

GROWTH PERFORMANCE OF MALLARD DUCKS AS INFLUENCED BY DIFFERENT LEVELS OF MMK LEAF MEAL SUPPLEMENTATION

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SDGs: **Goal 4 (Quality Education); Goal 1 (No Poverty)**

ABSTRACT

This study evaluated the growth performance of Mallard ducks (*Anas platyrhynchos*) fed commercial diets supplemented with varying levels of MMK leaf meal composed of Madre de Agua (*Trichanthera gigantea*), Moringa (*Moringa oleifera*), and Kangkong (*Ipomoea aquatica*). The research was conducted to determine the potential of MMK as an alternative, locally available feed supplement to reduce dependence on commercial feeds. A total of 180 ducklings were used in a Completely Randomized Design with six dietary treatments: 100% commercial feed, commercial feed supplemented with 5%, 10%, 15%, and 20% MMK, and 100% MMK, each replicated three times over a 90-day feeding trial. Growth parameters including final body weight, weight gain, average daily gain, feed intake, feed conversion ratio, mortality rate, and selected organ weights were measured and analyzed using analysis of variance. Results indicated that ducks fed purely commercial feed attained significantly higher final weight, weight gain, and feed efficiency compared with MMK-supplemented groups. Increasing MMK inclusion resulted in reduced growth performance, with the lowest values observed in ducks fed MMK alone. However, no significant differences were observed in internal organ weights, indicating no adverse physiological effects of MMK supplementation. The study concluded that while MMK leaf meal is safe for duck feeding and offers potential as a low-cost feed supplement, its inclusion should be limited and further optimized to improve growth efficiency and practical application in Mallard duck production.

Keywords: **Feed Conversion Efficiency; Mallard Duck; MMK Leaf Meal; Supplementation**

INTRODUCTION

Duck production plays an important role in the poultry industry, especially in developing countries, by contributing to food security, rural livelihoods, and household income. Mallard ducks (*Anas platyrhynchos*) are commonly raised due to their adaptability, disease resistance, and ability to utilize various feed resources efficiently. In the Philippines, duck farming is widespread in rural areas, valued for both meat and egg production. However, a major challenge in duck production is the high cost of commercial feeds, which forms a large part of total production expenses.

Rising prices of conventional feed ingredients, such as corn and soybean meal, have encouraged farmers and researchers to explore locally available, cost-effective, and nutritionally adequate alternatives. Plant-based supplements are promising because they are renewable, accessible, and rich in proteins, vitamins, minerals, and bioactive compounds. Among these, Madre de Agua, Moringa, and Kangkong have been identified as potential feed ingredients that support growth, feed efficiency, and overall health. Individually, these plants have shown benefits for poultry, and combining them into a single leaf meal supplement (MMK) may provide a balanced nutrient profile and enhance their complementary effects.

Tropical leaf meals such as madre de agua, provide protein content as well as structural carbohydrates and fiber that may affect digestibility and energy availability for poultry. Recent meta-analytical appraisals of fermented tropical leaf meals in broilers diets show that processing intervention (fermentation) can improve the bioavailability of nutrient and reduce its anti-nutritional factor which in turn improves growth performance and feed utilization (Ogbuewu et al., 2024; Ogbuewu & Mbajorgu, 2024). These results emphasize *T. gigantea* as a new potential sustainable local protein feed option, partly substitutive of conventional sources such as soybean meal or maize. Madre de agua is a fast-growing tropical shrub used as forage and leaf meal supplement with better nutritional characteristics and humidity adaptability. The leaves of *T. gigantea* are characterized with high crude protein (about 17% to 24% on a dry matter basis) and minerals including calcium and iron, indicating their potential as a good protein source for poultry feed. The compositional features have been described in peer-reviewed studies indexed in Scopus measuring foliage of tropical trees, making *T. gigantea* a strong candidate for potential feed ingredient (Leterme et al., 2005).

Moringa leaves have gained spreading recognition as nutrient-dense feed ingredient for poultry, which are found rich in crude protein as well some vital vitamins (A, C and E) and minerals (calcium, potassium and iron) supporting growth performance, production performance of birds and also physiological health promoting activity in birds' tissues including the liver (Zhang et al., 2023). Supplementation of broiler diets with moringa leaf powder or meal has been reported to enhance growth performance, carcass characteristics and intestinal microbiota composition (Zhang et al., 2023; Gul et al. 2024). The use of *M. oleifera* as feed in poultry diets has been extensively reviewed, and the aim is to utilize it as a functional feed supplement capable of improving production performance and also health status when incorporated into the diet (Egbu et al., 2024).

Dietary inclusion of moringa leaf meal in broiler chickens may improve growth performance, feed efficiency, and hematological parameters (Anam et al., 2025), suggesting its feasibility as an alternative protein source. Apart from being a protein source, moringa leaves also contain bioactive compounds (e.g., flavonoids, phenolic acids and antioxidants) that are shown to result in enhanced physiological responses and health status of poultry. These functional properties have been associated with improved gut health and nutrient utilization, which are supported by experimental studies that show better microbial balance and performance in broilers fed Moringa leaf meal (Zhang et al., 2023).

Another promising plant is *Ipomoea aquatica* (kangkong or water spinach), a nutrient-dense leafy aquaphyte extensively cultivated in the tropics. Leaves have been characterized biochemically and found to be moderately fibrous (14.6% DM) containing 19.6% protein DM, carbohydrates and vital minerals like potassium, calcium magnesium and iron (Saikia et al., 2023). Furthermore, kangkong leaves contain a variety of bioactive phytochemicals such as polyphenols, flavonoids, and other secondary metabolites (e.g., caffeic acid, ferulic acid, quercetin and chlorogenic acid) attributes antioxidant activity that may contribute to physiological effects. These compounds indicate that *I. aquatica* leaf meal can enhance gut health, immune action and the overall metabolic efficiency when used as a dietary supplement. While now there is certainly a scarcity of available direct feeding trials documented in the Scopus-indexed poultry literature, the existing nutrient density and bioactive composition documented coupled with their role in previous foodscapes would undoubtedly provide strong rationale for future exploration of kangkong as an alternative feed resource that holds sustainable potential in enriched poultry production systems, especially following the challenges facing tropical smallholder systems.

