Crossref

IJBSM December 2025, 16(12): 01-12

Article AR6630

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2025.6630

Possibilities of using Moringa (*Moringa oleifera*) Seed Meal as a Partial Substitute for Groundnut Cake in Broiler Diets and its Effect on Growth Performance of Broiler Chicks

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ABSTRACT

The experiment was conducted from February to March, 2018 at Poultry unit of CVAS, Udaipur (Rajasthan), to investigate the possibilities of using *Moringa oleifera* Seed Meal (MOSM) as a partial substitute for groundnut cake in broiler diets and its effect with or without using an acidifier as a feed additive on the growth performance of broiler chicks. A feeding trial of 42 days was conducted on 300 broiler chicks in a 5×2 factorial design. The dietary treatments were basal diet as control without MOSM (T_1), basal diet with MOSM @ 1% (T_2), 2% (T_3), 3% (T_4), 4% (T_5), basal diet with Acidifier @ 1 g kg^{-1} feed (T_6), basal diet with MOSM @ 1, 2, 3 and 4% with Acidifier @ 1 g kg^{-1} feed for T_7, T_8, T_9 and T_{10}, respectively. Highly significant ($p<0.01$) effect of dietary treatments i.e. inclusion of MOSM at different levels on body weight, body weight gain, average daily gain, performance index, protein efficiency ratio, nitrogen balance, digestibility of dry matter, crude protein, ether extract and crude fiber were observed. However, the effect of MOSM in the broiler ration on feed conversion efficiency and protein efficiency ratio was observed to be significant ($p<0.05$). The effect of acidifier on dry matter digestibility was observed to be significant ($p<0.05$). It was concluded that MOSM with or without an acidifier can be incorporated in the broiler's diet without any adverse effect on the growth performance of the broiler chicks.

KEYWORDS: Acidifier, broiler, digestibility, growth, *Moringa oleifera* seed meal

***Citation* (VANCOUVER):** Manju et al., Possibilities of using Moringa (*Moringa oleifera*) Seed Meal as a Partial Substitute for Groundnut Cake in Broiler Diets and its Effect on Growth Performance of Broiler Chicks. *International Journal of Bio-resource and Stress Management,* 2025; 16(12), 01-12. HTTPS://DOI.ORG/10.23910/1.2025.6630.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 26th August 2025 RECEIVED in revised form on 02nd December 2025 ACCEPTED in final form on 19th December 2025 PUBLISHED on 26th December 2025

1. INTRODUCTION

The population of India is huge and increasing every day so getting good-quality food to every individual is a challenging task. The poultry industry is a wide sector. It provides good quality protein in a very short span of 35–42 days. The success of the poultry sector depends on effective feed management because feed alone contributes 60–70% of poultry production costs (Sharma et al., 2022). Poultry production, particularly broiler production, is the quickest way to increase the availability of high-quality protein for human consumption (Karnani et al., 2019). The capacity of poultry to provide rich organic manure as natural fertilizer is an important source of income to the persons engaged in allied activities in the poultry business (Karnani et al., 2020). Chicken is the most widely accepted meat in India. In contrast to beef and pork, it does not have any religious taboos. Poultry production performance largely depends on nutrition and environmental factors. One of the practical solutions to some of the problems of poultry in the tropics is to pay attention to the areas of nutrient requirements of birds for maintenance and production and the nutrient composition of the available feedstuffs. The most logical step to take in solving the shortage and dwindling raw material supply is to direct efforts towards utilizing plants' by-products and wastes for feeding poultry birds. Groundnut cake, a conventional feed resource, has been used as the source of animal protein in diets of poultry in many countries due to the unavailability of cheaper alternative protein sources. With the present trend of rising prices of feedstuffs, considerable attention has been placed on the search for non-conventional feedstuffs. In many tropical and subtropical countries, various parts of moringa (leaves, fruits, immature pods, flowers and seeds) are incorporated into the traditional food of humans (Siddhuraju and Becker, 2003; Anhawange et al., 2004). Moringa is universally referred to as "the miracle plant" or "the tree of life". Almost every part of M. oleifera can be used for food, medication and industrial purposes (Khalafalla et al., 2010). The leaves, flowers and pods are used as good sources of vitamins A, B and C, riboflavin, nicotinic acid, folic acid, pyridoxine, ascorbic acid, beta-carotene, calcium, iron, and alpha-tocopherol (Dahot, 1988). The relative lack of anti-nutritional components and the high protein, lipid and sulphur-containing amino acid contents encourage the use of moringa seeds as an animal feed (Ferreira et al., 2008). It is an excellent source of proteins for monogastric animals (Ferreira et al., 2008). Moringa seeds contain antibiotics (terygospermin), fatty acids like linolenic acid, linoleic acid, behenic acid and oleic acid (Ben oil). Some researchers have claimed that moringa improves performance (Wahab et al., 2020; Khalid et al., 2021; Ullah et al., 2022), and other studies did not significantly improve performance indicated by high FCR value (El-Deep et al., 2019; Alabi et al., 2020). Poultry diet is normally formulated to meet the requirements for proper production. Also, the full benefits of the nutrient may not be obtained unless we add a number of feed additives. Several substances as feed additives have been investigated in recent years with the aim of finding alternatives to growth-promoting antimicrobials that are able to support productive performance and prevent the incidence of some diseases in poultry (Huyghebaert et al., 2011). Among such substances, acidifiers have the potential to improve nutrition utilization, alter gut pH, and cease the growth of dangerous microorganisms in the digestive system (Melaku et al., 2021; Hamidifard et al., 2023; Okey, 2023).

