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Effects of Dietary Supplementation of Lemongrass (*Cymbopogon citratus*) on Growth and Haemato-Biochemical Parameters of *Labeo rohita* (Hamilton, 1822) Fingerlings

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ABSTRACT

The present study was conducted to assess the effect of lemongrass (*Cymbopogon citratus*) leaf powder on the growth and haemato-biochemical parameters of *Labeo rohita* fingerlings. One hundred and eighty numbers of *L. rohita* fingerlings, with an average body weight (10.48 ± 0.16) g and body length (9.6 ± 0.11) cm, were randomly distributed into four experimental groups with three replicates each, following a completely randomized design. The experimental diet included different levels of lemongrass powder: C (0.0 g), T1 (0.5 g), T2 (1 g), and T3 (1.5 g) per basal diet. After the 60-day experiment, hemato-biochemical and growth parameters were analyzed. The results showed increased white blood cell count, red blood cell count, haemoglobin, packed cell volume, and other blood indices. The T3 group exhibited higher mean corpuscular volume, mean corpuscular haemoglobin, mean corpuscular haemoglobin concentration, lymphocytes, and monocytes. The fish fed with a diet containing 1.5 g/100 g of *C. citratus* leaf extract powder showed the highest specific growth rate (2.54 ± 0.04%) and the best feed conversion ratio (1.50± 0.07%). No mortality was observed in any of the experimental groups. And it has been concluded that the dietary inclusion of *C. citratus* leaf extract powder enhances body growth and significantly improves hemo-biological parameters in *L. rohita*.

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INTRODUCTION

The global aquaculture industry has experienced a significant increase in cultivation over the past five years. However, this growth has brought about several challenges in aquaculture feeds, including feed formulation and the escalating costs of fishmeal and fish oil (Yadav *et al*., 2025). Consequently, there is a pressing need to explore sustainable alternatives for aquaculture feed (Tabassum *et al*., 2021; Hussain *et al*., 2024). Additionally, the rapid expansion of aquaculture and the rising demand for fish have led to intensified fish cultivation, resulting in increased stress levels for fish and a subsequent higher risk of diseases (Pennells *et al*., 2025). Fish infections tend to occur more frequently when fish are under stress, often due to factors such as poor nutrition. Recognizing the crucial role of adequate feeds in promoting health and preventing diseases in farmed aquatic species, various measures like inclusion of herbal plants as growth or disease resistance promoter, high protein substitutes etc. are included to address issues associated with fish production (FAO, 2018; Révész and Biró, 2019).

Aquaculture can greatly benefit from the utilization of plants possessing medicinal properties, which can serve as natural and safe alternatives to antibiotics and immune booster (Fatima *et al*., 2024; Yousaf *et al*., 2025). These plants have gained popularity due to their ease of preparation, cost-effectiveness, and lack of adverse effects on consumers, animals, and the environment (Van Hai, 2015). Incorporating herbs and medicinal substances into fish feed not only helps in treating various illnesses but also promotes growth, stress resilience, and immune

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system enhancement in farmed fish. The use of herbs and herbal products in fish feed has minimal negative impacts on both the fish and consumers (Shakya, 2017). Moreover, it is a cost-effective and environmentally friendly approach (Ullah *et al*., 2021; Faisal *et al*., 2024).

The Poaceae family encompasses lemongrass (*Cymbopogon citratus*), a fragrant perennial grass characterized by its tall stature, rhizomes, and densely tufted fibrous roots. In different regions, lemongrass (LG) is also known as Gawati Chah, Nibugrass, and Puthiganda. LG contains a variety of substances that are known to have antioxidant and disease-preventing properties, including essential oils, compounds, minerals, and vitamins. Lemongrass essential oil (LGEO) has been demonstrated to ameliorate diabetes and accelerate wound healing (Adhikary *et al*., 2024). This herb possesses soothing properties and emits a pleasant aroma. LG is a native plant and belongs to the sweet-smelling tall sedge species (Wifek *et al*., 2016). LGEO consists of a total of 13 different components, accounting for 95.98% of its composition. The primary constituents found in LG include neral (31.5%), citral (26.1%), nonan-4-ol (6.54%), camphene (5.19%), 6-metil-hept-5-en2-one (4.36%), citronelol (2.95%), caryophyllene oxide (2.63%), γ-muurolene (2.46%), citronelal (3.83%), β-caryophyllene (3.26%), limonene (2.32%), geranyl acetate (2.27%), and geranial (2.15%), as reported by Brugger *et al*. (2019).

