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Research Article
The Effect of Earthworm *Eisenia foetida* Meal as a Protein Source on Carcass characteristics and Physico-Chemical Attributes of Broilers

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Abstract

Objective: This study aimed to investigate the effects of *Eisenia foetida* (*E. foetida*) meal on the carcass characteristics and physicochemical attributes of broiler chickens. **Materials and Methods:** A total of 180, 12 per treatment un-sexed day-old broiler chicks were randomly assigned to five dietary treatments (T) as follows: 0% (EW0), 1% (EW1), 3% (EW3) 5%, (EW5) and 10% (EW10) earthworm meal inclusion. At day 35, carcass characteristics and meat quality were measured. **Results:** The results revealed the dietary effect on the wing and drumstick yield ($p<0.05$), however, supplementation of *E. foetida* meal linearly ($p<0.05$) reduced wing yield. The gizzard yield was increased linearly ($p = 0.05$) by worm meal inclusion. In addition, there were dietary treatments effects ($p<0.05$) on the colour of breast muscles over time. The highest values for L* (lightness) and b* (yellowness) were found in EW5 birds while the highest values for a* (redness) were found in EW1 birds. The pH values were affected ($p<0.05$) by the dietary treatments at 1h post-mortem with the highest pH values observed in birds in EW3 and EW1. Dietary treatments had a significant influence ($p<0.05$) on cooking loss; even though, there were no differences ($p>0.05$) observed on shear force values. The cooking loss increased linearly ($p = 0.009$) by the inclusion of worm meal. **Conclusion:** In conclusion, the inclusion of *E. foetida* meal into diets of broilers had positive effects on carcass characteristics and physicochemical attributes.

Key words: Broiler, carcass characteristics, earthworm meal, meat colour, pH, tenderness

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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

Chicken is one of the most consumed meats in the world[1]. The perceived health-related issues attached to red meat by consumers have increased the demand for chicken meat. Hence, there is need to improve chicken production in order to meet the huge demand. The major challenge in poultry production is the availability of good quality feed at cheaper prices. Commercial poultry production is dependent on scarce and expensive conventional feed ingredients. Thus, this has resulted in the increase of the production cost of broilers[2].

Many alternative sources of protein as animal feed have been explored including house fly maggots, terminates, snails, grasshoppers, silkworm caterpillars and earthworms. Earthworms feed on organic waste, have high propagative rates, easy to process and store. The quality of earthworm varies with and within the species, *Eisenia foetida* has been found to be better in nutrient composition than *Allolobora coligonosa*, *Pherettma gullemi*, *Eudrilus eugentae* and *Pertonxy excavate*[3].

Hence, *Eisenia foetida* meal can be a solution to the limiting and high cost of protein source for chicken feed. Many authors reported that *E. foetida* is a good source of protein for chickens[2]. Its protein content ranges from 50-70% which makes it a better protein supplement than fish meal and meat meal[4]. Naturally, free-range chickens have known to feed on earthworms, therefore it can be easily used as a protein supplementation for chickens.

The researchers have focused on the use of alternative sources of proteins such as edible insects for animal feed[5]. Although the focus is on alternative sources of proteins, little has been done on how the quality of the end product is affected. To our knowledge, only one study reported on the effect of earthworm on physicochemical attributes of chicken meat[6]. There seems to be a lack of information on how *E. foetida* meal influences broiler meat quality. Therefore, considering its high protein content, there is a need to investigate the effect of *E. foetida* meal on carcass characteristics and physicochemical attributes of chicken meat. The objective of this study was to investigate the effect of inclusion levels of *E. foetida* meal on growth performance, carcass characteristics and meat quality.

MATERIALS AND METHODS

Study site: The experiment was carried out at Fort Cox Farm, Fort Cox College of Agriculture and Forestry, King Williams Town, South Africa. The mean daily temperatures during the trial ranged from 20-35°C.

Animals and experimental procedure: A total of 180 day-old unsexed Cobb broiler chicks were obtained from a commercial hatchery (Belyn, East London, South Africa) and were assigned to five treatments with three replicates with 12 birds per replication. The house floors were covered with six cm of wood shavings as litter material. These experimental pens were constructed within a house in which a 1 m high net wall was covered with wire mesh. The wire mesh was allowed for ventilation and natural light. The diets were then randomly allocated to the 15 pens. Chicks were inspected daily and dead birds were removed. Feed and fresh water were accessible *ad libitum* throughout the whole production cycle.

