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Poultry manure as a protein supplement in indigenous goat production in Zimbabwe

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The abundance of poultry litter in most farms in the sub-Saharan Africa is becoming an environmental problem. The objective of this study is to evaluate the proximate value, *in-vitro* digestibility of dried poultry manure (DPM) and its subsequent effect on growth, pH, and volatile fatty acid production of indigenous goats in Zimbabwe. Eighteen goats were randomly allocated to two treatment diets: grazing veld grass plus *ad libitum* browsing of *Luecaena leucocephala* (T1) and 25% dry poultry manure plus 75% maize meal (MM) (T2), in a completely randomised design. Three samples of 2 g each T_1 and T_2 diets were subjected to standard procedures, for proximate analysis; a two stage Tilley and Terry was used to evaluate dry matter (DM) and organic matter (OM) digestibility of the diets. The results show no significant differences between treatment diets for DM, ether extract (EE) and Ash; however T_1 had higher (P<0.05) CP, ADF and CF compared to T_2. The NDF content of T_2 was significantly higher (P<0.05) than T_1. There was a significant difference (P<0.05) in DM and OM digestibility between treatments; T_1 showed higher DM and OM digestibility compared to T_2. Diet and sex of animals significantly (P< 0.05) influenced DMI, ADG and total gain (TG). Male animals in the control diet consumed more feed, gained more per day and showed the highest growth rate compared to female animals (P<0.05). The rumen liquor pH for animals in T_1 was significantly higher (P<0.05) compared to T_2; however the sex of animal did not influence overall pH of rumen liquor (P>0.05). Diet and sex of animals significantly influenced (P<0.05) the total VFA production. Male animals in T_2 exhibited the highest (P<0.05) total VFAs. In conclusion, although there were some nutrient inadequacies (ash, ADF) in poultry manure feed, it can support goat production at a marginal scale and positively influence pH and VFA production.

Key words: Goats, digestibility, poultry manure, nutritive value.

INTRODUCTION

The poultry industry is one of the largest and fastest growing sectors of livestock production. Throughout the

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world there has been a 35% increase in meat and egg production in the past decade (FAO, 2010). According to Ghaly and Mac Donald (2012), rearing of birds has improved from a side-line occupation into a fully-fledged commercial enterprise. The 2010 world annual census data estimated the world flock to be over 18 billion birds with an estimated yearly output of 22 million tons of manure (FAO, 2010). A greater component of this poultry manure is left idle and decomposes in unfavorable areas that pose a challenge to nearby habitants. It is therefore envisaged that a more climate smart disposal way of poultry manure should be developed. One of such practical ways is its incorporation into ruminant animal diets. This is particularly important in sub-Saharan Africa due to the scarcity of animal feed during the dry period. Earlier studies by Nadeem et al. (1993) and Alam et al. (2008) demonstrated that agricultural and industrial wastes can be used for ruminants. The use of poultry manure would decrease the cost of feed and its polluting effects. Poultry manure is a form of non-protein nitrogen supply with crude protein (CP) content ranging between 15-30% (Nadeem et al., 1993). More than half of this CP is true protein, while the other half is non – protein nitrogen (Ajayi et al., 2016). A greater component of non-protein nitrogen in poultry manure is in the form of uric acid, which ruminant animals are able to utilize. This is possible through the rumen microbes that convert nitrates to ammonia (Ajayi et al., 2016). Ammonia is then absorbed by microbes for their own rumen microbial protein synthesis, with excess being absorbed into the blood stream or excreted as urine. Dried poultry manure has been used to feed goats (Reddy et al., 2012; Ajayi et al., 2016) sheep (Bello and Tsado, 2013) and cattle (Alam et al., 2008) with positive results. The main aim of this study is to evaluate the proximate value, digestibility and the subsequent effects of poultry manure on feed intake, growth, rumen pH and total volatile fatty acid production of Zimbabwean indigenous goats.

MATERIALS AND METHODS

Study site

The project was conducted at Africa University Farm, located in Old Mutare in Manicaland. The farm lies at a latitude of S 18° 53,786 and longitude of E 032° 36,036, with an altitude of 1104 m above sea level; its average annual rainfall is 772 mm. The average annual temperature is about 21.5°C, with January being the hottest month and June being the coldest month of the year. The variation in annual temperature is around 7.7°C. The area is dominated by sand clay loam, sand clay soils.

