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Efficacy of Feeding Earthworm Meal-Based Diet on Feed Intake, Weight Gain, and Apparent Digestibility Coefficient of Red Sokoto Goat

[1,3,8]Moshood Adewale Belewu, [2]Ling Shing Wong, [2]Geetha Subramaniam, [3]Elias Sulaiman Bogoro, [4]Jureerat Kijsomporn, [5]Kafayat Yemisi Belewu, [6]Kehinde Matthias Okukpe, [7]Akeem Abolade Oyerinde, [8]Hauwa Ohunene Sadiq, [1]Olurotimi Ayobami Olafadehan, [9]Akeem Owolabi Ganiyu and [1]Karimat Imam Aliyu

[1]*Department of Animal Science, University of Abuja, Nigeria*
[2]*Faculty of Health and Life Sciences, INTI University, Malaysia*
[3]*Department of Animal Science, Abubakar Tafawa Balewa University Bauchi, Nigeria*
[4]*School of Nursing, Shinawatra University, Bangtoey, Samkhok, Pathum Thani, Thailand, INTI, Malaysia*
[5]*Department of Agricultural Economics and Rural Ma, University of Ilorin, Nigeria*
[6]*Department of Crop Protection, University of Abuja, Nigeria*
[7]*Department of Fisheries Aquaculture and Wildlife, University of Abuja, Malaysia*
[8]*Department of Animal Production, University of Il, Nigeria*
[9]*Department of Dairy Science, University of Abuja, Nigeria*

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Corresponding Author:
Moshood Adewale Belewu
Department of Animal Science,
University of Abuja, Nigeria
Email: moshood.belewu@uniabuja.edu.ng

Abstract: Feed which contributes about 70-80% of the cost of feeding is one of the major problems of livestock production. Feeding nutritious feed to animals is vital for the vigor and wellbeing of livestock and human being and the nutrient it contains assist animal to grow, develop and reproduce. Hence, this study examined the impact of Earthworm Meal (EWM)-based diets on Red Sokoto goats' feed intake, digestibility, and weight gain at the Teaching and Research Farm of the University of Abuja in Nigeria. Thirty (30) Red Sokoto goats weighing 6-7 kg were used in the experiment. The experimental animals were randomized against the dietary Treatments A (control, 0% EWM), B (3% of EWM), and C (6% of EWM) using a complete randomized design model. With the 15-day acclimatization and 10-day digestibility periods, the entire experiment lasted 56 days. The findings showed increasing feed intake as the amount of earthworm meal increased (Treatment>C>B>A), with Treatment C having the highest Average dry matter Intake (AFI) (230.11g). Furthermore, the Average Feed Intake (AFI) and Average Daily Gain (ADG) (0.12 kg/d) showed a comparable pattern. Between the dietary treatments, there were significant differences ($p<0.05$) in the Feed Conversion Ratio and efficiency (FCR: 13.38, 9.96, and 8.94; FCE: 0.07, 0.10, and 0.11 respectively). The study showed that Treatment C was used more effectively in comparison to the other treatments, according to this study, red sokoto goat diets should contain up to 6% EWM for improved performance of livestock and mitigate poverty.

Keywords: Digestibility Coefficient, Feed Conversion, Efficiency, Feed Intake, Goat, Weight Gain, No Poverty

Introduction

A multipurpose animal, goats (*Capra hircus* L.) produce meat, milk, skin, and hair. According to Oyeyemi *et al.* (2001), they can flourish in environments that other animals might find difficult to survive. Their meat and milk are their primary commodities; in many regions of the world, their skin, wool, and hair also contribute to their economic value (Oyeyemi and Akusu, 1997). The quality and quantity of the nutrients that animals consume determine how well they perform and goats need to be fed nutritious feed to perform better.

According to Odeyinka and Ajayi (2004), goats are an essential part of rural Nigerian households, contributing to the food, culture and socioeconomic well-being of the populace. According to numerous scientific reports, the primary domesticated small ruminants in terms of total numbers, small body size, ease of management and food productivity are sheep and goats (Belewu, 2019).

The most prevalent and significant native goat breed in Nigeria is the Red Sokoto. According to Akintunde *et al.* (2024), there are roughly 1 million Red Sokoto goats in Nigeria's northern sub-humid and semi-arid regions, making up roughly 70% of the country's total goat population. Goats are important for the economy and society, particularly in developing and impoverished nations. In addition to being a vital source of meat protein and a major contributor to the animal protein consumed by humans, goats, which came in second, are raised for their profits, wealth, and employment opportunities (Raheem *et al*., 2024).

