Growth response and nutrient digestibility of broiler chickens to diets containing different levels of rumen digesta filtrate fermented earth ball (*Icacinia manni*) meal

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Abstract

A 28-day feeding trial was conducted to evaluate the growth response of broiler chickens fed rumen digesta filtrate (RDF) fermented earth ball meal at the finisher stage. One kilogram of the digesta was weighed into a bucket, and one litre of water was added, stirred, filtered, and incubated at 23–240 °C for 48 hours. The peeled earth ball roots were divided into three portions and the first portion sundried. In contrast, the second and third portions were packed into two separate capped plastic buckets containing cultured rumen digesta filtrate and a litre of water for the fermentation process at 24°C for 48 hours. The fermented samples were packed into bags, pressed, and sundried. Five broiler finisher diets were formulated, using RDF-fermented earth ball meal to replace maize in the control diet. One hundred and fifty, 28 -day-old broiler birds were divided into five groups, each assigned to one of the five diets in a completely randomized design. The result revealed that water and RDF fermentation medium increased ($P<0.05$) the crude protein content of the earth ball meal from 3.06% to 7.33 and 5.21%, respectively. The gross energy was reduced to 2.28 kcal/g by water fermentation media, while the crude fibre was reduced by RDF media to 9.64%. The ether extract digestibility increased from 54.17% in birds on the control diet to 68.47% in birds fed 10% RDF earth ball meal diet. It was concluded that RDF-fermented earth ball meal could replace maize at 20% in a broiler finisher's diet.
Keywords: Earth ball; fermentation; rumen digesta filtrate; incubation; digestibility.

Introduction

The poultry industry can provide high-quality animal protein for human nutrition as well as serve as a source of revenue while contributing significantly to economic growth in developing countries (Samuel, 2018). The high cost of conventional animal feed ingredients in most developing countries has motivated scientists to search for alternative sources of feed ingredients (Raju, 2016). The cost of feed in poultry production constitutes about 70 to 80 per cent of the total production cost, and out of these, about 95 per cent is meant to meet the energy and protein requirements of the diet (Ravindran, 2014).A persistent increase in the cost of poultry feed is a major global challenge for the poultry production industry (Dalolio *et al.*, 2016).

This obviously calls for more research into other non-competitive feed resources. The earth ball could be an alternative choice of raw material for animal nutrition since it is not consumed by humans. The earth ball is a shrub with a modified tuber root that is mainly carbohydrate and is one of the thirteen species of earth ball plant (Udedibie *et al.,* 2004). It is an all-season evergreen shrub with a well-defined root, stem, and leaves. According to Umoren *et al.* (2007), the stem arises from an underground tuber and is round in cross-section, thin, straight, or branched, attaining a height varying from 1-2m at maturity. The tubers weigh up to 20kg and vary in shape and colour, depending on the soil type and stage of maturity. The earth ball plant is commonly found in wild fields, fallow, or wasteland and is abundant in the humid tropical regions of Akwa Ibom and the Cross River States of Nigeria (Akobundu and Agyakwa, 1998).

The tuber contains some anti-nutritional factors such as hydrogen cyanide, alkaloids, phytate, oxalates, and tannins, which limit its use as animal feed (Antai and Obong, 1998). Processing methods such as toasting (Asuquo and Udedibie, 2012; Effiong *et al.*, 2014) and plain water fermentation (Umoren *et al.*, 2003; Umoren *et al.*, 2007) have been employed in improving the nutritive value of earth ball, allowing for an optimum inclusion level of 15% in broiler diets (Umoren *et al.*, 2007) and 10% in laying bird rations (Asuquo and Udedibie, 2006). Low utilization of the earth ball meal by birds, despite the various processing techniques employed by these authors, could be attributed to the high fibre contents of processed meal.

