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# DIETARY EFFECTS OF *Xylopia aethiopica*-SUPPLEMENTED DIET ON LENGTH-BASED GROWTH, ECONOMIC PERFORMANCE, AND METABOLIC RESPONSES OF AFRICAN CATFISH HYBRID (*Clarias gariepinus* ♀ × *Heterobranchus bidorsalis* ♂) FINGERLINGS

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## ABSTRACT

The present study evaluated the effects of dietary *Xylopia aethiopica* supplementation on growth performance, economic returns, and metabolic health of African catfish hybrids. Five experimental diets were formulated with graded levels of *Xylopia aethiopica* pod powder (0%, 0.5%, 1.0%, 1.5%, and 2.0%), designated as control, 0.5%XE, 1.0%XE, 1.5%XE, and 2.0%XE, respectively. Fish with an initial average length of 13.50 ± 0.15 cm were fed the diets for 56 days in triplicate groups. Growth performance was significantly enhanced ($p < 0.05$) at 1.0% XE, with improvements in final length, specific growth rate, relative growth rate, and feed conversion efficiency. Conversely, supplementation at 2.0% XE impaired growth indices ($p < 0.05$). Economic analysis revealed that 0.5% XE produced the highest revenue and return on investment. Hepatic metabolic enzyme activities, including aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP), were elevated at 1.0% and 1.5% XE. Antioxidant enzyme responses varied: superoxide dismutase (SOD) activity decreased at 0.5% XE but increased at 2.0% XE, glutathione peroxidase (GPx) activity declined consistently across supplemented groups, while catalase (CAT) activity remained unchanged ($p > 0.05$). Hepatic electrolyte balance was positively influenced by moderate supplementation. Moderate dietary inclusion of *Xylopia aethiopica* (0.5–1.5%) enhances growth, profitability, and metabolic health in African catfish hybrids, whereas excessive supplementation (≥2.0%) compromises nutrient utilization and physiological function.

**Keywords:** *Xylopia aethiopica*, African catfish hybrid, Growth performance, Metabolic enzymes, Oxidative stress, Economic performance.

## INTRODUCTION

Aquaculture is currently the fastest-growing food production sector globally. It provides a sustainable alternative to capture fisheries and addresses the increasing global demand for animal protein (Verdegem *et al.*, 2023). In sub-Saharan Africa, the cultivation of catfish, particularly *Clarias gariepinus* and its hybrids, is expected to persist due to their commercial viability, resilience, and rapid growth (Popoola, 2022). Intensive aquaculture relies on diets that are both cost-effective and nutritionally balanced (Tsairidou *et al.*, 2024). Diets that enhance fish health can improve growth performance, feed efficiency, body composition, and overall fish well-being Phytobiotics are becoming increasingly popular as a substitutive feed additive to synthetic supplements to provide a sustainable and economical alternative to synthetic additives and fill the gap of conventional synthetic supplements that have a negative ecological impact and contribute to drug resistance, accumulation of residues, and degradation of the environment (Abdel-Aziz *et al.*, 2023; Kabir *et al.*, 2025; Wei *et al.*, 2023). Moreover, due to their proven ability to improve growth, stabilize feed, and improve the health status of aquatic animals, phytobiotics are becoming an attractive option in sustainable aquaculture systems (Vijayaram *et al.*, 2024).

Phytogenic feed additives are natural compounds derived from herbs, spices, and medicinal plants. They have been studied for growth-promoting, antibacterial, antioxidant, and immunomodulatory effects (Mandey and Sompie, 2021). These additives are eco-friendly and cost-effective alternatives to synthetic growth enhancers and chemotherapeutics which are often known for their adverse ecological and health risk (Hernández-Contreras *et al.,* 2023). *Xylopia aethiopica*, also known as Ethiopian pepper, Negro pepper, or African pepper, is attracting more attention from scientists and academics (*Edem et al.,* 2025). This plant is common throughout tropical Africa and has been used for centuries as a spice and in herbal medicine. *Xylopia aethiopica* seeds contain many bioactive phytochemicals, such as alkaloids, flavonoids, tannins, and essential oils

(Okpoghono *et al.*, 2023). These have antibacterial, anti-inflammatory, antioxidant, and digestive-stimulating properties (Morakinyo *et al.*, 2025). The bioactive compounds in *Xylopia aethiopica* may positively influence nutrient digestion, balance gut microbiota, improve growth efficiency, and support overall fish health. Previous studies suggest that specific phytogenic feed additives can promote protein use and beneficial gut microbiomes (Wang *et al.*, 2021; Yang *et al.*, 2015). They may also stimulate lipid metabolism, leading to better nutrition retention and improved carcass quality in fish (Liu *et al.*, 2022). Certain plant-derived bioactives are known to alter gut histomorphology, such as increasing villi height and intestinal surface area, and may improve nutrient absorption (Caipang, 2020; Sumana *et al.*, 2025). Developing innovative feeding strategies that incorporate natural supplements is essential for enhancing fish health, increasing productivity, and supporting the sustainability of aquaculture systems (Sarker, 2023). Functional feeds that deliver both nutritional and therapeutic benefits are fundamental to the progress of the aquaculture sector (Olmos Soto *et al.*, 2015).

