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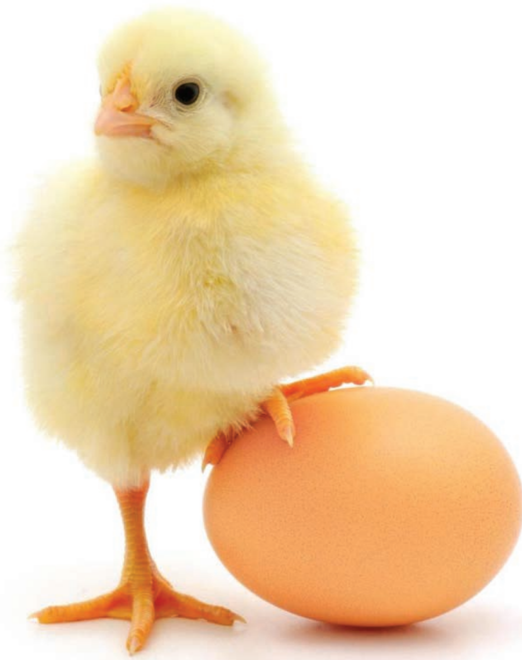

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Research Article
Growth Performance, Liveability and Physico Chemical Properties of Broiler Chicken Fed *Moringa oleifera* Based Diets

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Abstract
Objective: The study investigated the effect of *Moringa oleifera* on growth performance, liveability and the related physico-chemical properties of the broilers chicken. **Materials and Methods:** Forty-five day old broiler chicks (cobb 500) were randomly distributed into three dietary treatment groups. The treatments were T1 (control without *Moringa*), T2 (5% inclusion level of *Moringa oleifera* leaf meal) T3 (7% inclusion level of *Moringa oleifera* leaf meal). Clean fresh water was provided *ad libitum*, feed was provided according to recommended daily intake per bird. Left overs were weighed to get daily intake and feed conversion efficiency. Birds were vaccinated at the hatchery and research site. Medications were used according to disease diagnosed. **Results:** There was a significant effect of *Moringa oleifera* on weekly weight gain, feed intake and average daily gain ($p<0.05$). Results showed no significant effect of *Moringa oleifera* on final weight and feed conversion efficiency (p>0.0.05). Liveability was 100%. Diet supplemented with *Moringa oleifera* positively affected the physico-chemical properties, water holding capacity and colour of meat. There was no significant effect ($p>0.05$) on pH and marbling, although marbling tended to decrease with increase in *Moringa oleifera* inclusion. **Conclusion:** *Moringa oleifera* as a feed additive in broiler feed improved the feed intake, average daily gain and colour attributes (l* = lightness, a* = redness and b* = yellowness).

Key words: *Moringa oleifera*, broiler feed, meat qualities, water holding capacity, colour attributes

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Growth in poultry production has been noted since the year 2000, with Africa and Asia being the highest producers of broilers[1]. Approximately 20% of animal protein consumed in developing countries is obtained from chicken meat[2]. Broiler production is one of the most common enterprises in poultry with a quick turn over and is done on all scale sizes. It provides opportunities for increased animal protein consumption and has improved the livelihoods of many rural and urban people in Zimbabwe and other African countries. It has created employment and generated income especially to small holder farmers[3]. Chicken has high protein value, readily available fats, low cholesterol content and high nutritive value, is affordable and easy to process[4]. However chicken meat is susceptible to lipid peroxidation which is a process where cells are damaged as result of oxidative degeneration of lipids where free radicals "steal" electrons from lipids in cell membranes and it leads to decomposition of meat[1,5], bacterial contamination during storage, breakdown of hydro peroxides which results in offensive off flavors that make fats rancid thus leading to toxicity[6]. Oxidation reduces shelf life of meat. In addition, lipid peroxidation negatively affects colour, flavor, texture and nutritional value[7]. A lot of studies have demonstrated that shelf life can be improved by using synthetic antioxidants. However, consumers now prefer organic additives and favor birds that have been raised without sub therapeutic antibiotics.

Sub therapeutic antibiotics may cause drug resistance to humans when synthetic antibiotics are used as growth promoters for faster growth in poultry birds. This has led the other countries to limit the use of synthetic growth promoters as feed additives in poultry industry. European Union has banned the use of antibiotics in poultry feed since January 2006[8]. Consumer preferences have also driven the focus of research on antioxidants which are simple, cost effective, can improve growth and does not compromise human health, maintain animal health, give good carcass quality and productivity. Ali *et al.*[6] and David *et al.*[9] recommended the use of dietary antioxidants to increase storage duration of food stuff, improve lipid stability, maintain sensory and nutritional qualities of food and increase shelf-life to preserve product quality. Recent studies have found that natural antioxidants are safer than synthetic ones. Food rich in antioxidants has a pivotal role in prevention of diseases such as cardiovascular and cancers. Moyo *et al.*[10] highlighted that the use natural antioxidants from plants have gained popularity because they are safer than synthetic antioxidants. *Moringa oleifera* (MO) has been researched as a natural antioxidant with promising results[10].

Moringa oleifera is a genus from the *Moringaceae* family. The genus has 13 species which can be grown in tropical and sub-tropical climates. All parts of the MO tree have useful properties. It is known as multipurpose tree. All parts of MO tree have many uses which range from fertilizer, natural coagulants, fodder, food spices, herbal, nectar for bees, medicine, antioxidants and anti-inflammatory compounds. Leaves, pods and flowers are sources of ascorbic acid, nicotinic acid, folic acid, vitamins A, B and C, pyridoxine, beta carotene, riboflavin, iron, alpha-tocopherol and calcium. Pods are also important source of amino acids[9].

Moringa oleifera is reported to contain some significant levels of natural antioxidants, such as vitamin E, selenium and tannins, which decrease the rate of lipid and pigment oxidation. Antioxidants increase storage of food products, improves lipid stability of food and maintains sensory and nutritional qualities of food[6]. *Moringa oleifera* inhibits free radicals, enhances the oxidative stability of meat without having effects on its physico-chemical characteristics[11]. El Tazi[12] and Waskar *et al.*[13] stated that MO has a positive effect on meat quality, leaves have nutrients which are important for both humans and animals and has crude protein content (25-27%), soluble pepsin nitrogen (82-90%) and acid detergent insoluble protein (1-2%). *Moringa oleifera* leaves contain most of the nutrients to the animal[14,15]. *Moringa oleifera* leaves can be a natural growth promoter, an antioxidant which improves meat quality, promote fast growth of chicken and can be produced locally at a very low cost.

There has been growing concern among consumers about health, meat quality, susceptibility to lipid oxidation and faster bacterial contamination during storage which leads to reduced shelf-life of broiler meat. Lipid oxidation have adverse effects on meat quality parameters such as colour, water holding capacity and pH, thus leading to the reduction of shelf-life of the meat[16]. There is a great need to come up with natural ways to extend the shelf life of chicken meat that do not threaten the consumer health.

Moringa oleifera has been reported to have antioxidant properties therefore has a potential to decrease lipid peroxidation hence increased shelf life of meat. In addition, MO has the ability to promote growth in broilers, improve physico-chemical properties and health status of animals and humans by its medicinal effects.

Objectives: This study sought to determine the effect of *Moringa oleifera* based feed on growth, liveability and physico chemical properties (pH, colour, water holding capacity and marbling fat) of broiler chickens.

MATERIALS AND METHODS

Study site: The study was carried out at Bindura University of Science Education, Astra campus, 310°18" 11 east, longitude 17°18" 52 south latitude, with an altitude 1096 m. The site is in natural region 2a which receives about 750-1000 mm rainfall with mean annual temperatures of 25-32°C.

Study animals: Forty-five Irvine's day old chicks (Cobb 500) were used in this research. The chicks were vaccinated at the hatchery against infectious bursal disease at 14 and 18 days of age as well as at 21 days of age against new castle disease (NCD).

Design of study: A completely randomized design (CRD) was used in this study. All the chicks were fed a conventional starter diet for the first two weeks. Three dietary treatments (T1, T2 and T3) with different inclusion levels (0% control, 5% and 7%) of MOLM were then randomly assigned to birds for starter (up to 21 days) and finisher stage (22-42 days). Each treatment had three replicates with 5 birds each. Each replicate from every treatment was represented in each cage. Floor space was 33 birds per m^2 for day old chicks and was increased to 10 birds per m^2 at the age of 21-42 days.

Proximate analysis of broiler diet supplemented with MOL at starter and finisher phase is presented in Table 1, whereas diet composition is presented in Table 2.

Growth rate: Body weights were measured weekly (i.e. at 7th, 14th, 21st, 28th, 35th and 42nd days) which was used to calculate growth rate in grams per week.

Feed intake (FI): Feed intake was calculated as the difference between feed offered and left over.

Average daily gain (ADG): The average daily gain was calculated as the difference between the final and initial bird weight divided by the duration of the weighing period in days:

$$\text{ADG} = \frac{\text{Finish weight - start weight}}{\text{Duration of weighing period (in days)}}$$

Feed conversion efficiency (FCE): Feed conversion efficiency is the proportion of food that is converted into meat. It was calculated using the following equation:

$$\text{FCE} = \frac{\text{Feed intake}}{\text{Daily gain}}$$

Liveability: Liveability is the survival expectancy or the number of birds which survived divided by total birds at the start of the research.

Physico-chemical properties

Chicken pH: The ultimate pH of breast muscle was determined by a Crison pH25 (Crison instruments, Spain). Meter was calibrated before taking measurements using pH 4, 5 and 7 standard solutions. The pH meter was inserted in meat muscle and measurements of pH and temperature were recorded. The pH meter was rinsed with distilled water after taking readings of every sample (breasts).

Meat colour: The colour of meat was determined using the commission International de l'Eclairage (CIE), (1976) where l* = lightness, a* = redness and b* = yellowness. The l*, a*, b*

Table 1: Proximate analysis of broiler fed MOL diets at starter and finisher phase

	T1 (0%)		T2 (5%)		T3 (7%)	
Item (g kg^{-1})	Starter	Finisher	Starter	Finisher	Starter	Finisher
Ash	12.87	10.75	13.17	14.17	18.44	19.84
Ether extract	5.35	5.25	7.05	7.16	9.87	10.03
Crude protein	60.37	56.13	43.12	40.09	26.78	27.03
Crude fiber	16.99	20.85	28.56	29.01	39.98	40.73
Nitrogen free extracts	151.33	153.27	108.10	109.49	65.65	56.65
GE	246.91	246.25	200.00	199.92	160.72	154.28

Table 2: Ingredient composition of broiler starter and finisher diet

	T1 (0%)		T2 (5%)		T3 (7%)	
Ingredients	Starter/100 kg	Finisher/100 kg	Starter/100 kg	Finisher/100 kg	Starter/100 kg	Finisher/100 kg
Maize (%)	690	770	640	720	620	700
Soya cake (%)	290	210	290	210	290	210
Moringa (%)			50	50	70	70
Additives (%)	20	20	20	20	20	20

Target CP content 20% on starter and 18% on finisher of breast muscles were determined, 24 hrs after slaughter, using a colour-guide (precision calorimeter 100, Shenzhen, 3 nh South China). The colour guide was rotated 3 times at 90° on each sample, in order to obtain an average value of colour. Colour guide was calibrated before using it[17].

Water holding capacity (WHC): Water holding capacity (WHC) of breast muscle was determined according to the method described by Garcia *et al.*[18]. Briefly, a copper tube of 15 mm diameter was used to core meat samples of 2 cm long. These samples were put between two bond paper circles, wooden board and a steel block of 10 kg was put on top of samples for 5 min. Bond paper circles were weighed before putting samples and after pressing when samples were removed. The difference in bond paper circles was recorded as the WHC.

$$WHC = \frac{100 \times w\Delta\text{-}w_0}{w_0}$$

w_0 = Initial weight of bond paper
w_Δ = Difference in water content of bond paper circles

Marbling fat content (MFC) analysis: Soxhlet method was used to analyse the marbling fat content. Breast meat sample of 5 g was dried for 24 hrs at 105°C in a drying oven. The dried samples were then transferred to soxhlet equipment. The extraction was done using petroleum for 6 hours at 60°C. The flask with fat after solvents were evaporated, dried for 1 h at 100°C and cooled at room temperature in a desiccator[19]. Intramuscular fat content (percentage) was calculated as follows:

$$\text{Fat (\%)} = \frac{\text{Fat after extraction}}{\text{Wet sample weight}} \times 100$$

Statistical analyses: Growth, pH, WHC, marbling fat content and colour were analyzed using the general linear model (GLM) procedure of the Statistical Analysis System (SAS)[20]. Differences between means were compared using the PDIFF option[20].

$$y_{ij} = \mu + t_i + \varepsilon_{ij}$$

where:
y_{ij} = The individual observations
μ = The overall mean
t_i = Effect of dietary treatments
ε_{ij} = Random experimental error