Since monogastric animals, including poultry, lack enzymes with the capacity to digest fibre, it is imperative to utilize processing methods that could reduce the fibre level in the feedstuff. Effiong *et al.* (2016) noted that incubating rumen digesta filtrate anaerobically for 48 hours increased the population of bacteria, protozoa, and fungi, which are known to produce enzymes capable of degrading fibre and certain anti-nutrients. The authors further observed a significant reduction in the crude fibre level of earth ball meal fermented with the rumen digesta filtrate relative to the sample with the water-fermented media. There is no information in the literature stating the feeding value of rumen filtrate fermented earth ball meal, hence the need for this research.

Objectives of the Study

The study was designed to evaluate the feeding value of rumen digesta filtrate fermented earth ball meal as an energy source using finisher broiler chickens.

Materials and methods

Experimental Site

The chemical analysis and the biological evaluation were conducted at the Department of Animal Science Laboratory and the Poultry Unit at the Teaching and Research Farm, University of Calabar, Nigeria, respectively. The farm is located within latitudes 4°58.4282[1] and longitude E8°20.4602, with an annual precipitation of approximately 1830mm and an average temperature of 24°C to 30°C.

Processing of the Experimental Materials

Fresh rumen digesta was obtained immediately following the slaughter of cattle at the Anantigha abattoir in the Calabar South Local Government Area of Cross River State, Nigeria. The digesta was transported to the laboratory in an airtight polyethene bag. One kilogram of the fresh rumen digesta was weighed into a bucket, and one litre of water added, stirred for 10 minutes, filtered, and incubated in a capped plastic bucket at room temperature (23–240 °C) for 48 hours.

The earth ball roots, harvested from the wild in Ikot Nakanda, Akpabuyo Local Government Area, Cross River State, were peeled, washed in clean water, grated, and divided into three portions of 40kg each. The first portion was sundried and stored in an airtight container for analysis, while the second and third portions were packed into two (2) separate capped plastic buckets. The cultured rumen digesta filtrate was added to the earth ball meal in the first bucket, while three litres of water was added to the earth ball meal in the second plastic bucket, mixed thoroughly, and allowed to ferment at 24°C for 48 hours. The fermented samples were packed into jute bags, pressed using a mechanical press to drain out the water and thereaftersun-dried. The sun-dried samples were stored in an airtight plastic container prior to proximate analysis.

Proximate Analysis of the Processed Earth Ball Meals

The proximate analysesof the raw, rumen digesta filtrate and plain water fermented earth ball meals were carried out at the Faculty of Agriculture Central Laboratory, University of Calabar, using the method described by AOAC (2000). The fractions determined were crude protein, crude fibre, and ether extract. The nitrogen-free extract was determined by subtracting the total sum of moisture, crude protein, crude fibre, and ether extract. The gross energy contents of the three samples were equally determined using a Gallenkamp ballistic bomb calorimeter.

Experimental Diets

Five (5) isocaloric broiler finisher diets were formulated to supply between 19.6% and 20.27% of crude protein and 3,000 kcal/kg of metabolizable energy. The control diet (1) contained 100% of maize as its main energy source, while diets 2, 3, 4, and 5 had maize replaced by RDF fermented earth ball meal at 10, 20, 30, and 40%, respectively. Palm oil was used to balance the energy differences at 0.50, 1.25, 2.00, 2.75, and 3.50% for diets 1, 2, 3, 4, and 5, respectively.

Experimental birds and management

One hundred and fifty (150) 28-day-old broiler chickens (Abor acre) were purchased from the Agritech hatchery in Ibadan, Nigeria, for the experiment. The birds were divided into five groups on a weight-equalization basis, with thirty (30) birds per group. Groups were further divided into three replicates of ten (10) birds and assigned to one of the five experimental diets described earlier in a completely randomized design. The birds were provided with feed and water ad libitum, with necessary vaccinations and medications administered appropriately throughout the 28-day experimental period.

Data Collection

The average daily feed intake per bird was obtained by weighing the feed offered and the left-over feed 24 hours post-feeding and dividing the difference by the number of birds.

The body weight was taken weekly, and the value was divided by the number of birds per replicate to obtain the average daily weight per bird per replicate. The difference in weight at the beginning and the end of each week gave the average weekly body weight gain.

The feed conversion ratio was obtained by dividing the average daily feed intake per bird by the average daily weight gain.

Feed digestibility was carried out by selecting four (4) birds from each treatment, placing them in individual metabolic cages, and feeding 120g of the experimental diet per day for five days. The corresponding faecal droppings from feed consumption were collected on a treatment basis, dried in an oven at 60°C for 72 hours, bulked, and milled to obtain representative samples for chemical analysis. Laboratory analysis of the experimental diets and the faecal droppings was carried out. The crude protein, ether extract, nitrogen-free extract, and gross energy of the feeds and faecal droppings of birds from each treatment were determined, and values were used in calculating apparent nutrient retention as follows:

Apparent nutrient digestibility (%) = (Quantity of nutrient in feed consumed - Quantity of nutrient in faeces voided / Quantity of nutrient in feed consumed) x (100 / 1)

Data Analysis

The data generated were subjected to analysis of variance (ANOVA) as outlined by Obi (1990) based on a completely randomized design (CRD). Where

ANOVA detected significant treatment effects, means were compared using the New Duncan's Multiple Range Test (NDMRT) as outlined by Steel and Torrie (1980).

Results and discussion

Effect of fermentation process on the proximate composition of earth ball meal

The results of the proximate composition of the raw and fermented earth ball meals are shown in Table 2.

The fermentation process increased (P<0.05) the protein content of the raw earth ball meal from 3.06% to 5.69% and 7.73% for the water and rumen digesta filtrate (RDF) methods, respectively. The RDF method caused a significant reduction in the crude fibre content of the earth ball meal relative to the water-fermented method. The two fermentation methods reduced the gross energy content of the earth ball, with the highest reduction observed in the water-fermented sample. The RDF method significantly reduced the ether extract of the raw earth ball meal from 3.90% to 1.12%, whereas the water fermentation method increased the concentration of ash but reduced the nitrogen-free extract significantly.

The significant increase in the crude protein composition of the fermented sample, particularly with the rumen digesta filtrate fermentation, may be attributed to the hydrolysis of protein enzyme-tannin complexes to release free amino acids for new protein synthesis. Magdi (2011) observed that microbes secrete some extracellular enzymes (proteins) into their substrate in an attempt to make use of starch as a source of carbon skeleton for protein synthesis. Effiong *et al.* (2016) noted that an increase in the growth and proliferation of the fungi and bacteria complex in the form of single-cell proteins in 72 hours of cultured rumen digesta filtrate accounted for the apparent increase in the protein content of the *Icacinia manni* meal.

The result of this experiment is supported by the findings of Cui (2012), who reported an increase in the protein content of maize following fermentation. Nibe *et al.* (2009) also reported the potential of bacterial fermenters as a means of improving the nutritive value of feed resources. Ekpo and Udebibie (2012) stated an improvement in the nutritive value of water-fermented earth ball meal. The report of Anyiam (2023) indicating an increase in the crude protein content of *Macrotermesnigeriensis* after fermentation is consistent with the findings of this study. Significant reductions in the crude fibre content of the fermented earthball meals suggest the role of microbes in dietary fibre degradation. Microbes have the capacity to colonize, degrade, and ferment structural carbohydrates to provide volatile fatty acids for animals (Gabriella and Eric, 1997). Rumen digesta filtrate may have contained a greater proportion of these microbes relative to other fermentation media, hence its ability to effectively reduce the fibre level of the earth ball meal. A decrease in the nitrogen-free extract of fermented jackfruit seed meal was attributed to the high utilization of energy by microflora during fermentation, as stated in previous studies (Magdi, 2011). This result is consistent with most reports in the literature (Anyiam, 2022; Boukhers, 2022) showing a reduction in carbohydrate levels during the fermentation of different food materials. The decrease might also be due to the significant increase in protein content.