Diets: The feeding program comprised of a starter (1-21 days broilers), grower (22-28 days) broilers) and finisher diet (29-35 days), basal diets were formulated on Win-Feed 3.0 Formulation Software to meet the bird's dietary nutrient requirements. Five dry feeds were formulated based on the protein of the major feed ingredient mainly earthworm meal, canola oilcake and soya oilcake as shown in Table 1. Each basal feed was split into 5 treatment (EW) groups, with increasing inclusion levels of earthworm meal at 0% (EW0: control), 1% (EW1), 3% (EW3), 5% (EW5) and 10% (EW10). The earthworms were purchased from commercial supplier Ado Cruse at Port Elizabeth and they were oven-dried for 4 h before grinded into a meal. The nutrient composition of oven-dried *E. foetida* (DM) is presented in Table 2.

Slaughter procedure: At 35 days of age, 75 birds, 15 birds per treatment were randomly selected and fasted for 6 h with water offered *ad libitum*. The chickens were stunned individually on the head using 70 V prongs, heads were decapitated from the neck using a sharp knife.

Carcass performance: At the processing plant, birds were reweighed before slaughter to measure their live weights. After bleeding, scalding, plucking and washing, the feet, head and neck were removed.

Carcass yield and digestive organ: Gizzards and visceral organs (liver, heart and spleen) were removed by hand through an incision made around the vent and sternum. Visceral organs were weighed individually and expressed as a percentage of the live weight. Carcasses were dissected into drumsticks, wings, thighs and breasts, then cuts were weighed and yield was calculated.

Table 1: Ingredients and analysed the nutrient composition of the experimental diets on a dry basis

	Items														
	Starter					Finisher					Post finisher				
Ingredients	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
Maize	65.20	65.68	66.05	65.70	63.81	69.50	69.63	69.90	69.41	65.90	73.29	73.51	72.48	70.52	61.46
Soya	24.26	22.15	20.30	18.25	15.91	18.51	17.80	16.37	14.18	10.50	14.83	13.90	13.27	12.55	7.76
Sunflower	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Canola	2.84	3.50	3.27	3.85	0.00	4.85	4.57	4.02	4.85	5.00	5.00	5.00	5.00	5.00	5.00
Worms	0.00	1.00	3.00	5.00	10.00	0.00	1.00	3.00	5.00	10.00	0.00	1.00	3.00	5.00	10.00
Wheat mid	0.00	0.00	0.00	0.00	3.34	0.00	0.00	0.00	0.00	2.75	0.27	0.16	0.00	0.64	5.00
Canola oil	0.33	0.23	0.03	1.21	0.00	0.29	0.23	0.19	0.00	0.56	0.26	0.16	0.19	0.43	2.07
Limestone	1.41	1.34	1.27	0.51	1.21	1.10	1.34	1.06	0.96	0.87	0.94	0.92	0.90	0.88	0.69
Monocalcium	0.63	0.61	0.56	0.32	0.38	0.35	0.61	0.34	0.25	0.03	0.14	0.11	0.05	0.00	0.00
Salt	0.34	0.33	0.32	0.20	0.29	0.34	0.33	0.34	0.32	0.29	0.35	0.34	0.33	0.32	0.29
Methionine	0.20	0.21	0.20	0.13	0.19	0.16	0.24	0.16	0.15	0.13	0.13	0.13	0.12	0.10	0.08
Tryptophan	0.03	0.08	0.11	0.05	0.16	0.07	0.08	0.08	0.12	0.09	0.06	0.07	0.04	0.00	0.00
Threonine	0.06	0.06	0.06	0.42	0.04	0.05	0.60	0.05	0.03	0.00	0.02	0.03	0.01	0.00	0.22
Lysine	0.41	0.43	0.43	0.00	0.38	0.42	0.43	0.41	0.39	0.31	0.38	0.38	0.32	0.27	0.09
Choline Chlo	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.09	0.09	0.09	0.20
Premix	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.00
Avian plus	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Surmax	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.00	
Gluten 20%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nutrients levels															
ME,	12.80	12.60	12.40	12.90	13.00	12.90	12.80	12.70	12.70	13.00	13.00	13.00	13.00	13.00	13.00
CP	21.30	22.20	23.20	23.40	23.60	19.30	18.90	19.20	19.20	19.50	17.20	17.40	17.40	17.30	17.40
Ca	0.81	0.71	1.04	0.43	0.60	0.60	0.40	0.63	1.45	1.32	0.40	0.50	0.50	0.40	0.57
P	0.53	0.49	0.48	0.38	0.32	0.53	0.48	0.50	0.56	0.76	0.54	0.56	0.56	0.56	0.52

