The fingerlings were given prophylectic treatment with NaCl (3%) dip for 10 minutes and 0.5mg/L methylene blue bath for 24 hours. Faecal matter produced by fingerlings were removed everyday morning and evening. The pool water was partly (about 40%) replaced with fresh aerated water every morning. The fingerlings were not fed on first two days of acclimation. From the third day they were given pelleted diet containing fish meal, mustard oil cake, wheat flour and bran etc. having 30% dietery protein at the rate of 1% as maintenance ration. Normal dark- light period was maintained throughout the study period.

The experiment was conducted in metabolism chamber in a flow through water recirculatory system in laboratory of Fisheries Technology Department. Measurement of respiration rates in unfed, fed and post-fed condition were done in system of metabolism chambers according to the design made by Chakraborty (1992).

Three experimental diets A, B and C containing 28, 33 and 38% crude protein levels respectively were prepared by using fish meal, mustard oil cake, duck weed, rice bran and wheat bran (Table 1).The diets prepared as pellets were sun dried for 1 day followed by oven drying at 70^{0}C for over night. The proximate composition of these dry experimental diets are given in Table 1. The diets were fed at a known ration to three

treatment groups of fish in metabolism chambers. Each of three treatments had two replicates each having ten fishes of 10.8±0.56g fish in metabolism chambers. The metabolism chambers were marked as M_1, M_2, r and M_3 where the chamber "r" was used as reference and had no fish in it. A constant water flow- rate of 30 L/h through the flow meter was maintained in all metabolism chambers during direct monitoring of oxygen consumption by an oxygen probe kept in cuvette. After the first day in unfed condition for acclimation in the chambers, the fish fingerlings were subjected to measure resting metabolic rate for the following two unfed days over 24 hours period. The 24 hours measurement of the oxygen consumption (directly measured by oxygen probe of oxygen meter in the cuvette) in each three group of fish were measured as resting rate and the values were expressed as mg O_2/kg/h (Chakraborty *et al.* 1999).

Table 1. Formulation and proximate composition of experimental diets prepared from various ingredients

Ingredients	Diet (s)		
	A	B	C
Fish meal	20.00	35.00	50.00
Mustard oil cake	21.50	17.50	18.50
Duck weed	21.00	22.00	16.00
Rice bran	25.00	18.00	8.00
Wheat bran	10.00	5.00	5.00
Chromic oxide	0.50	0.50	0.50
Vitamin and Mineral premix*	2.00	2.00	2.00
Proximate composition (% dry matter basis)			
Parameters			
Dry matter	95.16	93.48	93.77
Moisture	4.84	6.52	6.23
Crude protein	28.08	33.82	37.29
Crude lipid	8.27	7.83	10.66
Ash	16.11	18.70	21.91
NFE**	42.20	32.53	23.41
Gross energy value (kJ/g)***	21.15	21.31	21.74

**Rhone Poulenc, Bangladesh*

*** NFE = Nitrogen free extract, calculated as 100 - (crude protein + lipid + ash + moisture)*

**** Calculated by Bomb calorimeter (Gallankamp)*

After 3 days, the fishes in metabolism chambers a, b and c were given known amount of diets having either 18, 33 or 38% crude protein. Feeding of fish started at 9.00 am and continued up to 4.00 pm. The pellets which were left uneaten and entered into faecal column collected, dried. The uneaten weight were subtracted from the amount offered to fish and the value was treated as the amount of diet ingested. Alternate hourly feeding of fish continued according to their response during feeding period. Twenty four hours hourly monitoring of oxygen consumption as mg O_2/kg/h of the post-fed fish group of fish in each metabolism chambers was recorded for alternate 13 days as days 3, 5, 7, 9, 11, 13. 15, 17, 19, 21, 23, 25 and 27 for each replicates.

