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Blending crop residues with poultry litterfor ruminantfeed formulationin Sub-Saharan Africa: A case study of North-Eastern Nigeria

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Abstract
The experiment was doneto assess the possible use of poultry litter as alternative protein sources whenformulating ruminant dietsusing local crop residue. Ten formulations (F1 – F10) were developed using locally and commonly used feed ingredients such as wheat offal, sorghum husk (energy source), while groundnut haulms and poultry litter (protein source). The formulation was based on 60% and 40% of energy and protein source feed material(s) respectively. Poultry litter was introduced to see its possible effect on the digestibility rates of some selected crop residues compared.The proximate composition of the feed ingredients, as well as that of the formulations, were determined. Dry matter content was within the range of 89.9 – 99.7%, 5.77 – 16.37% CP, 34.00- 80.5% CF, 2.0 – 8.0% Fat, 0.5- 13.0% Ash, and 14.64 – 15.52 GE MJ/Kg.DM. 3g each of the formulations were weighed into nylon bags and incubated for 6, 12, 18, 24, 36, 48 and 72 hours respectively. All the formulations used in this study recorded above 60% dry matter degradability at 24hours period of incubation. This implies that the formulations were highly degradable in the rumen. Significant variation (P<0.05) inthe rate ofdegradation was observed between the formulations except at 48 hours. The cost of production of each of the formulation was also calculated with F8 having highest cost per 100Kg formulation at ₦ 4059 followed by formulation F10 ₦3883.45 while the lowest cost was obtained in formulation F7 (₦2997.50).

Keywords: *poultry litter, rumen, degradation, diet, digestibility*

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I. Introduction

Animal production is increasing across the world due to modern knowledge in nutrition, husbandry and genetics. Feeds form a significant component of the performance and maintenance of animal well-being. However, the cost of feed is around 70% of the overall cost of animal production (Makkar 2016). This high cost has pushed small-scale livestock keepers to device ways to minimize cost. One important system practised in Nigeria is pasture grazing(Chukwuemeka et al. 2018). Pasture grazing as sole feeding regime, are generally low in quality as they contain mostly grasses with few legumes and almost no additive or other supplements(Olanite et al. 2009). Pasture grazing in semi-arid regions of Nigeria, last only four months (between Jun – Sept), other feeding systems are therefore needed to maintain livestock production. Ruminants have interesting digestion of feedstuff owing to the microbial characteristics of their rumen. Nevertheless, for efficient utilization of commonly available feed materials, it is important to understand and characterize the various feed components. This is important in formulating ration for different stages of livestock production(Cajarville et al. 2006).

For the past decades, Sub-Saharan Africa's crop production has received a major setback due to increased activities of terrorist in the region, especially in the North-Eastern part of Nigeria. This has caused a

great decline in the availability of crop residues commonly used in diet formulation to meet both maintenance and production requirements in the region. A major challenge is to utilize alternative protein sources to meet the requirement for protein availability in the ruminant diet in the region. This is based on studies which earlier indicated potential use of some feed supplements in meeting protein requirement in formulations(Fabian et al. 2015; Gidado et al. 2015)(Malgwi and Mohammed 2015).In this study, we re-evaluate the rumen degradation rates of some formulated diets mixed with poultry litter in North-Eastern Nigeria.