Herbal remedies have emerged as potent immunostimulants utilized in aquaculture due to their ability to enhance fish immune systems, promote growth performance, and possess antibacterial properties. These properties make herbal treatments an effective alternative to chemical-based therapies and antibiotics (Ghiasi *et al*., 2025). Studies indicate that chemical compounds present in LG, such as citral a, citral b, nerol geraniol, citronellal, terpinolene, geranyl acetate, myrcene, and terpinol methyl heptenone can boost fish immunity (Van Hai, 2015). Herbal compounds are considered immunostimulants in aquaculture, demonstrating their potential to improve growth, fish immunity, and antimicrobial properties. Moreover, they serve as favorable alternatives to chemical treatments and antibiotics, as they offer diverse biological activities such as antibacterial, antidiarrheal, analgesic, antidepressant, antimicrobial, antipyretic, antiseptic, bactericidal, diuretic, fungicidal, and insecticidal properties (Dev *et al*., 2024).

In recent years, the utilization of medicinal herbs in the prevention and treatment of fish infections has garnered attention, primarily due to their cost-effectiveness, environmental friendliness, and minimal adverse effects (Elumalai *et al*., 2020). In the freshwater aquaculture sector of India, the production of total freshwater fish is predominantly contributed by three Indian major carps: catla (*Catla catla*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus mrigala*). Among these, rohu is a widely distributed and highly prized freshwater fish in India, Bangladesh, and neighboring countries (Gupta *et al*., 2025). It is also one of the most commonly cultured fish among the major carps in India, due to its favorable growth characteristics and consumer preferences. Rohu plays a vital role in carp polyculture systems and serves as a significant dietary source of protein and polyunsaturated fatty acids (PUFA) (Memon *et al*., 2010). Additionally, according to Ahmed *et al*. (2012), rohu fish exhibits the highest protein content among carp species. Under normal conditions, rohu fish grows rapidly, reaching a total length of 35 to 45 cm and a weight of 700 g to 1000 g within a year (FAO, 2009). The objective of this research is to evaluate the effects of dietary supplementation of LG on the growth performance and haemato-biochemical parameters of *L. rohita* (Hamilton, 1822) fingerlings. This study determines the inclusion of LG, known for its antimicrobial and antioxidant properties, can enhance fish health, improve feed utilization, and promote better growth rates. By assessing parameters such as weight gain, feed conversion ratio, and blood indices, the research aims to explore the potential of LG as a natural, cost-effective dietary additive in aquaculture, contributing to the development of sustainable fish farming practices.

MATERIALS AND METHODS

Experimental location and fish sampling

The experiment was conducted for a duration of 60 days in the wet lab of the Department of Aquaculture, located at the Late Shri Punaram Nishad College of Fisheries in Kawardha, Chhattisgarh. The proximate composition analysis of the feed was carried out at the Department of Fish Harvest and Post-Harvest Technology, while the biochemical examination was conducted at the Aquaculture Nutritional Laboratory. The fish used in this study were *Labeo rohita* fingerlings, with an average body weight of 10.48 ± 0.16 g. The fish were obtained from a state private fish hatchery located in Arjunda, Durg, Chhattisgarh. Upon arrival, the fish were transferred to the wet lab for further experimentation. As a part of the initial process, the experimental fish underwent treatment with KMnO4 @ 5 ppm for 1 min. Subsequently, the fish were placed in a 1000 L circular FRP tank for a period of one week for conditioning and acclimatization. During this time, aeration was provided to ensure suitable environmental conditions for the fish.

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Experimental feed ingredients

Fresh LG leaves were gathered specifically for the purpose of preparing the experimental fish diet from the college site. Fresh LG leaves were gathered specifically for the purpose of preparing the experimental fish diet. These leaves were air-dried, grind into a powder, and stored in airtight packets at 4°C to maintain their freshness. Additionally, other ingredients such as groundnut oil cake, mustard oil cake, rice bran, wheat bran, fish meal, tapioca, vitamin premix, and vegetable oil were procured from the local market in Kawardha (AOAC, 2005).