The decrease in gross energy in water and RDF fermented earth ball meals as compared to raw earth ball meal, with a gross energy value of 3.12 kcal/g, may be due to the increase in microbial amylase activity. Magdi (2011) noted a sharp decrease in the glucose and carbohydrate content of pearl millet after 24 hours of fermentation and attributed it to the utilization of glucose by the microorganisms. The report of this author agrees with the findings of this research.

Ash content was lowest in the raw earth ball meal but increased with water and rumen digesta filtrate fermentations. The increase in the ash content of the fermented sample could be attributed to the enzymatic degradation of mineral-phytate complexes by microorganisms to release free minerals, causing an increase in mineral content and bioavailability (Ahmed *et al.*, 2020; Anyiam*et al.,* 2023). The result of this study was similar to the reports of Adejuwon*et al.* (2021) and Hassan *et al.* (2015), who observed an increase in the ash content with the fermentation of sweet potato and cocoyam, respectively.

Performance of broiler chickens fed diets with varying levels of RDF fermented earth ball meal

The results of the average daily weight gain of birds fed diets containing varying levels of RDF fermented earth ball meal are presented in Table 3.

There was no variation (P > 0.05) in the average daily weight gain among the treatment groups, although the values were observed to decrease with an increase in the dietary level of RDF fermented earth ball meal. The bulky nature of the test ingredient, relative to maize, may have contributed to a decrease in the weight gain of birds fed test diets. The trend observed in this work is in line with the findings of Umoren *et al.* (2007) and Effiong *et al.* (2014). The two authors reported a decline in weight gain in broiler birds with increasing dietary levels of processed earth ball meal.

The average daily feed intake showed no significant difference between birds fed the control diet and those fed diets with different levels of earth ball meal. Average daily feed intake was observed to reduce as the level of earthball meal kept on increasing in the diets. According to Hadgu (2016), factors such as feed quality (freshness, palatability, and mould) and animal and environmental factors could influence the feed intake of birds. On the other hand, nutrient imbalance can also influence feed intake by reducing the activity of microbes in the gastrointestinal tract. High concentrations of dietary energy and fibre can also depress feed intake due to the energy density and bulkiness of the feed. The above characteristics were observed in the experimental diet containing 40% RDF fermented earth ball meal, with 5.49% as a crude fibre content. Umoren *et al.* (2007) and Effiong *et al.* (2014) reported a reduction in the average daily feed intake of broiler birds with elevated levels of water-fermented and toasted earth ball meals, respectively. The reports by these authors agree with the findings of this study.

The feed conversion ratio showed that birds fed the control diet and those on diets containing different levels of earth ball meal had similar feed conversion ratio (FCR) values. The result implies that birds on treatment diets were able to convert their feed into muscular tissues as compared to those fed a control diet. Poultry Hub (2016) reported a FCR of 2.56 with a range of 1.91-3.49 at 53 days, yielding 2.18 kg live weight for broiler birds raised in tropical regions, depending on the level of management, feeding, and housing conditions. The FCR of 3.18 recorded in birds fed diet containing 20% RDF fermented earth ball meal was within the range reported by this author. Ekpo and Udebibie (2012), and Effiong *et al.* (2014) also reported an increase in FCR values of broiler chickens with an increasing level of moist heat-treated and toasted earth ball meal in diets.

There was no mortality among birds fed the treatment diets, implying that the RDF earth ball meal did not contain any substance that could impact negatively on animal survivability.

Apparent nutrient digestibility

The result of apparent nutrient digestibility presented in Table 4 revealed that broiler birds fed RDF-fermented earth ball meal diets had significantly ($P < 0.05$) higher ether extract digestibility than those fed control diet. The result suggests that the level of dietary inclusion of RDF fermented earth ball meal did not influence the rate of ether extract digestibility by birds. For instance, 68% of the ether extract digestibility recorded for birds on 10% RDF fermented earth ball meal diet was not statistically different from those on diets containing 20%, 30%, and 40% RDF fermented earth ball meals, respectively. Njik *et al.* (2014) reported a decrease in ether extract digestibility in broiler birds fed cassava root-leaf meal. According to Poorghasemi *et al.* (2013), the age of birds and the dietary fat sources can affect ether extract digestibility. Latshaw (2008) observed that dietary fat could increase the energy content of feed, improve the absorption of fat-soluble vitamins, and reduce the passage rate of the digesta through the gastrointestinal tract, thereby allowing for better nutrient digestion, absorption, and utilization. It is also established that unsaturated fats are better utilized, leading to higher metabolizable energy than saturated fats.

