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*Full Length Research*

# Nutrient profile of microbial fermented cassava (*Manihot esculenta,* Crantz) and growth response of broiler chicken (*Gallus domesticus*, L.)

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**ABSTRACT:** Cassava (*Manihot esculenta*, Crantz) is extensively grown in tropical areas like the Philippines, yet inefficient post-harvest practices result in substantial losses. Integrating cassava into poultry feed could help curb this waste and lower the rising expenses of poultry nutrition. However, its broader use is still constrained due to its comparatively low protein and amino acid levels, the presence of anti-nutritional elements, and the dusty texture it produces in feed formulations. This study aimed to improve the nutrient content of cassava through microbial fermentation and the addition of amino acids post-fermentation, and evaluated its effects on broiler chicken (*Gallus domesticus*, L.) growth performance over 21 days. A total of 180 heads of fourteen-day-old broilers were randomly assigned to six treatments replicated three times with 10 broilers in each replication following a Completely Randomised Design (CRD) factorial experiment. Factor A involved two protein-enrichment methods: microbial fermentation (M1) and adding amino acids L-lysine and DL-methionine post-fermentation (M2). Factor B represented different inclusion levels of microbial fermented cassava meal (MFCM): 50%, 55%, and 60%. Chemical laboratory analyses confirmed that synthetic amino acid supplementation (L-lysine and DL-methionine) significantly enhanced crude protein content and metabolizable energy ($p<0.01$) in MFCM. However, variations in protein enrichment methods and inclusion levels did not considerably affect key performance indicators, including feed intake, weight gain, feed conversion ratio, production cost, dressing percentage, morbidity, and mortality rates ($P>0.05$). These findings demonstrate that synthetic amino acids significantly improve the crude protein and metabolizable energy content of microbial-fermented cassava. Furthermore, 50%-60% amino acid-enriched MFCM can be incorporated into broiler diets with no negative effect on the performance of broiler chicken. This study highlights the potential of microbial fermented cassava meal as an alternative to ground yellow corn, offering farmers a viable way to utilise other locally available farm produce in broiler production.

**Keywords:** Broiler chicken, based-diet, cassava meal, feed ingredient, microbial fermentation, nutrient profile.

## INTRODUCTION

In poultry nutrition, protein products receive significant attention, as protein is a vital component of biologically active compounds within the body. It plays a crucial role in synthesising body tissues, which are essential for growth and repair. Because broilers have substantial dietary protein requirements, determining the optimal protein concentration in their diets, whether to enhance performance or improve profitability, requires a thorough understanding of their protein and amino acid needs and how these affect growth and development. Additionally, knowledge about available protein sources suitable for poultry diets is essential (Sleman *et al.,* 2015).

The continuous rise in the cost of conventional energy sources, due to limited resources and intense competition between humans, animals, and industries, has led to the search for alternative, affordable, and readily available energy sources for poultry production worldwide. One such alternative is cassava (*Manihot esculenta,* Crantz). However, cassava tuber is composed almost exclusively of carbohydrate, as well as approximately 1–3% crude protein (Borku, 2025), slightly lower than the 3.6% mentioned by Iyayi and Losel (2001) as cited by Nwakwor *et al.* (2024). Its carbohydrate range is from 81.0 to 87.1 g per 100g (Lambebo and Deme, 2022). Fresh cassava roots can be supplemented with urea and di-ammonium phosphate and fermented anaerobically with yeast to enhance protein content. Supplementing with protein-enriched cassava root has been shown to increase dry matter intake and growth rate (Manivanh and Preston, 2015).

