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**Research Article**

# Dietary *Aloe barbadensis* miller supplementation enhances growth performance in *Cirrhinus mrigala* fingerlings

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## Abstract

Aquaculture faces challenges due to slow growth, high mortality, disease outbreak and poor meat quality. *Aloe barbadensis* Miller (Aloe vera), a natural and sustainable plant based ingredients due to its immune stimulatory, antioxidant, antibacterial and growth enhancing properties can help to address these issues. This research was conducted to examine the effects of *A. barbadensis* supplemented feed on growth performance of *Cirrhinus mrigala* fingerlings. The present research was conducted at Fisheries Research Farm, Department of Zoology, Wildlife and Fisheries, University of Agriculture, Faisalabad. Before experiment, fingerlings of Mrigala Carp were acclimatized and then divided into four experimental groups each with three replicates, respectively. The fingerlings were fed 3% of their body weight for 45 days. Four experimental diets were formulated as: $T_0$ (control group), $T_1$ (500mg/kg *A. vera* extract), $T_2$ (1000mg/kg *A. vera* extract) and $T_3$ (2000mg/kg *A. barbadensis* extract. The experimental design of this study was completely randomized design (CRD) using Tukey's HSD post hoc test for comparing treatment means. The results revealed significant differences between treatments. Growth parameters in terms of body weight (g), body length (cm), SGR (%) and FCR (%) were measured on weekly basis. $T_1$ showed the highest weight gain (1.39g), length gain (1.36cm) and SGR (2.18%) with the lowest FCR (0.90). Maximum survival rate recorded in $T_1$ and $T_2$ (100%) followed by $T_0$ (80%) and $T_3$ (90%). Physico-chemical parameters i.e., temperature, DO and pH were recorded on weekly basis. The results revealed *A. vera* supplemented feed, particularly 500 mg/kg inclusion, significantly improved growth performance of *Cirrhinus mrigala* without any adverse effect.

**Keywords:** *Cirrhinus mrigala*, *A. barbadensis*, WG, FCR, SGR

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## Introduction

Aquaculture is the cultivation of fish and other aquatic life in a controlled environment. Fish production increased globally through aquaculture [1], and it has

gained importance and expanded volume. The aquaculture sector accounts for 50% of all worldwide edible fish production and it is growing faster than any other food-generating industry. This sector is considerably growing at a rate of approximately 5.8 percent each year [2]. Over the last four decades, global aquaculture production has increased dramatically, making a substantial contribution to the global supply of fish for human consumption. Its achievements and participation are expected to reduce hunger and poverty while simultaneously providing protein for the bulk of the world's dietary requirements [3 - 4]. The advancement of the aquaculture sector is highly based on affordable feed with exceptional growing ability within a short period of time [5].

Fish farming is facing common difficulties like slow growth rates, high mortality, disease outbreaks and poor meat quality that reduce production and profitability [6 - 7]. Approximately, 12.8% of the global consumption of animal protein is derived from freshwater fish [8]. Disease control is a key challenge for the aquaculture industry due to the intensive cultural methods employed to increase output. Synthetic chemicals are used to address these issues, but extended use can harm fish health, consumer safety and the environment [9]. These issues require the investigation of natural and sustainable alternatives, including plant-based supplements. *A. barbadensis*, a natural alternative with immune stimulatory, antioxidant and growth promoting properties has been studied for its effectiveness in aquaculture. However, its impact on growth performance, survival rate and meat quality is not fully understood. This knowledge gap requires systematic studies to address sustainable aquaculture development challenges [10]. Medicinal plants have been suggested to treat various human abnormalities and they are being explored in aquaculture to find safe and environmentally friendly compounds that can replace antibiotics and chemical compounds. Hence, they are helpful in improving the water quality and reducing stress in fish [11]. Medicinal plants can be utilized as appetite stimulators and to enhance growth. This is achieved by improving digestive enzymes, resulting in enhanced growth and survival rates of fish, leading to more sustainable aquaculture [12].

*A. barbadensis (*A. vera) is a member of Liliaceae or Aloeaceae family is highly distributed in tropical as well as subtropical regions of world [13]. Previously, *A. barbadensis* was shown to work as an alternate digestive stimulant, growth booster and appetizer in rainbow trout, carp and fowl [14]. *A. barbadensis* is regarded one of the most well-known bioactive components, containing more than 70 biologically active compounds. These bioactive substances are found in two forms of exudates (bitter yellow latex and mucilaginous gel) produced by Aloe leaves. *A. barbadensis* gel contains around 200 active components, more than 75 nutrients, 18 amino acids, 20 minerals and 12 vitamins, as well as substances such as aloin, anthraquinone, barbaloin and famotidine [15]. The importance of *A. barbadensis* in aquaculture has currently gained much recognition owing to its biological characteristics in terms of anti-inflammatory, antioxidant, gastrointestinal health, immune stimulating and hepato protective properties. Moreover, the use of *A. barbadensis* limits synthetic chemicals and proves to be cost effective for sustainable aquaculture practices [16].

Freshwater fish *Cirrhinus mrigala* belongs to the family Cyprinidae, Commonly known as Mori, Morakhi and Mrigal carp is a large size herbivorous fish and backbone of fishery in the Indian subcontinents. It is considered as an important freshwater aquaculture species throughout South Asia and has a high market value [17]. It inhabits

fast-flowing rivers and streams. It is a successful invader due to ecological conditions and its behaviour. Its invasiveness is due to its high reproductive rate, easy breeding, high culture ability and being adaptable. This specie is essentially a bottom feeder that feeds on plant detritus and organic waste and can be grown in a polyculture system along with Chinese Carps and other Major Carps. It is the most preferred by people because of its flavour and extremely high nutritional value as it is a rich source of protein. It has a high growth rate and accounts for 67% of total freshwater aquaculture productivity, along with *Labeo rohita* and *Catla catla* thus providing economic benefits [18]. C. *mrigala* is consumed commonly in Pakistan due to its taste and quality of meat [19].

