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Research Article
Influence of Amazon Sailfin Catfish, *Pterygoplichthys pardalis* on the Quality of Dairy Effluent

[1]Geetha, [2]Appasamy Surendran and [1]Antony Joseph Thatheyus

[1]Department of Zoology, The American College, Madurai, India
[2]Department of Food Science and Nutrition, The American College, Madurai, India

Abstract

Background and Objective: Dairy industry is one of the major food industries causing water pollution. Using animals like fish in the treatment of waste water is gaining importance. Hence the present study has been designed to test the efficiency of *Pterygoplichthys pardalis* on improving the characteristics of dairy effluent. **Materials and Methods:** Physical and chemical characteristics like total solids, total dissolved solids, total suspended solids, pH, total alkalinity and total hardness of dairy effluent were analyzed using standard methods. Then the fish were exposed to 10, 20, 30 and 40% dairy effluent for 5 days. Changes in the above-mentioned parameters were analyzed in the control and experimental tanks. Students t-test was employed to test the variation between control and experimental sets. **Results:** The *P. pardalis* was able to reduce the levels of total dissolved solids, pH and total alkalinity whereas, it was not able to reduce total solids, total suspended solids and total hardness significantly in treated dairy effluent after 5 days of treatment. **Conclusion:** *P. pardalis* exhibited the capacity to treat dairy effluent. Hence it can be used in bioremediation programmes for treating industrial effluents.

Key words: *Pterygoplichthys pardalis*, bio-treatment, dairy effluent, fish, wastewater treatment

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Corresponding Author: Antony Joseph Thatheyus , Department of Zoology, The American College, Madurai, India Tel: +0452 253 0070

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Dairy industries are found all over the world but their manufacturing process varies tremendously[1]. India is a large producer of milk and dairy products in the world with annual milk production crossing 85 million tones in the year 2002 and growing at the rate of 2.8% per annum. This sector generates huge volumes of wastewater and its pollution is primarily organic[2]. Dairy industry is of crucial importance to India. India has enacted Water (Prevention and Control of Pollution) Act, 1974 and amendments in order to treat the effluents generated by industries and maintain wholesomeness of natural water resources. Milk production in India has developed significantly in the past few decades from a low volume[3] of million tons in 1951 to 110 million tons in 2009.

Among the food industries, Dairy industry is one of the major industries causing water pollution. Considering the increased milk demand, the dairy industry in India is expected to grow rapidly and the waste generation and related environmental problems are also assuming increased importance. It is the most polluting in volume (generating from 0.2-10 L of effluent per liter of processed milk) with regard to its large volumes of water consumption. Poorly treated wastewater with high level of pollutants caused by poor design, operation or treatment systems creates major environmental problems when discharged to the surface water or land[4].

Bioremediation is progressively utilized as a solution to polluted waters all over the world, both marine and fresh, by employing species from various evolutionarily advanced positions to utilize their natural biological processes to treat polluted water. Such species, range from algae to fish, vertebrates and invertebrates, with varying abilities to filter, oxygenate and decontaminate the surrounding water column[5]. In this context, the present investigation was carried out to find out the influence of Amazon sailfin catfish, *Pterygoplichthys pardalis* on the characteristics of dairy effluent.

The *P. pardalis* belongs to the family Loricariidae which is originally from south America. It is considered as the largest catfish family, with 80 genera and 680 recognized species[6]. The sailfin catfish genus, *Pterygoplichthys* originally inhabited the entire Amazon basin (Peru, Bolivia and Brazil)[7,8]. As a result of inadequate control of the pet-fish trade, members of this family have been accidentally or intentionally introduced into several countries, where they have adapted successfully. Loricariids are characterized by having large bony plates and a ventral mouth. Loricariids with ten or more dorsal fin rays are members of the genus, *Pterygoplichthys* and are referred to as sailfin catfishes[9].

All specimens of *Pterygoplichthys* from southeastern Asia lack an elevated supraoccipital process and have the supraoccipital bone bordered posteriorly by three scutes. A group of four closely related species of *Pterygoplichthys* share these traits namely, *P. multiradiatus*, *P. anisitsi*, *P. disjunctivus* and *P. pardalis*[10].

