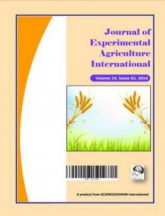

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# Feeding Preferences and Digestive Physiology of Indian Carps in Polyculture Pond System

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***Authors' contributions***

*All authors have collaborated and made significant contribution towards the compilation of this work. Author GS and AB designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Authors KA and SAA managed the analyses of the study, managed the literature searches, drafted the discussion and performed editing of the manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

Catla (*Catla catla*), mrigala (*Cirrhinus mrigala*) and rohu (*Labeo rohita*) are commercially significant pond species in India. Despite being cultured for a long time in village ponds, sufficient information on the feeding preference and digestive physiology variables of these species in managed and unmanaged polyculture pond systems in India is not available. We carried out the gut content analysis and estimated the forage ratio for catla, rohu and mrigala species. The intestinal enzymes and liver glycogen were also estimated. Analysis of gut contents of *C. catla* indicated that the fish is herbivorous or phytoplanktivorous. Gut contents of *L. rohita* from all the ponds indicated it is Omniplanktivorus fish. In case of *C. mrigala*, the gut contents indicated that the fish is zooplanktivorous. Based on the results of digestive physiology, it can be inferred that consumable plant material would probably be exploited with the highest intensity by *C. catla* compared to *L.*

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*rohita* and with the lowest intensity by *C. mrigala*. On the other hand, animal components would be utilized more intensively by *C. mrigala* followed by *L. rohita* and with least intensity by *C. catla*. Digestive enzyme activity appeared to be comparatively higher in managed ponds. This study provides a deeper insight on the occupation of different feeding stratus by the three species of fish within the available food in polyculture arrangement allowing better understanding of how good production occurs and revealing that each species is focusing on a particular feeding stratus.

*Keywords: Catla catla; Cirrhinus mrigala; digestive physiology; gut contents; intestinal enzymes, Labeo rohita; liver glycogen; plankton.*

## 1. INTRODUCTION

The potential roles of aquaculture, particularly small-scale aquaculture needs to be assessed for their contributions towards sustainable development. Pond fish culture is a major fragment of inland fisheries in a global context. Fishponds consist of stagnant water bodies of various magnitudes. Rational management of fish ponds is an inevitable condition for the feasibility and efficiency of fish production. In intensive systems, high fish stocking densities are fed with high-quality complete feeds which result in a higher yield per unit production system [1]. The production level in a fish pond is dependent essentially on how abundant fish food organisms are and the manifestation of suitable ecological and environmental pond conditions. In a fish pond, the first step in the food chain is established by primary producers (e.g. phytoplankton) which undergo photosynthetic activities to derive their nutritional requirements.

Various works have carried out studies on the functioning of the pond ecosystems including [2-10]. Growth characteristics of fish depend upon the type of food preference. The capacity of fish to utilize nutrients depends upon factors such as the presence of enzyme producing microorganisms, the magnitude of suitable enzyme production and enzymatic distribution along the gut lumen [11-18]. Digestive processes in fish are understood to a lower extent in comparison to mammals, even though the data availability on fish to date have demonstrated that digestive enzyme studies in fish are similar qualitatively in comparison to that observed for other vertebrate organisms.

Digestibility depends on the physical state of food, as well as the type and quality of enzymes secreted. The activity of digestive enzymes has been reported to change with the feeding habits of fish or the availability of fish food organisms [19]. Different works have looked into the endogenous digestive enzyme production in fish [11,12,14]. However sufficient material in relation to enzymatic production, source and implication in fishes is rare. Specific areas having insufficient understanding include the environmental relationship with the microflora in fish, bacterial spoilage [20], the monitoring of changes in the fish farm [21] and the profiling of antibiotic resistance presence and levels in indigenous flora [22].