Despite studies on individual plant supplements, limited research has investigated their combined use in Mallard duck diets. There is insufficient information on the optimal inclusion levels of MMK leaf meal and its effects on growth performance, feed efficiency, mortality, and internal organ development. This study addresses this gap by evaluating the effects of different levels of MMK supplementation on the growth performance of Mallard ducks under local production conditions.

The findings are relevant to small-scale farmers, extension workers, and policymakers. For farmers, MMK supplementation may reduce feed costs and reliance on commercial feeds, improving farm profitability. For agricultural practitioners, it provides guidance on sustainable feeding practices using locally available resources. Academically, the study contributes to the understanding of alternative feeds and supports future research on feed formulation and nutrient optimization. This study is guided by the Animal Nutrition Theory, which states that growth and productivity depend on the quality, balance, and availability of nutrients in the diet. The conceptual framework links MMK supplementation levels (0%, 5%, 10%, 15%, 20%, and 100%) to key growth and health indicators, including body weight, weight gain, feed intake, feed conversion ratio, mortality, and internal organ development. Appropriate MMK inclusion is expected to influence nutrient utilization and physiological outcomes.

Additionally, the study aligns with the United Nations Sustainable Development Goals (SDGs), including SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 12 (Responsible Consumption and Production), by promoting sustainable, affordable, and resource-efficient feeding strategies that improve food security and community well-being. And also, SDG 4 (Quality Education) by generating knowledge that can be incorporated into training programs, extension services, and educational materials for farmers and agricultural practitioners, promoting informed, sustainable, and science-based duck farming practices.

METHODOLOGY

Research Design

This study employed a quantitative experimental research design, which involves the objective measurement and analysis of numerical data to test specific hypotheses and evaluate relationships between variables (Creswell & Creswell, 2018). Quantitative research, rooted in the empirical sciences, allows for statistical testing and precise observation of measurable outcomes. It emphasizes structured procedures, replication, and statistical validity, making it suitable for studies involving performance evaluation in animal feeding trials.

This study employed a quantitative experimental research design to evaluate the effects of varying levels of MMK (Madre de Agua, Moringa, and Kangkong leaf meals) supplementation on the growth performance of Mallard ducks (*Anas platyrhynchos*). According to Creswell and Creswell (2018), experimental research is used to examine the effects of treatments or interventions on specific outcomes under controlled conditions. This design allows researchers to collect numerical data and objectively compare treatment effects through statistical analysis.

The independent variable in this study was the level of MMK supplementation in the feed (0%, 5%, 10%, 15%, 20%, and 100% MMK), while the dependent variables included final weight (g), total weight gain (g), average daily gain (g/day), feed conversion ratio (FCR), mortality rate, and visceral organ development. The quantitative experimental approach was appropriate because the study aimed to determine the effects of different feed treatments on measurable growth and production parameters of Mallard ducks and establish cause-and-effect relationships between the treatments and observed responses.

The experiment was arranged using a Completely Randomized Design (CRD) with six treatment groups (T1–T6) and three replications per treatment, each containing ten ducks. Gomez and Gomez (1984) stated that CRD is appropriate when experimental units are relatively homogeneous, as it minimizes bias and experimental error through random assignment of treatments. Since the ducks were of similar age and were reared under uniform management and environmental conditions, the use of CRD was considered suitable for the study. Measurements were taken consistently over a 90-day rearing period, and Analysis of Variance (ANOVA) was used to determine significant differences among treatment means. This design ensured reliable comparison of treatment effects and strengthened the validity of the study findings.

Research Locale and Duration of the Study

This study was conducted in the Municipality of Kapalong, located in the first district of Davao del Norte, Philippines, from January to March 2025. Positioned in the northwestern part of the province, Kapalong is bordered by Agusan del Sur to the north, the municipalities of Asuncion and Sto. Tomas to the south and east, and the Municipality of Talaingod and Bukidnon province to the west. The study's location was selected to reflect real-world farming conditions relevant to local duck producers. Data collection and observations focused on evaluating the growth performance of Mallard ducks under different levels of MMK (Madre de Agua, Moringa, and Kangkong) supplementation, offering practical insights for improving feed strategies in the region.

Experimental Design and Treatment

This study was laid out using simple Completely Randomized Design (CRD). The birds are randomly assigned into five treatments, replication three times with seven birds in each replication. The different treatments are as follows:

- T1 - Pure Commercial Feeds
- T 2 - Commercial Feeds + 5% MMK
- T3 - Commercial Feeds + 10% MMK
- T4 - Commercial Feeds + 15% MMK
- T5 - Commercial Feeds + 20% MMK
- T6 - MMK Alone

Animal Management and Husbandry

In this study, standard cultural practices for duck rearing were strictly followed to ensure uniformity and reliability of results. During the brooding phase, ducklings were housed in a clean, well-ventilated brooding area with adequate warmth provided by heat lamps to maintain optimal body temperature. Sanitation was prioritized through daily cleaning of pens, feeders, and drinkers to prevent the spread of diseases and promote healthy growth conditions. Ducks were fed according to their assigned treatment groups, with the MMK (Madre de Agua, Moringa, and Kangkong) leaf meal air-dried, ground, and incorporated into the commercial feed at varying inclusion levels (5%, 10%, 15%, 20%, and 100%). Clean drinking water was provided at all times and regularly replenished to ensure freshness. Health management included regular monitoring of duck conditions, timely vaccination, and immediate isolation of any sick birds. Throughout the 90-day feeding trial, consistent record-keeping of feed intake, weight gain, and mortality was conducted to assess the effects of MMK supplementation on Mallard duck growth performance. The materials used in the study were one hundred eighty (180) heads of five-day-old ducklings, commercial feeds, feeding and watering troughs, net, container, brooder cage, Madre de Agua leaf meal, Moringa leaf meal, and Kangkong leaf meal, bulb, electric wire, bamboos, charcoal, nail, hammer, saw, bolo, leaf newspaper, empty sacks, weighing device, notebook, and pencil.

Preparation of Brooder

One week before the arrival of the duckling, the brooder was thoroughly cleaned and disinfected with soap and water. It was exposed to the heat of the sun for three days after rinsing them with water to eliminate harmful microorganisms. The brooder was covered with old rice straw. Empty sacks were placed around the brooder to conserve heat during the brooding period.

Securing the Ducklings

One hundred eighty (180) ducklings were sourced from a reliable supplier prior to the commencement of the study. These ducklings were selected to ensure uniformity in age and health. The source was carefully chosen to guarantee the quality and genetic consistency of the animals. Prior to the study, the ducklings were kept in a controlled environment to acclimatize. This preparation ensured that the ducks were in optimal condition for the research.

Brooding and Caring for Ducklings

The ducklings were placed in a prepared brooder upon arrival. They swallowed to pick up food particles, which was placed in preferred feeding troughs. At the *ad libitum* feeding, the watering was employed during the brooding period, which lasts for 30 days from the day of the arrival. Artificial heat was provided using an electric bulb day and night until the end of the brooding period during cold weather, and during blackout, artificial heat was provided using an improvised charcoal heater.

Rearing the Ducklings

The thirty (30) ducklings per replication in the brooding cage were transferred to the rearing cages after 30 days, in accordance with the experimental treatment and design. They were carefully monitored and provided with appropriate care throughout the rearing period. The ducks were fed according to the designated treatment groups during this time. The ducks were kept in the rearing cages until they reached the age of three months. Regular observations and maintenance were carried out to ensure their health and growth.

Feeding and Watering

Ducklings in all treatments were provided with *ad libitum* feeding, ensuring they had unrestricted access to food. The feed was weighed before being given to the birds, and the remaining feed was weighed again to determine the total amount consumed each day. This process helped accurately monitor the daily feed intake. Clean and potable drinking water was made available to the ducklings at all times throughout the experiment. The provision of fresh water ensured that the birds remained hydrated and healthy during the study period.

Treatment Application

The ducklings were fed a combination of commercial feeds and varying portions of MMK leaf meal on an *ad libitum* basis. The ratio of commercial feeds to MMK leaf meal was carefully adjusted according to the specific treatment groups outlined in the study. This feeding strategy ensured that each treatment group received the intended supplementation of MMK leaf

meal while maintaining adequate access to commercial feeds. The ad libitum feeding approach allowed the ducklings to consume feed according to their needs, promoting optimal growth conditions throughout the experiment.

Prevention of Parasites and Diseases

Strict cleanliness protocols were followed throughout the study to prevent the spread of parasites and diseases. The feeding and watering containers were cleaned daily, ensuring no contamination. Similarly, the brooding and rearing cages, along with the surrounding areas, were thoroughly cleaned each day. This consistent attention to cleanliness helped maintain a hygienic environment for the ducklings.

Sanitation

Sanitation measures were rigorously maintained in the entire experimental area throughout the study. Daily cleaning of the feeding and watering equipment, as well as the removal of droppings, ensured a clean environment, minimizing the risk of disease. These sanitation practices were essential in promoting the health and well-being of the ducklings during the experiment.

Data Gathered

The data gathered in the study were the feed consumption, gain in weight, feed conversion ratio, and return on investments.

Feed Consumption

Data on feed consumption was recorded daily from the start of the rearing period until the end of the study. His data was computed using the formula below:

$$\text{Feed Consumption} = \frac{\text{Feed Offered (g/bird)} - \text{Feed Refuse (g/bird)}}{\text{Number of Birds Per Treatment Replication}}$$

Initial Weight

Data on initial weight were taken after weeks of brooding. The weight of ducklings in each cage was added and divided by the number of chicks per cage. This data was computed using the formula below:

$$\text{Initial weight} = \frac{\text{Weight of Ducklings (g/bird) at 14th day}}{\text{Number of Birds per Treatment Replication}}$$

Final Weight

After harvesting, the individual weight of Ducklings was determined and divided by the number of Ducklings in every cage. This data was computed using the formula below:

$$\text{Final weight} = \frac{\text{Weight of Day-old Duck (g/bird) at Harvest Days}}{\text{Number of Birds per Treatment Replication}}$$

Average Daily Gain Weight

This was calculated by dividing the total gain in weight of the mallard duck by the number of feeding days (45 days). This data was computed using the formula below:

$$\text{Average Daily Gain} = \frac{\text{Weight Gain} / \text{Growing Days}}{\text{Harvest Weight} / \text{Initial Weight}}$$

Gain in Weight

This is obtained by subtracting the initial weight from the final weight in every treatment. The difference was divided by the number of mallards per cage.

$$\text{Gain in Weight} = \frac{\text{Weight Gain} / \text{Growing Days}}{\text{Harvest weight} / \text{initial weight}}$$

Feed Intake

This was calculated by dividing the total feed consumed by the mallard duck by the number of feeding days (45 days). This data was computed using the formula below:

$$\text{Feed Intake} = \frac{\text{Feed Offered (g/bird)} - \text{Feed Refused (g/bird)}}{\text{Number of Birds per Treatment Replication}}$$

Feed Conversion Efficiency

The average feed conversion efficiency of the broiler was determined by dividing the average gain in weight of the mallard. This data was computed using the formula below:

$$\text{Feed Conversion Efficiency} = \frac{\text{Weight of Feed Intake (g/bird)}}{\text{Weight Gain (g/bird)}} \times 100$$

Mortality Rate

Mortality was taken per treatment percentage of duck that does not survive or die, particularly during their growth period. This data was taken to determine the number of mortality / total number of birds.

$$\text{Mortality Rate} = \frac{\text{Number of Deaths}}{\text{Number of birds / T/Rep}} \times 100$$

Cost of Feed

The cost of feed for each treatment group was determined by multiplying the total feed consumed by the unit cost of the feed. Feed consumption was recorded daily by subtracting the feed leftovers from the amount offered. The total feed cost per bird was then computed using the formula:

$$\text{Cost of Feed (currency/bird)} = \text{Feed Consumed (g/bird)} \times \text{Unit Price of Feed (currency/g)}$$

Visceral Organs

At the end of the feeding trial, the Mallard ducks were humanely slaughtered to assess visceral organ development. The organs assessed included the heart, liver, gizzard, proventriculus, small intestine, and large intestine. Each organ was carefully excised from each individual duck, cleaned to remove any contents or blood, blotted dry, and weighed using a digital balance. Organ weights are reported in grams (g).

Statistical Tools and Analysis

All data collected in this study were subjected to analysis of variance (ANOVA) using the F-test to determine whether significant differences existed among treatments. Statistical significance was interpreted at the 5% level ($p < 0.05$). When significant differences were detected, the Honestly Significant Difference (HSD) test was employed to compare treatment means and identify which treatments differed from each other.

Data were organized and analyzed using the Statistical Tool for Agricultural Research (STAR) software, which allowed for proper handling of replicates and calculation of coefficients of variation (CV). The CV was calculated for each parameter to assess experimental precision and data reliability. All results are presented as mean values per treatment, with variability expressed through the CV and standard deviations. This approach ensured that the effects of different levels of MMK leaf meal supplementation on the growth performance, feed efficiency, mortality, and internal organ development of Mallard ducks were rigorously evaluated, and conclusions were based on statistically valid comparisons.

Ethical Considerations

The study was conducted in full adherence to ethical standards to ensure the responsible and humane treatment of all research subjects. Although the study did not involve human participants, the welfare of the Mallard ducks was given highest priority throughout the experiment. All ducklings were handled gently, housed in clean and well-ventilated facilities, and provided with sufficient food, clean water, and proper environmental conditions to support their health and comfort. Procedures were carefully designed to minimize stress, injury, and discomfort, following best practices for poultry management and animal research.

For aspects of the study involving human assistance, such as access to privately owned facilities or technical support, informed consent was obtained from all individuals involved. Participants were fully informed about the objectives, procedures, and scope of the research. Confidentiality was strictly maintained by anonymizing personal information of farm owners, suppliers, and assisting personnel, which was used solely for research purposes. Additionally, the study followed institutional and national ethical guidelines for animal research. All experimental protocols, including housing, feeding, handling, and slaughtering of the ducks, were conducted under principles of responsible animal care and scientific integrity. This ensured that the research was carried out ethically, responsibly, and with respect for both animal welfare and human contributors.

RESULTS

Final Weight, Average Daily Gain, Gain in Weight and Dressed Weight

Table 1

Final Weight, Average Daily Gain, Gain in Weight and Dressed Weight of Mallard ducks Fed Diets Supplemented with Varying Levels of MMK Leaf Meal

Treatment	Growth Performance Parameters				
	IW	FW	ADG	GW	DW
T1 - Pure Commercial Feeds	741.67	1,015.00 ^a	9.76 ^a	273.33 ^a	990.00 ^a
T2 - Commercial Feeds + 5% MMK	722.00	858.33 ^b	4.87 ^b	136.33 ^b	833.33 ^b
T3 - Commercial Feeds + 10% MMK	716.67	825.67 ^b	3.89 ^b	109.00 ^b	800.67 ^b
T4 - Commercial Feeds + 15% MMK	720.00	836.33 ^b	4.15 ^b	116.33 ^b	811.33 ^b
T5 - Commercial Feeds + 20% MMK	718.00	830.00 ^b	4.00 ^b	112.00 ^b	805.00 ^b
T6 - MMK Alone	724.33	816.67 ^b	3.30 ^b	92.33 ^b	791.67 ^b
CV (%)	2.07	2.05	16.02	16.00	2.11
F-test		**	**	**	**

Means with the same letter are not significantly different from each other (HSD 0.05)

Analysis of variance indicated that dietary treatments had a significant effect on final weight, average daily gain, total weight gain, and dressed weight (F-test, $p < 0.05$). The initial body weights of the ducks ranged from 716.67 g to 741.67 g across treatments. At the end of the feeding trial, ducks fed pure commercial feed (T1) exhibited the highest final weight (1,015.00 g), average daily gain (9.76 g/bird/day), and total weight gain (273.33 g), as well as dressed weight (990.00 g). In contrast, ducks fed diets containing MMK leaf meal, either as a partial supplement (T2-T5) or as the sole feed source (T6), showed significantly lower final weights, daily gains, and total weight gains ($p < 0.05$). Among the MMK-supplemented treatments, there were small differences in growth performance. Ducks in T2 (5% MMK supplementation) had slightly higher final weight (858.33 g) and weight gain (136.33 g) compared to other MMK treatments (T3-T6), which ranged from 816.67 g to 836.33 g in final

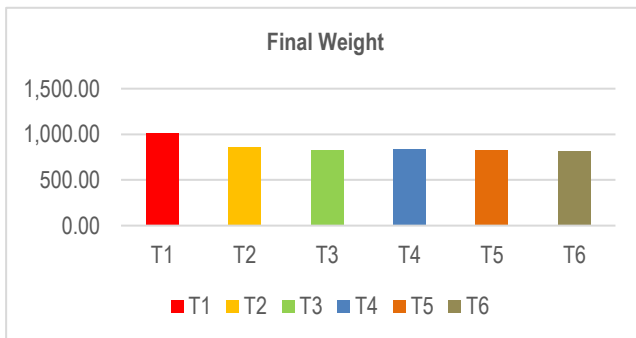


Figure 1. Final Weight of Mallard Ducks Fed Diets Supplemented with Varying Levels of MMK Leaf Meal

weight and 92.33 g to 116.33 g in total weight gain. Average daily gain in MMK-supplemented groups ranged from 3.30 to 4.87 g/bird/day. The supplementation with MMK leaf meal, particularly at levels above 5%, reduced growth performance compared to pure commercial feed, although some MMK treatments still supported moderate growth.

Feed Intake, Feed Conversion Ratio, Mortality Rate and Cost of Feed

Table 2
Feed Intake, Feed Conversion Ratio, Mortality Rate and Cost of Feed of Mallard Ducks Fed Diets Supplemented with Varying Levels of MMK Leaf Meal

Treatment	Production Efficiency Parameters			
	Feed Intake	Feed Conversion Ratio	Mortality Rate	Cost of Feed
T1 - Pure Commercial Feeds	7.00 ^a	2.59 ^b	10.00	182.00 ^c
T2 - Commercial Feeds + 5% MMK	7.16 ^{ab}	5.51 ^a	10.00	186.07 ^b
T3 - Commercial Feeds + 10% MMK	7.23 ^a	6.67 ^a	10.00	188.07 ^{ab}
T4 - Commercial Feeds + 15% MMK	7.26 ^a	6.26 ^a	10.00	188.85 ^{ab}
T5 - Commercial Feeds + 20% MMK	7.30 ^a	6.60 ^a	10.00	189.89 ^a
T6 - MMK Alone	6.27 ^c	6.81 ^a	6.33	94.00 ^d
CV (%)	0.88	13.00	16.46	0.72
F-test	**	**	ns	**

Means with the same letter are not significantly different from each other (HSD 0.05)

The production efficiency parameters of Mallard ducks fed different levels of MMK leaf meal supplementation are presented in Table 2. Analysis of variance revealed a significant difference in feed intake and FCR, but no significant difference in mortality rate. Feed intake ranged from 6.27 g/bird/day in ducks fed MMK alone (T6) to 7.30 g/bird/day in ducks fed commercial feed supplemented with 15% MMK (T5) whereas ducks in T6 exhibited the lowest feed consumption ($p < 0.05$). Ducks fed pure commercial feed (T1) had the most efficient feed utilization with an FCR of 2.59, while ducks fed MMK alone (T6) recorded the highest FCR (6.81), indicating poorer feed efficiency.

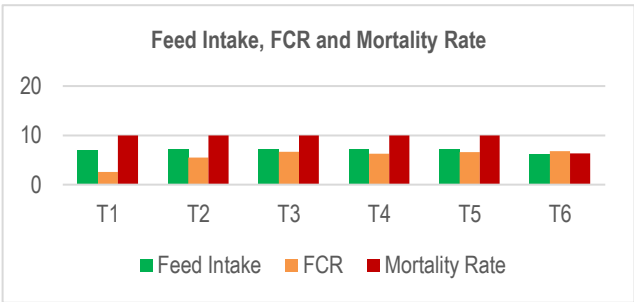


Figure 2. Feed Intake, FCR, And Mortality Rate of Mallard Ducks Fed Diets Supplemented with Varying Levels of MMK Leaf Meal

Mortality rate was not significantly different among most treatments ($p > 0.05$), with the exception of T6, which had a slightly lower mortality rate (6.33%) compared to the other treatments (10%). The cost of feed differed significantly across treatments ($p < 0.01$). Ducks fed MMK alone (T6) had the lowest feed cost (94.00), whereas ducks fed commercial feeds with 15% MMK (T5) incurred the highest feed cost (189.89).

Supplementation with MMK leaf meal increased feed consumption and cost but reduced feed efficiency compared to pure commercial feed, while MMK alone lowered feed intake and cost but led to higher FCR. These results suggest that MMK alone reduced feed intake and improved survival but led to higher FCR, whereas combination diets increased feed intake and cost while showing moderate efficiency.

Internal Organs (grams)

Table 3

Heart, Liver, Large Intestine, Small Intestine, Gizzard, and Proventriculus of Mallard Ducks Fed Diets Supplemented with Varying Levels of MMK Leaf Meal

Treatment	Visceral Organ Parameters					
	Heart	Liver	Large Intestine	Small Intestine	Gizzard	Proventriculus
T1 - Pure Commercial Feeds	11.33	40.00	37.67	55.33	29.00	13.00
T2 - Commercial Feeds + 5% MMK	12.33	38.67	36.67	54.67	29.00	13.00
T3 - Commercial Feeds + 10% MMK	10.67	40.00	37.33	54.67	28.67	12.33
T4 - Commercial Feeds + 15% MMK	11.00	39.67	36.67	56.00	29.00	13.00
T5 - Commercial Feeds + 20% MMK	11.33	39.33	37.33	54.00	29.00	12.33
T6 - MMK Alone	11.00	37.33	36.00	51.00	29.00	13.00
CV (%)	9.80	3.95	3.61	5.78	2.15	2.61
F-test	ns	ns	ns	ns	ns	ns

