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EFFECTS OF INORGANIC FERTILISERS ON MORINGA [*Moringa oleifera* (Lam.)] LEAF YIELD, NUTRIENT COMPOSITION, AND ON PRODUCTIVE PERFORMANCE IN BROILERS

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ABSTRACT

Poultry production is constrained by inadequate supply of quality feed and its escalating costs in Eswatini. One possible means of addressing the feed shortage can be use of Moringa oleifera leaves as supplement. An experiment was conducted to determine the effects of inorganic fertilisers on M. oleifera growth, leaf yield and nutrient contents; and on the performance of broilers fed with moringa leaf supplemented diet. The field experiment had four treatments: 1) Control (no inorganic fertiliser), 2) 100 kg/ha 2:3:2(22) + 100 kg/ha Limestone Ammonium Nitrate (LAN), 3) 200 kg/ha 2:3:2(22) + 200 kg/ha LAN, 4) 400 kg/ha 2:3:2(22) + 400 kg/ha LAN in randomised complete block design (RCBD) with four replications. The broilers experiment had five treatments; broiler finisher with the control (conventional broiler finisher, no moringa), and four treatments of broiler finisher supplemented with 20% M. oleifera feed grown under the fertiliser levels described in the above experiment in RCBD in five replications. Results showed that as the rate of inorganic fertiliser increased the growth parameters and leaf yield of M. oleifera were significantly (P < 0.01) increased, but no significant differences between [200 kg/ha 2:3:2(22) + 200 kg/ha LAN] and [400 kg/ha 2:3:2(22) + 400 kg/ha LAN]. Similarly, as the rates of fertiliser increased, crude protein and crude fibre contents of the leaves increased significantly. In contrast, broiler feed supplemented with M. oleifera grown at different rates of inorganic fertiliser resulted in significantly lower body weight gain as well as live, plucked and dressed weights while it significantly decreased faecal bacterial count. Thus, the application of 200 kg/ha 2:3:2(22) + 200 kg/ha LAN can be used for optimum early growth of M. oleifera to obtain nutritious leaf products while there is a need for further studies on M. oleifera supplementation to broilers feed at less than 20%.

***Keywords**: Bacterial count, Broilers, Crude protein, Limestone Ammonium Nitrate, Moringa leaf, 2:3:2(22) fertiliser.*

INTRODUCTION

Agriculture is the backbone of Eswatini's economy and a major source of employment for rural households with more than 70% of the population relying on this sector for their income (Nkondze *et al.,* 2014). However, it contributes only about 7.6% of the gross domestic product (World Bank, 2019) and 20–30% of the total export earnings (Musaba *et al.,* 2014), and as a result the country is food insecure. One way of alleviating the food insecurity would be to increase poultry production of smallholder farmers which accounts for about 60% of the total farmers in the country (MoA, 2015). There is also a high demand for broiler meat as consumers perceive it as a healthy product with less fat compared to beef or pork products (Karthivashan *et al.,* 2015). However, poultry production is constrained by the high cost of good quality feed. This shortage is caused by inadequate availability and expensive raw materials especially protein sources (Gakuya *et al.,* 2014).

The occurrence of periodic droughts and extensive dry spells in winter causes severe feed shortages in the country. This has led to a decrease in the animal feed ingredients, with subsequent increases of the feed cost. The present trend of rising prices of feed ingredients, has led to a search for other non-conventional feedstuff with the potential of improving broiler performance at reduced cost. *Moringa oleifera* Lam. has generated a lot of interest among farmers as it is drought tolerant. Thus, the potential of this economic plant for use as livestock and poultry feed needs to be evaluated and determined. In addition, the *M. oleifera* leaf meal has attracted research interest due to its nutritional and health benefits to man and livestock (Ebenebe *et al.,* 2013). *M. oleifera* tree leaves are high in crude protein and vitamin A and C, carotene, iron and in two amino acids which are generally deficient in other feeds, *i.e.* methionine and cystine (Makkar and Becker, 1996). Moreover, *M. oleifera* has been reported to have anti-microbial properties due to its unique combination of numerous phytochemicals such as alkaloids, saponins, steroids, phenolic acids, glucosinolates, flavonoids, and terpenes (Gupta *et al.,* 2018).

In broilers, the intestinal bacteria are also a concern in the pathogenesis of intestinal diseases since they influence the development of gut immunity and thus may prevent colonisation of pathogens in the intestine (Proietti *et al.,* 2009). However, there is lack of information in Eswatini on *M. oleifera* growth performance in response to inorganic fertilisers, nutritional content of its fodder and the benefits of using *M. oleifera* as a source of poultry feed (Gamedze, 2012).

This study was undertaken to determine the effects of different inorganic fertiliser application rates on *M. oleifera* growth, leaf yield and nutrient composition; to determine the effects of fertilised *M. oleifera* on the productive performance of broilers; and to determine the effects of supplementing *M. oleifera* feed on faecal bacterial number in broilers.

MATERIALS AND METHODS

Experiment 1: Effect of inorganic fertiliser application rates on growth, leaf yield and nutrient composition of moringa.