Cassava is abundant in most tropical countries, but due to inadequate post-harvest technologies, large quantities are wasted. According to executive director Jallorina, post-harvest losses among major farm commodities in the Philippines range from 10% to 50% (PhilMech, 2021). Increasing the use of cassava in poultry feed can significantly reduce this wastage and lower the high cost of poultry feed. However, the use of cassava in poultry nutrition has been limited by its lower nutritional value, especially in terms of protein and amino acids, the presence of anti-nutritional factors like cyanide, tannins, oxalate, phytate, and dustiness when used in poultry feed. Traditional processing methods have only achieved a 40% inclusion level of cassava in some poultry diets. Researchers are now focusing on developing advanced technologies and processing methods to enhance cassava utilisation in poultry nutrition, reduce wastage, improve its nutritional value, and maximise production (Omede *et al.*, 2017).

Proper processing could increase cassava's inclusion in poultry diets. Although extensive research has been conducted on cassava products for poultry, there remains an inconsistency in the measured nutritive values of cassava and its derivatives, leading to varying results in poultry studies (Morgan and Choct, 2016).

This experiment attempted to improve the nutritional value of cassava through microbial fermentation and the addition of amino acids L-lysine and DL-methionine to further enhance its protein content to assess its beneficial effects on the growth performance of broiler chickens using the following parameters: feed consumption, water consumption, final weight, gain in weight, average daily gain, feed conversion ratio, feed cost per kilogram of chicken produced, income over feed and chick cost, dressing percentage, morbidity rate, mortality rate, and return on investment.

## METHODOLOGY

### Experimental animals

This study utilised a mixed sex of the Cobb 500 strain of broiler chickens, renowned for their exceptional performance in terms of cost-effective feed efficiency, remarkable growth rate, suitability for processing, and competitiveness as breeders. Only healthy broiler chickens were selected after the 14-day brooding period to ensure consistent and accurate experimental results.

### Preparation of brooding and rearing pens

The experimental house and pens were meticulously cleaned with detergent powder and chlorine to eliminate dirt and debris before the experimental chickens arrived. Incandescent bulbs provided the necessary heat for brooding the birds, using the recommended 1-watt per bird to maintain body temperature. Rice hulls covered the brooding pen floor and were replaced daily to reduce ammonia buildup. Flappers were used to cover the entire pen during rainy days, protecting the flock from stray animals. The experimental house was divided into 18 partitions, with each bird allotted 1 square foot of space. The researcher ensured all necessary equipment and materials were available before the study commenced.

Strict biosecurity measures were implemented throughout the experimental period to protect the health of the chickens. Unauthorised individuals were prohibited from entering the area, and efforts were made to prevent dust and dirt from spreading in the chicken pens. Cleanliness and orderliness were meticulously maintained in the experimental area, with regular disinfection carried out. Manure removal and litter material replacement were conducted twice a week to prevent ammonia buildup and the introduction of diseases that could harm or kill the experimental broiler chickens.

### Brooding the experimental birds

The brooding period for the experimental birds lasted 14 days, with incandescent electric bulbs providing the necessary artificial heat at a rate of 1-watt per bird following the recommended 29.4 to 35.0°C during the first week of age and 26.7 to 32.2 °C on the second week of age (Deaton *et al*., 1996). The chicks' behaviour was closely monitored to determine the appropriate temperature: chicks huddling under the brooder indicated a need for more heat, while chicks moving away suggested excessive heat. Adequate floor space was provided to promote faster growth and minimise competition. The brooding house dimension was 18 meters by 8 meters.

## Grouping and weighing of birds

The birds were allocated to the pens based on the proposed treatments, with an average initial weight of 400.2 ±45.61 after the brooding period. Weekly weigh-ins were conducted every seven days to monitor their growth. The final weights were measured at the end of the study.

## Feeding and water management

The experimental birds were provided with the necessary amount and types of booster feeds, as well as the formulated protein-enriched cassava meal-based diets, from the starter to the finisher stage. The *ad libitum* feeding system was followed throughout the entire duration of the study. All experimental chickens were supplied with clean drinking water using plastic gallon waterers, ensuring fresh and clean water was readily available at all times.

## Preparation of the experimental diet

### *Cassava meal fermentation*

Fermentation is a crucial technique commonly used in various processing methods. Prior to microbial fermentation, a concentrated form of Effective Microorganism Inoculant (EM 1) was prepared, which primarily consists of photosynthetic bacteria (*Rhodopseudomonas palostris and Rodobactor spaeroids*), lactic acid bacteria (*Lactobacillus plantarum, Lactobacillus casei and Streptococcus lactis*), yeasts (*Saccharomyces cerevisiae and Candida utilis*), Ray fungi (*Streptomyces albs* and *Streptomyces griseus*) and fermenting fungi (*Aspergillus oryzae* and *Mucor hiemalis*) (Zuraini *et al*., 2010; Abdel Kader *et al*., 2023; EMRO, 2025). These microbes share similar physiological traits and can thrive together in a liquid culture environment.

To activate Effective Microorganism Inoculant (EM1) for nutrient enrichment, it was combined with molasses and water in a ratio of 94% water, 3% molasses, and 3% EM1. The mixture was stirred thoroughly, dissolved, and then stored in a plastic container for seven days, protected from direct sunlight because ultraviolet (UV) rays can damage or kill the beneficial microbes, reducing their viability and effectiveness. These microbes thrive in moist, shaded environments, and exposure to intense sunlight can disrupt their balance and activity. Keeping them away from direct sunlight helps maintain their potency (Masjoudi *et al*., 2021). Once the fermentation process was complete, the solution reached a stable pH of 3 and developed a distinct sweet and sour aroma, indicating its readiness for use (Orji and Akukalia, 2021; Wondmeneh *et al*., 2011). Cassava tubers were peeled and cut into small chips, which were then placed in a container. A mixture of 200 ml of Effective Microorganisms Activated Solution (EMAS) and 20 L of unchlorinated water was poured over the cassava chips. The cassava chips were soaked for seven days to ensure sufficient fermentation, followed by sun-drying to reduce moisture content at approximately 10-12% before grinding into small chunks using a mechanical feed grinder.

### *Mixing of synthetic amino acids with cassava meal*

The fermented cassava meal was enhanced with synthetic amino acids, such as DL-methionine and L-lysine, to boost its protein content following the recommended amino acid requirements for broiler starter, that is, 1.04% lysine, 0.41% methionine and for broiler finisher, which is 0.93% lysine and 0.35% methionine (Philsan, 2010). The feed formulations (Table 1) using protein-enriched cassava meal as the main ingredient were prepared as the basal diets for the experimental broiler chickens.

## Experimental design and treatments

A total of 180 broiler chickens were randomly assigned to a factorial experiment following a Completely Randomised Design. Factor A encompassed the different protein-enrichment methods for cassava meal, while Factor B represented the levels of protein-enriched cassava meal (PECM) in the diet. Each treatment had three replications, with ten birds per replication. The experimental treatments were as follows:

### *Factor A (Methods of protein enrichment)*

- M1 – Microbial fermentation (MF).
- M2 – Microbial fermentation plus amino acids (MF + AA).

### *Factor B (Levels of PECM in the diet)*

- L1 – 50% microbial fermented cassava meal (MFCM) in the diet.
- L2 – 55% microbial fermented cassava meal (MFCM) in the diet.
- L3 – 60% microbial fermented cassava meal (MFCM) in the diet.

## Data gathering and statistical analysis

### *Chemical laboratory analysis*

Samples of each feed formulation were brought to the Feed Chemical Laboratory for proximate analysis to

**Table 1.** The feed formulations in the study reflecting the varying levels of microbial fermented cassava meal.

| Ingredient | Amount (%) | | |
|---|---|---|---|
| | Level 1 | Level 2 | Level 3 |
| Ground yellow corn- #18 | 18.00 | 13.00 | 8.00 |
| Microbial fermented cassava meal (MFCM) | **50.00** | **55.00** | **60.00** |
| Soybean oil meal | 7.00 | 7.00 | 7.00 |
| Fish meal, 55% | 6.00 | 6.00 | 6.00 |
| Rice bran, D1 | 10.75 | 10.75 | 10.75 |
| Molasses | 4.00 | 4.00 | 4.00 |
| Vegetable oil | 2.00 | 2.00 | 2.00 |
| Limestone | 1.25 | 1.25 | 1.25 |
| Vitamin-mineral premix | 1.00 | 1.00 | 1.00 |
| Total | 100.00 | 100.00 | 100.00 |

determine the moisture, crude protein, ash, crude fiber, metabolizable energy, nitrogen free extract, and phosphorus content. To evaluate the impact of a microbial fermented protein-enriched cassava meal-based diet on the growth performance of broiler chickens, the following parameters were collected:

