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FACULTY OF AGRICULTURE AND ANIMAL SCIENCES

DEPARTMENT OF CROP SCIENCES

ARAPAI CAMPUS

ASSESSING GROWTH PERFORMANCE OF NILE TILAPIA (*Oreochromis niloticus*) RAISED WITH MAIZE BRAND MIXED WITH TERMITES *(Macroterms bellicosus*) IN POND CULTURE.

BY,

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STUDY REPORT SUBMITTED TOWARDS COMPLETION FOR THE CONDITIONS OF AWARD OF DEGREE IN AGRICULTURAL SCEIENCE OF BUSITEMA UNIVERSITY

SEPTEMBER 2026

DECLARATION

I, ONIRO BENARD, hereby declare that this dissertation entitled "Assessing Growth Performance of Nile Tilapia (*Oreochromis niloticus*) raised on Maize Bran mixed with Termites *(Macrotermes bellicosus*) in Pond Culture" is my original work and has not been submitted to any other institution of higher learning for the award of a degree or any other academic qualification.

All sources of information used in this dissertation have been duly acknowledged and referenced. Where the work of other researchers has been used, appropriate acknowledgement has been made in accordance with academic requirements.

Student's Name: ONIRO BENARD

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APPROVAL

This dissertation entitled "Assessing Growth Performance of Nile Tilapia (*Oreochromis Niloticus*) raised on Maize Bran mixed with Termites (*Macrotermes Bellicosus)* in Pond Culture" has been prepared and submitted for examination with the approval of the university supervisor.

Supervisor: MR. MUYINDA ROBERT

Signature: ____________

Date: 25-09-2026

DEDICATION

I cherished this dissertation to my beloved family for their un falling love, encouragement, prayers and support throughout my academic journey. Their patience, sacrifices and encouragement provided me with the strength and determination to complete this study.

I also dedicate this work to my lecturers, colleagues, friends and all those who contributed directly or indirectly to my academic development. Their guidance, encouragement and support were valuable throughout the course of my studies.

ACKNOWLEDGEMENT

I thank the Almighty God for granting me life, good health, wisdom, strength and perseverance throughout my studies and during the preparation of this dissertation. His grace enabled me to overcome the challenges faced during the research process and effectively complete this work.

I sincerely convey my appreciation to my supervisor, **Mr. Muyinda Robert**, for his professional guidance, constructive criticism, encouragement and valuable suggestions throughout the development and completion of this dissertation. His academic guidance significantly contributed to improving the quality of this work.

I further acknowledge my family members, friends and fellow students for their encouragement, cooperation and moral support throughout the study period. I am equally grateful to all individuals who contributed to the implementation of the experiment, data collection and completion of this dissertation. Their assistance and cooperation were highly appreciated.

Finally, I appreciate everyone who contributed in one way or another to the successful completion of this academic work. Although their individual contributions may not all be mentioned by name, their support was valuable and sincerely appreciated.

TABLE OF CONTENT

List of abbreviations

ANOVA... Analysis of Variance

BCR.. Benefit Cost Ratio

CP.. Crude Protein

DO ....Dissolved Oxygen

FAO.. Food and Agricultural Organization

FM ....Fish Meal

LSD.. Least Significance Difference

ROI.. Return On Investment

RCBD... Randomized Complete Block Design

SGR.. Specific Growth Rate

SE.. Standard Error

UGX.. Uganda Shillings

List of figures and tables

ABSTRACT

Nile tilapia (*Oreochromis niloticus*) is an important cultured fish species because of its fast growth, adaptability and contribution to food security and household income. However, the high cost of fish feed remains a major constraint to profitable aquaculture production. This study evaluated the effect of integrating termite meal (*Macrotermes bellicosus*) with maize bran on the growth performance, and economic performance of Nile tilapia. Three dietary treatments were evaluated: maize bran only, a mixture of maize bran + termite meal at a ratio of 1:1(5kg of maize bran+ 5kg of termite meal) and termite meal only. The feeding trial lasted 90 days. Growth performance was assessed using final body weight, weight gain and specific growth rate, while Economic performance was assessed using feed cost, revenue, net return and benefit-cost ratio. The results showed that the mixture of maize bran plus termite meal at a ratio of one to one (5kg of maize bran+5kg of termite meal diet yielded significantly superior growth performance, with the highest final body weight, weight gain and specific growth rate. Economically, the 100% maize bran diet had the lowest feed cost and the highest benefit-cost ratio, whereas the 5kg of maize bran + 5kg termite meal diet (a ratio of one-to-one nutritive dietary balance) generated the highest net return per fish. Overall, mixing *M. bellicosus* meal with maize bran improved growth and feed conversion compared with maize bran alone and termite alone and provided a favorable balance between biological performance and economic return. By providing an appropriate balance of nutrients and carbon, termites and maize bran enhance macro-microbial acceleration that provide natural food production to Nile tilapia, as such nutrient utilization by Nile tilapia is efficiently balanced resulted into increased body weight and reduced production cost. The maize bran + termite meal diet is therefore a promising alternative feeding option for Nile tilapia production under the conditions of the study.

Keywords: Nile tilapia, *Macrotermes bellicosus*, termite meal, maize bran, growth performance, Economic viability.