Animal management

Eighteen -one year old goats of 16.75 kg ± 0.35 average weight were randomly divided into two treatment groups (T_1 control; grazing veld grass plus 30% *Luecaena leucocephala*; T_2 grazing plus supplement with poultry manure (PM) and maize meal (MM) in a 1: 4; PM: MM by weight) with an equal sex representation. All goats grazed an abandoned pasture dominated with star grass *Luecaena* browse trees. The experiment was done over a period of 50 days. In treatment two, animals were allowed to graze after consuming the treatment diet which was made up of 20% poultry manure (PM) and 80% maize meal (MM). This diet was fed at 3% of body weight and left overs were used to determine daily dry matter intake (DMI) by difference. Animals were allowed to adapt to the diet for 14 days and weight gain measurements were taken weekly from week two to week five. Feeding was done in individual pens every day in the morning from 06.30 to 10.00 h. Animals were housed over-night and allowed to graze after 10.00 h every day until 16.00 h. The DMI for the control group was calculated using a 3% factor of average live weight and was adjusted over time (McDonald et al., 2011). A flexible polyvinyl chloride stomach tube was used to extract rumen liquor for pH and VFA analyses at day zero and after every twelve days from week two to week five of the experiment. All animals were dewormed using Valbazin, Pfizer and dipped using coopers ASSASSIN Sheep Dip - COOPERS - temephos 35% - organophosphate dip, prior to the experiment.

Chemical composition and In-vitro digestibility

A 1 m^2 quadrant was used to collect ten veld grass samples which were cut into a 10 cm stubble height from a 20 m^2 paddock, of which only 20% of the consortium was used. A proportional 30% of *Luecaena* leaves were also harvested from within the paddock. The samples were oven dried at 68°C for 48 h, ground through a 1 mm sieve and packed in khaki bags awaiting chemical analysis. Three samples weighing 2 g each of both treatments (T_1 veld grass plus 30% *L. leucocephala*; T_2 25% DPM: 75%MM) were subjected to proximate analysis and *in-vitro* digestibility in the Animal Science lab at Africa University. Crude protein (CP) was determined using the Kjeldahl procedure (AOAC, 2005); CF, EE, was also determined by standard procedures of AOAC (2005), while Neutral detergent fiber (NDF), acid detergent fiber (ADF) was analyzed by methods described by Goering and Van Soest, (1970). Total ash was obtained by igniting a dried sample in a muffle furnace at 500^0C for 24 h cooled to room temperature before determining ash content by difference. The Tilley and Terry (1963) method was used to determine the *in vitro* dry matter and organic matter digestibilities for the two diets. VFA production was determined by a method described by Mpofu (2006)

Poultry manure management

Raw, sun dried and not treated poultry litter was obtained from layers raised in a battery cage system at the university farm and bagged under room temperature. Prior to feeding, manure was crushed in a maize crusher through a 2 mm sieve and mixed with maize at a ratio of 1: 4, DPM: MM.

Statistical analysis

A general linear model of SAS version 9.3, (2003) was used to analyze the effects of PM inclusion to the diet on DMI, growth, rumen pH and VFA production of the goats. The general form of the model is presented as follows:

$$Y_{ij} = \mu + S_i + T_j + (ST)_{ij} + e_{ij}$$

where Yij is the dependent variable (DMI, VFA, weight gain), μ is the overall mean, S is the sex effect (i = 1, 2), T is treatment effect (j =1, 2), $(ST)_{ij}$ is the interaction between sex and treatment, e_{ij} is the residual error. The differences between means were assessed using the Tukey's Studentised Range Test of SAS.

Table 1. Proximate composition of treatment diets used to feed indigenous goats at Africa University.

Proximate fraction (%)	Treatments		SE	P -values
	T_1	T_2		
DM	88.66	88.80	8.875	0.489
CP	15.05^a	12.82^b	1.493	0.017
NDF	49.24^b	64.73^a	5.692	0.001
ADF	17.25^a	11.99^b	1,443	0.012
EE	2.82	2.69	2.758	0.495
CF	19.79^a	6.87^b	1.336	0.001
ASH	8.00	8.00	0.001	0.526

[ab] Row means with different subscripts are different at $P < 0.05$; T_1; veld grass, + 30% *L. leucocephala* T_2 : 20% poultry manure plus 80% maize meal, DM – dry matter , CP – crude protein, NDF – neutral detergent fiber , ADF – acid detergent fiber, EE – ether extract, CF – crude fiber.