Lugert (2016) and many other researchers have shown through their research over the past several decades that fish growth can be measured using fish length as a significant predictor of fish growth. In aquaculture research, length measurements are routinely used to monitor growth performance, adjust feeding regimes, and predict harvest size (Tonachella *et al.*, 2023). Jimoh et al 2023 examined the dietary effect of cinnamon supplementation using length-based growth as a metric.

Exotic medicinal plants such as fenugreek, coriander, and cinnamon have been tested on fish growth and health management (Chowdhury *et al.*, 2020; Jimoh *et al.,* 2023; Jimoh *et al.*, 2022b; Jimoh et al., 2024). However, few locally sourced Nigerian medicinal species have undergone rigorous scientific evaluation in the context of aquaculture. The effects of dietary *Xylopia aethiopica* on fish growth performance, economic outcomes, and metabolic enzyme activity remain insufficiently explored; thus, it requires additional investigation. This study investigates the impact of diets supplemented with *Xylopia aethiopica* on length-based growth performance, economic efficiency, and metabolic enzyme profiles in African catfish hybrids.

## MATERIALS AND METHODS

### *Sources, Processing of Ingredients and Experimental Diets*

*Xylopia aethiopica,* soybean meal, fish meal, and other feedstuffs were sourced from commercial suppliers in Ilorin, Nigeria. Each ingredient was pulverized and screened separately to achieve a uniform fine particle size. Duplicate samples underwent proximate composition analysis according to the Association of Official Analytical Chemists (AOAC, 2010) protocols. Experimental diets (Table 1) incorporated *Xylopia aethiopica* at 0, 0.5, 1.0, 1.5, and 2.0 grams per 100 grams, designated as CTR, 0.5%XE, 1.0%XE, 1.5%XE, and 2.0%XE, respectively. All diets were designed to provide equal energy and nitrogen content. Feed ingredients were ground and mixed thoroughly with hot water to enhance binding. The mixture was minced into 2 mm pellets and sun-dried at 30-32°C for 3 days. The dried diets were then stored in a cool environment until use.

Table 1. Gross and chemical composition of diets containing *Xylopia aethiopica* for African catfish hybrid.

| **Ingredient composition (%)** | Control | 0.5%XE | 1%XE | 1.5%XE | 2%XE |
|---|---|---|---|---|---|
| Fishmeal | 15.30 | 15.30 | 15.30 | 15.30 | 15.30 |
| SBM | 35.71 | 35.71 | 35.71 | 35.71 | 35.71 |
| GNC | 31.11 | 31.11 | 31.11 | 31.11 | 31.11 |
| Corn | 10.20 | 10.20 | 10.20 | 10.20 | 10.20 |
| Negro Pepper | 0.00 | 0.50 | 1.00 | 1.50 | 2.00 |
| Fish Premix | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Fish oil | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Soyoil | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Starch | 3.68 | 3.18 | 2.68 | 2.18 | 1.68 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

| | | | | | |
|---|---|---|---|---|---|
| **Proximate Composition (%)** | | | | | |
| Moisture | 9.69 | 9.67 | 9.65 | 9.63 | 9.61 |
| Crude Protein | 41.32 | 41.34 | 41.36 | 41.38 | 41.40 |
| Lipid | 6.83 | 6.84 | 6.85 | 6.86 | 6.87 |
| Ash | 6.64 | 6.65 | 6.67 | 6.69 | 6.70 |
| Fibre | 5.50 | 5.69 | 5.88 | 6.08 | 6.27 |
| NFE | 30.03 | 29.81 | 29.58 | 29.36 | 29.14 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Gross Energy (MJ/kg) | 18.71 | 18.63 | 18.56 | 18.48 | 18.41 |
| **Calculated Amino Acid Profile (%)** | | | | | |
| Arginine | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| Histidine | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 |
| Isoleucine | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 |
| Leucine | 3.06 | 3.06 | 3.06 | 3.06 | 3.06 |
| Lysine | 2.28 | 2.28 | 2.28 | 2.28 | 2.28 |
| Methionine | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 |
| Methionine + Cysteine | 1.21 | 1.21 | 1.21 | 1.21 | 1.21 |
| Phenylalanine | 2.03 | 2.03 | 2.03 | 2.03 | 2.03 |
| Phenylalanine + Tyrosine | 3.58 | 3.58 | 3.58 | 3.58 | 3.58 |
| Threonine | 1.48 | 1.48 | 1.48 | 1.48 | 1.48 |
| Tryptophan | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 |
| Valine | 2.07 | 2.07 | 2.07 | 2.07 | 2.07 |