Loricariids have successfully invaded new habitats, because these fish are protected by modified scales and by strong spines on the fins and also they show a high tolerance to low oxygen concentrations or desiccation (up to 20 h). The latter ability can be attributed to an enlarged and vascularized stomach, which functions as an accessory respiratory organ[11]. The fish have multiple-spawning, nest construction and parental care[12]. Additionally, *Pterygoplichthys* has been proven to have a high tolerance to salinity (up to ten parts per thousand)[13]. Hence the present study has been designed to study the biotreatment efficiency of *P. pardalis* in the remediation of dairy industry effluent.

MATERIALS AND METHODS

The study was carried out during the period of June, 2014 to April, 2015 at Department of Zoology, The American College, Madurai, Tamil Nadu, India. Dairy effluent samples were collected from Aavin milk factory, Madurai, Tamil Nadu, India and stored in a refrigerator for further analysis. Physico-chemical parameters such as total solids, total dissolved solids, total suspended solids, pH, total alkalinity and total hardness were analyzed based on Standard methods for the examination of water and wastewater (American Public Health Association)[14]. The fish were brought from Aquagardens fish farm, Madurai, Tamil Nadu, India. Their mean weight was 16.87±1.61 g. Then they were acclimatized to laboratory conditions for a period of one week. Later they were exposed to different concentrations of dairy effluent to determine the tolerance level and finally the working concentrations were chosen as 10, 20, 30 and 40%.

Total dissolved solids: A dry, clean evaporating dish was taken and weighed. About 100 mL of sample was filtered through filter paper and taken in an evaporating dish. The sample was evaporated on a hot water bath. When whole water was evaporated, the weight of evaporating dish was noted after cooling in a desiccator and the following formula was used for calculation:

$$TDS\ (g\ L^{-1}) = \frac{A - B}{V} \times 1000$$

Where:
TDS = Total dissolved solids
A = Final weight of evaporating dish
B = Initial weight of evaporating dish
V = Volume of sample taken

Total solids: To compute total solids, same procedure was followed as above, except that, the sample was not filtered.

Total suspended solids: Total suspended solids were calculated as below:

$$\text{Total suspended solids} = \text{Total solids-Total dissolved solids}$$

Total alkalinity: About 50 mL of sample was taken in an Erlenmeyer flask and 2-3 drops of phenolphthalein indicator were added. The solution was titrated against sulphuric acid until the solution becomes colourless. 2-3 drops of methyl orange indicator were added in the same flask and titrated against sulphuric acid until yellow colour of solution turns into orange. The reading was noted and the following formula was used for calculation:

$$\text{Total alkalinity (mg L}^{-1}) = t \times \frac{1000}{S}$$

Where:
S = Volume of sample
t = Total volume of titrant used for the two titrations

Total hardness: About 50 mL of sample was taken in a conical flask and 1 mL of ammonia buffer solution and 4-5 drops of eriochrome black-T indicator were added and titrated against EDTA solution until the wine red colour of solution turns blue. The total hardness was calculated by the following formula:

$$\text{Total hardness (mg L}^{-1}) = t \times \frac{1000}{V}$$

Where:
T = Volume of titrant
V = Volume of sample

Statistical analysis: Students t-test was applied to analyze the level of significance for the difference between control and experimental sets for all the parameters tested.

RESULTS

Table 1 describes the quality parameters of dairy effluent collected from dairy industry. The parameters that were analyzed are total solids, total dissolved solids, total suspended solids, pH, total alkalinity and total hardness. Among the tested parameters, pH was neutral while the levels of total alkalinity and total hardness were higher.

Total solids: The changes in the levels of total solids in dairy effluent after treatment with *P. pardalis* are shown in Fig. 1. The lowest level of total solids has been observed after 5 days of treatment in all the experimental concentrations of the effluent.

Total dissolved solids: Dairy effluent treatment with *P. pardalis* greatly decreased the level of total dissolved solids in all the four chosen concentrations as represented in Fig. 2. Except 30% effluent, all the other concentrations in the experimental set showed the lowest levels of total dissolved solids after 5 days of treatment with *P. pardalis*.