The proximate composition of the diets, fish and faeces were analysed according to standard procedure given in AOAC (1980). The gross energy content of fish, feeds and faeces were determined by Bomb Calorimeter (Gallankamp, Automatic Adiabatic Bomb Calorimeter). The gross energy loss through metabolism - respiration (R) was determined indirectly by measuring oxygen consumption (Brafield and Llewellyn 1982) of fish in the chambers. The values thus obtained were multiplied by the calculated Q_{ox} (oxycalorific co-efficient of respective substrate) value of individual diet which were 14.15, 14.01 and 13.87 J/mgO_2 respired by fish fed on diet A, B and C respectively.

Oxygen consumption by fish in the chambers was directly measured as mg/L by using an oxygen meter (Check:mate, oxygen probe) and calculated by the following formula:

$$\text{Oxygen consumption, mg } O_2\text{/ kg/ h} = \frac{(O_2\text{Sat} - O_2\text{out}) \times \text{water flow rate (L/h)} \times 100}{\text{wt. of fish (g) in chamber}}$$

where, O_2 Sat = Dissolved Oxygen (DO) in the reference chamber

O_2 out = Dissolved Oxygen (DO) in the out let of metabolism chamber containing fish.

The values thus obtained were multiplied by the respective Q_{ox} of 14.15, 14.01 and 13.87 J/mgO_2 for fish fed on diet A, B and C respectively to convert the values into energy.

Statistical analysis of the study was done by analysis of variance (ANOVA) to compare treatment means using the statistical package of Minitab (Ryan *et al.* 1985).

Results

Oxygen consumption of unfed *Catla catla* in different treatments showed no significant variation ($p>0.05$) for resting metabolism (Chakraborty *et al.* 1999). The mean oxygen consumption of fish during resting metabolism over 24 hours period were 151.66 ± 4.86, 153.91 ± 6.23 and 150.26 ± 4.38 mgO_2/kg/hr for treatments a, b and c respectively considering oxycalorific value of 13.56 (Brafield and Llewellyn 1982). These values were recalculated and found 5.40, 5.52 and 5.52 KJ/chamber/day in treatment a, b and c respectively.

Figure 1. shows the post-feeding oxygen consumption over resting rate of *Catla catla* fed on 28, 33 and 38% dietary protein. In all cases oxygen consumption started to increase after the feeding commenced and continued for several hours to a level to reach the highest (peak) and then started to decrease to the level of resting rate showing no further effect of feeding on respiration. Fish feeding at 38% dietary protein, the mean oxygen consumption over 24 hrs period were found a much higher value having a longer duration than those found with 28 and 33% protein diet (Fig. 1). Various aspects of oxygen consumption by fish in three treatments fed on diets A, B and C containing 28, 33 and 38% dietary protein respectively is shown in Table 2. The mean daily oxygen consumption (R) over 24 hrs in fish fed on 28, 33 and 38% protein diet in treatment a, b and c was found 341, 394 and 419 mgO_2/kg/h respectively. These values were found significantly different ($p<0.05$) from one another and found to increase with an increase

of dietary protein (Table 2). The higher mean peak value with a larger SDA magnitude was obtained in fish fed on 38% dietary protein. Table 2 also shows that the peak oxygen consumption by fish fed on diet A, B and C was 565.5, 657.5 and 696.0 $mgO_2/kg/h$ respectively with percent increase over mean resting rate (peak mean) of 273, 327 and 363 respectively. These values increased significantly ($p<0.05$) with the increase of dietary protein. Mean SDA duration was quite high with values of 21 to 22 plus hours in fish fed on the three diets.

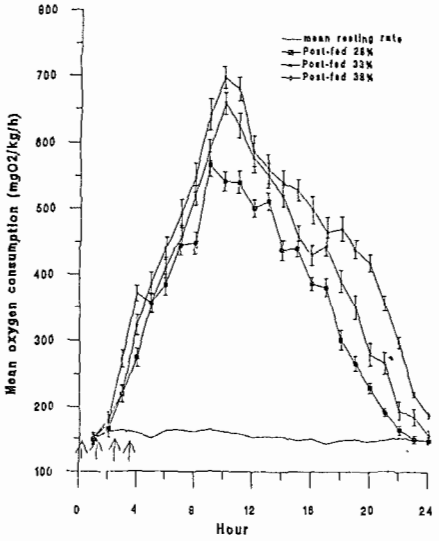

Fig. 1. Post feeding oxygen consumption over resting rate of *C. catla* fed on 28, 33 and 38% dietary protein.