Although *A. barbadensis* has been extensively studied for its medicinal and immunomodulatory properties in terrestrial animal and poultry, its potential as a functional feed additive in freshwater fish particularly *C. mrigala*, remains largely unexplored. Considering the economic importance of *C. mrigala* in aquaculture and the increasing demand for antibiotic free, natural growth promoters, there is a pressing need to investigate plant based alternatives that can enhance both productivity and flesh quality. Hence, the present study was undertaken to evaluate the effects of graded levels of *A. barbadensis* supplemented feed on growth performance of *C. mrigala*, with the objective of providing scientific evidence for its application in sustainable and eco-friendly aquaculture practices.

## Material and Methods

### Pre stocking management

Before starting the experimental trial, each glass aquarium was drained, cleaned and disinfected. As a precaution, thin netting gauze was placed over the aquariums to prevent fish from entering or leaving. All the aquaria were provided with aerators, which dissolve the oxygen in water. The fish specimens were brought from the Fish Seed Hatchery, Faisalabad. The procured specimens were transported precisely to Fisheries Research Farm in aerated polythene bags and then randomly put into experimental aquariums. Before experimentation, the fish were acclimatized for 1 week in the tanks under laboratory conditions. Standard laboratory conditions were maintained, including 12 hours of light and 12 hours of darkness with continuous aeration. During the acclimatization period, fish were fed a commercial meal equivalent to 3% of their body weight. Dead fish were eliminated from tank to prevent fouling of tank and water changed at daily basis.

### Post stocking management

After preliminary preparations, glass aquarium was stocked with 10 specimens in control group and 30 specimens in each experimental group (each with three replicates). Before stocking the growth parameters in terms of body weight, total lengths were measured and recorded on data sheet. After every 10 days, growth parameters were measured. Fish samples were put back to their respective aquariums after the measured data were recorded. Growth parameters Weight gain, Length gain, Food Conversion Ratio (FCR), Specific Growth Rate (SGR) and Survival percentage were measured during trial. Fish were fed at a rate of 3% of their body weight and water quality was regularly monitored.

### Feeding protocol

Juveniles of Mrigala carp were given feed to the 3% of their body weight. Diet was given 2 times a day and after the feeding, unconsumed feed was discarded and aquaria were washed and refilled with fresh water. To maintain water quality and physico-chemical parameters, water was

replaced twice a day in each aquarium.

### Formulation of basal and experimental diets

The basal diet was prepared by taking selected feed ingredients, such as fish meal, wheat flour, rice polish, soybean oil, maize flour, sunflower meal, fish oil, minerals and vitamins. These diet ingredients were stained and grinded well before preparing experimental diets [20]. *A. barbadensis* was obtained from the local market. It is advisable to rinse *A. barbadensis* leaves many times with pure water and peeled and processed into gel or powder form by drying 40-50$^0$C. The processed *A. barbadensis* incorporated into the feed at specific inclusion levels shown in Table 1. *A. barbadensis* was incorporated with test diets at the cost of wheat flour. Feed were kept in the airtight containers at 4 $^o$C. The control diet ($T_0$) was administered the basal diet free of *A. barbadensis*. The initial experimental treatment ($T_1$) was administered an experimental meal containing 500mg/kg of *A. vera*. The second treatment ($T_2$) involved adding 1000mg/kg *A. barbadensis* mixed diet. The third experimental diet ($T_3$) was administered a diet containing 2000mg/kg of *A. barbadensis* mixed diet.

Table 1: Composition of basal and experimental diets.

| Ingredients | Inclusion level % | | | |
|---|---|---|---|---|
| | To | $T_1$ | $T_2$ | $T_3$ |
| Fish meal | 40 | 40 | 40 | 40 |
| Wheat flour | 6.4 | 5.9 | 5.4 | 4.4 |
| Maize flour | 5.3 | 5.3 | 5.3 | 5.3 |
| Rice bran | 5.3 | 5.3 | 5.3 | 5.3 |
| Sunflower meal | 40 | 40 | 40 | 40 |
| Soybean oil | 3 | 3 | 3 | 3 |
| Vitamins and minerals | 1 | 1 | 1 | 1 |
| *A. barbadensis* | 0 | 0.5 | 1 | 2 |
| **Total (g)** | 100 | 100 | 100 | 100 |

### Determination of physico-chemical parameters

Water quality affects the productivity of fish, survival rate and feed conversion ratio in both direct and indirect ways. Water quality should be checked constantly during experimental trial. To maintain the quality of water, Physico-chemical factors such as pH, temperature, dissolved oxygen, total hardness and total alkalinity were measured [21]. From each tank, water was extracted in separate beakers for checking these factors.

### Determination of growth performance indices

Fish were sampled every week to check the growth. The weight and length readings were recorded on weekly basis. Scale was used to measure the length of Mrigala carp in unit of cm and weight balance (GF- 300, A&D business limited, USA) was used for the measurement of body weight in grams. At the end of the trial, the weight gain and length gain were compared using the mean value. The growth response was evaluated using the following formulae:

$$Weight\ gain(\%) = \frac{Final\ weight\ (gm) - Initial\ weight(gm)}{Initial\ weight(gm)} \times 100$$

$$Length\ gain\ (\%) = \frac{Final\ length\ (cm) - Initial\ length(cm)}{Initial\ length(cm)} \times 100$$

$$Specific\ growth\ rate\ (SGR) = \frac{ln\ WF - ln\ W1}{time\ duration} \times 100$$

$$Food\ conversion\ ratio\ (FCR) = \frac{Feed\ consumption\ (g)}{Total\ weight\ gain\ (g)}$$

$$Survival\ rate = \frac{Survived\ fish\ number}{Total\ number\ of\ fish} \times 100$$

### Statistical analysis of data

The data was statistically analyzed by using SPSS (version 21 IBM, USA), Statistics (software version 8.1) and Graphpad prism 8.0.1. The data was analysed using one-way analysis of variance (ANOVA) with

completely randomized design (CRD). Tukey's HSD post hoc test was used to compare the treatment means.