RESULTS

Composition of nutrients in diets: Ash, ether extracts (EE) and crude fibre (CF) increased as the inclusion level of MOLM increases. Crude protein (CP) and nitrogen free extracts (NFE) decreased as the inclusion level of MOLM increases. In starter feed ash values ranged from 12.87-18.44, EE ranged from 5.35-9.87, CF ranged from 16.99-39.98, CP and NFE declined from 60.37-26.78 and 246.9-65.65, respectively in starter feed. In finisher feed, ash values ranged from10.75-19.84, EE ranged from 5.25-10.03, CF ranged from 20.85-40.73 while CP and NFE values declined from 56.13-27.03 and 153.27-56.65, respectively.

Growth rate

Effect of diet on final weight (FWT) of birds: MOLM non-significantly affected the final weights. Final weight of birds decreased as inclusion level of MOLM increases (Table 3).

Supplementation of 0, 5 and 7% MOLM in the diet of broiler chicken had no significant effect on weight gain of birds.

Effect of diet on feed intake (FI): Feed intake increased significantly as the inclusion level of MOLM increased (Table 4).

The Highest feed intake was recorded in T3 (7% inclusion level of MOLM), followed by T2 (5% inclusion level of MOLM) and the least was recorded in control diet (0% inclusion level of MOLM). All diets were significantly different from each other.

Effect of diet on average daily feed intake: MOLM significantly affected feed intake. Feed intake increased as the inclusion level of MOLM increases.

Dietary treatment T3 (7%) had the highest average daily gain followed by T2 (5%) and the least was in T1 (0%) (Table 5).

Table 3: Effect of diet on final weight (FWT) of birds

MOLM inclusion level	FWT (LS Mean±SE)
0%	1408.6±126.3[a]
5%	1348.5±126.3[a]
7%	1380.7±126.3[a]

[a]Means with same superscripts within same column were not significantly different (p>0.05), FWT: Final weight, LS: Least square and SE: Standard error

Table 4: Effect of diet on feed intake

MOLM inclusion level	FI (LS Means±SE)
0%	479.5±12.29[a]
5%	700.4±12.29[b]
7%	749.4±12.29[c]

[a,b,c]Means with different superscripts within same column were significantly different (p<0.05), FI: Feed intake, LS: Least square and SE: Standard error

Table 5: Effect of diet on average daily gain (ADG)

MOLM inclusion level	ADG (LS Means±SE)
0%	187.80±2.7[a]
5%	194.62±2.7[ab]
7%	208.30±2.7[c]

[a,b,c]Means with different superscripts within same column were significantly different ($p<0.05$), ADG: Average daily gain, LS: Least square and SE: Standard error

Table 6: Effect of diet on feed conversion efficiency

MOLM inclusion level	FCE (LS Means±SE)
0%	3.3±0.09[a]
5%	3.3±0.09[a]
7%	3.5±0.09[a]

[a]Means with same superscripts within same column were not significantly different ($p>0.05$), FCE: Feed conversion efficiency, LS: Least square and SE: Standard error

Table 7: Colour and pH least square means table

Items	Diet	Breast (LS Means±SE)
l*	0	55.2±1.5[a]
	5	44.9±1.5[b]
	7	38.7±1.5[c]
a*	0	10.2±0.6[a]
	5	3.8±0.6[b]
	7	1.6±0.6[c]
b*	0	1.6±0.9[a]
	5	9.0±0.9[b]
	7	14.7±0.9[c]
pH	0	5.6±0.0[a]
	5	5.6±0.0[a]
	7	5.6±0.0[a]

[a,b,c]Means with different superscripts within same column were significantly different ($p<0.05$), LS: Least square and SE: Standard error

Effect of diet on feed conversion efficiency (FCE): MOLM non-significantly influenced the feed conversion efficiency.

Feed conversion efficiency was the highest in T3 (7%). The same value of feed conversion efficiency was recorded in T1 (0%) and T2 (5%) group (Table 6).

Liveability: Liveability was 100% across all diets and no mortalities were recorded.

Physico-chemical properties

pH: Diet supplemented with MOLM had no significant effect on pH of breast muscles ($p>0.05$).

Colour: All diets were significantly different ($p<0.0001$) from each other. l*(lightness) values decreased as the supplementation of MOLM increases, a* (redness) decreased as the inclusion level of MOLM increases and b* (yellowness) values increased with an increase in MOLM percentage (Table 7).

