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EFFECTS OF *MORINGA OLEIFERA* LEAF POWDER AND TURMERIC POWDER ON CARCASS COMPOSITION AND MEAT QUALITY OF BROILER CHICKENS

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ABSTRACT

The escalating demand for animal products has led to widespread antibiotics usage in broiler diets to maintain health and productivity. However, concerns regarding the emergence of antibiotic-resistant bacteria, potential negative impacts on animal welfare and public health, and consumer preferences for natural alternatives have driven the search for safer and more sustainable approaches. This study aimed to investigate the potential of *Moringa oleifera* leaf powder (MOLP) and turmeric powder (TP) as antibiotic growth promoter alternatives in broiler chickens, focusing on their impact on performance, carcass characteristics, and meat quality. In a 3x3 factorial experiment, 360 Cobb-500 broilers were allocated to nine treatment groups receiving varying dietary levels of MOLP (0%, 1%, 2%) and TP (0%, 0.25%, 0.5%). Additionally, a separate experiment with 80 birds evaluated the effects of flavomycin supplementation (0.1%) compared to a control group. The results demonstrated that MOLP supplementation significantly increased key performance parameters, including feed intake, body weight gain, final body weight, and production efficiency factor, particularly at the 2% inclusion level. TP supplementation did not significantly influence overall growth performance. Flavomycin, as a positive control, significantly improved final body weights compared to the control group. Interestingly, significant interactions were observed between MOLP and TP, influencing specific aspects of carcass composition and meat quality. Combined supplementation significantly affected liver yield and meat flavour, suggesting potential synergistic effects. However, no significant impacts were observed on other carcass composition parameters, physical meat measurements (colour, drip loss, cooking loss), or sensory attributes (appearance, juiciness, tenderness). Notably, supplementation with 2% MOLP increased dressed weight and breast yield while simultaneously reducing meat redness. Additionally, 0.5% TP supplementation significantly increased gizzard yield, indicating potential benefits for digestive function. Flavomycin supplementation did not significantly influence any carcass composition, physical, or sensory parameters. These findings offer promising evidence that MOLP and TP can be incorporated into broiler diets at levels up to 2% and 0.5%, respectively, as viable alternatives to antibiotic growth promoters. MOLP and TP demonstrated the potential to enhance broiler performance, influence specific carcass and meat quality attributes without compromising overall quality, and promote specific physiological processes like gizzard development. Further research is encouraged to explore the long-term effects of these additives, optimize their inclusion levels for specific benefits, and investigate their potential impact on broiler health and disease resistance.

Key words: Antibiotic alternatives, Broiler Meat, Moringa, Performance, Phytobiotics, Turmeric

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INTRODUCTION

Antimicrobial resistance (AMR) poses a significant threat to human and animal health, driven in part by the sub-therapeutic use of antibiotics in food animal production [1]. This has led to increased consumer demand for safer meat products, prompting the exploration of alternative feed additives. Emerging as promising alternatives to antibiotic growth promoters are various feed additives, including organic acids, prebiotics, probiotics, and phytogenic feed additives (PFAs) [2].

Phytogenic feed additives (PFAs) are natural substances derived from medicinal plants offering a range of benefits for livestock, including improved nutrition, enhanced health, antimicrobial properties, and increased production performance [3]. Their primary mode of action involves controlling potential pathogens and modulating gut microbiota [3].

Studies across diverse animal species have demonstrated the efficacy of PFAs. Kiambom *et al*. [4] found that ginger powder supplementation improved renal and hepatic functions in pigs while effectively treating gastrointestinal nematodes. Similarly, Giorgino *et al*. [5] observed improved milk fat content and coagulation in dairy goats fed a microencapsulated mixture of organic acids and botanicals, without impacting metabolic status.

In the poultry industry, PFAs hold a significant potential for promoting optimal bird performance by mitigating microbial threats, enhancing intestinal health, stimulating digestive secretions and enzymatic activities, and improving feed efficiency [3]. *Moringa oleifera* leaves and turmeric rhizomes, with their diverse bioactive compounds, are particularly promising for poultry due to their beneficial effects on bird growth, immunity, meat quality, and antioxidant status. For instance, Alshukri *et al*. [6] observed increased final body weight, body weight gain, and feed conversion ratio in broilers fed *Moringa oleifera* leaf meal. Additionally, Sahoo *et al*. [7] reported that turmeric powder supplementation improved immunity, antioxidant status, and gut health in broiler chickens.

Moringa's beneficial effects are attributed to its phytonutrients, acting as natural antioxidants, improving product quality, nutrient utilization, and broiler health [8]. Turmeric's role is primarily attributed to curcumin, a lipophilic polyphenol with diverse beneficial properties. While curcumin's bioavailability is limited, studies suggest that flavonoids like quercetin, abundant in Moringa leaves, can significantly enhance its bioavailability [9].

Although previous research has highlighted the individual benefits of Moringa and turmeric in broiler production, their combined effects remain unexplored,

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particularly in the context of Malawi. Investigating the efficacy of *Moringa oleifera* leaf powder (MOLP) and turmeric powder (TP) as a combined PFA in this region is crucial due to the challenges faced by local poultry farmers, including limited access to expensive feed additives and the need for sustainable and cost-effective production practices. This study aims to address this gap by evaluating the effects of MOLP and TP on the performance, carcass composition, meat physical attributes, and sensory parameters of Cobb-500 broiler chickens.

MATERIALS AND METHODS

Experimental Location

The research was conducted at the Animal Science Department's Student Farm Poultry Unit at Lilongwe University of Agriculture and Natural Resources (LUANAR), Lilongwe, Malawi (latitude 14°10'49.1" S, longitude 33°46'38.1" E).

Preparation of Test Ingredients

Sun-dried Moringa leaves and fresh turmeric rhizomes were purchased from local producers in Lilongwe city, Malawi. Following the procedure outlined by Oso *et al*. [10] the rhizomes were sun-dried for 5 days. The moisture content for the dried leaves and rhizomes were 8.21% and 9.17%, respectively as shown in Table 1. Both ingredients were then ground into fine powders using a 0.15 mm sieve and stored at room temperature in separate plastic bags until diet formulation.

Experimental Birds, Design, and Dietary Treatments

Ethical approval for the research was obtained from the Department of Animal Science, Faculty of Agriculture, Lilongwe University of Agriculture and Natural Resources. A total of 360-day-old Cobb-500 broiler chicks were purchased from Central Poultry 2000 Limited. After a two-week brooding period, the chicks were weighed and randomly assigned to 72-floor pens in a 3 x 3 factorial arrangement. The main effects were: turmeric powder supplementation (basal diet [TP_0], basal diet + 0.25% turmeric powder [$TP_{0.25}$], or basal diet + 0.5% turmeric powder [$TP_{0.5}$]), and *Moringa oleifera* leaf powder supplementation (basal diet [MP_0], basal diet + 1% MOLP [MP_1], or basal diet + 2% MOLP [MP_2]). The chosen inclusion levels of MOLP and TP were based on recommendations from previous studies investigating their effects on broiler performance [11, 12]. These studies suggested that levels up to 2% and 0.5% for MOLP and TP, respectively were well-tolerated and potentially beneficial for broiler growth and health. Concurrently, an additional experiment was conducted with 80 birds randomly assigned to two dietary treatments: basal diet without flavomycin supplementation (-VE) and basal diet with 0.1 flavomycin supplementation (+VE). All treatments were replicated eight times with five birds per replicate.

The individual feed ingredients' proximate composition (Table 1) was determined

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using the Association of Official Analytical Chemists (AOAC) methods [13]. Starter and finisher diets (Table 2) were formulated to meet or exceed the dietary requirements of the birds according to NRC recommendations [14].

Growth Performance

On day 15, individual chick weights were measured. Subsequent body weights were recorded weekly until day 42. Daily feed intake was calculated by subtracting the refusals from the previous day's feed offering. Body weight gain was calculated as the difference between initial and final body weight. Production efficiency factor was calculated using the formula provided by Alshukri *et al.* [6].

Carcass Composition

At the end of the feeding trial, four replicates per treatment were randomly selected using a two-stage sampling technique. One bird from each sampled replicate (4 birds per treatment) was then randomly chosen. After a 15-hour fasting period, the birds were weighed, humanely slaughtered by cervical dislocation, defeathered, eviscerated, and weighed again to determine carcass weight. Dressing percentage was calculated as a percentage of live weight. Individual primal cut weights were recorded and expressed as proportions of dressed weight. Breasts were collected, labelled, and stored at 4°C for 24 hours before undergoing physical and sensory analyses.

Dressing percentage (%) = (hot carcass weight (g) / final liveweight (g)) x 100   (I)

Meat Physical Analyses

Meat colour (L*, a*, b*) was measured using a calibrated CR-400 Chroma Meter (Konica Minolta Sensing, Inc., Tokyo, Japan) following International Commission of Illumination (CIE) lab values. Triplicate readings were taken for each meat sample after 30 minutes of air exposure to allow blooming. The colorimeter used D65 illuminant, with the standard observer angle set at 10° and the aperture size of 8mm.

After 24-hour storage at 4°C, cooking and drip losses were measured following the procedure described by Honikel and Ham [15]. Cooking loss (CL) and drip loss (DL) were calculated as the weight loss (corrected for size) and expressed as a percentage.

CL or DL (%) = [(initial weight (g) - final weight (g)) / initial weight (g)] x 100   (II)

Meat Sensory Evaluation

A panel of 16-trained panelists with prior knowledge and experience in sensory evaluation assessed the meat samples for tenderness, juiciness, flavour, and appearance using a 5-point intensity scale. Precooked meat samples (cooked at 75°C for 50 minutes) were presented to the panelists along with a questionnaire

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containing attributes for each sensory parameter. Tenderness was rated by how easy or tough it was to chew the meat sample, based on the procedure described by Love [16]. Juiciness was rated by considering the perceived moisture released by the meat during chewing and the amount of saliva required for mastication, as described by Winger and Hagyard [17]. Flavour was rated by considering the overall taste of the meat, evaluated by actual tasting and following the procedure outlined by Bett and Grimm [18]. Appearance was rated by determining the perceived colour and overall visual appeal of the cooked meat sample, evaluated based on its paleness or darkness.

Statistical Analysis

R version 4.1.3 [19] was used for statistical analysis of all data related to growth performance, carcass composition, physical measurements, and sensory evaluations. A two-way analysis of variance (ANOVA) was conducted using the general linear models' procedure to assess the main effects of *Moringa oleifera* leaf powder (MOLP) and turmeric powder (TP), as well as their interaction. Each individual pen was considered the experimental unit for growth performance analysis, while individual chickens were the units for carcass composition analysis. For meat physical and sensory analyses, each individual meat block was considered the experimental unit.

To evaluate the effect of flavomycin supplementation on growth performance, carcass composition, physical measurements, and sensory evaluations, a two-sample t-test was employed. Statistical significance was set at $P < 0.05$. Post hoc analysis using the TukeyHSD function further examined differences between treatment groups. Additionally, the Cohen.d function was used to compare the magnitude of differences between treatments by comparing the relative treatment differences between the flavomycin (+VE) group and individual TP (TP0.25, TP0.5) or MOLP (MP1, MP2) treatments.

RESULTS AND DISCUSSION

Growth Performance

Table 3 summarizes the effects of *Moringa oleifera* leaf powder (MOLP) and turmeric powder (TP) supplementation on daily feed intake (FI), final body weight (FBW), average daily gain (ADG), feed conversion ratio (FCR), and production efficiency factor (PEF). Combined supplementation of MOLP and TP did not influence ($P>0.05$) the growth performance of broiler chickens. This indicated that there were no synergistic benefits of combined supplementation of MOLP and TP in broiler performance.

Supplementation of MOLP in the diet led to a significant increase ($P < 0.05$) in FI, FBW and BWG. Birds receiving MP_2 exhibited the highest FI, FBW and BWG

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compared to unsupplemented birds throughout the entire experimental period (day 14 to day 42). The increase in feed intake due to MOLP supplementation could be attributed to the antioxidant properties of biologically active compounds present in Moringa leaves, which may stimulate voluntary feed intake by regulating glucose homoeostasis [20]. Additionally, the presence of natural antioxidants in Moringa leaves may help maintain feed palatability and prolong the shelf life of feed by delaying fat and vitamin oxidation. Moreover, MOLP supplementation may enhance growth by providing various minerals and phytonutrients that stimulate protein synthesis through the bird's enzymatic system [21].

While several studies have reported improvements in growth performance with MOLP supplementation [22, 23, 24], contradictory results have also been observed [20]. These discrepancies may be attributed to various factors, including the inclusion rate of MOLP, variations in the concentration of bioactive compounds in the leaves, and differences in the experimental environment.

Production efficiency factor reflects any inefficiencies or improvements in broiler growth and serves as a guide to the potential changes in the final achieved live cost. According to Table 3, MOLP supplementation affected ($P<0.05$) PEF, with birds fed 2% MOLP exhibiting highest levels. The increase in PEF indicates that MOLP supplementation improves the overall performance of broiler chickens. These findings align with previous studies reporting increased PEF due to MOLP supplementation [6]. Importantly, while MOLP positively influenced growth parameters and PEF, it did not significantly affect FCR. This suggests that MOLP supplementation does not negatively impact the birds' ability to convert feed into body mass.

On the other hand, Table 3 shows that dietary supplementation of TP did not have a significant influence ($P>0.05$) on FI, FBW, BWG, FCR and PEF of broiler chickens. Similar results were reported by Hosseini-Vashan *et al.* [25], who found no differences in body weight, feed intake, feed conversion efficiency, and production index of broiler chickens when supplemented with turmeric powder at 0.4% and 0.8%. Furthermore, Sugiharto *et al*. [26] reported that supplementation of acidified turmeric powder at 1% did not affect the total weight gain, cumulative feed intake and feed conversion ratio of broiler chickens. The non-significant results on performance due to turmeric powder supplementation suggests that, the diets were nutritionally adequate to meet the birds' growth requirements, rendering TP supplementation unnecessary for optimal performance.

It is important to note, however, that conflicting results exist in the literature. For example, Mondal *et al*. [27] reported improved growth performance in broiler chickens supplemented with turmeric powder. This discrepancy could be attributed

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to variations in the concentration of bioactive compounds present in the turmeric powder used, as these influence their biological activity.
Birds supplemented with flavomycin, an antibiotic growth promoter, exhibited significantly higher FBW and PEF compared to the control group (Table 3). This corroborates previous research highlighting the ability of antimicrobials as feed additives to enhance growth and production efficiency through improved feed utilization, gut health, and overall bird health [28]. Interestingly, the effects of flavomycin on FBW and PEF were comparable to those of MOLP supplementation when their respective treatments were compared using Cohen's d. This finding suggests the potential of MOLP as a viable natural alternative to antibiotic growth promoters in broiler production.

Overall, the results of the study suggest that *Moringa oleifera* leaf powder (MOLP) supplementation can significantly improve the growth performance of broiler chickens, including increased feed intake, final body weight, average daily gain, and production efficiency factor. The observed improvement may be attributed to the presence of antioxidants, minerals, and phytonutrients in Moringa leaves that stimulate feed intake, protein synthesis, and overall health. In contrast, turmeric powder supplementation did not significantly influence growth performance, suggesting that the diets provided adequate nutrients to meet the birds' growth requirements.

Carcass Composition
The effects of *Moringa oleifera* leaf powder (MOLP) and turmeric powder (TP) supplementation on dressed weight, dressing percentage, organ yields (liver, heart, gizzard), and primal cut yields (breast, drumstick, wing, thigh) are presented in Table 4. A significant interaction between MOLP and TP levels was observed only in liver yield, with birds fed MP_1+TP_0 exhibiting increased ($P<0.05$) liver yield compared to other treatment groups. This finding aligns with the suggestion of Zaefarian *et al*. [29] that higher liver yield indicates enhanced metabolic activity. It is possible that the supplementation enhanced the utilization of dietary energy and nutrients for maintenance functions, leading to increased liver size.

Irrespective of TP, MOLP supplementation significantly affected ($P<0.05$) dressed weight and breast yield. Birds fed 2% MOLP (MP_2) exhibited higher dressed weight and breast yield compared to birds that consumed the unsupplemented diet. These findings are consistent with previous studies demonstrating increased dressed weight and breast yield in broilers supplemented with MOLP [30, 31]. The observed results could be attributed to the optimal antioxidant activity of Moringa leaves, potentially stimulating protein synthesis in the birds' enzymatic system [27]. However, contradictory findings have been reported. Zanu *et al*. [32] observed no influence of MOLP on dressed weight, and Nkukwana *et al*. [20] found no

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significant effect on breast yield. Different MOLP quality, inclusion level in diet and bird health could explain the contradictory results found in previous studies. Despite affecting dressed weight and breast yield, MOLP supplementation did not influence dressing percentage, gizzard yield, heart yield, thigh yield, wing yield, or drumstick yield. This suggests that Moringa leaves provided adequate nutrients for normal muscle development in broilers. These findings align with the study of Alshukri *et al*. [6], which reported no effect of MOLP supplementation on thigh, wing, gizzard, and heart yields. However, Melesse *et al*. [30] observed significant effects on dressing percentage, thigh yield, and drumstick yield due to Moringa leaf meal supplementation.

Dietary TP supplementation affected (P<0.05) gizzard yield, with birds fed 0.5% TP ($TP_{0.5}$) exhibiting higher gizzard yield compared to the non-supplemented group (TP_0). The gizzard plays a vital role in poultry digestion, and its development is influenced by nutrition. The report of Nduku *et al*. [33] supports these findings, suggesting that increased gizzard yield reflects improved muscle development, potentially enhancing nutrient absorption through increased exposure to digestive enzymes and absorptive surfaces. Therefore, the results suggest that turmeric powder provided sufficient nutrients to promote gizzard development in the birds. However, contrasting results were reported by Mondal *et al*. [27], who found no significant effect of turmeric supplementation on gizzard yield. Turmeric powder (TP) supplementation did not significantly influence (P>0.05) dressed weight, dressing percentage, heart yield, thigh yield, drumstick yield, wing yield, or breast yield. This lack of significant effects suggests that TP provided sufficient nutrients to support normal muscle development in broiler chickens. These findings align with those of Sugiharto *et al*. [26] who reported no significant effects of turmeric supplementation on various carcass components.

Overall, this study demonstrates that MOLP and TP supplementation can influence specific carcass composition parameters in broiler chickens. MOLP significantly affects dressed weight, breast yield, and potentially liver yield, while TP affects gizzard yield. However, their effects vary depending on the supplementation level and interaction with each other. Further research is needed to fully understand the mechanisms underlying these observations and optimize the dietary inclusion levels of these phytogenic additives for optimal broiler performance.

Physical Meat Measurements

Meat colour

Poultry meat colour is a critical food quality attribute that is important for consumers' initial selection of raw meat products in marketplaces and their final evaluation and acceptance of the cooked product upon consumption. Table 5

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summarizes the effects of MOLP and TP supplementation on *L** (lightness), *a** (redness), and *b** (yellowness) values of broiler meat. No significant interaction effects were observed between MOLP and TP, suggesting no synergistic influence on meat colour.

MOLP supplementation significantly reduced ($P < 0.05$) *a** value, indicating a decrease in redness. Birds fed 1% MOLP (MP_1) exhibited the lowest *a** value compared to MP_2 and the control group. This reduction could be attributed to myoglobin oxidation to metmyoglobin, resulting in a colour change from red to brownish [34]. Similar findings have been reported in previous studies [34, 35]. However, other studies contradict these observations, showing an increase in *a** value due to MOLP supplementation [20, 32].

Despite its effect on *a**, MOLP did not influence *L** and *b** values, suggesting no significant impact on lightness and yellowness. Similarly, dietary supplementation of TP did not influence the *L**, *a**, and *b** values of broiler meat. The absence of significant effects due to MOLP or TP supplementation suggests that supplementation maintains the normal oxidative stability of broiler meat. These findings align with previous research [8, 32, 36].

Drip loss and cooking loss: Drip loss and cooking loss are commonly used parameters to measure water-holding capacity, which determines the visual acceptability, weight loss, cook yield, and sensory traits of meat. Table 5 presents the effects of MOLP and TP on drip loss and cooking loss of broiler meat. No significant influence was observed for either parameter, regardless of the supplementation level or combination. This suggests that the antioxidant properties of MOLP and TP helped preserve the integrity of cell membranes, leading to minimal water loss during storage and cooking [37]. Additionally, the high dietary fiber content of these additives might have contributed to water retention [35]. These findings align with previous studies reporting no significant effects of MOLP or TP on drip loss or cooking loss [28, 36, 38]. However, some studies have shown contrasting results [37, 39]. The lack of significant effects in this study could be attributed to the lower inclusion levels of MOLP and TP, which may not have been sufficient to influence these parameters.

Sensory properties: Sensory characteristics play a crucial role in consumer acceptability and eating satisfaction. Table 6 presents the effects of MOLP and TP on sensory attributes like appearance, flavour, juiciness, and tenderness. A significant interaction effect was observed for flavour, with birds fed MP_0+$TP_{0.5}$ exhibiting higher flavour scores compared to other treatment groups. This increase could be attributed to the presence of bioactive compounds in MOLP and TP, which may enhance flavour-producing reactions during cooking. No significant

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interaction effect was observed on meat appearance, juiciness and tenderness.

Neither MOLP nor TP supplementation individually influenced the appearance, juiciness, or tenderness of broiler meat. This suggests that their inclusion did not negatively affect meat palatability by altering colour, producing off-flavours, or impacting texture. These findings are consistent with previous research demonstrating no significant effects of phytobiotics on sensory qualities [31, 40]. However, some studies have reported contrasting results, showing positive effects of phytobiotics on certain sensory attributes [22, 39].

Overall, this study suggests that both MOLP and TP can be incorporated into broiler diets without negatively impacting meat colour, drip loss, cooking loss, or sensory properties. While individual effects on colour and flavour were observed, they were not detrimental to meat quality and consumer acceptability. Further research is needed to explore the synergistic effects of these additives and optimize their inclusion levels for enhancing specific sensory attributes or improving shelf-life of broiler meat.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Dietary supplementation with MOLP significantly improved broiler growth performance by enhancing feed intake, body weight, and production efficiency. Additionally, MOLP promoted muscle development, as evidenced by increased dress weight and breast yield. Importantly, MOLP supplementation did not negatively impact the physical and sensory properties of broiler meat.

Turmeric powder supplementation specifically increased gizzard yield, suggesting potential benefits for digestive function, without affecting other performance parameters or meat quality. Combining MOLP and TP influenced liver yield and meat flavor, indicating possible synergistic effects on specific metabolic and sensory characteristics. Flavomycin, an antibiotic growth promoter, improved final body weights but did not significantly impact carcass composition or meat quality. Notably, TP and MOLP demonstrated similar or greater effect sizes compared to flavomycin for certain parameters, suggesting their potential as natural alternatives. Based on these findings, this study recommends the inclusion of MOLP and TP in broiler diets at levels up to 2% and 0.5%, respectively, as natural alternatives to antibiotic growth promoters. These additives can enhance broiler performance, promote specific growth and metabolic processes, and maintain meat quality, contributing to a sustainable and ethical poultry industry.

Further research is encouraged to explore the synergistic effects of MOLP and TP combinations, optimize their inclusion levels for specific functional benefits, and investigate their long-term impact on broiler health and meat quality.

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Conflict of Interest
The authors declare that they have no conflict of interest.

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Credit authorship contribution statement
Ian Limbe: Conceptualisation, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Visualisation, Project administration. **Jonathan Tanganyika:** Methodology, Validation, Writing - review and editing, Supervision, Project administration. **Andy Safalaoh:** Methodology, Validation, Writing - review and editing, Supervision, Project administration.

Ethical of Approval
The study was approved by the Department of Animal Science, Faculty of Agriculture at Lilongwe University of Agriculture and Natural Resources.

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Table 1: Proximate composition (% on DM basis) of individual ingredients

Parameter	Maize meal	Soybean meal	MOLP	TP
Dry matter (%)	87.92	91.18	91.79	90.83
Crude protein (%)	8.70	40.78	21.10	7.01
Ether extract (%)	4.89	13.25	5.04	4.64
Crude fibre (%)	2.84	6.69	10.06	4.89
Ash (%)	1.55	4.27	12.29	6.19
Nitrogen-free extract (%)	69.94	24.19	43.30	68.10

MOLP = *Moringa oleifera* leaf powder; TP = turmeric powder

Table 2: Basal diet formulation for starter (0-21d) and finisher (22-42d) phases

Ingredient (kg)	Starter (0-21d)	Finisher (22-42d)
Maize	50.02	59.54
Soybean meal	45.72	36.34
Premix	0.30	0.30
Salt	0.40	0.40
Monocalcium phosphate	1.70	1.70
Limestone	1.65	1.85
DL-Methionine	0.17	0.15
L-Lysine	0.01	0.02
Total	100	100
Analysed chemical composition (%)		
Dry matter	93.98	93.78
Crude protein	23.35	20.37
Crude fibre	3.62	3.99
Ether extract	4.85	5.39
Ash	5.99	5.52
Nitrogen-free extract	56.17	58.51

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Table 3: Effect of *Moringa oleifera* leaf powder and turmeric powder on growth performance parameters of broiler chickens

Item		FI(g)	FBW(g)	BWG(g)	FCR	PEF
Moringa level	MP_0	3006^b	1695^b	1405^b	2.11	167^b
	MP_1	3070^a	1744^{ab}	1456^{ab}	2.10	185^{ab}
	MP_2	3094^a	1788^a	1497^a	2.06	186^a
Turmeric level	TP_0	3006	1695	1405	2.11	167
	$TP_{0.25}$	2979	1682	1393	2.11	172
	$TP_{0.5}$	2987	1704	1418	2.10	169
Moringa level x turmeric level	MP_0+TP_0	3006	1695	1405	2.11	166
	$MP_0+TP_{0.25}$	2979	1682	1393	2.11	172
	$MP_0+TP_{0.5}$	2987	1704	1418	2.10	169
	MP_1+TP_0	3070	1744	1456	2.10	185
	MP_2+TP_0	3094	1788	1497	2.06	186
	$MP_1+TP_{0.25}$	3150	1833	1544	2.04	198
	$MP_2+TP_{0.25}$	3134	1810	1526	2.04	197
	$MP_1+TP_{0.5}$	3034	1737	1451	2.07	181
	$MP_2+TP_{0.5}$	3207	1814	1527	2.07	192
Flavomycin level	-VE	3006	1695^b	1405	2.11	167^b
	+VE	3029	1763^a	1474	2.04	191^a
P-Value	Moringa	<0.001	0.006	0.005	0.335	0.033
	Turmeric	0.60	0.627	0.581	0.749	0.510
	Interaction	0.087	0.623	0.632	0.951	0.961
	Flavomycin	0.42	0.044	0.062	0.102	0.015
SEM		32.89	38.55	37.96	0.04	9.84

Means within columns with different superscript differ significantly at P < 0.05
FI = feed intake; FBW = final body weight; BWG = body weight gain; FCR = feed conversion ratio; PEF = production efficiency factor

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Table 4: Effect of *Moringa oleifera* leaf powder and turmeric powder on carcass composition of broiler chickens

Item		DW	DP	BY	TY	WY	DY	GY	HY	LY
Moringa level	MP_0	1440.5^{b}	68.8	35.01^{ab}	15.67	12.71	24.43	2.54	0.82	2.69^{a}
	MP_1	1898^{a}	69.4	33.94^{b}	14.92	12.57	24.21	2.35	0.76	3.55^{a}
	MP_2	1990.3^{a}	70.4	39.48^{a}	16.52	11.77	26.71	2.18	1.00	2.29^{b}
Turmeric level	TP_0	1440.5	68.8	35.01	15.67	12.71	24.43	2.54^{ab}	0.82	2.69
	$TP_{0.25}$	1576.8	68	33.23	15.37	12.56	25.11	2.51^{b}	1.01	2.99
	$TP_{0.5}$	1369	69.1	30.63	15.66	11.58	24.27	2.88^{a}	1.04	2.91
Moringa level x turmeric level	MP_0+TP_0	1440.5	68.8	35.01	15.67	12.71	16.47	2.54	0.82	2.69^{ab}
	$MP_0+TP_{0.25}$	1576.8	68	33.23	15.37	12.56	15.69	2.51	1.01	2.99^{ab}
	$MP_0+TP_{0.5}$	1369	69.1	30.63	15.66	11.58	16.32	2.88	1.04	2.91^{ab}
	MP_1+TP_0	1898	69.4	33.94	14.92	12.57	15.87	2.35	0.76	3.55^{a}
	MP_2+TP_0	1990.3	70.4	39.48	16.52	11.77	16.64	2.18	1.00	2.29^{b}
	$MP_1+TP_{0.25}$	2082	70.7	38.51	16.84	11.63	16.62	2.53	0.81	2.18^{b}
	$MP_2+TP_{0.25}$	1890.8	70.7	38.95	15.65	11.90	15.41	2.34	0.74	2.21^{b}
	$MP_1+TP_{0.5}$	1751.3	70	35.35	15.09	12.05	15.39	2.67	0.76	2.58^{ab}
	$MP_2+TP_{0.5}$	2033	70.2	33.72	16.33	11.55	16.22	2.81	0.76	2.53^{ab}
Flavomycin level	-VE	1440.5	68.8	35.01	15.67	12.71	16.47	2.54	0.82	2.69
	+VE	1718.3	70.5	33.66	16.00	12.00	16.52	2.13	0.79	2.59
P-Value	Moringa	<0.001	0.07	0.015	0.708	0.506	0.940	0.324	0.14	0.023
	Turmeric	0.202	0.934	0.076	0.921	0.376	0.728	0.030	0.99	0.155
	Interaction	0.197	0.829	0.291	0.567	0.675	0.530	0.854	0.235	0.012
	Flavomycin	0.351	0.129	0.63	0.76	0.39	0.94	0.12	0.82	0.76
SEM		84.08	0.87	1.73	0.87	0.49	0.66	0.17	0.09	0.19

