Growth response of *Catla catla* (Hamilton, 1822) raised in manured tanks on low fishmeal diets, with a note on carcass composition and digestive enzyme activity

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ABSTRACT

Low fishmeal diets (10%) with varied levels of maize (40-31%) and sardine oil (0-9%) were fed for 120 days to triplicate groups of catla (*Catla catla* Hamilton, 1822) fingerlings (average weight 1.84-1.90 g) stocked @ 1 fish per m² in cement tanks with soil base fertilised with poultry manure. Fish fed on diet containing 6% oil and 34% maize (T₂) showed the highest (p<0.05) growth, followed by those received 9/31 (T₃), 3/37 (T₁) and 0/40% (T₀) oil/maize supplemented diets. Food conversion ratio improved due to oil supplementation, while protein efficiency ratio was not affected significantly. Dietary lipid had a positive impact on carcass protein and lipid levels (p<0.05). Fish survival ranged from 90.73% in all the treatment groups to 92.58% in the control, without any significant (p>0.05) difference among them. Net fish production on termination of the experiment was lowest (820 g) in the control and the highest (1017.85 g) in T₂ treatment. Viscerosomatic index (VSI) varied from 3.59 (T₂) to 4.65% (T₀) and hepatosomatic index (HSI) from 1.13 (T₀) to 1.91% (T₃). RNA/DNA ratio was highest (3.05) in T₂ and lowest (1.84) in T₀. An increase in intestinal amylase activity was observed in the treated fish, while intestinal protease and lipase activity showed increase only with higher levels of oil supplementation (6 and 9%). No difference (p>0.05) in enzyme activity was observed in the hepatopancreas of the control and treated fish. The results indicated beneficial effects of incorporating maize and fish oil in low fishmeal diet for catla.

Keywords: Carcass composition, *Catla catla*, Digestive enzymes, Fishmeal, Growth response, Maize, Sardine oil

Introduction

Fishmeal is generally added to carp diets to increase feed efficiency and growth as it helps to enhance feed palatability, nutrient uptake, digestion and absorption. The balanced amino acid composition of fishmeal complements other animal and vegetable nutrients to provide synergistic effects that promote faster growth (Mile and Chapman, 2005). Furthermore, fishmeal has low fibre content and is also a valuable source of vitamins B₁, B₂, B₆ and B₁₂, in addition to calcium, phosphorous, magnesium, potassium and trace elements. However, due to uncertainty in availability, the high cost and environmental impact, it is advisable to keep the fishmeal component of fish diets low. This is generally done by replacing part of the fishmeal component with cheaper plant protein sources (Mbahinzireki et al., 2001) that have fairly good amount of protein and high levels of carbohydrate. In such diets, the energy content can be enhanced through the addition of oil.

Although carps can utilise carbohydrates efficiently, lipids are considered as important energy sources in carp diet (Steffens, 1996). Carbohydrates improve the pelleting quality and nutrient value of diets (Lovell, 1989) while lipids play important physiological roles in providing energy, essential fatty acids and fat soluble nutrients for normal growth and development of fish. Deficiency of dietary lipid may increase the use of protein for energy and result in increased ammonia excretion leading to water pollution (Kaushik and Cowey, 1991). Carbohydrate and oil have been demonstrated to spare protein in fish and crustaceans (Nankervis et al., 2000; Keshavanath et al., 2002; Ovie et al., 2005; Singh et al., 2006; Mohseni et al., 2011; Wang et al., 2014).

Knowledge of the optimal level of protein and the protein sparing effects of non-protein nutrients such as lipids or carbohydrates can be used effectively in reducing feed costs (Shiau and Lin, 1993). The aim of this study was to examine the growth response of *Catla catla*
(Hamilton, 1822) to diets containing low level of fishmeal with varying levels of maize and sardine oil, when grown in manured tanks. Catla is a fast growing Indian major carp, feeding mainly on zooplankton at the surface (Jhingran, 1991). It accepts artificial diets and therefore, is a popular species for polyculture in India.