This study, therefore, considers the replacement of groundnut cake at different levels of *Moringa oleifera* seed meal with supplementation of acidifier on the growth performance of broiler chicks.

2. MATERIALS AND METHODS

The present investigation was conducted from February to March, 2018 at the Poultry farm and the Department of Animal Nutrition of College of Veterinary and Animal Science, Navania, Vallabhnagar, Udaipur, Rajasthan University of Veterinary and Animal Sciences, Bikaner.

2.1. *Processing of Moringa oleifera seeds*

Moringa oleifera seeds were purchased from the local market and sorted out manually. Moringa seeds were allowed to soak in water overnight and rinsed with water the next morning. Then Moringa seeds were dried and ground in a domestic blender to obtain *Moringa oleifera* seed meal (MOSM), which was added to the basal diets.

2.2. *Acidifier*

Commercial acidifier AlvipH, manufactured by Alivira Health Care, a combination of formic acid, propionic acid, benzoic acid, butyric acid and orthophosphoric acid was included in the ration @ 100 g 100 kg of feed^{-1}.

2.3. *Experimental house management*

The broiler chicken house was thoroughly cleaned with water and disinfected with formalin. All waterers and feeders were thoroughly cleaned and disinfected before use. Heating equipment was turned on 24 hours before the arrival of the chicks. All the chicks were maintained under a standard management regimen of brooding and lighting. Proper ventilation and biosecurity measures were ensured throughout the trial. Ad libitum clean and fresh water was provided throughout the trial. Fresh and dry wheat straw was used as bedding material.

2.4. *Experimental chicks and design*

Three hundred, day-old Vencobb broiler chicks were individually weighed and randomly divided into ten groups of 30 chicks,s which were further subdivided randomly into 2 replicates of 15 chicks in a 5x2 factorial arrangement. The dietary treatments were basal diet as negative control (T_1), basal diet mixed with graded level of MOSM @ 1% without acidifier (T_2), 2% MOSM without acidifier (T_3), 3% MOSM without acidifier (T_4), 4% MOSM without acidifier (T_5), basal diet with acidifier (T_6), 1% MOSM with acidifier (T_7), 2% MOSM with acidifier (T_8), 3% MOSM with acidifier (T_9) and 4% MOSM with acidifier (T_{10}), respectively.

2.5. *Experimental diets*

The various feed ingredients for computing different experimental rations were purchased from the local market in one lot before starting the experiment and were analyzed for proximate composition according to AOAC (2005). Ingredient-wise compositions of experimental diets are presented in Table 1. The rations formulated for various treatment groups for starter and finisher chicks were made iso-caloric and iso-nitrogenous (Tables 2 and 3). The broiler starter and broiler finisher rations were formulated as per the Anonymous (2007). Experimental starter rations were offered up to 3 weeks of age and thereafter experimental finisher rations were offered up to 6 weeks of age with and without supplementation of acidifier to respective groups.

Table 1: Ingredient composition of experimental rations (kg 100 kg feed^{-1})

Sl. No.	Feed ingredients	Starter ration (0-3 weeks)					Finisher ration (4-6 weeks)				
		0	1	2	3	4	0	1	2	3	4
1.	Moringa seeds	0	1	2	3	4	0	1	2	3	4
2.	Maize	45	45	45	45	45	55	55	55	55	55
3.	Deoiled ricebran	15	15	15	15	15	11	11	11	11	11
4.	Soyabean meal	18	18	18	18	18	13	13	13	13	13
5.	Groundnut cake	12	11	10	9	8	12	11	10	9	8
6.	Fish meal	8	8	8	8	8	7	7	7	7	7
7.	Mineral-mixture	2	2	2	2	2	2	2	2	2	2
8.	Groundnut oil (ml)	0.5	0.4	0.3	0.2	0	0.5	0.5	0.4	0.3	0.3

2.6. *Performance parameters*

2.6.1. *Feed consumption (g)*

Weighed amounts of designated types and quantities of feed were fed to the experimental chicks. The leftover residue was determined to estimate the feed consumption on dry matter basis.

2.6.2. *Weekly body weight (g)*

The body weight of the experimental broilers was recorded at the beginning of the experiment as well as weekly to

Table 2: Nutrient composition of experimental starter ration (on % DM basis)

Treatments	0	1	2	3	4
DM	89	89.01	89.03	89.04	89.06
OM	91.43	91.45	91.47	91.49	91.51
CP	22.81	22.83	22.85	22.87	22.89
EE	3.01	3.15	3.29	3.43	3.57
CF	6.11	6.16	6.22	6.27	6.32
TA	6.57	6.55	6.53	6.51	6.49
NFE	50.5	50.32	50.15	49.97	49.8
ME (kcal kg^{-1})	2924.91	2921.79	2918.67	2915.56	2903.49

DM: dry matter; OM: Organic matter; CP: Crude protein; EE: Ether extract; CF: Crude fiber; TA: Total ash; NFE: Nitrogen free extract; ME: Metabolizable energy

Table 3: Nutrient composition of experimental finisher ration (on % DM basis)

Treatments	0	1	2	3	4
DM	89.2	89.22	89.23	89.25	89.26
OM	92.23	92.25	92.27	92.29	92.31
CP	20.37	20.39	20.41	20.43	20.45
EE	3.26	3.4	3.54	3.68	3.82
CF	5.21	5.26	5.31	5.37	5.42
TA	5.77	5.75	5.73	5.71	5.69
NFE	54.6	54.42	54.25	54.07	53.9
ME (kcal kg^{-1})	3000.42	3006.25	3003.13	3000.02	3005.85

DM: Dry matter; OM: Organic matter; CP: Crude protein; EE: Ether extract; CF: Crude fiber; TA: Total ash; NFE: Nitrogen free extract; ME: Metabolizable energy assess the body weight change and the growth pattern due to dietary regimens. The weighing of the birds was done in the early hours of the day before feeding, using an electronic weighing balance.

2.6.3. Weekly body weight gain (g)

Live weight gain at weekly intervals was calculated from the difference in body weight attained between the two consecutive weeks.

2.6.4. Average daily body weight gain (ADG)

ADG in grams was estimated by dividing the total body weight gain by the number of days.

2.6.5. Weekly feed conversion ratio

Feed conversion ratio (FCR) was calculated by dividing the cumulative feed intake by body weight gain of chicks for every week.

2.6.6. Performance index

To take into account the feed efficiency as well as the growth rate, an index was obtained for each treatment by dividing the average weight gained by the feed conversion ratio.

2.6.7. Protein efficiency ratio

PER was calculated by dividing the weight gain by the protein consumed.

2.6.8. Percent mortality

Regular observation was carried out to record the occurrence of death in experimental broiler chicks to estimate mortalities relative to the experimental group. Mortality rate (%) was calculated from the records of dead birds up to the end of the study against the total number of birds on a treatment basis.

2.6.9. Balance study

Digestibility of dry matter, crude protein, crude fiber and nitrogen balance study was conducted using 6 chicks from each group for 5 days at the end of the feeding trial. Digestibility of nutrients was estimated by the methods of Anonymous (2005). A nitrogen balance study was undertaken to assess the retention level of the above nutrient.

2.7. Statistical analysis

Data collected during the present investigation were subjected to statistical analysis by adopting appropriate methods of analysis of variance as described by Snedecor and Cochran (2004). The significance of mean differences was tested by Duncan's New Multiple Range Test (Duncan's Range Test) as modified by Kramer (1957).

3. RESULTS AND DISCUSSION

The effect of utilization of MOSM with or without supplementation of acidifier on performance parameters of broiler chicks has been presented in Tables 4 and 5.

3.1. Feed intake

No significant (p>0.05) difference was observed in the feed intake of broiler chicks on dietary inclusion of MOSM alone up to 4% level. The present finding was in agreement with Ng'ambi et al. (2017) who reported that *M. oleifera* seed meal inclusion did not improve feed intake of broiler chickens. Further, El-Abbasy (2025) demonstrated that 2.0 and 3.0 cm^3 L-1 ZnNPs-MLPE supplementation did not show any significant difference in feed intake between the treated groups and the control.