## Results

### Assessment of physico-chemical parameters

The growth and survival of aquatic animals are primarily influenced physico-chemical factors. Thus, the parameters mentioned earlier were closely examined throughout this research period. The measured physicochemical parameters remained within the acceptable range for freshwater fish throughout the experiment in Table 2. The results of statistical analysis driven by one way ANOVA revealed non-significant value of temperature (n=4, $F_{3, 24}$= 0.06; $p$ < 0.98), dissolved oxygen (n=4, $F_{3, 24}$= 0.06; $p$ < 0.98), pH (n=4, $F_{3, 24}$= 1.54; $p$ < 0.23), Hardness (n=4, $F_{3, 24}$= 0.21; $p$ < 0.89), Calcium (n=4, $F_{3, 24}$= 1.54; $p$ < 0.23), magnesium (n=4, $F_{3, 24}$= 0.12; $p$ < 0.95), that showed non significant impact on overall water quality in control and treated groups.

Table 2: Assessment of physico-chemical parameters in control and treated groups.

| Parameter | Mean value | SD | SE | F value | P value |
|---|---|---|---|---|---|
| Temperature (°C) | 27.84 | 1.2 | 0.23 | 0.06 | 0.98Ns |
| Dissolved Oxygen (mg/L) | 3.93 | 0.34 | 0.06 | 0.07 | 0.98Ns |
| pH | 7.19 | 0.21 | 0.04 | 1.54 | 0.23Ns |
| Hardness (ppm) | 257.97 | 4.9 | 0.93 | 0.21 | 0.89Ns |
| Calcium (mg/L) | 24.73 | 1.27 | 0.24 | 1.13 | 0.35Ns |
| Magnesium (mg/L) | 24.73 | 1.27 | 0.24 | 0.12 | 0.95Ns |

### Assessment of growth parameters

The growth performance of *C. mrigala* fingerling was significantly ($p$ < 0.05) effected by the varying levels of *A. barbadensis* in experimental diet as reported in Table 3.

Table 3: Assessment of growth parameters of *C. mrigala* on varying levels of *A. vera* in experimental diet.

| Parameters | To | T1 | T2 | T3 | F value | P value |
|---|---|---|---|---|---|---|
| IBW(g) | $4.04\pm0.26^{a}$ | $3.96\pm0.26^{a}$ | $3.44\pm0.15^{a}$ | $4.00\pm0.17^{a}$ | 1.69 | 0.19NS |
| FBW(g) | $9.34\pm0.17^{c}$ | $13.68\pm0.17^{a}$ | $11.95\pm0.12^{b}$ | $11.95\pm0.17^{b}$ | 132 | 0.00*** |
| WG(g) | $5.30\pm0.15^{d}$ | $9.72\pm0.19^{a}$ | $8.51\pm0.10^{b}$ | $7.95\pm0.13^{c}$ | 18.4 | 0.00*** |
| WG% | $137.5\pm11.3^{c}$ | $256.78\pm19.6^{a}$ | $251.8\pm11.3^{ab}$ | $202.52\pm10.2^{b}$ | 16.6 | 0.00*** |
| IL(cm) | $8.13\pm0.33^{a}$ | $8.14\pm0.26^{a}$ | $6.93\pm0.17^{b}$ | $8.01\pm0.23^{a}$ | 5.32 | 0.004*** |
| FL(cm) | $13.47\pm0.30^{c}$ | $17.69\pm0.42^{a}$ | $15.50\pm0.35^{b}$ | $15.70\pm0.28^{b}$ | 25.7 | 0.00*** |
| LG(cm) | $5.33\pm0.14^{c}$ | $9.55\pm0.29^{a}$ | $8.57\pm0.34^{ab}$ | $7.70\pm0.22^{b}$ | 49 | 0.00*** |
| LG% | $66.68\pm3.48^{c}$ | $118.23\pm4.69^{a}$ | $124.71\pm6.49^{a}$ | $97.01\pm4.15^{b}$ | 29.3 | 0.00*** |
| SGR% | $1.12\pm0.12^{b}$ | $1.66\pm0.14^{a}$ | $1.65\pm0.08^{a}$ | $1.45\pm0.08^{a}$ | 18.4 | 0.00*** |
| FCR | 1.4 | 0.9 | 0.94 | 1.04 | 422.52 | 0.00*** |
| Survival% | $80.00\pm0.13^{a}$ | $100.00\pm0^{a}$ | $100.00\pm0^{a}$ | $90.00\pm0.10^{a}$ | 1.32 | 0.28NS |

The mean + SE (n = 3) is used to display the data. On the basis of dietary lipid levels, a pairwise comparison between several groups is displayed using a one-way ANOVA and Tukey's HSD post hoc test. There were significant variations between the groups in every growth measure. Significant differences ($p$ < 0.05) between groups are indicated horizontally by different superscripts. WG weight gain, SGR specific rate of growth (BW% / number of days), SR% survival rate, ibw initial weight of bodyt, fbw final weight of body, IL initial length, FL final length, LG length gain and FCR feed conversion ratio. Non-significant = ns.