Table 8: Effect of diet on WHC of breast muscle

MOLM inclusion level	Breast muscle (Mean±SE)
0%	1.0±0.6[a]
5%	5.0±0.7[b]
7%	7.0±0.7[c]

[a,b,c]Means in the same column with different superscript are significantly different ($p<0.05$) and WHC: Water holding capacity

Table 9: Effect of Diet on Marbling Fat Content (MFC) of Breast Muscle

MOLM inclusion level	MFC (LS Means±SE)
0%	60.6±1.4[a]
5%	56.8±1.6[ab]
7%	53.5±1.6[b]

[a,b]Means in the same column with different superscript are significantly different and MFC: Marbling fat content

Effect of diet on WHC of breast: Breast muscle retained the highest quantity of water in T3 (7%) group, followed by T2 (5%) group and the least was in T1 (0%) (Table 8).

Effect of diet on MFC of breast: Results showed that the marbling fat content in breast muscle was higher in T3 (7%) than those of the birds fed T1 (0%) and T2 (5%) (Table 9).

DISCUSSION

Feed composition: Formulated broiler feeds were expected to provide 20% CP in starter and 18% CP in finisher diet[21]. Results showed that increase in MOLM percentage increased the ash, EE, CF but decreased the CP and NFE. This result agrees with the findings of Gadzirayi *et al.*[21] and contradict with Kakengi[12] who observed that CF and EE decreased as the inclusion level of MOLM increases and CP increased as MOLM inclusion increases. Differences in CP, NFE, CF and EE could be due to difference in soils, rainfall pattern, altitude and nutrient contents of soil where MOL was harvested.

Growth

Final weight gain (FWT): Final weight decreased as MOLM inclusion increases. Similar results were reported by Gadzirayi *et al.*[21]. Decline in final weight gain could be due to pre-slaughter stress because broilers were starved for 6 hrs prior to slaughter (feed restriction but water provided). Broilers fed T2 (5%) and T3 (7%) were more stressed than those fed on T1 (control diet). This was due to the fact that they were used to take more feed every day before feed restriction prior to slaughter.

Feed intake (FI): Results showed that different levels of MOLM significantly affected feed intake of broilers. However, this result is different from Gadzirayi *et al.*[21] who reported that different levels of MOLM had no significant effect on FI of broilers. The FI increased as MOLM percentage increases. Growth factor affect the FI of chickens, as broilers grow they tend to take more feed to satisfy their nutrient requirements. On the 3rd week of the experiment a reduction in feed intake was observed which may be due to respiratory distress. However, in week 4, feed intake was improved after treatment with Aliseryl WS containing antibiotics and vitamins. The improved feed intake resulted in an increase in weight gains. Similar results were reported by Gadzirayi *et al.*[21] who studied the performance of broiler chickens fed on mature MOLM as protein supplement to soyabean meal. Increase in feed intake as MOLM percentage increases may be attributed to the fact that MO inclusion in diets changes feed colour form light to a darkish colour. The sensory impression (vision) is attributed to increase in FI. It can also be due to bulk metabolizable concentration of *Moringa oleifera*.

Feed conversion efficiency: Results showed no significant difference in feed conversion efficiency across diets. The lowest FCE was observed in T1 (0%) and the highest in T3 (7%). Gakuya *et al.*[22] conducted a study on the effect of MOLM supplementation on broiler chicken and obtained similar results. The highest FCE was recorded during first and second week, however, it declined between weeks 2 and 3 with a further decline in week 4. This was due to fact that as broilers grow their feed intake increased but conversion of the feed into meat was lower due to the possibility of genetic causes. In similar study, Gadzirayi *et al.*[21], used Hubbard breed, whilst this study used Cobb 500.

Liveability: Liveability was 100% in this study which may be a due to standard rearing practices. Bio security and brooding was done under optimum conditions. Cages were disinfected using virukill. Wet bedding was removed every morning to protect birds from bacterial diseases. Water troughs were cleaned every day and fresh water was provided. The cages were behind a building which acted as a wind break, cages were being covered during at night and infra red lamp was put to protect chicks against cold weather. The strict monitoring was done in brooding stage especially at night time in the first 3-7 days when bloody stained droppings were seen in control birds. Also mosquito bites lesions were discovered from broilers fed on control diet at slaughter. No unauthorised visitors were allowed near the broilers cages. Interventions were quickly instituted whenever a deviation from the normal appearance was noted.