Fish always take a large number of bacteria into their gut system from water, sediments and food that are populated with bacteria [23] and are a rich source of nutrients. Some reports are available on the microbial enzymatic production in fish gastrointestinal tract [13-18] however there is a deficit of information relating to these enzymes generating endosymbionts in fish gut. It is clear from such studies that the quality and quantity of these enzyme-producing microorganisms vary and that there are variations in the amounts of enzymes present in fish gastrointestinal tracts. Sufficient information on the feeding preference and digestive physiology variables of Catla (*Catla catla*), mrigala (*Cirrhinus mrigala*) and rohu (*Labeo rohita*) in managed and unmanaged polyculture pond systems in India is not available. Polyculture arrangement allows fish to use a different feeding stratus within the available natural food, this study can provide a deeper insight of whether any species are occupying expected trophic level, therefore allowing a good production given that each species is focusing on a particular feeding stratus.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

For this study, two polyculture ponds were identified in the district of Kurukshetra which is located in the Haryana state of India (Longitude, 76º-26'E and Latitude, 29º-52'N) (Fig. 1). The first pond (pond A) had sufficient infrastructure and management of household effluents with

restricted cattle movement (managed pond). The second pond (pond B) was unmanaged with no management of incoming effluents from domestic sources and movement of cattle in and out of the pond area. The detailed description is available in Singh [24]. Both pond location had similar geographical features, had clay bottom soil and unrestricted exposure to sunlight.

## 2.2 Gut Content Analysis and Forage Ratio of Indian Major Carps

Live specimens of 120 adult freshwater fishes for each species of *C. catla, C. mrigala* and *L. rohita* from each of the ponds were selected for the present study (total of 360 specimens). Fish were sampled using a cast net in the weight range of 248.00 to 298.00 g at fortnight intervals between April 2010 and March 2011. These specimens included both juveniles and adult fish assuming they have had a well-established pattern of feeding and digestion. After collection, the fish were pithed and the ventral surface was brushed with 1% iodine solution [25]. Following this, fishes were immediately dissected and the digestive tract along with its contents was removed and preserved in 10% formalin for laboratory analysis. The gut contents volume was measured and the food organisms were identified in different taxonomic groups up to the genus level. The quantitative and qualitative analysis was carried out as described in Garg [26].

## 2.3 Forage Ratio

Plankton samples from each respective pond were collected and the quantities of different taxonomic groups were analyzed up to genus level. The forage ratio was calculated using Equation 1 shown below:

$$F=g/w \quad (1)$$

Where F is the forage ratio, g is the percentage of organisms in the gut contents and w is the percentage of organisms present in the water sample. F = 1 indicates random selection of food from the environment, F < 1 indicates avoidance of particular food item and F > 1 indicates that the item is actively preferred/chosen by the fish. The higher the value of F is the more preferred the food item is.

## 2.4 Analysis of Digestive Physiology

Fish alimentary tracts were homogenized with 10 parts of subzero 0.89% NaCl solution [14]. Proteolytic enzyme activity was measured using Bovine Serum Albumin (BSA) as 1% substrate following the methods of Walter [27]. Proteins were estimated as outlined in Lowry [28]. Intestinal amylase activity was estimated by utilizing starch solution as 1% substrate following the methods of Bernfield [29]. Intestinal cellulose activity was measured using microcrystalline cellulose as 1% substrate.