The consumption of calorific crops (rice, sorghum, millet, wheat, and cassava) at the expense of consuming nutrient-dense diets was a major focus of the Sustainable Development Goal (SDG) on Zero Hunger. Therefore, food security should be replaced with nutrition security as a paradigm shift (Swaminathan, 2014). Approximately two billion people worldwide suffer from diets lacking in macro and micronutrients (Swaminathan, 2014). Therefore, reducing food insecurity and advancing other goals may be possible through the effective implementation of SDG 2. However, SDG 2 primarily addressed crop cultivation, with less emphasis placed on livestock farming, pastoralism, fisheries, and aquaculture.

Researchers are currently concentrating on nutritional deficiencies that can be addressed using feed-based approaches and feed substitutes (new feed such as insects, algae, fungi, and earthworm meals) that are not competitive with humans. The potential of earthworm meal as a substitute source of animal protein in feed has been the subject of several studies due to its high nutritional value Siyun *et al*. (2019); Tedesco *et al.* (2020); Gunya and Masika (2022); Kostecka *et al*. (2022). Earthworm meal has a high protein content (63.06%), with isoleucine (1.98% on a dry matter basis) dominating the essential amino acid content. Earthworms (L. rubellus) contain a peptide group with 62 amino acids called "lumbricin I," which has antibacterial properties (Gunya and Masika, 2022).

One of the main macroflora in soil, earthworms are regarded as a farmer's friend. Prior research revealed that the meal of earthworms (Lumbricus rubelus) contained 65.63% crude protein (Dedeke *et al.,* 2010), *Lumbricus terestris* earthworms contained 32.60% crude protein (Julendra, 2003), and *Perionyx excavatu* earthworms contained 57.2% crude protein and complete amino acid (Gunya and Masika, 2022). Even though earthworm meal's unique quality has long been recognized as a possible substitute for fish meal as a source of protein (Yaqub, 1991), more research is required to determine the essential amino acid composition of earthworms. According to reports, the poultry birds benefited from the EWM in ways such as improved feed conversion, reduced feed intake and increased final body weight (Julendra *et al*., 2010); enhanced weight gain and decreased feed conversion in quail (Prayogi, 2011); adding 10% earthworm meal (*Clsenia foetida)* to broiler chickens increased weight gain, severe chest muscles and protein intake (Rezaeipour *et al*., 2014). However, given the lack of feedstuffs for creating a high-quality goat diet and the nutritional value of earthworm meal, adding it to the goat's diet will be essential to improving goat productivity. Therefore, the purpose of this study was to assess how earthworm meal affected the Red Sokoto goats' feed intake, weight gain, and digestibility coefficient.

Materials and Methods

Site of the Experiments

The experiment was carried out at the Teaching and Research Farm, Ruminant Unit of the University of Abuja in the Federal Capital Territory of Nigeria. Geographically, the University of Abuja is situated at latitude 8*58'50N and longitude 7*10'43E. The average temperature was 37˚C, the humidity was 21% and the wind speed was 5 km/h. (http://en.Wikipedia.org/wiki/University of (2013).

Cultivation, Gathering, and Processing of Earthworms

In this study, earthworms were cultivated using the Vermiculture method, which involves artificially rearing or cultivating earthworms. The first step in the process was gathering and using cardboard, paper, and animal dung waste as growth culturing media. For the earthworm to grow as best it could, factors like pH, humidity, and temperature were taken into account. By increasing the number of earthworms (*Ephyriodrilus afroccidentalis*), the process helped turn trash into compost. The worms were gathered during the harvesting season, cleaned of debris in clean water, and then processed further to create an earthworm meal. After being sun-dried for roughly two days, the cultured earthworms were oven-dried for six hours at about 40˚C, to prevent rotting. The earthworms were then milled and stored in a plastic container before their inclusion in the experimental diet.

Management of Experimental Animals

The experimental animals were thirty healthy male Red Sokoto goats weighing 6-7 kg that were purchased from a reliable market in Abuja, Nigeria. Each goat had an ear tag and was kept in a cage to help them adjust to the new surroundings. Before the study started, the goats were given antibiotics (Terramycin® L.A.) to treat cold and catarrh and Ivermectin (Bimectin®) to treat internal and external parasites.

Some components of the experimental diet, such as rice husk and cassava waste, were provided during the two-week preliminary period to facilitate both the experimental diet and environmental adaptation. While the cages, feeding, and water troughs were cleaned every day, the experimental diets and water were given freely. Accurate records of body weight gain, feed conversion ratio, and daily feed consumption were kept for 56 days.