Experimental site description

The experiment was carried out at Crop Production Department Research and Demonstration Farm, Luyengo Campus of the University of Eswatini in 2016. The site is located at 26º 32'S latitude and 31º 14'E longitude and at an altitude of 735 m above sea level. It receives an annual rainfall of 980 mm of which 83% falls from October to March, with peaks in December and January (Zubuko, 2017). The average annual air temperature is 19.0 °C with the coldest month in June with an average temperature of 14.7 °C. Soil at the experimental site is classified under Malkerns series, deep red loam with a pH of 5.4 (Murdoch, 1968).

Treatments and experimental design

There were four treatments, *i.e.* 1) Control (no inorganic fertiliser), 2) 100 kg/ha 2:3:2(22) + 100 kg/ha LAN, 3) 200 kg/ha 2:3:2(22) + 200 kg/ha LAN, and 4) 400 kg/ha 2:3:2(22) + 400 kg/ha LAN. Each treatment was replicated four times in a randomised complete block design. The treatment number and treatment descriptions are indicated in Table 1. Compound fertiliser 2:3:2 (22), consisting of 6.3 % N, 9.4 % P and 6.3 % K, and Limestone Ammonium Nitrate (LAN) containing 28% nitrogen were used as sources of inorganic fertiliser.

Table 1. Treatment number and treatment description.

Treatment number	Fertiliser application rate	Nutrients (kg/ha)		
		N	P	K
1	Control (no inorganic fertiliser)	0	0	0
2	100 kg/ha 2:3:2(22) + 100 kg/ha LAN	34.3	9.4	6.3
3	200 kg/ha 2:3:2(22) + 200 kg/ha LAN	68.6	18.8	12.6
4	400 kg/ha 2:3:2(22) + 400 kg/ha LAN	137.2	37.6	25.2

Management of experimental field

Land preparation was done by conventional tillage using disc ploughing followed by two harrowings with a tractor. The plot size was 12.25 m long and 7.25 m wide. The seedlings were planted in summer of 2016 at three months of age at a spacing of 50 cm ×50 cm. These seedlings were raised in the greenhouse at the University of Eswatini, Luyengo campus. Fertiliser 2:3:2 (22) was applied during seedling planting and LAN was applied four weeks after planting following the application levels in Table 1. Irrigation was done when necessary, using over-head sprinklers. Weeding was done manually using hoes whenever required.

M. oleifera growth and leaf yield data

M. oleifera canopy cover was determined at nine weeks after planting (WAP) and every week thereafter until 13 WAP, using a step point system. The step pointer frame had 10 points (holes) and a spoke. When the spoke was inserted through each hole and in turn touched the leaves it was counted as positive. Each plot was rated out of 10 and the values obtained were converted to percentages. Canopy height was measured as the distance from ground level to the tip of the top growing shoot using a meter stick from ten plants per plot at nine WAP and every week thereafter up to 17 WAP and the canopy height was averaged per plant. Number of leaves and number of branches per plant were recorded by counting the leaves and branches produced per plant starting at nine WAP and then every week until 14 WAP from ten plants per plot and then averaged to per plant. Mass of dry *M. oleifera* leaves per plot was determined at six months after planting after oven drying at 72 °C for 72 hours. The oven dried mass was then converted to kg/ha.

Determination of nutrient composition of *M. oleifera* leaves

M. oleifera leaves were analysed for nutritional composition for all 16 plots each in duplicate. To determine the crude

protein, first nitrogen concentration of moringa leaves was determined by grinding the plant material, its digestion and distillation by Kjeldahl method (AOAC, 1994). Crude protein content was determined as a product of N × 6.25. The ash content was determined by the method described in AOAC (1994). For each sample, 2 g was measured into two crucibles and combusted for 3 hours at 550 ºC in a muffle furnace. After this time, the crucibles were withdrawn, cooled in a dessicator for 30 minutes and then weighed. Ether extractable fat from the dried and ground leaf sample was determined with diethyl ether which dissolves fats, oils, pigments and other fat soluble substances. The ether was then evaporated from the fat solution and the resulting residue was weighed and referred to as ether extract or crude fat. The leaf moisture content was determined by oven drying the fresh leaves at 72 °C for 24 hours.
Crude fibre (CF) of the *M. oleifera* leaf was determined using the fibretec hot extractor. Sample (2.0 g) was boiled in 150 mL of 1.25 % H_2SO_4 solution for 30 minutes under reflux. The boiled sample was washed in several portions of hot water using a two-fold cloth to trap the particles. It was returned to the flask and boiled again in 150 mL of 1.25 % NaOH for another 30 minutes under same conditions. After washing in several portion of hot water, the sample was allowed to drain dry before being transferred to a weighed crucible where it was dried in the oven at 105 °C to a constant weight. It was thereafter taken to a muffle furnace where it was burnt, only ash was left of it. The weight of the fibre was determined as:
CF (%) = $\frac{(W2-W1)}{Ws)} \times 100$, where; (W2) was crucible + ash weight, (W1) was crucible + sample weight and (Ws) was sample weight.