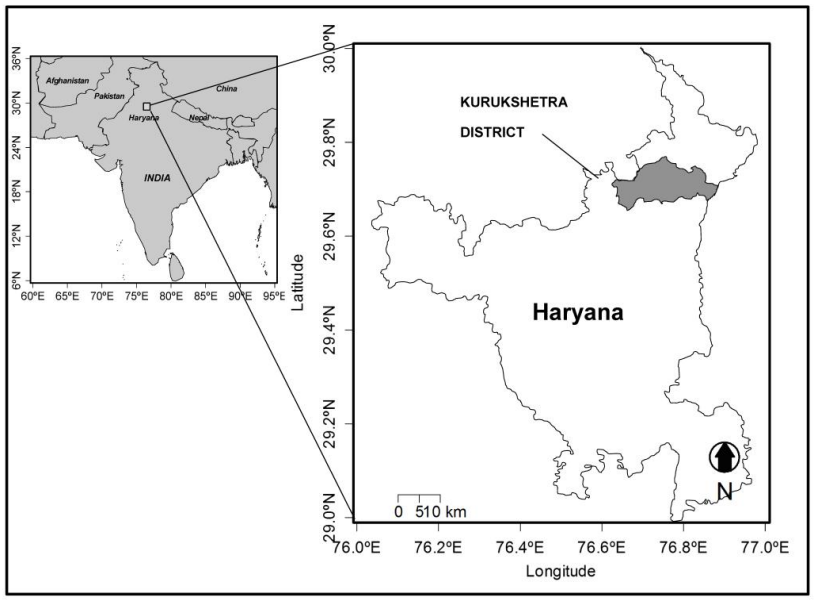


**Fig. 1. The location of the Kurukshetra district in Haryana, India is presented**

#### 2.4.1 Preparation of extract for lipase assay

The intestinal tissue was homogenized in a homogenizer with two volumes of ice-cold acetone. The prepared homogenate was filtered and washed with acetone, followed by acetone-ether mixture and ether. The residue was then air dried. One gram of the residue was stirred with 20 mL of ice-cold water for 15 minutes prior to use. The contents were centrifuged for a period of 10 minutes at 15,000 rpm. Following this, the supernatant was used as crude enzyme extract. Lipase activity was estimated from the extract using the method outlined in Colowick and Kaplan [30].

### 2.5 Estimation of Liver Glycogen

The liver was extracted from the fish and the extra blood was removed from the surface by blotting with filter paper. The liver was then transferred into a weighed stoppered test tube which contained 2.0 mL of 30% KOH solution per gram of the liver sample and was re-weighed. The liver tissue was digested by placing in a water bath at boiling temperature for 90 minutes. It was cooled and two volumes of 95% ethanol were added and re-heated to boiling temperature in a water bath. Following this content was left overnight under cold conditions. The contents were centrifuged at 3,000 rpm for 20 minutes and the precipitate that was obtained was dissolved in approximately 5-10 mL of lukewarm water. The glycogen was then re-precipitated with two volumes of 95% ethanol and the precipitate was collected through centrifugation at 5,000 rpm for approximately 15-20 minutes at 4°C and rinsed several times with 60% (v/v) ethanol. The precipitates were further transferred to a container with 2N H2SO4 per gram of liver. Hydrolysis of the contents was done by placing in a water bath at boiling temperature for 3 to 4 hours. Upon cooling down the contents it was neutralized with 6N NaOH using phenol red as an indicator. Following this, the volume was made to and filtered. The glucose content was estimated in an appropriate aliquot. The factor of 0.93 was employed for conversion of glucose to glycogen. The sugar was measured following the methods of Dubois [31] which depends on a color chemical reaction between concentrated $H_2SO4$, phenol and simple sugars.

### 2.6 Statistical Analysis

To determine if significant differences existed between the different ponds for each parameter, ANOVA was applied followed by Duncan Multiple range test. The coefficient of correlation was calculated using the SPSS package.

## 3. RESULTS

### 3.1 Gut Content Analysis and Forage Ratio of Indian Carps – Pond A

*C. catla* gut contents from the pond A indicated the presence of members of *Bacillariophyceae* (23.80%), *Chlorophyceae* (16.66%) along with unidentified matter and debris (40.48%) (Table1). Forage ratio indicating the preferred food items were calculated (Table 2) and results have revealed significantly ($p$<0.05) high value of *C. catla* forage ratio for *Cyclotella* (2.53) and *Spirogyra* (2.28) whereas the value for zooplankton was much lower in significance. This indicated that *C. catla* is a phytoplanktivorous and *Cyclotella* and *Spirogyra* are its preferred food items.

In case of *C. mrigala* gut contents showed the presence of members of *Rotifera* (12.78%) and *Cladocera* (12.79%) along with some unidentified matter and debris (46.66%) (Table1). Forage ratio (Table 2) revealed significantly (p<0.05) high value of forage ratio for *Diaptomous* (2.53) and *Daphnia* (2.43). This clearly indicated that *C. mrigala* is zooplaktovorous and *Diaptomous* and *Daphnia* are its preferred food items.

For *L. rohita*, the gut contents showed the presence of *Bacillariophyceae* (15.91%), *Chlorophyceae* (15.91%) and *Copepoda* (10.22%) along with unidentified matter and debris (44.31) (Table1). Forage ratio (Table 2) showed significantly (p<0.05) high value for *Spirogyra* (2.47), *Diaptomous* (1.65), *Synedra* (1.46) and *Brachionus* (1.41). This indicates that *L. rohita* is omnivorous and *Spirogyra*, *Diaptomous*, *Synedra* and *Brachionus* are its preferred food items.