All experimental groups showed significant differences in ultimate body weight (n=4, $F_{3, 24}$= 132; $p$ < 0.00), WG (n=4, $F_{3, 24}$= 18.40; $p$ < 0.00), WG% (n=4, $F_{3, 24}$= 16.60; $p$ < 0.00), FL (n=4, $F_{3, 24}$= 25.7; $p$ < 0.00), LG (n=4, $F_{3, 24}$= 49; $p$ < 0.00), LG% (n=4, $F_{3, 24}$= 29; $p$ < 0.00), SGR% (n=4, $F_{3, 24}$= 18.40; $p$ < 0.00) and FCR (n=4, $F_{3, 24}$= 422.52; $p$ < 0.00), according to the statistical analysis of the results using one-way ANOVA. Tukey's HSD comparison indicated the initial experimental treatment ($T_1$) containing 500mg/kg of *A. barbadensis* had the best growth performance, following the second treatment ($T_2$) containing1000mg/kg *A. vera* mixed diet and third experimental diet ($T_3$) containing 2000mg/kg of *A. barbadensis* mixed diet, whereas the control diet ($T_0$) had lowest growth performance. The survival rate of all experimental fish showed no significant difference (SR%, n=4, $F_{3, 24}$= 1.32; $p$ < 0.28).

**Weekly assessment of final body weight (FBW)**

Observations of weekly final body weight of *Cirrhinus mrigala* fingerlings in control and treated groups is graphically represented in Figure 1. Results revealed that significant differences were observed in the weekly final body weight of *C. mrigala*. FBW in the Control group (T0) showed gradual increases starting from about 4.0g at the 1st week of treatment and reaching 9.2g at the 7th week of treatment. Significant differences (p < 0.05) were observed among sampling weeks, as indicated by different superscript letters. The week with the highest FBW was the 7th week and the week with the lowest FBWs were the first 3 weeks. The fish in the 1st week of Treatment 1 (T1) had an average FBW of about 4.0 g, which increased to 13.8 g in the 7th week. FBW started to increase after 4th week with significant growth in the 5th, 6th and 7 weeks.

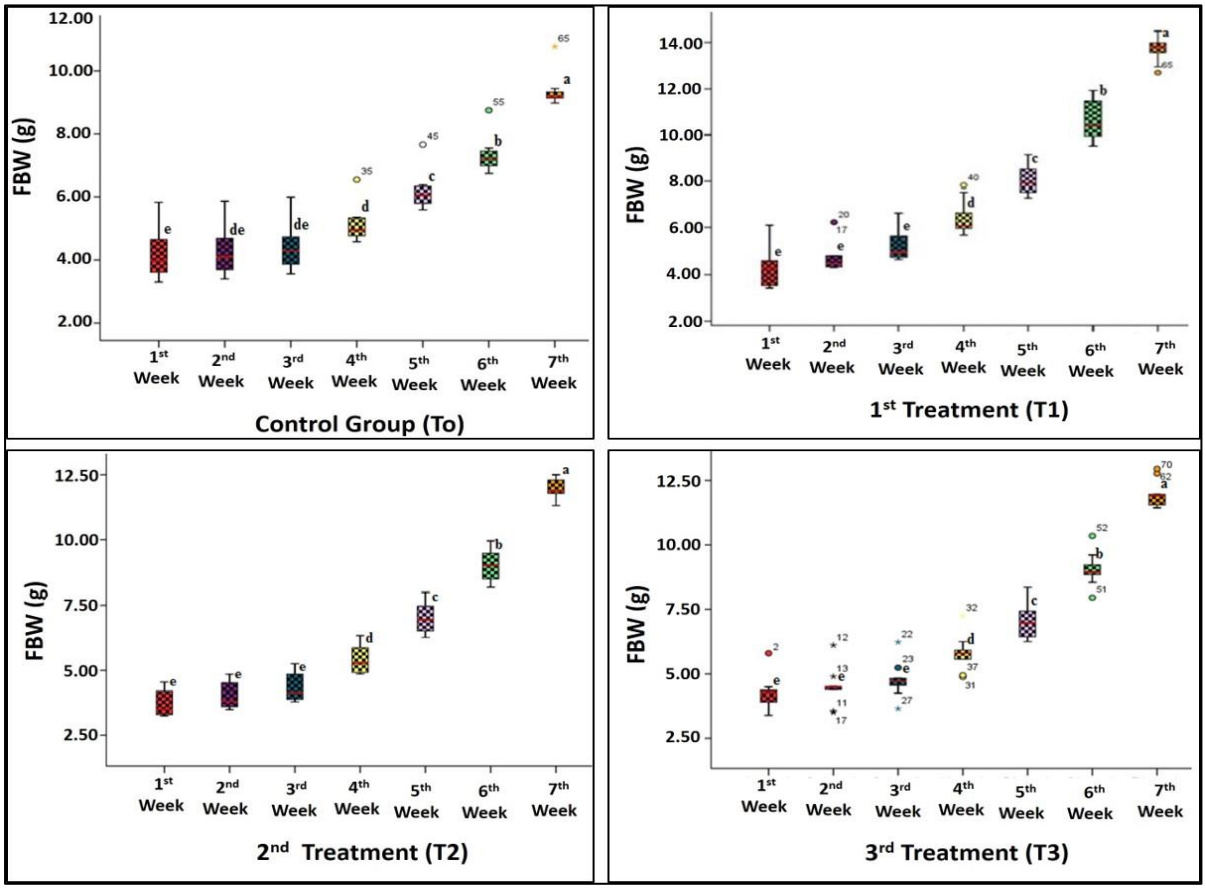


Figure 1: Graphical representation of Final body weight (FBW) on weekly basis.