- Average Initial Weight (AIW): Birds were weighed using a digital scale before feeding them the formulated diet.
- Average Feed Consumption (AFC): Calculated by dividing the total feed given, minus leftovers, by the number of chickens.
- Water Consumption (WC): Measured by subtracting the water leftover from the amount provided.
- Average Final Weight (AFW): Birds were weighed with a digital scale at the end of the study.
- Average Gain in Weight (AGW): Calculated by subtracting the initial weight from the final weight, then dividing by the total number of chickens.
- Average Daily Gain (ADG): The difference between the final and initial body weight divided by the total feeding days.
- Feed Conversion Ratio (FCR): Total feed intake divided by total weight gain.
- Feed Cost per Kilogram of Chicken Produced (FCKCP): Derived by multiplying the FCR by the cost of feed per kilogram.
- Income Over Feed Cost (IOFC): Calculated by subtracting the feed cost from the gross sale of chicken.
- Dressing Percentage (DP): Carcass weight divided by live weight, multiplied by 100.
- Morbidity Rate (MoR): The number of diseased chickens divided by the total number of chickens, multiplied by 100.
- Mortality Rate (MR): The number of dead chickens divided by the total number of chickens, multiplied by 100.

The data was statistically analysed using analysis of variance for a Completely Randomised Design using the Statistical Tool for Agricultural Research version 2.0, with means compared using the Least Significant Difference (LSD) method.

## RESULTS AND DISCUSSION

This chapter includes the analysis, interpretation, and discussion of all the data gathered during the experiment. The following are the results and discussion of the parameters being tested:

### Nutrient profile of microbial fermented cassava meal

The chemical laboratory analysis conducted in this research, as presented in Table 2, demonstrates that the crude protein (CP) and metabolizable energy (ME) of microbial-fermented cassava meal were significantly enhanced by supplementing it with synthetic amino acids, L-lysine and DL-methionine after microbial fermentation. Statistical analysis of the results confirms highly significant improvements in crude protein percentage and metabolizable energy when L-lysine and DL-methionine are added post-microbial fermentation ($p<0.01$), which was further enhanced by the addition of these two essential amino acids, thus increasing the potential of MFCM to be used as replacement for ground yellow corn in broiler chicken diet. These findings align with Yasmeen and Ahmad (2025), who reported that cassava can be fermented to increase its protein content.

Likewise, Jumare *et al.* (2024), noted that physical and microbial pretreatments, including fermentation, effectively reduce cyanide levels in cassava waste. In particular, solid-state fermentation utilises moist, solid, and non-soluble organic matter as a nutrient and energy source. Various factors, including moisture content, particle size,

**Table 2.** Nutrient profile of the diet with varying methods and levels of microbial fermented cassava meal.

| Nutrient | M1L1 | M1L2 | M1L3 | M2L1 | M2L2 | M2L3 | SEM[1] | P-value[2] |
|---|---|---|---|---|---|---|---|---|
| Moisture, % | 10.7±1.1[a] | 9.6±0.1[a] | 10.2±0.1[a] | 10.1±0.1[a] | 10.1±0.3[a] | 8.7±0.2[a] | 0.5647 | 0.3984 |
| Crude protein, % | 9.9±0.5[b] | 9.8±0.8[b] | 8.4±0.1[b] | 21.2±0.2[a] | 21.7±0.6[a] | 21.7±1.0[a] | 0.5121 | 0.0000 |
| Ash, % | 6.7±0.1[a] | 8.5±0.1[a] | 7.6±0.2[a] | 6.5±0.6[a] | 7.2±0.1[a] | 6.6±0.2[a] | 0.5637 | 0.2134 |
| Crude fiber, % | 3.0±0.7[a] | 3.1±0.4[a] | 2.8±0.2[a] | 3.0±0.1[a] | 2.9±0.2[a] | 2.3±0.2[a] | 0.2357 | 0.3782 |
| Metabolizable energy, kcal | 2,966.0[b] | 2,993.0[b] | 2,984.0[b] | 3,089.0[a] | 3,048.0[a] | 3,074.0[a] | 14.37 | 0.0034 |
| Nitrogen free extract, % | 66.1[a] | 64.3[a] | 66.9[a] | 63.7[a] | 63.0[a] | 56.9[a] | 2.29 | 0.1172 |
| Phosphorus, % | 0.34±0.04[a] | 0.41±0.03[a] | 0.29±0.01[a] | 0.34±0.02[a] | 0.33±0.01[a] | 0.25±0.01[a] | 0.8845 | 0.3539 |

[1]Standard error mean. [2]P value for one-way ANOVA. Values in the same row that share the same superscripts are not statistically different (p>0.05) according to the LSD comparison test.

temperature, pH, medium composition, microbial inoculum type, and its density, play a crucial role in increasing protein levels, digestibility, amino acids, enzymes, and vitamins, thereby significantly enhancing cassava's potential as animal feed. Additionally, this study supports the conclusions of Omede *et al.* (2017), that supplementing cassava-based diets with essential amino acids, specifically methionine and lysine, is an effective strategy for improving poultry feed quality.

Likewise, Sengxayalth and Preston (2017) found that fermentation enhanced the true protein content of cassava pulp. The observed rise in crude protein levels during the process was likely due to the loss of 40% of the substrate's dry matter (DM), effectively concentrating and enriching the crude protein fraction as fermentation progressed. Egbune *et al.* (2023) also observed that fermented peeled and unpeeled cassava roots could be a safe and nutritionally beneficial replacement for maize in broiler diet. Further advancements in research are essential to enhance the nutritional value of cassava through various biotechnological methods, optimising its role as an energy source for broiler chickens (Ogbuewu *et al*., 2023).

Statistically, no significant differences among treatment means on the methods of protein enrichment and levels of inclusion on the average feed consumption, water consumption, gain in weight, average daily gain, and feed conversion ratio of the experimental broiler chickens fed with varying levels of MFCM in the diet (Table 3). There was no interaction effect found between the method of protein enrichment and levels of inclusion replacing ground yellow corn with MFCM from 44.00-55.56% in the diet on the performance of broiler chickens used in this experiment, which indicates that means of M1 and M2 of protein enhancement and L1, L2, and L3 of the levels of inclusion of MFCM are comparable with each other. The outcome of this experiment, where elevated levels of crude protein (CP) and metabolizable energy (ME) did not enhance broiler performance compared to diets with lower CP-ME content, may be attributed to several key factors. First, *nutrient imbalance or amino acid deficiencies* can occur despite increased CP, as broilers require specific essential amino acids (e.g., lysine, methionine, threonine) rather than total protein. An unbalanced amino acid profile leads to inefficient protein utilisation, with the excess being broken down for energy and potentially increasing the metabolic load without enhancing growth.

Second, *energy-protein synchrony* is vital. If ME is raised without aligning digestible protein and amino acid availability, birds may utilise nutrients inefficiently, resulting in fat deposition rather than lean tissue growth, or underperformance due to an amino acid bottleneck. Third, *environmental heat stress*, common in tropical regions like the Philippines, can depress feed intake. Under such conditions, broilers may consume less of the high-nutrient feed to regulate body temperature, negating its potential benefits.

