

(Okomoda et al., 2024). Among these indicators, haematological parameters are particularly useful because changes in blood characteristics provide valuable information on fish health status on the health status and stress responses of fish (Melefa et al., 2020; Okomoda et al., 2024). Previous studies have shown that environmental changes can significantly affect erythrocyte and leukocyte profiles, highlighting the sensitivity of blood indices as indicators of fish health (Oluah et al., 2020; Mangkunegara et al., 2023).

Disease outbreaks remain a major constraint to sustainable aquaculture, particularly under intensive culture conditions where fish are exposed to multiple stressors (Mohammed et al., 2025). Antibiotics have traditionally been used to control disease problems; however, concerns over antimicrobial resistance have increased interest in alternative approaches to fish health management. Evidence suggests that excessive use of antibiotics in aquaculture may promote the emergence and spread of resistant microorganisms within aquatic environments (Mohammed et al., 2025). Consequently, attention has shifted towards sustainable dietary strategies that improve fish health without posing ecological risks (Akpomughe et al., 2024; Le Xuan, 2026).

One area that has attracted growing interest is the use of phytobiotics as functional feed additives. These plant-derived products contain bioactive compounds capable of influencing growth, metabolism, immune responses, and disease resistance in cultured fish (Le Xuan, 2026). Several studies have shown that phytobiotics can enhance digestive processes, improve nutrient utilization, and stimulate innate immunity. Their incorporation into aquafeeds is therefore increasingly regarded as an important component of sustainable aquaculture development because they offer health benefits while reducing dependence on synthetic drugs and chemotherapeutic agents (Le Xuan, 2026).

Among the various phytobiotics investigated in catfish culture, garlic (*Allium sativum*) and ginger (*Zingiber officinale*) have received considerable attention because of their beneficial effects on growth and health (Megbowon et al., 2024). Dietary supplementation with these herbs has been associated with improved growth performance, feed utilization, and body composition in African catfish fry and juveniles (Nyadjeu, 2021; Nyadjeu et al., 2021). Studies have also shown that the combined use of garlic and ginger can enhance physiological performance and growth responses in juvenile fish (Nyadjeu et al., 2023). Similarly, ginger supplementation has been reported to improve nutrient utilization and promote improved health status in catfish, supporting its potential as a functional feed ingredient (Wei et al., 2023; Uddin et al., 2025).

Neem (*Azadirachta indica*) has also gained recognition as a promising natural additive because of its antimicrobial, immunomodulatory, and prophylactic properties (Yusuff and Ibidapo Obe, 2024). Previous studies have demonstrated that neem-based products can contribute to disease prevention and improve health management in African catfish production systems (Oyebola et al., 2020). Therapeutic applications of neem have been linked with enhanced physiological resilience and improved health status in catfish species (Parvin et al., 2023). More recently, nano-formulated neem products have been reported to stimulate immune responses and increase resistance to disease, further emphasizing the biological potential of neem-derived compounds in aquaculture (Ibrahim et al., 2023).

The effects of dietary phytobiotics are often reflected in haematological characteristics because blood parameters respond readily to changes in nutritional and physiological conditions (Melefa et al., 2020). Parameters such as red blood cell count, haemoglobin concentration, and packed cell volume are commonly used to assess oxygen transport capacity and metabolic efficiency in fish (Okomoda et al., 2024). Likewise, white blood cell counts and differential leukocyte profiles provide useful information on immune responses and disease resistance mechanisms (Oluah et al., 2020; Sayed et al., 2022). For this reason, haematological analysis has become an important tool for evaluating the influence of dietary interventions on fish health and welfare.

Although garlic, ginger, and neem have each been reported to exert beneficial effects in fish, information comparing their relative contributions to welfare-related responses in *Clarias gariepinus* remains limited (Megbowon et al., 2024). Most existing studies have concentrated on growth performance or immune responses separately, with relatively few investigations adopting a more integrated approach that considers both physiological wellbeing and