Experiment 2: Effect of supplementing moringa leaf feed grown at different inorganic fertiliser levels on the productive performance and faecal bacterial egg count of broilers

Treatments and experimental procedure
The experiment was conducted at the University of Eswatini (UNESWA) poultry Farm, Luyengo Campus, house number 3. One hundred day-old mixed sex broiler chicks of the Cobb 500 strain were purchased from National Chicks, a local commercial hatchery. The care and use of broiler chickens were performed following the ethical guidelines of the University of Eswatini, Department of Animal Science Board that approved the protocol used in the experiment. The birds were vaccinated with lasota, infectious bursal disease vaccine and mild strain gumboro vaccine against Newcastle disease, infectious bursal disease and gumboro diseases, respectively, as per the recommendations. The chicks were fed a maize and soyabean-based commercial starter diet until they were 21 days old. On day 22, they were assigned to stainless steel pens (each with four birds). The birds were allowed *ad libitum* access to feed and water from day 22 to day 42. They were inspected daily for any health-related problems.

The three weeks-old broiler chickens were allocated to five dietary treatment groups. Each dietary treatment had five replicates with four birds each. The poultry house was partitioned to 25 pens and due to suspected temperature gradient in the poultry house the experiment was conducted in a randomised complete block design. The treatment number and treatment descriptions are shown in Table 2.

Table 2. Treatment number and treatment description for the feeding trial.

Treatment number	Treatment description
T1	Control (conventional broiler finisher, no moringa)
T2	Broiler finisher with moringa with no inorganic fertiliser
T3	Broiler finisher with moringa with 100 kg/ha 2:3:2(22) + 100 kg/ha LAN
T4	Broiler finisher with moringa with 200 kg/ha 2:3:2(22) + 200 kg/ha LAN
T5	Broiler finisher with moringa with 400 kg/ha 2:3:2(22) + 400 kg/ha LAN

The broiler finisher that was used for the different treatments had the ingredients shown in Table 3. Instead of 10 kg of bran in the conventional broiler finisher, broilers in treatments 2, 3, 4 and 5 were given 10 kg of moringa leaf powder per 50 kg of feed.

Table 3. Ingredients (kg/50 kg) of experimental finisher diets given to the broilers from three weeks of age.

Ingredients	Treatments				
	T1	T2	T3	T4	T5
Yellow maize	29.82	29.82	29.82	29.82	29.82
Prime gluten	1.5	1.5	1.5	1.5	1.5
Bran	10	0	0	0	0
Moringa	0	10	10	10	10
Extruded FF Soya	4.5	4.5	4.5	4.5	4.5
Sunflower O/C	2.9	2.9	2.9	2.9	2.9
DL methionine	0.04	0.04	0.04	0.04	0.04
Lysine HCL	0.17	0.17	0.17	0.17	0.17
Mono calcium Phos	0.12	0.12	0.12	0.12	0.12
Limestone	0.1	0.1	0.1	0.1	0.1
Salt	0.51	0.51	0.51	0.51	0.51
Coccidiostat	0.17	0.17	0.17	0.17	0.17
3.5 Br grower premix	0.17	0.17	0.17	0.17	0.17

Broilers' performance determination

Feed intake (FI), body weight gain (BWG) and feed conversion ratio (FCR)

Chickens were group weighed by pen at the beginning (day 22) and then weekly thereafter until day 43. Then average body weight gain (g/bird/day) was calculated. Also, feed offered and left was weighed per pen daily in order to calculate average FI per bird per day. Then feed conversion ratio (FCR) was calculated as the total amount of feed consumed by the birds divided by the amount of weight gained on weekly basis for three weeks.

Carcass and internal organs characteristics of broilers fed finisher diets with moringa leaf

On day 43, two birds from each pen were weighed in order to determine live weight at slaughter. The birds were slaughtered by stunning manually and slitting the throat of each bird with a sharp knife. The birds were immediately immersed in boiling water and plucked off their feathers, the carcasses were weighed to determine plucked weight. Carcasses were then dressed and weighed to determine dressed weight. During evisceration, the internal organs (liver, intestine, heart, gizzard) were removed and weighed. Lastly, the right hand wings and legs were cut and weighed.

Bacterial faecal egg counts (FEC)

Faecal samples were taken before the feeding trial started and at the end of the feeding trial. Faecal samples of broilers were collected in sterile polyethylene bags. All samples were taken directly to the Crop Production Department plant pathology laboratory of the University of Eswatini, Luyengo Campus, for the bacterial egg count. The pour plate method was used; this method reports the number of colonies in a plate. One ml of dilutions of the faecal suspension was introduced into a Petri dish with 9 ml of distilled water. Then from that suspension 1 ml was taken to make three serial dilutions. After that 0.1 ml was poured into a plate. The nutrient medium, in which the agar was kept liquid by holding it in a water bath at about 50 °C, then it was poured over the sample, which was then mixed into the medium by gentle agitation of the plate. The plate was then kept in a dark cardboard for 12, 18 and 36 hours; and the number of colonies was counted, respectively. The number of bacteria/ml was obtained as number of colonies on plate × reciprocal of dilution of sample.