Table 2: Chemical composition of *Eisenia foetida*

Ingredients	Nutrient composition
Proximate analysis (%)	
Protein	51.62
Moisture	6.75
Fat	7.76
Fibre	3.80
Ash (%)	19.74
Starch	0.00
Sugar	0.31
NDF	7.70
ADF	2.81
Total fat	8.21
Minerals	
Ca (%)	5.03
P (%)	1.21
Na (%)	1.09
Salt (%)	3.12
Mg (%)	0.25
K (%)	2.04
Cu (mg kg^{-1})	420.91
Mn (mg kg^{-1})	0.00
Fe (mg kg^{-1})	73245.00
Zn (mg kg^{-1})	183.00

Meat colour: The colour of the meat (L* = Lightness, a* = Redness and b* = Yellowness) was determined on the 75 breast muscles of individual chicken carcasses at 1, 24 and 48 h after slaughter using a colour guide 45/0 BYK-Gardener GmbH machine, with a 20 mm diameter measurement area and illuminant D65-daylight, 10° standard observer. Three readings were taken by rotating the Colour Guide 90° between each measurement in order to obtain a representative average value of the colour.

Meat pH: The pH of the breast muscle for each chicken was measured using a portable pH meter (Crison pH 25 CRISON Instruments SA, Spain) after calibration with pH4, pH7 and pH9 standards solutions (CRISON Instrument, SA and Spain). Measurements were done at approximately 1, 24 and 48 h after slaughter and thereafter the chickens were refrigerated at 0-3°C.

Cooking loss: Chicken breasts were individually sliced in 50 mm thick (maximum) pierce. Individual pieces were placed in thin-walled plastic bags were placed in warm water bath, with the bag opening extending above the water surface. Samples were cooked to a defined internal temperature of 85°C for 45 min. Thereafter, samples were removed from the water bath and cooled, removed from bags, blotted dry and weighed. Cooking loss was calculated using the following formula:

$$\text{Cooking loss} = [(\text{Weight before cooking-weight after cooking}) \div \text{weight before cooking}] \times 100$$

Tenderness: Tenderness of the broiler right breast meat was determined using the Instron- Warner-Bratzler Shear Force (WBSF). Following cooking, sub-samples of specified core diameter were parallel to the grain of the meat. Three sub-samples measuring 10 mm core diameter were cored parallel to the grain of the meat. The samples were sheared perpendicular to the fibre direction using a Warner Bratzler Shear device mounted on Instron (Model (3344), Universal Testing apparatus. The mean maximum load (N) was recorded.

Statistical analysis: The effects of different inclusion levels *E. foetida* meal on carcass yield, meat colour, pH, cooking loss and tenderness were analysed statistically by one-way analysis of variance (ANOVA) with dietary treatments(EW0, EW1, EW3, EW5 and EW10) as a fixed effect using SPSS (IBM SPSS Statistics 24). The model used was:

$$Y_{ij} = \mu + \alpha_i + eij$$

where, Y_{ij} is response variable, μ is the common mean, α is the effect of dietary treatment (EW0, EW1, EW3, EW5 and EW10) and e_{ij} is random error. The experimental unit was the individual bird. The differences among means were tested for significance ($p<0.05$) using Tuckey's range test. Polynomial contrasts were used to examine the linear effect of *E. foetida* inclusion levels.

RESULTS

Carcass characteristics: Table 3 depicts the effect of the inclusion level of earthworm meal on carcass characteristics of broilers. All carcass traits were significantly ($p<0.05$) influenced by dietary treatments except for dressing percentage. As the inclusion level of earthworm increased, the weights of birds decreased.

Carcass yield: The breast and thigh yield were not significantly influenced ($p>0.05$) by diets, however, wing and drumstick yield were influenced ($p<0.05$). Supplementation of *E. foetida* meal linearly ($p = 0.02$) reduced wing yield (Table 4).