The results of nitrogen-free extract (NFE) and gross energy digestibility showed no significant difference among the treatment groups. Similarities in the gross energy digestibility between birds fed control and treatment diets indicate that birds on treatment diets were as efficient in utilizing the energy of earth ball meal as those fed maize-based diet.

Cost implications of feeding graded levels of RDF fermented earth ball meal diets to broiler chickens at finisher phase

Table 5 shows the cost implications of feeding graded levels of RDF fermented earth ball meal diets to broiler chickens at the finisher phase.

The cost of feed production varied significantly ($P<0.05$), with the cost of producing a kilogram of control diet being the highest, while the cost of producing 40% RDF earth ball meal diet was the least. The cost reduced with an increase in the level of RDF fermented earth ball meal in the diets. The cost of producing diets with 30% and 40% earth ball meal was observed to be similar. The result obtained from this work was in agreement with the reports of Effiong and Nton (2010) and Effiong *et al.* (2012). The authors observed a reduction in the cost of feed production due to the inclusion of non-conventional energy sources in broiler birds' diets. Non-conventional energy feed resources have been considered the cheapest energy source, complementing the most expensive and scarce conventional sources like maize, millet, and sorghum.

The replacement of maize with RDF fermented earth ball in the broiler finisher's diet as an energy source reduced ($P<0.05$) the cost of daily feed consumption per bird from ₦ 1572.82 in the control diet to ₦ 1488.21, ₦1386.21, N1299.09, and ₦ 1214.86, respectively, for 10, 20, and 30% and 40% RDF fermented earth ball meal diets, respectively.

The cost of producing a kilogram of meat was lowest on diet containing 10% RDF fermented earth ball meal and highest on diet with 40% RDF fermented earth ball meal. The cost of producing a kilogram of poultry meat with the control diet (₦ 1203.38) was statistically similar to that of producing a kilogram of poultry meat on diet with 20% RDF fermented earth ball meal.

Conclusion

From the results of this study, it was concluded that

The rumen filtrate has proved to be a better option for the fermentation of earthball meal.

During the period of scarcity, RDF fermented earth ball meal could be used to replace maize at 20% in broiler finishers' diets for maximum returns on investment.

Recommendation

Dietary inclusion of multi-enzyme in future research to reduce the bulky nature of the feed has been recommended.

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Fig. 1: Earth ball root

Table 1. Ingredient composition of experimental diets

	Levels of earth ball meal				
Ingredients	**0%**	**10%**	**20%**	**30%**	**40%**
Maize	61.34	55.21	49.08	42.95	36.82
Earthball meal	-	6.13	12.26	18.39	24.52
Soybean meal	28.86	28.86	28.86	28.86	28.86
Fish meal	1.50	1.50	1.50	1.50	1.50
Wheat offal	5.00	5.00	5.00	5.00	5.00
Bone meal	2.50	2.50	2.50	2.50	2.50
DL-Methionine	0.10	0.10	0.10	0.10	0.10
L-Lysine	0.10	0.10	0.10	0.10	0.10
*Vitamin premix	0.30	0.30	0.30	0.30	0.30
Salt	0.30	0.30	0.30	0.30	0.30
Total	**100**	**100**	**100**	**100**	**100**
Calculated					
Crude Protein (%)	20.27	20.19	20.11	20.04	19.96
Crude fibre (%)	3.56	4.03	4.5	4.95	5.49
Metabolizable energy (kcal/(g)	3000	3000	3000	3000	3000