Total suspended solids: Figure 3 shows the changes in the levels of total suspended solids after treatment with *P. pardalis*. The lowest levels of total suspended solids were noticed in all the experimental concentrations after 5 days of treatment.

pH: The changes in the levels of pH in dairy effluent after treatment with *P. pardalis* are exhibited in Fig. 4. Though the experimental sets showed fluctuations in pH in the earlier days of treatment, after 4 and 5 days of treatment all the four experimental concentrations exhibited neutral pH.

Total alkalinity: Figure 5 depicts the changes in the levels of total alkalinity in dairy effluent after treatment with *P. pardalis*. All the four experimental concentrations showed the lowest

Total hardness: Figure 6 illustrates the changes in the levels of total hardness in various concentrations of dairy effluent

Table 1: Characteristics of dairy effluent

Parameters (unit)	Values
Total solids (g L^{-1})	37.2
Total dissolved solids (g L^{-1})	4.9
Total suspended solids (g L^{-1})	32.2
pH	7.0
Total alkalinity (mg L^{-1})	574.0
Total hardness (mg L^{-1})	1120.0

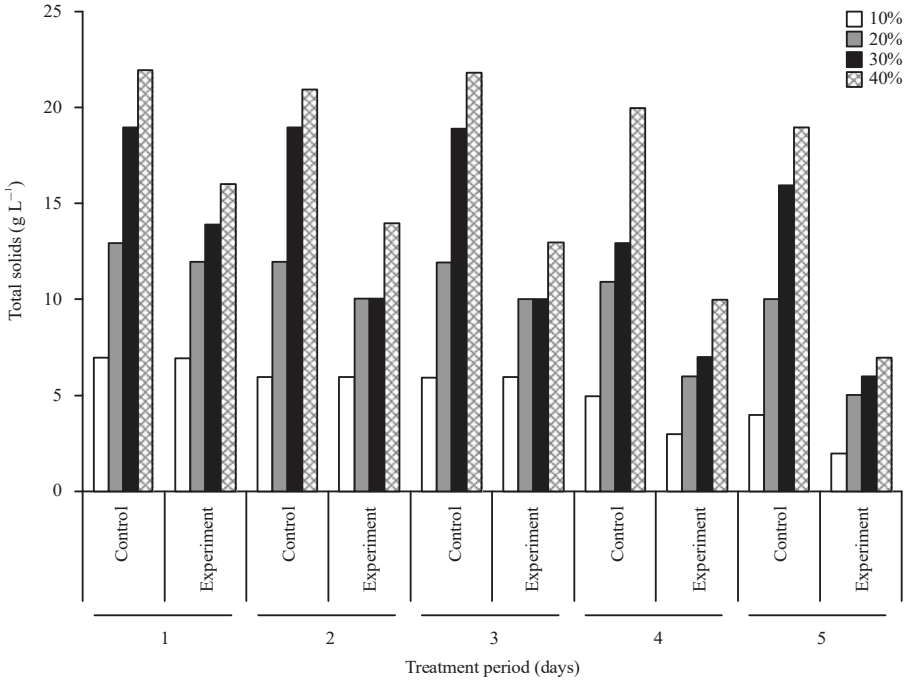

Fig. 1: Changes in the levels of total solids (g L^{-1}) in dairy effluent after treatment with *P. pardalis*