Data analysis

M. oleifera growth, leaf yield and nutrient composition data; and broilers' performance data (feed intake, body weight gain, feed conversion ratio, carcass characteristics, and bacterial faecal egg counts) were subjected to analysis of variance appropriate to randomised complete block design using GENSTAT statistical package 18th edition software (GENSTAT 2015). The model used for the analysis was $Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij}$ where Y_{ij} = the observation on the jth block and the ith treatment; μ = common mean effect; τ_i = effect of treatment i; β_j = effect of block j; and ε_{ij} = experiment error. Log transformation was used for bacterial faecal egg count data to conform to normality. Where significant differences were detected, treatment means were separated using the Least Significant Difference (LSD) test at 5 % level of probability.

RESULTS

Growth of *M. oleifera*

Canopy cover (%)

There was a significant (P < 0.01) effect of the fertiliser application rates on the canopy cover of *M. oleifera* at all weeks of measurement (Figure 1). As the rate of inorganic fertiliser increased, there was a significant increase in canopy cover (%). However, there were no significant differences between treatment 3 [200 kg/ha 2:3:2(22) + 200 kg/ha LAN] and treatment 4 [400 kg/ha 2:3:2(22) + 400 kg/ha LAN] at all the weeks except week 11. Moreover, with increased rates of inorganic fertiliser, the plants reached 100% canopy cover early (12th WAP) while the treatment with no inorganic fertiliser did not reach 100% canopy cover even at 13 WAP.

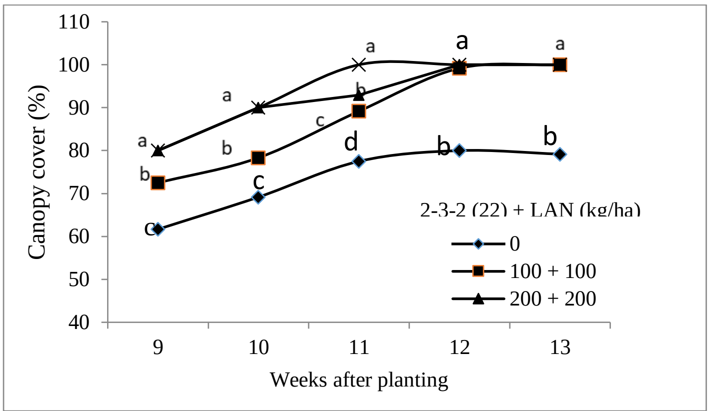

Figure 1. Canopy cover (%) of moringa from nine to 13 weeks after planting as affected by the inorganic fertiliser application rates.
Mean values for each week followed by the same letter are not significantly different at P = 0.05 according to LSD test.

Canopy height (cm)

There was a significant (P < 0.01) effect of the fertiliser application rate on moringa canopy height at all weeks of sampling (Table 4). As the fertiliser rate increased, the canopy height increased significantly in most of the weeks of sampling. However, plants that received treatment 3 [200 kg/ha 2:3:2(22) + 200 kg/ha LAN] and treatment 4 [400 kg/ha 2:3:2(22) + 400 kg/ha LAN] had statistically at par canopy height at weeks 9, 11, 13 and 14 (Table 4). The rate of increase in canopy height along the weeks was also increased with increased rates of fertiliser with the highest being recorded with treatment 3 [200 kg/ha 2:3:2(22) + 200 kg/ha LAN].

Table 4. Canopy height (cm) of moringa from nine to 17 weeks after planting as affected by the application rates of inorganic fertilisers

Fertiliser rate [2:3:2(22) + LAN (kg/ha)]	Weeks after planting								
	9	10	11	12	13	14	15	16	17
0 (control)	16.42c	18.04d	27c	37.62d	45.7c	65.8c	85.1d	124.9d	158.4c
100 + 100	25.67b	45.42c	65.12b	86.92c	112.1b	129.2b	156.6c	181.3c	217.7b
200 + 200	31.17a	54.79b	71.88a	95.67b	124.4a	143.1a	170.1b	211.2a	224.4a
400 + 400	30.08a	55.5a	73.24a	96.83a	123.4a	141.8a	171.8a	203.9b	218.1b
Significance	**	**	**	**	**	**	**	**	**
LSD (0.05)	1.399	0.560	1.416	0.876	3.441	1.976	1.279	6.85	5.694
CV (%)	3.4	0.8	1.5	0.7	2.1	1	0.5	2.4	1.7

Mean values within the same column followed by the same letter are not significantly different at P = 0.05; ** = significant at P = 0.01, LSD = Least Significant Difference; CV = Coefficient of variation

Number of leaves

The effect of the fertiliser rates was significant (P < 0.01) on the number of leaves at all weeks of sampling (Table 5). In general, as the rate of fertiliser increased, the number of leaves per plant increased. However, there were no significant differences in numbers of leaves between treatment 3 [200 kg/ha 2:3:2(22) + 200 kg/ha LAN] and treatment 4 [400 kg/ha 2:3:2(22) + 400 kg/ha LAN]. The treatment that was planted with no fertiliser had the lowest number of leaves that ranged between 70 and 199 while the number of leaves obtained at the highest rate of fertiliser [400 kg/ha 2:3:2(22) + 400 kg/ha LAN] ranged from 89 to 369 (Table 5).