Experimental Design

Using a completely randomized design model, the experimental goats were randomized against the experimental dietary treatments (Table 1). Each diet or treatment had ten animals while feeding and watering were provided at will.

Feed Consumed

Throughout the course of the study, the experimental diet and the associated orts were weighed and recorded every day. Over the course of the experiment, subsamples of the provided feeds and orts were combined for each animal. Additionally, each treatment's composite orts/refusal samples were combined. For chemical analysis, the feed and the orts/refusal diets were kept in airtight containers. The difference between the offered and refused diets was used to compute the daily dry matter and nutrient intake. The ratio of daily body weight gain to daily feed consumption was used to estimate the feed conversion ratio.

The following parameters were calculated:

$$\text{Total Dry Matter Intake (DMI) (\%BW)} = DMI(g)/BW \times 100$$

$$\text{Total DMI (Metabolic BW (g) / Kg } W^{0.75}) = DMI\,(g)\,/\,BW^{0.75}$$

$$\text{ADWG (Average daily weight gain)} = \frac{\text{Final BW-Initial BW}}{\text{Total number of feeding days}}$$

$$\text{Feed Conversion Efficiency} = \frac{\text{Daily weight gain}}{\text{Total DMI.}}$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Total Dry matter Intake}}{\text{Weight gain}}$$

Digestibility Coefficient Trial

Following the feeding trial, all experimental animals were housed in metabolic cages for seven days in order to collect all of their feces. Each animal's daily excrement was weighed and combined. 10% of the collected feces were sampled and kept at-200C in a refrigerator. In preparation for chemical analysis, the stool samples were first dried at 65 OC for two days, then ground and kept in airtight containers. The McDonald *et al*. (2002) equation was used to determine the apparent coefficient digestibility:

$$\text{Apparent digestibility coefficient} = \frac{\text{Total nutrient consumed in the diet -Total nutrient in the feces} \times 100}{\text{Total nutrient}}$$

$$\text{Metabolic energy intake} = ME\ (MJ/Kg\ DM) = DOMD \times 0.016$$

$$DOMD = \text{Digestible organic matter}$$

$$DODM\ /g\ /\ Kg\ DM = \frac{\text{OM in feed-OM in feces} \times 100}{\text{DM in feed}}$$

Chemical Analysis

The Kenneth (1990) method was used to determine the chemical analyses of the feeds and feces. The estimated amount of crude protein was $N \times 6.25$.

Statistical Analysis

The analysis of variance of a complete randomized design (Steel and Torrie, 1980) model was used to examine all of the data collected while Duncan's (1955) multiple-range test was used to separate the means.

Results and Discussion

Earthworm Meal (EWM) Proximate Composition

Table (1) displays the experimental diets used in this study as well as the proximate composition of the EWM. The EWM's crude protein content in this investigation ranged between 57.9 and 71.3%, which is consistent with the value reported by Heuze *et al*. (2020). However, the value exceeded the 51.70% crude protein content reported by Tedesco *et al*. (2020); Gunya and Masika (2022). The type of earthworms, the soil / culturing technique, and the processing method could all be responsible for the variation in the crude protein content. According to this study, earthworm meal crude protein content was 57.35%, suggesting that it may be able to meet the needs of both maintenance and growth. Hence, the earthworm meal used in the current study can be considered good quality and fulfilled goats' maintenance and production requirements.

Table 1: Composition of the test diets

Diets (%)	Treatment A	Treatment B	Treatment C
Cassava waste	53.00	53.00	53.00
Rice husk	35.00	35.00	35.00
Soyabean cake	10.00	7.00	4.00
Salt	1.00	1.00	1.00
Premix	1.00	1.00	1.00
Earthworm meal	0.00	3.00	6.00
Total	100.00	100.00	100.00

The crude fiber content of EWM used in this experiment (3.60%) was comparable to the range of values (2.4-7.8%) reported by Heuze *et al.* (2020); Abdel-Azeem *et al.* (2022), but it was higher than the value (2.23%) reported by Gunya and Masika (2022). The study found that the experimental diets had a higher level of crude fiber than the 12% reported by Mamoon (2008). The inclusion of high-fibrous ingredients (rice husk and cassava waste) in the diets may be the cause of the high crude fiber levels in the diets in this study. Since earthworm meal was used in the diets, the ether extract of the experimental diets reported in this study was comparable to the reports of Heuze *et al.* (2020.

The experimental diets in this study had an organic matter content ranging from 79.18-82.95%, which was consistent with values reported by Ibrahim *et al.* (2022); Bala *et al.* (2021) of 51.50-84.38%. The types of feed that the animals are fed may be the cause of the minor variations.