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CHAPTER ONE

1.0 INTRODUCTION

Fish production is estimated at 130.9million tones globally with Asian countries including Chiana, Indian, Japan, Bangladesh, Malaysia, south and north Korea being the leading producers(FAO, 2010). Africa contributes about 1.9% accounting for 2.5 million tones (S, Lord Bacground, 2024). Egypt, Nigeria and Uganda collectively account for approximately 90% dominated by Nile tilapia (*Oreochromis niloticus*) and African cat fish (Adeleke et al., 2020). In Uganda fish farming is estimated to contribute 3.950Kt of the aquatic animal production (Atukunda et al., 2021). It has evolved from a predominantly subsistence activity to commercial production contributing about 10% of the total world fish production. Uganda's aquaculture sector has experience substantial growth, making it one of the leading producers in sub- Sahara Africa with 23% annual increase in production Volume over the past decades(A. Ssekyanzi et al., 2025). Aquaculture is the farming of aquatic organisms such as fish, crustaceans, mollulscs, and plant under controlled or semi-controlled conditions (excluding ornamental fish) (House, 2026). Aquaculture can be done on natural water bodies such as in lakes, rivers and swamps as well as on land notably ponds and tanks (House, 2026).Aquaculture industry is one of the world's fastest food producing sector ,with development, expansion and interventions occurring practically every region.(Pérez & Rojas, 2020) Aquaculture is one of the world's fastest growing food producing sectors ,mainly driven by the need to meet rising demand for fish amidst declining fish stock and stagnant production from capture fisheries tremendously over the past two decade following the significant decline of the world fish catch (Elfitasari & Albert, 2017). Uganda has 24348 fish ponds and only 17108 are stocked with fish (House, 2026). Pond culture is practiced by all districts in Uganda due to water surface area of 20% of its total surface area and is a good potential for fish farming as all the waters can support fish growth and development. About 6500 fish ponds have been established all over the country with a potential of 1500 tons of Nile tilapia and 500 tons of African cat fish (A. Van Huis, 2013). However, the protein requirement for Nile tilapia is about 28-36% of crude protein which can be achieved by feeding fish on fish meal yet its current costs are high (A. Van Huis, 2013).

Termites are cheap and rich in crude protein of about 36.15% & lipid that can improve the quality of food and replacement of un affordable protein source like fish meal in rural community (Abro et al., 2022). Similarly, termites have a moisture content of approximately 8.34% which is appropriate to maintain a good shelf life because of reducing microbial proliferation, fiber content up to (0.20%-1.60%) good for peristalsis movement in the gut of fish, fat of (41.2-49.1%) good for structural and biological functions of the cell (Resources, 2018) making termites the promising feed supplement in the dietary requirement of fish (*Current Aquaculture Ingredients in African and Asia*, n.d.). On the hand, termites are known not to spread diseases but are notorious in eastern Uganda for aggressive foraging and heavy destruction of crops right at the roots like maize, seedling, timbers and are mount -builders in houses(*J Ethnobiology Ethnomedicine Article in Press Farmers ' Perception of Termite Infestation , Economic Importance , and Control Practices in IN IN*, 2026)Feed represents one of the highest operating costs in aquaculture system (Padhan, 2022). *Nile tilapia* (Oreochromis niloticus) is the commonly grown fish species in aquaculture due to preferences on wide variety of food, resistance to diseases and adoptable to environmental conditions. Furthermore, due of their prolific development and ease of care(Abaho et al., 2025). Nevertheless, small scale fish farmers are still one of the most vulnerable communities with low income and limitation in carrying out their fish farms business (Elfitasari & Albert, 2017). Nile tilapia growth performance is highly affected by managerial factors (Mengistu, 2020) such as stocking density, food quality and quantity, culturing system, feeding frequency, and rate, and water quality parameters such as water dissolved oxygen, salinity, water temperature, pH, and ammonia, nitrite (NO2), and nitrate (NO3) concentrations, which severely constrained by escalating costs of commercial feeds, and in response, small-holder farmers frequently turned to locally available agricultural products (Fisheriesaquaculture & Paper, n.d.) like maize bran which are inexpensive and abundant among farmers. However, products like maize brand alone are insufficient since it lacks the crude protein ingredient (Yamdeu, 2022) required for optimal growth of *Nile tilapia*, which require 28-36% of crude protein. In order to reduce the feed cost, farmers increasingly use insects as an alternative cheap source of protein to supplement the expensive and unfordable fish meal and soy protein sources in the feeding of fish in their ponds.

Integrating *Macroterms bellicosus* with maize brand could improve the nutritional quality of feed (Marela et al., 2023) while reducing dependance on commercially expensive fish pellet and, un sustainable protein ingredient. Although several studies have investigated the use of insect -based feeds in aquaculture, there is limited information on the growth performance of *Nile tilapia fed* diets formulated from maize brand integrated with *macroterms bellicosus* under local conditions. There for this study seeks to assess the growth performance of *Nile tilapia* fed on maize brand integrated with *macroterms bellicosus* in kalaki district kalaki sub-county eastern part of Uganda. The purpose of this research is to assess the growth performance of Nile tilapia, feed utilization of *Nile tilapia*, and economic viability of *tilapia* when fed a diet of maize brand integrated with termites (*Macrotermes bellicocus).* By doing so, the aims are to contribute to the development of affordable, locally sourced and sustainable feeding strategies that can enhanced fish production and improve profitability of small holder farmers and per capita household income in the district, and the potential of aquaculture to support sustainable development in rural communities especially in Teso sub-region.

1.1 STATEMENT OF PROBLEM

Fish farming in Sub-Saharan African remains a source of livelihoods for many households, but increased production is severely constrained by the high costs of feeds through the use of fish meal (FM) which is usually not easily available and when available is expensive (Wachira et al., 2021). Additionally, the high cost of fish feed was reported by aquaculture census 2025 in Uganda as the major constraint to aquaculture production with many small-scale farmers unable to afford quality feeds constantly, limited access to extension services, inadequate supply and limited availability to quality seed, predators especially among pond base fish farming(House, 2026). This research therefore aims at assessing the growth performance of Nile tilapia (*Oreochromis niloticus*) fed on maize brand integrated with termites (*Macrotermes bellicocus*) and to recommend measures that may increase productivity, assess the performance of aquaculture and its integration, identifying challenges and opportunities to inform policy and practice

1.2 JUSTIFICATION

In recent years, farmers are increasingly using insects as an alternative cheap source of protein to supplement the expensive and un fordable fish meal and soy meal in the diets of fish in Africa. Termites are rich in crude protein (8.34%), fiber content of up to (0.20%-1.60%), and fat content (41.2-49.1%) good for structural and biological functions of the cell (Resources, 2018),easily accessible by small holder fish farmers and have modest environmental impacts. Additionally, Farmers have good understanding of the abundance and distribution of termites in their areas (G. sileshi, p.Nyeko. p.o Nkunika et al, 2009). Thus, making them the promising supplement to fish meal based -fish diet. Feed represent one of the highest operating costs in aquaculture system (Fisheriesaquaculture & Paper, n.d.). Commercial floating pellets made from fishmeal (*silver* *fish/mukene*) and soya are prohibitively expensive for small rural farmers. The high feed prices of commercial feeds cause many small fish pond farmers to aboded or underutilized their ponds(*A Review of the Performance of Fish Seed Systems in Africa A Review of the Performance of Fish Seed Systems in Africa*, n.d.). However, by providing a low -cost on-farm formulated feeds using locally available ingredients may drastically lower production costs and improve margins for fish farmers, enhance livelihoods, provide food security and trade to the local communities. Additionally, this study also brings significant benefits like identifying areas for improvements, informing policy decisions and consequently lead to boosting local revenues in the local government of Kalaki District.1.2.0 General objective

To evaluate the effect of integrating termites (*Macroterms bellicosus)* into maize brand-based diet on the growth performance, and economic viability of *Nile tilapia* (*Oreochromis Niloticus*)

1.2.1 Specific objectives

1. To determine the growth performance of Nile tilapia fed on Termites *(Macroterms bellicosus)* integrated with maize brand.
2. To assess the economic viability of utilizing *Macroterms Bellicosus* integrated with maize brand as an alternative feed for Nile tilapia.

1.3 Hypothesis of the study

1. There is no different in the growth performance of Nile tilapia fed on termites (*macroterms bellicosus)* integrated with maize brand.
2. There is no economic advantage in using a termite and maize bran integrated diet compared to conventional diets

1.4 SIGNIFICANCE OF THE STUDY

This study contributes meaningfully to policy makers, academic knowledge, research and practical agricultural production and development. Academically, it creates a deep understanding of sustainable farm management by providing evidence on how to utilize different feed ingredients to enhanced the growth performance of Nile tilapia in pond aquaculture system in Teso region. In terms of research, the study helps fill the knowledge gaps and may encourage more study on natural feed supplements and climate -smart agriculture practices to boost aquaculture growth and development in the district. At the policy level, the findings help to support national priorities mentioned in Uganda's National Development plan III, sustainable industrialization for inclusive growth, environmental sustainability, food security, climate resilience and sustainable land use. Practically, the results provide important guidance to fish farmers and extension workers on the use of affordable and locally available feed ingredients such as maize bran, rice husks, sorghum flour and natural feeds like termites. These practices can help improve human health, increased fish production and household income. The study also provides the foundation for future innovations and informed decision -making in sustainable agriculture, soil, water, and environment.

1.5.0 SCOPE/FOCUS OF THE STUDY

1.5.1 Content scope

This study assessed the growth performance on Nile tilapia fed on maize bran integrated with termites (*Macroterms bellicosus)* in the earthen pond system of fish farming. It was conducted at kalaki sub-county kalaki district eastern Uganda which has higher potential for aquaculture development because of abundance natural water bodies like swamps, rivers and lake kyoga and abundance notorious *Macrotermes bellicosus* which is aggressive to crops right at the roots but natural food for fish and do not cause diseases in fish, higher production of maize among small holder farmers which fetch little price at the market. These variables are important for this study because the literature that has been surveyed pinpoints issues of prices about fish feeds, knowledge of feeds and fish production extension services as the major culprits for low production of fish in kalaki district eastern Uganda.

Geographical scope.

This study was conducted in Kalaki district. However, a sample experiment was established from the sub county of kalaki sub county at the farm of Mr. Ogira Charles a fish farmer in kakere parish Katanga village.

CHAPTER TWO

LITERATURE REVIEW

2.1 Aquaculture development and feed constraints

Aquaculture has developed into one of the key sectors in global fisheries contributing greatly to food security around the world. Amidists a growing population and increased need for protein sources (Wasik et al., 2025), nutrition, employment, and income generation. According to the Food and Agriculture Organization("State Food Secur. Nutr. World 2024," 2024), world aquaculture production exceeded 130 million tons in 2022, supplying more than half of all aquatic foods consumed by humans. Asia dominates global aquaculture production, while Africa contributes less than 3%, despite possessing abundant freshwater resources suitable for fish production. Uganda is among Africa's leading aquaculture-producing countries, mainly culturing *Nile tilapia* (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). The sub-sector has 9463 farms producing 65.444 metric tons of fish with Nile tilapia accounting for more than 82% of the output (House, 2026). Aquaculture development in Uganda has expanded rapidly due to increasing fish demand, declining capture fisheries, and government support programs (Mwanja et al., 2007). Nevertheless, productivity remains below potential because of several constraints, including inadequate quality fingerlings, poor management practices, limited technical knowledge, and especially the high cost of commercial feeds (G. Ssekyanzi et al., 2025).

Feed quality greatly determines fish growth, survival, feed conversion efficiency, and profitability(Wang, 2024). Fish require balanced diets containing proteins, carbohydrates, lipids, vitamins, and minerals(Novriadi et al., n.d.). Protein is the most expensive dietary component and accounts for the largest proportion of feed cost. Nile tilapia juveniles generally require dietary crude protein levels between 26% -30% for optimum growth(Novriadi et al., n.d.). Farmers often rely on maize bran because it is affordable and locally available; however, maize bran alone cannot meet the protein requirements necessary for rapid fish growth(Omoike, 2012).

Consequently, researchers have increasingly investigated insect meals as sustainable protein alternatives capable of partially or completely replacing conventional fish meal(Astika et al., 2023).

2.2 Nutritional value of maize bran

Maize (*Zea mays*) is one of the world's most important cereal crops and is widely cultivated throughout Uganda. During maize milling, bran is produced as a by-product and is commonly used in livestock and fish feeding because of its low cost and wide availability(Rose et al., 2010).

Maize bran contains carbohydrates that provide dietary energy essential for fish metabolism and growth. It also contains moderate levels of fiber, vitamins, minerals and small amounts of protein. However, its crude protein content usually ranges between 9% and 14%, which is considerably lower than the protein requirement of growing Nile tilapia (Saeed et al., 2021)

Although maize bran serves as an excellent energy ingredient, excessive inclusion without adequate protein supplementation may reduce growth performance because fish must utilize dietary protein for muscle development rather than energy production. Furthermore, maize bran has deficiencies in essential amino acids such as lysine and methionine(Omoike, 2012), both of which are important for tissue growth and efficient feed utilization.

Several researchers therefore recommend combining maize bran with high-protein ingredients to produce nutritionally balanced diets(Omoike, 2012). Integrating maize bran with termite meal may improve dietary protein concentration while maintaining relatively low feed costs(Submitted et al., 2020).

2.3 Potential of *Macrotermes bellicosus* as an alternative protein source

The search for alternative protein ingredients has stimulated considerable interest in edible insects(Ashim et al., 2025). Among these, termites (*Macrotermes bellicosus*) have attracted attention because they occur naturally in many African countries and are readily collected by rural communities. Studies indicate that termite meal contains between 35% and 49% crude protein, approximately 30–45% lipid, essential amino acids, vitamins, and minerals necessary for fish growth(Susan et al., 2023). The high lipid content provides additional dietary energy while reducing protein catabolism during fish growth. Compared with conventional fish meal, termites offer several advantages including, low production cost, local availability, minimal environmental impact, high palatability to fish, renewable biological resource and reduced dependence on imported feed ingredients(Nutritional Evaluation of Termite (Macrotermes Subhyalinus) Meal as Animal Protein Supplements in the Diets of Heterobranchus Longifilis (Valenciennes, 1840)

Fingerlings, n.d.) reported that insects represent sustainable protein sources capable of supporting future livestock and aquaculture production while reducing pressure on capture fisheries. Similarly, (Lisboa et al., 2024) concluded that insect protein has substantial potential to replace fish meal in aquaculture feeds provided processing techniques and quality standards are maintained. Despite these advantages, termites are still underutilized in Ugandan aquaculture(Kagezi et al., 2023), and little information exists regarding their incorporation into maize bran-based diets under pond production systems.

2.4.0 Growth performance of Nile tilapia fed on termite-maize bran diets

2.4.1 Growth performance of Nile tilapia

Growth performance is one of the most important indicators used to evaluate feed quality in aquaculture(Chen & Mai, 2026). Common growth parameters include; final body weight, weight gain, average daily gain, specific Growth Rate (SGR), survival rate and condition factor. According to (El-Sayed, 2021)**,** growth performance depends primarily on dietary nutrient balance, feeding rate, water quality, stocking density, and fish genetics. Several studies have demonstrated that insect-based diets can support satisfactory growth in Nile tilapia. Diets containing insect meals generally produce growth rates comparable to conventional fish meal when dietary protein requirements are met(Skrzypczak et al., 2026). The presence of highly digestible protein and essential amino acids enhances muscle deposition and feed intake. However, studies specifically evaluating termite meal combined with maize bran remain extremely limited. Most published work has focused on black soldier fly larvae, mealworms, and cricket meals rather than termites. Consequently, information regarding the growth response of Nile tilapia fed termite-maize bran diets under Ugandan pond conditions is insufficient. This knowledge gap justifies the current study.

2.4.2 Weight gain

Weight gain measures the increase in fish body weight over the experimental period and is calculated as, Weight Gain = Final Weight − Initial Weight. Higher weight gain indicates better nutrient utilization and superior feed quality. Previous studies have reported that insect protein improves weight gain by supplying essential amino acids (Hammed et al., 2023)lacking in cereal-based diets. Since maize bran is relatively low in protein, supplementation with termite meal is expected to improve fish growth through increased protein intake and enhanced tissue synthesis. Nevertheless, no published study has evaluated weight gain of Nile tilapia fed different inclusion levels of *Macrotermes bellicosus* integrated with maize bran under pond conditions in Eastern Uganda.

2.4.3 Specific growth rate (SGR)

Specific Growth Rate (SGR) measures the percentage increase in body weight per day and provides a standardized method of comparing fish growth between treatments. SGR is calculated using: SGR (%) = [(ln Final Weight − ln Initial Weight)/Number of Days] ×100 Studies indicate that fish receiving balanced diets with adequate protein generally record significantly higher SGR than fish fed protein-deficient diets. If termite meal successfully improves dietary protein concentration in maize bran diets, higher SGR values are expected relative to fish fed maize bran alone.(Poku, 2014).

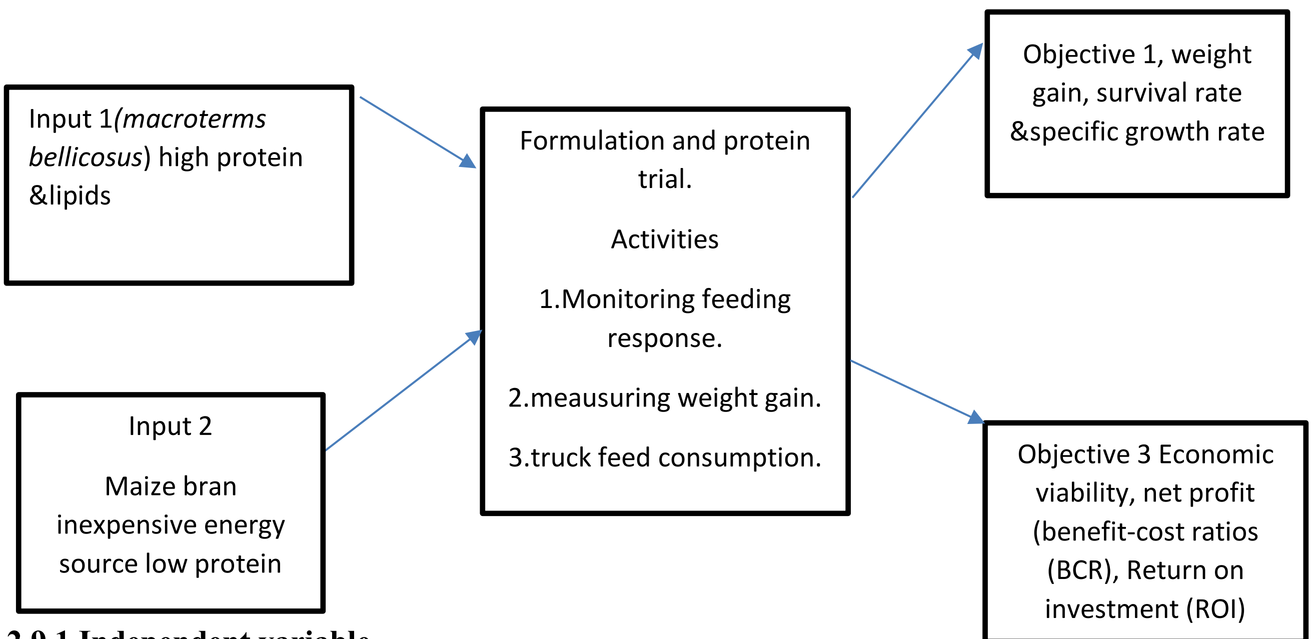
2.5 Feed utilization efficiency of termite-based diets

Feed utilization efficiency describes how effectively fish convert feed nutrients into body mass. Efficient feed utilization reduces production costs and increases farm profitability. The major indicators include: Termite meal contains digestible protein, beneficial lipids, vitamins, and minerals that may improve nutrient digestibility and metabolism. Previous studies involving insect meals have generally reported improved feed utilization when insect proteins replace part of fish meal in poultry production(Susan et al., 2023). However, the digestibility of termite meal depends on processing methods, termite caste, and inclusion level. Excessive inclusion may reduce nutrient digestibility because of chitin present in insect exoskeletons (Dametti et al., 2026).

2.6 Economic viability of termite-maize bran diets

Economic viability is essential for adoption of alternative feeds by smallholder farmers. Even when biological performance is satisfactory, farmers are unlikely to adopt technologies that increase production costs (Aldeb, 2024). Feed contributes between 60% and 80% of total production costs in intensive aquaculture (Hasan, 2007). Therefore, replacing expensive ingredients with locally available alternatives may substantially improve profitability. Termites occur naturally in many farming communities and require minimal financial investment for collection. Maize bran is inexpensive and readily available from local milling industries. Their integration may therefore reduce feed costs while maintaining acceptable fish growth. Economic indicators commonly evaluated include: Feed cost per kilogram, Cost of producing one kilogram of fish, Gross margin, Net profit, Benefit-Cost Ratio (BCR) and Return on Investment (ROI). Few studies have evaluated the economics of termite-based diets in pond aquaculture. Most research has emphasized nutritional composition rather than profitability. Consequently, there is inadequate information regarding the economic benefits of integrating *Macrotermes bellicosus* with maize bran under smallholder pond farming systems in Uganda.

2.7.0 Conceptual framework



2.9.1 Independent variable

Levels of termite meal (*Macrotermes bellicosus*) integrated with maize bran

T1 = 100% maize bran, T2 = 50% maize bran + 50% termite meal and T3 = 100% termite meal

2.9.2 Intervening variables

Water quality (temperature, pH, dissolved oxygen, ammonia), Stocking density, Pond management, and Feeding frequency Fish health

2.9.3 Dependent variables

Weight gain, Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Survival rate, Feed cost, Profitability, and Benefit-Cost Ratio.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was conducted in Kalaki District, eastern Uganda, with the experimental feeding trial established in Kalaki Sub-county, Kakere Parish, Katanga Village, at the fish farm of Mr. Ogira Charles**,** a local fish farmer. The site was selected because it provided established pond facilities suitable for conducting a controlled Nile tilapia feeding experiment.

The experimental work was conducted under pond conditions using Nile tilapia (*Oreochromis niloticus*) as the test fish. The feeding trial lasted approximately three months, from **June to Sept 2026**.

3.2 Research Design

The study employed a quantitative experimental approach using a randomized complete block design (RCBD)**.** The dietary treatments consisted of maize bran, termite meal from *Macrotermes bellicosus*, and a combination of maize bran and termite meal. The treatments were randomly allocated to the experimental ponds to minimize systematic allocation bias and provide a basis for comparison of fish performance under the different diets.

Three experimental diets were evaluated as shown in Table 3.1.

Table 1: shows description of experimental dietary treatments

Treatment	**Diet composition**
100% maize bran	100% maize bran and 0% termite meal
50% maize bran + 50% termite meal	50% maize bran and 50% termite meal
100% termite meal	0% maize bran and 100% termite meal

Each experimental diet was prepared in a total quantity of **50 kg**.

3.3 Experimental Materials

The main materials used in the experiment were juvenile Nile tilapia, maize bran, *Macrotermes bellicosus* termites, weighing equipment, feed containers, milling equipment, sampling containers and pond management equipment. Water quality measurements were carried out using appropriate instruments for temperature, dissolved oxygen and pH, while ammonia was determined using a suitable ammonia test procedure.

3.4 Collection and Preparation of Termites

3.4.1 Collection of *Macrotermes bellicosus*

M. bellicosus termites were collected directly from termite mounds within the study area. A lateral opening was made on the termite mound using a hoe to expose the termite galleries. A bundle of dry tree branches or brush material was inserted into the opening to attract and collect the termites. The material containing the termites was subsequently removed and shaken over clean containers to separate the termites from the collection material.

The collected termites were placed in clean containers and transported to the experimental preparation area for processing.

3.4.2 Processing of termite meal

The collected termites were first cleaned to remove soil and other foreign materials. They were then boiled in water at approximately **100°C** to reduce microbial contamination and prepare them for drying. After boiling, the termites were dried under sunlight until sufficiently dry for processing. The dried termites were milled into a fine meal using a feed mill or suitable milling equipment. The resulting termite meal was stored in clean, dry and labelled containers until formulation of the experimental diets.

3.5 Procurement and Preparation of Maize Bran

Maize bran was obtained from local maize millers within the study area. The bran was inspected to remove visible foreign materials and stored in clean, dry containers to prevent contamination and moisture absorption before use in diet preparation.

3.6 Formulation and Preparation of Experimental Diets

The three diets were formulated on a weight basis according to the treatment proportions. For the 100% maize-bran diet, the required quantity of maize bran was used without termite meal. For the 50% maize bran + 50% termite meal diet, equal quantities of maize bran and termite meal were thoroughly mixed. For the 100% termite-meal diet, termite meal constituted the entire diet.

Each diet was thoroughly mixed to obtain a uniform feed mixture and prepared to a total quantity of 50 kg. The prepared feeds were placed in separately labelled airtight containers and stored in a dry place throughout the experimental period.

3.7 Experimental Fish

Healthy juvenile Nile tilapia (*Oreochromis niloticus*) with an initial average body weight of approximately **3 g** were used in the feeding trial. Fish were obtained from a reliable source and carefully transported to the experimental site.

Before stocking, the fish were acclimatized to the pond environment and handling conditions. Fish showing signs of poor health or physical injury were excluded from stocking. The fish were randomly allocated to the experimental ponds at a stocking rate of 20 fish per pond.