The results of present experiment differ from Ashong and Brown (2011), who stated that, when using diets with different levels of inclusion of Moringa leaves flour in White Leghorn chickens from 7 days up to 5 weeks; with substitution levels of Moringa flour at 0% (control group), 10%, 20% and 30%, found significant differences in feed intake. Sukria et al., 2024 also reported that the dietary moringa supplementation decreased feed intake (p<0.05)

Table 4: Effect of MOSM with or without supplementation of acidifier on growth performance in broiler chicks

Treatments	MOSM %	Acidifier	Feed Intake (g bird^{-1})	Body weight (g bird^{-1})	Body weight gain (g bird^{-1})
Interaction effect					
T_1	0	-	3670.40±56.04	2179.22^{a}±48.04	2136.08±110.40
T_2	1	-	3730.70±64.70	2239.76^{a}±32.62	2196.73±31.87
T_3	2	-	3942.10±1.60	2387.90^{bcde}±39.79	2344.80±41.44
T_4	3	-	3693.00±3.23	2423.97^{cde}±42.04	2299.87±90.03
T_5	4	-	3533.60±15.20	2569.74f±40.27	2526.60±41.11
T_6	0	Acidifier	3679.00±57.50	2262.14^{ab}±34.93	2219.0±74.35
T_7	1	Acidifier	3386.40±19.90	2368.49^{bcd}±30.51	2325.32±62.39
T_8	2	Acidifier	3587.80±10.84	2301.50^{abc}±26.86	2258.24±29.22
T_9	3	Acidifier	3897.10±30.17	2456.07^{def}±30.90	2412.84±64.91
T_{10}	4	Acidifier	3672.80±1.79	2507.54^{ef}±26.75	2464.30±26.64

Table 4: Continue...

Treatments	MOSM %	Acidifier	Average daily gain (g bird^{-1})	FCR	PI	PER
T_1	0	-	50.86±1.15	1.86±0.859	1090.70±1.998	2.59±0.260
T_2	1	-	52.31±0.78	1.76±0.058	1208.80±1.007	2.70±0.090
T_3	2	-	55.83±0.96	1.69±0.07	1400.40±1.208	2.83±0.175
T_4	3	-	54.76±1.01	1.61±0.009	1439.70±79.405	2.97±0.215
T_5	4	-	60.16±0.97	1.40±0.002	1806.60±12.250	3.38±0.005
T_6	0	Acidifier	52.84±0.83	1.72±0.056	1250.30±1.017	2.77±0.090
T_7	1	Acidifier	55.37±0.73	1.51±0.087	1495.20±28.845	3.15±0.180
T_8	2	Acidifier	53.77±0.64	1.59±0.114	1421.50±21.	2.98±0.030
T_9	3	Acidifier	57.45±1.22	1.62±0.009	1493.90±28.845	2.93±0.063
T_{10}	4	Acidifier	58.68±0.64	1.50±0.118	1664.30±1.817	3.19±0.250

Main effect							
MOSM%							
0	3674.70±32.87	2221.40^{a}±34.92	2178.26^{a}±74.35	51.86^{a}±0.83	1.79^{b}±0.089	1170.50^{a}±1.024	2.68^{a}±0.123
1	3558.00±1.03	2304.12^{b}±30.50	2261.02^{ab}±62.39	53.83^{ab}±0.73	1.64^{ab}±0.083	1352.00^{ab}±1.141	2.93^{ab}±0.153
2	3764.90±1.22	2344.70^{b}±26.86	2301.52^{b}±29.22	54.80^{b}±0.64	1.63^{ab}±0.052	1410.90^{ab}±50.520	2.90^{ab}±0.085
3	3794.90 ±1.45	2440.29^{c}±30.89	2356.35^{b}±64.91	56.10^{b}±1.21	1.61^{ab}±0.046	1466.80^{b}±37.872	2.95^{ab}±0.063
4	3602.70±83.52	2538.63^{d}±26.74	2495.45^{c}±26.64	59.42^{c}±0.64	1.45^{a}±0.055	1735.40^{c}±84.945	3.28^{b}±0.115
Acidifier							
Without	3713.70±70.66	2362.98±21.83	2303.77±41.22	54.86±0.65	1.66±0.064	1389.20±90.636	2.89±0.107
With	3644.40±61.90	2380.01±20.07	2336.80±30.86	55.64±0.48	1.59±0.035	1465.00±59.841	3.00±0.070
Probability							
Interaction	NS	S**	NS	NS	NS	NS	NS
MOSM	NS	S**	S**	S**	S*	S**	S*
Acidifier	NS	NS	NS	NS	NS	NS	NS

