



EFFECT OF GARLIC (*Allium sativum*) ON GROWTH PERFORMANCE, SURVIVAL AND BODY COMPOSITION OF *Heterobranchus bidorsalis* FINGERLINGS

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ABSTRACT

Aquaculture production in developing countries is constrained by high feed costs and reliance on synthetic growth promoters. This study evaluated the effect of dietary garlic (*Allium sativum*) supplementation on the growth performance, nutrient utilization, survival, apparent digestibility, carcass composition and economic efficiency of *Heterobranchus bidorsalis* fingerlings. A total of 180 fingerlings (8.55 ± 0.15 g) were randomly distributed into five dietary treatments consisting of a control diet and garlic-supplemented diets at 10, 20, 30, and 40 g kg⁻¹, with each treatment replicated. Fish were fed a 40% crude protein diet for sixteen weeks. Growth performance indices, feed utilization parameters, apparent nutrient digestibility, carcass composition, water quality parameters, and cost-benefit analysis were evaluated. Results showed that fish fed the 30 g kg⁻¹ garlic diet recorded the highest weight gain (165.22 g), specific growth rate (0.03 % day⁻¹), condition factor (3.37), survival rate (95%), protein efficiency ratio (2.87), and the lowest feed conversion ratio (1.06). Apparent protein and lipid digestibility, as well as carcass crude protein content (73.35%), were also highest at this inclusion level. Water quality parameters remained within acceptable limits throughout the experimental period. Economic analysis indicated that the 30 g kg⁻¹ garlic diet was the most profitable. The study concludes that dietary garlic at 30 g kg⁻¹ can be used as natural growth promoter for *Heterobranchus bidorsalis* culture.

Keywords: Garlic; *Heterobranchus bidorsalis*; Growth Performance; Nutrient Utilization; Apparent Digestibility

INTRODUCTION

Aquaculture has become one of the fastest-growing food-producing sectors globally and plays a critical role in food security, nutrition, and income generation, particularly in developing countries (FAO, 2020). In Nigeria and many parts of Africa, aquaculture production is dominated by catfish farming; however, its expansion and profitability are largely constrained by the high cost of fish feeds, which account for over 60–70% of total production costs (Gabriel *et al.*, 2007; Aniebo *et al.*, 2009). Fish feed technology remains relatively underdeveloped in the region, and the heavy dependence on imported commercial feeds has resulted in increased production costs, reduced profit margins, and limited farm expansion, thereby contributing to low fish output and high market prices (Adikwu, 1992).

The increasing demand for affordable and sustainable aquaculture production has intensified research efforts toward the use of locally available feed additives capable of improving growth performance, feed utilization, and survival of cultured fish. In recent years, phytoadditives have received considerable attention as natural alternatives to synthetic growth promoters in aquaculture nutrition. Plant-derived additives have been reported to stimulate appetite, enhance voluntary feed intake, improve nutrient utilization, and promote fish health through antimicrobial and immunomodulatory actions (Gabor *et al.*, 2010; Levic *et al.*, 2008). Unlike synthetic additives, phytoadditives are biodegradable, environmentally friendly, and pose minimal risks to consumer health.

Garlic (*Allium sativum*) is one of the most widely studied medicinal plants with proven bioactive and nutritional properties. Originating from Asia Minor and now cultivated worldwide, garlic is rich in carbohydrates, calcium, phosphorus, vitamin B₁, and sulfur-containing compounds that contribute to its high nutritive value (Gabor *et al.*, 2010). It also contains vitamins A, B-complex, and C, iodine salts, and silicates, which have been associated with improved

circulatory, skeletal, and metabolic functions (Drăgan *et al.*, 2008). Garlic has been reported to possess antimicrobial, antioxidant, antihypertensive, hypolipidemic, hepatoprotective, and immunostimulatory properties (Shang *et al.*, 2019).

In aquaculture, dietary garlic supplementation has been shown to inhibit pathogenic bacteria and fungi, thereby improving fish health and survival (Corzo-Martínez *et al.*, 2007). Several studies have reported enhanced growth performance, feed efficiency, digestibility, immune response, and carcass quality in fish fed garlic-supplemented diets (Rezaei, *et al.*, 2022). These effects have been attributed to improved palatability, enhanced digestive enzyme activity, and favorable modulation of gut microbiota.

