

2.6 Proximate analysis of experimental diets

Samples of the experimental diets were analysed for moisture content, crude protein, crude fibre, ether extract, ash content, and nitrogen-free extract according to the standard procedures of the Association of Official Analytical Chemists (AOAC, 2000). Nitrogen-free extract was determined by difference after subtracting the percentages of moisture, crude protein, crude lipid, crude fibre, and ash from 100.

2.7 Feeding trial and growth monitoring

Following acclimatization, the fish were weighed and measured before the start of the feeding experiment. Feeding was carried out twice daily between 08:00-09:00 h and 17:00-18:00 h at a rate equivalent to 3% of body weight. Feed ration was adjusted periodically in line with changes in fish weight.

Throughout the study, feeding behaviour and feed acceptance were observed and recorded. Body weight and total length measurements were taken monthly using a digital weighing balance and a graduated measuring board, respectively.

2.8 Water quality monitoring

Water quality parameters were monitored throughout the experiment to ensure favourable conditions for fish growth and survival. Water temperature was measured using a calibrated thermometer, dissolved oxygen concentration was determined following APHA (1998) procedures, and pH was measured with a digital pH meter.

2.9 Length-weight relationship

The length–weight relationship was determined using the equation:

$$W = aL^b$$

where W represents body weight (g), L represents total length (cm), a is the intercept, and b is the growth coefficient.

Length-weight relationships are widely used to evaluate growth performance, biomass accumulation, and population condition in cultured and natural fish populations (Musa et al., 2021; Ekpemikoghene et al., 2024). Regression analysis was used to estimate the growth coefficient following established fisheries procedures.

2.10 Condition factor

The condition factor (K) was calculated as:

$$K = \frac{1000W}{L^3}$$

where W is body weight (g) and L is total length (cm).

Condition factor provides an integrated measure of fish well-being because it reflects the relationship between body weight and length under specific environmental and nutritional conditions (Isibor et al., 2023; Sadauki et al., 2024).

2.11 Haematological analysis

At the end of the feeding trial, fish were randomly selected from each treatment and transported alive to the laboratory for blood collection. Blood samples were collected using sterile syringes and transferred into ethylenediaminetetraacetic acid (EDTA) tubes for subsequent analysis.

The haematological parameters determined were packed cell volume (PCV), haemoglobin concentration (Hb), red blood cell count (RBC), white blood cell count (WBC), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC).