

Indigovita: Assessing the Efficacy of Fermented *Indigofera Zollingeriana* Miq. Leaves as an Alternative Fish Feed Supplement for African Catfish (*Clarias gariepinus*)

Davin, Aaliyah Nicolle G¹, Abao, Andrea Caryll M², Andales, Paul Dominique I³, Batindaan, Juliah Kate C⁴, Cabarse, Derek Neiro P⁵, Gayud, Greyl Emman Louise C⁶, Lozano, Chryzylle Anne E⁷, Selma, Benedict C⁸, Suaviso, Jamilah M⁹, Ellaga, Mark Jobert C¹⁰, Bacan, Cleford Jay D¹¹

Cor Jesu College, Inc. Senior High School Digos City

DOI: <https://doi.org/10.51244/IJRSI.2025.12040062>

Received: 22 March 2025; Accepted: 04 April 2025; Published: 09 May 2025

ABSTRACT

The increasing cost of commercial fish feed presents a growing challenge for sustainable aquaculture, especially among small-scale fish farmers. This financial burden reduces profitability and limits the accessibility of quality nutrition essential for optimal fish growth. This study explored the potential of fermented *Indigofera zollingeriana* Miq. Leaves as a natural fish feed supplement for African Catfish (*Clarias gariepinus*), offering a plant-based alternative to conventional feeds and assessing its effectiveness in promoting growth performance. A total of thirty African Catfish fingerlings were used, divided into four experimental groups and one control group, each group containing six fingerlings. The experimental groups received varying percentages of *I. zollingeriana* leaf meal (0%, 15%, 30%, 45%), while the control group was fed commercial feed. Researchers measured and recorded the length and weight before and after treatment, with growth performance assessed using Feed Conversion Ratio (FCR) and Specific Growth Rate (SGR). The data were analyzed using Kolmogorov-Smirnov and Kruskal-Wallis Test to determine statistical significance. The results indicated no significant differences between the experimental and control groups, suggesting that *I. zollingeriana* performed comparably to commercial feeds supporting fish growth. Among the treatments, the 45% *I. zollingeriana* leaf meal group (T4) recorded the lowest FCR of 1.51% and the highest SGR (3.48%/day). The control group exhibited an FCR of 1.51% and an SGR of 3.44%/day, demonstrating similar feed efficiency. While statistical significance was not achieved, the comparable growth performance implies that *I. zollingeriana* could still serve as a viable, cost-effective, and sustainable alternative to commercial fish feeds. Further studies are recommended to optimize formulation ratios, extend feeding trials, and assess its long-term effects on fish health and overall aquaculture productivity.

Keywords: Aquaculture, *Indigofera zollingeriana* Miq., African Catfish (*Clarias gariepinus*), Quantitative Research, True Experimental Design

INTRODUCTION

Aquaculture contributes to economic development, which is crucial for human consumption and industrial implications. It involves fishing, cultivating marine species, and ensuring sufficient feeding for fish. However, the rising cost of conventional fish feed supplements poses a significant demand for sustainable aquafarming. Commercial feed expenses hinder small-scale fisheries' ability to maintain profits in aquaculture production, leading to financial drawbacks. Additionally, there is a significant potential for improving the overall growth performance of fish by utilizing cost-effective, natural ingredients as alternative fish feed supplements.

Increasing fish meal and fish oil prices create financial challenges for the global aquaculture industry, highlighting the need for cost-effective and sustainable fish feed alternatives. Aquaculture accounts for nearly 50% of the world's fish consumption, with India producing 12.60 million metric tons, of which 65% comes from inland sources and 50% from aquaculture. However, the significant decline in fish meal and fish oil supplies has led to a sharp price increase, ranging from \$1,600 to \$1,800 per metric ton. This surge places a heavy financial burden on small-scale farmers, making it difficult to sustain production and remain competitive

in aquaculture (Hodar et al., 2020). Similarly, in Sub-Saharan Africa, high fish feed supplement costs comprising 60% to 75% of total production expenses adversely impact aquaculture profitability (Adéyèmi et al., 2020). As a result, the growing demand for cost-effective fish feed alternatives is becoming increasingly crucial for global aquaculture sustainability.

Various Asian countries have experienced the problem of rising feed prices, and many studies have tried to find solutions. Chowdhury et al. (2021) discovered that during the COVID-19 pandemic, various unprecedented ecological and social factors affected the livelihood of fish culturists and fisherfolks in Malaysia. These factors include climate change, pollution, and resource degradation, reinforcing the need for sustainable and cost-effective alternative fish feeds to ensure the stability of aquaculture. In Cambodia, Asian seabass farming mainly uses trash fish as feed, but the cost of this feed is rising. Chankakada et al. (2020) mentioned that in Cambodia, the production cost of Asian seabass would be elevated since feed is generally the primary single component of production costs in marine fish farming. Moreover, during the 2021 International Conference on Aquaculture in Indonesia (ICAI), the Asosiasi Pengusaha Catfish Indonesia (APCI) noted that due to expensive commercial feeds, pangasius production was shortened (Aqua Culture Asia Pacific, 2022). Due to the high cost of fish feed, farmers struggled to sustain their operations, leading to shorter production cycles and lower harvests, emphasizing the need for more affordable and sustainable feed alternatives.

Sustainable aquaculture practices offer significant socio-economic benefits for developing countries, particularly for small-scale fish farmers who face challenges related to high feed costs and limited resources. By adopting alternative feed strategies and environmentally conscious methods, farmers can reduce production expenses and improve their profit margins, ultimately contributing to poverty reduction and food security. For instance, in Bangladesh, sustainable aquaculture practices have led to a 2.1% annual increase in per capita income among participating households, highlighting their role in economic development (WorldFish, 2021). In Madagascar, community-based marine resource management not only improved fish stocks but also enhanced income and food availability in rural coastal communities (World Wildlife Fund [WWF], 2022). Moreover, the Food and Agriculture Organization [FAO], (2020) emphasizes that sustainable aquaculture can create employment opportunities, stabilize rural economies, and support long-term resilience in low-income countries.

The use of *Indigofera zollingeriana* Miq. as an alternative fish feed supplement has demonstrated both promising benefits and limitations in global aquaculture studies. According to Utomo and Jusadi (2018), incorporating up to 10% *I. zollingeriana* protein in tilapia (*Oreochromis niloticus*) feeds significantly enhanced growth performance, specifically in daily growth rate and feed efficiency, without affecting survival rates. Similarly, Tarigan et al. (2018) found that diets containing 90% *I. zollingeriana* increased daily weight gain and improved feed utilization efficiency. Furthermore, Setiyowati et al. (2023) found that adding *Indigofera* leaf flour to striped catfish feed significantly improved weight gain, specific growth rate, and feed efficiency. In relation to this, Mugwanya et al. (2022) found that replacing fishmeal with fermented plant proteins in aquaculture diets improved growth and feed efficiency and boosted antioxidant and digestive enzyme activities in various species.

The use of *I. zollingeriana* as a plant-based protein source in aquafeeds has been widely studied for its potential to maintain feed conversion efficiency in fish. Hussain (2024) reported that properly processed plant-based protein sources could sustain feed conversion ratio (FCR) values comparable to fishmeal-based diets, highlighting their efficiency when appropriately prepared. Additionally, Einstein-Curtis (2019) stated that balanced amino acid profiles in plant-based diets contribute to improved feed efficiency, ensuring fish can metabolize alternative protein sources effectively. However, Duque-Estrada and Petersen (2023) found that unprocessed plant proteins often result in higher FCR due to reduced digestibility, emphasizing the importance of processing methods in improving nutrient absorption.

The ability of *I. zollingeriana* to sustain growth performance without adverse effects further supports its potential as an alternative protein source in fish feed. Kurniasih et al. (2024) noted that plant-based feed ingredients could support optimal growth when their amino acid profile and digestibility are sufficient. However, Chong (2022) found that excessive inclusion of plant-based proteins has been linked to reduced feed

efficiency due to anti-nutritional factors. Furthermore, Nadir et al. (2024) emphasized that the effectiveness of Indigofera-based diets depends on the processing method used to enhance digestibility. These findings collectively suggest that *I. zollingeriana*, when properly processed, can serve as a viable alternative to conventional fish feeds without compromising growth performance.

Despite the potential of *I. zollingeriana* as an alternative feed, studies reveal that its impact on growth performance varies across species and inclusion levels. Gustria et al. (2024) observed that while *I. zollingeriana* increased the growth rate and length in bonito fish (*Rasbora* sp.), but there is no significant difference in weight gain, feed efficiency, or survival rates between various treatments. These findings suggest that while *I. zollingeriana* is a viable protein source, but its effectiveness depends on fish species and formulation levels. Putri et al. (2019) also found no significant improvements in survival rates and growth when feeding tilapia with fish meal mixed with Indigofera leaf flour, except at a 20% fish meal and 30% Indigofera combination, which achieved optimal results. Furthermore, Bahar et al. (2023) reported that Indigofera supplementation had no significant impact on average daily gain or feed conversion rate in certain fish species. These mixed findings indicate that while *I. zollingeriana* has the potential to enhance aquaculture sustainability, determining the optimal inclusion level is crucial to maximizing its benefits for African catfish growth performance.

Aquaculture is a significant source of livelihood in the Philippines but faces challenges in maintaining profitability and sustainability due to rising feed costs. The Food and Agriculture Organization stated that the Philippines is vital in global fisheries, ranking 11th worldwide and contributing 1.01% to total fish production. In 2023, the country's aquaculture production reached approximately 2.38 million metric tons (Balita, 2024). As of 2020, around 233,725 individuals (11% of registered fisherfolk) relied on aquaculture for their livelihood, underscoring its economic importance (Bureau of Fisheries and Aquatic Resources, 2020). However, the rising cost of commercial feeds, ranging from ₱34.00 to ₱36.00 per kilogram, poses a significant challenge, particularly for small-scale fish farmers. With feeds accounting for 50% of production costs, profitability and sustainability are increasingly threatened (Southeast Asian Fisheries Development Center, 2025). Limited access to affordable, high-quality feeds remains a significant obstacle for small-scale fish farmers striving to sustain their livelihoods and contribute to industry growth (Biovet, 2022).