In contrast, synthetic antibiotics such as chloramphenicol have historically been used as growth promoters in animal and fish feeds due to their broad-spectrum antibacterial activity. Chloramphenicol is effective against Gram-negative bacteria, rickettsia, and anaerobic bacteria, and its inclusion in feeds has been reported to improve growth performance and feed conversion efficiency (Somjetlerdcharoen, 2002; Shalaby *et al.*, 2006). However, prolonged use of chloramphenicol has been associated with serious adverse effects, including aplastic anemia, blood dyscrasias, and carcinogenic risks in humans (Shalaby *et al.*, 2006). Furthermore, the widespread use of antibiotic growth promoters in aquaculture has raised concerns regarding antimicrobial resistance and antibiotic residues in fish products, leading to increased regulatory restrictions and consumer opposition (Baruah *et al.*, 2008).

Among cultured fish species in Nigeria and other parts of Africa, *Heterobranchus bidorsalis* is one of the most economically important members of the family Clariidae. The species is widely cultured due to its rapid growth rate, efficient feed utilization, resistance to disease, tolerance to low dissolved oxygen levels, and ability to thrive under adverse environmental conditions (Vanden and Bernacsek, 1990; Fagbenro *et al.*, 1992). *Heterobranchus bidorsalis* can

utilize a wide range of feed ingredients and is highly accepted by consumers due to its flesh quality and market value (Adebayo and Olanrewaju, 2000; Ojutiku, 2008). The species also commands high economic returns whether sold fresh or processed (Banyigyi et al., 2001).

Despite extensive research on the use of garlic as a growth promoter in livestock and in some fish species, information on its effects on the growth performance, survival, nutrient utilization, and body composition of *Heterobranchus bidorsalis* remains limited. In particular, comparative studies evaluating garlic against conventional antibiotics such as chloramphenicol in the diet of this species are scarce. Addressing this knowledge gap is critical for promoting safer, cost-effective, and sustainable feeding strategies in catfish aquaculture.

Therefore, the present study was conducted to evaluate and compare the effects of dietary garlic (*Allium sativum*) and chloramphenicol on growth performance, survival, nutrient utilization, body composition, and economic efficiency of *Heterobranchus bidorsalis*. The findings are expected to provide scientific evidence supporting the use of natural phytoadditives as alternatives to synthetic antibiotics in aquaculture nutrition.

MATERIALS AND METHODS

Study Area

The feeding trial was conducted at the Department of Biology, Faculty of Life Sciences, Ahmadu Bello University, Zaria, Nigeria. The experiment was carried out in concrete ponds under ambient environmental conditions suitable for catfish culture.

Source of Experimental Fish

A total of 180 apparently healthy fingerlings of *Heterobranchus bidorsalis* with a mean initial body weight of 8.55 ± 0.15 g were obtained from the Fish Hatchery Unit of the National Institute of Freshwater Fisheries Research (NIFFR), New Bussa, Niger State, Nigeria. The fish were transported in 50-L plastic containers to the experimental facility. Upon arrival, the fish were acclimated for two weeks and fed a commercial diet containing 40% crude protein at 5% of body weight per day. At the end of acclimation, fish were batch-weighed and measured to determine initial mean weight and length using a Sartorius electronic balance (Model CP 8201) and a measuring board, respectively.

Experimental Design

Fish were randomly distributed into nine dietary treatments at a stocking density of 10 fish per concrete pond ($40 \times 100 \times 40$ cm³; 400 L water capacity). Each treatment was replicated twice, resulting in a total of 18 experimental units.

The experimental diets consisted of a control diet (without garlic or antibiotic) and diets supplemented with graded levels of garlic (*Allium sativum*) powder at 10, 20, 30, and 40 g kg⁻¹ diet, as well as chloramphenicol at 10, 20, 30, and 40 mg kg⁻¹ diet. The experimental feeding trial lasted for 16 weeks.

Feed Formulation and Preparation and Compounding

Garlic bulbs were purchased from Samaru Market, Zaria, air-dried, and ground into fine powder, while chloramphenicol was obtained from a licensed pharmacy. A basal diet containing 40% crude protein was formulated using fish meal, soybean meal, yellow maize, wheat bran, blood meal, palm oil, salt, vitamin premix, and cassava starch as binder, following the formulation described by Fagbenro and Adebayo (2005).

Dietary ingredients were milled to particle sizes <250 µm and weighed according to Pearson's square method. The dry ingredients were thoroughly mixed to ensure homogeneity, after which cassava starch was added as a binder. Water (20–30%) was gradually added until a uniform dough was formed. The dough was pelleted using a fabricated pelletizer with a 2-mm die, sun-dried, packaged in airtight plastic bags, and stored under ambient conditions until use.

Feeding

Fish were fed twice daily at 09:00 h and 17:00 h at a feeding rate of 3% body weight per day. Feeding was done to apparent satiation, which was assumed when feed particles began to float after approximately 7 min of hand feeding. Fish were fed for 13 consecutive days, while no feed was given on the 14th day, during which fish were weighed and measured. Feed quantities were adjusted fortnightly based on biomass changes. Fish health and mortality were monitored and recorded throughout the experimental period.

Proximate Composition Analysis

Proximate composition of dietary ingredients, experimental diets, whole-body fish samples, and faecal samples was determined according to standard AOAC (1990) procedures at the Department of Animal Science, Ahmadu Bello University, Zaria. Parameters analyzed included moisture, crude protein, crude lipid, and ash content.

Crude Protein

Crude protein was determined using the micro-Kjeldahl method, with nitrogen content multiplied by a factor of 6.25. Moisture content was determined by oven-drying samples to constant weight. Ash content was determined by incineration in a muffle furnace at 550 °C for 6 h. Crude lipid content was determined using Soxhlet extraction with acetone as solvent.

Moisture

Moisture content was calculated using the formula below. Samples will be weighed before and after drying.

$$\text{Moisture} = \frac{\text{final mass} - \text{initial mass}}{\text{initial mass}} \times 100 \quad (1)$$

(Sulivan, 2008)

Ash Content

To determine the ash content, samples were weighed before and after being placed in a muffle furnace for approximately 6 h or until powdery white. Then cooled, and then place in a desiccator for further cooling to room temperature before the final mass is taken. The formula below was used to calculate the ash content.

$$\text{Ash} = \frac{\text{final mass} - \text{initial mass}}{\text{initial mass}} \times 100 \quad (2)$$

(Sulivan, 2008)

Lipid

To determine the crude lipid content, the Soxhlet method (AOAC, 1990) was used to extract the lipid from the samples. Approximately 1g of sample was placed in the cellulose thimble and extracted using 150ml of acetone solvent. The system was heated in a water bath for approximately 10 hours after which time the solvent is evaporated using a rotary evaporator. The flask was then placed in a drying oven for 1 hour to remove water. After cooling, the flask was weighed and the lipid content calculated using the following formula.

$$\text{Lipid} = \frac{\text{final flask mass} - \text{initial flask mass}}{\text{initial flask mass}} \times 100 \quad (3)$$

(Sulivan, 2008)

Water Quality

Monitoring Water quality parameters were monitored throughout the experimental period. Water temperature and

pH were measured using a Hanna digital meter (Model HI 98129), while dissolved oxygen was determined using the titrimetric method. Pond water was completely drained and replaced weekly. All parameters were maintained within acceptable ranges for catfish culture as recommended by Boyd and Lickocoper (1990).

Growth Performance and Survival

Growth performance was evaluated using weight gain (WG), specific growth rate (SGR), survival rate, and condition factor (K).

Weight Gain (WG)

Weight gain was calculated as the difference between final and initial body weights. Specific growth rate was calculated as the natural logarithmic increase in body weight per day. Survival rate was calculated as the percentage of fish that survived at the end of the experiment relative to the number initially stocked. Condition factor was calculated using fish weight and length as an indicator of physiological condition.

$$WG = \frac{FBW - IBW}{IBW} \times 100 \quad (4)$$

(Ricker, 1979)

Where, FBW is final mean body weight (g), IBW is initial mean body weight (g).

Specific Growth Rate

Is the instantaneous change in weight of fish expressed as the percentage increase in body weight per day over any given time interval? It is calculated by taking natural logarithms of body weight, and expresses growth as %·day⁻¹ (Ricker, 1979).

$$SGR = \ln FBW - \ln IBW \quad (5)$$

(Ricker, 1979)

Survival Rates of Fish

$$WG = \frac{\text{Initial number stocked}}{\text{Number survived}} \times 100 \quad (6)$$

(Ricker, 1979)

Condition Factor (K)

Is information relating to the physiological status of the fish.

CF will be calculated as:

$$K = \frac{W}{L^3} \times 100 \quad (7)$$

Nutrient Utilization

Indices Feed utilization efficiency was evaluated using:

Feed conversion ratio (FCR)

Conversion of feed stuffs into high quality protein by fish for human consumption at a profit for the farmer is the main objective of fish culture (Balogun *et al.*, 2005) FCR is defined as the amount of dry feed fed per unit live weight gain (Nelson, 2005). It often serves as a measure of efficiency of the diet. The more suitable the diet for growth, the less food is required to produce a unit weight gain, i.e. a lower FCR (De Silva and Anderson, 1995). It is calculated as;

$$FCR = \frac{\text{Live weight gain}}{\text{Feed fed}} \quad (8)$$

(De Silver and Aderson, 1995)

Protein Efficiency Ratio (PER)

Protein efficiency ratio (PER) is defined as the ratio between the weight gain of fish and the amount of protein fed (De Silva and Anderson, 1995):

$$PER = \frac{\text{Weight gain}}{\text{Crude protein fed}} \quad (9)$$

(De Silver and Aderson, 1995)

Productive Protein Value (PPV)

Productive Protein Value (PPV) is determined by carcass analyses of samples of fish taken before and after feeding with the evaluated protein, and generally expressed as a percentage of the protein fed.

$$PPV = \frac{\text{Retained protein in tissues}}{\text{Dietary protein consumed}} \times 100 \quad (10)$$

(De Silver and Aderson, 1995)

Digestibility Coefficient

Apparent digestibility coefficients (ADC) of nutrients were calculated using nutrient concentrations in the diet and faeces according to the method described by Bureau *et al.* (1999). Digestibility was expressed as the percentage difference between nutrient intake and nutrient excreted in faeces relative to nutrient intake.

$$\text{Digestibility} = \frac{\text{Nutrient in feed} - \text{Nutrient in faeces}}{\text{Nutrient in feed}} \times 100 \quad (11)$$

Where D is the concentration of the nutrient or FA (or kJ/g gross energy) in the diet, F is the concentration of the nutrient or FA (or kJ/g gross energy) in the faeces, Di is the concentration of the inert marker in the diet and Fi is the concentration of the inert marker in the faeces.

Cost Analysis

A simple economic analysis was conducted to assess the cost effectiveness of the diets to be used for this experiment. Only the cost of feed was used in the calculations with the assumption that all other operating costs remained constant. A cost of the feeds was calculated using market 45 prices of ingredients (Nelson, 2008). Vincke (1969) proposed what he called Incidence Cost (IC), which is governed by the unit cost of the feed and its apparent FCR;

$$IC = \frac{\text{weight of fish produced}}{\text{cost of feeding}} \quad (12)$$

IC is actually the cost of feed to produce a kg of fish (relative cost per unit (weight gain), and the lower the value the more profitable using that particular feed. The value of fish will be calculated using the sale price of kg-1 fish. Miller (1976) also suggested another simple parameter called the Profit Index:

$$\text{Profit Index} = \frac{\text{value of fish}}{\text{cost of feeding}} \quad (13)$$

Data Analysis

All data were subjected to one-way analysis of variance (ANOVA) to determine significant differences among treatments. Where significant differences were observed, Duncan's multiple range test was used to separate treatment means at a 5% significance level ($p < 0.05$). Statistical analyses were performed using SAS software (Version 6.0 for Windows).

Table 1: Experimental Diets Supplemented with Garlic (*Allium sativum*)

Ingredients (g/kg diet)	Control (0)	10	20	30	40
Fish meal (72%)	171.7	171.7	171.7	171.7	171.7
Blood meal (77%)	171.7	171.7	171.7	171.7	171.7
Soybean meal (44%)	171.7	171.7	171.7	171.7	171.7
Wheat bran (16.4%)	227.4	227.4	227.4	227.4	227.4

Ingredients (g/kg diet)	Control (0)	10	20	30	40
Yellow maize (8.5%)	227.4	227.4	227.4	227.4	227.4
Garlic powder	–	10.0	20.0	30.0	40.0
Vitamin premix	15.0	15.0	15.0	15.0	15.0
Methionine	5.0	5.0	5.0	5.0	5.0
Lysine	5.0	5.0	5.0	5.0	5.0
Palm oil	2.5	2.5	2.5	2.5	2.5
Salt	2.5	2.5	2.5	2.5	2.5

Table 2: Proximate Composition (%) of Garlic-Supplemented Experimental Diets

Parameters	Control (0)	10	20	30	40
Dry matter (DM)	95.42±0.30 ^{ab}	94.49±0.47 ^c	96.29±0.23 ^a	95.35±0.23 ^{abc}	95.50±0.50 ^{ab}
Ash	7.83±0.01 ^{ab}	5.55±0.01 ^c	6.09±0.01 ^{dc}	6.35±0.01 ^{cdc}	8.51±0.00 ^a
Ether extract (EE)	4.90±0.32 ^c	11.70±0.10 ^c	9.21±0.02 ^d	18.12±0.52 ^a	17.83±0.83 ^{ab}
Crude fibre (CF)	4.55±0.01 ^b	3.39±0.05 ^c	5.00±0.01 ^b	4.18±0.19 ^{bc}	4.81±1.00 ^b
Nitrogen free extract (NFE)	6.78±0.01 ⁱ	7.39±0.01 ^g	8.06±0.01 ^d	7.87±0.01 ^e	7.77±0.01 ^f
Crude protein (CP)	42.32±0.01 ^{bc}	42.20±0.01 ^{cd}	42.31±0.01 ^{bc}	42.25±0.01 ^{cd}	42.45±0.01 ^b

Mean with the Same Superscripts Across the Columns Were Not Significantly Different ($p>0.05$) Keys: DM – Dry Matter, ASH – Ash content, EE – Ether Extract, CF – Crude Fibre, NFE – Nitrogen Free Extract, CP – Crude Protein

RESULTS AND DISCUSSION

Results

Growth Performance and Survival

The growth performance and survival of *Heterobranchus bidorsalis* fed garlic-supplemented diets for sixteen (16) weeks are presented in Table 1. Fish fed diets containing 30 g/kg garlic recorded the highest final body weight (173.82 g), weight gain (165.22 g), and percentage weight gain (1921.11%). Weight gain at 30 g/kg garlic inclusion was significantly higher ($p < 0.05$) than that of the control diet

(89.44 g). Specific growth rate (SGR) increased with increasing garlic inclusion up to 30 g/kg, after which a decline was observed at 40 g/kg. Condition factor (K) was significantly higher ($p < 0.05$) in fish fed 30 g/kg garlic compared to the control diet, which recorded the lowest value (2.40). Survival rate ranged from 75% to 95%, with the highest survival recorded in fish fed 30 g/kg garlic-supplemented diet. Overall, garlic supplementation improved growth performance, survival, and physiological condition of *H. bidorsalis* relative to the control.

Table 4: Growth Performance and Survival of *Heterobranchus bidorsalis* Fed Garlic-Supplemented Diets for Sixteen (16) Weeks

Parameters	Control (0 g/kg)	10 g/kg	20 g/kg	30 g/kg	40 g/kg
IL (cm)	10.10±0.10 ^a	10.35±0.05 ^a	10.25±0.05 ^a	10.55±0.05 ^a	10.55±0.05 ^a
FL (cm)	15.13±0.02 ^c	17.45±0.45 ^{ab}	17.60±0.50 ^{ab}	18.95±1.05 ^a	17.35±0.05 ^{ab}
IBW (g)	8.55±0.15 ^a	8.80±0.00 ^a	8.55±0.05 ^a	8.60±0.00 ^a	8.30±0.00 ^a
FBW (g)	97.99±14.70 ^c	153.29±9.41 ^{ab}	164.34±16.20 ^{ab}	173.82±24.63 ^a	150.85±4.10 ^{ab}
WG (g)	89.44±14.89 ^c	144.49±9.41 ^{ab}	155.79±16.15 ^{ab}	165.22±24.63 ^a	142.56±4.16 ^{ab}
PWG (%)	104.94±92.57 ^b	164.18±106.87 ^a	182.11±78.24 ^a	192.11±86.40 ^a	171.75±50.06 ^a
SGR (%/day)	0.022±0.00 ^a	0.025±0.00 ^a	0.030±0.00 ^a	0.030±0.00 ^a	0.030±0.00 ^a
K	2.40±0.14 ^b	2.86±0.07 ^{ab}	2.94±0.06 ^{ab}	3.37±0.21 ^a	2.78±0.06 ^{ab}
SR (%)	75.00±5.00 ^c	90.00±0.00 ^{ab}	90.00±5.00 ^{ab}	95.00±0.00 ^a	85.00±5.00 ^{ab}

Means with the Same Superscripts Across the Columns Were Not Significantly Different ($p>0.05$) Key: IL – Initial Length, FL – Final Length, IBW – Initial Body Weight, FBW – Final Body Weight, WG – Weight Gain, , SGR – Specific Growth Rate, PWG – Percentage Weight Gain, K – Condition Factor, SR – Survival Rate.

Nutrient utilization of *Heterobranchus bidorsalis* fed with experimental diets for sixteen (16) weeks

Nutrient utilization indices of *H. bidorsalis* fed chloramphenicol-supplemented diets are shown in Table 2.

The best feed conversion ratio (1.13) and protein efficiency ratio (2.81) were observed at 30 mg/kg chloramphenicol inclusion. However, no significant differences ($p > 0.05$) were recorded among treatments.

Table 5: Nutrient Utilization of *Heterobranchus bidorsalis* Fed Garlic-Supplemented Diets

Parameters	Control	10 g/kg	20 g/kg	30 g/kg	40 g/kg
FI (g)	96.24±4.76 ^b	128.64±2.18 ^{ab}	138.82±19.36 ^a	157.18±32.60 ^a	117.47±9.86 ^{ab}
FCR	1.92±0.11 ^a	1.12±0.07 ^a	1.16±0.28 ^a	1.06±0.20 ^a	1.22±0.07 ^a
PF (g)	40.71±2.01 ^d	54.29±0.93 ^{abc}	58.72±8.19 ^{ab}	66.10±2.91 ^a	49.92±4.19 ^{bcd}
PER	2.17±0.26 ^a	2.64±0.15 ^a	2.75±0.66 ^a	2.87±0.16 ^a	2.52±0.48 ^a
PPV (%)	5.24±0.26 ^c	0.37±0.01 ^g	5.33±0.75 ^c	3.13±0.14 ^{dc}	4.17±0.35 ^{cd}

Mean with the Same Superscripts Across the Columns Were Not Significantly Different ($p>0.05$) Keys: FI – Feed Intake, FCR – Feed Conversion Ratio, PF – Protein Feed, PPV – Productive Protein Value, PER – Protein Efficiency Ratio

Apparent Nutrient Digestibility of *Allium Sativum* Diets for *Heterobranchus bidorsalis*

The apparent nutrient digestibility of garlic-supplemented diets is presented in Table 6. Diets containing 30 g/kg garlic recorded the highest apparent lipid digestibility (87.68%), apparent protein digestibility (92.20%), apparent gross energy

digestibility (72.42%), and apparent carbohydrate digestibility (40.31%). These values were significantly higher ($p < 0.05$) than those of the control and other inclusion levels. Digestibility parameters increased with garlic inclusion up to 30 g/kg and declined thereafter at 40 g/kg.

Table 6: Apparent Nutrient Digestibility (%) of Garlic-Supplemented Diets

Parameter	Control	10 g/kg	20 g/kg	30 g/kg	40 g/kg
ALD	79.90±0.53 ^{cd}	84.12±0.82 ^b	82.90±0.63 ^{bc}	87.68±0.59 ^a	86.10±0.06 ^a
APD	85.05±0.52 ^{cd}	89.53±0.06 ^b	89.90±0.63 ^b	92.20±0.75 ^a	90.89±0.31 ^b
AGED	62.64±0.60 ^{dc}	67.36±0.74 ^b	66.26±0.83 ^b	72.42±0.83 ^a	71.12±0.15 ^a
ACD	28.78±0.85 ^d	33.95±0.54 ^b	31.25±0.69 ^c	40.31±0.66 ^a	39.34±0.74 ^a

Means with The Same Superscript Across Rows Were Not Significantly Different ($p > 0.05$), ALD – Apparent Lipid Digestibility, APD – Apparent Protein Digestibility, AGED – Apparent Gross Energy Digestibility, ACD – Apparent Carbohydrate Digestibility

Carcass Composition of *Heterobranchus bidorsalis* Fed Garlic Supplemented Diets

Whole-body carcass composition of *H. bidorsalis* fed garlic-supplemented diets is shown in Table 7. Crude protein content

increased with garlic inclusion up to 30 g/kg, where the highest value (73.35%) was recorded, followed by a decrease at 40 g/kg. Differences among treatments were not statistically significant ($p > 0.05$).

Table 7: Carcass Composition of Whole Body (% Dry Matter Basis) of *Heterobranchus bidorsalis* Under Different Treatments for Sixteen (16) Weeks

Parameter	Control	10 g/kg	20 g/kg	30 g/kg	40 g/kg
Lipid	10.16±0.04 ^b	12.25±0.05 ^a	12.56±0.42 ^a	14.56±0.33 ^a	12.16±0.22 ^{cd}
Ash	7.25±0.05 ^c	8.42±0.28 ^d	9.22±0.18 ^c	10.25±0.25 ^b	8.25±0.05 ^d
Dry matter	97.25±0.05 ^a	97.50±0.06 ^{ab}	95.21±0.23 ^d	96.01±0.05 ^c	96.65±0.01 ^{bc}
Crude protein	69.01±0.01 ^a	72.06±0.50 ^a	73.35±0.15 ^a	73.35±0.15 ^a	68.62±0.19 ^a

Means with the Same Superscripts Across the Columns Were Not Significantly Different ($p > 0.05$)

Cost-benefit Analysis of the *Allium Sativum* Diet Fed *Heterobranchus bidorsalis*

Economic evaluation of garlic-supplemented diets is presented in Table 8. The highest profit index (3.41) was

recorded at 10 g/kg garlic inclusion, while the highest incidence cost (0.38) occurred at 30 g/kg inclusion. Garlic supplementation was economically viable at moderate inclusion levels.