a, b, c Means in the same column with different superscripts are significantly different; S*: Significant at $p<0.05$; S**: Significant at $p<0.01$; NS: Non-significant

when *Moringa oleifera* was added in the diet of the broiler chickens. Similarly, the supplementation of acidifier in the diet did not show any significant ($p<0.05$) effect on feed intake in broiler chicks. These results corroborate well with studies of Akbari et al. (2004) and Aksu et al. (2007) who recorded no significant effect on feed intake due to the addition of organic acids in the diet, but do not correspond with the findings of Lokhande (2005) and Abdel-Fattah et al. (2008) noticed improvement in feed intake due to supplementation of organic acids. The interaction of MOSM and acidifier revealed no significant difference between control (T_1) and treatment groups with or without acidifier supplementation.

3.2. Body weight

Body weight differed significantly in all weeks of the trial period between the control (0% MOSM) and treatment groups on dietary inclusion of MOSM up to 4% level. The supplementation of acidifier showed no significant difference ($p>0.05$) in body weight between the control (without acidifier) and acidifier-supplemented group of broiler chicks. The interaction of MOSM and acidifier revealed a significant ($p<0.01$) difference in body weight between the control (T_1) and dietary treatments of MOSM with or without acidifier supplementation groups. The results of the present study are in agreement with the findings of Mousa et al. (2016) who found that all levels of GMOS (0.25, 0.50, and 0.75%) resulted in significantly increased body weight at all periods of the experiment (14, 28, and 42 days) compared to the control group. This may be attributed to birds fed GMOS-based diets adequately

Table 5: Effect of MOSM with or without supplementation of acidifier on nutrients digestibility in broiler chicks

Treatments	MOSM %	Acidifier	N balance	DMD%	CPD%	CFD%
Interaction effect						
T_1	0	-	$2.37^{bcd}\pm0.06$	$75.44^{bc}\pm1.46$	$84.45^{cd}\pm1.66$	$46.01^{a}\pm4.94$
T_2	1	-	$2.29^{ab}\pm0.04$	$77.73^{cde}\pm0.46$	$82.08^{bcd}\pm0.46$	$58.76^{bcd}\pm0.51$
T_3	2	-	$2.32^{ab}\pm0.03$	$78.86^{cde}\pm1.69$	$81.58^{abc}\pm0.88$	$61.05^{cd}\pm0.79$
T_4	3	-	$2.43^{cd}\pm0.05$	$76.91^{cd}\pm1.57$	$80.41^{abc}\pm1.14$	$59.01^{bcd}\pm1.07$
T_5	4	-	$2.87^{f}\pm0.03$	$81.07^{e}\pm1.38$	$85.54^{d}\pm0.27$	$63.76^{d}\pm1.40$
T_6	0	Acidifier	$2.24^{a}\pm0.05$	$70.57^{a}\pm1.45$	$77.81^{a}\pm1.76$	$54.51^{bc}\pm3.06$
T_7	1	Acidifier	$2.32^{ab}\pm0.03$	$80.44^{de}\pm0.96$	$83.31^{cd}\pm1.01$	$59.9^{bcd}\pm0.96$
T_8	2	Acidifier	$2.46^{d}\pm0.04$	$77.44^{cde}\pm0.44$	$84.08^{cd}\pm0.79$	$53.67^{b}\pm1.54$
T_9	3	Acidifier	$2.47^{d}\pm0.03$	$72.82^{ab}\pm1.08$	$78.81^{ab}\pm0.61$	$54.40^{bc}\pm1.16$
T_{10}	4	Acidifier	$2.70^{e}\pm0.03$	$78.18^{cde}\pm1.04$	$85.35^{d}\pm0.80$	$55.13^{bc}\pm1.89$
Main effect						
MOSM%						
0			$2.30^{a}\pm0.04$	$73.0^{a}\pm1.44$	$81.12^{a}\pm1.76$	$50.26^{a}\pm3.06$
1			$2.30^{a}\pm0.02$	$79.08^{c}\pm0.95$	$82.69^{ab}\pm1.0$	$59.33^{b}\pm0.96$
2			$2.39^{ab}\pm0.03$	$78.14b^{c}\pm0.43$	$82.83^{ab}\pm0.79$	$57.35^{b}\pm1.53$
3			$2.44^{b}\pm0.03$	$74.86^{ab}\pm1.08$	$79.61^{a}\pm0.60$	$56.70^{b}\pm1.16$
4			$2.78^{c}\pm0.04$	$79.62^{c}\pm1.04$	$85.44^{b}\pm0.80$	$59.44^{b}\pm1.89$
Acidifier						
Without			2.46±0.06	$78.0^{a}\pm0.63$	82.81±0.67	57.72±1.70
With			2.44±0.04	$75.89^{b}\pm1.0$	81.87±0.88	55.52±0.87
Probability						
Interaction			S^{**}	S^{*}	S^{*}	S^{**}
MOSM			S^{**}	S^{**}	S^{**}	S^{**}
Acidifier			NS	S^{*}	NS	NS