Means with the same letter are not significantly different from each other (HSD 0.05)

The weights of internal organs of Mallard ducks fed diets supplemented with varying levels of MMK leaf meal are presented in Table 3. Analysis of variance indicated no significant differences (ns) among treatments for any of the internal organs measured (F-test, $p > 0.05$). The organs measured included the heart, liver, large intestine, small intestine, gizzard, and proventriculus. Across all treatments, no significant differences were observed in the weights of these organs ($p > 0.05$). Heart weights ranged from 10.67 g (T3) to 12.33 g (T2), liver weights from 37.33 g (T6) to 40.00 g (T1 and T3), and large intestine weights from 36.00 g (T6) to 37.67 g (T1). Small intestine weights varied from 51.00 g (T6) to 56.00 g (T4), while gizzard weights remained relatively consistent, ranging between 28.67 g and 29.00 g. Proventriculus weights ranged from 12.33 g (T3 and T5) to 13.00 g (T1, T2, T4, T6).

The coefficients of variation (CV) ranged from 2.15% for gizzard weight to 9.80% for heart weight, indicating low to moderate variability among the experimental units. The F-test confirmed that there were no statistically significant differences (ns) for any of the internal organs measured, suggesting that the level of MMK leaf meal supplementation, whether partial (5-20%) or complete (100%), did not affect organ development. These results indicate that,

while MMK supplementation influenced growth performance and feed utilization, the physiological development of vital organs remained stable, demonstrating that the supplement does not impose adverse effects on organ health.

The consistency in organ weights across treatments suggests that Mallard ducks can maintain normal organ development even under dietary variations, emphasizing the resilience of key physiological systems such as the heart, liver, and digestive organs. This stability is important because it indicates that nutrient allocation to essential organs is preserved, even when the diet is partially or fully replaced with plant-based MMK leaf meal. Moreover, the uniformity of gizzard and proventriculus weights implies that digestive efficiency and enzymatic processing capacity are not compromised, which is essential for maintaining overall metabolic health. These findings support the use of MMK leaf meal as a safe and practical dietary supplement for Mallard ducks. It can be incorporated into feeding programs as a partial or complete alternative to conventional commercial feeds without risking organ health, making it a promising option for reducing feed costs while maintaining physiological well-being and supporting sustainable duck production.

DISCUSSION

Final Weight, Average Daily Gain, Gain in Weight, and Dressed Weight

The results demonstrated that dietary treatments significantly affected the growth performance of Mallard ducks, as indicated by the F-test showing highly significant differences ($p < 0.01$) in final weight, average daily gain (ADG), gain in weight, and dressed weight. Mallard ducks fed pure commercial feed (T1) attained the highest final body weight (1,015.00 g), whereas all MMK-supplemented treatments (T2-T6) recorded significantly lower final weights. The observed findings indicate that substituting commercial feed with MMK leaf meal could adversely influence body weight development in a direct adjustment to energy density, amino acid profiles, or anti-nutritional factors present in the MMK plant itself that limit nutrient utilization. The decreases recorded in the present study are fairly compensated by partial supplementation of commercial feed with MMK leaf meal (T2-T5) which can still add certain nutritional advantages derived from Moringa, Madre de Agua, and Kangkong leaves such as proteins, essential amino acids, vitamins, minerals, and bioactive compounds without totally sacrificing growth. Feeding the ducks MMK only (T6) provided the lowest gains in body weight, indicating that single feeding of MMK was not fulfilling all nutritional needs for Mallard ducks. These observations correlate well with reports by previous studies conducting poultry nutrition research where reduced growth performance was noted when conventional diets were partially or completely supplemented with plant-based feed ingredients devoid of sufficient digestible energy and/or nutrient balance (Abdollahi et al., 2013; Babatunde et al., 2021; Obianwuna et al., 2024). As a conclusion, Moringa, Madre de Agua and Kangkong leaf meal are better used as an additional resource for the main commercial fowl feed to improve or complement the nutritional needs of birds based on its functional properties rather than replacing all feeds with these vegetable byproducts.

Total gain in weight followed a pattern similar to final weight, with ducks in T1 achieving the highest gain (273.33 g) and MMK-fed groups exhibiting significantly lower gains. This decline in weight gain indicates reduced growth efficiency when MMK was included in the diet. The reduced growth response may reflect decreased digestibility or poorer amino acid availability associated with plant-derived feed materials. This decline in weight gain may reflect reduced nutrient digestibility and poorer amino acid availability associated with plant-derived feed materials, as many plant ingredients contain anti-nutritional factors (e.g., protease inhibitors, phytate, tannins) that can bind proteins and impair amino acid absorption, ultimately limiting nutrient utilization and growth performance in poultry (Alabi & Adedokun, 2025).

Average daily gain (ADG) was significantly affected by diet, with T1 showing the highest growth rate (9.76 g/day). All MMK-supplemented treatments exhibited lower ADG values (3.30-4.87 g/day), indicating that inclusion of plant-derived ingredients such as Moringa, Madre de Agua, and Kangkong reduced growth efficiency. Notably, increasing MMK levels did not produce a strictly proportional decline in ADG, suggesting a threshold effect in which even low levels of plant inclusion may limit nutrient utilization due to the presence of anti-nutritional factors and reduced amino acid digestibility (Jha & Mishra, 2021; Anam et al., 2025; Zhang et al., 2023).