The 7th week showed the maximum FBW and was significantly different ($p < 0.05$) from all the other weeks. Likewise, Treatment 2 (T2) showed significant growth and FBW changed from about 3.8 g during the 1st week to 12.1 g during the 7th week. During the experimental period, there was a significant increase in the weekly scores, especially from the 4th week. The highest FBW was observed in the 7th week followed by the 6th week. In T3 (Treatment 3) FBW grew continuously over the weeks, rising from 4.2g at week 1 to 11.7g at week 7. An improvement is noted with significant achievement after 4th week and the best performance achieved during the 7th week. The growth in T3 was still higher than that in the control, but still lower than the T1 and T2. The average final FBW values were T1> T2> T3> T0, which means that the treatments with the diet had a significant impact on fish growth when compared with

the control treatment. T1 showed the highest FBW, 13.8g, and thus this treatment was the most effective in promoting fish growth. Letters for each treatment are different and statistically significant differences exists between weeks ($p < 0.05$).

**Weekly assessment of specific growth rate (SGR)**

Effect of *A. barbadensis* supplemented fed on SGR of *C. mrigala* fingerlings in control and treated groups is graphically represented in Figure 2. The results of ANOVA showed that on weekly basis there is highly significant differences in the SGR between control and treated groups.

In the Control group (T0), the value of SGR was fairly low in the first three weeks of production ranging from about 2-5% of day$^{-1}$. The SGR was much higher in the fourth week as it reached about 20% day$^{-1}$, increased again in the fifth and sixth week. The maximum SGR was achieved during the seventh week, which is about 33-35% day$^{-1}$. Within weeks, significant differences ($p < 0.05$) are noted with different superscript letters.

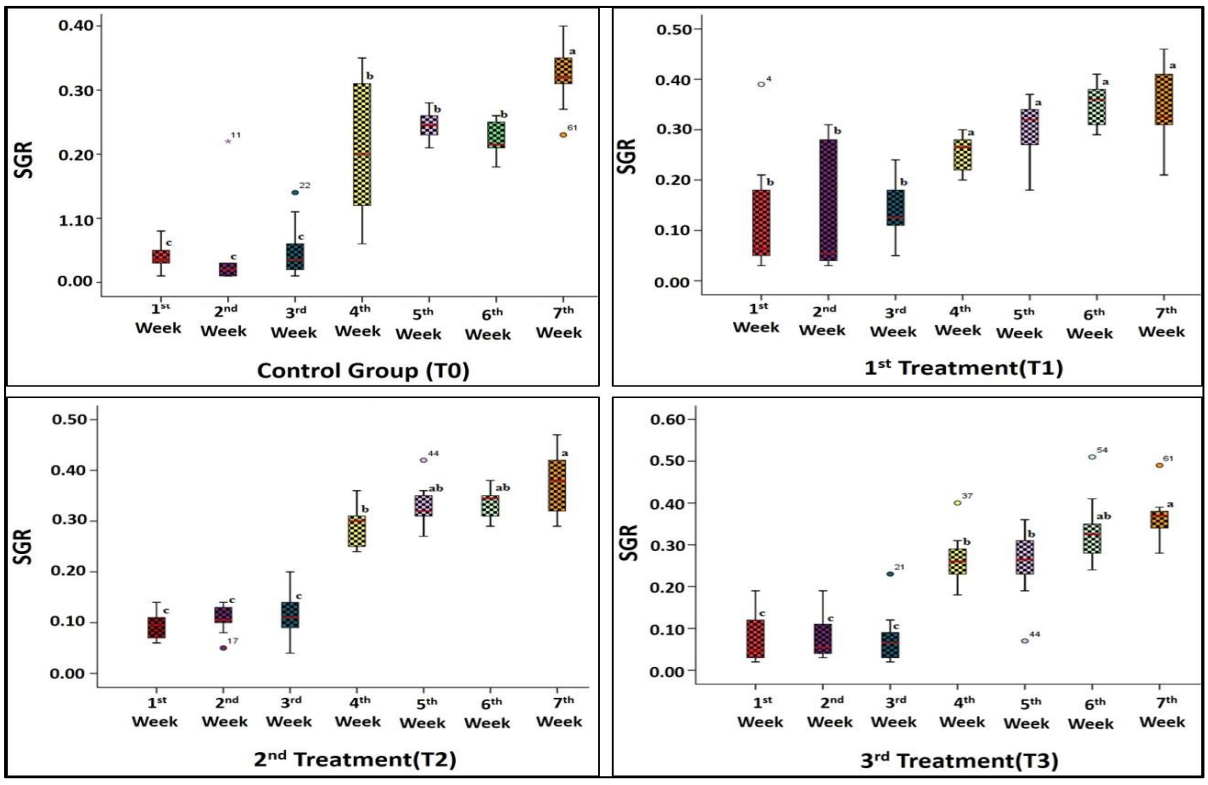


Figure 2: Graphical representation of Specific growth rate (SGR) on weekly basis.

For Treatment 1 (T1) SGR rose in the first week from around 0.10–0.18% day$^{-1}$ to 0.40–0.45% day$^{-1}$ in the seventh week. There was a general increasing trend seen in all the weeks of the study, but when compared statistically, the steady increase in the later weeks (weeks 4-7) showed no significant difference as indicated by the same superscript letter ("a"), suggesting that the growth in the latter part of the study was not increasing significantly, but is pointing towards a leveling off.

Overall, the best SGR values were obtained for the second treatment (T2). The SGR grew from around 8-12% (day$^{-1}$) in the first week to 40-42% (day$^{-1}$) in the seventh week. A marked rise was noticed from 4 weeks and the most raised values were noted during 6th and 7th week. Significant difference ($p < 0.05$) was observed between early and later stage of the experiment which shows the better growth performance of this treatment. In the same manner, the SGR gradually increased in Treatment 3 (T3) for the entire experimental period. Initial values of around 0.04–0.10% day$^{-1}$, rising to around 0.35–0.40% day$^{-1}$ during the 7th week. After the fourth week, growth was increasingly more vigorous with marked differences being seen between the early weeks (1–3) and later weeks (4–7).

