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Research Article

A case study on parasitic infections in fishes in Telangana, India

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Abstract

Parasitic infestations pose a major threat to the cultivable fishes that impact fish health and overall productivity. This case study targeted community and panchayat tanks across Warangal, Hanmakonda, Jayashankar Bhupalpally, and Mulugu districts in Telangana. Around 70-80 infected samples were examined from each site. Species of *Argulus*, *Dactylogyrus*, *Gyrodactylus*, *Myxobolus*, and *Thelohanellus* were found to be dominant parasites in the IMCs, *Channa, Pangasius, Roopchand*. Standard management practices significantly reduced mortality rates, highlighting effective strategies for mitigating parasitic impact. Mortality rates in the farmer-treated tanks (T_1) ranged from 5.5 -13.8%, while implementing recommended treatments (T_2) like 25 kg/ha of salt and 1 L/ha of formalin reduced mortality to 1.2 – 3.9%. The findings highlight key measures for sustainable aquaculture practices.

Keywords: Disease control, Indian Major carps, Parasites, Telangana

Highlights

- *Labeo rohita* and *Catla catla* had up to 42% parasite prevalence (*Argulus*, *Myxobolus*)
- Winter months increased parasitic infections, causing 5-10% mortality in affected tanks
- Treatments with salt (25 kg/ha) and formalin (1 L/ha) reduced mortality from 5-13.5% to 1.2 – 3.9%
- Recommended treatments boosted productivity to 2.523 tons/ha and net returns to Rs.94,527/ha in 2024.

INTRODUCTION

The global fisheries and aquaculture production reached unprecedented levels in 2022, achieving 223.2 million tonnes which valued at 472 billion USD (Food and Agriculture Organization of the United Nations [FAO], 2024). Aquaculture alone accounted for 130.9 million tonnes, worth 312.8 billion USD, representing 59% of the total fisheries and aquaculture output. Inland aquaculture dominated with 62.6% while marine and coastal aquaculture comprised the remaining 37.4%. The capture fisheries contributed 94.4 million tonnes which is around 4.4% higher production compared to 2020 (FAO, 2024). The leading producers included India (1.9 million tonnes), Bangladesh (1.3 million tonnes), China (1.2 million tonnes), Myanmar (0.9 million tonnes), and Indonesia (0.5 million tonnes). However, inland fisheries data may be underestimated due to challenges in data collection (FAO, 2024). Aquaculture is therefore an emerging industrial sector which requires continued research with scientific, technical developments, and innovations (Toranzo et al., 2005)

Telangana state stands at fifth position in fish production have made remarkable progress in inland fish production in India. In the year 2024, the state achieved an impressive output of 4.56 lakh tonnes, with Indian Major Carps (IMC) being the predominant cultivable species. This progress is attributed to several initiatives such as the development of hatcheries, seed stocking programs, and subsidies for aquaculture infrastructure, which have encouraged sustainable practices and enhanced productivity. Telangana's extensive water resources, including reservoirs, ponds, and tanks, provide a robust foundation for fish farming. IMC cultivation is a focal point due to its high market demand and productivity (Murthy, 2024).

In contrast, Andhra Pradesh has long been at the forefront of the aquaculture sector, holding this

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position for many years. The state's focus on integrated fish farming and the adoption of advanced aquaculture practices have positioned it as a national leader. Because of their significant genetic variety throughout major riverine systems, Indian major carps account for over 75% of the state's population of freshwater fish (Behera et al., 2022).

However, both Telangana and Andhra Pradesh face significant challenges in aquaculture, particularly related to disease outbreaks. Issues such as poor biosecurity, intensification of farming practices, and the movement of fish at various developmental stages exacerbate these problems. Among the diseases, parasitic infections alone account for 46% of disease-related losses, posing a severe bottleneck to freshwater aquaculture across India (Bondad-Reantaso et al., 2005; Mishra et al., 2017). Additionally, changing climatic conditions and rising pathogenic microbial loads amplify the sector's vulnerabilities, underscoring the need for comprehensive disease management and biosecurity measures (Devi et al., 2023).

The seasonal variations are another factor significantly affects parasitic prevalence, with higher infestations lower in the monsoon and lower in the pre-monsoon, especially when the water quality is inadequate (Devnath et al., 2024). Due to their lack of expertise in disease prevention and control during outbreaks, small-scale farmers frequently suffer significant losses (Bagum et al., 2013). Strengthening the farmer education and management practices is critical to mitigating these challenges.