The costs of commercial aquatic feeds in the Philippines are increasing due to the growing number of aquaculture activities. Large numbers of indigenous raw materials from poultry by-product meals, blood meals, oilcake, cereal by-products, vegetables, and leaf meals are used in developing feeds for the culture of various fish species. In the study of Naorbe (2021), *C. gariepinus* was fed with chopped raw chicken entrails at three different feeding rates (3%, 4%, 5%). Those who were fed at 4% and 5% of the body weight showed significantly higher weight gain (WG), specific growth rate (SGR), and better feed conversion ratio (FCR). Feeding *C. gariepinus* with raw chicken entrails resulted in an increased growth rate and lower FCR and showed 100% SR. Furthermore, Obeda et al. (2023) found that dietary benfotiamine in a high carbohydrate diet improves growth and resistance to abrupt shifts to higher salinity in African catfish juveniles. The study showed that adding benfotiamine, a synthetic pro-vitamin B1, to a high-carbohydrate fry diet at a concentration of 0.02% enhanced performance and increased survival rates of African catfish (Gonzalez, 2023).

Conducting a comparative analysis of various alternative feed ingredients provides aquaculture practitioners with a broader understanding of the most efficient, cost-effective, and nutritionally valuable options available. While ingredients like *I. zollingeriana*, cacao pod husk, and soybean meal have shown potential as replacements for fishmeal, their effectiveness can vary significantly based on digestibility, amino acid profile, cost, and environmental impact. For instance, *I. zollingeriana* leaves, when fermented with *Aspergillus niger*, have demonstrated improved digestibility and protein content, enhancing growth performance in Jaya Sakti goldfish (*Cyprinus carpio*) (Fitria, 2023). Similarly, incorporating heated air-dried cacao pod husk into the diet of whiteleg shrimp (*Litopenaeus vannamei*) has been found to promote growth and immunocompetence cost-effectively (Chang et al., 2023). Additionally, soybean meal serves as a cost-effective alternative protein source, effectively replacing fishmeal in the diets of various fish species, including stinging catfish (*Heteropneustes fossilis*), without compromising growth or health (Howlader et al., 2023). By evaluating these alternatives side by side, researchers and farmers can better determine which feed supplements align with species-specific nutritional requirements and sustainable aquaculture practices.

Plant ingredients that contain high protein content, high digestibility of crude protein, and low antinutritional components can replace fishmeal as a substitute protein source for fish. Soy products, including soybean meal and soy protein concentrate (SPC), have been researched as potential protein substitutes for fishmeal (Trejo-Escamilla et al., 2017). Moreover, Magbanua and Ragaza (2022) stated that when soybean meal was subjected to solid-state fermentation using *Saccharomyces cerevisiae*, the fermentation process increased hydrolyzed amino acids and total protein content. In addition, cacao pod husk (CPH) is another protein source that can replace fishmeal (Macusi et al., 2023). Using this product as a replacement for fishmeal will eliminate environmental waste since it can be obtained at little to no cost to aquaculture farmers. An early study on the growth of Nile tilapia (*Oreochromis niloticus*) fingerlings fed various levels of cocoa pod husk diets from zero (control) to 10% and 20% incorporation in the diet discovered gains in fish weight and specific growth rates to be higher with an above 10% inclusion level in the diet. Regardless of the high crude protein content of CPH, it commonly lacks amino acids, which limits the growth of the aquaculture species.

The rising cost of conventional fish feed is becoming a significant challenge for fish farmers who struggle to maintain profitability. Although many studies have addressed the increasing feed prices and their effects on the aquaculture industry, there is still a gap in finding effective and sustainable alternatives. While plant-based fish feed supplements have been explored, there has been limited research on using fermented *I. zollingeriana* Miq. leaves as a viable alternative, particularly in the local context. This study aimed to utilize fermented *I. zollingeriana* leaves as an effective alternative feed supplement for African catfish to enhance fish growth performance. The researchers intend to evaluate the effectiveness of the feed supplement as a cost-effective and sustainable alternative for fish feed.

Theoretical Framework

This study is anchored on two pivotal theories: Kleiber's Law of Max Kleiber in 1947 and the Sustainable Development Theory of Graham Harley Bundtland in 1987.

Kleiber's law suggests that as an animal increase in size, its metabolism becomes more efficient (Kleiber, 1947). This law is not caused by a decrease in the metabolic rate of individual cells as an organism grows but because each cell's mass increases as the organism's overall size grows (Thommen et al., 2019). This study aligns with Kleiber's Law, examining how the nutritional components of the feed supplement affect the metabolism and growth rates of African catfish. According to Abbaspour (2024), the plant's fermentation process enhances the bioavailability of nutrients, making them more accessible for absorption and utilization. When the animals consume higher-quality, fermented feed, their growth rates improve, showcasing the benefits of a nutritionally optimized diet (Predescu et al., 2024).

Moreover, the Sustainable Development Theory states that sustainable development addresses the needs of the present while ensuring that future generations can meet their needs, which perfectly aligns with this study. Utilizing sustainable resources is more efficient and economically practical. Furthermore, using plant-based resources as fish feed shows promising sustainability (Zlaugotne et al., 2020). The Sustainable Development Theory is linked to this study as researchers find alternative fish feed solutions. It was discovered that developing alternative fish feed can improve fish health, reduce disease, and promote sustainable aquaculture (Fantatto et al., 2024). Furthermore, alternative fish feed is vital for today's demands; the best options for its ingredients include insects, animal by-products, and plant-based feeds, which show favorable sustainability outcomes (Shahin et al., 2023).

Kleiber's Law and the Sustainable Development Theory align with the study by emphasizing efficient resource use and long-term ecological balance. Kleiber's Law, which focuses on the metabolic efficiency of organisms (Leiva & Schramski, 2022), supports the idea of optimizing fish feed formulations, like *I. zollingeriana*, to promote healthier growth with minimal resource input. Meanwhile, the sustainability theory supports the study's focus on environmental, economic, and social aspects (Shi et al., 2019), as it explores a renewable, cost-effective alternative that reduces environmental strain while supporting the livelihoods of fish farmers. Together, these frameworks highlight the importance of resource efficiency and sustainable practices in aquaculture.

Statement of the Problem

The main objective of this research was to assess the efficacy of the fermented *Indigofera zollingeriana* Miq.

leaves as an alternative supplement for fish feeding in African Catfish (*Clarias gariepinus*). Specifically, the study aimed to answer the following questions:

1. What is the average growth performance of African catfish (*Clarias gariepinus*) based on Feed Conversion Ratio (FCR) when supplemented with an alternative fish feed of fermented *Indigofera zollingeriana* Miq. leaves compared to a control group based on the following treatments:
 - 1.1 0% *I. zollingeriana* leaf meal;
 - 1.2 15% *I. zollingeriana* leaf meal;
 - 1.3 30% *I. zollingeriana* leaf meal;
 - 1.4 45% *I. zollingeriana* leaf meal; and
 - 1.5 Commercial feed as the control group?
2. What is the average growth performance of African catfish (*Clarias gariepinus*) based on Specific Growth Rate (SGR) when supplemented with an alternative fish feed of fermented *Indigofera zollingeriana* Miq. leaves compared to a control group based on the following treatments:
 - 1.1 0% *I. zollingeriana* leaf meal;
 - 1.2 15% *I. zollingeriana* leaf meal;
 - 1.3 30% *I. zollingeriana* leaf meal;
 - 1.4 45% *I. zollingeriana* leaf meal; and
 - 1.5 Commercial feed as the control group?
3. Is there a significant difference in the fish growth performance based on Feed Conversion Ratio (FCR) using different formulations of fermented *Indigofera zollingeriana* Miq. leaves supplementations as an alternative fish feed in contrast to commercial fish feed?
4. Is there a significant difference in the fish growth performance based on Specific Growth Rate (SGR) using different formulations of fermented *Indigofera zollingeriana* Miq. leaves supplementations as an alternative fish feed in contrast to commercial fish feed?

Hypothesis

To answer the problems listed in the preceding section objectively, the given null hypothesis was formulated:

H₀₁: There is no significant difference in the fish growth performance based on Feed Conversion Ratio (FCR) using different formulations of fermented *Indigofera zollingeriana* Miq. leaves supplementation as an alternative fish feed in contrast to commercial fish feed.

H₀₂: There is no significant difference in the fish growth performance based on Specific Growth Rate (SGR) using different formulations of fermented *Indigofera zollingeriana* Miq. leaves supplementation as an alternative fish feed in contrast to commercial fish feed.

Significance of the Study

It is crucial to assess the efficacy of fermented *Indigofera zollingeriana* Miq. leaves as an alternative fish feed supplement. Addressing the increasing demand for cost-effective fish feed supplements in aquaculture is essential. Hence, the researchers conducted this study, which could be beneficial to the following:

Department of Agriculture (DA) Officials. The findings of this study will assist the Department of Agriculture (DA) officials in obtaining insights and extensive knowledge of the usage of fermented *I. zollingeriana* leaves as a potential alternative fish feed supplement. Through this quantitative study, fish farmers of the Department of Agriculture can utilize the data of this research to promote sustainability, improve feed quality, and provide a cost-effective natural feed supplement for aquaculture.

Department of Science and Technology (DOST) Officials. The finding of this study will provide the Department of Science and Technology (DOST) officials with scientific data on the effectiveness of fermented *I. zollingeriana* leaves as an alternative fish feed supplement. This government agency can use the information from the study's findings to fund and support further research into optimizing the fermentation process and improving the nutritional profile of *I. zollingeriana* as a fish feed supplement. Additionally, DOST can develop and promote innovative feed processing technologies, conduct pilot projects in aquaculture farms to test the feed's practical application, and establish partnerships with feed manufacturers to scale production.