Experimental design

The experiment was carried out for a duration of 60 days in the wet lab of the College of Fisheries in Kawardha. The experimental setup consisted of 12 rectangular FRP tanks measuring 0.94 × 0.70 × 0.47 m^3 in size, with a water capacity of 300 L per tank. The tanks were covered with nylon netting to prevent fish escape. Prior to the experiment, all tanks were thoroughly cleaned and disinfected using a potassium permanganate solution (4 mg/L). Clean bore well water was then filled to the tanks, and continuous aeration was provided throughout the entire experimental period.

A total of 180 *L. rohita* fingerlings were randomly divided into four different experimental groups, with each group having three replicates. The distribution of the fish followed a completely randomized design (CRD). Each tank was stocked with 15 fingerlings, which had an initial average weight of 10.48 ± 0.16 g and an average body length of 10 ± 0.05 cm. The water level in each tank was maintained at 210 L throughout the experimental period.

Feed formulation and preparation of experimental diet

The reference diet was formulated using various ingredients, including groundnut oil cake, mustard oil cake, rice bran, wheat bran, fish meal, tapioca, vitamin premix, and vegetable oil. The formulation followed the method outlined by the Association of Official Analytical Chemists (AOAC, 2005). The experimental feed comprised four treatments: control (0.0 g LG powder), T1 (0.5 g LG), T2 (1 g LG), and T3 (1.5 g LG). Table I represents the specific details of the reference diet formulation. Before formulating the experimental diet, the nutritional chemical composition of LG was analysed. Table II, based on the study conducted by Choudhary *et al.* (2017), provides information on the different nutritional components of LG.

To prepare the fish feed, all the ingredients except for the vitamin-mineral mixture, were mixed together in a plastic container. Water was added to the mixture to form a dough-like consistency. The dough was then allowed to rest for one hour to ensure proper conditioning. Afterward, it was steamed for 15 min using a pressure cooker. Once steamed, the dough was chilled, and the vitamin and mineral combination was added. Using a hand pelletizer with a 2 mm diameter, the dough was shaped into pellets. These pellets were then dried at room temperature until the moisture content dropped below 10%. After drying, the pellets were carefully labeled and placed in sealed polythene bags for storage.

The fish under the experiment were fed with different levels of LG (T1, T2, and T3) diet for 60 days. Fish were fed twice a day at 09:00 am and 04:00 pm. Siphoning was done regularly to remove uneaten feed and fecal matter.

Table I. Percentage composition of diet used in the experiment.

Ingredients	Composition (g/100g of feed)			
	Control	T1	T2	T3
Mustard oil cake	30	30	30	30
Fish meal	5	5	5	5
GNOC	35	35	35	35
Rice bran	8	8	8	8
Wheat flour	14	13.5	13	12.5
Tapioca	5	5	5	5
Vegetable oil	2	2	2	2
Vitamin premix	1	1	1	1
Lemongrass powder	0	0.5	1	1.5
Total	100	100	100	100

Table II. Proximate composition of lemongrass (*C. citratus*) per 100g.

Content	Value (%)
Moisture	8.31 ± 0.01
Protein	7.5 ± 0.02
Carbohydrate	70.3 ± 0.01
Fat	2.45 ± 0.03
Ash	11.30 ± 0.02

*Values are expressed as a mean ± standard deviation.

Physico-chemical parameters of the tank

During the experiment, various water quality parameters were measured, including temperature, pH, dissolved oxygen (DO), free carbon dioxide, and total hardness. The measurements were taken before feeding the fish in the morning. The water quality parameters

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were sampled every 15th day in all the experimental tanks, following the method described in APHA (2005). The water temperature was measured using a thermometer, while pH was measured using a pH meter. DO levels were determined using appropriate equipment or testing kits. The total hardness of the water was measured using titration methods, and alkalinity was also determined through titration (APHA, 2005).

Growth parameters

The growth rate of the fish in each treatment group and replicate was assessed by measuring the percentage of weight gain at fortnightly intervals throughout the experimental period. Several growth parameters, including percent weight gain, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), and average daily gain (ADG), were calculated using the data collected during the experiment. The growth performance of the fish was evaluated using formulas derived from studies such as Halver and Hardey (2002) and Lal *et al*. (2022, 2023). These formulas were employed to calculate the growth parameters mentioned above, providing insights into the fish's growth and overall performance throughout the experiment.