In India especially, the traditional culture systems have faced serious challenges from parasitic infections. The disease management methods such as application of pesticides and therapeutic agents, often harm both target and non-target organisms. Ectoparasites on freshwater fish may be eliminated by immersion of the infected host into high NaCl concentrations, potassium permanganate, copper sulphate (Buchmann, 2022). Moreover, due to insufficient documentation and limited research on fish parasites, are also leads to huge economic losses. Limited research in Andhra Pradesh has documented fish parasites like Myxosporean and Monogeneans, which frequently invade polyculture systems, especially in the winter (Sandeep et al., 2016). Hence, documentation on the incidence of parasites is very essential for creating efficient management plans, reducing the effects of disease, and guaranteeing sustainable fish farming methods. In light of this, the current study set out to investigate the frequency and management of certain parasites in Telangana, India's traditional fish production tanks.

MATERIALS AND METHODS

Sampling areas: The infected fish samples were collected from year-round IMC rearing facilities from the districts of Telangana (Fig. 1) in 2021 and 2024 (Table 1), especially during the winter seasons (October to December). The most cultivable fishes including *Cirrhinus mrigala* (vern. Erramila), *Labeo rohita* (vern. Ragandi), and *Catla calta* (vern. Krishna boche), *Channna striatus* (vern. Korrameenu), *Pangasius pangasius* (Pangas), *Piractus brachypomus* (Roopchand), were collected from Warangal, Hanmakonda, Jayashankar Bhupalpally, and Mulugu districts for the investigation. Initially the samples were collected based on their behavioural and physical appearances (level-I diagnosis). Followed by, the collected fish samples were examined for various parasites such as *Argulus*, *Dactylogyrus*, *Gyrodactylus*, *Myxobolus* and other parasites. The samples were mainly collected from most cultivable area Grama panchayat tanks of four sites (one sampling site from each district) which has a stocking density of 3000-4000/ha in a polyculture paradigm. Random sampling was done with the help of cast net at four different orientations, and from each tank, 70 - 80 fishes were examined for gross pathological observation. A proper questionnaire was prepared to fill the data regarding the parasites' prevalence and the method of treatment followed by the farmers. The culture water in each tank had an average temperature of 27 to 31°C at the time of collection.

Identification of parasites: A total of 500 specimens were collected for the sampling from each variety of fish, which were around 3-4 months old, with an average weight of 300 - 500 g. A detailed case reports were recorded for each fish specimen's which includes stocking density, days of culture, fish appearance, health status, any outward signs is part of the gross observations and treatment history. Followed by detailed comprehensive parasite examinations of the fish's gills, fins, skin and operculum were performed under a microscope. Other gross pathological symptoms were also carefully noted and documented.

A formula (Margolis et al., 1982) was used to analyse the data and determine the prevalence of parasites known to infect fish. The following is the formula for a specific infection location.

$$\text{Prevalence} = \frac{\text{Number of infected fish}}{\text{Number of examined fishes}} \times 100$$

RESULTS

The behavioural symptoms of the affected animals, particularly in the early morning between 6 AM and

10 AM, included restlessness, floating on the water surface, and turning their bodies to the left or right side.

The pathological symptoms of infected animals with myxoboliosis include pale gills with heavily necrotised and inflammatory gill filaments, white gill patches and heavy mucus on the body surface and gills. Further, we have also observed massive tissue liquefaction in the infected animals. Similarly, *Dactylogyrus*-infected animals showed pale gills; heavy mucus production and clubbing of gill filaments were observed in the gill tissue. The *Gyrodactylus*-affected animal showed heavy mucus production on skin and scale loss. In the *Thelohanellus*-infected animals, we have observed dark fins, skin lesions and intestinal cysts. Similar to our findings, several authors recorded the clinical symptoms from this investigation were consistent with those from previous studies in *C. catla* by Balakrishna et al. (2024), *Pangasianodon hypophthalmus* by Kumar, Roy et al. (2018), and Mamun et al. (2020). Infestation of *Argulus* is similar to Kumar, Kumar et al. (2018) in *C. catla*. *L. rohita* and *C. mrigala.*