### 3.2 Gut Content Analysis and Forage Ratio of Indian Carps – Pond B

Gut contents of *C. catla* from pond B indicated the presence of members of *Bacillariophyceae* (29.74%), and *Chlorophyceae* (11.90%) along with some unidentified matter and debris (43.47%) (Table1). Calculated forage ratio (Table 3) revealed significantly (p<0.05) high value of forage ratio for *Cyclotella* (4.28), *Synedra* (2.14), *Navicula* (1.60) and *Closterium (*1.60). The value for zooplankton was much lower in significance

**Table 1. Gut content analysis of *Catla catla, Cirrhinus mrigala* and *Labeo rohita* from pond A and pond B of the Kurukshetra district. Values shown are in percent**

| Gut contents | Cultured species | | | | | |
|---|---|---|---|---|---|---|
| | *Catla catla* | | *Labeo rohita* | | *Cirrhinus mrigala* | |
| | Pond A | Pond B | Pond A | Pond B | Pond A | Pond B |
| **Phytoplankton** | | | | | | |
| Debris | 40.48 | 43.47 | 44.31 | 45.83 | 46.66 | 49.01 |
| *Bacillriophyceae* | 23.80 | 29.74 | 15.91 | 23.21 | 10.66 | 9.27 |
| *Chlorophyceae* | 16.66 | 11.90 | 15.91 | 7.73 | 6.40 | 6.95 |
| **Zooplankton** | | | | | | |
| *Rotifera* | 7.14 | 2.97 | 6.81 | 5.16 | 12.78 | 6.95 |
| *Cladocera* | 7.14 | 5.95 | 6.81 | 10.32 | 12.79 | 11.58 |
| *Copepoda* | 4.76 | 5.95 | 10.22 | 7.73 | 10.66 | 16.22 |

indicating that *C. catla* is phytoplanktivorous and *Cyclotella*, *Synedra*, *Navicula* and *Closterium* are preferred food items.

The gut contents of *C. mrigala* from pond B indicated the presence of members of *Copepoda* (16.22%) and *Cladocera* (11.58%) along with some unidentified matter and debris (49.01%) (Table 1). Forage ratio (Table 3) revealed significantly ($p<0.05$) high value for *Daphnia* (2.31) and *Diaptomous* (1.73). This clearly indicated that *C. mrigala* is zooplanktvorous and *Daphnia* and *Diaptomous* have preferred food items.

In case of *L. rohita*, the gut contents showed the presence of members of *Bacillariophyceae* (23.21%) and *Cladocera* (10.32%) along with some unidentified matter and debris (45.83%) (Table 1). Forage ratio (Table 3) indicated significantly ($p<0.05$) high values for *Cyclotella* (3.87), *Closterium* (2.18) and *Daphnia* (1.96). This indicated that *L. rohita* omnivorous and *Cyclotella*, *Closterium* and *Daphnia* are preferred food items.

## 3.3 Intestinal Enzymes and Liver Glycogen

### 3.3.1 Pond A

Total and specific protease, amylase and cellulase activity were high but total and specific lipase activity and liver glycogen were low in *C. catla* in comparison to *L. rohita* and *C. mrigala*. For *L. rohita* total and specific protease, amylase and cellulase activity were high, while lipase activity and liver glycogen were in moderate quantity. In case of *C. mrigala* total and specific protease, amylase and cellulase activity were

**Table 2. Forage ratio of *Catla catla, Cirrhinus mrigala* and *Labeo rohita* in the pond A of the Kurukshetra district**

| Forage ratio | Cultured species | | |
|---|---|---|---|
| | *Catla catla* | *Labeo rohita* | *Cirrhinus mrigala* |
| **Phytoplankton** | | | |
| *Synedra* sp. | 0.67 | 1.46 | 1.01 |
| *Navicula* sp. | 1.14 | 1.23 | 0.76 |
| *Cyclotella* sp. | 2.53 | - | 1.14 |
| *Closterium* sp. | 1.10 | 0.60 | 1.32 |
| *Microspora* sp. | - | 1.10 | - |
| *Spirogyra* sp. | 2.28 | 2.47 | - |
| Total phytoplankton | 7.72 | 6.86 | 4.23 |
| **Zooplankton** | | | |
| *Brachionus* sp. | 1.30 | 1.41 | 0.86 |
| *Diaptomous* sp. | 1.01 | 1.65 | 2.53 |
| *Daphnia* sp. | 1.82 | 1.32 | 2.43 |
| *Moina* sp. | - | 1.10 | - |
| *Cyclops* sp. | - | - | 1.01 |
| Total zooplankton | 4.13 | 5.48 | 6.83 |