Haemato-immunological parameters

At the end of the experiment, ten fish from each replicate of every treatment group were selected for blood sampling. Prior to blood collection, the fish were anesthetized using clove oil with a dosage of 0.20 mL per 500 mL of water, following the method described by Fernandes *et al*. (2016). The fish were then gently immobilized for blood collection. Blood samples were collected from the caudal vein using a 1 ml syringe, and the blood was immediately transferred into vials coated with EDTA to prevent coagulation. Haematological parameters, including haemoglobin (Hb) concentration, erythrocyte count, leukocyte count, haematocrit (Hct) percentage, mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), mean corpuscular volume (MCV), platelet count, neutrophil count, lymphocyte count, and monocyte count, were analyzed. An automatic haematology analyser (Benesphera H33s next gen haematology analyzer) was utilized for the analysis of these parameters.

The complete blood count (CBC) analysis included several haematological parameters such as haemoglobin, red blood cells (RBC), white blood cells (WBC), and blood platelets. The estimation of blood Hb was done using the cyanmethemoglobin method as described by Bluxhall and Daisley (1973). Platelet counts were determined using the Neubauer haemocytometer. The RBC count was measured using an improved Neubauer haemocytometer following the method outlined by Shah and Altindag (2004). The WBC count was performed using the same method as the RBC count.

Mean corpuscular constants, including MCV, MCH and MCHC, were estimated using conventional equations. These equations were derived based on the values of Hct, Hb, and RBC counts, as described by Zehra and Khan (2018). These calculations allow for the determination of the average volume, haemoglobin content, and concentration of Hb in individual red blood cells.

Statistical analysis

To determine significant differences between the various treatments, analysis of variance (ANOVA) was conducted at a significance level of 5%. After performing ANOVA, further analysis was carried out using the Duncan multiple range tests. This post-hoc test allows for the comparison of means between different treatment groups, identifying significant differences among them. For these statistical analyses, Statistical Package for Social Sciences (SPSS) version 21 was utilized.

RESULTS AND DISCUSSION

Water quality parameters

Water temperature is a crucial environmental factor that influences various biological and chemical processes in water bodies. In this study, the physico-chemical parameters of water, including temperature (°C), pH, DO (mg/L), alkalinity (mg/L), and total hardness (mg/L), were measured. The average values of these parameters for all the treatment groups are presented in Table III. These measurements provide valuable insights into the water quality and conditions experienced by the fish during the experimental period. Water temperature plays a crucial role in determining the effectiveness of fish growth. In this study, the water temperature varied among the different treatments, ranging from 23°C to 28°C. These temperature ranges align with the findings of Adebayo *et al*. (2020), who concluded that fish can develop and thrive well within temperatures of 24 to 28.0 °C. pH also plays a significant role in the physiological well-being of aquatic organisms. In this experiment, the pH range observed was between 7.60 and 8.0 (as shown in Table III). The addition of LG leaf powder did not have any noticeable effect on water pH. The optimal pH level for carp culture typically falls within the range of 7.5 to 8.5. These findings are consistent with the research conducted by Padala *et al*. (2018). DO concentration in water significantly impacts the growth,

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Table III. Physico-chemical water quality parameters in various experimental groups.

Treatment	Control	T1	T2	T3
Temperature (°C)	24.00 – 28.00	25.00 – 28.00	23.00 – 28.00	24.00 – 28.00
pH	7.60 – 8.00	7.60 – 8.00	7.60 – 8.00	7.60 – 8.00
DO (mg/L)	5.12-6	5.3-6.1	5.5-6.2	5.4-5.8
Alkalinity	97 – 106	100 – 110	95-103	98 – 105
Hardness	106-113	110-120	115-125	115-123

See Table I for details of various groups. Do, dissolved oxygen.

Table IV. Nutritional composition of the different experimental diets (%).

Treatments	Protein	Fat	Carbohydrate	Ash	Moisture	NEF
Control	29.05±0.05	7.12±0.01	6.52±0.01	7.73±0.02	8.10±0.27	40.10±0.05
T1	29.80±0.02	7.09±0.02	6.41±0.01	7.55±0.04	8.03±0.01	41.25±0.07
T2	29.91±0.06	7.03±0.00	6.31±0.01	7.72±0.02	8.01±0.01	41.01±0.08
T3	30±0.05	7.10±0.02	6.32±0.01	7.22±0.0	8.08±0.05	41.27±0.09

For details of groups see, Table I. *Values are expressed as a mean ± standard deviation.