Table 2. Different aspects of specific dynamic action (SDA) in fish in three treatment groups A,B and C fed on28, 33 and 38 % dietary Protein (N = 2)

Treatment	Total fish wt.(g) in metabolism chambers	Mean ration (g/day)	Mean resting rate ($mgO_2/kg/h$)	Peak oxygen consumption ($mgO_2/kg/h$)	Peak mean (% increase over mean resting rate)	Time to reach the peak
A	109.50	2.19	151.66	565.50	272.87	7
B	110.40	2.21	153.90	657.50	327.19	8
C	112..80	2.10	150.26	6996.00	363.20	8
Treatment	Duration (h)	*Mean* metabolism (mgO_2 /kg/h)	*SDA* magnitude (mgO_2/chamb/day)	*Mean daily* energy intake (KJ/day)	*SDA Coeff* (%)	"R" as % of "C^"
A	21	341.00	497.59	47.09	14.95	26.93
B	22+	394.10	638.72	47.10	19.00	31.17
C	22+	419.40	736.53	45.65	22.36	34.74

The post feeding effect in fish fed on 38% dietary protein still had some effect which continued beyond the scope of measurement due to data recording time over 24 hours cycle. However, this amount being an insignificant was overlooked. The mean SDA magnitude in post fed fish in treatment a, b and c over 24 hours was recorded as 498, 639 and 737 mgO_2/chamber/day respectively (Table 2). When recalculated the mean

metabolism (R) in fish in each chamber fed on 3 diets was found significantly different ($p<0.05$) having the values of 896, 1048 and 1143 mgO_2/chamber/day and showed an equivalent energy loss of 12.68, 14.68 and 15.86 KJ/chamber/day respectively (Table 2). Whereas, the equivalent energy of SDA magnitude was 7.04, 8.95 and 10.21 KJ/chamber/day in fish fed on diet A, B and C respectively with resulting SDA coefficients of 14.95, 19.00 and 22.36% in fish in treatment a, b and c respectively showing a significant increase with the increase of dietary protein (Table 2). Total daily metabolic expenditure including resting metabolic rate - R, as % of total ingested energy (consumption, C^) was 26.93, 31.17 and 34.74% which was found directly dependent on the dietary protein content (Table 2). The regression model drawn for the relationship between energy in consumption- C^ and energy lost in metabolism, R as % of C^ is expressed by the following metabolical model :

$Y = 5.1737 + 0.781 X$ ($r^2 = 0.9976$)

Where, Y = Energy lost in metabolism, R as % of ingestion C^.

X = Dietary protein level (28 to 38% range).

Discussion

There have been reports about the values of oxygen consumption for resting metabolism in different fish species and a large variation is evident (Hamada and Maeda, 1983, Chakraborty *et al.* 1992) depending upon some factors like size of fish, water temperature, fish species etc. Thus, Kausch (1969) found that 10 ± 0.5 g size young carp, *Cyprinus carpio* had resting metabolic rate of 80, 136 and 214 mgO_2/kg/h at 10, 15 and 20°C respectively whereas, Huisman (1974) showed that *Cyprinus carpio* of 31-47g and 2-16g had resting metabolic rate of 48 and 83 mgO_2/Kg/h respectively. However, Chakraborty *et al.* (1992) obtained mean resting rate for unfed common carp of 70 ± 10g size as 152 mgO_2/Kg/h. Therefore, this experiment had showed a quite reasonable value among the reported values for resting metabolic rate.