**Table 3. Forage ratio of *Catla catla, Cirrhinus mrigala* and *Labeo rohita* in the pond B of the Kurukshetra district**

| Forage ratio | Cultured species | | |
|---|---|---|---|
| | ***Catla catla*** | ***Labeo rohita*** | ***Cirrhinus mrigala*** |
| **Phytoplankton** | | | |
| *Synedra* sp. | 2.14 | 1.45 | 0.92 |
| *Navicula* sp. | 1.60 | 1.45 | 1.38 |
| *Cyclotella* sp. | 4.28 | 3.87 | 0.92 |
| *Closterium* sp. | 1.60 | 2.18 | 1.38 |
| *Ulothrix* sp. | 1.28 | - | - |
| Total phytoplankton | 10.90 | 8.95 | 4.60 |
| **Zooplankton** | | | |
| *Brachionus* sp. | 0.40 | 0.72 | 1.03 |
| *Diaptomous* sp. | 0.80 | 0.72 | 1.73 |
| *Daphnia* sp. | 1.07 | 1.94 | 2.31 |
| *Cyclops* sp. | - | 0.41 | 0.79 |
| Total zooplankton | 2.27 | 3.79 | 5.86 |

lowest but total and specific lipase activity and liver glycogen were highest as compared to *L. rohita* and *C. mrigala* (Table 4).

### 3.3.2 Pond B

Total and specific protease, amylase and cellulase activity were high but total and specific lipase activity and liver glycogen were low in *C. catla* in comparison to *L. rohita* and *C. mrigala*. In case of *L. rohita* total and specific protease, amylase and cellulase activity, lipase activity and liver glycogen were in moderate quantity. In case of *C. mrigala* total and specific protease, amylase and cellulase activity were lowest but total and specific lipase activity and liver glycogen were highest as compared to *L. rohita* and *C. mrigala* (Table 5).

## 4. DISCUSSION

In Delince [2] it was emphasized that the elements which have significant influence on fish production, do not act in isolation but in a network of interactions. The three main influences are food availability, dissolved oxygen levels and the concentration of ammonia in the water [2]. Our study reported that low fish production coincides with high BOD, high ammonia and low DO. A study on the influence of environmental conditions on the population growth of the American catfish by Cuenco [32] showed that, apart from the availability of food and oxygen in the water, non-ionized ammonia was also a significant factor influencing population growth.

The natural food of fish in the present study has been unraveled by different works through examination of the gut contents [33,34,35,36,37] which revealed that they are planktivorous. Analysis of gut contents of *C. catla* indicated that apart from debris/decaying matter, *Bacillariophyceae* and *Chlorophyceae* were the dominant groups. Although detritus/debris was high, the preferred food items as determined by calculating forage ratio were *Cyclotella*, *Spirogyra*, *Synedra* and *Closterium* indicating that the fish is herbivorous, i.e. phytoplankton feeder or phytoplanktivorous. Forage ratio for zooplanktons was lower than phytoplankton in all cases for *C. catla*. Kumar [33] reported similar results. No significant differences were observed within the unmanaged and pond A.

In case of *C. mrigala*, analysis of gut contents revealed the dominance of *Cladocera*, *Copepoda* or *Rotifera* groups which are all zooplankton along with large quantities of mud debris irrespective of the cultural practice (managed or managed). The forage ratio was low for phytoplanktons indicating that the fish is zooplanktivorous. Gut contents of *L. rohita* from all the ponds indicated large quantities of members of *Bacillariophyceae*, *Chlorophyceae*, *Copepoda* and *Cladocera*. High forage ratio was observed for *Spirogyra*, *Cyclotella*, *Cyclops* and *Diaptomus* and sometimes *Daphnia*. This indicated that *L. rohita* as Omniplanktivorus fish. Mohanty [38] also reported similar results and found that since *L. rohita* is a column feeder, it takes in all type of planktons. The large quantities of debris/decaying matter in the gut of all three species (Table 1) may be due to the physiological structures of the mouth. In selection of the preferred food item, the mouth structures may also be allowing debris and decaying matter