Aquaculture Industry Workers. This study can improve the practices of aquaculture industry workers in using fermented *I. zollingeriana* leaves to enhance fish growth performance, producing more cost-effective and naturally made alternative feeds. Through this study, workers in the aquaculture industry can better understand the potential benefits of implementing natural ingredients to reduce feed expenses and promote sustainable aquaculture practices.

Fish Feed Manufacturers. This study can benefit fish feed manufacturers by providing insights into using fermented *I. zollingeriana* leaves as a natural ingredient in fish feed formulation. Moreover, this research offers valuable data that could support feed manufacturers experimenting with different ratios of natural ingredients, leading to the development of more cost-effective, highly nutritious, and eco-friendly pellet formulations.

Individual Fish Farmers. This study will provide the individual fish farmer with valuable insights into enhancing feed quality and sustainability in aquaculture by utilizing fermented *I. zollingeriana* leaves as a potential alternative feed supplement, helping reduce costs and decrease reliance on conventional feeds. Furthermore, the study's findings will provide knowledge to individual fish farmers to improve fish health, increase growth rates, and potentially reduce feeding costs, contributing to more efficient and sustainable farming practices.

Future Researchers. This study holds great potential for future researchers, as it aims to provide knowledge about the potential of fermented *I. zollingeriana* leaves as an effective alternative feed supplement for fish. The findings of this study will also provide opportunities for future researchers to explore the nutritional properties of other underutilized feed materials, which can serve as a reference for future development in related research projects.

Scope and Limitations

This study focused mainly on assessing the efficacy of *I. zollingeriana* fermented leaves as an alternative fish feed supplement. The research was conducted during the first and second semesters of the 2024 to 2025 academic year. This research was undertaken in Digos City, Davao del Sur. Furthermore, the researchers utilized 30 African catfish (*Clarias gariepinus*) fingerlings in a controlled aquaculture environment within the Davao del Sur province for the experimental trials.

This study did not conduct an in-depth analysis of the nutritional composition and long-term effects of *I. zollingeriana* on fish. Factors such as immune response, reproductive performance, and survival rates beyond

the 14 days were not assessed. Instead, it focused on assessing African catfish fingerlings' growth performance and overall health outcomes when supplemented with varying levels of fermented *I. zollingeriana* leaves during the 14-day trial period.

Definition of Terms

The following terms were expounded to further comprehend the components of this study.

African Catfish. This refers to a type of freshwater fish commonly raised in fish farming systems (Segaran et al., 2023). This study used these specific fish species as experimental and control groups. They were cultured to determine whether the alternative fish feed showed a high efficacy rate in the fish's growth performance.

Aquaculture. This refers to cultivating African catfish in controlled environments, such as tanks, ponds, or other water systems (Adeleke et al., 2020). This study used three ponds, each with 15 holes, to cultivate fish for two weeks, aiming to evaluate fermented *I. zollingeriana* leaves as a cost-effective alternative fish feed supplement to improve the growth of African catfish in these aquaculture systems.

Feed Supplement. This refers to an extra feed added to an animal's diet to improve its health or growth (Yang, 2023). In this study, feed supplement refers to fermented *I. zollingeriana* leaves added to the African catfish's diet to improve their growth and development, serving as a cost-effective alternative to regular fish feed.

Indigofera zollingeriana Miq. This refers to an erect shrub or small tree commonly found in tropical and subtropical regions (Fern, 2025). This study explored its leaves as a potential alternative fish feed for African catfish to enhance their growth performance. This study evaluated the efficacy of fermented *I. zollingeriana* leaves as a potential feed supplement.

METHODS

This chapter encompasses the methodologies employed in carrying out the study. It covers aspects such as research design, the subject of the study, sampling methodologies, data sources, data collection procedures, measurement techniques, methods of analysis and interpretation, and ethical considerations.

Research Design

In this quantitative research, the researchers utilized a true experimental research design, specifically a pretest-posttest control group design, to evaluate the effectiveness of fermented *Indigofera zollingeriana* Miq. leaves as an alternative fish feed supplement and examined its impact on the growth performance of African catfish (*Clarias gariepinus*). According to DeCarlo et al. (2022), a true experiment allows researchers to manipulate one or more independent variables as treatments. Three formulations were evaluated by observing dependent variables after subjects were randomly assigned to different treatment levels. This design helped determine the growth performance of the fish, enabling the researchers to evaluate the observations better and draw conclusions regarding the effectiveness of the plant as an alternative feed supplement for African catfish.

There were four formulations: 0%, 15%, 30%, and 45% *I. zollingeriana*, as well as a control group. These formulations differed in the ratios of *I. zollingeriana*, with the 0% formulation containing no alternative supplementation. The control group was provided with commercial feed. This study employed a completely randomized design for selecting African catfish for experimentation. A pretest-posttest approach assessed the growth performance, measuring its key parameters before and after the experimental period. This method allowed a comprehensive evaluation of the potential of *I. zollingeriana* as a viable alternative feed supplement for African catfish.

Subject of the Study

This experimental study investigated the evaluation of fingerlings, particularly with the African catfish. This study aimed to evaluate the efficacy of fermented *I. zollingeriana* leaves as an alternative fish feed supplement

for enhancing the growth of African catfish using four treatments of fermented *I. zollingeriana* leaves. For this study, a total of 30 African catfish fingerlings were required, with four experimental groups and one control group, with each group having two fingerlings per replica (represented as R1, R2, and R3), a total of 6 fingerlings per group. Researchers measured and recorded growth parameters with an average weight of 3 grams and an average length of about 7 cm. Grouping the fingerlings into control and experimental groups allowed the researchers to determine the effectiveness of *I. zollingeriana* on growth rate. The researchers studied the growth performance effects of *I. zollingeriana* in an aquaculture setting, using African catfish fingerlings as subjects. In assessing improvements, the researchers measured and recorded growth parameters, including length and weight. Furthermore, the study was conducted in Digos City, Davao del Sur.

Sampling Technique

In this study, the researchers used a complete random design (CRD) to assess the effects of alternative feeds on African catfish (*Clarias gariepinus*). The complete random design is the simplest experimental design, where treatments are assigned to experimental units at random without any systematic bias (Costello, 2023). Each experimental group had an equal chance of receiving any treatment. CRD was suitable for this study because it allows alternative feeds to be assigned randomly to each group of catfish. The randomization ensured that each experimental unit had an equal chance of receiving any feed alternatives and ensured that results were reliable. With the use of the CRD, the study demonstrated unbiasedness and generalizability. Since treatments and control groups were assigned randomly, the risk of bias in the experiment was reduced. Furthermore, it ensured generalizability as it increased the probability that the same sample closely represented the larger population.

Measures

In measuring the growth performance of the African catfish, the researchers used two indicators: Feed Conversion Ratio (FCR) and Specific Growth Rate (SGR). The Feed Conversion Ratio (FCR) was the feed ratio provided to the fish population's weight gain (Fry et al., 2018). This metric assessed how effectively African catfish convert various feed supplements into weight gain by the end of the rearing period. Additionally, the Specific Growth Rate (SGR) was another important measure that quantified the growth performance of fish populations over a specific time frame (Johnston et al., 2007). Researchers used SGR to evaluate the percentage increase in the weight of African catfish per day after treatment. These indicators served as the basis for determining the effectiveness of *I. zollingeriana* as a fish feed supplement and measuring the growth performance of African catfish.

$$FCR (\%) = \frac{F}{Wt - Wo}$$

Where, FCR = Feed Conversion Ratio (%)

F = feed intake during the rearing period (grams)

Wt = Final weight (grams)

Wo = Initial Weight (grams)

Table 1. Feed Conversion Ratio formulation and interpretation, restated by Fry et al. (2018)

FCR% Value Range	Description	Interpretation
> 2.4 %	High FCR	Inefficient growth
1.0 - 2.4 %	Moderate FCR	Balanced growth
< 1.0 %	Low FCR	Efficient growth

Based on the Feed Conversion Ratio (FCR) formulation, values below 1.0% indicate a lower FCR, suggesting efficient growth. This means that smaller feed intake significantly impacts the weight and length of the African catfish. An FCR value between 1.0% and 2.4% represents moderate efficiency, indicating balanced growth where the amount of feed consumed is proportional to the weight and size gain. Finally, values above 2.4% indicate a high FCR, which is interpreted as inefficient growth, meaning a larger amount of feed is required to achieve good results.

$$\text{SGR (\%)} = \left(\frac{\ln W_f - \ln W_i}{\Delta t} \right) \times 100$$

Where, SGR = Specific Weight Growth Rate (%/day) (grams)

W_f = Final weight of the fish at the end of the rearing period (grams)

W_i = Starting weight of the fish during the rearing period (grams)

t = Length of maintenance time (days)

Table 2. Specific Growth formulation and interpretation of Johnston Rate et al. (2007)

SGR % Range	Description	Interpretation
> 2.0 % / day	High SGR	Optimal growth
1.0 - 2.0 % / day	Moderate SGR	Stable growth
< 1.0 % / day	Low SGR	Slow growth

Based on the Specific Growth Rate (SGR) analysis, values above 2.0% per day suggest optimal growth, indicating high SGR. A high SGR implies that the fish are growing fast under ideal conditions, including proper feeding and environment. An SGR value between 1.0% and 2.0% per day classifies as moderate SGR, indicating stable growth where the fish are gaining weight consistently in proportion to their feed intake and environmental factors. Finally, values below 1.0% per day indicate low SGR, which is interpreted as slow growth, meaning the fish are gaining minimal weight, potentially due to inadequate nutrition or suboptimal conditions.

Data Gathering Procedure

In the data-gathering process for the study, the researchers followed specific procedures to acquire information.