Dry Matter and Nutrient Consumed

Tables (2-3) shows the experimental goats' average daily dry matter and nutrient intake. The difference between total dry matter intake and dietary intake was significant ($p<0.05$). Goats ate all of the EWM-based diets without dissenting and there was no discernible difference between them. As the EWM in the diets increased, the average daily feed intake also increased.

In comparison to Treatment A (Control, without EWM inclusion), the dry matter intake and other nutrient intakes for Treatments B and C were higher ($p<0.05$). The current study findings demonstrated that EWM-based diets were better consumed than the control, most likely as a result of their higher crude protein and balanced amino acid content. This supported the report of Das *et al.* (2024).

Table 2: Physicochemical analysis of the experimental diets and earthworm meal

Parameters	Treatments (%) A	B	C	Earthworm meal
Dry matter	94.04	94.12	90.32	25.30
Crude Protein	8.45	8.96	8.10	57.35
Ether extract	4.35	3.95	5.66	3.50
Crude fibre	17.38	17.32	17.32	3.60
Ash	11.09	11.18	11.14	2.35
Organic matter	82.95	82.94	79.18	22.95
NFE	58.73	58.59	57.78	-------
ME (K.cal/Kg)	2798.56	3272.56	3329.20	2340kcal/g

Table 3: Dry matter and nutrient intake of the experimental diets (g/d/animal)

Parameters	Treatments (%) A	B	C	± SEM
Total DMI (g/d)	204.92^{b}	220.92^{a}	230.11^{a}	5.50
Total DMI (%BW)	3.39	2.80	3.00	0.35
Total DMI (g/Kg$^{W0.75}$)	53.09	46.90	49.92	2.35
Total OM intake(g/d)	181.3^{c}	195.29^{b}	203.23^{a}	4.02
Total CP Intake	23.43^{b}	25.14^{a}	26.14^{a}	2.15
Total CF intake	70.52	76.55	79.92	2.79
Total EE intake	6.00	6.05	6.12	0.55
Total ash intake	23.59^{b}	25.63^{a}	26.88^{a}	5.60
NFE intake	81.27^{c}	87.55^{b}	91.25^{a}	2.85

Means having same superscripts along the rows are not significantly different ($p>0.05$)

Significantly higher ($p<0.05$) total DMI was observed in Treatment C (230.11 g/d/animal), closely followed by Treatment B and lowest for Treatment A (control). According to Becholie *et al*. (2005), lamb fed a basal diet had higher TDMI, OM, and CP intake when their diet was supplemented with protein sources. As a result, the TDMI value in this study was between 204.92 and 230.11 g/d/animal, which was within the range of values reported by Luthfi1 *et al*. (2024) who fed a diet consisting of faba bean haulms and barley bran. As a result, the present study concluded that EWM significantly influences goats' intake of dry matter and other nutrients.

The differences in the inclusion levels of EWM may be the cause of the significant differences in protein intake ($p<0.05$) between the various treatment groups. Treatments C, B, and A were found to have higher CP intakes, respectively. Animals fed EWM-based diets (B and C) consumed more CP than those fed diet A, the control. According to the NRC (1981), a goat weighing 5-10 kg needs 0.08Ib g CP to meet its growth-related nutritional needs. According to this recommendation, a goat' daily CP intake of 23-26 g across all treatments is sufficient for both maintenance and the desired average daily gain. There was no significant difference ($p>0.05$) in the TDMI based on body weight (% BW) among diets. The DMI per day based on 2.80-3.39% BW in this study was within the ranges of 2.6-3.2% noted by Luthfi *et al*. (2024) for the Kacang goat.

Apparent Digestibility Coefficient

Tables (4-5) displayed the apparent DM and nutrient digestibility coefficient that were reported in this investigation. Dry Matter Digestibility (DMD), Ether Extract Digestibility (EED), and Crude Fiber Digestibility (CFD) did not differ significantly (p<0.05). In this study, the apparent DMD ranged from 75-79%. The result was greater than the value Desta *et al*. (2017) reported and the difference may have been caused by the animal's species and dietary intake. Compared to the dietary treatments, Treatment C had a higher apparent Digestibility of Crude Protein (CPD) (85.79%), most likely as a result of the CPI of EWM-based diets. Additionally, the makeup of other ingredients consumed may affect how diets are digestible (McDonald *et al*., 2002). Consequently, the outcomes of the results of the present study suggested that the inclusion of EWM in a total ration/diet of goats was better for the productive performance of goats (both feed intake and digestibility).