Table 2. Growth rate of Indigenous goats at Africa University.

Proximate fraction	Treatments			Sex			P values		
	T_1	T_2	SE	M	F	Se	T	S	T x S
DMI(kg)	0.57^b	1.48^a	0.004	1.12^a	0.92^b	0.006	0.001	0.001	0.001
Initial weight (kg)	16.73	16.73	0.001	18.12^a	15.43^b	0.035	0.901	0.02	0.871
Final weight (kg)	19.61^a	17.8^b	0.294	20.29^a	17.14^b	0.294	0.001	0.001	0.001
ADG (g/day)	57.6^a	21.4^b	2.94	43.4^a	34.2^b	2.94	0.001	0.001	0.001
Total gain (kg)	2.88^a	1.07^b	0.12	2.17^a	1.71^b	0.21	0.023	0.032	0.04

[ab] Row means with different subscripts are different at $P < 0.05$; T_1; veld grass + 30% *L. leucocephala,* T_2 : 20% poultry manure plus 80% maize meal, DMI – dry matter intake , ADG average daily gain.

RESULTS

The two treatment diets were subjected to proximate analysis and results are shown in Table 1. There were no significant differences between treatment diets for DM, EE and Ash; however T_1 had higher (P<0.05) CP, ADF and CF compared to that of T_2. The NDF content of T_2 was significantly higher (P<0.05) than T_1. The treatment diets and sex of animals significantly (P<0.05) influenced DMI, ADG and total gain (TG) of goats (Table 2). Male animals consumed more feed, gained more per day and showed the highest growth rate compared to female animals (P<0.05) in both treatments. Male animals exhibited a higher DMI of 0.2 kg, higher ADG of 9.2 g and a higher total gain of 0.46 kg. Although the average initial weight of goats was the same for both treatments, the ADG, final weight and total gain were significantly different (P< 0.05) for the two treatments. The average initial weight for male animals in the control group was significantly higher (P<0.05) than T_2 group (Figure 1). The highest rate of gain was exhibited by animals in T_2 from day 38 onwards. The same is also true for male and female animals, but this is not exhibited by animals in T_1. Animals in T_2 exhibited a significant loss (P<0.05) of 1.3 kg LW from day zero until day 26. The rumen pH for animals in T_1 was significantly higher (P<0.05) compared to T_2; however the sex of animal did not influence the overall pH of rumen liquor (Table 3). Diet and sex of animals significantly influenced (P<0.05) the total VFA production. Male animals in T_2 exhibited the highest (P<0.05) total VFAs production. There was a significant difference in DM and OM digestibility between treatments; T_1 showed higher (P<0.05) DM and OM digestibility compared to that of T_2. The total VFA production did not change with time for T_1 while there is a significant change (P<0.05) for T_2. Male and female animals showed a significant increase in VFA production with time. This phenomenon was not exhibited by animals in T_1. The total VFA production plumates by 98% from day 26 to day 50 for T_2 (Figure 2). There is no significant difference (P>0.05) in VFA production between sexes. The sex of animals had no effect on pH values over time; however treatment diets significantly (P<0.05) influenced pH of rumen liquor over time. Animals in T_1 maintained rumen pH between 6.5 and 6.7 while animals in T_2 exhibited a significant (P<0.05) drop in pH from 6.6 to 5.6 over the fifty days of the experiment (Figure 3). Animals in T_2 exhibited a significant (P<0.05) drop in pH within the first fourteen days of the experiment

DISCUSSION

The DM and ash content observed in this study are within

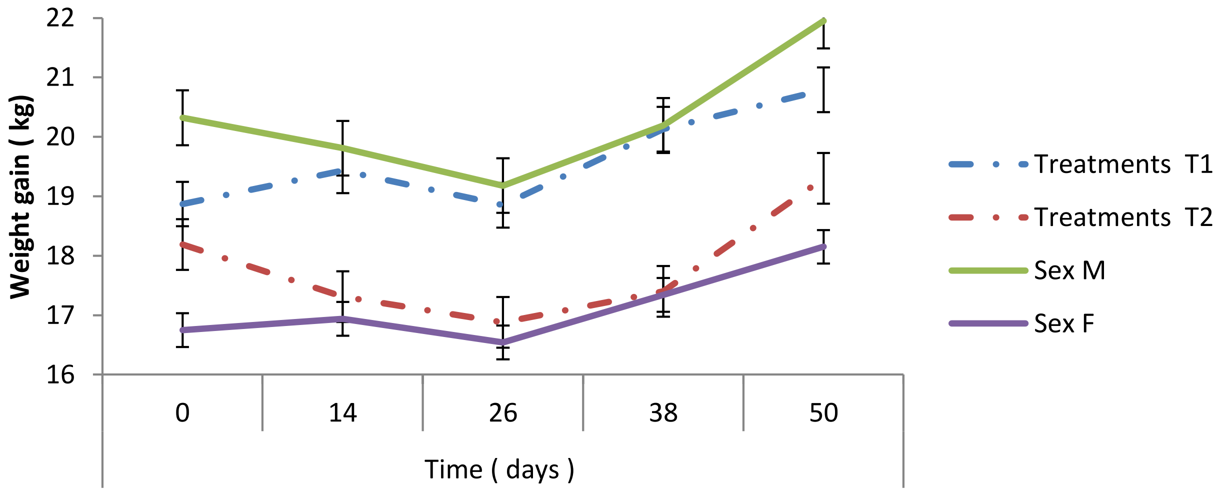

Figure 1. Changes in weight gain over time for Indigenous goats at Africa University; T_1; veld grass + 30% *L. leucocephala* T_2: 25% poultry manure plus 75% maize meal.

Table 3. *In- vitro* digestibility co-efficiencies of Indigenous goats on two treatment diets.

Proximate fraction	Treatments			Sex			P values		
	T_1	T_2	Se	M	F	Se	T	S	T x S
pH	6.51[a]	6.00[b]	0.002	6.25	6.25	0.002	0.001	0.999	0.999
IVDMD	84,90[a]	73.40[b]	2.469	nd	nd	1.493	0.002	-	
IVOMD	61.8[a]	48.6[b]	2.469	nd	nd	1.493	0.003	-	
Total VFAs	54.67[b]	77.05[a]	4.930	66.08[a]	65.64[b]	1.493	0.001	0.002	0.001

[ab] Row means with different subscripts are different at $P<0.05$; T_1; veld grass + 30% *L. leucocephala* T_2 : 25% poultry manure plus 75% maize meal, nd – not determined.