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survival, dispersal, and physiology of shrimps and other aquatic organisms (Solis, 1988). In the present study, the range of DO content in the water was observed to be between 5.3 and 6.2 mg/L. These results are in agreement with the findings of Boyd (1982), who stated that the optimal concentration of DO for aquatic organisms typically falls between 6 and 9 mg/L. Total alkalinity refers to the concentration of bicarbonate, carbonate, and hydroxyl ions in water bodies. It plays a vital role in buffering the diurnal changes in pH. In this study, the alkalinity of the water ranged from 97.5 to 106 mg/L. Water with higher alkalinity is considered more productive in terms of oxygen production and photosynthesis. Regarding water hardness, levels ranging from 50 to 400 mg/L are considered ideal for aquaculture (Saraswathy *et al*., 2015). Fish development is deemed satisfactory with a hardness level of 150 ppm or above, and lime supplementation is not necessary, as mentioned by Swingle (1967). In the present experiment, the water hardness varied between 105 and 125 in different treatments.

Nutritional composition of experimental diet

The nutritional composition of the different experimental diets is represented in Table IV. LG has gained popularity in fish feed due to its potential benefits to growth performance, health, and overall nutritional profile in various fish species. LG has been shown in studies to be an effective feed additive, improving both physiological and biochemical parameters in aquaculture (Linh *et al*., 2020). The protein composition of the diets ranged from 29.05% to 30.0%, while the fat content ranged from 7.03% to 7.10%. The ash concentration varied between 7.22% and 7.73%, and the moisture level was determined to be between 8.01% and 8.10%. The fibre content ranged from 6.32% to 6.52%. The variations in major nutrient content among the diets can be attributed to differences in the proximate composition of the ingredients used in each diet. These variations reflect the different nutritional compositions of the ingredients incorporated into the experimental diets. Studies indicate that the addition of LGEO or powder at specific inclusion rates significantly improves growth metrics in fish species such as Tambaqui (*Colossoma macropomum*) and African catfish (*Clarias gariepinus*). For instance, an optimal inclusion of 0.5 g per 100 g of feed was shown to enhance weight gain and feed conversion ratios in African catfish (Adebayo *et al*., 2020). Similarly, the use of LGEO in tambaqui diets resulted in improved growth rates and muscle glycogen levels (Copatti *et al*., 2022). LG supplementation has been associated with positive changes in blood biochemistry, including increased total protein, albumin, and globulin levels. These changes suggest enhanced immune responses and better overall health in fish. Additionally, LG exhibits antioxidant properties that can mitigate oxidative stress, further promoting health and resilience against diseases (Alagawany *et al*., 2021).

Growth performance

Figure 1 shows the growth performance parameters of the different experimental groups observed at fortnightly

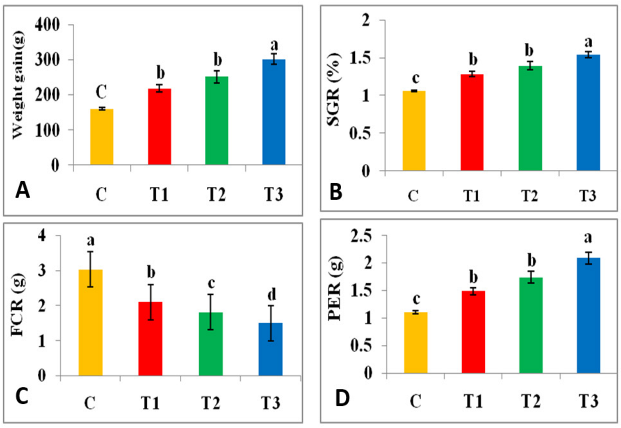

Fig. 1. Growth performance of *L. rohita* recorded under different treatment groups after the feeding of experimental feed; A, weight gain; B, specific growth rate; C, food conversion ratio; D, protein efficiency ratio. *Values are expressed as a mean ± standard error. [abcd]Values with different superscripts differ significantly (P<0.05).