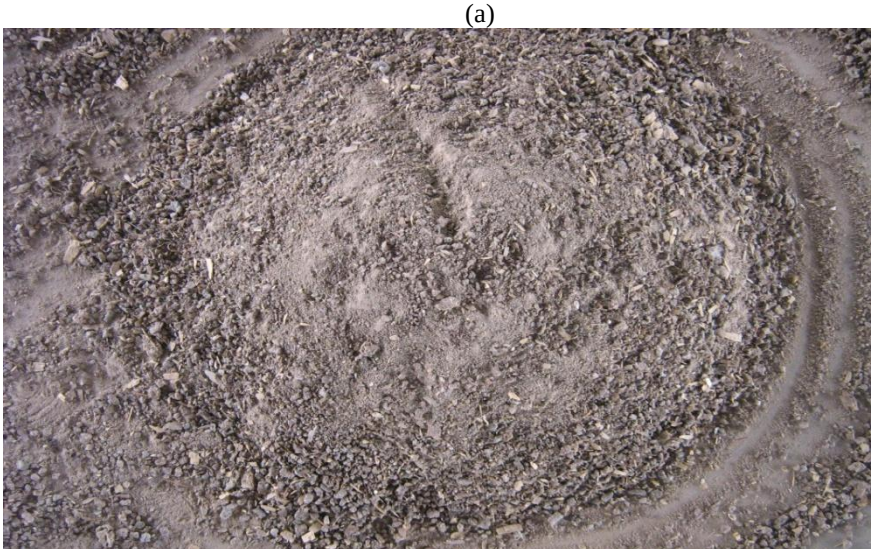
II. Materials And Methods

All experiments are conducted under the animal welfare and ethics of the University of Maiduguri, Nigeria. The experimental set up was designedaccording to our previous studies(Malgwi and Mohammed 2015).

Experimental Location: This experiment was performed at the University of Maiduguri Teaching and Research Farm. Maiduguri is located in northern Nigeria and is considered to be a Sahelian Region (Semi-Arid Zone) of West Africa, which is generally known for its short rainfall period of just 3 – 4 months. Annual precipitation is around 300 – 500 mm; while the temperature in April and May is between 35 – 45 °C(Alaku 1983).

Sample Collection and Preparation of Poultry litter:
The samples were collected from the farm, weighed and prepared at the animal science laboratory for analysis.

(a)



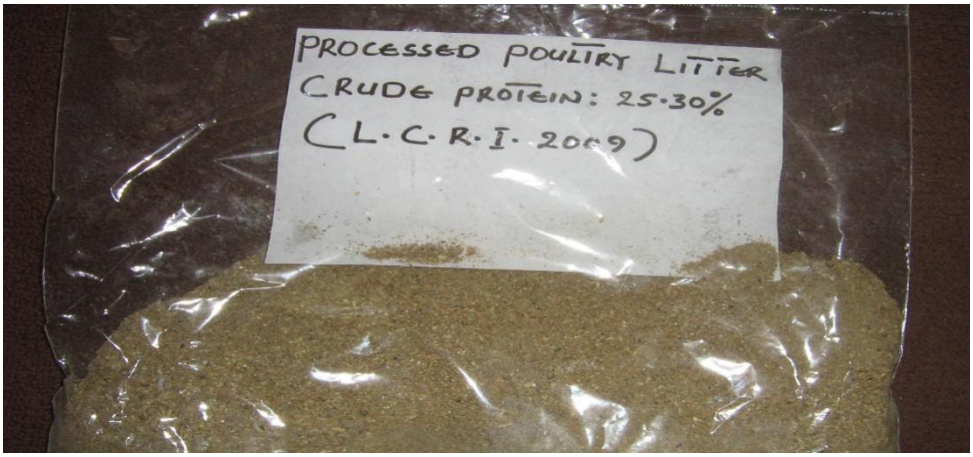
(b)

Image 1a, b, Unprocessed Poultry litter(Image extracted from our unpublished practical training session at Lake Chad research institute (L.C.R.I)for the proposed use of poultry litter in ruminant diet)

Processing of the litter was aimed at destroying pathogens, improve storage and to maintain or improve the palatability of poultry litter. The two most important steps were:

Sifting: the product was sifted before feed formulation to remove foreign material, lumps and bird carcasses.

Dehydration: mild heat treatment (60 ^{o}C, oven-dried) was applied to destroy pathogens until constant weights were attained. This was done to inhibit the activities of harmful micro-organisms and to obtain a uniform litter product on a dry matter basis.