Number of branches per plant

The results showed a significant (P < 0.01) effect of the fertiliser application rates on the number of branches per plant at all weeks of sampling (Table 6). Overall, the number of branches per plant increased significantly as the fertiliser application rates increased, but the differences between treatment 3 [200 kg/ha 2:3:2(22) + 200 kg/ha LAN] and treatment 4 [400 kg/ha 2:3:2(22) + 400 kg/ha LAN] were not significant at all weeks of sampling except at week nine after planting. The number of branches per plant ranged from 9 to 14 at no fertiliser application while it ranged from 12 to 22 at treatments 3 and 4 along the weeks after planting (Table 6).

Leaf yield (kg/ha) of moringa

The application rate of inorganic fertiliser had a significant (P < 0.01) effect on moringa dry leaf yield harvested six months after planting (Table 7). The leaf yield was significantly increased as the inorganic fertiliser application rates increased from the control to 400 kg/ha 2:3:2(22) + 400 kg/ha LAN. The highest dry leaf yield (1485.8 kg/ha) was obtained at 400 kg/ha 2:3:2(22) + 400 kg/ha LAN and it was statistically at par with the leaf yield obtained at 200 kg/ha 2:3:2(22) + 200 kg/ha LAN while the lowest leaf yield (622 kg/ha) was obtained from the control (Table 7).

Table 7. Dry leaf yields (kg/ha) of moringa at 6 months after planting as affected by the rates of inorganic fertiliser.

Fertiliser rates	Dry leaf yield (kg/ha)
Control (no inorganic fertiliser)	622 c
100 kg/ha 2:3:2(22) + 100 kg/ha LAN	1111 b
200 kg/ha 2:3:2(22) + 200 kg/ha LAN	1439 a
400 kg/ha 2:3:2(22) + 400 kg/ha LAN	1485 a
Significance	**
LSD (0.05)	173.3
CV (%)	18.1

Mean values within the same column followed by the same letter are not significantly different at P = 0.05; ** Significant at P = 0.01, LSD = Least Significant Difference, CV = Coefficient of variation.

Nutrient composition of moringa leaves

The application of different rates of inorganic fertiliser had significant (P < 0.01) effects on crude protein percentages (CP %), crude fibre (CF) and ether extractable fat while the effects on ash, dry matter and moisture content were not significant (Table 8). As the rate of application of the fertilisers increased, the crude protein and crude fibre percentage increased (Table 8). The highest crude protein content (21.0%) and the highest fibre content (17.3%) were recorded at 400 kg/ha 2:3:2(22) + 400 kg/ha LAN and they were statistically at par with 200 kg/ha 2:3:2(22) + 200 kg/ha LAN. In contrast, leaves from the control (no fertiliser) had significantly the lowest crude protein (15.5%) and crude fibre (11.9%) (Table 8).

Feed intake, body weight gain and feed conversion ratio of broilers

The different formulated feeds had no significant effects on feed intakes in all the three weeks (Table 9). However, the effects of feed were significant on body weight gain (g/bird/day) and feed conversion ratio in week 2 and week 3 (Table 9). The highest body weight gains in week 2 (125.7 g/bird/day) and in week 3 (171.4 g/bird/day) were recorded for the control diet without moringa supplement while the other feeds supplemented with moringa produced significantly lower weight gains that ranged from 79.9 g/bird/day to 87 g/bird/day in week 2 and from 98.5 g/bird/day to 106.2 g/bird/day in week 3 (Table 9).

Significantly lowest feed conversion ratios of 0.628 in week 2 and 0.413 in week 3 were obtained for broilers that were fed with the standard broiler finisher alone indicating higher efficiency of the broilers in converting feed into food. In contrast, broiler finisher with moringa supplement had significantly higher feed conversion ratio that ranged from 0.995 to 1.117 in week 2 and from 0.717 to 0.823 in week 3 (Table 9). There were no significant differences among the diets with moringa grown in different rates of inorganic fertiliser in body weight gain and feed conversion ratio of the broilers.

Carcass and internal organs of broilers fed finisher diet with moringa

The treatment diets had highly significant ($P < 0.01$) effects on live weight, plucked weight and dressed weight and significant ($P < 0.05$) effects on heart and wing weights while the effects on the other measured organs were not significant (Table 10). Significantly the highest live weight (4799 g), plucked weight (4406 g), dressed weight (4255 g), heart weight (0.022 g) and wings weight (135.2 g) were recorded for the broilers that were fed with the control (conventional broiler finisher, no moringa) (Table 10). In contrast, broilers fed with moringa supplements had significantly lower live weight, plucked weight and dressed weight. On the other hand, broilers fed with moringa supplement grown at fertiliser rates of 200 kg/ha 2:3:2(22) + 200 kg/ha LAN had statistically at par heart weight with the control. No significant differences were noted among all diets with moringa grown in different rates of inorganic fertiliser for plucked weight, dressed weight and heart weight. For all the carcass and internal organs measured, the control diet had higher values compared to diet supplemented with moringa (Table 10).

Faecal bacterial count (per ml of the sample) of broilers

No significant differences were noted on broilers faecal bacterial count before feeding started and the numbers of bacterial faecal count ranged from 34867 to 53667 per ml of the sample (Table 11). In contrast, there was a significant ($P < 0.01$) difference on faecal bacterial count of the broilers after the end of the feeding. Faecal bacterial count of broilers that were fed with the control diet was the highest (52267/ml) at the end of the feeding trial; while broilers that were fed with finisher feed supplemented with moringa leaf recorded significantly lower faecal bacterial count that ranged from 15533 to 24000 per ml of the sample (Table 11). Bacterial count at the end of the feeding trial showed an increase in the control (conventional broiler finisher, no moringa) as compared to the count before the start of the feeding trial while in all the diets supplemented with moringa the numbers were decreased.