*Each kg of HI-MIX fish premix contains Vitamin A 1.600.00 U.I, Vitamin D3 300.000 U.I, Vitamin E,12.000mg, Vitamin K3 1.200mg, Vitamin B1 3.000mg, Vitamin B2 4.000mg, Vitamin B6 3.000mg, Vitamin B12 4mg, Niacin 14.000mg, Biotin 100mg, Calcium D-panthothenate 9.000mg, Folic acid1.000mg, Vitamin C(protected) 30.000mg, Iron(Iron (II) sulphate monohydrata) 4.00mg, Zinc 18.000mg, Copper(copper (II) sulphate penthahydrate)1.000mg, Iodine (potassium iodide) 200mg, Manganese (Manganese (II) oxide) 4.000mg, Selenium (Sodium Selenite) 40mg. Antioxidants, Calcium carbonate included

***Biochemical analysis***

Moisture content was assessed by heating samples at 105 °C for 24 hours in a Memmert oven, in accordance with AOAC (2010) protocols. Thereafter, ash content was determined by incinerating the samples in an Omegalux furnace at 600 °C for four hours. Subsequently, crude protein was quantified using a Foss Tecator KjeltecTM 8400 auto-analyzer, following acid digestion, with a nitrogen-to-protein conversion factor of 6.25. Crude lipid was extracted via a Foss Tecator Soxtec™ 8000 equipment, while raw fibre was assessed with a Foss Tecator Fibertec hot extraction fibre analyser. Each analysis was conducted in duplicate.

***Culture Condition***

The experiment took place in the Department of Aquaculture and Fisheries wet laboratory at the University of Ilorin, Nigeria. Heteroclarias fingerlings, a hybrid of African catfish, were purchased from a well-known hatchery in Ilorin. The fish were acclimated to Laboratory conditions for 15 days, during which they were fed 1.8 mm Skretting commercial feed. After this period, 15 fish fingerlings were placed in each replicate tank and measured to the nearest 0.1 cm, with an average length of 13.50 ± 0.15 cm. The fish were then separated into five dietary groups, with three replicates per group. Before starting the feeding trial, the fish were fasted for 24 hours to help standardize their digestive systems, boost their appetite for the test diets.. Fifteen rectangular plastic tanks, each holding 84 liters and filled with 70 liters of water, were utilized for housing, with gentle aeration given. For 56 days, the fish were fed by hand twice a day between 9:00 am and 5:00 pm to apparent satiation. Every two weeks, the fish were weighed in groups to adjust feed levels and track growth. During the experiment, water temperature, dissolved oxygen, and pH were kept within appropriate levels.

***Growth assessment***

The following variables were calculated using the methods outlined by Lugert et al. (2016)for assessing growth.

$$\text{Absolute Growth (cm)} = \text{Final Length} - \text{Initial Length}$$

$$\text{Relative Growth Rate (\%)} = \frac{(\text{Final Length} - \text{Initial Length})}{\text{Initial Length}} \times 100$$

$$\text{Specific Growth Rate (\% d}^{-1}) = \frac{\ln(\text{Final Length}) - \ln(\text{Initial length})}{\text{culture period (day)}}$$

$$\text{Relative Percentage Survival} = \left(1 - \left(\frac{\text{No of mortality in test treatment group}}{\text{No of mortality in control group}}\right) \times 100\right)$$

***Condition factor and body indices***

The condition factor (K) and body indices were calculated according to the methods described by (Jimoh *et al.*, 2022a)

$$K = \frac{W}{L^3} \times 100$$

W: Final weight of each fish to the nearest 0.01g.
L: Final Length of each fish to the nearest 0.1cm

Body indices were calculated as follows:

$$\text{Hepatosomatic Index (HSI, \%)} = \frac{\text{Liver weight}}{\text{whole body weight}} \times 100$$

$$\text{Viscerosomatic Index (VSI, \%)} = \frac{\text{Viscera weight}}{\text{whole body weight}} \times 100$$

$$\text{Total Yield (kg/m}^3) = \frac{\text{Live Weight Gain}}{\text{Tank Volume}}$$

***Economic Performance Study***

The economic performance study was conducted using methods adapted from Sezu et al. (2024)after computing the cost per kg of each dietary treatment (Table 2).

$$\text{Initial Biomass (kg)} = \text{initial Weight (kg)of fish Stocked} \times \text{initial number of fish}$$

$$\text{Final Biomass (kg)} = \text{Final Weight (kg)of fish Stocked} \times \text{final number of fish}$$

$$\text{Total Biomass gain (kg)} = \text{Final Biomass} - \text{initial Biomass}$$

$$\text{Farm Feed Cost (₦)} = \text{FCR} \times \text{Cost per kg of each experimental diet}$$

$$\text{Farm Revenue (₦)} = \text{Total Yield} \times \text{Market price of 1kg catfish}$$

$$\text{Farm Raw Margin (₦)} = \text{Farm Revenue} - (\text{Total Yield} \times \text{Farm Feed Cost})$$

$$\text{Return on Investment (\%)} = \frac{\text{Farm Raw Margin}}{(\text{Total Yield} \times \text{Farm Feed Cost})} \times 100$$