(c)

Image C, Processed poultry litter(Image extracted fromour unpublished presentation slides from lake Chad research institute (L.C.R.I) in 2009 during one of our in house meetings for the proposed use of poultry litter in ruminant diet)

Table 1 Approximate composition of broiler litter on a dry basis

Nutrient	%
Moisture	10 – 24
Crude protein	10 - 26
True protein (% of CP)	40 - 60
Crude fibre	22 - 25
Ash	10 - 17
TDN	45 - 65
ME (MJ/kg)	6 - 7.3
Calcium	1.5 – 3.0
Phosphorus	1.2 - 1.8

Source: (Van Ryssen 2001)

Feed Formulation: A total of 10 different rations were formulated using sorghum husk, wheat offal as an energy source while groundnut haulms and poultry litter were used as the protein source. The formulation was done based on the energy to protein ratio of 60:40.Ingredients used were weighted separately and then mixed up on a clean floor using the shovel to turn and mixed thoroughly until homogeneously mixed. One hundred (100) kilograms each of ten different diets wereformulated. Formulations were manually done using standardized locally proposed method of 60:40 (Energy sources: Protein sources) ratio by(Balami et al. 2015)and (Gidado et al. 2015). Washing loss soluble (WLS) portion of the feed was determined by weighing 5 g of the feed samples into nylon bags in replicates, whichwas soaked in warm water at 40 °C for one hour, removed and washed under a running tap for 15 minutes in two circles till clear water was obtained. The bags were oven-dried at 60 °C for 48 hours to constant weight,according to the specifications of(Orskov et al. 1980).

Chemical Analysis: Feed samples were analyzed for Dry Matter (DM), Crude Protein (CP), Crude Fiber (CF) and Ash, using the methods of (Pérez-Marín et al. 2004) AOAC, 2000).

Cost of Producing the Formulations: The cost of producing the ten formulations was calculated using current prices of feedingredients at the Maiduguri Cattle Market in Naira (₦) and the Kg of ingredient used.

Rumen Degradation Study: This is an in vitro digestibility involving the insertion of nylon bags with feed inside into the rumen and monitoring the digestibility over a specified period usually between 0-120 hours(Church 1997). The nylon bags (in vitro) technique for determination of the degradation of feedstuff in the rumen at various incubation periods can be used to screen feeds at initial stages of assessing their nutritive

value. The balance of nutrients potentially made available from and the digestibility of the dry matter in the rumen is the most important criteria of the potential of a basal diet. Digestibility primarily establishes the intake of the basal diet feed once nutrient deficiencies for the rumen microbes have been corrected, however, intake is affected by climate and a range of other factors (housing, feed quality and quantity, breed, sex, reproductive status etc).

Statistical Analysis: Results from the proximate analysis were subjected to analysis of variance (ANOVA) using Statistical Package for the Social Sciences (SPSS) version 20 (SPSS, 2014), as described by (Steel and Torrie 1960)

III. Results

Fig. 1 shows the nutrient composition in (%) of individual crop residue used in these studies. In practice, wheat offal, sorghum husk, maize bran, etc have been utilized in trying to supplydietary energy requirements of ruminants in northeastern Nigeria. Wheat offal is composed of germ and bran after extracting flour from wheat. It contains 14.8 - 17.6% of CP, 10% CF, and 3.4 - 6.4% of crude ash (Amaefule et al. 2009). Sorghum husk has a high level of deoxyanthocyanins which are considered a good source of antioxidant and has is used in human nutrition for beverage jellies etc(Hou et al. 2017). Poultry litter is considered a cheap source of protein for cattle feeding, in addition, being a source of beneficial microbes that aid in digestion(Millam et al. 2018)(Gidado et al. 2015). It contains 4.7 – 39.0% of moisture, 15 – 41% of CP and 11 – 51% of CF (Martin et al. 1997). These proximate composition values are similar to the values reported by (Balami et al. 2015), who reported 95.5% DM, 14% CP, 20% CF, 5% EE, 6.08% Ash, and 50.5%NFE. However, our values as shown in figure 1, are consistent with that of (Balami et al. 2015).Groundnut haulm is also another source of protein in animal diets, its digestibility among ruminants is estimated to be around 74 – 88% (N et al. 1997). The crude protein of groundnut haulms has been reported to be between 8 – 15% CP, while the fibre fractions of PDF, ADF and ADL are 47%, 36.5% and 6.3% respectively (N et al. 1997). These cheap, affordable, and accessible feedstuffs, when combined in the right proportion, will meet most of the basic requirement for maintenance, performance and lactation of ruminantsin these regions.

All feedstuff had > 93% DM, From Fig. 1. Groundnut haulm as expected had the highest protein content (>30%). (Prathiba and Reddy 1994) estimated the seed protein contents of groundnut to be between 17 – 25%, more or less this higher protein content upon oil extraction is also recorded in oilseed rape meal(Bernard 2016).

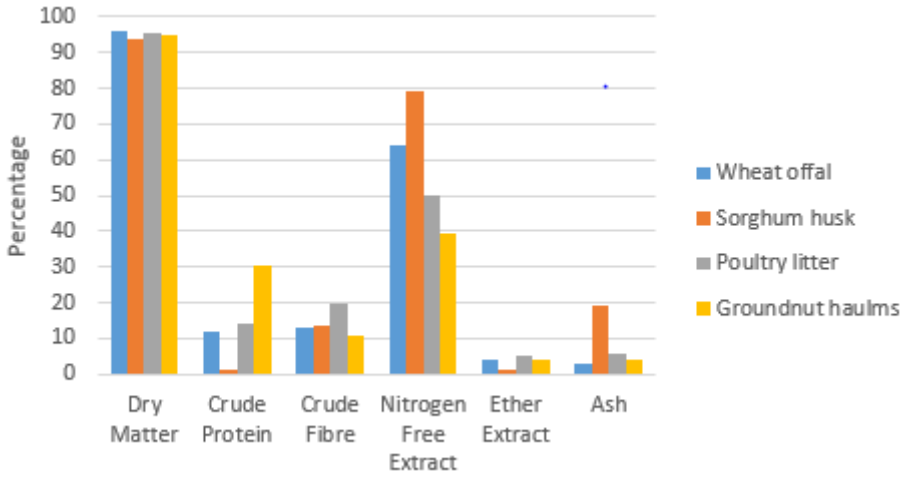


Figure-Error! No text of specified style in document.**1** Proximate Composition of the Feed Ingredients (%)

Groundnut haulms showed the highest crude protein and least crude fibre content,30.35 % CP and 10.65% CF respectively. Thus, this implies that crude fibre and crude protein is inversely correlated. This agrees with a much earlier study done by (Mongeau et al. 1989).

Nitrogen free extract is composed mainly of water-soluble sugars. Starch, Sorghum had the highest NFE content (79%) while the Groundnut haulms had the least (39%).

Other organic molecules soluble in ether (ether extract) were measured, all feedstuff except Sorghum husk were between 4 – 5%EE content.

The inorganic residues after an oxidation process also known as ash were measured. Sorghum husk had a very high ash content of 19%, which is more than all the other feedstuff combined.

Table 2: Feed Formulation in (100kg)

Ingredients	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Sorghum husk	25	30	24	30	20	24	50	10	35	34
Wheat offal	35	30	36	30	40	36	10	50	25	26
Poultry litter	25	20	18	10	25	16	30	10	15	21
Groundnut haulms	15	20	22	30	15	24	10	30	25	19
Total (Kg)	100	100	100	100	100	100	100	100	100	100

Table 2,gives a descriptive summary of the formulation of different diets(F1 – F10) based on levels of energy and protein plant materials and poultry litter used to make the individual diet. For this experiment, we used a 60:40 energy to protein ratio as recommended in previous studies by (Malgwi and Mohammed 2015)using wheat offal and sorghum husk as energy sources while groundnut haulms and poultry litter as protein sources. F8 and F7 have the highest energy inclusion level of a single crop residue (50% of wheat offal and 50% of sorghum husk).

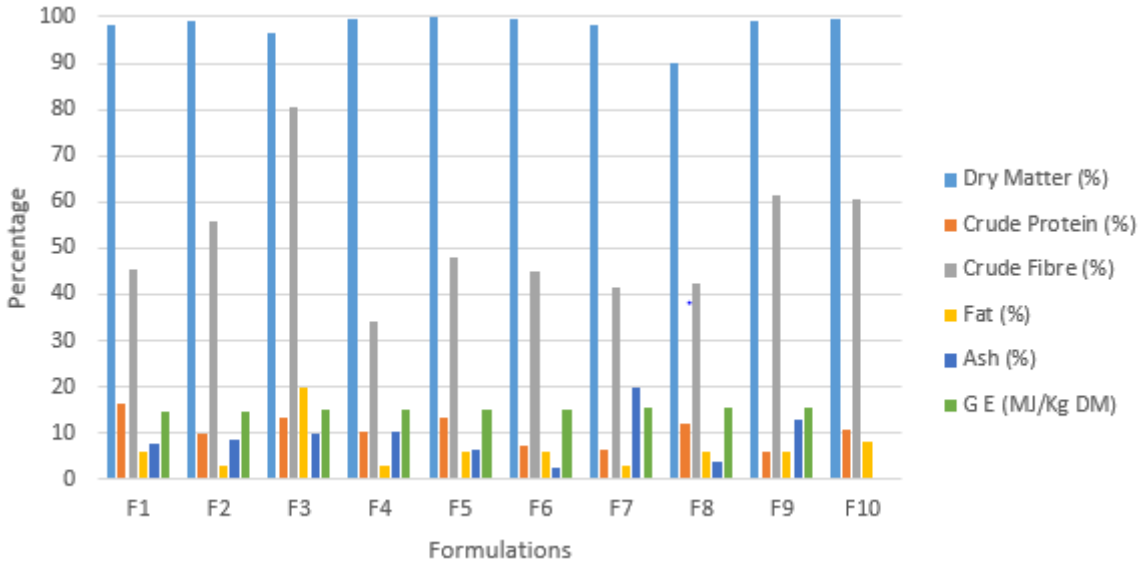


Figure-2.Proximate Composition of the Formulation

Figure 2 shows a summary of the proximate composition of the formulations. The dry matter content of the feed ranges from 89.9 to 99.7%, with the highest dry matter recorded in F4 (99.7%) and F8 with 89.80% DM recorded the least.

The crude protein, crude fibre, fat, ash and most importantly the energy content were all measured for each formulation. The energy content ranged from 14.64 – 15.52 MJ/kg DM.

Table 3: Cost of production of the Formulation (100kg)

Ingredients	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Total
Sorghum husk	709.00	850.80	680.64	850.80	567.2	680.64	141.80	283.60	992.60	964.24	7997.52
Wheat offal	1640.80	1406.0	1687.68	1406.4	1875.2	1687.68	468.8	2344.0	1172	1218.88	14907.84
Poultry litter	500	400	360	200	500	320	600	200	300	420	3800
Groundnut haulms	616.05	821.4	903.54	1232.10	616.05	985.68	410.7	1232.1	1026.75	780.35	8624.70
Total (₦)	**3465.85**	**3478.60**	**3631.86**	**3689.30**	**3558.45**	**3674.00**	**2897.50**	**4059.70**	**3491.35**	**3383.45**	**35330.24**

Source: Maiduguri Cattle Market in Naira (₦), 2019

Table 3 provides a summary of the total cost of producing each formulation per 100 kg. The highest feed cost was found in F8 with₦ 4059.70, followed by F4 while the lowest formulation cost was observed in ₦F7 2897.50. In terms of feed ingredient cost, wheat offal had the highest recorded cost of greater than ₦2300 in F8 with poultry litter having been the cheapest ingredient with a cost of about₦200 only as seen in F8.Total cost of feed ingredient used in the formulation from F1 – F10 shows that wheat offal has the highest cost per

100 kg formulation of nearly ₦14,907.52, followed by groundnut haulms and sorghum husk at ₦8,624.70 and ₦7,997.52 respectively. Poultry litter had the lowest cost of just ₦3,800.00. All dietary crop residues and poultry litter costs were calculated based on a 100kg diet formulation.

Table 4: Percentage Dry Matters Degradation of the Formulations.

HOURS	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	SD
6hours	57 ^{ab}	47 ^{cd}	61 ^{ab}	51 ^{bc}	50 ^{bc}	42 ^{d}	45 ^{cd}	61 ^{a}	48 ^{cd}	53 ^{bc}	6.16
12hours	61 ^{ab}	57 ^{d}	63 ^{ab}	56 ^{bc}	56 ^{bc}	55 ^{bc}	52 ^{cd}	63 ^{a}	53 ^{cd}	55 ^{bc}	3.72
18hours	64 ^{ab}	60 ^{d}	65 ^{abc}	61 ^{abcd}	60 ^{bcd}	57 ^{d}	56 ^{d}	66 ^{a}	58 ^{cd}	63 ^{abc}	3.25
24hours	67 ^{a}	63 ^{b}	66 ^{ab}	64 ^{ab}	63 ^{ab}	60 ^{b}	60 ^{b}	67 ^{a}	64 ^{ab}	66 ^{ab}	2.44
36hours	69 ^{ab}	63 ^{b}	66 ^{ab}	67 ^{ab}	67 ^{ab}	63 ^{b}	66 ^{ab}	72 ^{a}	67 ^{ab}	67 ^{ab}	2.49
48hours	70 ^{a}	67 ^{a}	70 ^{a}	73 ^{a}	73 ^{a}	65 ^{a}	68 ^{a}	74 ^{a}	69 ^{a}	71 ^{a}	2.72
72hours	73 ^{abcd}	70 ^{bcd}	74 ^{abc}	72 ^{abcd}	76 ^{ab}	67 ^{d}	69 ^{cd}	77 ^{a}	70 ^{cd}	73 ^{abcd}	2.98
SD	5.13	6.94	4.03	7.49	8.53	7.78	8.31	5.47	7.85	7.03	

$^{a, b, c,d}$ =Means in the same row bearing different superscript are significantly different ($p < 0.05$).

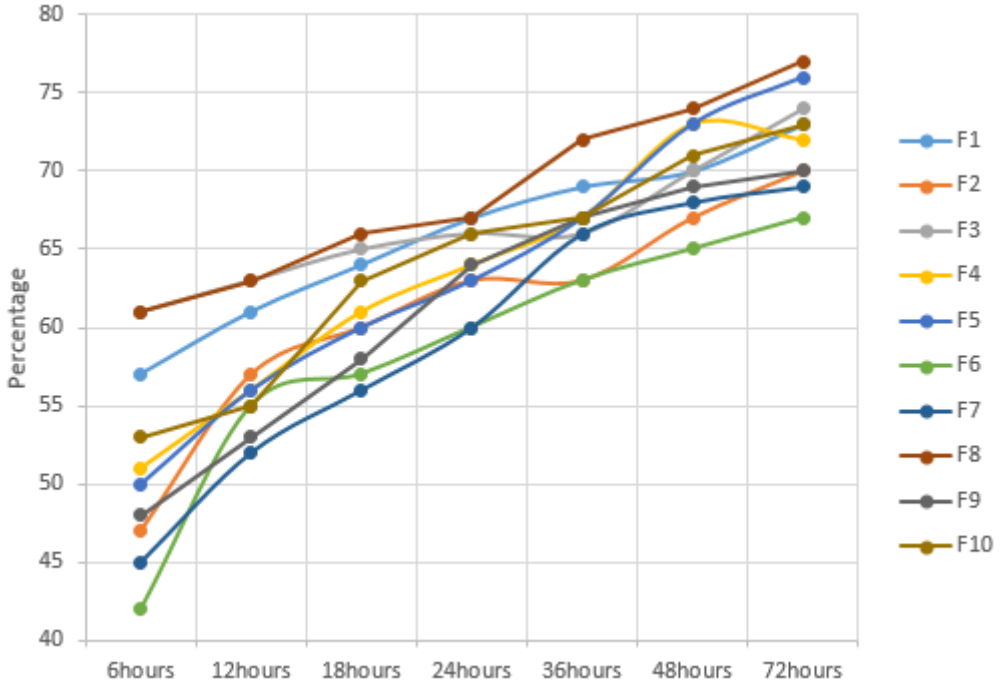


Figure 3.Degradability potential of formulated diets from 6 – 72 hours

Table 4 shows the percentage of dry matter degradation from 6 – 72 hours.At 6 and 12 hours of incubation, there is a slower degradation rate among the formulations with no significant variations. No difference in degradability rate between F3 and F4 at 6 and 12 hours ($P < 0.05$). At 24 and 36 hours, all formulations recorded > 60% DM degradability. No statistical difference between F2, F6 and F7 as well as F3, F4, F5, F9 and F10 at 24 hours of incubation ($P < 0.05$). F8 had the highest degradation percentage (74%). At 48 and 72 hours, all formulations recorded about 70% degradability with F8 having highest while F6 had the least degradation rate.