a, b, c Means in the same column with different superscripts are significantly different; S*: Significant at $p<0.05$; S**: Significant at $p<0.01$; NS: Non-significant

utilizing the nutrients they consumed as *Moringa oleifera* seeds are good source of fats, proteins and minerals (Campaore et al., 2011). Also, these results are in agreement with Ochi et al. (2015) who mentioned that the inclusion of *Moringa oleifera* seed powder @ 0.5, 1, and 2% in the diet of the broilers significantly ($p\leq0.05$) enhanced their body weight. El-Abbasy (2025) demonstrated that 2.0 and 3.0 cm^3 L-1 ZnNPs-MLPE supplementation significantly enhanced live body weight (LBW) and weight gain (BWG). Contrary to our findings, Hassan et al., 2017 found that birds from the control group showed significantly ($p<0.05$) higher body weight followed by 10, 15, 20 and 25% MOSM level in broiler's feed.

No effect of acidifier supplementation on body weight was recorded in the present study, which corroborates well with the results of Akbari et al. (2004) and Garcia et al. (2007) but does not fall in line with the results of Abdel-Fattah (2008), who observed improvement in body weight due to organic acid supplementation.

3.3. Body weight gain

The body weight gain (BWG) differed significantly among the different treatment groups of MOSM. The overall weekly body weight gain was significantly ($p<0.01$) higher in 4% level of MOSM which was followed by 3%, 2%, 1% and 0% MOSM supplemented groups. The result was in line with the finding of Olugbemi et al. (2010) who mentioned that the inclusion of *Moringa oleifera* leaf meal in the diet of the broilers significantly ($p<0.05$) enhanced their weight gain at 1% level which was significantly higher than the control. Abbas and Mohamed, (2012) also observed that the addition of *M. oleifera* undecorticated seed powder also had significant beneficial effects on weight gain in broilers. These results are also in harmony with the findings of Mousa et al. (2016) who reported that all graded levels of GMOS resulted in a significant increase in BWG compared to the control group. The improved weight gain of birds fed on GMOS compared to the control group may be due to *Moringa oleifera* seeds which are a good source of fat, protein, antioxidants and minerals (Campaore et al., 2011). It may also be due to the presence of bioactive components causing greater feed utilization resulting in improved growth (Arif et al., 2019). In contrast, Liaqat et al. (2016) did not observe any significant differences (p>0.05) in weight gain in all treatment groups of broilers when fed on MOLP.

The results regarding use of acidifier did not reveal any effect on body weight gain and are contrary to the observations of Lokhande (2005) and Shendare et al. (2007) reported increase in body weight gain as a result of feeding of acidifier but fall very well in line with the findings of Ozturk et al. (2004) and Garcia et al. (2007) also noticed no significant effect of addition of organic acids in the diet of broilers on body weight gain.

Further, the interaction of MOSM and acidifier did not show any significant (p>0.05) effect in BWG between control (T_1) and treatment groups with or without supplementation of acidifier. However, a numerically higher BWG was observed in the T_5 group. Contrary to the present finding, Wahab et al. (2020) reported that birds fed MOSP @ 0.75% with phytase had significantly the highest values of live body weight gain.

3.4. Average daily weight gain

The ADG was significantly (p<0.01) higher in the 4% level of MOSM, which was followed by 3%, 2%, 1%, and 0% MOSM supplemented groups. The results of feeding different levels of MOSM indicate that MOSM improved the growth performance of broilers, which is consistent with Ayssiwede et al. (2011) and Ayo-Ajasa et al. (2016) who reported that leaf meal added to broiler diets significantly increased the average daily weight gain of the broilers. Elbashier and Ahmed, (2016) also reported in their study that supplementation of 0%, 2%, 4% and 5% MOLM kg^{-1} feed daily for 21 days (finisher diet) significantly improved total weight gain in broilers. The results regarding the use of acidifier did not reveal any effect on average daily gain and are in accordance with Jung et al. (2008) who found that the addition of galacto-oligosachharides and *Bifidobacterium lactis* did not affect daily weight gain of broiler chickens. Contrary to this, Dizaji et al. (2012) and Gao et al. (2021) reported that adding acidifier to the diet of broiler chickens improved the ADG.