## Correlation analysis

Pearson correlation analysis was performed to examine the relationships between dietary *A. barbadensis* (*A. vera)* supplementation and key growth performance parameters final body weight (FBW), weight gain (WG), weight gain% (WG%), initial length (IL), final length (FL), length gain (LG), length gain % (LG%), specific growth rate (SGR), feed conversion ratio (FCR), and survival in the study as shown in Figure 3.

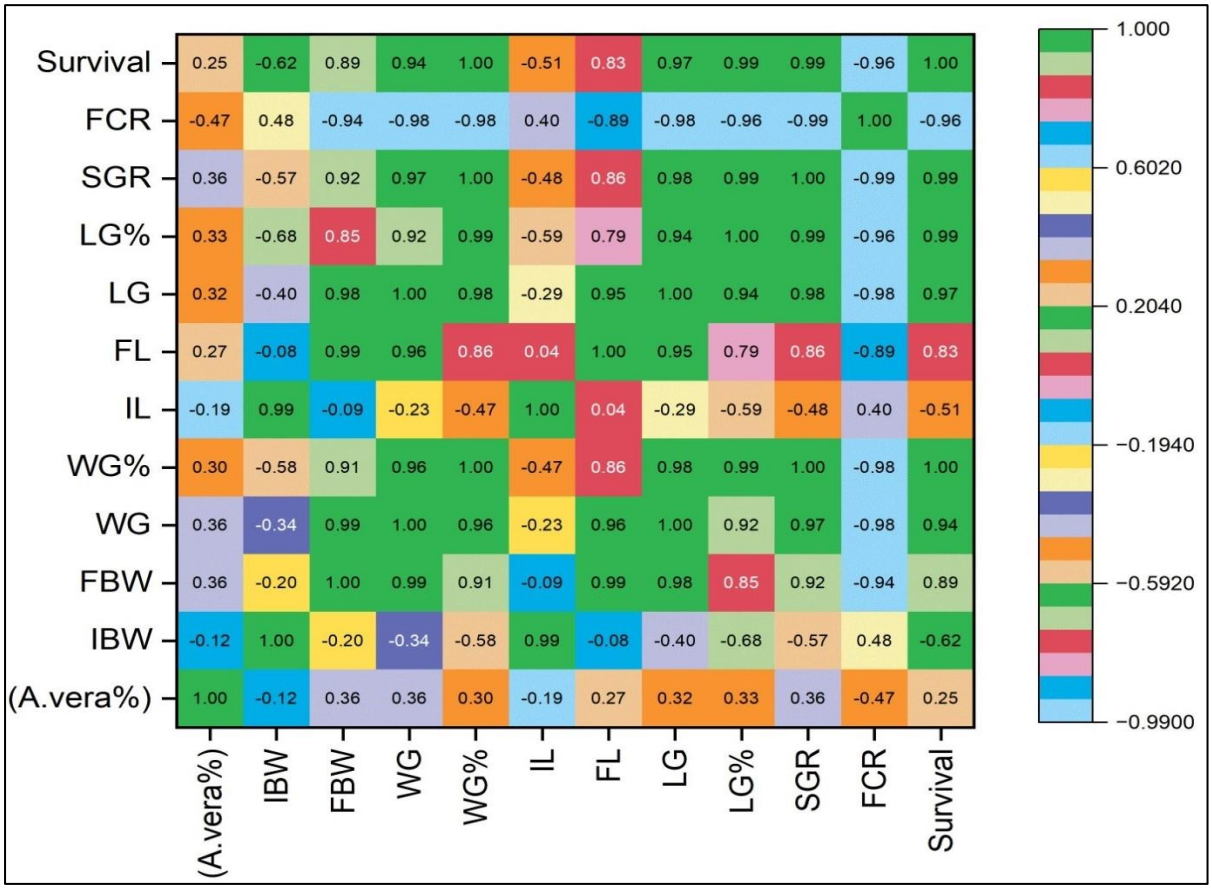


Figure 3: Correlation analysis between dietary *A. vera* supplementation and key growth performance parameters**.**

The correlation matrix showed that *A. barbadensis* supplementation (A. vera %) had a positive correlation with growth parameters, including FBW (r = 0.36), WG (r = 0.32), WG% (r = 0.30), LG (r = 0.32), LG% (r = 0.33), and SGR (r = 0.36). There was a significant positive relationship between *A. barbadensis* inclusion levels and growth rate as well as biomass. However, *A. barbadensis* showed a negative correlation with FCR (r = –0.47) indicating that feed utilization efficiency increased with the feeding of *A. barbadensis*. Some other parameters also showed a positive correlation with survival; albeit weak, r = 0.25 suggesting potential beneficial effect of A. barbadensis on fish survival. Overall, the positive findings indicated feeding *A. barbadensis* as a diet component had a positive impact on fish growth, feed efficiency and survival.

The correlation among the growth parameters was very high, ranging from 0.85 to 1.00, except for FBW and WG, which were almost equal (r = 0.98). This means that the growth of one parameter was strongly correlated with the growth of the other. On the contrary, FCR had a strong negative correlation with most growth parameters and survival (r = –0.89 to –0.99), indicating that improved feed conversion efficiency is positively correlated with improved fish growth and survival. Moreover, considerable positive correlation was observed between the growth indices and survival (r = 0.83–1.00), which indicated that increased growth performance resulted in increased survival rate.