IV. Discussions

From Fig 1, as stated earlier, we can observe a negative correlation between crude fibre and crude protein content in Groundnut haulms; this is similar to the results of Mongeau et al. (1989) and (Mongeau et al. 1989), who also confirmed a negative correlation between crude fibre and protein. After energy demand, the next requirement in ruminant nutrition is protein supply; however, the high fibre content in diet limits protein absorption. Protein was found to be a limiting factor in diet formulation including its role to overall carcass yield(Miller 2002).It is important toconsider protein and fibre content as well as their inclusion rate for sustainable and efficient feed utilization. When there is a shortage in energy supply, nitrogen intake is affected and consequently protein intake as well(Norgan et al. 2012). Therefore, there is a need to formulate rationscontaining a good balance between energy and protein sources. A general ratio of 60:40 energy to protein ration is widely used in feed formulation(Dewhurst et al. 2000)(Malgwi and Mohammed 2015), using this ratio

with a little adjustment, we observed a great variation in terms of the total cost for each formulation with respect to degradation percentage due to protein supply and use of less fibrous feed resource with adequate protein supply. The degradability rates of these formulated feed in this current experiment were coherent with reports of previous studies(Fabian et al. 2015; Gidado et al. 2015);(Malgwi and Mohammed 2015)and way greater than the 60% recommended by (Vazquez and Smith 2000). There isabout 69% in degradability of formulation F7 when poultry litter was included at a 30% level of the whole diet. This agrees with (Balami et al. 2015) who included up to 30% poultry litter in the diet of ruminants for better performance.However, the degradability of the diet (F7) was 7% less than the reported diet degradability of a 30% poultry litter included diet by (Balami et al. 2015) who reported up to 76.95% dry matter degradability.After 72hours, F8 had the highest degradation percentage of 77% followed by F5 (76%) the high wheat offal amount included in these formulations (50% and 40% respectively) could explain this high degradation rate. F6 had the lowest degradation rate after 72 hours with 67%, which could be explained due to the high sorghum husk and groundnut haulms (48%). In the study,(Mshelizah et al. 2015) also reported similar degradation percentage among different feed ingredient, although the degradation of their formulation reached 82%. The efficiency of rumen degradation is dependent on how long the feed composition and how long it remains in the rumen (Prathiba and Reddy 1994). Poultry litter inclusion in ruminant diets could enhance the active utilization of fibrous feed materials and crop residues used in formulation. It could also possibly have role in supplying active microbial network that could enhance digestibility and degradability of rumen dietary fractions. However, the validity of this assumption needs to be carefully evaluated and examined under a more advanced experimental trial.

V. Conclusion

Our experiment has shown that blending crop residues with poultry litter could meet the challenging nutritional requirement in this Sub-Saharan region of northern Nigeria and Africa at large, which is faced with the limited and high cost of available crop residues. Thus, 30% level of inclusion of poultry litter might be used to replace the use of expensive protein sources such as groundnut haulms. However, we recognize the teaming challenges associated with the ethics of using poultry litter in animal feeding regimes. Therefore, further studies and deliberations on the ethical acceptability of poultry litter as a protein source in feed formulation are suggested.

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Conflict of Interest

Authors declare that there is no conflict of interest

Author contribution

Mohammed Ibrahim Dukku (Full Professor): Conceptualization, Methodology, Validation, Funding acquisition, Supervision. **Jaji Mohammed:** Investigation, Formal analysis. **Kefas Luka Baiyi:** Formal analysis, Writing -Original Draft, Visualization. **RosineIshimwe:** Writing - Review & Editing. **Isaac Hyeladi Malgwi:** Writing - Original Draft, Visualization, Project administration, Methodology, Validation, Formal analysis. **HarunaGadoYakubu:** Writing - Review & Editing, analysis. **YarsminYunusZeebone;** Writing - Review & Editing.

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