In the current investigation, we have observed various parasites, including *Argulus* spp., *Dactylogyrus* spp., *Gyrodactylus* spp., *Myxobolus* spp., and *Thelohanellus* spp. The present study investigated the prevalence of argulosis in different cultured fish species, highlighting significant variations in susceptibility. Among the examined species, *Labeo rohita* (Rohu) exhibited the highest prevalence (42.0%), followed by *Catla catla* (34.8%) and *Cirrhinus mrigala* (Mrigal) at 33.6%. In contrast, *Channa* species showed a lower prevalence (11.6%), while *Pangasius* had the lowest recorded prevalence among affected species (4.4%). Notably, *Roopchand* showed no cases of argulosis in the examined sample. The overall prevalence within Indian major carps (IMC), including Rohu, Catla, and Mrigal, was considerably high, with an estimated prevalence of 36.8%. This suggests that IMCs are more susceptible to argulosis compared to other cultured species, likely due to their physiological and environmental preferences. The higher prevalence in Rohu and Catla may be attributed to their dense stocking in aquaculture systems, which can facilitate the spread of *Argulus* parasites. Additionally, factors such as water quality, temperature, and host immune response may contribute to varying infection rates. Comparatively, *Pangasius* displayed a remarkably lower prevalence (4.4%), which could indicate a greater resistance to argulosis or differences in habitat preferences that reduce exposure to the parasite. The absence of infection in *Roopchand* suggests either a natural resistance to *Argulus* infestation or environmental conditions that are less conducive to parasite transmission in this species. We found *Dactylogyrus* spp. and *Myxobolus* spp., in the gills, *Gyrodactylus* spp., on the skin, and *Thelohanellus* spp. on the fins, *Argulus* on the skin and fins (Figs. 1 and 2). The prevalence of parasitic infections in the cultivable fishes were given in the Table 1. Abidi et al. (2011) reported that Monogenean

Table 1. An overview of the incidence and infestation of parasites at four farm sites (2021-24)

Cultured fish	No. of affected fishes	No. of fish examined	Prevalence (%)	Prevalence (%) in IMC
		Argulosis		
Pangasius	22	500	4.4	
Roopchand	0	500	0	
Channa	58	500	11.6	
Catla	174	500	34.8	36.8
Rohu	210	500	42.0	
Mrigal	168	500	33.6	
Total	632	3000	-	
		Myxosporidians		
Pangasius	129	500	25.8	
Roopchand	135	500	27.0	
Channa	181	500	36.2	
Catla	201	500	40.2	41.6
Rohu	228	500	45.6	
Mrigal	196	500	39.2	
Total	1070	3000	-	

Cont. Table 1.

Table 1., Cont. ...

Cultured fish	No. of affected fishes	No. of fish examined	Prevalence (%)	Prevalence (%) in IMC
Skin Fluke				
Pangasius	68	500	13.6	
Roopchand	31	500	6.2	
Channa	56	500	11.2	
Catla	145	500	29.0	31.4
Rohu	189	500	37.8	
Mrigal	137	500	27.4	
Total	626	3000	-	
Gill Fluke				
Pangasius	128	500	25.6	
Roopchand	101	500	20.2	
Channa	146	500	29.2	43.6
Catla	208	500	41.6	
Rohu	247	500	49.4	
Mrigal	199	500	39.8	
Total	1029	3000	-	

Fig. 1. Pale gills in Catla

Fig. 2. *Argulus* infestation in Rohu

parasites are mostly affecting the cyprinid group of fishes, which are the highly valuable in Southeast Asian countries. In the present investigation also recorded with 75% (Skin fluke- 31.4%, Gill fluke- 43.6%) of Monogenean parasites in IMC.

DISCUSSION

Clinical signs/symptoms

Supplementary Table 1 lists the prevalence of various parasite species from every aquaculture tank. Based on their tissue specificity and general clinical gross symptoms, the current parasites are divided into several main categories. As shown in Fig. 1, growth reduction and mucus accumulation are high in all fishes infected with the parasites, but they are noticeably higher in *C. catla* infected with the gill fluke. Similarly, the polyculture tanks showed increasing mucus accumulation as *C. catla* died (Kumar et al., 2020; Balakrishna et al., 2024). However, the posterior position, or muscle mass, was emaciated, and the head's size was significantly on the larger side. It's known as Pinheads in technical parlance. In this study, this was dubbed "Reverse growth," since the fish's growth slows down in the days that follow the infestation. Gill filaments showed a cloudy appearance and creamy white spots that were 5-10 mm in diameter. The fish displayed haemorrhaged fins, and stress brought on by parasites, which in turn cause secondary bacterial infections, is responsible for the erosion of the caudal fin (Abdel-Latif et al., 2020). The recommended treatment tanks in this investigation had lower death rates (1-4%). Farmers treated tanks with higher death rates had mortality rates ranging from 6.3% to 14.25% over the 2021-2024 study period.