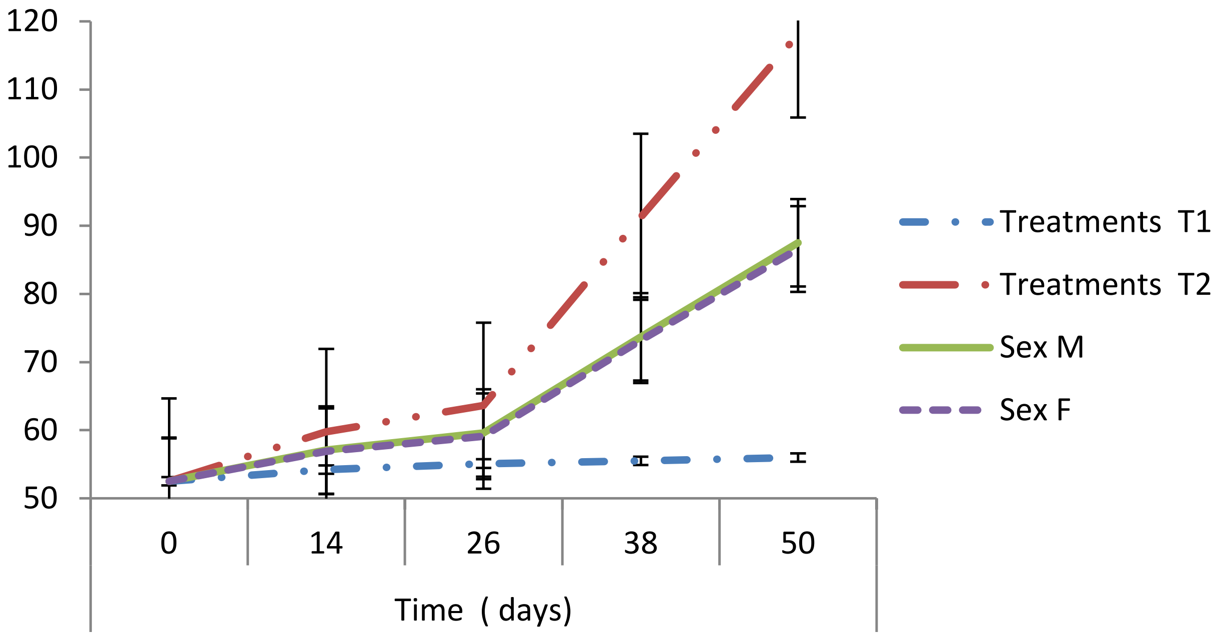

Figure 2. Total VFAs measured from rumen liquor of indigenous goats at Africa University.T_1; veld grass + 30% *L. leucocephala* T_2: 25% poultry manure plus 75% maize meal.

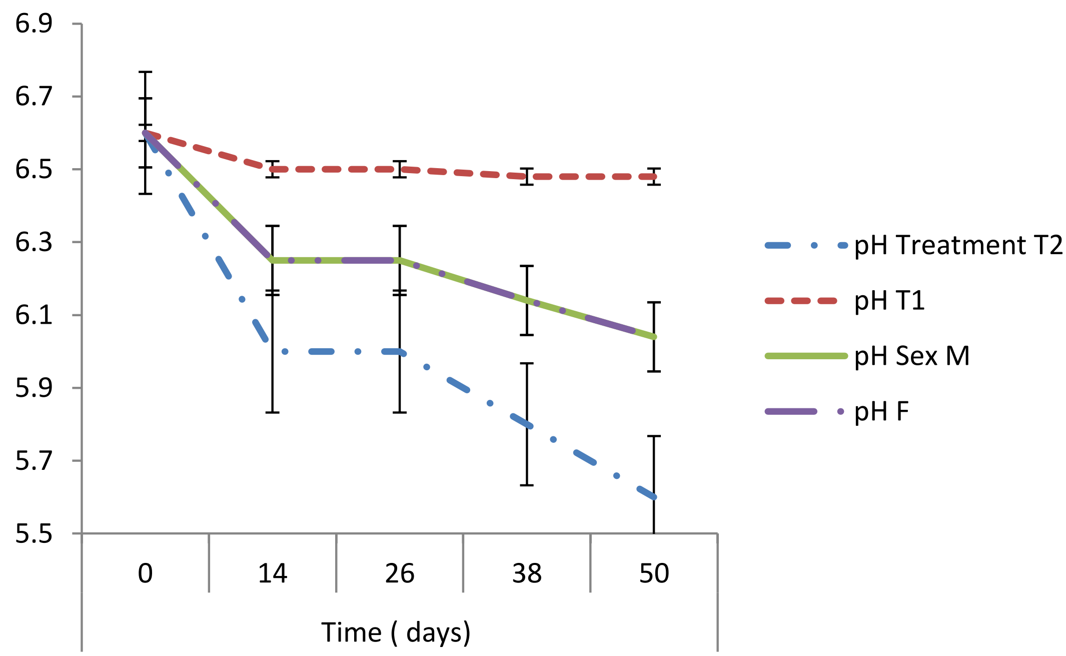

Figure 3. pH values measured from rumen liquor of indigenous goats at Africa University. T_1; veld grass + 30% *L. leucocephala* T_2: 25% poultry manure plus 75% maize meal.

the expected limits for normal rumen functions (NRC, 2007); however, the CP content of PM was quite low compared to results by Obeidat et al. (2011) and Ghaly and MacDonald (2012). This is however, acceptable as poultry manure has a wide variability in terms of its nutrient content (Azizi et al., 2016). Furthermore, Animut et al, (2002) and Alam et al. (2008) also identified that broiler litter is more nutritious compared to layer litter which was used in this study. Nevertheless the CP content is above the dietary requirement of 7.3 – 7.8 g/kgDM as reported by NRC, (2007) for goats. The NDF content of PM in the current study is considered adequate for ruminant animals although the ADF was quite low. This was also expected since poultry litter is low in energy (Nurfeta, 2010). The CF content obtained in this study is similar to the results obtained by Ghaly and MacDonald, (2012) and has been reported to be inadequate for ruminant animals (NRC, 2007). Irrespective of some deficiencies, Obeidat et al. (2011) suggest that poultry manure is a valuable ruminant feed relative to any other environmentally-friendly way of poultry manure disposal (Elemam et al., 2009. Feed intake was relatively low in the first two weeks of the trial but steadily increased with time until the last week of the experiment. This concurs with the observations made by Bello and Tsado, (2013), who reported that, feed intake increases with time for housed goats.