**Table 4. Intestinal enzyme activity of *Catla catla, Cirrhinus mrigala* and *Labeo rohita* from pond A of the Kurukshetra district**

| Component | Cultured species | | |
|---|---|---|---|
| | ***Catla catla*** | ***Labeo rohita*** | ***Cirrhinus mrigala*** |
| Total protease activity | $3.67 \pm 0.43^{A}$ | $3.63 \pm 0.20^{A}$ | $3.25 \pm 0.49^{A}$ |
| Specific protease activity (μg $g^{-1}h^{-1}$) | $3.10 \pm 0.08^{A}$ | $2.84 \pm 0.04^{B}$ | $2.41 \pm 0.01^{C}$ |
| Total amylase activity | $5.22 \pm 0.53^{A}$ | $4.11 \pm 0.98^{A}$ | $4.04 \pm 1.81^{A}$ |
| Specific amylase activity (mg $g^{-1}$ $h^{-1}$) | $2.04 \pm 0.04^{A}$ | $1.64 \pm 0.00^{B}$ | $1.45 \pm 0.02^{C}$ |
| Total cellulase activity | $5.36 \pm 0.37^{A}$ | $1.90 \pm 0.03^{B}$ | $1.87 \pm 0.78^{B}$ |
| Specific cellulase activity (mg $g^{-1}$ $h^{-1}$) | $1.32 \pm 0.00^{A}$ | $1.12 \pm 0.00^{B}$ | $0.91 \pm 0.02^{C}$ |
| Total lipase activity | $2.64 \pm 0.06^{C}$ | $3.16 \pm 0.03^{B}$ | $3.57 \pm 0.05^{A}$ |
| Specific lipase activity (mg $g^{-1}$ $h^{-1}$) | $1.10 \pm 0.02^{C}$ | $1.42 \pm 0.02^{B}$ | $1.68 \pm 0.02^{A}$ |
| Liver glycogen (mg $g^{-1}$) | $1.74 \pm 0.04^{C}$ | $2.60 \pm 0.06^{B}$ | $3.52 \pm 0.02^{A}$ |

*$^{A, B, C}$ Values having same superscripts do not have significant difference whereas values having alternate superscripts have significant difference*

**Table 5. Intestinal enzyme activity of *Catla catla, Labeo rohita* and *Cirrhinus mrigala* from pond B of the Kurukshetra district**

| Component | Cultured species | | |
|---|---|---|---|
| | ***Catla catla*** | ***Labeo rohita*** | ***Cirrhinus mrigala*** |
| Total protease activity | $3.39 \pm 0.01^{A}$ | $3.27 \pm 0.25^{A}$ | $3.66 \pm 0.00^{A}$ |
| Specific protease activity (μg $g^{-1}h^{-1}$) | $2.74 \pm 0.04^{A}$ | $2.54 \pm 0.04^{B}$ | $2.32 \pm 0.00^{C}$ |
| Total amylase activity | $7.42 \pm 0.73^{A}$ | $7.00 \pm 0.47^{A}$ | $6.18 \pm 0.25^{A}$ |
| Specific amylase activity (mg $g^{-1}$ $h^{-1}$) | $1.70 \pm 0.07^{A}$ | $1.55 \pm 0.00^{A}$ | $1.36 \pm 0.00^{B}$ |
| Total cellulase activity | $3.35 \pm 0.98^{A}$ | $1.48 \pm 0.21^{A}$ | $1.25 \pm 0.30^{A}$ |
| Specific cellulase activity (mg $g^{-1}$ $h^{-1}$) | $1.15 \pm 0.03^{A}$ | $0.98 \pm 0.01^{B}$ | $0.85 \pm 0.02^{C}$ |
| Total lipase activity | $2.54 \pm 0.06^{C}$ | $3.00 \pm 0.08^{B}$ | $3.40 \pm 0.02^{A}$ |
| Specific lipase activity (mg $g^{-1}$ $h^{-1}$) | $0.99 \pm 0.02^{C}$ | $1.35 \pm 0.05^{B}$ | $1.53 \pm 0.01^{A}$ |
| Liver glycogen (mg $g^{-1}$) | $1.54 \pm 0.04^{C}$ | $2.40 \pm 0.02^{B}$ | $3.21 \pm 0.05^{A}$ |

*$^{A, B, C}$ Values having same superscripts do not have significant difference whereas values having alternate superscripts have significant difference*

to enter the gut. Further work may be needed to verify this.