3.8 Experimental Pond Preparation and Allocation

The experimental ponds were cleaned and prepared before stocking. The ponds were checked for water retention, unwanted organisms and general suitability for fish culture. Water was maintained at a suitable level for Nile tilapia throughout the experimental period.

The experimental units were the fish ponds, with dietary treatments randomly assigned to the ponds. Each treatment was represented by replicate ponds. Random allocation was used to minimize positional and management effects among ponds.

Table 2: shows Randomized arrangement of dietary treatments in experimental ponds

Replication	**Pond 1**	**Pond 2**	**Pond 3**
Replicate 1	100% maize bran	maize bran + termite meal at 1:1 ratio	100% termite meal
Replicate 2	100% termite meal	100% maize bran	maize bran + termite meal at 1:1 ratio
Replicate 3	maize bran + termite meal at 1:1 ratio	100% termite meal	100% maize bran

3.9 Feeding Management

The fish were fed twice daily, in the morning and evening. Feeding was based on the biomass of fish in each experimental pond, with the daily feeding rate maintained within the range of 2–4% of body weight**.**

Fish were weighed at scheduled sampling intervals and the quantity of feed supplied was adjusted according to the estimated biomass. The feed assigned to each pond was measured before feeding, and feed remaining after the feeding period was monitored where applicable to estimate actual feed consumption.

The same feeding management procedures were applied to all dietary treatments throughout the experimental period.

3.10 Data Collection

Data were collected throughout the feeding trial using direct measurements of fish growth, feed utilization and economic performance. The main growth and feed utilization parameters were weight gain, specific growth rate, feed intake and feed conversion ratio.

3.10.1 Final body weight

At the end of the experimental period, fish from each experimental pond were harvested and weighed individually using a sensitive weighing balance. The mean final body weight for each experimental unit was calculated from the recorded fish weights.

3.10.2 Weight gain

Weight gain was determined as the difference between final and initial mean body weight:

Weight gain (WG)

$$WG = W_f - W_i$$

Where:

WG = weight gain (g)
W_f = final mean body weight (g)
W_i = initial mean body weight (g)

3.10.3 Specific growth rate

Specific growth rate was calculated using the logarithmic change in body weight over the experimental period:

Specific growth rate (SGR)

SGR (%/day) = [(ln Wf - ln Wi) / t] × 100

Where:

SGR = specific growth rate (%/day)
Wf = final mean body weight (g)
Wi = initial mean body weight (g)
t = duration of the feeding trial (days)

3.10.4 Feed intake

Feed intake was determined from the quantity of feed provided to the fish during the experimental period. Feed supplied to each experimental unit was recorded, and the amount consumed was used to determine mean feed intake per fish.

3.10.5 Feed conversion ratio

Feed conversion ratio was calculated as:

FCR = Feed consumed (g) / Weight gain (g)

Where:

FCR = feed conversion ratio
Feed consumed = total feed consumed during the experimental period (g)
Weight gain = increase in fish body weight (g)

3.11 Water Quality Monitoring

Water quality was monitored throughout the experimental period because environmental conditions can affect feeding behavior and growth of Nile tilapia. The main water quality variables monitored were temperature, dissolved oxygen, pH and ammonia.

Water temperature was measured using a thermometer, dissolved oxygen was measured using a dissolved oxygen meter, and pH was measured using a pH meter. Ammonia concentration was determined using an appropriate ammonia test procedure. Measurements were taken at regular intervals during the experimental period, and observations were used to ensure that pond conditions remained suitable for the fish.

3.12 Economic Analysis

The economic performance of the experimental diets was assessed from the cost of preparing each diet and the returns obtained from fish fed on the respective treatments.

The cost of feed per kilogram was determined from the quantities and prices of the ingredients used in preparing each experimental diet. Feed cost per fish was calculated from the quantity of feed consumed and the corresponding diet cost.

Revenue per fish was calculated from the final weight of fish and the prevailing selling price of fish. Net return was determined as:

Net return

Net return = Revenue - Feed cost

Where:

Revenue = income obtained from fish sold (UGX)
Feed cost = total cost of feed used (UGX)

For benefit-cost ratio:

Benefit-cost ratio (BCR)

BCR = Revenue / Feed cost

Where:

Revenue = income obtained from fish sold (UGX)
Feed cost = total feed expenditure (UGX)

The economic analysis was conducted separately for each dietary treatment to compare the relative cost and return associated with the three feeding regimes.

3.13 Data Management and Statistical Analysis

Data collected during the experiment were checked for completeness, coded and entered into a spreadsheet before statistical analysis. Quantitative data on growth performance and feed utilization were analyzed using one-way analysis of variance (ANOVA) in R statistical software, version 4.6.1**.**

Where the ANOVA indicated significant differences among dietary treatments, treatment means were separated using Fisher's Least Significant Difference (LSD) test) at the 5% significance level. Statistical significance was declared at $p < 0.05$.

Results were summarized using treatment means and standard errors, and differences among treatment means were presented using superscript letters in the results tables.

Economic variables calculated at the treatment level were summarized descriptively because the economic calculations were made once for each dietary treatment rather than independently for each experimental replicate.

3.14 Ethical and Experimental Considerations

The fish were handled carefully during stocking, weighing, sampling and harvesting to minimize unnecessary stress and injury. Appropriate pond management practices were maintained throughout the experiment, and dead fish were removed promptly and recorded. The experimental procedures were conducted under the supervision of the responsible researcher and farm personnel at the study site.

CHAPTER FOUR

4.1 Growth Performance of Nile Tilapia

Growth performance of Nile tilapia fed on the experimental diets was evaluated using weight gain and specific growth rate (SGR). The results are presented in Table 4.1.

Table 3: shows growth performance of Nile tilapia under the different dietary treatments

Treatment	**Weight gain (g)per fish**	**SGR (%/day)**
100% maize bran	82.85 ± 2.49^{c}	3.71 ± 0.030^{c}
50% maize bran + 50% termite meal	111.55 ± 3.35^{a}	4.06 ± 0.033^{a}
100% termite meal	94.65 ± 2.84^{b}	3.84 ± 0.031^{b}
LSD (0.05)	10	0.11
F-value	24.92	31.00
p-value	<0.001	0.029
CV (%)	5.19	1.42

Values are presented as means ± standard error (SE). Within each column, means followed by different superscript letters are significantly different at $p < 0.05$ *according to Fisher's Least Significant Difference (LSD) test.*

Weight gain was highest among fish fed 50% maize bran + 50% termite meal, followed by those fed 100% termite meal, while fish fed 100% maize bran recorded the lowest weight gain. The differences among the dietary treatments were statistically significant ($p < 0.001$), with each treatment differing significantly from the others.