**Table 2**. Cost per kg of the experimental diets containing of *Xylopia aethiopica* supplemented diets fed to African catfish

| Ingredients | Cost/kg | Control | 0.5% XE | 1% XE | 1.5% XE | 2% XE |
|---|---|---|---|---|---|---|
| Fishmeal@65cp | 3000 | 459.00 | 459.00 | 459.00 | 459.00 | 459.00 |
| SBM@42%cp | 640 | 228.54 | 228.54 | 228.54 | 228.54 | 228.54 |
| GNC@45%cp | 380 | 118.22 | 118.22 | 118.22 | 118.22 | 118.22 |
| Corn@10%cp | 550 | 56.10 | 56.10 | 56.10 | 56.10 | 56.10 |
| Negro Pepper | 1200 | 0.00 | 6.00 | 12.00 | 18.00 | 24.00 |
| Fish Premix | 4000 | 80.00 | 80.00 | 80.00 | 80.00 | 80.00 |
| Fish oil | 2400 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 |
| Soy oil | 1700 | 17.00 | 17.00 | 17.00 | 17.00 | 17.00 |
| Starch | 1000 | 36.80 | 31.80 | 26.80 | 21.80 | 16.80 |
| Total | | 1019.66 | 1029.66 | 1039.66 | 1049.66 | 1059.66 |

### *Hepatic Total Protein and Enzymes Quantification*

Subsequent to the feeding study, liver tissue samples (n=3 per treatment) were procured from the experimental fish. Samples were homogenised in a cold 250 mM sucrose solution to maintain protein integrity, following the techniques established by Abdelazim *et al.* (2018) and Jimoh *et al.* (2021). The liver homogenate was centrifuged at 3,000 rpm for 5 minutes to obtain the supernatant. Hepatic total protein was quantified using the Lowry method. Enzyme activities were assayed using established protocols: AST and ALT were determined by the Reitman–Frankel method (Bergmeyer and Bernt, 1974), ALP activity by the King method (King *et al.*, 1951), GST activity by conjugation of GSH to CDNB, reduced glutathione (GSH) by the Ellman's reagent assay, SOD activity by inhibition of NBT reduction, GPx activity by NADPH oxidation in a coupled assay with glutathione reductase, and catalase activity by monitoring $H_2O_2$ decomposition at 240 nm. Absorbance was read using a UV-visible spectrophotometer (Shimadzu, Japan) Lactate dehydrogenase (LDH) and malondialdehyde (MDA) were measured utilising commercially available kits from Randox™, United Kingdom, following the manufacturer's guidelines.

### *Hepatic Electrolyte Quantification*

Concentrations of chloride (Cl-), potassium (K+), calcium (Ca2+), and sodium (Na+) in liver tissue were determined using atomic absorption spectrophotometry as described by Willis (1960)

### *Statistical Analysis*

Prior to statistical analysis, data were tested for homogeneity of variance and normality using the Levene and Shapiro–Wilk tests. One-way ANOVA was then applied to evaluate differences in growth performance, nutrient retention, tissue protein content, metabolic enzyme activities, antioxidant status, oxidative stress biomarkers, and liver electrolyte concentrations. Where significant effects were observed ($p < 0.05$), Tukey HSD's post hoc test was conducted to identify pairwise differences. All analyses were performed using SPSS software (version 17.0), and results are presented as mean ± standard error of the mean (SEM).

### *Ethical Considerations*

This study adhered to ethical standards and received approval from the Departmental Ethical Review Committee at the Department of Aquaculture and Fisheries, Faculty of Agriculture, University of Ilorin, Nigeria (PROTOCOL ID: DERC/AQF/0030; DERC APPROVAL NUMBER: DERC/AQF/2024/1230) to ensure humane treatment of the animals.

## RESULTS

### *Growth responses, physiological indices and economic performance*

Supplementation with *Xylopia aethiopica* (XE) markedly influenced the growth, physiological parameters, and economic returns of hybrid African catfish (Table 3). The starting lengths did not demonstrate significant differences ($p > 0.05$) across treatments, hence confirming uniform stocking. Significant improvements ($p < 0.05$) were seen in ultimate length, absolute growth, relative growth rate, and specific growth rate. Fish administered 1% XE displayed the most pronounced growth, while other XE-supplemented groups showed results similar to the control (p > 0.05). Growth performance declined at higher inclusion levels, especially at 2% XE, indicating that excessive supplementation may hinder growth. The condition factor diminished markedly with increased supplementation, although the hepato-somatic index elevated at moderate amounts (1-1.5% XE). In contrast, the viscero-somatic index decreased with elevated XE levels