DISCUSSION

Growth, leaf yield and nutrient composition of M. oleifera

Growth

As the rate of inorganic fertiliser increased, there was a significant increase in percent canopy cover, canopy height, number of leaves per plant, and number of branches per plant of the moringa plant. The soils in the study area were deficient in major nutrients especially nitrogen, phosphorus, and potassium (Haque and Lupwayi, 2003). Therefore, adding inorganic fertilisers containing these major nutrients might have improved the growth of moringa. Nitrogen plays a vital role in plant metabolism and photosynthesis as it is an integral component of protein and nucleic acids and when it is sub-optimal, growth is reduced (Leghari *et al.*, 2016). Similarly, phosphorus is involved in energy storage and transfer and required for growth, nucleus formation, photosynthesis, utilisation of sugar and starch, and cell division**.** Potassium is also required for several plant activities such as photosynthesis, carbon assimilation and translocation of carbohydrates and provides resistance to drought and disease. The application of inorganic fertilisers might have increased photosynthetic processes, leaf area production, thus produced more branches. Leghari *et al.* (2016) also illustrated that deficiency of nitrogen causes reduced growth, appearances of chlorosis, and appearances of red and purple spots on the leaves, restrict lateral bud growth. These nutrients also enhance increased synthesis of chlorophyll, thus increase the number of leaves per plant.

In line with result from this study, Isaiah (2013) reported the highest number of leaves, plant height, stem girth, and number of branches with the application of 120 kg N:P:K/ha. Similarly, Darwish (2015) obtained significantly highest plant height, number of leaves per plant, stem diameter and number of lateral branches per plant of moringa at highest rate of NPK (300-300-150) kg/ha than 100-100-50 and 200-200-100 kg NPK/ha.

No significant growth differences were noted between fertiliser rates [200 kg/ha 2:3:2(22) + 200 kg/ha LAN] and [400 kg/ha 2:3:2(22) + 400 kg/ha LAN], which might indicate that the optimum rate for early growth of moringa to be 200 kg/ha 2:3:2(22) + 200 kg/ha LAN. This also indicates that excessive fertiliser application does not guarantee constantly increasing growth and yields and might result in low nutrient use efficiency, can cause environmental problems in agro-ecosystems and is costly (FAO, 2006).

Leaf yield (kg/ha)

Dry leaf yield of moringa was significantly increased as the inorganic fertiliser rates were increased from the control to 200 kg/ha 2:3:2(22) + 200 kg/ha LAN and showed non-significant increase at fertiliser rate of 400 kg/ha 2:3:2(22) + 400 kg/ha LAN. The increased leaf yield with the increased rates of the inorganic fertiliser might be due to balanced supply of nitrogen, phosphorus and potassium that increased canopy cover, number of leaves per plant and number of branches per plant. The increased inorganic fertiliser rate might have enhanced photosynthesis resulting in more dry matter accumulation in the plants. The results of this study demonstrated the positive relationship between inorganic fertiliser level and leaf yield of moringa until optimum fertiliser rate. In agreement with these results, González-González and Crespo-López (2016) reported that the balanced application of 27 kg N, 27 kg P and 36 kg K per ha with 4 tonnes of cattle manure per ha at planting and mixture of 65 kg of urea (30 kg N/ha) with 2 tonnes of cattle manure per ha per cutting produced the highest yield of total dry matter (20.11 t/ha) of moringa leaves. Likewise, Abdullahi *et al.* (2013) obtained nitrogen fertiliser (urea) rate of 200 kg/ha to be the best for the maximum biomass production of moringa than 400 kg/ha of urea.

The non-significant increase of dry leaf yield at the highest rate of inorganic fertiliser [400 kg/ha 2:3:2(22) + 400 kg/ha LAN] application might be due to excess supply of nutrients that created antagonistic effects that disturb the nutrient balance. Over fertilisation does not only reduce leaf yield and quality but also produces suboptimal economic returns (FAO, 2006).

Nutrient composition of moringa leaves

There was a significant increase on the crude protein and crude fibre content as the rate of the inorganic fertiliser increased. The increase in crude protein content with increased rate of the inorganic fertiliser could be due to increased amount of nitrogen which is the building block of protein. Moreover, the increase in the concentrations of crude protein and crude fibre might be due to the role of fertiliser in leaves chlorophyll content, which in turn enhances photosynthesis leading to increased synthesis of these substances. In agreement with these results, Isaiah (2013) recorded the highest protein content (19.01%) at the highest fertiliser rate of 120 kg N:P:K per ha.