Fourth, *anti-nutritional factors or digestibility challenges,* such as the presence of hydrocyanic acid in cassava, can hinder nutrient absorption. Without mitigating these factors or improving digestibility, enhanced nutrient content won't translate into better performance. Fifth, the *genetic potential of broilers* imposes an upper limit on growth. Once birds reach their genetically predetermined growth ceiling, additional CP and ME do not produce further gains. Lastly, *nutrient partitioning and metabolic cost* must be considered. High-CP diets elevate the burden of nitrogen excretion, consuming energy that could otherwise support growth. In some cases, lower-protein diets with optimised amino acid supplementation prove more efficient than diets with excessive crude protein.

This discovery aligns with Chauynarong *et al.* (2009), who highlighted that hydrocyanic acid released from cyanogenetic glycosides restricts the use of cassava. However, with appropriate processing, it is possible to increase the dietary inclusion of cassava meal for cost-effective poultry farming. Likewise, these findings are consistent with the results of Sultana *et al.* (2012) and Agunbiade et al. (2002), which demonstrated that the live weights of broilers were unaffected by any dietary group, regardless of the inclusion of cassava tuber meals.

In contrast, the findings of this study do not align with those of Sugiharto *et al.* (2020), who reported higher feed consumption and an increased feed conversion ratio (FCR) of broilers fed with fermented cassava roots. Similarly, Akapo *et al*. (2014) found that the inclusion of peeled cassava root meal (PCRM) in broiler diets led to significant increases in final live weight, weight gain, and feed intake. Additionally, Hossain *et al.* (2013) reported

**Table 3.** Average feed consumption (AFC), water consumption (WC), gain in weight (GW), daily gain (ADG), and feed conversion ratio (FCR) of Broiler chicken fed with varying levels of MFCM in the diet.

| Code | Description | AFC (g/b) | WC (L/b) | GW (g/b) | ADG (g/b) | FCR |
|---|---|---|---|---|---|---|
| Method of protein enrichment (M): main effect | | | | | | |
| M1 | Microbial Fermentation | 2736.89[a] | 0.168[a] | 1004.99[a] | 47.86[a] | 2.77[a] |
| M2 | Microbial Fermentation + Amino Acids | 2743.33[a] | 0.172[a] | 1118.54[a] | 53.26[a] | 2.48[a] |
| Level of inclusion (L): | | | | | | |
| L1 | 50 % MFCM | 2747.17[a] | 0.167[a] | 1025.37[a] | 48.83[a] | 2.72[a] |
| L2 | 55 % MFCM | 2737.17[a] | 0.175[a] | 1109.82[a] | 52.85[a] | 2.54[a] |
| L3 | 60 % MFCM | 2736.00[a] | 0.169[a] | 1050.11[a] | 50.01[a] | 2.61[a] |
| Method X Level (MXL): interaction effect | | | | | | |
| M1L1 | Microbial Fermentation, 50 % MFCM | 2761.00[a] | 0.167[a] | 1011.85[a] | 48.18[a] | 2.78[a] |
| M1L2 | Microbial Fermentation, 55 % MFCM | 2698.00[a] | 0.171[a] | 985.90[a] | 46.95[a] | 2.83[a] |
| M1L3 | Microbial Fermentation, 60 % MFCM | 2751.67[a] | 0.168[a] | 1017.21[a] | 48.44[a] | 2.70[a] |
| M2L1 | Microbial Fermentation + Amino Acids, 50 % MFCM | 2733.33[a] | 0.167[a] | 1038.90[a] | 49.47[a] | 2.67[a] |
| M2L2 | Microbial Fermentation + Amino Acids, 50 % MFCM | 2776.33[a] | 0.179[a] | 1233.73[a] | 58.75[a] | 2.25[a] |
| M2L3 | Microbial Fermentation + Amino Acids, 50 % MFCM | 2720.33[a] | 0.170[a] | 1083.00[a] | 51.57[a] | 2.52[a] |
| SEM | | 136.92 | 0.0084 | 107.83 | 5.13 | 0.3133 |
| P-value | | 0.9928 | 0.5641 | 0.2911 | 0.2914 | 0.5123 |
| F-test | | **ns** | **ns** | **ns** | **ns** | **ns** |
| CV, % | | **6.12** | **5.36** | **12.44** | **12.44** | **14.62** |

ns- not significant. Means with the same letter are not significantly different.