Collection of *Indigofera zollingeriana* Miq. leaves

The following procedures were adapted from the study of Huda et al. (2022):

1. The researchers traveled to a local area in Mahayahay, Hagonoy, to harvest *I. zollingeriana* leaves. The researchers used clean cutting tools, such as pruning shears and scissors, to ensure the leaves were free from pests and visible damage. The harvested leaves were placed in clean, breathable bags for transport to the processing area.
2. The researchers inspected the harvested leaves at the processing area, removing any damaged or discolored ones. The selected leaves were then washed thoroughly under running water to remove dirt and impurities while ensuring they remained intact. After washing, they were drained in clean drying baskets to reduce excess water.
3. To start the air-drying process, the partially drained leaves were spread on clean mats in a well-ventilated, shaded area. The researchers ensured the leaves were evenly spread, not stacked, and periodically turned them to achieve uniform drying without exposing them to direct sunlight to preserve their nutrient content.

4. Once the leaves were dried, the researchers ground them using a blender and then sieved them using a strainer to achieve a fine powder or small, consistent pieces to ensure they were ready for fermentation.
5. After grinding, the researchers weighed exactly 100 grams of the ground *I. zollingeriana* leaves using a calibrated weighing scale. The weighted leaves were then stored in clean, airtight bags to keep them fresh and uncontaminated until they were used for fermentation.

Collection of Yellow Mealworm (*Tenebrio molitor* L.)

The following procedures were adapted from the studies of Melis et al. (2018) and Kröncke et al. (2019):

1. The researchers gathered one kilogram of mealworm (*Tenebrio molitor* L.) from a local area in Bansalan, Davao del Sur, to ensure they were clean and free from contaminants.
2. The mealworms were then placed in a container, and after that, they were placed in the freezer for 1 day at a temperature of -20°C (0°F) to ensure that the mealworms were euthanized.
3. After euthanizing the mealworms, the researchers cleaned them thoroughly by rinsing them under running water to remove dirt or residues.
4. Once the mealworms were cleaned, they were subjected to drying to reduce their moisture content and extend shelf life. The researchers used an oven set at 120°C for 1 hour at the ventilation stage, ensuring the mealworms were adequately dried and crispy.
5. The researchers then transferred the dried and crispy mealworms to a blender and ground them until they achieved a fine, flour-like consistency.
6. After grinding the mealworms, the researchers sifted the pulverized dried mealworms using a strainer to ensure a uniform particle size. If there were any larger particles remaining, they were ground again for consistency.
7. After completing these processes, the researchers transferred the mealworm powder to a clean, airtight bag. It is stored in a cool, dry place to keep it fresh and avoid contamination until the start of the fermentation process.

Fermentation Process of the Different Formulations

The following procedures were adapted from the study of Huda et al. (2022):

1. The researchers prepared four separate fermentation containers, each corresponding to a different formulation of *I. zollingeriana*: 0%, 15%, 30%, and 45%. In each container, the researchers added the required amounts of *I. zollingeriana* powdered leaves, Yellow mealworm powder, and other ingredients, including soybean meal, rice bran, cornstarch, coconut cake, tapioca starch, and Vitamin E.
2. The prepared probiotic solution was made by mixing 20 mL of *Lactobacillus casei* culture with 40 mL of clean, non-chlorinated water in a sterile container, which was gradually poured into each of the four containers. The researchers stirred the mixtures continuously using a sterile plastic stirring rod to ensure all ingredients were evenly moistened.
3. The researchers ensured that each mixture formed a compact, evenly moistened mass without any dry areas. The researchers avoided excess liquid to prevent over-saturation, which could hinder fermentation.
4. The researchers used a simple airlock system in each container to maintain anaerobic conditions. A plastic tube was inserted through a small hole in the lid of each container, with the other end submerged in a small bottle of water. This setup allowed the carbon dioxide (CO₂) to escape from the container without allowing oxygen to enter, preventing spoilage.
5. The moistened materials in each container were then transferred into airtight plastic containers, compressing the mixtures tightly to eliminate air pockets and create the anaerobic environment necessary for fermentation.
6. The researchers securely sealed each container to prevent oxygen from entering and labeled them according to their respective formulation percentages (0%, 15%, 30%, and 45%). The researchers also indicated the fermentation start time and duration.

7. The sealed containers were stored in a warm, dark location with a temperature range of 30°C to 35°C for 48 hours to allow the fermentation process.
8. The researchers periodically checked the containers for gas buildup. If excess gas accumulates, the airlock system allows it to escape naturally. However, if necessary, the researchers carefully opened the bags to release gas and resealed them immediately.
9. After the 48-hour fermentation period, the researchers removed the fermented materials from the airtight containers. Each formulation was spread evenly on clean trays and air-dried in a shaded, well-ventilated area until it achieved a stable moisture content suitable for storage.
10. Once dried, the researchers weighed the fermented formulations separately to ensure accurate measurements for each percentage group. The materials were transferred into airtight bags to preserve their quality until they were used in feed preparation.
11. The fermented formulations were stored in a cool, dry place to maintain their freshness and nutritional value. The researchers labeled each container according to its respective formulation percentage and stored feeds until they were ready to feed African Catfish.

Table 3. Composition of feed ingredients in each treatment (g)

	Feed raw materials	T1	T2	T3	T4
1	<i>I. zollingeriana</i>	-	15	30	45
2	Mealworm	32.53	32.78	33.53	35.53
3	Soybean meal	20	14	9	2
4	Rice Bran	10.45	10.45	10.45	6.45
5	Cornstarch	20.5	15.2	9.75	3.7
6	Coconut cake/copra	12.5	9.8	5.25	6.3
7	Tapioca starch	4	2.75	2	1
8	Vitamin E	0.02	0.02	0.02	0.02
	Total	100	100	100	100

Rearing of African Catfish Fingerlings

The following procedures were adapted from the study of Dauda et al. (2022) and Okomoda et al. (2017):

1. The researchers gathered 30 African catfish fingerlings from a local area located at Bansalan, Davao del Sur.
2. The initial weight of each fish was measured and recorded at the start of the study.
3. The number of fish was divided into one control group and four experimental groups, which were grouped based on their size and weight to reduce competition for food and space.
4. Each group had two fish placed in a rectangular pond with a dark background coloration. The pond's dimensions are 0.58 m in length and width, with a depth of 0.70 m. The pond would hold 0.58 m³ of water, with a temperature between 26°C and 32°C and a pH level ranging from 6.5 to 7.5.
5. The fish was fed thrice daily (morning, noon, and afternoon) with its respective treatments. The daily amount of feed will be 12% of the fish's total body weight and divided into three equal portions for each feeding session. The total amount of feed given to each tank was also weighed and monitored.
6. The control group received standard commercial fish feed, while the experimental groups were provided with fish feed supplemented with fermented *I. zollingeriana* leaves. Any uneaten feed was promptly removed to prevent water contamination and ensure accurate feed intake measurement.
7. Water renewals were performed weekly to maintain optimal water quality.
8. The fish were observed for abnormal behavior, such as sluggishness, feed refusal, or erratic swimming patterns, throughout the trial period.

Growth Assessment of African Catfish

The following procedures were adapted from the study of Fitria et al. (2023):

1. The researchers measured the fish's initial weight using a weighing scale. The measurements were recorded to establish a baseline for subsequent growth comparison.
2. The feed consumed by each group was calculated. This precise calculation was done by measuring the feed provided daily and the remaining after a set period.
3. After the experimental period, each fish was weighed and measured to its total weight. The final measurements provided the final growth data to assess the overall growth performance.
4. Statistical analysis was performed using the Kolmogorov-Smirnov and Kruskal-Wallis Tests to compare growth parameters (SGR and FCR) between the control and experimental groups.

Analysis and Interpretation of Data

In analyzing the data, the mean Kolmogorov-Smirnov and Kruskal-Wallis tests were utilized. These tools were essential for ensuring accurate, reliable, and meaningful interpretation of the collected data.

Mean indicates the average value of a specific growth performance metric (such as feed conversion ratio or specific growth rate) within the five (5) groups, including the four experimental groups with varying formulations of *I. zollingeriana* and one control group.

The Kolmogorov-Smirnov test is a statistical method used to evaluate the similarity between two probability distributions without assuming a specific underlying distribution. It calculates the maximum difference between the two samples' cumulative distribution functions (CDF) (Khadka, 2023). The Kolmogorov-Smirnov test is an essential statistical method for evaluating the growth performance of African catfish fingerlings under varying dietary treatments. This study will involve two groups: one will be fed a diet incorporating *I. zollingeriana* leaf meal, and the other will receive a standard commercial feed as a control. The primary focus is to analyze the distribution of growth metrics, such as weight gain and specific growth rate (SGR), between the two groups. By applying the Kolmogorov-Smirnov test, the research aims to ascertain whether the dietary formulation significantly alters the growth distribution of *C. gariepinus* fingerlings, thus providing insights into the potential benefits of utilizing *I. zollingeriana* leaf meal in aquaculture practices.

The Kruskal-Wallis test is a method used to determine if samples come from the same distribution without assuming a normal data distribution. It assesses whether differences between groups are statistically significant or simply due to random variation (Thomas, 2024). By employing the Kruskal-Wallis test, the research aims to determine whether significant differences exist in the median growth performance of *C. gariepinus* fingerlings across the different *I. zollingeriana* formulations and the commercial feed for the control group provide valuable insights into the effectiveness of alternative feed sources in aquaculture practices.

Ethical Consideration

This study places significant importance on ethical considerations to ensure the protection from harm and the rights of the subjects of the study. It will adhere to four (4) key ethical principles: Animal Welfare and Well-Being, Sample Size and Minimization of Harm, Post-Experimental Handling, and Ethical Responsibility and Scientific Integrity.

Animal Welfare and Well-being. It is a vital component of this study to ensure that animal welfare evaluations address physiological, psychological, behavioral, and social factors. Feeding was conducted according to species-specific needs, and handling was minimized to reduce unnecessary distress, ensuring the well-being of the fish. Additionally, fish were housed in appropriate social groups to encourage healthy interactions while minimizing aggression (Gonzalez, 2022). Researchers also continue to focus on understanding species-specific welfare parameters, including the nutritional requirements of fish in farming systems (Ciliberti et al., 2024).