Fig. 1 shows that the post-prandial oxygen consumption in response to feeding of different diets containing 28, 33 and 38% crude protein increased with increase of dietary proetin. Similar results were obtained in blue gill, *Lepomis machrochirus* by Pierce and Wissing (1974); in *Cyprinus carpio* by Chakraborty *et al.* (1992b). The time to reach the peak oxygen consumption in this study varied from 7 to 8 hours after feeding and was not significantly affected by the energy intake and dietary protein content (Table 2). In the study with largemouth bass, *Micropterus salmoides* Tandler and Beamish (1981) observed that maximum oxygen uptake reached within 2 to 4 hours of feeding whereas, Chakraborty *et al.* (1995) obtained this time to reach the peak value by *C. carpio* with 1 to 7 hours after feeding. Jobling and Davies (1980) noted that the peak level of oxygen consumption in plaice, *Pleuronectus platessa* reached before satiation and concluded that the processes of producing the SDA effect are limited by cellular metabolism. Hamada and Ida (1973) reported two peaks in post-fed common carp, one 3-4 hours after feeding and the other after 5-7 hours after feeding which was dependent to the amount of food intake. The duration of elevated metabolic rate is variable between fish species under different experimental condition. Present study shows a small difference in duration (h)

of elevated metabolic of 21 to >22 hours (Table 2). Similarly, the SDA duration ranged between 10 to 19 hours, 12 to 19 hours and 10 to 21 hours in common carp fed on 20, 35 and 50% dietary protein respectively which was dependent on ration size but not dietary protein content (Chakraborty 1992). This study showed the similar findings that there was no significant variation in duration of SDA effect of fish fed on different protein diets. Tandler and Beamish (1981) showed that the rate of oxygen uptake remained elevated which was positively related to energy ingested, negetively related to body weight and unrelated with protein content of the diet in bass (*Micropterus salmoides*). Soofiani and Hawkins (1982) obtained similar results for juvenile cod, *Gadus morhua*. LeGrow and Beamish (1986) working with rainbow trout *Salmo gairdneri* found that protein content in the diet does not significantly influence the duration of elevated metabolism. SDA magnitude in this study was found clearly related to protein content in the diets (Table 2) and increased significantly with increase of dietary protein.Chakraborty *et al.* (1992b) obtained that SDA magnitude was related to both energy intake from varying dietary protein content. In largemouth bass, the SDA magnitude increased linearly with the protein content of the diets (Tandler and Beamish, 1980). SDA coefficient values in this study with *C. catla* fed on 28, 33 and 38% dietary protein were 14.95, 19.00 and 22.36% respectively (Table 2). Cho *et al.*, (1976), Jobling and Davies (1980), Tandler and Beamish (1980) obtained the SDA co-efficient values of 8.0-12.0% in *Salmo gairdneri* , 10.0-18% in *Pleuronectes platessa* and 5.1-17.5% in *Micropterus salmoides* respectively. Similarly, Medland and Beamish (1985) and Chakraborty *et al.* (1992b) obtained the SDA co-efficient as 8.5-33.7% in *Salmo gairdneri*, 8.99-15.94% in *Cyprinus carpio* respectively. Noted that SDA co-efficient is dependent on the protein content of the diet in rainbow trout. LeGrow and Beamish (1986) and Chakraborty *et al.* (1992b) found that SDA co-efficient in rainbow trout and common carp respectively increased with the protein content of the diet as has been obtained in this study with *Catla catla*.

In the present study the oxygen consumption was considered as total energy of metabolism comprising resting, feeding and restricted active metabolism and was designated as 'R'. Whereas, SDA was determined by subtraction between 'R' and 'mean resting metabolism value' for feeding metabolism. However, this study showed a significant ($p<0.05$) increase in metabolic rate with increase in dietary protein (Table 2). Similarly, Chakraborty *et al.* (1992b) obtained the values of 'R' as 27.92% to 30.51% of energy in 'C^' which showed were increasing with the increase of dietary protein in *Cyprinus carpio.*

From the model developed for % energy lost in 'R' is of importance for aquaculturist because, the post-feeding oxygen requirement in the intensive culture system can be calculated where the protein levels (and if ration levels) are known. This is also important in energy budgeting to determine the amount of energy wasted or expended as 'SDA' or 'R'.

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(Manuscript received 11 August 1999)