Specific growth rate was highest in fish fed 50% maize bran + 50% termite meal, followed by 100% termite meal, while 100% maize bran recorded the lowest SGR. The differences among treatments were statistically significant ($p = 0.029$), with all three treatment means differing significantly.

4.2 Economic Performance of the Experimental Diets

The economic performance of the three experimental diets was evaluated using feed cost per kilogram, feed cost per fish, revenue per fish, net return per fish and benefit-cost ratio.

Table 4: Shows cost and economic returns of the different experimental diets

Treatment	**Feed cost (UGX/kg)**	**Feed cost per fish (UGX)**	**Revenue per fish (UGX)**	**Net return per fish (UGX)**	**Benefit-Cost Ratio**
100% maize bran	1,200	188	1,718	1,530	8.14
50% maize bran + 50% termite meal	2,100	375	2,292	1,917	5.11
100% termite meal	3,000	495	1,954	1,459	2.95

Feed cost per kilogram was lowest for 100% maize bran, followed by 50% maize bran + 50% termite meal, while 100% termite meal recorded the highest feed cost.

Feed cost per fish was lowest for 100% maize bran, followed by 50% maize bran + 50% termite meal, while 100% termite meal recorded the highest feed cost per fish.

Revenue per fish was highest in fish fed 50% maize bran + 50% termite meal, followed by those fed 100% termite meal, while 100% maize bran recorded the lowest revenue per fish.

Net return per fish was highest under the 50% maize bran + 50% termite meal diet, followed by 100% maize bran, while the 100% termite meal diet recorded the lowest net return per fish.

The benefit-cost ratio was highest for 100% maize bran, followed by 50% maize bran + 50% termite meal, while 100% termite meal recorded the lowest benefit-cost ratio.

The optimum profitability vs yield: Even though the 100% maize brand diet yielded the highest cost benefit ratio (8.14) due to its lower price per unit kg of feeds, relying solely on maize bran may limit peak growth performance of Nile tilapia due to lower crude protein availability. The 50% maize brand +50% termites meal combination produce the highest absolute profit (Net return of 1917 ugx per fish). This demonstrates clear synergistic effect where the high crude protein present in termite meal improves on the biomass gain of Nile tilapia sufficiently to offset the increased feed formulation cost

CHAPTER FIVE

DISCUSSION

5.1 Growth Performance of Nile Tilapia Fed on Termite Meal Integrated with Maize Bran

The higher growth response observed with the combined maize bran and termite meal diet suggests that the integration of the two feed ingredients provided a more favorable nutrient supply than either ingredient used alone. The trend, in which the combined diet performed better than the sole maize-bran and sole termite-meal diets, is consistent with the general principle that growth of Nile tilapia depends not simply on crude protein concentration but on the balance between digestible protein, energy and essential amino acids available to the fish. (Konnert et al., 2022) demonstrated that the protein-to-energy relationship of Nile tilapia diets has a curvilinear influence on growth and feed efficiency, with both inadequate and excessive dietary protein relative to energy reducing nutrient utilization. (Mengistu, 2020) similarly identified dietary crude protein as an important determinant of growth and feed conversion in Nile tilapia. The improved response under the mixed diet may also be related to the complementary nutritional characteristics of the two ingredients. *Macrotermes bellicosus* is nutritionally substantial and has been reported in Uganda as containing appreciable protein, fat and energy, although its composition varies according to developmental stage and preparation. (Resources, 2018) reported substantial protein and fat concentrations in *M. bellicosus*, together with appreciable mineral content and digestible energy. More broadly, reviews of African edible insects show that termites provide protein, lipids and minerals that can contribute to livestock and aquaculture diets. The response in the present study is also in agreement with evidence from other insect-based diets, although the magnitude and direction of the response vary with insect species and inclusion level. (Kazemi & Valizadeh, 2025), found that insect meals can influence specific growth rate and feed conversion in aquaculture species, while the response depends strongly on the insect type and dietary inclusion level. Similarly, a broader meta-analysis reported that fish generally tolerate moderate insect-meal inclusion while high inclusion levels produce more variable responses depending on insect species and diet formulation.

The superiority of the intermediate inclusion level in the present study is particularly relevant because complete replacement with an insect ingredient does not necessarily produce the best growth. This pattern has been observed in several insect-meal studies. (Abozaid et al., 2025), for example, found that increasing inclusion of *Spodoptera littoralis* meal progressively reduced growth and feed intake at higher inclusion levels in Nile tilapia. In contrast, partial substitution with black soldier fly larvae has produced favorable growth responses without compromising performance in other tilapia studies. Differences between the present findings and some studies reporting little or no growth advantage from insect meals may arise from differences in insect species, processing method, nutrient composition, fish size, feeding period and basal diet. (Maulu et al., 2022) noted that although insects have substantial potential as aquafeed ingredients, their nutritional value and effects on fish performance differ among insect species and inclusion levels. The relatively limited literature specifically evaluating *Macrotermes bellicosus* in fish diets therefore makes the present findings useful in extending evidence on termite-based aquafeeds.

