

because they respond to nutritional status, stress, and disease conditions. Previous studies have demonstrated that haematological variables serve as sensitive indicators of physiological changes in African catfish (Melefa et al., 2020; Okomoda et al., 2024). The differences recorded among the dietary treatments suggest that the herbal supplements elicited distinct physiological responses.

Fish fed the garlic-supplemented diet recorded the highest packed cell volume and haemoglobin concentration. These parameters are closely associated with oxygen transport and are often used to assess the physiological status of fish. Reduced values have been linked with stress and impaired metabolic activity, whereas elevated values are generally associated with improved oxygen-carrying capacity and better physiological condition (Dawood et al., 2022; Okomoda et al., 2024). The results obtained in the present study suggest that garlic promoted erythropoietic activity and enhanced blood oxygen transport.

This pattern was further reflected in the red blood cell counts, which were considerably higher in fish fed garlic and neem diets than in those receiving the control diet. Red blood cells are responsible for transporting oxygen to tissues and are therefore important for metabolic processes. The beneficial effects of garlic observed in the present study agree with earlier reports indicating that garlic supplementation improves physiological condition and innate immune responses in African catfish (Nyadjeu et al., 2023; Megbowon et al., 2024). These findings highlight the potential of garlic as a functional feed additive capable of improving blood characteristics in cultured fish.

Among the herbal treatments, neem produced the strongest response in terms of immune-related parameters. Fish fed the neem diet recorded the highest white blood cell counts and neutrophil percentages. White blood cells and neutrophils are important components of the innate immune system and are involved in defence against invading pathogens. Previous studies have shown that neem-derived compounds possess immunostimulatory properties and can enhance disease resistance in cultured fish (Oyebola et al., 2020; Ibrahim et al., 2023). The elevated leukocyte values observed in this study are therefore indicative of enhanced immune competence rather than pathological stress.

Although the erythrocytic responses obtained with ginger were less pronounced than those observed with garlic and neem, the measured blood parameters remained within normal physiological limits. This suggests that ginger supported normal physiological function throughout the feeding period. Earlier studies have consistently reported beneficial effects of ginger on growth, antioxidant status, and overall health in African catfish (Wei et al., 2023; Uddin et al., 2025). Differences in inclusion level, feeding duration, and phytochemical composition may explain the relatively moderate responses recorded in the present study.

Another notable finding was the increase in white blood cell counts across all herbal treatments compared with the control group. This trend indicates that the three phytobiotics stimulated aspects of innate immunity, although the magnitude of response varied among treatments. Similar observations have been reported in studies advocating the use of phytogenic additives as sustainable alternatives to antibiotics in aquaculture (Mohammed et al., 2025; Le Xuan, 2026). The results of the present study support the growing interest in plant-based feed additives as practical tools for improving fish health and reducing dependence on conventional chemotherapeutic agents.

5 Conclusion

This study examined the effects of dietary supplementation with garlic (*Allium sativum*), ginger (*Zingiber officinale*), and neem (*Azadirachta indica*) on the nutritional quality of formulated diets and the haematological responses of *Clarias gariepinus*. The inclusion of these herbal additives improved the nutrient composition of the diets through increases in crude protein, ash, crude fibre, and ether extract, accompanied by a reduction in nitrogen-free extract. These changes indicate that the herbs contributed not only bioactive compounds but also nutrients capable of enhancing feed quality.

The haematological results showed that the phytogenic supplements influenced fish health in different ways. Fish fed the garlic-supplemented diet recorded higher packed cell volume, haemoglobin concentration, and red blood cell counts, suggesting improved oxygen transport and better physiological condition. In contrast, neem