Means within columns with different superscript differ significantly at $P < 0.05$ SEM= standard error of means; DW (g) = dressed weight; DP (%) = dressing percentage; GY (%) = gizzard yield; LY (%) = liver yield; HY (%) = heart yield; BY (%) = breast yield; TY (%) = thigh yield; WY (%) = wing yield; DY (%) = drumstick yield

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Table 5: Effect of *Moringa oleifera* leaf powder and turmeric powder on colour parameters, cooking loss and drip loss of broiler meat

Item		Lightness (L*)	Redness (a*)	Yellowness (b*)	Cooking loss (%)	Drip loss (%)
Moringa level	MP_0	66.29	4.88[a]	11.40	29.79	10.13
	MP_1	64.11	2.43[b]	11.01	29.96	7.36
	MP_2	62.65	3.73[ab]	12.65	30.65	8.23
Turmeric level	TP_0	66.29	4.88	11.40	29.79	10.13
	$TP_{0.25}$	67.77	3.50	12.51	30.31	5.58
	$TP_{0.5}$	64.48	4.76	10.87	32.40	6.50
Moringa level x turmeric level	MP_0+TP_0	66.29	4.88	11.40	29.79	10.13
	MP_0+$TP_{0.25}$	67.77	3.50	12.51	30.31	5.58
	MP_0+$TP_{0.5}$	64.48	4.76	10.87	32.40	6.50
	MP_1+TP_0	64.11	2.43	11.01	29.96	7.36
	MP_2+TP_0	62.65	3.73	12.65	30.65	8.23
	MP_1+$TP_{0.25}$	64.40	3.47	11.29	31.06	8.94
	MP_2+$TP_{0.25}$	65.20	4.26	12.79	29.28	8.28
	MP_1+$TP_{0.5}$	63.83	2.55	10.58	29.56	8.71
	MP_2+$TP_{0.5}$	63.93	1.87	13.15	32.48	4.93
Flavomycin level	-VE	66.29	4.88	11.40	29.79	10.13
	+VE	66.97	3.50	11.93	29.99	7.14
P-Value	Moringa	0.335	0.007	0.186	0.879	0.692
	Turmeric	0.497	0.382	0.813	0.580	0.422
	Interaction	0.897	0.058	0.959	0.635	0.228
	Flavomycin	0.831	0.189	0.83	0.95	0.11
SEM		1.63	0.60	1.33	1.42	1.41

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Table 6: Effect of *Moringa oleifera* leaf powder and turmeric powder on appearance, juiciness and tenderness of broiler meat

Item		Appearance	Flavour	Juiciness	Tenderness
Moringa level	MP_0	4.10	2.68	3.13	3.33
	MP_1	3.42	2.79	3.02	3.19
	MP_2	3.46	2.79	2.77	3.08
Turmeric level	TP_0	4.10	2.68	3.13	3.33
	$TP_{0.25}$	4.00	2.38	3.42	3.63
	$TP_{0.5}$	3.83	3.21	3.67	4.13
Moringa level x turmeric level	MP_0+TP_0	4.10	2.68^{ab}	3.13	3.33
	MP_0+$TP_{0.25}$	4.00	2.38^{b}	3.42	3.63
	MP_0+$TP_{0.5}$	3.83	3.21^{a}	3.67	4.13
	MP_1+TP_0	3.42	2.79^{ab}	3.02	3.19
	MP_2+TP_0	3.46	2.79^{ab}	2.77	3.08
	MP_1+$TP_{0.25}$	3.46	2.79^{ab}	3.63	3.92
	MP_2+$TP_{0.25}$	3.40	2.88^{ab}	3.19	3.29
	MP_1+$TP_{0.5}$	3.92	2.33^{b}	3.17	3.21
	MP_2+$TP_{0.5}$	4.08	2.89^{ab}	3.17	3.42
Flavomycin level	-VE	4.10	2.68	3.13	3.33
	+VE	3.63	2.71	3.46	3.79
P-Value	Moringa	0.067	0.483	0.326	0.236
	Turmeric	0.206	0.748	0.175	0.207
	Interaction	0.237	0.047	0.829	0.376
	Flavomycin	0.289	0.918	0.387	0.315
SEM		0.22	0.18	0.27	0.27

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