In another study by Elemam et al. (2009), DMI increased in lambs fed a diet containing 450 g/kg sun-dried poultry litter compared with those fed 0, 150 or 300 g/kg of poultry litter. This suggests that generally poultry manure does not influence DMI. The ADG and TG of goats under PM were low compared to grazing animals. This was not expected although it concurs with reports by Talib and Ahmed (2008); Abdel-Baset and Abbas, (2010) however, the major reason for this could be the effect of Star grass and *Luecaena leucocephala* browse species in which the goats had free access throughout the trial. Nevertheless the growth rates fall within the acceptable range as reported by Mirmohammadi et al. (2015) and NRC (2007).

Furthermore animals under T_2 showed a higher growth rate from day 38 to day 50 of 1.9 kg compared to 0.3 kg for T_1. This affirms the positive effect of poultry manure on the growth of goats. Ruminants usually require a balance of natural protein and non-protein nitrogen for both weight gain and feed intake (Baluch-Gharaei et al., 2015). The poor growth rate of the goats could have been attributed by an imbalance of natural proteins and non-protein nitrogen. Many rumen bacteria require specific amino acids to grow, which probably were not available in PM diet. Bacteria use peptides, amino acids and ammonia for their growth. Rumen microbes that ferment non-structural carbohydrates obtain two thirds of nitrogen from dietary amino acids or peptides whilst fibre digesting bacteria derive all their nitrogen from ammonia. Uric acid is the principle nitrogen (N) component of poultry excreta which degrades more slowly than urea (Abdel-Baset and Abbas, 2010) creating a favourable ammonia pattern for efficient utilization in ruminants. If in excess higher concentrations of ammonia limit the growth of cellulolytic microorganisms and reduce rumen fibre digestion and hence microbial protein production (Santra and Karim, 2003; McDonald et al., 2011).

The gradual decline in pH for T_2 animals was expected. This is also in line with earlier conclusions made by Xie et al. (2015) and Calsmiglia et al. (2002) who concluded that feeding ruminants with concentrate diets reduces ruminal pH. In the current study as pH declines, the total amount of VFA in the undissociated state increases. This was also reported by Gäbel et al. (2002). Hence, a reduction in pH would increase the proportion of undissociated VFA that could be found in the rumen fluid. A pH between 5 and 6 has been purported to best suit VFA production in ruminants (NRC, 2007); close to neutral pH values promote production of more butyrate than acetate and propionate. In contrast pH values below 5.8 have been reported to reduce fibre and nutrient digestibility in goats by Calsamiglia et al, (2002) and Beauchemin et al. (2003) and pH of 5.6 has been reported, a threshold for acidosis (Cummins et al., 2009) of which animals in the current study maintained an average pH above this threshold. Furthermore this has significantly affected the total VFA production, with close to 98% more VFA being produced in this study. The pH of rumen liquor is negatively related to the amount of VFAs produced; this is attributed to the fact that high energy diets are quickly fermented hence produce high levels of lactic acid which lowers rumen pH as described earlier on by Sutton et al. (2003). It is well established in literature (Carro et al., 2000; Cummins et al., 2009) that a low pH decreases the acetate: propionate ratio. This is preferred because propionate acts a hydrogen sink in ruminants and reduces the loss of energy in the form of either methane or carbon dioxide (Washaya et al., 2017).

Conclusion

Based on the findings of the present study it can be concluded that DPM can be used as a protein source; however its effects on growth are marginal. The DPM contained adequate DM, CP, and NDF for goat production while the ash and ADF contents were limiting. DPM had a positive effect on pH and total VFA production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdel-Baset NS, Abbas SF (2010). Study on the use of dried poultry litter in the Camel's ration. Veterinary Research Forum 1(2):65-71.

Ajayi FT, Omotoso SO, Dauda TO (2016). Performance and nutrient digestibility of West African Dwarf goats fed corncob-poultry dropping silage. The Pacific Journal of Science and Technology 17:278- 287.

Alam MS, Khan MJ, Akbar MA, Kamruzzaman M (2008). Broiler litter and layer manure in the diet of growing bull calves. Bangladesh Veterinarian 25:62-67.