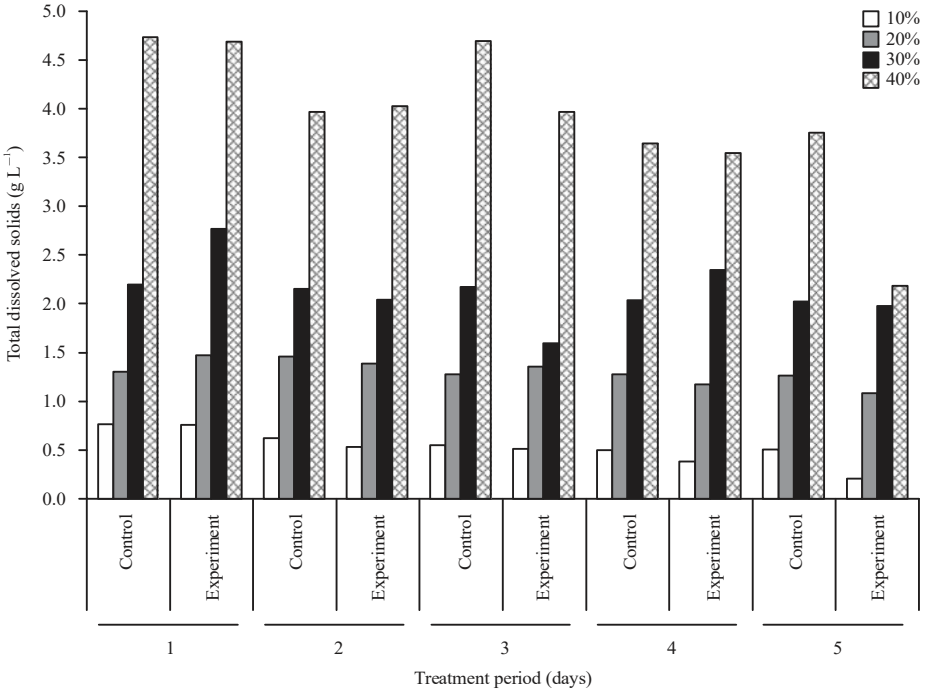

Fig. 2: Changes in the levels of total dissolved solids (g L^{-1}) in dairy effluent after treatment with *P. pardalis*

levels of total alkalinity after 5 days of treatment with the fish. after treatment with *P. pardalis*. The lowest values of total hardness were noticed in all the experimental concentrations after 5 days of treatment.

Statistical analysis: Table 2 shows the results of students t-test for all the parameters examined for dairy effluent comparing treated and untreated sets. There was statistically significant variation between control and experimental sets

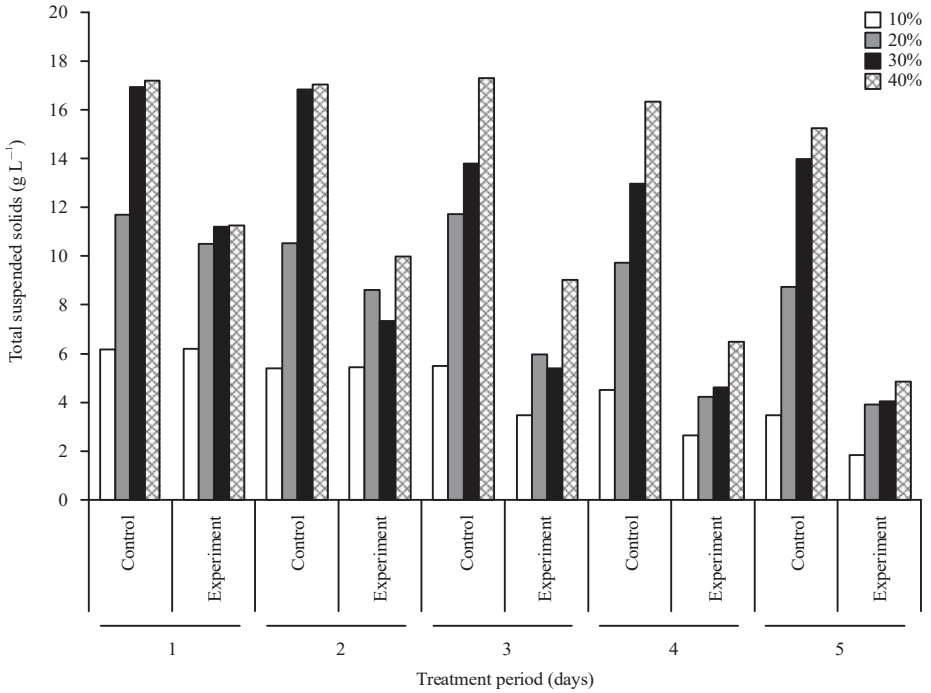

Fig. 3: Changes in the levels of total suspended solids (g L^{-1}) in dairy effluent after treatment with *P. pardalis*