On the other hand, dressed weight was significantly affected by dietary treatments, with ducks fed pure commercial feed exhibiting the highest dressed weight (990.00 g). Although MMK-fed ducks recorded lower dressed weights ranging from 791.67 g to 833.33 g, these values reflected the overall reduction in live body weight rather than disproportionate carcass loss. The observed decrease in dressed weight suggests that reduced nutrient intake and growth performance translated into lower carcass yield. The observed decrease in dressed weight suggests that reduced nutrient intake and growth performance translated into lower carcass yield. These findings are consistent with Olukosi et al. (2019), who demonstrated that nutritionally balanced diets improve carcass yield and growth efficiency in poultry, and with Nkukwana et al. (2014), who reported that suboptimal nutrient intake from alternative plant-based feed ingredients can lead to reduced carcass development and overall performance in broiler chickens.

Feed Intake, Feed Conversion Ratio, Mortality Rate and Cost of Feed

Feed intake was significantly influenced by dietary treatments ($p < 0.01$). Treatment 1 was significantly among all the treatments. Mallard ducks fed commercial diets supplemented with MMK at 5-20% (T2-T5) exhibited slightly higher feed intake compared with the control group (T1), while ducks fed MMK alone (T6) recorded the lowest feed intake (6.27 g/bird/day). The increased feed intake observed at partial MMK inclusion levels may reflect compensatory feeding behavior in response to reduced dietary nutrient density as MMK levels increased. In contrast, the reduced intake in ducks fed MMK alone suggests limitations in palatability and digestibility when plant components fully replace commercial feeds, consistent with observations that high dietary fiber can decrease feed intake and nutrient absorption in poultry. (Jha & Mishra, 2021).

Feed conversion ratio (FCR) differed significantly among treatments ($p < 0.01$). Ducks fed pure commercial feed (T1) exhibited the most efficient feed utilization, with the lowest FCR

value (2.59). In contrast, all MMK-supplemented treatments (T2-T6) recorded significantly higher FCR values, ranging from 5.51 to 6.81, indicating poorer feed efficiency. Notably, even the lowest MMK inclusion level (5%) resulted in a marked reduction in feed conversion efficiency, suggesting that MMK negatively affected nutrient utilization even at minimal inclusion. The decline in feed efficiency may be attributed to the presence of anti-nutritional factors, reduced protein quality, or imbalanced amino acid profiles in unconventional leaf meals like Moringa or similar plant forages (Mahfuz & Piao, 2019). Similar trends have been reported in ducks and broilers when plant leaf meals were included at moderate to high levels, emphasizing the need for careful optimization of inclusion rates to balance cost-effectiveness with feed efficiency and overall growth performance (Ngamsaeng et al., 2004).

Mortality rate was not significantly affected by dietary treatments ($p > 0.05$). Most treatments recorded a mortality rate of 10.00%, while ducks fed MMK alone (T6) showed a slightly lower mortality rate (6.33%). Although differences were not statistically significant, the results indicate that MMK supplementation, even when used as the sole feed source, did not adversely affect survivability under the conditions of the study. This suggests that MMK leaf meal did not exert acute toxic effects on Mallard ducks during the experimental period. Although differences in growth performance and feed efficiency were observed among treatments, mortality was not significantly affected by dietary inclusion of unconventional feed ingredients ($p > 0.05$), with most groups showing similar survival rates over the study period. This finding aligns with results from other duck nutrition experiments in which inclusion of plant-based supplements or alternative protein sources did not increase mortality, indicating that such dietary treatments did not exert acute toxic effects under standard rearing conditions (Yang et al., 2020; Zhou et al., 2019). The cost of feed varied significantly among treatments ($p < 0.01$). Ducks fed MMK alone (T6) incurred the lowest feed cost (94.00), reflecting the lower cost of MMK compared with commercial feeds. In contrast, ducks fed commercial feed supplemented with 20% MMK (T5) recorded the highest feed cost (189.89), while other MMK-supplemented treatments exhibited intermediate costs. Although MMK inclusion reduced feed cost when used as the sole diet, this economic advantage was offset by poor feed conversion efficiency and reduced growth performance. These findings suggest that while MMK leaf meal may reduce feed cost, its inclusion compromises production efficiency, limiting its suitability as a complete or partial replacement for commercial feed. Partial inclusion of MMK leaf meal increased feed intake but negatively affected feed efficiency, while complete replacement reduced feed intake and feed cost but resulted in poor nutrient utilization. These results indicate that MMK leaf meal has limited potential as a feed ingredient for Mallard ducks under the conditions of this study.

Visceral Organs

The analysis of variance revealed no significant differences in internal organ weights of Mallard ducks, indicating that MMK supplementation did not affect organ development. The heart weights of Mallard ducks did not differ significantly among treatments, with values ranging from 10.67 g to 12.33 g. This indicates that MMK supplementation, whether partial or complete, did not affect cardiac development. Despite the observed reductions in growth performance associated with MMK inclusion, heart weight remained stable, suggesting that cardiac tissue is relatively conserved even under nutritionally suboptimal diets. A similar pattern in monogastric nutrition is that many plant-based dietary inclusions can change production variables without

causing changes in visceral morphology. Studies in quail showed that phytogetic supplementation had no significant effect on internal organ weights (Essien et al., 2022). Studies have also shown that moderate inclusion levels of *Moringa oleifera* leaf meal did not lead to any significant changes in internal organ weights in poultry feed which is consistent with the observations made as result from this experiment. For instance, Nkukwana et al. (2014) and the viscera is less developed in chickens fed higher levels of *M. oleifera* leaf meal compared with control birds, suggesting that inclusion of this feedstuff may not have any detrimental impact on visceral development. Likewise, Cui et al. (2018) reported no adverse effects on organ weight parameters of broilers fed diets with *M. oleifera* leaves, supporting the interpretation that morphology of body organs such as heart and other vital organs is unaffected when non-cultivated plant feeds are introduced in diet at significant levels.