## Discussion

The current study titled “evaluating the effects of *A. vera* on the growth performance of *C. mrigala*" was aimed to assess the growth parameters of *C. mrigala* given diet containing varying concentrations of *A. barbadensis* (A. vera). The research was carried out to examine the effect of *A. barbadensis* on the fish physiological and meat related aspects. For this purpose, *A. barbadensis* was used as a test diet along with formulated feed in the groups $T_1$, $T_2$ and $T_3$ and also used in the groups $T_0$ as a control diet for comparison. Weekly reading were taken to assess the weight gain, length gain, SGR and FCR in treatment groups. The maximum growth performance in terms of average weight gain, length gain, SGR and improved FCR was recorded in $T_1$ group fed with 500mg/kg *A. barbadensis*, followed by that in $T_2$ group (1000mg/kg), $T_3$ (2000mg/kg) and $T_0$ treatment groups.

In aquaculture, incorporating medicinal herbs into fish diets may enhance the natural defence mechanism of fish against infections during periods of stress, including intense farming, grading, vaccination and reproduction [21]. In the aquaculture sector, the primary focus for commercial production is ensuring the safety and improvement of fish health. Medicinal plants possess natural organic compounds that are highly beneficial in aquaculture and can be utilized for their pharmacological properties, specifically in reducing fish mortality without harming the fish or the ecosystem. Plants are inherent providers of bioactive compounds that have a significant role in antiviral, antibacterial and antioxidant enzymatic activity.

The present study revealed a significant enhancement in weight gain of fish fed with a diet containing 500mg/kg *A. barbadensis*. It has been found that *A. barbadensis* contains number of bioactive substances, including flavonoids, polysaccharides, saponins and vital vitamins all of which help fish immune, digestive enzyme activity and nutrient absorption. These qualities could have a significant impact on *C. mrigala* growth rates and feed efficiencies. These results are comparable with previous research, which found a significant increase in weight gain and specific development rate in *C. mrigala*

fingerlings fed *A. barbadensis* extract [22]. The plants antioxidant and antibacterial properties, which promote overall fish health and digestion, were cited as reasons for the improvement. observed similar results, with *C. mrigala* showing improved feed conversion efficiency and survival when fed *A. barbadensis* enriched diets. Overall, the growth improvement in *C. mrigala* resulting from *A. barbadensis* feeding demonstrates its potential as a natural growth stimulant in aquaculture [23].

The research findings indicate that highest weight gain and length gain observed in $T_1$ and $T_2$. In contrast to the control group, the treated groups showed higher growth rates and feed conversion efficiency, demonstrated that supplementation had a positive impact on tissue development, metabolism and nutrient absorption. This improvement is most likely due to the presence of bioactive substances in *A. barbadensis*, such as Vitamins, enzymes, amino acids and antioxidants. These findings are comparable with findings, which demonstrated a significant improvement in the length growth of *Labeo rohita* fingerlings following food supplementation with *A. barbadensis* [24]. Adding *A. barbadensis* to the diet of fish improved their body length and health status significantly.

The current study found that *C. mrigala* with *A. barbadensis* supplemented feed had significantly higher specific growth rates (SGR). Specifically, adding 500mg/kg ($T_1$), 1000mg/kg ($T_2$) *A. barbadensis* to the meal increased *C. mrigala* SGR, which could be attributable to the bioactive chemicals in *A. barbadensis* that stimulate digestive enzyme activity and facilitate effective nutrient absorption. These findings are consistent with studies in which was observed that *A. vera* extract improved SGR in *Labeo rohita* fingerlings. Similarlyfound that nutritional supplementations with *A. barbadensis* increased growth rates in aquatic fish, most likely because to its antioxidant and immune-stimulatory qualities [24 - 25].

The study also revealed that the feed conversion ratio (FCR) was most efficient in the $T_1$ and $T_2$ groups. FCR is a critical measure of how effectively fish convert feed into body mass, with lower ratios indicating better efficiency. The improved FCR in these groups suggest that *A. vera* enhance the digestive and metabolic efficiency of fish. The optimal supplementation levels ensured that the fish utilized the feed more effectively, converting a greater proportion into body mass. Excessive supplementation, however did not improve FCR, revealed the importance of balanced nutrient levels [26].

Survival rates were monitored throughout the study period to assess the effects of supplementation on the overall health and resilience of the fish populations. Higher survival rates (100%) in supplemented groups i.e. $T_1$ and $T_2$ compared to the control group (80%) were observed which indicates the potential benefits of *A. barbadensis* supplementation in enhancing fish survival under various conditions, including environmental stressors or disease challenges similar to the results of in some studies. The reason behind it might be that these medicinal plants helps to protect fish from diseases. This can contribute to better survival rates, especially during periods of high stress [27].

The present study showed that all the experimental groups gained consistently body weight over the 7-week feeding period in freshwater (FBW). Dietary treatments fish recorded significantly higher weight gain than the control fish which shows that dietary supplementation has a positive effect on weight gain. However, among the treatments T1 gave the highest feedback weight after the experiment indicating the positive effect of

nutrition provided in the formulated diets on feed utilization and hence growth efficiency. The increase in growth in the treated groups can be explained by increased availability of nutrients and digestibility which will favor protein synthesis, tissue development and energy utilization. Providing adequate nutrients in the diet is crucial for optimizing fish growth and feed conversion efficiency, especially in the early growth stages when fish demand high nutrient needs. Better dietary quality can also bring digestive enzymes into the organism into more functional activity and increase absorption of the nutrients, leading to increased growth rate. An increase in growth rate was found in all treatment groups after the fourth week, indicating a cumulative effect of dietary supplementation. Nutrient assimilation will enhance as fish get accustomed to the experimental feeds and eat more, leading to greater biomass gain [28]. Importantly, there are differences among the weekly measurements, which further suggest that the treatments had a long-lasting impact on fish growth during the measurement period. An increase in growth rates is especially crucial in aquaculture, as it can shorten production cycles and boost profits. Finally, the excellent growth performance of the fish in relation to the different dietary treatments (T1 > T2 > T3 > T0) proves successful dietary manipulation. The best FBW recorded in T1 suggests that this treatment could be the most efficient treatment with nutrients balance. The results are in accordance with the published works of various authors that indicated that better food formulations led to greater weight gain, growth rate and total production in cultured species of fish. Based on the results of this study, it can be concluded that the dietary supplementation treatments have potential to significantly improve the growth of fish with Treatment 1 demonstrating the highest possibility for the production of biomass.