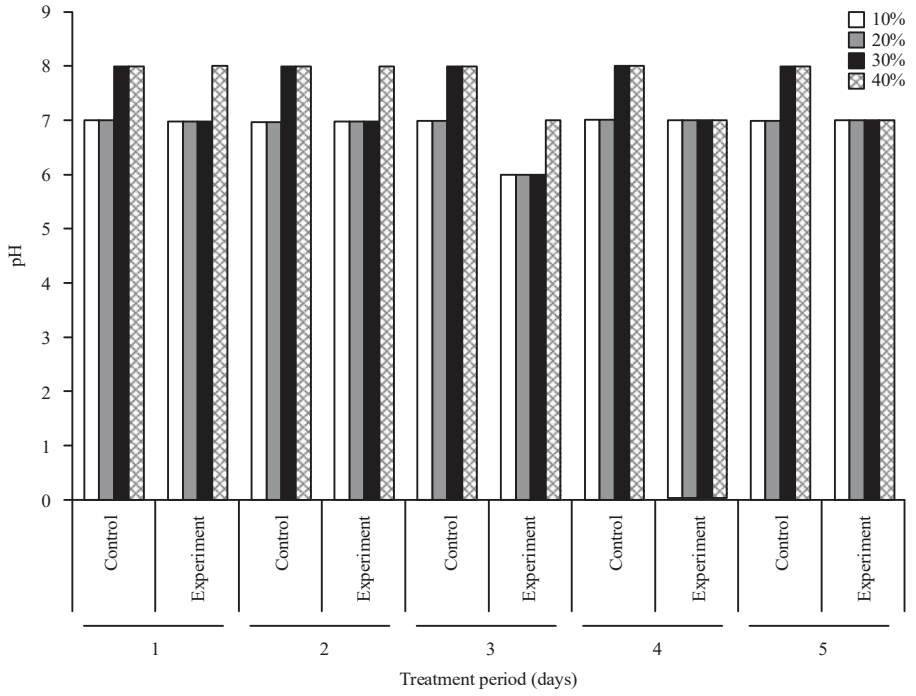

Fig. 4: Changes in the levels of pH in dairy effluent after treatment with *P. pardalis*

in all the four effluent concentrations for total dissolved solids. The variations between control and experimental sets were statistically significant only in the lowest effluent concentration for total solids and total suspended solids. The variations between control and experimental sets were statically significant in 10 and 20% concentrations for total

hardness, 10, 30 and 40% concentrations for total alkalinity and 10, 20 and 40% effluent concentrations for pH.

DISCUSSION

Dairy effluents contain dissolved sugars and proteins, fats and residues of additives which are the main contributors to the organic load of these waste waters. Due to the presence of high organic load, dairy effluents degrade rapidly and deplete dissolved oxygen level of the receiving streams and become the propagation sites for mosquitoes and flies carrying malaria and other perilous diseases such as dengue fever, yellow fever and chikungunya[15]. The wastes are also characterized by strong odour and heavy black flocculated sludge masses. Conventional advanced wastewater treatment typically requires large capital investments and consumes large amounts of energy. This has stimulated the development of alternative wastewater treatment systems which will be more efficient and less expensive than conventional treatment systems. Bioremediation may be a solution and is growing in popularity as a natural and economical alternative for purifying wastewater[16].

Table 2: Results of Students t-test for the various parameters of dairy effluent comparing treated and untreated sets

	Level of significance at 0.05 level			
	Dairy effluent concentration (%)			
Parameters	10	20	30	40
Total solids	S	NS	NS	NS
Total dissolved solids	S	S	S	S
Total suspended solids	S	NS	NS	NS
pH	S	S	NS	S
Total alkalinity	S	NS	S	S
Total hardness	S	S	NS	NS