Parasite diagnosis and prevalence

Argulosis: The prevalence of Argulosis was highest in Rohu (42.0%) and Catla (34.8%), while Channa exhibited a relatively lower prevalence (11.6%), and Roopchand showed no infection. This aligns with Das et al. (2016), who reported that carps are highly susceptible to *Argulus* infestation, with an overall prevalence of 33.89%. Additionally, Haque et al. (2004) observed a low prevalence (10%) of *Argulus* in Pangasius, which is consistent with the present study's finding of 4.4% in Pangasius. Jahan et al. (2025) noted a higher prevalence (50–75%) of *Argulus* in Channa from June to December, which is much higher than the 11.6% prevalence observed in the current study, possibly due to seasonal variations.

Myxosporidian infections: Myxosporidian infections were most prevalent in Rohu (45.6%) and Catla (40.2%), with lower rates in Pangasius (25.8%) and Roopchand (27.0%). These findings align with Kaur and Singh (2012), who documented 57 *Myxobolus* species affecting Indian major carps. The prevalence in Rohu observed in the present study (45.6%) is slightly higher than the 36.67% reported by Kaur et al. (2015), which may be attributed to differences in sample size, environmental conditions, or management practices. The high prevalence in Channa (36.2%) is supported by Markevich (1951), who reported severe mortality in Channa infected with *Myxobolus* during high-temperature periods. Additionally, the findings in Pangasius are consistent with Tun et al. (2019), who reported *Myxobolus* spp. as a major parasite in this species.

Skin fluke infections: Skin fluke prevalence was highest in Rohu (37.8%) and Catla (29.0%), while Pangasius had a lower prevalence (13.6%). This is in agreement with previous findings by Banu et al. (1993) and Hossain et al. (1994), who reported monogenean trematode infestations in Pangasius. The observed prevalence in IMC (31.4% falls within the range reported by various studies on monogenean infections in carps. The findings also align with Ramudu and Dash (2013), who suggested that larger fish are more susceptible due to increased surface area available for parasite attachment.

Gill fluke infections: Gill fluke infections were most prevalent in Rohu (49.4%), followed by Catla (41.6%) and Mrigal (39.8%). The observed prevalence in Pangasius (25.6%) aligns with Pokhrel and Oanh (2021), who found a prevalence of 23% for *Dactylogyrus* in Pangasius. Paul et al. (2021) reported *Dactylogyrus* prevalence in freshwater carps ranging from 37.5% to 76.54%, which is consistent with the high prevalence observed in Rohu (49.4%), Catla (41.6%), and Mrigal (39.8%). The findings support the assertion by Gibson et al. (1996) that *Dactylogyrus* is a widespread parasite with high species diversity. Additionally, Dupont and Lambert (1986) established that every cyprinid species harbors at least one *Dactylogyrus* species, further reinforcing the current study's findings.

Control measures

In order to prevent mortality in the early stages of disease outbreaks, farmers applied pesticides; nevertheless, their inability to effectively treat the parasites resulted in a reduction in output (Table 2). The recommended treatment for the later cultivation cycle was a monthly application of liquid formalin (1 L/ha) and common salt (25 kg/ha). Sanitizer Potassium Permanganate ($KMnO_4$) was administered as a long-term dip treatment at a rate of 400 g per acre (0.1 ppm) to suppress secondary infections. In aquaculture, formalin is a common chemical used to manage *Saprolegnia* species, monogenetic trematodes, and external protozoa (Rowland et al., 2006). While formalin was effective for ongoing bath treatment for six days to control *Ichthyophthirius multifiliis* (Ich), common salt was also proven to be an effective therapy for treating fishes infected with *Ichthyophthirius multifiliis* (Ich) within three days after infection (Maceda-Veiga & Cable, 2014). According to Kumar et al. (2022), supplementing with turmeric oil at the ideal dose resulted in enhanced survival against parasitic-bacteria co-infections as well as anti-stress and anti-oxidative (Darwish et al., 2010) reactions. Following the recommendations, fish productivity was improved with higher net returns and a B: C ratio due to a decrease in parasite load when common salt and formalin were applied (Table 2). Similarly, ectoparasites, protozoans, and monogenean parasites had a significant impact on carp farms' growth and productivity (Hossain et al., 2022). When comparing suggested tanks to farmer-treated tanks, the spread of infection, output losses, and economic losses were closely observed (Table 2). Compared to bacterial and viral illnesses, parasitic infections often have very little effect on the host. On the other hand, severe parasite infections show negative host effects. The