*Vitamin/mineral premix containing the following per kg. Vitamin A 8,000000 I.U; Vitamin D3 1,600000 IU; Vitamin E 5,000 IU; Vitamin K 2,000 mg; Thiamine 1,500 mg; Riboflavin B2 4,000 mg; Pyridoxine B6, 1,500mg; anti-oxidant 125 g; Niacin1,500 mg; Vitamin B12 10 mg; Pantothenic acids 5,000 mg; Folic acid 500 mg; Biotin 20 mg; Choline chloride 200 g, manganese 80 g; Zinc 50 g; 1 ron 20 g; copper 5 g; Iodine 1.2 g; Selenium 200 mg; Cobalt 200 mg

Table 2.Effect of fermentation process on the proximate composition of earth ball meal

Parameters	Raw earth ball	RDF FEM	PWFEM	±SEM
Dry Matter (%)	97.00^{a}	91.20^{b}	83.32^{c}	3.96
Crude Protein (%)	3.06^{c}	7.73^{a}	5.71^{a}	1.35
Crude Fibre (%)	15.90^{a}	9.64^{c}	12.36^{b}	1.81
Ether extract (%)	3.90^{a}	1.12^{b}	3.61^{a}	0.88
Ash (%)	1.50^{c}	5.91^{b}	10.38^{a}	2.56
NFE (%)	75.64^{a}	66.80^{b}	51.26^{c}	7.13
Gross Energy (kcal/g)	3.12^{a}	2.75^{b}	2.28^{c}	0.24

^{abc}Means of the same row with different superscripts are significantly different ($p<0.05$)

±SEM – Standard error of mean
RDF FEM - Rumen digesta filtrate fermented earth ball meal
PWFEM: Plain water fermented earth ball meal

Table 3. Performance of broiler birds fed earth ball meal diets at finisher phase

Levels of earth ball meal						
Parameters	0%	10%	20%	30%	40%	±SEM
Initial weight/bird(g)	999.33	998.00	990.00	1000.00	996.67	1.77
Final body weight/bird(g)	2300.00	2270.00	2180.00	1980.00	1930.00	74.80
Average daily weight gain/bird (g	46.67	45.43	42.50	35.00	33.32	19.76
Average daily feed intake/bird(g)	144.52	140.74	135.03	130.48	125.93	0.96
Feed conversion ratio	3.10	3.10	3.18	3.73	3.78	0.15
Mortality (%)	0.00	0.00	0.00	0.00	0.00	0.00

±SEM – Standard error of mean

Table 4. Apparent nutrient retention of broiler chickens fed RDF fermented earth ball meal diets

	Levels of earth ball meal					
Parameters	**0%**	**10%**	**20%**	**30%**	**40%**	**±SEM**
Crude Protein (%)	49.38	49.28	47.44	44.86	42.28	1.37
Ether Extract (%)	54.17^{b}	68.47^{a}	62.37^{ab}	67.55^{a}	67.91^{a}	2.71
Nitrogen Free Extract (%)	18.77	16.90	18.34	18.07	18.75	0.34
Gross Energy (%)	29.62	29.75	30.91	31.59	32.75	0.59

^{abc}Means of the same row with different superscripts are significantly different ($p<0.05$)
SEM – Standard error of mean

Table 5: Cost implication of feeding graded levels of RDF fermented earth ball meal diets to broiler chickens at finisher phase

	Levels of earth ball meal					
Parameters	**0%**	**10%**	**20%**	**30%**	**40%**	**±SEM**
Cost of feed (₦ /kg)	388.68a	377.65b	366.64b	355.58c	344.54c	2.02
Cost of feed consumed/bird (₦)	1572.82a	1488.21b	1386.21b	1299.09b	1214.86c	5.66
Cost/kg weight gain (₦)	1203.38b	1169.98c	1164.88b	1325.60a	1302.10a	12.56

^{abc}Means of the same row with different superscripts are significantly different ($p<0.05$)
SEM – Standard error of mean