Specific growth rate (SGR) is considered one of the most critical growth performance indicators in fish and represents the efficiency that fish have for turning their feed eaten into their body mass/weight. All treatments groups showed the significant improvement of SGR during the experimental period, which meant the culture conditions were good and the nutrient was provided sufficiently. However, there were significant differences between the treatments, indicating that nutrient utilization and growth efficiency was affected by the dietary supplements used. It is believed that the SGR exhibited gradually by all groups is similar to the progression of body size which is correlated with greater nutrient assimilation and feed intake in cultured fish. The results showed that fish in treatment group 1 and 2 had higher growth performance in terms of SGR as compared to growth recorded during the initial weeks of culture, indicating their response to the sustained feed on the experimental feed during the culture period. All experimental treatments showed significant growth superiority over the control treatment in the later stages of the trials with T2 having the highest SGR. The growth improvement seen in T2 could be due to improved digestibility, utilization efficiency of feed and availability of essential nutrients for tissue synthesis and metabolism. Ensuring an adequate dietary protein and energy level has been shown to promote somatic growth via muscle development and cellular proliferation, resulting in increased growth.

There is a remarkable jump in SGR after the fourth week which indicates the cumulative effect of dietary supplementation. Nutrient assimilation and metabolic effectiveness of formulated diets increased as fish became accustomed to the diets, leading to higher growth rates. The same was observed in earlier experiments, and long-term overconsumption of nutritionally improved foods led to an increased yield of growth parameters such as the weight gain and specific growth rate (Inzaghi et al., 2022).

Treatment 1 (T1) and Treatment 3 (T3) showed significant improvement in SGR but their growth response was little lower than T2. This variation may be correlated with the variation in the nutrient composition, palatability, digestibility or bioavailable nutrient composition of feeds. However, both treatments were able to positively affect fish development, since they both significantly improved growth compared with the first culture period. The significant difference found between the sampling weaks also reflect the strong effect on feeding duration in growth. It is however noticeable that the SGR values were higher in the last few weeks of the experiment suggesting that the fish were still continuing to make the best of their nutrients and were not as yet at a growth plateau. This is significant to aquaculture production since increased costs are typically correlated with shorter culture periods and better economic profit from the SGR results. The outcome shows that growth of fish was improved with the dietary supplementation as well, where Improvement 2 was the best specific growth rate. This treatment performed better, allowing this treatment to have a more balanced nutritional value for growth and increase the feed utilization efficiency. Additional studies on feed conversion ratio, protein efficiency ratio, nutrient digestibility and physiological responses would further help to elucidate mechanisms of the observed improvement in SGR [29].

The correlation analysis showed that dietary *A. barbadensis* supplementation positively influenced fish growth. Positive correlations with FBW, WG, LG, WG%, LG%, and SGR (r = 0.30–0.36) indicate that increasing *A. barbadensis* levels improved growth performance and biomass accumulation. The growth-promoting effects of *A. barbadensis* may be due to its bioactive compounds, such as polysaccharides, vitamins, minerals, and antioxidants, which enhance digestion, nutrient absorption, and metabolism [30]. Similar improvements in growth and feed efficiency have been reported in fish fed herbal supplements. *A. barbadensis* showed a negative correlation with FCR (r = –0.47), suggesting better feed utilization, and a weak positive correlation with survival (r = 0.25), indicating potential health and immunostimulatory benefits. The results suggest that *A. barbadensis* supplementation can improve growth, feed efficiency, and survival in fish. The correlation analysis revealed strong positive relationships among growth performance parameters, including final body weight (FBW), weight gain (WG), length gain (LG), specific growth rate (SGR), and survival rate (r = 0.83–1.00). These findings indicate that improvements in body weight and length were associated with enhanced growth efficiency and higher survival. In contrast, feed conversion ratio (FCR) showed strong negative correlations with FBW, WG, LG, SGR, and survival (r = −0.89 to −0.99), suggesting that lower FCR values were associated with better feed utilization and superior growth performance. The positive association of *A. barbadensis* supplementation with growth parameters further suggests its potential role in enhancing nutrient utilization and overall fish performance. Overall, the correlation matrix demonstrates that efficient feed conversion is a key determinant of growth and survival in the experimental fish.

## Conclusion

The results of this study clearly demonstrate that dietary inclusion of *A. barbadensis* has a beneficial role in enhancing the overall performance of *C. mrigala*. The 500mg/kg inclusion level ($T_1$) yielded the most promising outcomes, reflecting significant improvements in growth rate, nutrient utilization and meat composition. The present study demonstrated that dietary treatments significantly improved both fresh body weight (FBW) and specific growth rate

(SGR) of fish throughout the seven-week experimental period. Treatment 1 (T1) resulted in the highest final body weight, whereas Treatment 2 (T2) exhibited the greatest specific growth rate, indicating enhanced nutrient utilization and growth performance. The positive association of *A. barbadensis* supplementation with growth parameters suggests its potential role in enhancing nutrient utilization and overall fish performance. These outcomes underline *A. barbadensis's potential* as a natural and effective feed additive in aquaculture. Future investigations are recommended to explore its long-term impact, optimal dosing and applicability across diverse fish species under varied culture conditions.

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