Table 4: Apparent digestibility coefficient of dry matter and nutrients of Red Sokoto goats fed earthworm meal-based diets

Parameters	Dietary treatments			
(%)	A	B	C	± SEM
Dry matter digestibility	77.14	75.75	79.12	2.45NS
Crude protein digestibility	81.30	82.90	85.79	3.67NS
Crude fibre digestibility	87.32	78.14	81.95	3.40NS
Ether extract digestibility	83.12	79.24	83.10	3.98NS
NFE digestibility	78.90	72.58	75.85	2.40NS
Digestible energy digestibility (MJ/kg/day)	335.15	308.66	324.54	6.12NS

Means having the same superscripts along the rows are not significantly different (p>0.05)

Table 5: Digestible dry matter and nutrients of Red Sokoto goats fed earthworm meal-based diets

Parameters	Dietary Treatments			
(%)	A	B	C	± SEM
Digestible dry matter	60.52	59.44	62.11	2.11NS
Digestible crude protein	9.26	9.43	9.75	0.56NS
Digestible crude fibre	30.13	27.08	28.46	2.34NS
Digestible ether extract	2.44	2.17	2.11	0.12NS
Digestible NFE	31.29	28.76	30.80	1.23NS
TDN	76.17	70.15	73.76	2.30NS
digestible energy (MJ/kg/day)	335.15	308.66	324.54	6.19NS
ME (M.Cal/Kg)	274.82	253.10	266.12	5.35NS

Means having the same superscripts along the rows are not significantly different (p>0.05)

Table 6: Overall body weight change feed conversion efficiency, feed conversion ratio of Red Sokoto goats fed earthworm meal-based diets

Parameters	Dietary treatments			
(%)	A	B	C	± SEM
Initial body weight (Kg)	6.33	7.42	7.23	0.98NS
Final body weight (Kg)	12.26^{c}	14.26^{a}	14.10^{ab}	1.23*
Weight gain	5.93	6.84	6.87	0.88
Average daily gain (kg/day)	0.11^{b}	0.12^{a}	0.12^{a}	0.67*
Feed conversion efficiency	0.07^{c}	0.10^{b}	0.11^{a}	0.05*
Feed conversion ratio	13.38^{a}	9.96^{b}	8.93^{c}	1.78*

Means having same superscripts along the rows are not significantly different (p>0.05)

Crude fiber digestibility was unaffected by the rise in CP intake. CFD, however, was comparable across diets. The apparent digestibility coefficient and the digestible dry matter and other nutrients showed a similar pattern. Dietary Treatment C had the highest levels of the majority of the digestible nutrients. The high nutrient content of this diet (dietary treatment C) may be the cause of this.

Feed Conversion Ratio and Body Weight Gain

Table (6) displays the average body weight and FCR. Among the animals, the Average Daily Gain (ADG) varied significantly (p<0.05). C>B>A had the highest ADG, respectively. Differences in feed intake and the nutritional content of the diets could cause the gain variation. The goat grew at a rate of 26g/day, which was nearly identical to the value reported here and the ADG of animals on C was highest because of the high nutrient intake of the diet. Compared to the values (11.67-29g/d) reported by Bala *et al.* (2021), the ADG reported here was higher. The study's higher ADG may have resulted from the adequate energy and protein content of the diets which are critical for the growth of livestock. The EWM might have helped the rumen microbes use the diets more effectively due to its rich nutrient contents and which could have enhanced weight gain of the animals (Dedeke *et al*., 2010).

Conclusion

The study showed that inclusion of EWM (6%) in the diet of Red Sokoto goats holds a good prospective and it should be embraced by goat farmers.

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The inclusion of up to 6% EWM is advised because the study's findings demonstrated the efficacy and efficiency of EWM-based diets in improving Red Sokoto goat performance.

Author's Contributions

Moshood Adewale Belewu: Conceived the idea and written of manuscript.

Kehinde Matthias Okukpe, Akeem Owolabi Ganiyu and Karimat Imam Aliyu: Performed the fieldwork in conjunction with the collection of data.

Elias Sulaiman Bogoro, Jureerat Kijsomporn, Kafayat Yemisi Belewu, Akeem Abolade Oyerinde and Olurotimi Ayobami Olafadehan: Verified the analytical method and analyzed the data.

Ling Shing Wong, Geetha Subramaniam and Hauwa Ohunene Sadiq: Edited the manuscript.

Proofreading and final submission for publication were approved by every author.

Ethics

This article is original and has not been published anywhere. The corresponding author confirms that all authors have read and approved the manuscript and no ethical issues arise. The authors declare no conflict of interest, financially or otherwise. The animals were handled following the best animal welfare procedures.

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