5.2 Economic Viability of Using *Macrotermes bellicosus* Integrated with Maize Bran

The economic pattern shows an important distinction between absolute profitability and returns relative to feed expenditure**.** The maize-bran diet had the lowest feeding cost and the highest benefit-cost ratio, whereas the combined diet generated the highest revenue and net return per fish. This indicates that a diet with the lowest unit feed cost does not necessarily produce the highest absolute financial return. Economic evaluation of alternative aquafeeds therefore needs to consider feed expenditure together with the biological output achieved. The higher cost of termite-containing diets is consistent with the wider literature on insect-feed production. (New & Food, n.d.) reported that the economics of insect-based feed production are strongly affected by labor and substrate costs and that insect feeds do not automatically have an economic advantage over inexpensive plant-based feeds. More recent work has also emphasized that insect-meal production remains constrained by scaling, processing costs and consistency of production, particularly where insect production has not yet reached industrial scale. This cost consideration is particularly relevant to the present study because *M. bellicosus* was used as a relatively high-cost ingredient compared with maize bran. The economic response therefore depended not only on the price of the ingredient but also on the production obtained from the diet. The combined diet occupied an intermediate position in feed cost while producing the strongest revenue and net-return response, illustrating the importance of evaluating alternative feed ingredients at the whole-diet and production level**,** rather than judging them solely by the price per kilogram of ingredient. The relatively favorable economic performance of the combined diet is broadly consistent with studies of insect-based aquafeeds in East Africa. (Maina et al., 2025) reported that black soldier fly larvae could substitute conventional protein sources in Nile tilapia diets while maintaining economic returns, although the exact cost-benefit response varied among dietary treatments. Similarly, a 2024 study found that partial replacement of fishmeal with black soldier fly larvae improved profit margins without compromising tilapia growth, demonstrating that the economic effect of insect inclusion depends on the relationship between feed cost and fish performance. Evidence from Uganda also supports the broader economic relevance of insect-based feed systems. (Abro et al., 2022) estimated substantial potential economic benefits from the development of insect-based animal-feed value chains in Uganda, although their analysis focused principally on black soldier fly rather than termites. The study highlighted the high cost of conventional protein ingredients and the potential for locally produced insect feed to contribute to the economics of livestock and fish production. The lower benefit-cost ratio of the termite-only diet compared with the other treatments is understandable in the context of insect-feed economics because increasing reliance on a relatively expensive insect ingredient raises feed expenditure. Reviews of insect aquafeeds have repeatedly identified production cost and availability as important constraints to widespread adoption. (Ahmad et al., 2025)specifically identified cost and scaling-up of insect production among the major challenges limiting the broader use of insect meals in aquaculture. Nevertheless, the economic findings should not be interpreted as showing that termite meal itself is uneconomical. Rather, they show that the economic outcome depends on the inclusion level and the resulting biological response**.** In this study, integrating termite meal with maize bran provided a more favorable economic balance than using termite meal as the sole dietary ingredient. This agrees with the broader feed-formulation principle that partial replacement of conventional ingredients can capture nutritional benefits while limiting the cost penalty associated with alternative ingredients. Studies of insect meals in aquafeeds similarly report that intermediate inclusion levels can perform better than complete replacement, although the optimum differs among species and formulations.

Overall, the findings support the use of *Macrotermes bellicosus* as a complementary rather than necessarily exclusive feed ingredient for Nile tilapia under the conditions of this study. The most important contribution of the results is therefore the indication that termite meal can be incorporated with maize bran while maintaining favorable growth, feed conversion and economic returns. Further work should assess different termite inclusion levels, nutrient balancing and methods of reducing termite-processing costs before recommendations for wider commercial adoption are made.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Growth performance. The inclusion of *Macrotermes bellicosus* in the diet of Nile tilapia influenced growth performance. The diet containing 50% maize bran and 50% termite meal produced the most favorable growth response compared with diets based entirely on maize bran or termite meal.

Feed utilization. The dietary treatments significantly affected feed intake and feed conversion ratio. The 50% maize bran + 50% termite meal diet resulted in the most favorable feed conversion, while the maize-bran-only diet recorded the least favorable conversion.

Economic performance. The cost and financial returns varied among the dietary treatments. Although the maize-bran-only diet had the lowest feed cost and highest benefit-cost ratio, the 50% maize bran + 50% termite meal diet generated the highest net return per fish.

Potential of termite meal. *Macrotermes bellicosus* has potential for use as an alternative feed ingredient for Nile tilapia, particularly when incorporated with maize bran rather than used as the sole dietary ingredient.

Overall dietary performance. Among the diets evaluated, the 50% maize bran + 50% termite meal combination provided the most favorable overall balance of growth performance, feed conversionand net return, making it the most promising treatment under the conditions of the study.

6.2 Recommendations

Use of integrated termite-maize bran diets. Fish farmers may consider incorporating *Macrotermes bellicosus* meal with maize bran at an appropriate proportion, particularly the 50:50 combination evaluated in this study, as an alternative dietary option for Nile tilapia.

Termite meal should not necessarily be used alone. Complete replacement of maize bran with termite meal is not recommended based on the comparatively lower overall economic performance observed with the termite-only diet.

Further feeding trials. Further studies should evaluate a wider range of termite meal inclusion levels to determine the optimum inclusion rate for Nile tilapia while maintaining favorable growth, feed conversion and economic returns.

Economic optimization. Research should investigate methods of reducing the cost of collecting, drying and processing *M. bellicosus* so that termite-based diets can become more economically competitive with conventional feed ingredients.

Nutritional characterization. Further studies should determine the detailed proximate composition, amino-acid profile, digestibility and mineral composition of locally sourced *M. bellicosus* to support more precise formulation of termite-based aquafeeds.

Larger-scale validation. The performance of the maize bran plus termite meal diet should be evaluated under farmer-managed pond conditions and at larger production scales before wider commercial recommendations are made.

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Appendix 1

Work Plan for the study

DATE	ACTIVITY	PERSON RESPONSIBLE
July /1/2026	Research proposal writing.	Researcher and Supervisor
JULY/10/2026	Proposal sharing with the supervisor	Researcher and Supervisor
July 18th 2026	Developing research instrument	Researcher and Supervisor
July 20th 2026	Stocking fish	Researcher and Su
August 4th 2026	Data collection	Researcher
September 2026	Data analysis and interpretation	Researcher and Supervisor
September 2026	Data presentation and submission	Researcher and Supervisor

Appendix 11

Proposed Budget for the study

No.	ITEM	Quantity	Cost/Unit	Total cost
1	Stationery	1 (ream)	18,000	18,000
2	Printing & Binding	--	100,000	100,000
3	Communication	--	100,000	100,000
4	Transport	--	100,000	100,000
5	Lunch	15days	10,000	150,000
6	Research Assistants	4	100,000	400,000
7	Miscellaneous	--	400,000	400,000
Total				1,268,000

Field photos

Figure 1: fish conditioning

Figure 2: Raising hapas

Figure 4: Termites feeds

Figure 3: Data collection

Figure5: maize brand+ termites

Figure 6: Weighing of fish