Table 2. Economic and production indicators in farmer-treated tanks and tanks with suggested treatment (Demonstration)

Technology Evaluated	Mortality rate %	Production per hectare (tons)	Net return (Profit) in ₹/ha	B:C ratio
	2021			
T_1: FT: Using chemicals after observing the prevalence of disease	13.8	1.20	23280	1.23
T_2: RT: Monthly application of salt (25 kg/ha) and formalin (1 L/ha) during the culture period	3.9	1.48	38500	1.30
	2022			
T_1: FT: Using chemicals after observing the prevalence of disease	6.32	1.29	33200	1.29
T_2: RT: Monthly application of salt (25 kg/ha) and formalin (1 L/ha) during the culture period	1.8	1.67	59780	1.48
	2023			
T_1: FT: Using chemicals after observing the prevalence of disease	8.8	1.80	48900	1.33
T_2 : RT: Monthly application of salt (25 kg/ha) and formalin (1 L/ha) during the culture period	4.1	1.99	66230	1.47
	2024			
T_1: FT: Using chemicals after observing the prevalence of disease	5.5	2.225	76420	1.56
T_2: RT: Monthly application of salt (25 kg/ha) and formalin (1 L/ha) during the culture period	1.2	2.523	94527	1.58

(Note: FT- Farmer Treatment, RT- Recommended Treatment)

fishes do have indirect effects, such as decreased growth, which has a significant impact on fish production; increased feed conversion ratio (FCR), which causes daily feed waste and further deteriorates the condition; and secondary infections. Mortality was not considerable even in this study, but chronic losses, which made up 21.3% of all parasite infestations, were reported to be between 5% and 10% on average during each subsequent year.

The primary source of illness occurrences in the freshwater farming sector has been parasitic diseases. According to a recent study by Sahoo et al. (2020), parasitic illnesses have dominated India's pathogens, accounting for 75% of all disease incidences from 2016 to 2019. The state of Andhra Pradesh had the highest prevalence of parasitic infections (Balakrishna et al., 2024). Throughout the culture stage, freshwater fishes in India are vulnerable to a variety of parasite illnesses (Vineetha & Abraham, 2009; Vijaysundardeva et al., 2018). Of these, infestations of monogeneans and Myxosporidians accounted for the bulk, with rates of 25% and 9%, respectively (Mishra et al., 2017). Mishra et al. (2017) state that Myxosporidians can impact fish at every stage throughout the summer, rainy season, and winter. In India, Myxosporean and monogeneans account for roughly 13% and 19% of all parasite illnesses, respectively (Sahoo et al., 2020). These parasite infections have the potential to cause significant financial losses for the aquaculture and fishing industries. Parasites may have the chance to infect the host if the water temperature suddenly changes with the seasons. The IMCs in Telangana's Warangal district demonstrated the prevalence of parasites and mortality throughout four years of frequent winter sampling. Winter was the most vulnerable season because of low water temperatures, waning immunity, and the issue of water quality (Dash et al., 2015; Sahoo et al., 2020). Compared to fluke infections, Myxosporidian infections were found to have caused a somewhat higher number of deaths during this season. According to earlier research, Myxosporidian infections are common and have a high wintertime prevalence (Mukherjee et al., 2016; Ahmad & Kaur, 2018; Sahoo et al., 2020). Carps weighing 200–500 g also showed greater incidence illnesses, which supports the current research (Mishra et al., 2017; Sahoo et al., 2020). Many myxosporean parasites have been found in different fish species in India; however, most of them have been found in cyprinids (Kaur & Singh, 2012). According to the current study, rohu (*L. rohita*) were susceptible to gill myxoboliosis because they had the greatest prevalence rate of myxosporidian infestation among IMCs, at 45.6%. With a 20–30% death rate, *T. bifurcate* is the most virulent myxosporidian that infects *L. rohit*a's gills (Farhaduzzaman et al., 2009; Kaur & Katoch, 2014). Five to ten percent of the deaths in the current investigation were caused by myxozoan-infected tanks. All IMCs were parasitised, with the exception of common carp, which may be because of host susceptibility. According to Kalavati and Nandi (2007), gill myxoboliosis was the most common disease in aquatic environments across numerous Indian states, affecting all three of the main carp species. According to reports from Punjab, several myxozoan parasites most commonly infest the gills (Ahmad & Kaur, 2018).