**Materials and methods**

**Diet**

Four low-protein diets were formulated (Varghese et al., 1976) to contain 24% protein (Table 1). The feed ingredients (fishmeal, groundnut oil cake, rice bran and maize) were dried, pulverised and sieved to obtain uniform particle size (400 µm). Sardine oil was substituted by weight at 3, 6 and 9% levels in diets T₁, T₂ and T₃ respectively, by reducing the quantity of maize to that extent. Diet T₀ without oil supplementation served as the control. Oil incorporation to the diets was done by adding the requisite amount of oil to 250 ml of water containing a few drops of Tween-80 (Polysorbate-80, Himedia Laboratories, Mumbai, India), mixing thoroughly with the help of a glass rod and using the suspension along with additional 550 ml of water per kg of ingredient. The diets were prepared following the method described by Jayaram and Shetty (1981) to obtain pellets of 2 mm dia. The pellets were dried in a thermostatic oven at a temperature of 40°C and packed in heavy duty plastic bags until use.

**Experimental set up**

The experiment was carried out over a period of 120 days in 12 cement tanks of 18 m² each, with 15 cm thick soil base. The tanks were cleaned and dried, limed at 400 kg ha⁻¹ (0.72 kg per tank) and initially fertilised with poultry manure at 2000 kg ha⁻¹ (3.6 kg per tank), while subsequent fertilisation was done at 5% of the initial dose at fortnightly intervals. The manure contained 2.51% nitrogen, 2.72% phosphorus, 1.95% potassium and 2.30% calcium. Ground water was used to fill the tanks, maintaining a depth of 90±5 cm throughout the experimental period. Catla fry obtained from B. R. Project Fish Farm, Shimoga were acclimatised for a week and were stocked at a density of 1 per m² (18 per tank) as practiced by Indian aquafarmers (Jhingran, 1991). Their initial average weight in the different treatments ranged from 1.84 to 1.90 g. The four test diets were fed to triplicate groups of fishes every day once in the morning at 5% body weight as per Varghese et al. (1976), using plastic trays suspended into the tanks 50 cm below the water surface. A minimum of 50% of the stocked fish from each tank was sampled every fortnight for assessing growth. The quantity of feed given was adjusted after each fish sampling, taking into consideration the weight of the fish. On termination of the experiment, the surviving fish were weighed, based on which the following parameters were calculated:

- **Specific growth rate** (SGR) = \( \frac{(\text{ln Final weight} - \text{ln Initial weight})}{\text{Experimental duration in days}} \) × 100
- **Feed conversion ratio** (FCR) = \( \frac{\text{Feed consumed (g)}}{\text{Weight gain (g)}} \)
- **Protein efficiency ratio** (PER) = \( \frac{\text{Weight gain (g)}}{\text{Protein intake (g)}} \)
- **Condition factor** (K) = \( \frac{W \times 100}{L^2} \)
  where, \( W \) = weight of fish (g), \( L \) = length of fish (cm)
- **Yield** (g) = Mean body weight (g) x Total number of live fish at harvest
- **Viscerosomatic index** (VSI) (%) = Weight of viscera (g)/Weight of fish (g) x 100
- **Hepatosomatic index** (HSI) (%) = Weight of liver (g)/Weight of fish (g) x 100

| Ingredient (%) | T₀ | T₁ | T₂ | T₃ |
|---------------|----|----|----|----|
| Fishmeal      | 10 | 10 | 10 | 10 |
| Groundnut oil cake | 25 | 25 | 25 | 25 |
| Rice bran     | 24 | 24 | 24 | 24 |
| Maize         | 40 | 37 | 34 | 31 |
| Sardine oil   | 0  | 3  | 6  | 9  |
| Vitamin and mineral mixture | 1  | 1  | 1  | 1  |

| Proximate composition (%) | T₀ | T₁ | T₂ | T₃ |
|---------------------------|----|----|----|----|
| Moisture                  | 7.41±0.15 | 8.00±0.02 | 7.92±0.92 | 7.88±0.62 |
| Crude protein             | 24.54±0.15 | 24.08±0.56 | 23.78±0.40 | 23.84±0.52 |
| Lipid                     | 7.01±0.11 | 9.23±0.08 | 11.56±0.19 | 13.19±0.22 |
| Ash                       | 13.12±1.02 | 13.20±0.91 | 13.01±0.68 | 12.86±0.91 |
| Crude fibre               | 8.12±0.53 | 7.95±0.61 | 7.76±0.42 | 7.51±0.16 |
| NFE                       | 39.80 | 37.54 | 35.97 | 34.72 |
| Total energy (kJ g⁻¹)     | 15.12 | 15.49 | 16.06 | 16.49 |
| CHO: L ratio              | 5.68 | 4.01 | 3.11 | 2.63 |
**Water quality**