Sample Size and Minimization of Harm. This follows the principles of the Three R's (Replacement, Reduction, Refinement) to minimize the number of animals used while ensuring statistically valid results. These principles aim to reduce animal pain and distress and to achieve critical scientific objectives that contribute to advances in health and medicine. The Three R's—Replacement, Reduction, and Refinement—are key concepts designed to reduce animal use and suffering (Russell & Burch, 1960).

Post-Experimental Handling. This was applied when the following experiments were done, and the procedures for post-experimental handling must adhere to ethical standards and regulatory requirements. The researchers will continue rearing the experimental fish until natural mortality occurs. This approach ensures that no harm is inflicted on the test subjects or the environment throughout the study.

Ethical Responsibility and Scientific Integrity. This emphasizes honesty and complete transparency of the data analyzed regarding the methods, data, and results. There was no fabrication, falsification, or manipulation of data, and all efforts will be made to avoid plagiarism. Researchers were also transparent about their funding sources and any potential conflicts of interest that may influence the results of their research. By adhering to honesty, objectivity, accuracy, transparency, and responsibility, researchers ensure their work is trustworthy, reliable, and high-quality (Colaiacono, 2023).

RESULTS AND DISCUSSION

This chapter deals with the presentation, analysis, and interpretation of data. The first part describes the average growth performance of the African catfish supplemented with fermented *Indigofera zollingeriana* Miq. based on the Feed Conversion Ratio (FCR) and Specific Growth Rate (SGR). The second part presents the significant difference in the average growth performance of the African catfish supplemented with fermented *I. zollingeriana* Miq. based on FCR and SGR.

Average Growth Performance of the African Catfish Supplemented with Fermented *Indigofera zollingeriana* Miq. based on Feed Conversion Ratio

The study aimed to determine the effectiveness of *I. zollingeriana* Miq. fish feed formulation with four different treatments: Treatment 1 – 0% *I. zollingeriana* leaf meal; Treatment 2 – 15% *I. zollingeriana* leaf meal; Treatment 3 – 30% *I. zollingeriana* leaf meal; Treatment 4 – 45% *I. zollingeriana* leaf meal; and a control group consisting of commercial feeds. To assess the effectiveness of these treatments, the researchers measured the Feed Conversion Ratio (FCR) in percentage, which is calculated by dividing the amount of feed consumed by the weight gained by the fish. A lower FCR indicates better feed efficiency, while a higher FCR suggests the feed was less effective at promoting growth. The FCR was measured in each replication, which led to the following results.

Table 4. Average Growth Performance of the African Catfish Supplemented with Fermented *Indigofera zollingeriana* Miq. based on Feed Conversion Ratio

Treatments	Growth Performance of the African Catfish						Mean	SD	Description
	Feed Conversion Ratio (%)								
	R1		R2		R3				
	Fish 1	Fish 2	Fish 1	Fish 2	Fish 1	Fish 2			
T1	2.52	1.26	3.36	1.68	1.26	2.24	2.05	0.82	Moderate
T2	6.72	2.52	2.52	1.68	1.26	1.68	2.73	2.02	High
T3	1.68	2.52	2.52	6.72	1.68	5.04	3.36	2.06	High
T4	2.52	1.68	5.04	0.96	0.56	2.52	2.21	1.60	Moderate
Control	2.24	1.68	1.68	1.68	5.04	0.63	2.16	1.51	Moderate

The findings of this study differ from multiple existing studies. According to Fitria et al. (2023), the feed conversion ratio (FCR) across treatments ranged from 2.92 to 3.37. Their results indicated that *I. zollingeriana* leaf flour formulations produced distinct outcomes compared to P1 (control group). Similarly, Raimi and Fatuase (2021) found that the highest formulation levels, T4 (75%) and T5 (100%) *Morinda lucida* feed, led to significantly higher FCR values in fish. In contrast, the present study demonstrated that T4 (2.86 SD), the highest formulation in this experiment, was comparable to the control group (2.37 SD) and exhibited a lower FCR, suggesting a different trend in growth performance. This finding suggests that *I. zollingeriana* can be effectively incorporated into fish diets without compromising feed efficiency. The lower FCR values observed in this study imply that fish could convert feed into body mass more efficiently, making the treatment group as effective as the control diet.

Furthermore, the comparable results between the treatment and control groups indicate that both are equally effective in supporting growth performance. Haryati et al. (2021) suggest that including *I. zollingeriana* in rabbit feed at levels up to 20% did not result in a significant difference from the control group, demonstrating that feed efficiency remained comparable. Similarly, *I. zollingeriana* has been shown to provide a reliable and abundant source of protein, which plays a crucial role in supporting fish growth (Fitria et al., 2023). However, Wei et al. (2024) reported contrasting findings, where African catfish fed with 2% and 3% ginger leaf powder (GLP) performed better than the control group. These findings contrast with the present study, where the treatment group performed similarly to the control rather than exceeding its performance.

Average Growth Performance of the African Catfish Supplemented with Fermented *Indigofera zollingeriana* Miq. based on Specific Growth Rate

Table 5 presents the growth performance based on the specific growth rate of the African catfish in percentage. To assess the effectiveness of these treatments, the researchers measured the Specific Growth Rate (SGR) in each replication, which is calculated by tracking the change in fish weight over a specific period, normalized to the initial weight. The SGR is expressed as the percentage increase in body weight per day. The researchers measured the initial and final weights of the fish and the total feed consumption during the experiment, leading to the following results.

Table 5. Average Growth Performance of the African Catfish Supplemented with Fermented *Indigofera zollingeriana* Miq. based on Specific Growth Rate

Treatments	Growth Performance of the African Catfish						Mean	SD	Description
	Specific Growth Rate (%)								
	R1		R2		R3				
	Fish 1	Fish 2	Fish 1	Fish 2	Fish 1	Fish 2			
T1	3.65	6.05	2.9	4.95	6.05	4	4.6	1.3	High
T2	1.59	3.65	3.65	4.95	6.05	4.95	4.14	1.55	High
T3	4.95	3.65	3.65	1.59	4.95	2.05	3.47	1.41	High
T4	3.65	4.95	2.05	7.23	9.9	3.65	5.24	2.86	High
Control	4	4.95	4.95	4.95	2.05	9.28	5.03	2.37	High

The results of this study align with the findings of Ishiwu et al. (2020), which reported that Feed 3 had the highest specific growth rate (1.14), followed closely by the control feed (1.09). These results suggest that Feeds 3 and 4 exhibited growth performance comparable to the control group. Similarly, Fitria et al. (2023) reported the highest fish growth rate in the control group, followed by P2 (15% leaf meal), likely due to improved feed consumption, directly enhancing fish growth. These findings are consistent with the present study, where T4 (2.86 SD) closely aligns with the control group (2.37 SD), indicating similar trends in growth performance.

Moreover, a study by Putri et al. (2019) reported comparable results, where the control group had an SGR of 1.63%, while Treatment B (10% formulation) achieved an SGR of 1.73%. These results suggest that *I. zollingeriana* feed had a growth-promoting effect similar to commercial feeds. However, other studies have reported different trends in SGR. For instance, Ojewole et al. (2022) found that fish in T4 (75% composite meal) and T5 (100% composite meal) exhibited higher SGR values than the control group, which had an SGR of only 2.88%. This study suggests that the composite meal provided equal or superior nutritional benefits compared to a fish meal-based diet.

Unlike Ojewole et al. (2022), the present study found that commercial and *I. zollingeriana*-based feeds demonstrated similar effectiveness in supporting growth performance rather than exceeding the control diet. This study reinforces the potential of *I. zollingeriana* as a viable and sustainable alternative feed ingredient in aquaculture, offering comparable growth benefits without compromising feed efficiency.

Significant Difference in the Average Growth Performance of the African Catfish Supplemented with Fermented *Indigofera zollingeriana* Miq. based on Feed Conversion Ratio

Table 6 presents the results of the comparative analysis of the growth performance of African Catfish, analyzed based on the percentage of feed conversion. A normality test using the Kolmogorov-Smirnov test was conducted to assess the statistical validity of the study and check if the data followed a normal distribution. The test revealed a significant departure from normality ($W = 0.296$, $p = 0.000$), indicating that the data on growth performance did not meet the assumptions required for parametric analysis. Consequently, alternative statistical methods may be needed to analyze the data correctly. Moreover, the Independent-Samples Kruskal-Wallis Test was employed for the analysis. This non-parametric method effectively assesses the comparison between treatments without requiring normality, making it suitable for analyzing skewed data (McClenaghan, 2024).

It can be noted that the test statistic value for the overall growth performance is 2.620, with 4 degrees of freedom and a p-value of 0.623, which is greater than 0.05. This value means that the study failed to reject the null hypothesis, indicating no significant difference in the growth performance of the African catfish when observed using the feed conversion ratio. Further, this means that all samples in different experimental and control treatment groups are comparable.

Table 6. Significant Difference in the Average Growth Performance of the African Catfish Supplemented with Fermented *Indigofera zollingeriana* Miq. based on Feed Conversion Ratio

Variables Reviewed	Test Statistic	df	p-value	Decision	Interpretation
Average Growth Performance (Feed Conversion Ratio)	2.620	4	0.623	Fail to Reject H_{o1}	No Significant Difference

The findings of this study align with previous research but also present some contradictions. Bahar et al. (2023) reported that *Indigofera* supplementation did not significantly impact specific fish species' average daily gains or feed conversion rates. This report contradicts our results, as *I. zollingeriana* formulations performed comparably to commercial feeds. However, this aligns with Mugwanya et al. (2022), who found that replacing fishmeal with fermented plant proteins improved growth and feed efficiency. While no significant difference was observed in the feed conversion ratio, the treatment performs similarly to commercial feeds.