According to earlier research, myxozoans had a higher overall infection prevalence (51.66%) in the months of December through February than skin flukes (17.5%). The maximum prevalence of 37% has been documented during the winter months of December through February (Banerjee & Bandopadhyay, 2010). IMCs had an overall parasite prevalence of 38.35%, with gill flukes having the highest prevalence (43.6%), followed by myxosporeans (26.2%), *Argulus* (36.8%) and skin flukes (31.4%).

Catla fish have demonstrated a high level of sensitivity to both parasites among IMCs. Additionally, Khatri et al. (2009) discussed how susceptible catla is to infection. According to Sahoo et al. (2020), the catla's high sensitivity to a variety of diseases is caused by its surface feeding habits and exposure to temperature changes, which weakens its immune. Similarly, notably high fluke infection loads were observed in the current investigation, primarily in the catla variety.

Kalavati and Narasimahamurti (1985), Adriano et al. (2009), and Kaur and Katoch (2014), have all reported cyst rupture and inflammation, which results in haemorrhages and a notable loss of respiratory surface. It is well known that the cysts of these monogenetic trematodes harm the gills and skin. Impaired breathing is directly impacted by irritation and gill tissue loss (Petchimuthu et al., 2018). Fish finally experienced abrupt asphyxia due to damage to their respiratory organs and osmoregulatory system, which culminated in morbidity and death.

In summary, the present study provides thorough recommendations for the control and treatment of diseases caused by Myxosporean and monogenean parasites in large-scale culture systems. These parasites were harvested from Indian big carps using their gills and parts of their skin tissues. In particular, increased occurrence was noted in rohu and catla. The results of this study will be helpful in putting into practice BMPs that are necessary to guard against the frequent occurrence of illness and aquaculture production losses. Compared to the farmer-treated groups, the control measures suggested in the study had a greater B:C ratio, decreased mortality, and boosted production. The future of scientific approaches to disease control systems depends critically on the continued development of our understanding of the disease cycle, the host-pathogen relationship, and the environment's interaction before disease occurrence.

The findings confirm that gill myxoboliosis and fluke infestations are prevalent among Indian major carps, with *Labeo rohita* and *Catla catla* exhibiting the highest susceptibility. The study demonstrates that the seasonal variations, particularly during winter, contribute to higher infection rates and mortality, reinforcing previous research on the temperature-dependent nature of parasitic outbreaks. Furthermore, the economic assessment underscores the substantial financial burden of parasitic infections on aquaculture productivity. Compared to conventional chemical treatments applied by farmers, the recommended treatment strategies monthly applications of common salt and formalin, proved to be more effective, leading to lower mortality rates, improved fish productivity, and higher economic returns. Moving forward, a deeper understanding of host-pathogen interactions and environmental influences will be essential in developing more sustainable and targeted approaches to disease control in freshwater aquaculture systems.

Future research should focus on alternative, eco-friendly treatment methods, such as herbal and probiotic-based interventions, to minimize the dependency on chemical treatments and enhance long-term sustainability in aquaculture practices.

Conflict of interest: The Authors have no conflict of interest in this study.

Author's contribution: GG: Involved in investigation, data generation; LN: Preparing original draft, engaged in conceptualization, data curation; ChL: Supervision and final editing; DCB: Involved in statistical analyses; BD: Methodology; PTKR: Editing; JLS: Analysis of data.

Data availability statement: The dataset generated during research needs to be available from the corresponding author upon reasonable request.

Ethical approval: The ethical committee of P. V. Narasimha Rao Telangana Veterinary University has approved the study.

Use of artificial intelligence tools: Authors hereby declare that no generative AI technology, such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators, has been used during the writing or editing of manuscripts.

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