that broilers fed cassava-treated diets exhibited significantly higher feed intake, while live weight was notably reduced, whereas cassava-treated diets resulted in poorer feed conversion efficiency. Sultana *et al.* (2012) similarly found that broilers on a control diet (excluding CTM) had significantly higher body weight, while those given diets with the highest amount of CTM (45 $gkg^{-1}$) had the lowest body weight. Additionally, feed intake was significantly increased at 21 and 28 days of age for broilers supplemented with CTM, but no significant differences were observed among dietary treatments at 33 days of age. The feed conversion ratio (FCR) varied significantly throughout the trial, with broilers on a diet without CTM supplementation showing a superior FCR compared to others. This finding also contradicts Agunbiade *et al*. (2002), who noted that birds on a cassava-based diet consumed more feed daily to compensate for low protein and energy levels, but were more efficient in converting feed into body weight.

Results presented in Table 4 revealed no significant differences among treatment means on the methods of protein enrichment and levels of inclusion on the average feed cost per kilogram of broiler produced, income over feed cost, dressing percentage, morbidity rate, and mortality rate of the experimental broiler chickens fed with varying levels of MFCM in the diet. There was no interaction effect observed on the methods of protein enrichment and the varying levels of inclusion in the broiler chicken diets. This means that neither the method of protein enrichment nor the levels of inclusion replacing ground yellow corn with MFCM from 44.00 to 55.56% in the diet affect the parameters tested in this experiment. The absence of notable differences across performance and economic parameters suggests that microbial fermented cassava meal (MFCM), regardless of the protein enrichment technique or inclusion level (ranging from 44.00% to 55.56% substitution for ground yellow corn), performed comparably with each other. This indicates that MFCM, when properly fermented and enriched, can adequately support broiler productivity by providing similar levels of accessible nutrients, especially carbohydrates and fermentative by-products that sustain energy and protein availability. This parity across treatments implies that all diets were nutritionally balanced and met the birds' basic dietary requirements, even with significant corn replacement.

Broiler chickens are known for their digestive adaptability, particularly when alternative feed sources are introduced progressively. Their enzymatic and microbial systems likely adapted to the modified diet, mitigating fluctuations in nutrient profiles and preserving both physiological performance and feed efficiency. When fermentation and protein enrichment are effectively applied, they likely reduce anti-nutritional factors such as hydrocyanic acid in cassava and enhance digestibility. This reinforces the idea that the quality of feed processing has a more pronounced

**Table 4.** Average feed cost per kilogram of chicken produced (FCKCP), income over feed cost (IOFC), dressing percentage (DP), morbidity rate (MoR), and mortality rate (MR) of broiler chicken fed with varying levels of MFCM in the diet.