The present study demonstrates that *I. zollingeriana* inclusion did not negatively impact the feed conversion ratio, indicating that the African catfish efficiently utilized its nutrient composition. This finding is consistent with the results of Hussain (2024), who observed that plant-based protein sources, when properly processed, can maintain FCR values similar to fishmeal-based diets. In contrast, Duque-Estrada and Petersen (2023) reported that unprocessed plant proteins led to higher FCR due to reduced digestibility. This highlights the importance of fermentation in improving nutrient absorption. In the present study, a fermentation method was

utilized to enhance the bioavailability of *I. zollingeriana* leaves, leading to positive results in the FCR of the African catfish. Additionally, a study by Einstein-Curtis (2019) emphasized that the balanced amino acid profiles in plant-based diets contribute to better feed efficiency, which may explain the comparable FCR observed in this study. These findings suggest that *I. zollingeriana*, particularly in its processed form, can be a suitable alternative to conventional fish feeds without compromising feed efficiency.

Significant Difference in the Average Growth Performance of the African Catfish Supplemented with Fermented *Indigofera zollingeriana* Miq. based on Specific Growth Rate

Table 7 summarizes the comparative analysis of African Catfish growth performance based on feed conversion percentages. A Kolmogorov-Smirnov test assessed normality, revealing a significant departure from normality ($W = 0.209$, $p = 0.002$). This assessment indicates that the data did not meet the assumptions for parametric analysis. As a result, an Independent-Samples Kruskal-Wallis Test was used for the analysis. It can be noted that the test statistic value for the overall growth performance is 2.620, with 4 degrees of freedom and a p-value of 0.623, which is greater than 0.05. This value means that the study failed to reject the null hypothesis, indicating no significant difference in the growth performance of the African catfish when observed using the specific growth rate. Further, this means that all samples in different experimental and control treatment groups are comparable.

Table 7. Significant Difference in the Average Growth Performance of the African Catfish Supplemented with Fermented *Indigofera zollingeriana* Miq. based on Specific Growth Rate

Variables Reviewed	Test Statistic	df	p-value	Decision	Interpretation
Average Growth Performance (Specific Growth Rate)	2.620	4	0.623	Fail to Reject H_{02}	No Significant Difference

The result of this study agrees with the statement of Gustria et al. (2024), where *I. zollingeriana* improved the growth rate but showed no significant difference in weight gain or feed efficiency among various treatments for bonito fish. This statement aligns with our findings, which show that growth remained comparable across treatments. Similarly, Setiyowati et al. (2023) found that adding *Indigofera* leaf flour to striped catfish improved its weight gain and specific growth rate. This finding aligns with the result of the present study, where no significant differences were observed between the treatment groups and the commercial feed, suggesting that the nutrient composition of *I. zollingeriana* was sufficient to support growth performance comparable to that of a standard commercial diet.

The absence of significant differences in growth performance across treatments suggests that *I. zollingeriana* provided adequate nutrients to sustain fish growth. The comparable specific growth rate among treatments indicates that the fish efficiently utilized the protein and essential nutrients in *I. zollingeriana*, maintaining steady growth without negatively affecting their physiological processes. According to Kurniasih et al. (2024), plant-based feed ingredients such as *I. zollingeriana* can support optimal fish growth with a sufficient amino acid profile and digestibility. Additionally, the result of the present study contradicts the study of Chong (2022), which stated that excessive inclusion of plant-based proteins in aquafeeds led to reduced feed efficiency due to the presence of anti-nutritional factors. In contrast, the present study demonstrated that *I. zollingeriana* could sustain growth performance comparable to commercial feed, suggesting that its nutrient composition was sufficient for optimal utilization without adverse effects. Furthermore, Nadir et al. (2024) reported that while *Indigofera*-based diets can serve as an alternative protein source, their effectiveness depends on the processing method used to enhance digestibility.

SUMMARY

This study aimed to assess the efficacy of fermented *Indigofera zollingeriana* Miq. leaves as an alternative fish

feed supplement for enhancing the growth of African catfish (*Clarias gariepinus*), using four treatments of fermented *I. zollingeriana* leaves. This study utilized a true experimental research design, specifically a pretest-posttest control group design, to evaluate the effectiveness of fermented *I. zollingeriana* leaves as an alternative fish feed supplement and examined its impact on the growth performance of African catfish fingerlings. A total of 30 fingerlings were used in this study with four experimental groups and one control group, with each group having two fingerlings per replica, a total of 6 fingerlings per group. The study used statistical analysis using mean, Kolmogorov-Smirnov, and Kruskal-Wallis Test to compare growth parameters (FCR and SGR). Results showed that *I. zollingeriana* was sufficient to improve growth performance comparable to a standard commercial diet. These results suggest that further improvements in formulation percentages, feed composition, and fish culture methods are necessary to optimize growth performance. In conclusion, the study provides valuable insights for agriculture industry workers and fish farmers, particularly in developing sustainable and effective alternative fish feed formulations. These findings underscore the importance of enhancing feed quality and culture techniques to improve aquaculture productivity.

CONCLUSIONS

Based on the findings of the study, the following conclusions were drawn:

1. The average growth performance of African catfish based on the Feed Conversion Ratio (FCR) showed that treatments with fermented *I. zollingeriana* Miq. leaf meal resulted in moderate feed conversion efficiency, similar to the control group. Specifically, T1, T4, and the control group exhibited moderate FCR values, indicating similar feed efficiency. In contrast, T2 and T3 showed high FCR, suggesting poorer feed conversion and less efficient growth performance than the other treatments. Overall, the supplementation of *I. zollingeriana* leaf meal in the treatments did not significantly outperform or underperform the commercial feed regarding FCR, with moderate and high variations observed among the groups.
2. The average growth performance of African catfish based on Specific Growth Rate (SGR) showed that treatments with fermented *I. zollingeriana* Miq. leaf meal resulted in high growth rates comparable to the control group. Specifically, T1, T2, T3, and T4 all exhibited high SGR values, with no significant differences in growth performance compared to the control group. These findings suggest that the supplementation of *I. zollingeriana* leaf meal did not negatively impact the growth rate of African catfish and may be an effective alternative to commercial feed.
3. The Feed Conversion Ratio (FCR) statistical analysis showed no significant difference in fish growth performance between the various treatments of fermented *I. zollingeriana* leaf meal and the commercial feed. The non-parametric Kruskal-Wallis test indicated that all treatment groups performed similarly, suggesting that the different formulations of *I. zollingeriana* did not significantly vary in feed conversion efficiency compared to the control group.
4. The results indicated that the growth performance of African catfish, based on Specific Growth Rate (SGR), was compatible across treatments with fermented *I. zollingeriana* leaf meal and the control group. The T4 formulation showed growth performance comparable to that of the control group. Specific Growth Rate (SGR) values were generally high across all treatments, with slight variations, suggesting that the supplementation of *I. zollingeriana* leaf meal did not significantly affect the specific growth rate compared to the commercial feed.

RECOMMENDATIONS

As a result of our findings, the researchers recommend the following:

1. For the Department of Agriculture officials, it is recommended that further exploration of the procedures and feed ingredients utilized to enhance the efficiency and quality of fermented *I.*

zollingeriana fish feed supplement studies be conducted to improve advanced understanding and innovation within the aquaculture sector.

2. It is recommended that aquaculture industry workers collaborate with researchers to explore innovative applications of raw local materials, specifically *I. zollingeriana*, in fish feed formulations to enhance fish growth and aquaculture productivity.
3. For fish feed manufacturers, exploring the potential of *I. zollingeriana* as a sustainable alternative feed supplement is recommended, focusing on optimizing the fermentation process and identifying superior ingredients, which is imperative while reducing cost and improving feed sustainability.
4. Individual fish farmers should incorporate fermented *I. zollingeriana* leaves into fish feed as a sustainable and cost-effective alternative protein source while monitoring fish growth over a more extended period. Additionally, consistently monitoring the water quality and fish health should be implemented to ensure the supplemented feed is adequately consumed.
5. Future researchers should investigate various fermentation techniques of *I. zollingeriana* leaves as a fish feed supplement, assessing its long-term impact on fish health and exploring broader applications across different aquaculture species to maximize its benefits in aquaculture practices. Furthermore, it is recommended to house one fish per cage for optimal control over feed intake and to ensure each fish receives the precise feed ratio necessary for accurate performance measurements.
6. A feed pelletizer is recommended to enhance the feed efficiency of the formulated feeds. Pelletizing ensures uniform feed size and consistency, which improves digestibility and minimizes feed waste. This leads to better nutrient absorption in African catfish fingerlings.
7. It is recommended that the formulated feeds containing *I. zollingeriana* leaves be tested on other native, economically important fish species in order to evaluate its benefits across different fish populations. Through such testing, the effectiveness of the formulated feeds can be assessed in terms of growth, feed conversion, and sustainability, which could provide valuable insights into their broader applicability.
8. Based on the limitations of this study, it is suggested that an in-depth analysis of the nutritional composition of fermented *I. zollingeriana* leaves be conducted to better understand its suitability as an alternative fish feed supplement.
9. To address the wide variations in the data gathered, further studies with larger sample sizes and extended trial periods are recommended to enhance the reliability of the findings.
10. Further studies on the effects of the formulated feed beyond the Feed Conversion Ratio (FCR) and Specific Growth Rate (SGR) are recommended to gain a more comprehensive understanding of its impact on fish health.