**Table 3**. Length-based growth, body indices, and economic performance of hybrid African catfish fed *Xylopia aethiopica*--supplemented diets

| Parameter | Control | 0.5% XE | 1% XE | 1.5% XE | 2% XE |
|---|---|---|---|---|---|
| Initial mean length (cm) | 14.14±0.16$^{a}$ | 13.47±0.28$^{a}$ | 13.23±0.31$^{a}$ | 12.92±0.37$^{a}$ | 13.75±0.17$^{a}$ |
| Final mean length (cm) | 20.53±0.02$^{c}$ | 20.76±0.01$^{bc}$ | 21.16±0.14$^{a}$ | 20.59±0.01$^{c}$ | 20.88±0.01$^{b}$ |
| AG (cm) | 6.39±0.15$^{b}$ | 7.29±0.27$^{ab}$ | 7.92±0.17$^{a}$ | 7.67±0.37$^{a}$ | 7.13±0.18$^{ab}$ |
| RGR(%) | 45.24±1.57$^{b}$ | 54.25±3.07$^{ab}$ | 60.01±2.78$^{a}$ | 59.67±4.67$^{a}$ | 51.95±1.98$^{ab}$ |
| SGR (%day$^{-1}$) | 0.67±0.02$^{b}$ | 0.77±0.04$^{ab}$ | 0.84±0.03$^{a}$ | 0.83±0.05$^{a}$ | 0.75±0.02$^{ab}$ |
| Condition factor (K) | 0.59±0.01$^{a}$ | 0.91±0.01$^{b}$ | 0.64±0.01$^{c}$ | 0.62±0.02$^{d}$ | 0.54±0.01$^{e}$ |
| VSI | 7.84±0.01$^{a}$ | 7.11±0.01$^{b}$ | 6.63±0.02$^{c}$ | 5.59±0.01$^{d}$ | 4.61±0.01$^{e}$ |
| HSI | 0.78±0.01$^{c}$ | 0.84±0.01$^{b}$ | 1.01±0.02$^{a}$ | 1.01±0.01$^{a}$ | 0.83±0.00$^{b}$ |
| **Economic Performance** | | | | | |
| Total Initial Biomass (kg) | 0.20±0.01$^{a}$ | 0.20±0.01$^{a}$ | 0.20±0.01$^{a}$ | 0.20±0.01$^{a}$ | 0.20±0.01$^{a}$ |
| Total Final Biomass (kg) | 0.62±0.01$^{c}$ | 0.75±0.01$^{a}$ | 0.68±0.01$^{b}$ | 0.62±0.01$^{c}$ | 0.48±0.01$^{d}$ |
| Total Biomass Gain (kg) | 0.38±0.01$^{c}$ | 0.51±0.01$^{a}$ | 0.44±0.01$^{b}$ | 0.39±0.01$^{c}$ | 0.24±0.01$^{d}$ |
| Total Yield (kg/m$^{3}$) | 5.40±0.16$^{c}$ | 7.29±0.08$^{a}$ | 6.24±0.05$^{b}$ | 5.51±0.05$^{c}$ | 3.40±0.15$^{d}$ |
| Feed Conversion Ratio | 1.63±0.03$^{ab}$ | 1.47±0.09$^{b}$ | 1.53±0.07$^{ab}$ | 1.60±0.01$^{ab}$ | 1.77±0.03$^{a}$ |
| Farm Feed Cost (N) | 1733.88±19.67$^{b}$ | 1541.48±65.56$^{c}$ | 1652.09±47.48$^{bc}$ | 1775.38±7.21$^{ab}$ | 1916.85±24.41$^{a}$ |
| Farm Revenue (N) | 13504.13±392.29$^{c}$ | 18236.09±192.60$^{a}$ | 15604.16±112.95$^{b}$ | 13779.11±119.63$^{c}$ | 8491.56±381.88$^{d}$ |
| Farm Raw Margin | 4137.22±144.45$^{c}$ | 6993.45±500.09$^{a}$ | 5288.33±258.78$^{b}$ | 3994.51±71.16$^{c}$ | 1975.56±63.91$^{d}$ |
| Return on Investment | 44.22±1.63$^{bc}$ | 62.78±7.01$^{a}$ | 51.58±4.47$^{ab}$ | 40.82±0.58$^{bc}$ | 30.47±1.67$^{c}$ |

Values (Mean±SEM) within the same row with different superscripts are significantly different (p<0.05) from each other.
AG: Absolute Growth, SGR: Specific Growth Rate, AGR: Absolute Growth Rate, RGR: Relative Growth Rate, VSI: Viscerosomatic Index, HSI: Hepatosomatic Index. Market value of 1kg Fish = ₦2500 1 USD= 1530 NGN Tank Volume = $7 \times 10^{-2}$ m$^{3}$

Economic metrics exhibited considerable variation (p<0.05) among treatments. Final biomass, biomass gain, yield, and farm revenue were significantly higher (p<0.05) in fish administered 0.5% XE, followed by those getting 1% XE. The feed conversion ratio was markedly more advantageous (p<0.05) at 1% XE, indicating improved feed utilization compared to the control group. The return on investment was maximized (p<0.05) at 0.5% XE and decreased significantly at 2% XE, indicating the adverse economic effects of excessive supplementing despite reduced feed expenses. Figure 1 illustrates the impact of varying dietary inclusions of *Xylopia aethiopica* (XE) powder on the relative percentage survival of the experimental fish. The relative proportion of survival varied considerably among treatments (p < 0.05). The 0.5% XE diet resulted in the highest relative percentage of survival, significantly exceeding (p<0.05) all other treatments. Diets containing 0.1%, 1.5%, and 2.0%XE yielded moderate relative percentage survival rates that were statistically comparable (p>0.05) among themselves, however significantly superior to the control group (p < 0.05).