intervals during the experimental period. Significant differences ($p < 0.05$) in body weight were observed among all experimental groups on the 15th, 30th, 45th, and 60th days, except for the initial weight ($p > 0.05$). The highest weight gain was observed in the T3 group (301.17 ± 14.55 g), while the control group showed lower weight gain (160.39 ± 2.50 g) compared to the other treatment groups. These findings are in line with the study conducted by Al-Sagheer *et al*. (2018), who reported that the addition of LEO to the baseline diet significantly improved growth parameters and feed utilization in fish. Similarly, Adeniyi (2020) found that fish fed a diet containing 10 g LGM/kg (lemongrass meal) exhibited improved weight gain, SGR, and PER, as well as a lower FCR. Overall, the results indicate that incorporating LG-derived additives in the fish diet positively affects growth performance and feed efficiency.

Haemato-immunological parameters

Haematological measures are valuable tools for assessing the physiological processes and overall health of fish raised for consumption, particularly in response to nutritional factors (Khan, 2013). The blood Hb levels of the various experimental groups are presented in Table V. The T3 group exhibited the highest Hb content (8.43 ± 0.95), while the control group had the lowest (6.86 ± 0.29). Similar findings were reported by Adebayo *et al*. (2020), who observed improved blood parameters, including Hb content, in *C. batrachus* with an increase in the quantity of *C. citratus* in the feed.

Regarding packed cell volume (PCV), the T3 group showed the highest level (27.03 ± 0.71), whereas the control group had the lowest (20.20 ± 2.95). PCV levels increased from T1 to T3 groups as the LG content in the feed increased from 0.5% to 1.5%. These findings align with the study conducted by Adebayo *et al*. (2020), where improved PCV levels were observed in *C. batrachus* as the quantity of *C. citratus* in the feed increased from 0% to 1% for treatments T1 to T3. In terms of red blood cell (RBC) count, the T3 group recorded the highest value (1.62 ± 0.32), followed by the T2 group (1.11 ± 0.15), the T1 group (1.09 ± 0.15), and the control group (0.55 ± 0.13). These findings support the notion that the incorporation of 1.5% LG in the diet resulted in higher growth and metabolic efficiency.

Table V. Effect of experimental diets on hematological parameters (%) in *L. rohita* fingerlings.

Parameters	Control	T1	T2	T3
Haemoglobin (%)	6.86 ± 0.29^c	7.43 ± 0.63^b	7.60 ± 1.00^b	8.43 ± 0.95^a
PCV (%)	20.20 ± 2.95^c	23.70 ± 3.52^{ab}	25.96 ± 2.54^a	27.03 ± 0.71^a
RBC (%)	0.55 ± 0.13^b	1.09 ± 0.15^{ab}	1.11 ± 0.15^{ab}	1.62 ± 0.35^a
WBC (%)	37.63 ± 15.27^c	38.12 ± 8.81^b	38.12 ± 5.77^b	45.11 ± 0.88^a
Lymphocytes (%)	90.60 ± 0.66^b	92.33 ± 0.88^{ab}	94.7 ± 0.33^{ab}	93.66 ± 0.88^a
Monocytes	4.00 ± 0.57^a	4.00 ± 0.57^a	4.00 ± 0.57^a	4.2 ± 0.57^a
Platelets	0.30 ± 0.02^b	1.00 ± 0.36^{ab}	1.3 ± 0.17^{ab}	1.58 ± 0.25^a
MCV	169.62 ± 7.95^c	164.43 ± 4.03^b	156.88 ± 2.5^{ab}	153.43 ± 5.45^a
MCH	45.75 ± 4.17^c	50.19 ± 2.78^b	51.74 ± 1.23^b	55.18 ± 3.22^a
MCHC	29.21 ± 1.20^b	30.83 ± 1.43^b	31.68 ± 1.43^a	31.68 ± 1.75^a

*Values are expressed as a mean ± standard deviation. [abcd] values with different superscripts in a row differ significantly (P<0.05). PCV, packed cell volume; RBC, red blood cell; WBC, white blood cell; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration.