On liver, liver weight was not significantly influenced by dietary treatment, with values ranging from 37.33 g to 40.00 g across all groups. This suggests that MMK supplementation did not impair liver development, even though growth performance and feed efficiency were reduced in MMK-fed ducks. The stability of liver weight reflects the liver's critical metabolic role and its capacity to maintain mass under varying dietary conditions. The stability of liver weight is consistent with findings from poultry nutrition research; for example, Akib et al. (2024) reported that inclusion of *Moringa oleifera* leaf powder in broiler diets did not significantly affect the relative weights of internal organs such as liver or digestive organs, despite performance changes among treatments. This pattern suggests that the liver's critical metabolic role and structural resilience enable it to maintain mass under varying dietary conditions. Bautista et al. (2018) similarly emphasized that nutrient allocation in ducks prioritizes essential organs such as the liver when alternative feed ingredients are used. Liver weight remained a stable physiological parameter regardless of MMK inclusion level.

In addition, no significant differences also were observed in large intestine weight among treatments. This indicates that MMK supplementation did not influence large intestine development. Despite reduced growth performance in MMK-fed ducks, the relative stability of large intestine weight suggests resilience of the digestive system. This pattern aligns with broader poultry nutrition research showing that inclusion of dietary fiber or plant-derived feed components can modulate gut physiology and microbiota composition without necessarily altering gross intestinal organ weights, reflecting maintenance of large intestine integrity under varied dietary conditions (Jha & Mishra, 2021).

The observed variations in small intestine were within normal physiological limits, indicating that MMK inclusion did not alter small intestine development. This stability suggests that structural adaptation to dietary changes may occur at the micro-architectural level (e.g., villus height and surface area) rather than through changes in organ mass. MMK supplementation did not significantly affect small intestine development, as evidenced by the observed differences in small intestine weight being within typical physiological bounds. This stability implies that rather than through significant changes in organ mass, structural adaptation to dietary changes mostly takes place at the micro-architectural level (e.g., villus height, crypt depth, and absorptive surface area). These modifications enable the digestive system to continue operating efficiently in spite of declines in feed efficiency or growth performance. This

interpretation is consistent with research from Scopus-indexed studies that found that adding dietary fiber or plant-based feed ingredients to poultry diets changed intestinal morphology to maximize nutrient absorption but did not significantly alter intestinal organ weights (Jha & Mishra, 2021; Akib et al., 2024).

Proventriculus weight remained consistent across treatments, ranging from 12.33 g to 13.00 g, indicating that MMK supplementation did not affect the development of this organ. The limited variation reflects the essential role of the proventriculus in enzymatic digestion and its relative resistance to morphological change under nutritional stress. The significance of functional resilience has been illustrated in the studies on dietary fiber where it was observed that although micro-moderating mechanisms (e.g., secretion of digestive enzymes, gut motility, and mucosal morphology) that correlate with gastrointestinal physiology could modify feed ingredients at a small scale; most often outlets from such adaptations, including the mass/size of organs involved in digestion (including digestive glands), remain within physiological norms across diets comprising contrasting fibrous contents thus denoting high organ function for digestive apparatus (for example proventricular girdle) under variable nutrition conditions (Jha & Mishra, 2021).

Conclusion

This study examined the effects of replacing commercial feeds with different levels of MMK leaf meal on the growth performance, feed efficiency, internal organ development, and survival of Mallard ducks. The results showed that ducks fed with pure commercial feeds had better growth performance, higher weight gain, improved feed conversion, and greater dressed weight compared to those receiving MMK-supplemented diets. Increasing the level of MMK in the diet led to poorer growth performance, and ducks fed with MMK alone showed the weakest results and experienced mortality. Although MMK supplementation negatively affected growth and feed efficiency, it did not significantly influence the weights of internal organs. The heart, liver, intestines, gizzard, and proventriculus remained normal across all treatments, indicating that MMK did not impair internal organ development. These findings suggest that while MMK leaf meal is not harmful to vital organs, it does not provide sufficient nutrients to support optimal growth when used as a major feed component. MMK leaf meal cannot effectively replace commercial feed in Mallard duck production without reducing growth performance and feed efficiency.

Recommendations

Based on the findings of this study, commercial feeds should remain the primary diet for Mallard ducks to ensure optimal growth performance, feed efficiency, and survival. MMK leaf meal should not be used as a complete feed replacement and may only be considered at very low inclusion levels, as higher levels were associated with reduced growth and poor feed utilization. Future studies should employ larger sample sizes and further investigate physiological, biochemical, and digestive parameters to better elucidate the mechanisms underlying the observed effects. In addition, subsequent research should evaluate carcass

characteristics and meat quality traits, including dressing percentage, muscle yield, and chemical composition, to determine the implications of MMK leaf meal on meat production.

Limitations of the Study

Despite providing valuable information on the effects of MMK (Madre de Agua, Moringa, and Kangkong) leaf meal supplementation on the growth performance of Mallard ducks, this study has several limitations. First, the experiment was conducted in a single location under specific environmental and management conditions, which may limit the applicability of the findings to other production settings. Second, the study focused on growth performance, feed efficiency, mortality, and visceral organ development, without assessing blood biochemical parameters, immune response, nutrient digestibility, or meat quality traits. Third, the feeding trial was limited to a 90-day production period and did not evaluate the long-term effects of MMK supplementation on reproductive performance and overall health. Finally, the study evaluated MMK as a combined supplement and did not determine the individual effects of Madre de Agua, Moringa, and Kangkong. Future research should conduct multi-location trials, investigate additional physiological and economic parameters, and assess the individual and synergistic effects of these plant materials to further validate and expand the findings of this study.

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