Table 3: Carcass characteristics of broilers fed different inclusion of *Eisenia foetida*

	Dietary treatments							
Attributes	EW0	EW1	EW3	EW5	EW10	SEM	p-value	L
Live weight	1.9	2.00	2.1	1.8	1.7	0.47	0.04	0.004
Pluck weight	1.7	1.80	1.7	1.6	1.6	0.47	0.01	0.004
Pluck (%)	90.3	91.03	87.9	89.0	90.5	0.96	0.48	0.83
Carcass weight	1.4	1.40	1.5	1.3	1.4	0.29	0.01	0.02
Dressing (%)	76.3	73.90	75.1	75.1	75.5	0.80	0.87	0.95

EW0, EW1, EW3, EW5 and EW10 contained graded levels of *Eisenia foetida* 0, 1, 3, 5 and 10% of DM intake, respectively, SEM: Standard error, L: Linear contrast among *Eisenia foetida* levels, ADFI: Average daily feed intake, ADG: Average daily gain

Table 4: Carcass yield of broilers fed with different inclusion levels of *Eisenia foetida*

	Dietary treatments							
Attributes	EW0	EW1	EW3	EW5	EW10	SEM	p-value	L
L*(Lightness)								
1	44.4^{a}	44.0^{a}	45.0^{a}	45.6^{a}	42.9^{a}	0.77	0.170	0.58
24 h	45.3^{a}	45.9^{a}	47.0^{ab}	49.6^{b}	44.7^{a}	0.77	<0.001	0.32
48 h	45.7^{a}	45.7^{a}	47.9^{ab}	49.0^{b}	46.1^{a}	0.77	0.006	0.09
a*(Redness)								
1 h	3.7^{a}	2.7^{a}	3.2^{a}	2.8^{a}	3.4^{a}	0.68	0.060	0.09
24 h	3.6^{a}	3.3^{a}	3.1^{a}	3.4^{a}	3.4^{a}	0.68	0.860	0.83
48 h	4.7^{ab}	4.9^{b}	4.0^{ab}	3.5^{a}	4.3^{ab}	0.68	0.020	0.02
b*(Yellowness)								
1 h	14.3^{ab}	13.7^{a}	14.9^{ab}	16.1^{b}	15.2^{ab}	0.73	0.050	0.02
24 h	14.1^{ab}	13.3^{a}	15.2^{ab}	16.7^{b}	13.8^{a}	0.73	0.040	0.27
48 h	15.5^{a}	16.4^{a}	16.5^{a}	16.8^{a}	15.2^{a}	0.73	0.390	0.90
pH								
1 h	6.4^{ab}	6.3^{a}	6.6^{b}	6.5^{ab}	6.6^{b}	0.06	0.010	0.03
24 h	6.1^{a}	6.1^{a}	6.2^{a}	6.2^{a}	6.2^{a}	0.06	0.410	0.31
48 h	5.8^{a}	5.6^{a}	5.7^{a}	5.7^{a}	5.7^{a}	0.06	0.230	0.71

^{a,b,c}Mean within the same row that does not share a common superscript are significantly different ($p<0.05$). EW0, EW1, EW3, EW5 and EW10 contained graded levels of *E. foetida* 0, 1, 3, 5 and 10 of DM intake, respectively, SEM: Standard error, L: Linear contrast among *Eisenia foetida* levels

Table 5: Effect of *Eisenia foetida* meal as protein source on colour and pH coordinates

	Dietary treatments							
Attributes (%)	EW0	EW1	EW3	EW5	EW10	SEM	p-value	L
Breast	27.6	25.5^{a}	24.4^{a}	26.3^{a}	26.2^{a}	0.99	0.14	0.18
Wing	4.4^{b}	4.0^{ab}	4.4^{ab}	4.2^{b}	3.7^{a}	0.16	0.03	0.02
Thigh	5.5^{a}	5.1^{a}	5.6^{a}	5.0^{a}	4.9^{a}	0.25	0.23	0.11
Drumstick	4.2^{ab}	4.2^{ab}	4.4^{b}	3.8^{a}	3.9^{a}	0.18	0.06	0.12
Gizzard	2.8^{b}	2.8^{b}	2.6^{ab}	2.7^{ab}	3.1^{c}	0.11	0.01	0.05
Liver	1.9^{a}	1.9^{a}	1.7^{a}	2.0^{a}	2.0^{a}	0.09	0.12	0.36
Heart	0.5^{a}	0.5^{a}	0.5^{a}	0.5^{a}	0.5^{a}	0.02	0.09	0.30
Spleen	0.1^{a}	0.1^{a}	0.1^{a}	0.1^{a}	0.1^{a}	0.01	0.60	0.39

Means within the same row that do not share a common superscript are significantly different (p<0.05); EW0-control, EW1, EW3, EW5 and EW10 contained graded levels of *Eisenia foetida* 1, 3, 5 and 10% of DM intake, respectively

Table 6: Cooking loss and tenderness values of broilers fed different levels of *Eisenia foetida*

	Dietary treatments							
Attributes	EW0	EW1	EW3	EW5	EW10	L	SEM	p-value
Cooking loss (%)	7.3^{a}	9.7^{ab}	7.2^{a}	8.8^{a}	12.0^{b}	1.18	0.04	0.009
Tenderness(N)	5.5^{a}	6.7^{a}	7.0^{a}	5.4^{a}	6.2^{a}	0.58	0.06	0.400

^{a,b,c}Mean within the same row that does not share a common superscript are significantly different (p<0.05). EW0, EW1, EW3, EW5 and EW10 contained graded levels of *Eisenia foetida* 0, 1, 3, 5 and 10% of DM intake, respectively, SEM: Standard error, L: Linear contrast among *Eisenia foetida* levels

No significant differences (p>0.05) were observed in the liver, heart and spleen percentage. The gizzard yield was increased linearly (p = 0.05) by worm meal inclusion

Colour values: Dietary treatments had significant effects (p<0.05) in the lightness at 24 and 48 h post-mortem but lightness at 1h post-mortem was not influenced (p>0.05) (Table 5). The redness of meat at 48h post-mortem was reduced linearly (p = 0.02) by the inclusion of earthworm meal in the diets. No significant effects (p>0.05) of diet was observed on yellowness of meat at 48 h post-mortem, however; yellowness at 1 and 24 h were influenced (p<0.05). Supplementation of *E. foetida* meal linearly (p = 0.02) increased the yellowness of meat (Table 6).

pH values: No significant differences (p>0.05) in pH values were observed at 24 and 48 h post-mortem (Table 5). The pH values of the breast meat from birds fed different inclusion levels of *E. foetida* meal at 1 h post-mortem increased linearly (p = 0.03).

Cooking loss and tenderness: Dietary treatments had a significant effect (p<0.05) on the cooking loss of breast meat. The cooking loss increased linearly (p = 0.009) by the inclusion of worm meal (Table 6). No significant differences were observed among dietary treatments in the shear force values of breast meat (p>0.05).

DISCUSSION

The inclusion of 3% of *E. foetida* meal in the diet of broilers provided superior results in terms of live weight, carcass dressing percentage and carcass yield as compared to the control group. This could be attributed to the increased feed intake, the growth rate of the birds of EW3 group resulting in better muscle growth, hence had the higher performance of carcass characteristics. The current findings contradict with the report of Rezaeipour *et al.*[7] who observed a linear increase in body weight with increasing silkworm pupae. Our findings are contrary to findings of Khatun *et al.*[8] who observed that birds received a higher level of maggot meal had significantly better dressing percentage and carcass weight.

Supplementation of various inclusion levels of *E. foetida* meal failed to induce any significant effect on breast and thigh percentage of broilers. In agreement with Khan *et al.*[9] who found that earthworm meal did not influence carcass yield, nevertheless in the current study supplementation of *E. foetida* meal linearly reduced the wing yield. This is in line with the results found by Bahadori *et al.*[10] who reported that wing yield was heavier on the low protein diet.

Gizzard yield in this study was influenced by dietary treatments and the high yield of gizzard that was observed in birds fed 10% inclusion level of *E. foetida* meal. This could be due to the increasing frequency of contraction of this organ[11] due to more protein inclusion. Current findings are in accordance with the report conducted by Sobayo *et al.*[12] who observed that high protein inclusion diets increase gizzard yield. The decreased gizzard yield in birds of EW3 group may be attributed to the partial hydrolysis and destruction of cell wall components of feed ingredients, thereby reducing the grinding action of gizzard and its relative weight[9].