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Similarly, Adebayo *et al*. (2020) reported improved RBC levels in *C. batrachus* as the quantity of *C. citratus* in the feed increased, but showed decreased levels in treatments with higher levels of LG (1.5% and 2%). The T3 group exhibited the highest level of WBC count (45.11 ± 0.88), while the control group had the lowest count (37.63 ± 15.27). WBC levels increased from T1 to T3 groups as the LG content in the fish feed increased from 0.5% to 1.5%. Adebayo *et al*. (2020) also reported improved WBC levels in *C. batrachus* with an increase in the quantity of *C. citratus* in the feed but showed reduced levels when fed higher levels of LG (1%, 1.5%, and 2%). The control diet group exhibited the lowest percentage of lymphocytes (90.60 ± 0.66), while the T3 group had the highest values (93.66 ± 0.88), followed by the T2 group (92.33 ± 0.88) (Table V). Similarly, Adebayo *et al*. (2020) found improved lymphocyte levels in *C. batrachus* as the quantity of *C. citratus* in the feed increased from 0% to 1.5% for the treatments, but decreased levels were observed when fed with feed containing higher levels of LG (2%). The T3 group recorded the highest level of monocyte count (4.2 ± 0.58), while the control group, T1 group, and T2 group had slightly lower monocyte counts (4.00 ± 0.57). Adebayo *et al*. (2020) reported no significant difference in monocyte count in *C. gariepinus* when fed LG but recorded 0% when fed 1.5% of LG. A higher number of platelet counts were recorded in the T3 group (1.58 ± 0.25) with 1.5% LG incorporation, followed by the T2 group (1.10 ± 0.17) with 1% LG, the T1 group (1.00 ± 0.36) with 0.5% LG, and the lowest in the control group (0.30 ± 0.02) with 0% LG incorporation. These results indicate that as the quantity of LG in the feed increases, the platelet count in the fish blood also increases accordingly. However, Odioko and Daniel (2016) reported a negative impact of sponge plant leaf extract on the platelet count of *C. gariepinus*, demonstrating that different plant extracts can have varying effects on fish platelet counts. The MCV, MCH, and MCHC levels of the various experimental groups are presented in Table V. The control group exhibited the highest level of MCV (168.62 ± 7.95) with 0% LG incorporation, followed by the T1 group (166.32 ± 4.03), the T2 group (156.88 ± 2.58), and the T3 group had the lowest level of MCV (153.43 ± 5.45) with 1.5% LG incorporation. Similarly, Adebayo *et al*. (2020) observed decreasing values of MCV in treatments T1 to T5, with 0%, 0.5%, 1.0%, 1.5%, and 2.0% LG incorporation in the feed, respectively. The T3 group had the highest level of MCH (55.18 ± 3.22), followed by the T2 group (51.74 ± 1.23), the T1 group (50.19 ± 2.78), and the control group had the lowest MCH content (45.75 ± 4.17). Similarly, Alagbe (2020) recorded improved MCH% levels in birds with an increase in the quantity of *C. citrates* in the feed from 0% to 0.2% for treatments T1 to T3, respectively. The T3 group recorded the highest level of MCHC (31.68 ± 1.75), while the control group had the lowest Hb content (29.21 ± 1.20). de Souza *et al*. (2019) reported increasing MCHC levels in Nile tilapia fed *Ocimum bacillum* essential oil. Higher levels of MCHC provide a greater oxygen supply for growth, indicating improved oxygen-carrying capacity in the blood.

CONCLUSION

Based on the findings of this study, it can be concluded that the leaf powder of the medicinal herb LG plays a significant role in improving the growth performance of rohu fingerlings. Incorporating 1.5gm/kg of lemongrass leaf powder into the diets of rohu fingerlings is a simple and effective method. Additionally, the immune-stimulatory potential of *C. citratus* observed in the experimental fish suggests that it can be used as an immunomodulatory agent in fish farming. Overall, the use of lemongrass leaf powder offers a promising ingredient , providing a natural and cost-effective solution to enhance the growth and immune response of fish in aquaculture systems.

DECLARATIONS

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IRB approval

This study was reviewed and approved by the Institutional Review Board (IRB) of Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg, Chhattisgarh-491995, India. All procedures involving animal were carried out in accordance with the ethical standards of the IRB and relevant national guidelines.

Ethical statement

This study was conducted in accordance with the ethical standards and guidelines laid down by Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg, Chhattisgarh-491995, India. All experimental protocols were reviewed and approved by the "Animal Care and Use Committee". The research adhered to national and

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international regulations on the ethical treatment of animals.

Generative AI and AI-assisted technology statement

The authors declare that they have not used generative AI or AI-assisted technologies in the writing or editing of this manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

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