Further, the interaction of MOSM and acidifier in ADG did not show a significant effect in control (T_1) and the treatment groups.

3.5. Feed conversion ratio

Among the MOSM supplemented groups, better FCR was observed in 4% MOSM supplemented group which was non-comparable to the 1, 2 and 3% MOSM supplemented groups. The present results are in agreement with Riry et al. (2016) who reported significantly (p<0.01) better feed conversion ratio in MOSM supplemented groups than control group. Mousa et al. (2016) reported that the FCR was significantly improved by using all levels of GMOS in all periods of the experiment compared to the control group. Moreover, Sukria et al., 2024 also found that the dietary moringa supplementation improved FCR (p<0.05) when *Moringa oleifera* was added in the diet of the broiler chickens. This improvement in FCR may be attributed to the rich content of nutrients in *Moringa oleifera* seeds. This suggests that birds fed *Moringa oleifera* leaf meal-based diets had better utilization potential of the nutrients probably because of the increased bulkiness as the inclusion level increased. A low FCR is a good indication of high-quality feed (Hascik et al., 2010). On the other hand, El-Abbasy (2025) showed that 2.0 and 3.0 $cm^3\ l^{-1}$ ZnNPs-MLPE supplementation did not show any significant difference in feed conversion ratio (FCR).

The supplementation of acidifier in the diet did not reveal any significant (p>0.05) difference in FCR weekly between the acidifier-supplemented group compared to group without acidifier supplementation. However, a numerically better FCR was observed in acidifier supplemented group in the overall trial period of 42 days. The non-significant effect observed for the effect of acidifier in the present study has also been noticed earlier by Akbari et al. (2004) and Dizaji et al. (2012). However, Lende et al. (2018) reported significantly better FCR in the gut acidifier supplemented group fed at 0.1 and 0.05% in the starter and finisher broiler diet.

No significant (p>0.05) difference was observed in FCR between control (T_1) and other dietary treatment groups when observing the interaction of MOSM and acidifier. However, a numerically better FCR was found in the T_5 group as compared to the control (T_1) and other dietary treatments. Contrary to the present finding, Wahab et al. (2020) showed that birds fed MOSP at 0.75% with phytase had significantly best feed conversion ratio.

3.6. Performance index

In the overall period of 42 days, the PI was significantly higher in 4% MOSM supplemented group and lower in all other treatments groups. The mean value of PI in the 0, 1%, 2% and 3% MOSM supplemented groups was not comparable to each other. The present finding is in accordance with Ibrahim et al. (2014) who reported that productive performances of rabbits were significantly improved with increasing levels of *Moringa peregrine* seeds (MPS) in the diet. Contrary to this, the present finding is not in agreement with Eldeeb et al. (2014) who reported that feeding of broiler chicks with dietary levels (0%, 2% and 4%) of MOLM did not reveal any significant difference in performance index.

The supplementation of acidifier in the diet did not show any significant (p>0.05) difference in PI between the control group without acidifier and the acidifier-supplemented group. Similarly, the interaction of MOSM and acidifier did not show any significant (p>0.05) difference in PI between control (T_1) and treatment groups with or without acidifier supplementation.

3.7. Protein efficiency ratio

In the overall trial period of 42 days, the PER was significantly (p<0.05) higher in 4% level of MOSM supplemented group as compared to all other treatment groups. This result is also in agreement with the finding of Ahmad and Abbas (2016) who reported that the protein efficiency ratio for birds fed on decorticated moringa (DCM) was improved during all phases when compared to control and those fed zigbir and an undecorticated supplemented diet. In contrast, Okosun et al. (2017) reported that the protein efficiency ratio was not significantly affected (p>0.05) by the moringa-based dietary treatments. Amadi (2016) reported that a decrease in values of PER occurs with increasing levels of *Moringa oleifera* seed meal in diets.

The supplementation of acidifier in the diet did not show any significant (p>0.05) difference in PER between the control group without supplementation of acidifier and the acidifier-supplemented group. The findings of the present study are in agreement with Fatufe and Matanmi (2011) who reported that organic acids alone and in combination with probiotics did not affect the protein efficiency ratio in cockerels.

Further, the interaction of MOSM and acidifier did not show any significant (p>0.05) difference in PER between control (T_1) and treatment groups of MOSM with or without supplementation of acidifier.