Water samples were collected at 15 day intervals between 07.00 and 08.30 hrs for analysis of temperature, dissolved oxygen, pH, free carbon dioxide and total alkalinity. Water temperature was recorded using a thermometer and pH was measured with a digital pH meter (ELICO, India). Dissolved oxygen, free carbon dioxide and total alkalinity were determined following standard procedures (APHA, 1992). Plankton samples were also collected by filtering 100 l of water from different locations of each experimental tank using a net made of bolting silk (No. 30) having 60 µm mesh size. Dry weight of plankton was determined by drying the samples in a hot air oven at 100°C till a constant weight was obtained. Quantitative estimation of plankton was done by the direct census method using a Sedgewick Rafter cell having 100 equal squares (Jhingran et al., 1969).

**Biochemical composition**

Proximate composition of feed ingredients, diets and fish carcass was analysed in triplicate. Three fish from each tank were used for carcass analyses. Protein was determined by Kjeltc (Tecator-1002), lipid by Soxtec (Tecator-1043) and fibre by Fibreetec (Tecator-1017). Ash was analysed by incineration (AOAC, 1995) and nitrogen free extract (NFE) by the ‘difference method’ of Hastings (1976). Energy content of the feed ingredients and diets was calculated using values of 22.6 kJ g⁻¹ for protein, 38.9 kJ g⁻¹ for lipid and 17.2 kJ g⁻¹ for carbohydrate as NFE (Mayes, 1990).

**Enzyme assay**

On termination of the experiment, the activity of digestive enzymes, amylase, protease and lipase in the intestine and hepatopancreas of the experimental fish was analysed in triplicate as per the methods of Bernfeld (1955), Kunitz (1947) and Bier (1955) respectively. Pooled tissues from six fishes per treatment were used for enzyme assay.

**Estimation of muscle DNA and RNA**

Nucleic acids from the experimental fish muscle were extracted using perchloric acid (Burton 1956). DNA was determined by the diphenylamine method of Giles and Myres (1965) and RNA as described by Ceriotti (1955).

**Statistical analysis**

Comparison among different dietary treatments was done by one-way analysis of variance (ANOVA), followed by Duncan’s multiple range test (p<0.05) (Duncan, 1955; Snedecor and Cochran, 1968).