Physico-chemical properties

pH: Results showed that diet has no significant effect on pH of breast meat. This is supported by Qwele *et al.*[17] who studied the effects of dietary mixtures of *Moringa Oleifera* leaves and crushed maize on antioxidative potential and physico-chemical characteristics of breast meat of broilers and found that dietary supplementation had no effect on pH. Nkukwana[23] also obtained similar results and reported that diet has no significant effect on pH of meat. In this study pH of breast meat ranged from 5.29-5.55 in T1 (control diet), 5.55-5.64 in T2 (5%) and 5.67-5.79 in T3 (7%). Klont[24] indicated that pH of meat fall between 5.2-7.0 with highest meat quality obtained pH between 5.7-6.0. In this study all pH values fall within the recommended values, however, the pH value in T3 (7%) produced the highest quality of meat. In a similar study Nkukwana *et al.*[25] discovered that meat with high pH retains moisture, appear dark in colour and influence meat quality. Muchenje *et al.*[11] reported that meat with high pH results in a condition known as dark firm dry (DFD), which makes meat to be inferior quality, off flavour, dark in colour and the condition is mostly favoured by bacterial growth because of high moisture content. Nkukwana *et al.*[25] also reported that if there is a decline in pH, meat losing its moisture and appear light in colour and results in a condition called pale soft exudative (PSE). The two conditions DFD and PSE are rare in broiler[23]. Oxygen radical absorbance capacity (ORAC) value is a representation of the total antioxidant phenolic in a sample. *Moringa* has relatively high ORAC values[26] this entails that diets with MOLM have lower oxidative damage due to free radical scavenging property that results in higher pH. Results of the present study showed that an increase in MOLM percentage results in an increase in pH.

Colour: Results showed that diet had significant effect on breast values of l*, a* and b*. The results are also supported by El Tazi[12]. l* (lightness) values decreased as MOLM percentage increases, a* (redness) value decreased as MOLM percentage increases and b* (yellowness) values increased with an increase in MOLM percentage. Similar results were made by Mukumbo *et al.*[27] who claimed that yellowness value increased as MOLM percentage increases. Lightness values (l*) were higher in control birds than those of the birds fed T2 (5%) and T3 (7%). Redness (a*) values were higher in birds fed T1 (control) than those of the birds fed T2 (5%) and T3 (7%). Meat of the Broiler fed T3 (7%) showed the greater yellowness values (b*) than those of the birds fed on T1 (control diet) and T2 (5%). Yellowness of meat could be due to carotenoids in *Moringa oleifera*. All unfeathered tissues of broilers which were fed on diet with MO inclusion were yellow in colour, yellowness was observed in broilers fed T2 (5%) and more pronounced in broilers fed T3 (7%). Similar findings were obtained by Gadzirayi *et al.*[20]. There is a possibility that with the passage of time, people will prefer yellow chicken meat.

Water holding capacity (WHC): Diet affected WHC of breast meat. The dietary treatment T1 (0%) (control) had the lowest WHC followed by T2 (5%) and T3 (7%) had the highest WHC. According to Huff-Lonergan and Lonergan[28] WHC is the ability of post-mortem muscle (meat) to retain water even though external pressures are applied to it. In a similar study by Huff-Lonergan and Lonergan[28] stated that meat with low WHC tends to produce inferior processed product and the meat with high WHC produce super quality processed products. Cheng *et al.*[29] reported that water content of meat is an important parameter in meat industry as it determines final yield of meat. During meat processing water is lost at each and every stage. Meat with low WHC leads to reduced yield due to numerous procedures during meat processing. Meat with high WHC is recommend for better yield and greater consumer satisfaction in terms of colour, flavour appearance, juiciness and tenderness.

Marbling fat content (MFC): Dietary treatment had no effect on marbling fat content of breast meat.

CONCLUSION

Moringa oleifera as a feed additive in broiler feed showed the best results and improved feed intake, average daily gain and colour attributes (l* = lightness, a* = redness and b* = yellowness). Inclusion of MOLM in broiler diet changes feed colour and add flavour which increase the feed intake. *Moringa oleifera* has antimicrobial effect which was shown in broilers fed T2 (5%) and T3 (7%). Unlike control birds, they did not succumb to bloody droppings even after sharing same cages. Carotenoids in MO brought about colour variation in broiler meat and increased the ability to retain water.

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