Table 8: Cost–Benefit Analysis of Garlic-Supplemented Diets

Parameter	Control	10 g/kg	20 g/kg	30 g/kg	40 g/kg
Cost of feeding	28.56±1.41 ^d	42.06±0.71 ^{bc}	50.78±7.09 ^b	61.19±2.33 ^a	47.76±4.01 ^b
Profit index	3.12±0.37 ^{ab}	3.41±0.19 ^{ab}	3.18±0.77 ^{ab}	2.72±0.51 ^b	2.99±0.17 ^{ab}
Incidence cost	0.33±0.04 ^a	0.30±0.02 ^a	0.33±0.11 ^a	0.38±0.10 ^a	0.33±0.02 ^a

Means with the Same Superscripts Across the Columns Were Not Significantly Different ($p > 0.05$)

Water Quality Parameters

Water quality parameters monitored during the feeding trial are summarized in Table 9. No significant differences ($p > 0.05$) were observed among treatments. Temperature ranged

from 27.6–28.05°C, pH from 7.07–7.42, and dissolved oxygen from 4.10–4.17 mg/L, all within acceptable limits for catfish culture.

Table 9: Mean Water Quality Parameter Observed During the Experimental Period

Parameter	Control (0 g/kg)	10 g/kg	20 g/kg	30 g/kg	40 g/kg
Temp (°C)	27.60±0.20 ^a	27.80±0.10 ^a	27.60±0.40 ^a	27.75±0.15 ^a	28.05±0.45 ^a
pH	7.25±1.01 ^a	7.07±0.03 ^a	7.42±0.93 ^a	7.29±0.96 ^a	7.34±0.98 ^a
DO (mg/L)	4.11±0.10 ^a	4.11±0.90 ^a	4.11±0.22 ^a	4.17±0.39 ^a	4.10±0.01 ^a

Means with the Same Superscripts Across the Columns Were Not Significantly Different ($p > 0.05$) Keys: Temp. – Temperature, pH – Hydrogen ion concentration, DO – Dissolved Oxygen

Discussion**Growth Performance, Nutrient Utilization and Survival Rates of *H. bidorsalis* Fed Experimental Diets**

The growth performance and nutrient utilization of *Heterobranchus bidorsalis* fed garlic-supplemented diets revealed significant improvements in final body weight, weight gain, percentage weight gain, feed intake, and specific growth rate compared to the control diet. Growth performance increased progressively with increasing garlic inclusion levels from 10 g/kg to 30 g/kg, after which a marked decline was

observed at 40 g/kg. The highest growth performance was recorded at 30 g/kg garlic inclusion, indicating this level as the optimum dietary concentration for *H. bidorsalis*. These findings are consistent with Shalaby *et al.* (2006), who reported enhanced growth performance in fish fed garlic-based diets, and with Diab *et al.* (2002) and Metwally (2009), who documented improved growth in *Oreochromis niloticus* at garlic inclusion levels ranging from 25–32 g/kg. The improvement in growth performance may be attributed to the bioactive compound allicin present in garlic, which has been

reported to enhance intestinal microflora balance, stimulate digestive enzyme activity, and improve nutrient absorption (Khalil *et al.*, 2001). Feed intake and specific growth rate increased with increasing garlic inclusion up to 30 g/kg, followed by a decline at 40 g/kg. The reduced performance at higher inclusion levels may be associated with the strong and offensive odour of garlic, which could negatively affect feed palatability and acceptance by fish, thereby reducing nutrient intake and utilization. Feed conversion ratio (FCR) decreased with increasing garlic inclusion levels, indicating improved feed efficiency. Similarly, protein efficiency ratio (PER) and productive protein value (PPV) increased with garlic inclusion, suggesting enhanced protein utilization and amino acid balance. These parameters are widely recognized as quality indicators for fish diets and protein metabolism (Khalil *et al.*, 2001; Shalaby *et al.*, 2003; El-Dakar *et al.*, 2004; Khattab *et al.*, 2004). Survival rate ranged from 85% to 95% in garlic-fed groups, with the highest survival recorded at 30 g/kg inclusion. This may be attributed to the immunostimulatory properties of garlic, which have been reported to enhance disease resistance, reduce stress, and improve overall fish welfare (Rees *et al.*, 1993; Corzo-Martínez *et al.*, 2007). Mortality recorded during the experiment was minimal and may have resulted from handling stress during sampling, as reported in similar feeding trials (Ashraf *et al.*, 2010; Bichi and Ahmed, 2010; Jonny *et al.*, 2011). The condition factor (K) ranged from 2.78 to 3.37 and was significantly higher in garlic-fed fish compared to the control, indicating better physiological condition and welfare. Condition factor is an important indicator of fish health, feeding intensity, and growth efficiency (Nath *et al.*, 2006; Ndemele *et al.*, 2010).