**Results and discussion**

Water quality parameters recorded in the tanks during the experimental period were: water temperature - 20.0 to 22.8°C; pH - 7.46 to 8.42; dissolved oxygen - 4.56 to 8.62 ppm; free carbon dioxide - 0 to 2.40 ppm and alkalinity (CaCO₃) - 55.44 to 98.28 ppm, which were within the tolerable limits for catla. The diets (T₀-T₃) used in this study had varying levels of maize (decreasing from 40 to 31%), a rich carbohydrate source and sardine oil (increasing from 0 to 9%), a major lipid source and their fishmeal content was constant at 10%. The crude protein content of diets varied between 23.24% (T₀) and 24.54% (T₃), while lipid content ranged from 7.01% (T₀) to 13.19 (T₃), increasing with oil supplementation, but not exactly reflecting the added oil percentage. The carbohydrate:l lipid (CHO:L) ratio was found decreasing with increase in fish oil addition, with the lowest value in diet T₀ (2.63), highest in T₃ (5.68), 4.01 in T₁ and 3.11 in T₂. Fish fed diet T₀ containing 34% maize and 6% added oil (NFE 35.97% and fat 11.56%) showed the best growth (62.33 g); this probably indicates the optimum level of carbohydrate and fat required by catla fingerlings when fed a diet having 24% protein and grown under pond conditions. Best growth of catla was recorded in T₀ treatment, followed by T₁ (57.29 g), T₃ (55.21 g) and T₂ (49.22 g), growth being significantly (p<0.05) higher in all the treatment groups compared to the control (T₃). Specific growth rate (% per day) followed the same trend (Table 2). Based on the performance of fish, CHO:L ratio of 3.11 may be considered as optimal for catla. Erfanullah and Jafri (1998) recorded maximum weight gain, SGR, FCR, PER, protein retention and energy retention in catfish, Clarias batrachus fed a 35% protein, 27% carbohydrate and 8% lipid diet, corresponding to a CHO:L ratio of 3.38. The optimum CHO:L ratio found in the present study is close to that of catfish, even though the protein content of the diets used was lower at 24%, an indication of lower protein requirement by catla. Nonetheless, it is pertinent to consider the protein contribution by natural food, since the present experiment was conducted in manured tanks. In systems where fertilisation is used to enhance natural feed production, a part of the nutritional requirement of the fish is met by the natural food (Priyadarshini et al., 2011). According to Albrecht and Breitsprecher (1969), the mean protein, carbohydrate and lipid contents of natural food are 51.1, 27.3 and 7.7% respectively, with calorific value ranging from 6.7 to 23.8 kJg⁻¹. Hephert (1988) reported 18-35% protein, 7-10% lipid and 27-48% ash content (dry matter basis) for planktonic algae in ponds, which indicates the nutritive value of natural food. Natural food also improves the utilisation of artificial diets by supplying certain digestive enzymes (Jhingran, 1991). The mean plankton density (no l⁻¹) recorded in different treatments over the experimental
duration is given in Table 3. The average dry weight of plankton in $T_1$, $T_2$, and $T_3$ treatments varied from 2.39 to 70.44, 2.01 to 65.48, 2.45 to 50.14 and 2.67 to 71.25 mg 100 l$^{-1}$ respectively over the experimental duration. The mean phytoplankton density showed a steady increase till the 60th day of the experiment and a decline thereafter. Phytoplankton belonging to Chlorophyceae, Cyanophyceae and Bacillariophyceae were encountered. Chlorophyceae consisted of *Closterium* sp., *Pediastrum* sp., *Pandorina* sp., *Eudorina* sp., *Volvox* sp., *Ulothrix* sp. and *Scedesmus* sp. Among Cyanophyceae, *Anaabaena* sp., *Microcystis* sp. and *Spirulina* sp. were conspicuous. The dominant Bacillariophyceae were *Synedra* sp., *Melosira* sp., *Fragilaria* sp. and *Navicula* sp. No clear cut trend was observed in mean zooplankton density. The important zooplankton belonged to the groups Rotifera represented by *Brachionus* sp., *Keratella* sp., *Asplanchna* sp., *Polyarthra* sp. and *Filinia* sp. Copepoda with *Cyclops* sp. and *Diaptomus* sp. and cladocera consisting of *Moina* sp. The increase in mean plankton density might be due to the effect of poultry manure used as well as the fertilising effect of the fish fecal matter and the decline thereafter is attributable to effective grazing by the growing fish whose protein requirement would be higher. Lovell (1975) observed that natural food plays a key role in the determination of dietary protein requirements of fish under pond conditions. When mirror carp was grown with both natural food and a high protein supplemental feed, fish growth and specific growth rate were positively correlated with the natural food (Lam and Shephard, 1988).

The use of protein energy from diet is wasteful from the nutritional, economic and ecological points of view when compared to lipids and carbohydrates and therefore, it is worthwhile supplying much of the required energy as possible through lipid and carbohydrate (Peres and Oliva-Teles, 1999). Watanabe et al. (1987) observed that it would be advisable to use high lipid (15%) with low protein (30%) in the diet of common carp in order to reduce nitrogen excretion and pollution of the environment, without hampering fish growth. Nandeesha et al. (1999) reported improved SGR and food conversion in common carp fed a 30% protein diet, with increasing level of sardine oil incorporation. Gangadhar et al. (1997) reported that the growth of rohu (*Labeo rohita*) fingerlings fed a diet containing 25% protein and 9% lipid was comparable with those fed 30% protein and 6% lipid. Their results indicate that growth induced by 3% dietary oil is comparable to that produced by 5% dietary protein. It may be presumed that with decreased dietary protein levels, optimal lipid requirement increases. All fish groups receiving supplemental oil in the present study performed better than the control, indicating protein sparing by the three supplemented oil levels tested, through diets that had different levels of maize. Protein sparing by lipid has been demonstrated in a number of fish species (Gangadhar et al., 1997; Weatherup et al., 1997; Mongile et al., 2014).