The capability of fish to utilize nutrients from food is dependent upon several factors and digestive enzymes are one of them. Fish are quite specific in the digestive capability of different groups of food. It is necessary to understand the association amongst the type of food consumed and quality and quantity of the appropriate enzymes produced in the alimentary tract. It was observed that specific cellulase and amylase activities were higher in *C. catla* which also advocate the phytoplanktivorous feeding habit of this fish species. It was further observed that these activities are higher in pond A in comparison to pond B. In Dhage [11], Sarbahi [39] and Phillips [40] it was stated that the amylase activity in the intestinal tract of herbivores carps is more intensive in comparison to the carnivorous fish. Bairagi [16] reported the presence of amylolytic bacteria (responsible for exogenous amylase production) from the gut of *C. catla* even after 24 hours of starvation. Analysis of digestive enzymes from the gut of *C. mrigala* revealed more lipase in comparison to other enzymes. Dhage [11] also reported that lipase activity is more concentrated in the intestine of *C. mrigala*. Liver glycogen was also high, supporting the zooplanktivorous nature of the fish as revealed by gut content analysis. In case of *L. rohita* amylase as well as protease activity was high. In addition, the values were higher for pond A in comparison to pond B, advocating better digestibility and hence high growth. Presence of high amounts of amylase and protease further support the omniplanktivorous nature of the fish. Das and Tripathi [14] have also determined high activity of amylase in the gastrointestinal tract of fish having omnivorous feeding habit. Bairagi [16] reported considerable amount of proteolytic and amylolytic bacteria present in the gastrointestinal tract of *L. rohita* and suggested that along with endogenous source there is also exogenous source for protease and amylase.

Hepatic glycogen was low in *C. catla* and *L. rohita*. Bhattacharya [41] reported that hepatic glycogen is hydrolyzed by *α*-amylase and *β*-amylase and later metabolized in the glycolytic sequence. In the present studies amylase was high in *C. catla* and *L. rohita* and thus glycogen was low. All enzymatic activities were recorded at elevated levels in the gut of fishes reared in pond A advocating higher growth. Based on the results of enzymatic profiling, it can be inferred that consumable plant material would probably be exploited with the highest intensity by *C. catla* compared to *L. rohita* and with the lowest intensity by *C. mrigala*. On the other hand, animal components would be utilized more intensively by *C. mrigala* followed by *L.rohita* and with the lowest intensity by *C. catla*. This study provides a deeper insight on the occupation of different feeding stratus by the three species of fish within the available food in polyculture arrangement allowing better understanding of how good production occurs and revealing that each species is focusing on a particular feeding stratus.

The difference in utilization efficiency was more marked in pond A and this is because of digestive enzymes being quantitatively higher, there are better digestibility and feed utilization and higher growth rate. Digestion depends on the physical state of food, as well as the kind and quantity of enzymes secreted. It has been reported that in addition to endogenous digestive enzymes [11,12,14] in fish gastrointestinal tracts there is also evidence of digestive enzymes from microbial origin [13,16,42]. The population growth of these microbes depends upon the food taken in by the fish, digestive secretions and fragments which have scaled off the mucosal epithelium [15,43,44]. Fish take in a large number of bacteria into their gut from their aquatic environment and some of these microbes colonize the gut of the fishes forming persistent populations adhering to intestinal mucosa and assisting in the production of intestinal enzymes as an exogenous source. It can be said that environmental conditions play a significant role in the development of gut adherent microbial populations and the type and amount of enzyme production. This could be the reason for differences in the number of enzymes from the fish guts in unmanaged and pond A.

## 5. CONCLUSION

This work was aimed at looking at the feeding preference and digestive physiology of Indian major carps in managed and unmanaged polyculture pond systems. Based on the results of digestive physiology, it can be inferred that consumable plant material would probably be exploited with the highest intensity by *C. catla* compared to *L. rohita* and with lowest intensity by *C. mrigala*. On the other hand, animal components would be utilized more intensively by *C. mrigala* followed by *L. rohita* and with least intensity by *C. catla*. Digestive enzyme activity appeared to be comparatively higher in pond A. This study provides a deeper insight on the occupation of different feeding stratus by the three species of fish within the available food in polyculture arrangement allowing better understanding of how good production occurs and revealing that each species is focusing on a particular feeding stratus.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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