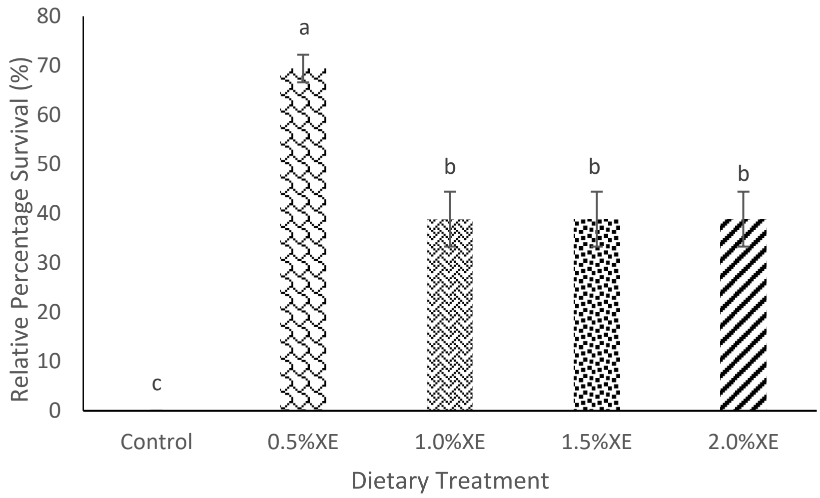


**Figure 1**. Relative Percentage Survival of African catfish hybrids (*Clarias gariepinus* ♀×*Heterobranchus bidorsalis*♂) fed XE-based dietary treatments. Different superscripts above bars denote significant (p<0.05) differences among means within each week, error bars indicate SE

***Hepatic Total Protein and Metabolic Enzyme Responses***

Table 4 presents the liver protein concentrations and enzyme activities in hybrid African catfish that received meals supplemented with *Xylopia aethiopica*. Total protein concentrations showed significant variations (p<0.05) across treatments, especially within the 0.5%+XE group. This value was significantly greater (p < 0.05) than those seen in the control and higher inclusion groups. The 1.5% and 2%XE groups demonstrated the minimal protein concentrations. The activity of aspartate aminotransferase (AST) was markedly increased (p<0.05) in the 1%XE group compared to the control and higher XE concentrations. Aminotransferase (AST) activity was significantly higher (p < 0.05) in the 1%XE group. At the same time, alkaline phosphatase (ALP) activity also showed a notable difference (p < 0.05), peaking at 1.5% XE and reaching its lowest point in the control group. Similarly, alanine aminotransferase (ALT) activity reached a maximum of 1.5%XE and was significantly different (p < 0.05) from the control group.

**Table 4**. Hepatic total protein and metabolic enzyme activities of hybrid African catfish fed *Xylopia aethiopica*-supplemented diets

| Parameter | Control | 0.5%XE | 1%XE | 1.5%XE | 2%XE |
|---|---|---|---|---|---|
| Total protein (g/dL) | $18.77 \pm 0.11^{b}$ | $21.10 \pm 0.26^{a}$ | $19.06 \pm 0.09^{b}$ | $17.07 \pm 0.46^{c}$ | $16.88 \pm 0.68^{c}$ |
| AST (U/L) | $27.84 \pm 0.53^{c}$ | $29.98 \pm 0.93^{c}$ | $39.73 \pm 0.72^{a}$ | $36.60 \pm 0.93^{b}$ | $30.93 \pm 0.60^{c}$ |
| ALP (U/L) | $28.65 \pm 0.47^{d}$ | $34.93 \pm 0.29^{c}$ | $39.43 \pm 0.49^{a}$ | $40.86 \pm 0.25^{a}$ | $36.87 \pm 0.62^{b}$ |
| ALT (U/L) | $22.93 \pm 0.50^{c}$ | $24.67 \pm 0.61^{c}$ | $31.27 \pm 0.97^{ab}$ | $33.17 \pm 0.67^{a}$ | $29.20 \pm 0.35^{b}$ |

Values (Mean±SEM) within the same row with different superscript are significantly different (p<0.05) from each other.
AST: Aspartate Aminotransferase;ALT: Alkaline Phosphatase; ALP: Alanine Aminotransferase