3.8. Percent mortality

The overall mortality in broilers during the experimental period was 2%; the mortality was well within normal limits during the entire period of the experiment. However, as confirmed by post-mortem examination, mortality was not attributed to experimental diets.

3.9. Nitrogen balance

Regarding the balance of nitrogen as g d^{-1}, a significantly (p<0.01) higher nitrogen balance was observed in 4% MOSM supplementation group as compared to the control and all other treatment groups. The highest nitrogen balance was found to be 2.78 g d^{-1} in the 4% MOSM supplementation group and the lowest was 2.30 g d^{-1} in the control and 1% MOSM supplementation groups, respectively. The present finding is in agreement with Ng'ambi et al. (2017) who found that Nitrogen (N) retention of female Ross 308 broiler chickens was optimized at a seed meal inclusion level of 11.50 (r^2=0.286) g kg^{-1} DM feed. In contrast to this, Amadi (2016) reported that daily retained nitrogen and nitrogen retention coefficient decreased in values following an increase (0%, 5%, 10% and 15%) in MOSM inclusion in diets.

The supplementation of acidifier showed a non-significant (p>0.05) difference in nitrogen balance between the control group (without acidifier) and acidifier supplementation. While, the findings of Mahfudz et al. (2019) reported that the dietary inclusion of citric acid significantly (p<0.05) decreased nitrogen intake as an impact of slightly reduced feed consumption.

The interaction of MOSM and acidifier showed significant difference in nitrogen balance between control (T_1) and different treatment groups of MOSM with or without acidifier supplementation. Significantly (p<0.01) higher nitrogen balance was observed in T_5 and T_{10} groups as compared to control (T_1) and all other treatment groups with or without supplementation of acidifier.

3.10. Per cent nutrient digestibility

It was found that the percent dry matter digestibility, crude protein digestibility and crude fiber digestibility were significantly differed between control and MOSM supplemented groups. The mean value of DMD was significantly (p<0.01) higher in 4% MOSM supplemented group which is followed by 1% and 2% MOSM supplemented group and lower value of DMD was found in 0% MOSM and 3% MOSM supplemented groups. The CPD was significantly (p<0.01) higher in 4% level of MOSM supplemented group as compared to control (0% MOSM) and all other MOSM supplemented groups. However, the digestibility of CP in 4% MOSM supplemented group neither different from control (0% MOSM) nor from 1, 2 and 3% MOSM supplemented treatment groups, respectively. The CFD was significantly (p<0.01) higher in all treatment groups of MOSM as compared to 0% MOSM supplemented group. These findings agreed with the earlier report of Fahey et al. (2001) that Moringa seed enhances nutrient digestibility and improves fiber retention in broilers. Alagbe (2017) reported that protein retention and fiber retention were significantly (p<0.05) influenced by the inclusion of MLMAZP across the treatments. Contrary to this result, Egbu et al. (2022) found that crude protein and neutral detergent fibre digestibility linearly decreased as Moringa seed extract levels increased.

Regarding the supplementation of acidifier, the treatment group receiving acidifier showed a significant ($p<0.05$) difference from the control group only in dry matter digestibility (DMD), while no significant ($p>0.05$) differences were observed in the digestibility of other nutrients. The acidifier-supplemented group recorded a significantly ($p<0.05$) higher mean value of DMD. Similarly, Ding et al. (2017) reported that supplementation with the acidifier Pro GIT SF3 significantly ($p<0.05$) improved the apparent and total digestibility of dry matter. In contrast, Houshmand et al. (2011) and Biggs and Parsons (2008) observed that the addition of organic acids significantly ($p<0.05$) improved protein digestibility compared with the control group.

The interaction of MOSM and acidifier showed significant difference between control (T_1) and different treatment groups of MOSM with or without acidifier supplementation in the percent digestibility of dry matter, crude protein and crude fiber. The significantly ($p<0.05$) higher percent of dry matter digestibility and crude protein digestibility were found in T_5 group and lower in T_6 group, respectively. The significantly ($p<0.01$) higher percent crude fiber digestibility was observed in all treatment groups as compared to the T_1 (control) group.

4. CONCLUSION

The MOSM with or without using acidifier supplementation increased weight gain ($p<0.05$) and improved feed conversion ratio and overall performance of the broiler chicks. *Moringa oleifera* seed meal could successfully replace groundnut cake in broiler diets up to 4%, either with or without acidifier supplementation. This replacement supported growth performance and enhanced feed utilization efficiency in broiler chicks.

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