### Table 2. Growth parameters and carcass composition (mean±SD) of catla from different treatments

| Parameter                        | $T_1$          | $T_2$          | $T_3$          | $T_4$          |
|----------------------------------|----------------|----------------|----------------|----------------|
| Initial weight (g)               | 1.88±0.04a     | 1.84±0.03a     | 1.86±0.05a     | 1.90±0.03a     |
| Final weight (g)                 | 49.22±1.10a    | 55.2±0.52b     | 62.33±1.09a    | 57.29±1.26a    |
| Initial length (cm)              | 5.42±0.02a     | 5.44±0.07a     | 5.43±0.02a     | 5.43±0.03a     |
| Final length (cm)                | 13.58±0.04a    | 14.50±0.13b    | 15.29±0.23a    | 14.70±0.06a    |
| Net weight gain (g)              | 47.34±0.81a    | 53.37±0.51b    | 60.47±1.11a    | 55.39±1.27a    |
| SGR (%)                          | 1.18±0.2b      | 1.22±0.01b     | 1.27±0.01a     | 1.23±0.01b     |
| FCR                             | 2.18±0.055     | 2.08±0.025     | 2.09±0.026     | 2.10±0.056     |
| PER                             | 1.60±0.045     | 1.71±0.01     | 1.70±0.035     | 1.67±0.045     |
| Survival (%)                     | 92.58±1.85a    | 90.73±1.85a    | 90.73±1.85a    | 90.73±1.85a    |
| Condition factor                 | 1.96           | 1.81           | 1.74           | 1.80           |
| VSI                             | 4.65±0.17a     | 4.44±0.07a     | 3.59±0.29a     | 4.55±0.16a     |
| HSI                             | 1.13±0.14a     | 1.47±0.13b     | 1.59±0.07b     | 1.90±0.18b     |
| RNA/DNA ratio                    | 1.84           | 2.42           | 3.05           | 2.73           |

Values with the same superscript in each row are not significantly different (p>0.05).
However, excessive dietary lipid reduces feed intake and growth performance of fish (Regost et al., 2003; Kim et al., 2006).

FCR was the best in T2 treatment, being significantly different from that of the control. Though PER improved with oil supplementation, there was no significant (p>0.05) difference between treated groups and the control. No effect of dietary lipid/CHO:L ratio was observed on the survival of catla which varied from 90.73% in all the treated groups to 92.58% in the control. Net fish yield ranged from 820 g (T0) to 1017.85 g (T3), it being 901.58 g and 935.55 g in tanks of 18 m2 for 120 days in T1 and T2 treatments. The values of condition factor ‘K’ were 1.96, 1.81, 1.74 and 1.80 in T0, T1, T2 and T3 respectively. Condition factor is vital to culture system management, because it reflects the specific condition under which organisms grow (Araneda et al., 2008). Higher condition factors indicate good health with an isometric growth, which is desirable in fish farms (Ayode, 2011). Lee and Kim (2009) observed significant influence of dietary CHO:L ratio on condition factor, as well as VSI and HSI of grower rockfish. VSI of catla from T1 treatment was significantly lower than the rest of the treatments and the control, whereas HSI showed significant increase with every level of oil supplementation (Table 2). This reflects better utilisation of mesenteric fat under T1 and an increase in liver glycogen/fat of treated fish with increasing dietary lipid level. Kim et al. (2012) found that varied lipid levels and sources significantly increased HSI in the olive flounder (Paralichthys olivaceus), but did not affect VSI; and they attributed changes in HSI to changes in lipid composition of the diets. VSI and HSI are important indicators of digestion and absorption; synthesis and secretion of digestive enzymes as well as carbohydrate metabolism (McLaughlin, 1983). Ighwela et al. (2014) used these indices for the measurement of condition in Oreochromis niloticus fed varying dietary maltose levels. The RNA/DNA ratio was highest (3.05) in T1 treatment and lowest (1.84) in T3, reflecting the trend of fish growth. RNA concentration and the RNA/DNA ratio have usually been related to the tissue growth rate (Perago’n et al., 2000), changes in RNA/DNA ratio reflecting recent changes in growth rate (Bulow, 1987). The increasing RNA/DNA ratio and the fish growth recorded with all the test diets in this study can be correlated with increased protein synthesis. Organisms in good condition tend to have higher RNA/DNA ratios than those in poor condition (Chicharo and Chicharo, 2008).

Effect of the test diets on the chemical composition of carcass was found to be significant. Significant (p<0.05) reduction in carcass moisture content in fishes was recorded in T3, while in the other two treatments the reduction was marginal. Protein and lipid contents were higher (p<0.05) in all fish groups receiving oil supplement, the highest being in T2 (13.98%) and T3 (3.54%) treatments respectively (Table 2). Earlier studies have shown a significant positive correlation between fish weight and carcass lipid levels, as found in the present study (Hemre and Sandnes, 1999; Torstensen et al., 2001; Ghanawi et al., 2011). Increase in carcass/muscle lipid with increasing dietary lipid has been reported for most species investigated (Bazaz and Keshavanath, 1993; Gangadhar et al., 1997; Erfanullah and Jafri, 1998; Nandeesh et al., 1999; Reftie et al., 2001; Jan et al., 2013).