***Stress and Antioxidant Enzyme Responses***

Dietary supplementation with *Xylopia aethiopica* significantly influenced hepatic stress markers in African catfish hybrids (Table 5). Nitric oxide (NO) and Malondialdehyde (MDA) concentrations decreased progressively with XE inclusion, reaching the lowest value at 1.5%XE for NO and 1,0%XE for MDA. Sharp elevation was observed at 2%XE for MDA, which was significantly higher than all other treatments (p < 0.05). The activities of antioxidant enzymes exhibited dose-dependent variations. Superoxide dismutase (SOD) activity was significantly reduced at 0.5%XE compared to the control, but increased again at 2%XE. Glutathione peroxidase (GPx) activity consistently declined across all XE-supplemented groups, with the lowest activity recorded at 1.0%XE. Catalase (CAT) activity did not differ significantly among treatments (p > 0.05), indicating limited responsiveness to XE supplementation. Glutathione (GSH) concentrations decreased progressively with XE inclusion, reaching the lowest value at 1.5%XE, before rising again at 2% XE.

**Table 5.** Stress and antioxidant enzyme activities in the liver of African catfish hybrid fed *Xylopia aethiopica* supplemented diet

| **Stress Marker** | Control | 0.5% XE | 1.0% XE | 1.5% XE | 2% XE |
|---|---|---|---|---|---|
| Nitric Oxide (µmol/L) | 46.43±0.15$^{a}$ | 37.97±0.38$^{c}$ | 37.60±0.61$^{c}$ | 35.30±0.57$^{d}$ | 40.10±0.78$^{b}$ |
| MDA (nmol/min/mg protein) | 2.12±0.02$^{b}$ | 2.05±0.01$^{bc}$ | 2.01±0.01$^{c}$ | 1.83±0.03$^{d}$ | 3.97±0.03$^{a}$ |
| **Antioxidant Enzymes** | | | | | |
| SOD (U/mg protein) | 53.11±0.04$^{a}$ | 40.36±0.08$^{d}$ | 45.78±0.03$^{c}$ | 45.86±0.04$^{c}$ | 49.93±0.07$^{b}$ |
| GPx (U/mg protein) | 30.73±0.07$^{a}$ | 29.57±0.08$^{b}$ | 25.91±0.08$^{d}$ | 28.45±0.13$^{c}$ | 28.75±0.05$^{c}$ |
| CAT (U/mg protein) | 17.30±0.04$^{a}$ | 13.13±1.96$^{a}$ | 12.75±0.82$^{a}$ | 13.52±2.45$^{a}$ | 17.00±0.06$^{a}$ |
| GSH (U/mg protein) | 42.02±0.09$^{a}$ | 33.24±0.02$^{c}$ | 32.19±0.11$^{d}$ | 27.21±0.11$^{e}$ | 37.25±0.09$^{b}$ |

Values (Mean±SEM) within the same row with different superscripts are significantly different ($p<0.05$) from each other. GSH: Glutathione, SOD: Superoxide Dismutase, GPX: Glutathione peroxidase, CAT: Catalase; MDA: Malate Dehydrogenase

### *Hepatic Electrolytes*

Table 6 summarizes the effects of *Xylopia aethiopica*–supplemented meals on hepatic electrolytes in hybrid African catfish. No notable changes ($p > 0.05$) were detected in hepatic electrolyte levels between the experimental groups. While hepatic potassium ion ($K^+$) concentrations were quantitatively elevated at 0.5% and 1% *Xylopia aethiopica* extract (XE) relative to the control, the differences were not statistically significant ($p > 0.05$). Reduced $K^+$ levels were noted at 1.5%XE. Chloride ion ($Cl^-$) concentrations diminished in the 1.0% and 1.5% XE groups relative to the control and 2% XE groups; however, these variations lacked statistical significance ($p > 0.05$). The differences were not statistically significant ($p > 0.05$). Hepatic calcium ion ($Ca^{2+}$) levels were reduced in all supplemented groups. Hepatic $Ca^{2+}$ values diminished progressively from 0.5% XE to 2% XE compared to the control.

**Table 6.** Hepatic electrolytes of hybrid African fed *Xylopia aethiopica*--supplemented diets

| Parameter | Control | 0.5% XE | 1.0% XE | 1.5% XE | 2.0% XE |
|---|---|---|---|---|---|
| $K^+$ (µmol/g tissue) | 8.59±0.48$^{a}$ | 13.09±0.80$^{a}$ | 10.04±0.93$^{a}$ | 6.89±0.27$^{a}$ | 10.18±1.09$^{a}$ |
| $Na^+$ (µmol/g tissue) | 46.31±5.26$^{a}$ | 53.43±1.88$^{a}$ | 48.21±1.34$^{a}$ | 38.56±2.97$^{a}$ | 60.65±4.79$^{a}$ |
| $Cl^-$ (µmol/g tissue) | 32.04±0.73$^{a}$ | 30.71±1.67$^{a}$ | 21.89±4.22$^{a}$ | 17.15±2.52$^{a}$ | 29.13±1.36$^{a}$ |
| $Ca^{2+}$ (µmol/g tissue) | 93.50±2.16$^{a}$ | 77.65±2.23$^{a}$ | 72.40±1.83$^{a}$ | 71.74±1.67$^{a}$ | 56.03±2.35$^{a}$ |

