

welfare indicators simultaneously (Nyadjeu et al., 2023; Megbowon et al., 2024). This limitation has hindered the development of evidence-based feeding strategies aimed at improving fish welfare while sustaining productivity under commercial farming conditions (Awhefeada et al., 2025; Le Xuan, 2026).

Against this background, a comparative evaluation of dietary supplementation with garlic, ginger, and neem in *Clarias gariepinus* is necessary. Understanding how these phytobiotics influence physiological wellbeing and welfare-related parameters will provide valuable information for the development of sustainable nutritional strategies. Such approaches have the potential to improve fish health and reduce dependence on conventional chemotherapeutic agents, thereby supporting more environmentally responsible aquaculture practices (Mohammed et al., 2025; Le Xuan, 2026).

## 2. Materials and Methods

### 2.1 Study area

The feeding trial was carried out at the Fisheries Research Farm and Fisheries Laboratory, Delta State University, Asaba Campus, Delta State, Nigeria. Laboratory analyses were conducted under controlled conditions following standard aquaculture and fish health procedures.

### 2.2 Experimental fish and rearing conditions

A total of 120 healthy hatchery-produced African catfish (*Clarias gariepinus*) fingerlings with an average body weight of 10.6 g and an average total length of approximately 9 cm were obtained from the Department of Fisheries and Aquaculture Research Farm, Delta State University, Abraka.

The fish were acclimatized to the experimental conditions for 24 h before the commencement of the feeding trial. After acclimatization, the fish were randomly assigned to twelve plastic tanks (150 L capacity) at a stocking density of 10 fish per tank. Each tank was covered with mosquito mesh to prevent escape and protect the fish from external predators. Water in the tanks was renewed every three days throughout the experimental period to maintain suitable water quality.

### 2.3 Experimental design and duration

The experiment was arranged in a Completely Randomized Design (CRD) consisting of four dietary treatments, each replicated three times, giving a total of twelve experimental units. The feeding trial lasted for three months, from May to July.

The dietary treatments were as follows:

- T1: Control diet without herbal supplementation (0%)
- T2: Diet containing 2% garlic (*Allium sativum*) powder
- T3: Diet containing 2% ginger (*Zingiber officinale*) powder
- T4: Diet containing 2% neem (*Azadirachta indica*) leaf powder

### 2.4 Preparation of herbal additives

Fresh garlic bulbs and ginger rhizomes were purchased from a local market in Abraka, Delta State, whereas fresh neem leaves were collected from mature trees within the university environment. The plant materials were washed thoroughly and air-dried before being milled into fine powder. The powdered samples were stored in airtight containers until they were incorporated into the experimental diets.

### 2.5 Diet formulation

Experimental diets were formulated using Pearson's square method. The major feed ingredients consisted of maize, fishmeal, groundnut cake, palm kernel cake, wheat meal, bone meal, vitamin-mineral premix, palm oil, and cassava starch. Depending on the treatment, garlic, ginger, or neem powder was incorporated into the diets at an inclusion level of 2%.

The diets were pelleted, air-dried, and stored under dry conditions until use.