Carcass Composition

The carcass composition analysis revealed that crude protein content increased with garlic inclusion levels up to 30 g/kg, after which a decline was observed at 40 g/kg. All garlic-treated groups showed significantly higher crude protein values compared to the initial carcass composition, indicating enhanced tissue protein synthesis rather than mere weight gain. This agrees with the findings of Nwanna and Bolarinwa (2001) and Arunlertaree and Moolthongnoi (2008), who reported improved carcass protein content following dietary supplementation.

The increase in carcass protein suggests efficient nutrient assimilation and muscle deposition, supporting the observed improvements in growth performance. This further confirms that garlic supplementation promotes qualitative growth in *H. bidorsalis* as earlier reported by Fuller (1969), Ipinjolu (1999), and Banyigyi *et al.* (2001).

Nutrient Digestibility

Apparent protein digestibility increased significantly with garlic inclusion from 10 to 30 g/kg, indicating improved dietary protein availability and utilization. Protein digestibility is a critical determinant of fish growth performance and is influenced by dietary ingredient quality (Halver and Hardy, 2002). The highest apparent lipid digestibility was also recorded at 30 g/kg garlic, suggesting efficient lipid metabolism at this inclusion level. The observed decline in digestibility at lower and higher inclusion levels may be related to fatty acid composition and fat melting point, which strongly influence digestibility (Kirchgessner *et al.*, 1986). Apparent gross energy and carbohydrate digestibility values were generally high, indicating efficient energy utilization, possibly due to reduced carbohydrate complexity during feed processing (Falaye *et al.*, 2014).

Cost–Benefit Analysis

The cost–benefit analysis revealed that garlic inclusion significantly influenced profitability. Diets containing 30 g/kg garlic recorded the highest profit index, indicating optimal economic returns due to improved growth and feed utilization. Although feed cost increased with higher garlic inclusion, the enhanced performance compensated for the cost, supporting the economic viability of garlic supplementation in aquaculture. This aligns with Sogbesan *et al.* (2004), who emphasized feed efficiency as a major determinant of aquaculture profitability.

Water Quality Parameters

Water quality parameters monitored during the experimental period showed no significant differences among treatments. Temperature, pH, and dissolved oxygen values remained within optimal ranges for freshwater fish culture, indicating that garlic supplementation did not adversely affect the rearing environment. Similar observations were reported by Ayoola and Fedrick (2012), who recommended dissolved oxygen levels of 3–8 mg/L for freshwater fish production.

CONCLUSION

The findings of this study demonstrated that dietary supplementation of garlic (*Allium sativum*) significantly enhanced the growth performance, nutrient utilization, survival rate, and carcass composition of *Heterobranchus bidorsalis* compared to the control diet. Among the tested inclusion levels, the diet containing 30 g/kg garlic produced the best overall performance, recording the highest weight gain (165.22 g), specific growth rate (0.03), condition factor (3.37), survival rate (95.00%), and protein efficiency ratio (2.87), as well as the lowest feed conversion ratio (1.06).

Carcass composition analysis showed that the highest crude protein content (73.35%) was recorded in fish fed the 30 g/kg garlic diet, indicating improved protein deposition and tissue synthesis. Apparent protein digestibility was also highest at this inclusion level, suggesting enhanced digestive efficiency and effective utilization of dietary nutrients.

Water quality parameters, including dissolved oxygen (4.03–4.34 mg/L), temperature (27.00–28.05 °C), and pH (7.07–7.57), remained within acceptable ranges for freshwater fish culture, confirming that garlic supplementation did not negatively affect the rearing environment.

Furthermore, the cost–benefit analysis revealed that the diet containing 30 g/kg garlic was the most economically viable, recording the highest profit index (3.37). Overall, garlic supplementation at 30 g/kg diet was established as the optimal inclusion level for improving biological performance and economic returns in *H. bidorsalis* culture.

Garlic (*Allium sativum*) should be included at 30 g/kg diet as a natural growth promoter in the diet of *Heterobranchus bidorsalis* to enhance growth performance, feed efficiency, survival, and profitability while Future research should focus on long-term feeding trials, immune response, and disease resistance of fish reared on garlic-based diets under different culture systems.

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