| Code | Description | FCKCP (Php) | IOFC (Php) | DP (%) | MoR (%) | MR (%) |
|---|---|---|---|---|---|---|
| Method of protein enrichment (M): main effect | | | | | | |
| M1 | Microbial Fermentation | 68.21[a] | 114.27[a] | 73.50[a] | 0.00[a] | 3.33[a] |
| M2 | Microbial Fermentation + Amino Acids | 74.79[a] | 122.84[a] | 72.84[a] | 1.11[a] | 5.56[a] |
| Level of inclusion (L): | | | | | | |
| L1 | 50 % MFCM | 74.97[a] | 112.67[a] | 73.35[a] | 0.00[a] | 5.00[a] |
| L2 | 55 % MFCM | 68.77[a] | 126.57[a] | 71.23[a] | 0.00[a] | 1.67[a] |
| L3 | 60 % MFCM | 70.75[a] | 116.43[a] | 74.94[a] | 1.67[a] | 6.67[a] |
| Method X Level (MXL): interaction effect | | | | | | |
| M1L1 | Microbial Fermentation, 50 % MFCM | 69.64[a] | 114.03[a] | 75.06[a] | 0.00[a] | 3.33[a] |
| M1L2 | Microbial Fermentation, 55 % MFCM | 69.60[a] | 111.43[a] | 69.53[a] | 0.00[a] | 3.33[a] |
| M1L3 | Microbial Fermentation, 60 % MFCM | 65.37[a] | 117.36[a] | 75.91[a] | 0.00[a] | 3.33[a] |
| M2L1 | Microbial Fermentation + Amino Acids, 50 % MFCM | 80.29[a] | 111.32[a] | 71.63[a] | 0.00[a] | 6.67[a] |
| M2L2 | Microbial Fermentation + Amino Acids, 50 % MFCM | 67.94[a] | 141.72[a] | 72.92[a] | 0.00[a] | 0.00[a] |
| M2L3 | Microbial Fermentation + Amino Acids, 50 % MFCM | 76.13[a] | 115.49[a] | 73.97[a] | 3.33[a] | 10.00[a] |
| SEM | | 8.20 | 20.42 | 4.58 | 1.92 | 6.94 |
| P-value | | 0.4964 | 0.6712 | 0.7550 | 0.4582 | 0.7761 |
| F-test | | **ns** | **ns** | **ns** | **ns** | **ns** |
| CV,% | | **14.05** | **21.09** | **7.66** | **424.26** | **191.21** |

ns- not significant. Means with the same letter are not significantly different.

impact on nutritional effectiveness than merely increasing the inclusion rate.

A plateau in biological response may also account for the uniformity in outcomes, especially in traits like dressing percentage, morbidity, and mortality, where biological systems often exhibit diminishing returns beyond a certain threshold of dietary change. Lastly, the lack of interaction between enrichment method and inclusion level indicates functional independence, confirming that neither approach hindered nor enhanced the other. This stability across substitution ranges supports MFCM as a reliable, cost-efficient alternative to ground yellow corn, with promising implications for feed sustaina-bility and greater use of locally available ingredients, a reflection of several efforts and commitment to resource optimisation and practical innovation in agriculture.

This observation aligns with Akinfala *et al.* (2011), who demonstrated that substituting maize with CPM in broiler diets can lower production costs. Likewise, Bhuiyan and Iji (2015) noted that it is possible to use cassava pellets in diets for broiler chickens at a level close to 50% of the diet to reduce the cost of production. Thereby, utilising locally available resources that can effectively substitute traditional feeds (Salas *et al.,* 2025). Wherein, Sultana *et al.* (2012) also found that mortality rates of broiler chickens were unaffected by any of the dietary treatments incorporated with cassava-treated meal.

## Conclusion

Due to the low protein content of cassava tubers as well as the presence of antinutritional factors, it needs to undergo processing such as peeling, slicing, fermentation, sun-drying, and grinding before it can be used as an ingredient in broiler diet, which is quite laborious, especially when a large quantity is needed. The addition of vegetable oil in the feed formulation to eliminate dustiness was an additional burden. Proper feed formulation is also necessary to avoid nutrient imbalance. Based on the study's findings, the crude protein content and metabolizable energy of microbial-fermented cassava meal can be significantly enhanced by supplementation with synthetic amino acids L-lysine and DL-methionine. Despite these nutritional enhancements, variations in supplementation levels resulted in comparable effects on the growth performance of broiler chickens. These findings suggest that either the M1 or M2 fermentation method, combined with 50% (L1), 55% (L2), or 60% (L3) MFCM, can be effectively incorporated into broiler chicken feed, replacing 44.00 to 55.56% of the ground yellow corn with no negative effect on the production performance. The experiment underscores the potential of microbially fermented cassava meal as an alternative to ground yellow corn, offering farmers a viable way to utilise other locally available farm produce in broiler production.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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