Similarly, Anamayi *et al.* (2016) reported that application of 5 g NPK (15:15:15) per pot produced the highest protein (27.70%) and fibre (11.80%) as compared to the control. In contrast, Mendieta-Araica *et al.* (2012) obtained no significant differences in crude protein, acid detergent fibre and ash content between 0 and 261 kg/ha nitrogen while the effects on dry matter, neutral detergent fibre and lignin were significant. The crude protein, crude fibre, and crude fat contents obtained in this study were in agreement with the ranges reported by Mahfuz and Piao (2019) where they reported crude protein of 17.01% to 22.23%, crude fibre of 6.77% to 21.09%, and crude fat of 2.11% to 6.41% for *M. oleifera*.

Productive performance and faecal bacterial egg count of broilers

Feed intake, body weight gain and feed conversion ratio of the broilers

Whilst moringa leaf is evidently a good protein, energy and mineral source (Makkar and Becker, 1996), the results of this study showed a significant decrease in body weight gain and a significant increase in feed conversion ratio for broilers supplemented with moringa as compared to the conventional finisher. Decrease in body weight gain and increase in feed conversion ratio could be due to the negative effects of the anti-nutritional factors such as tannin and lignin present in moringa leaf meal possibly due to high amount of moringa supplementation (20 %) used in this study. In line with these results, Onu and Aniebo (2011) reported lower weight gain in some of the chickens fed moringa leaf meal despite its higher crude protein content. Likewise, Olugbemi *et al.* (2010); and Gakuya *et al.* (2014) suggested using maximum level of 5 % and 7.5 % supplementation of moringa, respectively, so as not to have any harmful effects on growth performance and feed conversion ratio in broilers. In contrast, Gadzirayi *et al.* (2012) did not find significant differences on feed intake and body weight gain between the control and 25 % level of moringa supplementation. Ayssiwede *et al.* (2011) also noted no adverse effects on body weight, average daily weight gain, and feed conversion ratio in indigenous Senegal chickens with dietary supplementation of moringa leaf meal up to a level of 24 %.

Carcass and internal organs of broilers

Results of this study showed a significant decrease in live weight, plucked weight, dressed weight, heart weight and wing weight of birds when fed with moringa supplemented feed as compared to the conventional broiler finisher. The decreased weights could be as a result of the effect of high fibre and the anti-nutritional components such as tannin and lignin in moringa (Moyo *et al.*, 2011) possibly due to high proportion (20 %) of moringa supplementations used in this study. In agreement with results of this study, Onunkwo and George (2015) recorded the highest carcass dressing percentage in birds fed with control diet compared to those supplemented with moringa leaf meal. Similarly, Abbas (2013) indicated a decrease in egg mass production, egg production percentage, and egg weight at a higher level of moringa leaf meal (20 % or more) mainly due to low digestibility of energy and protein. In contrast, Moreki and Gabanakgosi (2014) obtained higher growth performance in broilers with dietary supplementation of moringa leaves at 5 % to 20 % level. Likewise, Ebenebe *et al.* (2013) reported higher final live weight, average weight gain, and feed conversion ratio in 10 % moringa leaf meal supplemented diets than the control through a 35-day trial period.

Faecal bacterial count

Results of this study showed that using moringa supplement on the broiler feed diets caused significant reduction of the pathogenic faecal bacteria counts. The reduction in bacterial count might be due to the antimicrobial properties of moringa as it contains unique combinations of numerous phytochemicals such as alkaloids, saponins, steroids, phenolic acids, glucosinolates, flavonoids, and terpenes (Gupta *et al.*, 2018). In line with these results, Oluduro (2012) reported that the activity of moringa leaf extracts to be comparable to those of antibacterial antibiotics such as ciprofloxacin, amoxicillin, gentamicin and erythromycin.

CONCLUSION

Vegetative growth, leaf yield, crude protein and crude fibre contents of moringa were significantly increased with an increased application rates of the inorganic fertiliser up to 200 kg/ha 2:3:2(22) + 200 kg/ha LAN. On the other hand, supplementation of broilers with moringa leaves had negative effects on the feed intake, body weight gain, and feed conversion ratio and on major carcass characteristics while it significantly reduced the bacterial egg count of the broilers than conventional finisher feed. Thus, application of 200 kg/ha 2:3:2(22) + 200 kg/ha LAN can be used for the optimum early growth of moringa to obtain nutritious leaf. However, there is a need for further research on the optimum amount of moringa leaf to supplement broilers, its anti-bacterial mechanisms and its practical use for poultry production on larger scale.

Table 8. Nutrient composition of *M. oleifera* leaves at different fertiliser application rates.

Fertiliser rate [2:3:2(22) + LAN (kg/ha)]	Nutrient composition (% DM)				
	Crude protein	Crude fibre	Ether extractable fat	Ash	Moisture
0 (control)	15.5c	11.9c	6.5a	8.4a	35.5a
100 + 100	18.5b	14.7b	5.1b	7.5a	36.2a
200 + 200	21.0a	17.1a	5.2b	9.3a	36.8a
400 + 400	21.0a	17.3a	5.1b	8.0a	36.1a
Significance	**	**	**	NS	NS
LSD (0.05)	0.93	1.44	0.59	1.3	2.9
CV (%)	6.0	11.5	13.0	19.4	9.6

Mean values within the same column followed by the same letter are not significantly different at P = 0.05; ** = significant at P = 0.01, NS = non-significant, LSD = Least Significant Difference, CV = Coefficient of variation.