The findings of the current study are in line with the results of Jahanian and Golshadi[13] who reported the non-significant effect of earthworm meal on the heart and spleen percentage of broilers. This may be attributed to the fact that the spleen and heart are associated with an immune function[14] which explains the current findings where there was no dietary effect on them.

The findings showed that the L* values of the breast meat was influenced by different dietary inclusion levels of *E. foetida* worm meal. According to Corzo *et al.*[15], meat lightness is an important characteristic to determine the incidence of paleness, soft and exudative (PSE) condition in the broiler breast meat. Petracci *et al.*[16] reported that normal L* values of breast meat ranged from 50-56, pale meat having values greater than 56 and darker meat having L* value less than 50. In the current study, L* values were less than 50 and were darker. This could be associated with high pH, higher than 5.9[17] recorded in this study, accompanied by lower levels of glycogen, glucose, hexo phosphate, trio phosphate and lactate[18].

The a* values of the breast meat were influenced by the dietary treatment in this study. The a* values at 1 and 24 h post-mortem were within the normal range according to Fletcher *et al.*[19] which then, increased gradually at 48 h after slaughter. The current finding is in line with the study of Khan *et al.*[9] who stated that a* value increases with storage time. This could attributed to reflection of myoglobin concentration in meat[20]. According to Jiang *et al.*[21], a higher a* value of meat is always favoured by customers.

This study revealed that inclusion of earthworm in broiler feed had a positive effect on the colour coordinates of breast meat. However, the findings of the current study differ from the results of Van Lack and Lane[22], who reported that there was no significant difference in breast colour among birds fed different earthworm meal diets. This deviation may be due to low inclusion levels of worm meal and the type of worm *Perionyx excavates* used by Van Lack and Lane[22].

Karaoglu *et al.*[23] reported that normal breast meat pH value for broilers is 5.69, although it was within the normal range as reported by Berri *et al.*[24]. However, in the current study, pH values were slightly higher than the normal values that reported by Abdulla *et al.*[25]. The higher pH values found in this study may be due to the presence of lysine in diets[26]. Increasing the level of lysine in the diet of broilers which is high in *E. foetida*, improves breast meat yield which then reduces drip loss during storage by increasing its pH[27]. Moreover, it could be protein intake, since protein intake increases meat pH by decreasing breast muscle glycogen content. Breast meat pH values significantly decreased gradually with time (from one to 48 h *post-mortem),* due to glycolysis, lactic acid formation and a decrease of oxygen in muscle. The normal pH range found in this study is an evidence of good quality meat from birds fed with *E. foetida* meal. Dietary treatments had a significant effect on pH values observed in the current study at 1 and 24 h post-mortem. At 1 h post-mortem pH values were between 6.6 and 6.2 with EW10 and EW3 having the highest pH values.

Supplementation of *E. foetida* meal in the diet increased cooking loss in the breast meat of chickens which indicated that *E. foetida* meal compressed meat quality of broiler chickens. The high cooking loss observed in birds fed with 10% of *E. foetida* meal may be due to the low ability of meat from the broiler to hold on water[28]. Birds supplemented with 3% inclusion level of worm meal can be considered to have a better meat quality than those in other dietary treatments since they had the least cooking loss. The low cooking loss in breast meat may be a result of the low loss of protein into the water during cooking[29].

No differences were observed in tenderness of breast meat among birds fed different inclusion levels of *E. foetida* meal. Shear force values among all treatments were below 30 N, an indicator of very tender meat that is acceptable to consumers[29].

CONCLUSION

This study showed that among dietary, birds in EW5 group improved weight gain and those in EW3 beneficially influenced on carcass characteristics of breast meat while the visceral organs were better in the diet of 10% *E. foetida*. Thus, it is suggested that *E. foetida* meal can be used in broiler diet without deleterious effect on carcass characteristics and meat quality attributes.

SIGNIFICANCE STATEMENT

This study discovers the effect of *Eisenia foetida* earthworm meal as a protein source that can be beneficial for broiler chickens. This study will help the researcher to uncover the effects of earthworm meal on carcass and meat quality attributes of broilers that many researchers were not able to explore. Thus, new theory regarding supplementing of broiler diets with different inclusion levels of *E. foetida* meal may be arrived at.

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