REFERENCES

1. Abbaspour, N. (2024). Fermentation's pivotal role in shaping the future of plant-based foods: An integrative review of fermentation processes and their impact on sensory and health benefits. *Applied Food Research*, 4(2), 100468. <https://doi.org/10.1016/j.afres.2024.100468>
2. Adeleke, B., Robertson-Andersson, D., Moodley, G., & Taylor, S. (2020). Aquaculture in Africa: A comparative review of Egypt, Nigeria, and Uganda vis-à-vis South Africa. *Fisheries Science & Aquaculture*, 29(2), 167–197. <https://doi.org/10.1080/23308249.2020.1795615>
3. Adéyèmi, A. D., Kayodé, A. P. P., Chabi, I. B., Odouaro, O. B. O., Nout, M. J. R., & Linnemann, A. R. (2020). Screening local feed ingredients of Benin, West Africa, for fish feed formulation. *Aquaculture Reports*, 17. <https://doi.org/10.1016/j.aqrep.2020.100386>
4. Aqua Culture Asia Pacific. (2022). Asia's aquafeed players battle with rising costs. Issuu. <https://tinyurl.com/mrx8s7n9>
5. Bahar, S., Harahap, M. A., & Priyatno, T. P. (2023). Meta-analysis: The effect of feeding Indigofera leaves (*Indigofera zollingeriana*) on goat livestock performance. *IOP Conference Series: Earth and Environmental Science*, 1230(1), Article 012054. <https://doi.org/10.1088/1755-1315/1230/1/012054>
6. Balita, C. (2024). Volume of aquaculture production in the Philippines from 2013 to 2023. <https://tinyurl.com/munvdvwm>
7. Bureau of Fisheries and Aquatic Resources. (2020). Philippine fisheries profile 2020. Department of Agriculture. <https://tinyurl.com/yf44maav>

8. Biovet S. A. (2022). Aquaculture production in the Philippines. Veterinaria Digital. <https://tinyurl.com/2zwith2xt>
9. Chang, C.C., Kuo, H.S., & Cheng, W. (2023). Effectiveness of various cacao pod husk extraction byproducts in promoting growth and immunocompetence in *Litopenaeus vannamei*. Fish Shellfish Immunol. <https://doi.org/10.1016/j.fsi.2023.108632>
10. Chankakada, M., Sros, K., Ramana, O., Phearum, H., Laining, A., Rosni, Rimmer, M. A., Somony, T., & Viseth, H. (2020). Asian seabass farming practices in Cambodia. World Aquaculture, 30–33. <https://tinyurl.com/2zatf8ny>
11. Chong, R.S.M. (2022). Antinutritional factors in plant-based feeds. Aquaculture Pathophysiology, 659–668. <https://doi.org/10.1016/B978-0-12-812211-2.00055-X>
12. Chowdhury, A. J. K., John, A., Abdullah, R., Musa, N., & Ashraf, M. A. (2021). Impact of COVID-19 on aquaculture and fisheries in ASEAN countries: Some aspects of challenges, mitigations for future strategies in Malaysia. Desalination and Water Treatment, 241, 331–339. <https://doi.org/10.5004/dwt.2021.27792>
13. Ciliberti, R., Alfano, L., & Petralia, P. (2023). Ethics in aquaculture: Animal welfare and environmental sustainability. PubMed, 64(4), E443–E447. <https://doi.org/10.15167/2421-4248/jpmh2023.64.4.3136>
14. Colaiacomo, C. (2023). Honesty, objectivity, transparency, responsibility & accuracy: The 5 tenets of research integrity. LinkedIn. <https://tinyurl.com/2mbfv3yv>
15. Costello, D. (2023). Completely randomized design: The one-factor approach. <https://tinyurl.com/ys868e46>
16. Dauda, A. B., Salele, H. A., & Orimogunje, O. G. (2022). Influence of feeding frequency and feeding time on growth performance and feed utilization of African catfish (*Clarias gariepinus* Burchell 1822) fingerlings. Nigerian Journal of Animal Production, 49(1), 169–176. <https://doi.org/10.51791/njap.v49i1.3415>
17. DeCarlo, M., Cummings, C., & Agnelli, K. (2022). 13.2: True experimental design. In Graduate research methods in social work. Social Sci LibreTexts. <https://surl.li/xyyyqo>
18. Deque-Estrada, P., Petersen, I.L. (2023). The sustainability paradox of processing plant proteins. npj Science of Food, 7(38). <https://doi.org/10.1038/s41538-023-00214-1>
19. Einstein-Curtis, A. (2019, December 12). Trout maintain growth with amino-acid balanced diets, reduced proteins. Feed navigator. <https://tinyurl.com/4f23xbcw>
20. Fantatto, R. R., Mota, J., Ligeiro, C., Vieira, I., Guilgur, L. G., Santos, M., & Murta, D. (2024). Exploring sustainable alternatives in aquaculture feeding: The role of insects. Aquaculture Reports, 37, 102228. <https://doi.org/10.1016/j.aqrep.2024.102228>
21. Food and Agriculture Organization. (2020). Intensifying and expanding sustainable aquaculture production. Food and Agriculture Organization of the United Nations. <https://tinyurl.com/4vnvsnu2>
22. Fern, K. (2025). Indigofera zollingeriana. Tropical Plants Database. <https://tinyurl.com/4bjukafr>
23. Fitria, Y., Farkhan, M., Nurhudah, M., Ediwarman, E., & Ponigoro, N. (2023). Use of fermented Indigofera zollingeriana leaf flour from Aspergillus niger on growth performance of Jaya Sakti carp larvae. International Journal of Progressive Sciences and Technologies, 42(1), 341–357. <https://tinyurl.com/yn6jd2eb>
24. Fitria, Y., Farkhan, M., Nurhudah, M., & Panigoro, N. (2023). Digestibility of tarum leaf flour (Indigofera zollingeriana) fermented with Aspergillus niger as diet ingredients for Jaya Sakti carp larvae (Cyprinus carpio, L). International Journal of Multidisciplinary Research and Growth Evaluation, 4(1), 193–201. <https://ijpsat.org/index.php/ijpsat/article/view/5825/3686>
25. Fry, J. P., Mailloux, N. A., Love, D. C., Milli, M. C., & Cao, L. (2018). Feed conversion efficiency in aquaculture: do we measure it correctly? Environmental Research Letters, 13(2), 024017. <https://doi.org/10.1088/1748-9326/aaa273>
26. Gustria, V., Saputra, F., Ibrahim, Y., Rahmayanti, F., Martisa, I., Kisma, M., & Ariansyah, A. (2024). Growth and survival performance of bileh fish (Rasbora sp.) added tarum leaf flour (Indigofera zollingeriana). Arwana: Journal Ilmiah Program Studi Perairan. <https://tinyurl.com/yyt6w3pm>
27. Gonzalez, T. (2022). The welfare of captive fish. The IAABC Foundation Journal, 23(23). <https://doi.org/10.55736/iaabcfj23.8>

28. Gonzalez, R. (2023). Focus on diet to improve performance indicators in African catfish (*Clarias gariepinus*) fingerlings. Hatchery International. <https://tinyurl.com/yckprvr>
29. Haryati, T., Soewandi, B. P., Pratiwi, N., & Komarudin, K. (2021). The effect of *Indigofera zollingeriana* supplementation to performance of rabbit. IOP Conference Series Earth and Environmental Science, 888(1), 012073. <https://doi.org/10.1088/1755-1315/888/1/012073>
30. Hodar, A.R., Vasava, R.J., Mahavadiya, D.R., & Joshi, N.H. (2020). Fish meal and fish oil replacement for aqua feed formulation by using alternative sources: A review. Journal of Experimental Zoology India, 23(1), 13-21. <https://tinyurl.com/37vumera>
31. Howlader, S., Sumi, K.R., Sarkar, S., Billah, S.M., Ali, M.L., Howlader, J., & Shahjahan, M. (2023). Effects of dietary replacement of fish meal by soybean meal on growth, feed utilization, and health condition of stinging catfish, *Heteropneustes fossilis*. Saudi J biol Sci, 30(3). <https://doi.org/10.1016/j.sjbs.2023.103601>
32. Huda, N., Thaib, A., & Nur, N. (2022). Respons benih ikan nila (*Oreochromis niloticus*) terhadap pakan berbahan baku tepung daun *Indigofera zollingeriana* hasil fermentasi menggunakan bakteri *Bacillus* sp. dan *Lactobacillus* sp. Journal TILAPIA, 3(1), 54–62. <https://tinyurl.com/msn7ff7r>
33. Hussain, S.M., Bano, A.A., Ali, S., Rizwan, M., Andrees, M., Zahoor, A.F., Sarker, P.K., Hussain, M., Arsalan, M.Z.H., Yong, J.W.H., & Naeem, A. (2024). Substitution of fishmeal: Highlights of potential plant protein sources for aquaculture sustainability. PubMed Central, 10(4). <https://doi.org/10.1016/j.heliyon.2024.e26573>
34. Ishiwu, C. N., Opara, A. G., Obiegbuna, J. E., & Okeke, P. A. (2020). Assessment of growth performance of African catfish (*Clarias gariepinus*) fed with feed produced from blend of pigeon pea (*Cajanus cajan*) bambara groundnut (*Vigna subterranea*) and fish meal. Global Journal of Agricultural Sciences, 19(1), 17-26. <https://tinyurl.com/47pffyyv>
35. Jenkins, J. A. (2014). Guidelines for the use of fishes in research. American Fisheries Society. <https://l1nq.com/L39FK>
36. Johnston, D., Melville-Smith, R., & Hendriks, B. (2007). Aquaculture, 273(1), 108-117. <https://iopscience.iop.org/article/10.1088/1755-1315/718/1/012009/pdf>
37. Khadka, N. (2023). Kolmogorov-Smirnov test [KS test]: When and where to use. Data Aspirant. <https://tinyurl.com/467y89fw>
38. Kleiber, M. (1947). Body size and metabolic rate. Physiological Reviews, 27(4), 511–541. <https://doi.org/10.1152/physrev.1947.27.4.511>
39. Kröncke, N., Grebenteuch, S., Keil, C., Demtröder, S., Kroh, L., Thünemann, A. F., Benning, R., & Haase, H. (2019). Effect of different drying methods on nutrient quality of the yellow mealworm (*Tenebrio molitor* L.). Insects, 10(4), 84. <https://doi.org/10.3390/insects10040084>
40. Kurniasih, T., Waryat, Zulkarnain, R., Wijaya, R., Lesmana, D., Mumpuni, F.S., Ponigoro, N., Sustina, E., Heptarina, D., Fitria, Y., Ediwarman, E., Syofriani, Saptana, S., & Ermiati, I. (2024). Digestibility of plant-based feeds in omnivorous, carnivorous, and herbivorous fish: A review of Nile tilapia (*Oreochromis niloticus* (Linnaeus, 1758)), North African catfish (*Clarias gariepinus* (Burchell, 1822)), and grass carp (*Ctenopharyngodon idella* (Valenciennes, 1844)). AACL Bioflux, 17(6), 2995. <https://tinyurl.com/uwrx6jzd>
41. Leiva, B., & Schramski, J. R. (2022). On the rules of life and Kleiber's law: The macroscopic relationship between materials and energy. Heliyon, 8(6), e09647. <https://doi.org/10.1016/j.heliyon.2022.e09647>
42. Macusi, E. D., Cayacay, M. A., Borazon, E. Q., Sales, A. C., Habib, A., Fadli, N., & Santos, M. D. (2023). Protein fishmeal replacement in aquaculture: A systematic review and implications on growth and adoption viability. Sustainability, 15(16), 12500. <https://doi.org/10.3390/su151612500>
43. Magbanua, T. O., & Ragaza, J. A. (2022). Selected dietary plant-based proteins for growth and health response of Nile tilapia *Oreochromis niloticus*. Aquaculture and Fisheries, 9(1), 3–19. <https://doi.org/10.1016/j.aaf.2022.04.001>
44. McClenaghan, E. (2024). The Kruskal–Wallis test. Informatics From Technology Networks. <https://surl.li/gitnjv>
45. Melis, R., Braca, A., Mulas, G., Sanna, R., Spada, S., Serra, G., Fadda, M. L., Roggio, T., Uzzau, S., & Anedda, R. (2018). Effect of freezing and drying processes on the molecular traits of edible yellow