Digestive enzyme activity was influenced by the test diets (Fig. 1). Significant (p<0.05) increase in intestinal amylase, protease and lipase activity was recorded in the treated fish, with the exception of the latter two in T3. However, no difference (p>0.05) in the activity of these enzymes was observed in the hepatopancreatic tissue of fish from control and treatment groups. The increased amylase activity in the treated fish could be attributed to effective utilisation of carbohydrate from the diet. Carps are known to utilise carbohydrate preferentially over lipid due to high amylolytic activity (Jafri et al., 1995). Higher protease activity in the treated fish can be correlated with higher carcass protein. De Silva et al. (1991), Keshavanath and Jagadeesh (1994) and Vergara et al. (1999) reported that increasing dietary lipid level

### Table 3. Mean plankton density (no. l−1) in different treatments

| Plankton | Treatment | Days | 0 | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 |
|----------|-----------|------|---|----|----|----|----|----|----|-----|-----|
| Phytoplankton | T0 | 169<sup>a</sup> | 1218<sup>b</sup> | 4489<sup>b</sup> | 9286<sup>b</sup> | 10779<sup>b</sup> | 8474<sup>c</sup> | 5417<sup>c</sup> | 7248<sup>c</sup> | 3875<sup>c</sup> |
| Phytoplankton | T1 | 212<sup>c</sup> | 1674<sup>b</sup> | 3039<sup>b</sup> | 7605<sup>c</sup> | 9574<sup>b</sup> | 7185<sup>c</sup> | 5144<sup>c</sup> | 4354<sup>c</sup> | 3569<sup>c</sup> |
| Phytoplankton | T2 | 168<sup>b</sup> | 1122<sup>b</sup> | 3447<sup>b</sup> | 6626<sup>c</sup> | 10587<sup>c</sup> | 6500<sup>c</sup> | 4292<sup>c</sup> | 3933<sup>c</sup> | 2016<sup>c</sup> |
| Phytoplankton | T3 | 190<sup>b</sup> | 1675<sup>b</sup> | 5902<sup>b</sup> | 8359<sup>c</sup> | 11975<sup>c</sup> | 6833<sup>c</sup> | 3500<sup>c</sup> | 3454<sup>c</sup> | 5166<sup>c</sup> |
| Zooplankton | T0 | 55<sup>a</sup> | 27<sup>b</sup> | 117<sup>c</sup> | 228<sup>c</sup> | 372<sup>c</sup> | 389<sup>c</sup> | 290<sup>c</sup> | 187<sup>c</sup> | 186<sup>c</sup> |
| Zooplankton | T1 | 16<sup>c</sup> | 15<sup>c</sup> | 87<sup>b</sup> | 130<sup>c</sup> | 150<sup>c</sup> | 150<sup>c</sup> | 185<sup>c</sup> | 181<sup>c</sup> | 105<sup>c</sup> |
| Zooplankton | T2 | 15<sup>c</sup> | 84<sup>c</sup> | 60<sup>c</sup> | 132<sup>c</sup> | 61<sup>c</sup> | 102<sup>c</sup> | 44<sup>c</sup> | 54<sup>c</sup> | 129<sup>c</sup> |
| Zooplankton | T3 | 17<sup>c</sup> | 35<sup>c</sup> | 66<sup>c</sup> | 93<sup>c</sup> | 81<sup>c</sup> | 104<sup>c</sup> | 91<sup>c</sup> | 84<sup>c</sup> | 182<sup>c</sup> |

Values with the same superscript in each column are not significantly different (p>0.05)
increased protein retention, enhancing the proportion of dietary protein utilised for growth. Increased lipase activity/lipid digestibility was found in mahseer (Bazaz and Keshavanath, 1993), rohu (Gangadhar et al., 1997) and European seabass (Peres and Oliva-Teles, 1999) fed increasing levels of dietary lipid.

Incorporation of maize and sardine oil into the diets influenced growth, food conversion, protein efficiency, carcass protein and lipid contents and digestive enzyme activity, but not fish survival. Among the levels tested, 34% maize and 6% additional oil proved more effective, inducing the best growth. The results clearly show that in manured tanks, low protein diet supplemented with maize and sardine oil augments the growth of catla.

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