S: Significant, NS: Not significant

The process of bioremediation is a well-established and powerful technique for treating domestic and industrial effluents[17]. Animals can be used to extract or stabilize nutrient, microbial, heavy metal and organic pollution load. This can be achieved by the harvesting of wild populations of animals to extract pollutants, supplementation or maintenance of wild populations to stabilize pollutants or the introduction, culture and harvest of animals to extract pollutants-a form of aquaculture. The identification of suitable animal taxa for bioremediation could involve surveys of polluted aquatic habitats and subsequent bio-prospecting for individuals that are able to stabilize, transform, degrade or hyperaccumulate pollutants. *Anadonta woodiana* filters water and absorbs elements or compounds in it through mouth, gills and then empties into the chiffon. Some are accumulated in the body's cells and partly excreted. *Limnodrilus hoffmeistri*

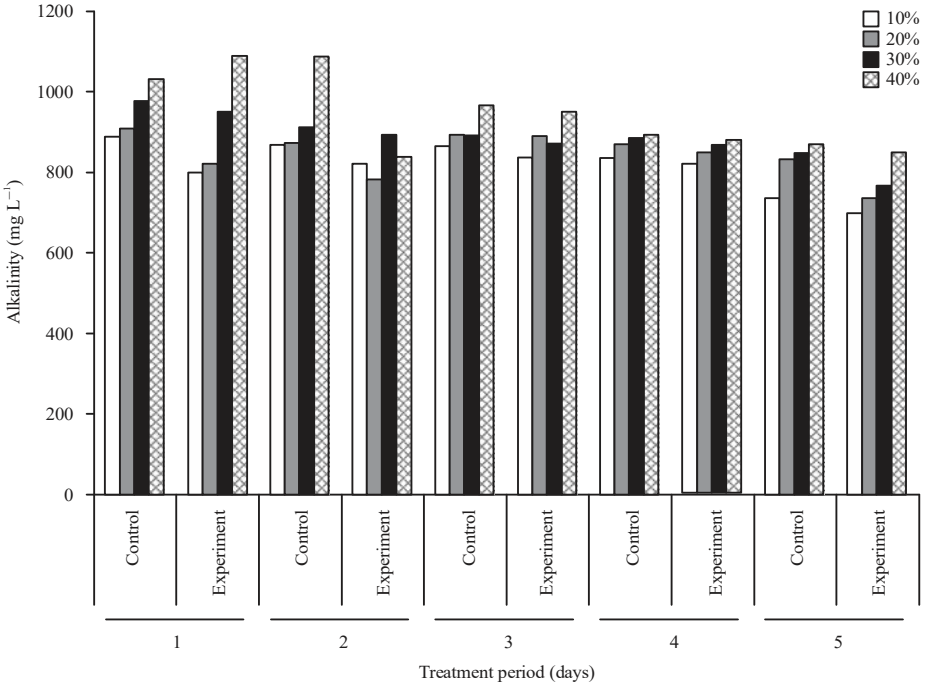

Fig. 5: Changes in the levels of total alkalinity (mg L^{-1}) in dairy effluent after treatment with *P. pardalis*