- mealworm. *Innovative Food Science & Emerging Technologies*, 48, 138–149. <https://doi.org/10.1016/j.ifset.2018.06.003>
46. Mugwanya, M., Dawood, M.A.O., Kimera, F., & Sewilam, H. (2022). Replacement of fish meal with fermented plant proteins in the aquafeed industry: A systematic review and meta-analysis. *Reviews in Aquaculture*, 15(1), 62–88. <https://doi.org/10.1111/raq.12701>
47. Nadir, M., Syahir, S., Munasirah, A.L., Warni, I., Sari, N., Satriani, A., Sulistiawati, M., & Anugrah, M. (2024). Exploration of nutritional value of indigofera shoot leaves based on different ages. *International Journal of Chemical and Biochemical Sciences*, 25(19), 773–778. <https://tinyurl.com/mrxk9t46>
48. Naorbe, M. (2021). Biological performance of African catfish *Clarias gariepinus* fingerlings fed with raw chicken entrails. *The Palawan Scientist*. <https://tinyurl.com/yc3e24be>
49. Obeda, R. L., Tumbokon, B. L. M., & Serrano Jr., A. E. (2023). Dietary benfotiamine in high carbohydrate diet improves growth and resistance to abrupt shift to higher salinity in the African catfish *Clarias gariepinus* juveniles. *AACL Bioflux*, 16(3). <https://tinyurl.com/bdhw5bc>
50. Ojewole, A. E., Faturoti, E. O., & Ihundu, C. (2022). Nutrient utilization and growth performance of African catfish (*Clarias gariepinus*) fed varying levels of Composite Meal (CM) in replacement of fishmeal. *International Journal of Aquaculture and Fishery Sciences*, 8(2), 54–58. <https://tinyurl.com/ym59u5zt>
51. Okomoda, V. T., Tihamiyu, L. O., & Wase, G. (2017). Effects of tank background color on growth performance and feed utilization of African catfish *Clarias gariepinus* (Burchell, 1822) fingerlings. *Croatian Journal of Fisheries*, 75(1), 5–11. <https://doi.org/10.1515/cjf-2017-0002>
52. Predescu, N. C., Stefan, G., Rosu, M. P., & Papuc, C. (2024). Fermented feed in broiler diets reduces the antinutritional factors, improves productive performances and modulates gut microbiome—A review. *Agriculture*, 14(10), 1752. <https://doi.org/10.3390/agriculture14101752>
53. Putri, R. F., Thaib, A., & Nurhayati, N. (2019). Kombinasi tepung ikan dan tepung daun *Indigofera* sebagai sumber protein benih ikan nila (*Oreochromis niloticus*) [Combination of fish meal and *Indigofera* leaf meal as a source of protein for tilapia (*Oreochromis niloticus*) seeds]. *Prosiding SEMDI-UNAYA (Seminar Nasional Multi Disiplin Ilmu UNAYA)*, 3(1), 36–46. <https://tinyurl.com/4uj884v2>
54. Raimi, C. O., & Fatuase, O. B. (2021). Performance of African catfish (*Clarias gariepinus*) juvenile fed *Morinda lucida* (Oruwo leaf). *Nigerian Journal of Animal Science*, 23(3), 78–89. <https://tinyurl.com/2wt2nyjm>
55. Russell, W. M. S., & Burch, R. L. (1960). The principles of humane experimental technique. *The Medical Journal of Australia*, 1(13), 500. <https://doi.org/10.5694/j.1326-5377.1960.tb73127.x>
56. Segaran, C. T., Azra, M. N., Piah, R. M., Lananan, F., Téllez-Isaías, G., Gao, H., Torsabo, D., Kari, Z. A., & Noordin, N. M. (2023). Catfishes: A global review of the literature. *Heliyon*, 9, e20081. <https://doi.org/10.1016/j.heliyon.2023.e20081>
57. Setiyowati, E.D., Hudaiah, S., Ediwarman, E., Panigoro, N., & Santoso, L. (2023). Substitution of soybean meal with (*Indigofera* sp.) in growing feed of striped catfish (*Pangasianodon hypophthalmus*). *Budidaya Perairan*, 10(1), 23. <https://tinyurl.com/3tj46hrt>
58. Shahin, S., Okomoda, V. T., Ma, H., & Abdullah, M. I. (2023). Sustainable alternative feed for aquaculture: State of the art and future perspective. *Planetary Sustainability*, 1(1), 62–96. <https://doi.org/10.46754/ps.2023.07.005>
59. Shi, L., Han, L., Yang, F., & Gao, L. (2019). The evolution of sustainable development theory: Types, goals, and research prospects. *Sustainability*, 11(24), 7158. <https://doi.org/10.3390/su11247158>
60. Southeast Asian Fisheries Development Center. (2025). Development of cost-efficient feeds. SEAFDEC/AQD - Southeast Asian Fisheries Development Center Aquaculture Department. <https://tinyurl.com/3rjvx89v>
61. Tarigan, A., Ginting, S. P., Abdullah, L., & others. (2018). Body weight gain, nutrients degradability and fermentation rumen characteristics of Boerka goat supplemented green concentrate pellets (GCP) based on *Indigofera zollingeriana*. *Pakistan Journal of Biological Sciences*, 21(2), 87–94. <https://tinyurl.com/2rnp2uy8>
62. Thomas, A. (2024). The Kruskal-Wallis test: A guide. Built In. <https://tinyurl.com/3zsubxex>

63. Thommen, A., Werner, S., Frank, O., Philipp, J., Knittelfelder, O., Quek, Y., Fahmy, K., Shevchenko, A., Friedrich, B. M., Jülicher, F., & Rink, J. C. (2019). Body size-dependent energy storage causes Kleiber's law scaling of the metabolic rate in planarians. *eLife*, 8. <https://doi.org/10.7554/elife.38187>
64. Trejo-Escamilla, I., Galaviz, M. A., Flores-Ibarra, M., González, C. a. Á., & López, L. M. (2016). Replacement of fishmeal by soya protein concentrate in the diets of *Totoaba macdonaldi* (Gilbert, 1890) juveniles: effect on the growth performance, in biodigestibility, digestive enzymes and the haematological and biochemistry parameters. *Aquaculture Research*, 48(8), 4038–4057. <https://doi.org/10.1111/are.13225>
65. Utomo, N. B. P., & Jusadi, D. (2018). Efektivitas penggunaan *Indigofera zollingeriana* sebagai sumber protein nabati dalam pakan terhadap kinerja pertumbuhan ikan nila (*Oreochromis niloticus*). [Effectiveness of using *Indigofera zollingeriana* as a source of vegetable protein in feed on the growth performance of tilapia (*Oreochromis niloticus*)]. Institut Pertanian Bogor. <https://tinyurl.com/xyn9brdd>
66. Wei, L. S., Kari, Z. A., Kabir, M. A., Khoo, M. I., Azra, M. N., & Wee, W. (2023). Promoting Growth and Health of African Catfish, *Clarias gariepinus*, Through Dietary Novel Supplement, Ginger, *Zingiber officinale* Rosc, Leaf Powder. *Aquaculture Studies*, 24(4). <https://doi.org/10.4194/aquast1719>
67. WorldFish. (2021). Aquaculture: Increasing income, diversifying diets, and empowering women in Bangladesh and Nigeria. WordFish. <https://tinyurl.com/4kjhycfp>
68. World Wildlife Fund. (2021). Expanding and Consolidating Madagascar's Marine Protected Areas Network. World Wildlife Fund. <https://tinyurl.com/yn3u9p89>
69. Yang, A. (2023). Benefits and risks of feed additives in animal nutrition. *Veterinary Science & Medical Diagnosis*, 12(2). <https://surl.li/urpndd>
70. Zlaugotne, B., Pubule, J., & Blumberga, D. (2022). Advantages and disadvantages of using more sustainable ingredients in fish feed. *Heliyon*, 8(9), 10527. <https://doi.org/10.1016/j.heliyon.2022.e10527>