Values (Mean±SEM) within the same row with different superscript are significantlydifferent ($p<0.05$) from each other.
$K^+$ : Potassium ion; $Cl^-$ : Chloride ion; $Na^+$ : Sodium ion; $Ca^{2+}$ : Calcium ion

## DISCUSSION

Medicinal plants are increasingly investigated as dietary interventions in aquaculture due to their potential to improve fish health, growth, and productivity (Doan *et al.*, 2020). The growth rates and economic productivity of the hybrid African catfish were enhanced in this study with the modest supplementation of *Xylopia aethiopica*. The importance of balancing biological advantages and production expenses is evidenced by the observation that a 0.5% addition yielded the highest financial returns, whilst a 1% addition resulted in optimal growth and feed efficiency. These findings align with previous research Ibrahim *et al.* (2024)which similarly noted beneficial effects of *X. aethiopica* on catfish growth and feed efficiency (Ahmadifar *et al.*, 2021; Faheem *et al.*, 2022; Reverter *et al.,* 2021). Medicinal plants bolster the immune system, stimulate appetite, facilitate nutrient absorption, and promote growth by functioning as antioxidants, immune enhancers, and growth stimulants (Dawood *et al.*, 2018). Current study substantiates these effects, indicating that moderate supplementation (0.5–1.5%) enhances liver health and protein turnover by elevating total liver protein levels and metabolic enzyme activity (AST, ALT, and ALP). Bioactive compounds produced from plants have demonstrated an influence on the gene expression of growth and immune-related markers

(Ahmadifar *et al*., 2021; Faheem *et al*., 2022). Nonetheless, growth and financial gain were impeded at levels of 2%, perhaps attributable to antinutritional factors or an overabundance of bioactive components that hinder food digestion and processing. This biphasic, dose-dependent response aligns with previous studies indicating that moderate doses of medicinal herbs can improve aquaculture outcomes, whereas excessive doses may lead to toxicity, metabolic disturbances, or oxidative stress (Ahmadifar *et al*., 2021; Reverter *et al*., 2021). The 2% concentration in this study induced hepatic stress, reduced protein content, and diminished enzyme activity, illustrating the dual characteristics of phytochemicals: beneficial at low levels but possibly detrimental at elevated concentrations. Nitric oxide and malondialdehyde concentrations decreased, whereas antioxidant enzyme activities (SOD, GPx, CAT, and GSH) increased with moderate supplementation (0.5–1.5%), indicating improved redox balance. Conversely, fish treated with 2% had increased antioxidant enzyme activity and elevated levels of nitric oxide and malondialdehyde, indicating an adaptive response to heightened oxidative stress. Plant compounds demonstrate a dual role as prooxidants and antioxidants, where higher levels negate the advantageous effects observed at lower to moderate concentrations (Reverter *et al*., 2021). The electrolyte balance was likewise influenced by *X. aethiopica*. Potassium and sodium retention, crucial for cellular stability and osmoregulation, were enhanced at moderate concentrations (0.5–1%). Elevated concentrations (1.5–2%) led to reduced calcium and chloride levels, potentially compromising ionic balance and membrane integrity. The detected growth inhibition at elevated supplementation levels was likely attributable to these anomalies. Similar findings in previous plant-based research suggest that diminished performance at elevated doses may result from the disturbance of sodium–potassium adenosine triphosphatase ($Na^+/K^+$-ATPase) activity, an essential membrane-bound enzyme responsible for maintaining ionic equilibrium by actively transporting sodium and potassium ions across the cell membrane (Ahmadifar *et al*., 2021).

## CONCLUSION

These data substantiate the idea that, when administered in suitable amounts, medicinal plants like as *X. aethiopica* can improve aquaculture outcomes. The optimal addition is modest (0.5–1%), which enhances economic performance, growth, metabolism, and oxidative equilibrium. Elevated concentrations (2%XE) induce electrolyte imbalances, oxidative stress, and metabolic disturbances. These findings advocate for the utilisation of plant-derived additives as eco-friendly alternatives to synthetic growth enhancers and provide valuable recommendations for formulating aquafeed.

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## AUTHORS' CONTRIBUTIONS

W. A. Jimoh directed the conceptualization process and composed the final manuscript. A. K. Arise oversaw project administration. O. Y. Yusuf oversaw the advancement of the project. O. L. Adeniyi supervised the execution of length-based growth methods and composed the preliminary draft. I. O. Maliki supervised the research on hepatic health and authored the preliminary draft. A. A. Aremu discussed cost issues and composed the preliminary draft. L. A. Babatunde orchestrated the comprehensive project documentation.

## POTENTIAL CONFLICT OF INTEREST

The authors declare that there were no personal or financial conflicts of interest associated with this work.

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