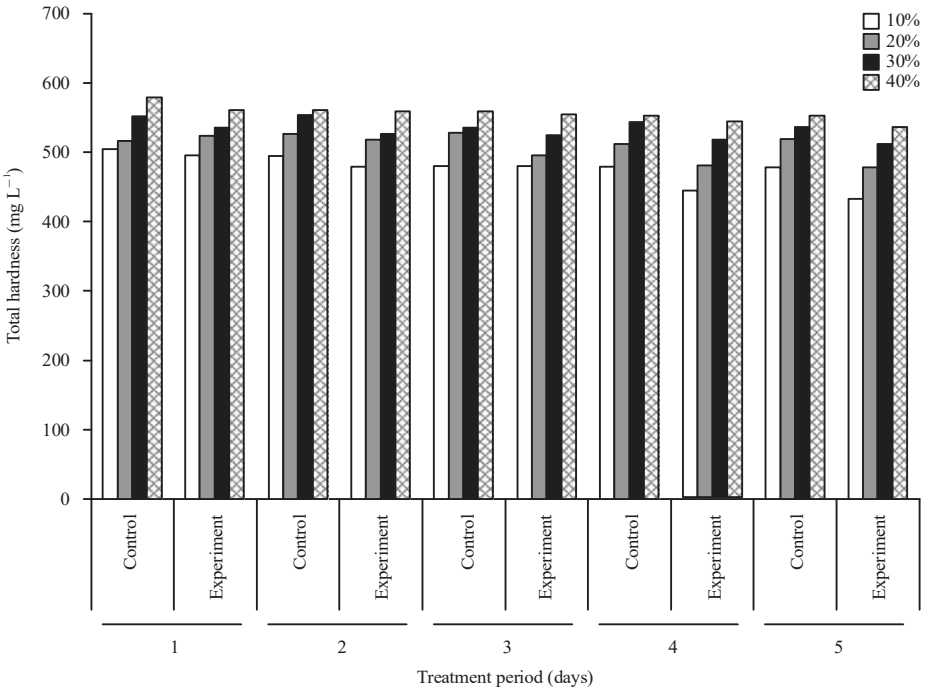

Fig. 6: Changes in the levels of total hardness (mg L^{-1}) in dairy effluent after treatment with *P. pardalis*

remodel organic pollutants by releasing enzymes. Aquatic animals can do zoo extraction, zoo stabilization and zoo degradation[18].

One such animal that can be used for the purpose of bioremediation is the Amazon sailfin catfish, *P. pardalis*. It is not regarded as important commercial fish, because of its hard body armour, very little meat, propensity to compete for food resources and its potential to bioaccumulate heavy metals in polluted environments[19-21]. Nonetheless, the hardy nature of this genus, its capacity to down regulate metabolism during periods of scarcity of food[22], its tolerance to poor water conditions and its ability to breathe air under hypoxic conditions enabled this fish to invade and successfully establish itself even in disturbed freshwater systems[23].

Wastewater treatment process is influenced by environmental factors namely temperature, turbidity, pH, the content of inorganic and organic elements, BOD, COD and content of nitrate compounds and phosphates. Wastewater turbidity is determined by the presence of dissolved and suspended particles in it. The presence of high level of total suspended solids and total dissolved solids was due to organic and inorganic matter present in the effluent. Increased turbidity reduces the quality of water by impeding sunlight from penetrating the water column. As a result, there may be decreased photosynthesis, which may lead to reduced dissolved oxygen content in water. The level of suspended solids in extremely clean waters is below 1 mg L^{-1}. The concentration of suspended solids in dairy effluent varied in the range[24] of 0.024-4.5 g L^{-1}. The *P. pardalis* has been proved to reduce the presence of such particles in the present study. The pH of dairy waste waters depends on the nature of end products and can range from 6.6-12.2. The pH varied in the range[25,26] of 4.7-11. The effluent indicating acidic conditions could have an adverse effect on soil and microflora[27]. In the present study, pH of the untreated effluent was slightly alkaline but after biotreatment with *P. pardalis*, the values were overall nearer to neutral.

Alkalinity is a measure of buffering capacity of water and it is an important parameter which indicates the ability of water to neutralize acids from wastewater. The higher values of alkalinity are associated with increase in the presence of bicarbonates and carbonates from effluents. In the present work, alkalinity was found be in the range of 700-1090 mg L^{-1} while values of 408-452 mg L^{-1}, from milk processing unit at Punjab have been reported[28]. Total hardness is the property of water which prevents the lather formation with soap and increases the boiling point of water. Hardness of water mainly depends upon the amount of calcium and magnesium salts or both. In the present study, values of hardness were between 434-578 mg L^{-1}. The values of hardness were found to be low after treatment with *P. pardalis*.

CONCLUSION

Analysis of certain characteristics in the treated dairy effluent showed that *P. pardalis* has the capacity to remediate dairy effluent. Therefore, it can be employed as an agent in the treatment of dairy effluent.

SIGNIFICANCE STATEMENT

This study discovered the efficiency of *P. pardalis* in treating the dairy effluent that can be beneficial for wastewater treatment and bioremediation programmes for restoring water quality. This study will help the researchers to uncover the critical areas of using *P. pardalis* for biotreatment that many researchers were not able to explore. Thus a new theory on using *P. pardalis* for treating industrial effluents may be arrived at.

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