Table 9. Feed intake, body weight gain, and feed conversion ratio of broilers fed diets supplemented with moringa leaves produced in different rates of inorganic fertiliser.

Treatment†	Feed intake (g/bird/day)			Body weight gain (g/bird/day)			Feed conversion ratio		
	Week 1	Week 2	Week 3	Week 1	Week 2	Week 3	Week 1	Week 2	Week 3
T1	48.5 a	77.9 a	69.8 a	60.72 a	125.7 a	171.4 a	0.799 a	0.628 b	0.413 b
T2	46.9 a	79.3 a	70.9 a	65.1 a	80.9 b	100.9 b	0.736 a	0.995 a	0.717 a
T3	53.1 a	87.9 a	78.4 a	67.14 a	80.9 b	98.5 b	0.793 a	1.117 a	0.823 a
T4	51.2 a	82.3 a	74.9 a	65.05 a	79.9 b	101 b	0.79 a	1.026 a	0.74 a
T5	52.7 a	90.4 a	80.5 a	63.59 a	87 b	106.2 b	0.827 a	1.053 a	0.761 a
Significance	NS	NS	NS	NS	**	**	NS	*	*
LSD (0.05)	NS	NS	NS	NS	11.5	16.69	NS	0.28	0.23
CV (%)	22.9	19.1	19	5.6	9.4	10.8	24.1	21.7	25

†

T1 = Control (conventional broiler finisher, no moringa), T2 = Broiler finisher + moringa with no fertiliser, T3 = Broiler finisher + moringa with 100 kg/ha 2:3:2(22) + 100 kg/ha LAN, T4 = Broiler finisher + moringa with 200 kg/ha 2:3:2(22) + 200 kg/ha LAN, T5 = Broiler finisher + moringa with 400 kg/ha 2:3:2(22) + 400 kg/ha LAN.
Mean values within the same column followed by the same letter are not significantly different at P = 0.05; *, **, NS = significant at P = 0.05, significant at P = 0.01, and non-significant, respectively; LSD = Least Significant Difference, CV = Coefficient of variation.

Table 10. Carcass and internal organs of broilers (g per two broilers) fed a finisher diet with moringa leaves produced in different rates of inorganic fertiliser.

Carcass characteristics	Treatments†							
	T1	T2	T3	T4	T5	Significance	LSD (0.05)	CV (%)
Live weight	4799a	2851c	3157b	2992bc	2975b[c]	**	299.7	6.7
Plucked weight	4406[a]	2514b	2634b	2695b	2697b	**	339.4	8.5
Dressed weight	4255[a]	2404b	2480b	2591b	2592b	**	334.3	8.7
Feathers	210.8a	130b	133.8b	123.8b	145b	**	39.96	20
Livers	0.103a	0.08a	0.07a	0.09a	0.076a	NS	NS	27.5
Intestines	0.487a	0.368a	0.41a	0.368a	0.423a	NS	NS	16.8
Hearts	0.022a	0.016b	0.015b	0.019ab	0.016b	*	0.0045	18.9
Gizzards	0.124a	0.114a	0.106a	0.117a	0.11a	NS	NS	16.6
Wings	135.2a	109.2ab	76.2b	122.2a	133.2a	*	36.6	23.7
Leg	372a	219a	231a	273a	260a	NS	NS	48.8

†T1 = Control (conventional broiler finisher, no moringa), T2 = Broiler finisher + moringa with no fertiliser, T3 = Broiler finisher + moringa with 100 kg/ha 2:3:2(22) + 100 kg/ha LAN, T4 = Broiler finisher + moringa with 200 kg/ha 2:3:2(22) + 200 kg/ha LAN, T5 = Broiler finisher + moringa with 400 kg/ha 2:3:2(22) + 400 kg/ha LAN.
Mean values within the same row followed by the same letter are not significantly different at P = 0.05; *, **, NS = significant at P = 0.05, significant at P = 0.01, and non-significant, respectively, LSD = Least Significant Difference, CV = Coefficient of variation.

Table 11. Faecal bacterial count (number per ml of sample) of broilers before and after feeding diets supplemented with moringa.

Treatment	Before treatment†	After treatment
Control (conventional broiler finisher, no moringa)	46200 (4.546) a	52267 (4.635) a
Broiler finisher + moringa with no fertiliser	42533 (4.549) a	15533 (4.098) b
Broiler finisher + moringa with 100 kg/ha 2:3:2(22) + 100 kg/ha LAN	34867 (4.486) a	17600 (4.06) b
Broiler finisher + moringa with 200 kg/ha 2:3:2(22) + 200 kg/ha LAN	45533 (4.56) a	24000 (4.227) b
Broiler finisher + moringa with 400 kg/ha 2:3:2(22) + 400 kg/ha LAN	53667 (4.62) a	16800 (4.14) b
Significance	NS	**
LSD (0.05)	NS	0.26
CV (%)	7	8.5

†Values in parenthesis are log transformed and those out of parenthesis are the original values.
Mean values within the same column followed by the same letter are not significantly different at P = 0.05; NS, ** = Non-significant and significant at P = 0.01, respectively; LSD = Least Significant Difference, CV = Coefficient of variation.

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