Animut G, Merkel GRC, Abebe G, Sahlu T, Goetsch AL (2002). Effects of level of broiler litter in diets containing wheat straw on performance of Alpine doelings. Small Ruminant Research 44:125-134.

Association of the Official Analytical Chemists (AOAC) (2005). Official Methods of Analysis of AOAC International (17th ed.). Association of the Official Analytical Chemists. Gaithersburg. MD: USA.

Azizi A, Sharifi A, Azarfar A, Kiani A, Jolazadeh A (2016). Performance and ruminal parameters of fattening Moghani lambs fed recycled poultry bedding. Animal Nutrition Journal 2:1-19.

Baluch-Gharaei H, Rouzbehan Y, Fazaeli H, Rezaei J (2015). Effect of deep-stacking broiler litter on pathogenic bacteria, intake, digestibility, microbial protein supply and rumen parameters in sheep. Animal Feed Science and Technology 199:73-83.

Beauchemin KA, Yang WZ, Rode LM (2003). Effects of particle size of alfalfa-based dairy cow diets on chewing activity, ruminal fermentation, and milk production. Journal of Dairy Science 86:630-643.

Bello AA, Tsado DN (2013). Feed intake and nutrient digestibility of growing Yankasa rams fed sorghum stover supplemented with graded levels of dried poultry droppings based diets. Asian Journal of Animal Science 7:56-63.

Calsamiglia S, Ferret A, Devant M (2002). Effects of pH and pH fluctuations on microbial fermentation and nutrient flow from a dual-flow continuous culture system. Journal of Dairy Science 85:574-579.

Cummins B, Kiely PO, Keane MG, Kenny DA (2009). Feed intake pattern, behaviour, rumen characteristics and blood metabolites of finishing beef steers offered total mixed rations constituted at feeding or ensiling. Irish Journal of Agricultural and Food Research 48:57-73.

Carro MD, Valdés C, Ranilla MJ, González JS (2000). Effect of forage to concentrate ratio in the diet on ruminal fermentation and digesta flow kinetics in sheep offered food at a fixed and restricted level of intake. Animal Science 70:127-134.

Elemam MB, Fadelelseed AM, Salih AM (2009). Growth performance, digestibility, N-balance and rumen fermentation of lambs fed different levels of deep-stack broiler litter. Research Journal of Animal and Veterinary Science 4:9-16

Food and Agriculture Organization (FAO) (2010). Agricultural Handbook: Poultry Meat and Eggs. (1st ed). FAO Investment Centre Division, Rome: Italy.

Gäbel G, Aschenbach JR, Müller F (2002). Transfer of energy substrates across the ruminal epithelium: implications and limitations. Animal Health Research Reviews 3:15-30.

Ghaly AE, MacDonald KN. (2012). Drying of poultry manure for use as animal feed. American Journal of Agricultural and Biological Sciences 7:239-254

Goering HK, Van Soet PJ (1970). Forage Fibre Analysis. Agricultural Handbook ARS: USA. pp. 1-20.

McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA, Sinclair LA, Wilkinson RG (2011). Animal Nutrition. (7th ed.). Pearson Education limited, England.

Meissner HH, Scholtz MM, Palmer AR (2013). Sustainability of the South African Livestock Sector towards 2050. Worth and impact of the sector. South African Journal of Animal Science 43:282-297.

Mirmohammadi D, Rouzbehan Y, Fazaeli H (2015). The effect of the inclusion of recycled poultry bedding and the physical form of diet on the performance, ruminal fermentation, and plasma metabolites of fattening lambs. Journal of Animal Science 93:3843-3853.

Mpofu IDT (2006). Determination of volatile fatty acids, Agricultural Biochemistry, Department of Animal Science, University of Zimbabwe. Harare. Zimbabwe.

Nadeem MA, Ali A, Azim A, Khan AG (1993). Effect of feeding broiler litter on growth and nutrient utilisation by Barbari goats. Asian Journal of Animal Science 6:73-77.

National Research Council (NRC) (2007). Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids and New World Camelids. National Academy Press, Washington DC: USA.

Nurfeta A (2010). Feed intake, digestibility, nitrogen utilization, and body weight change of sheep consuming wheat straw supplemented with local agricultural and agro-industrial by products. Tropical Animal Health and Production 42:815-824.

Obeidat BS, Awawdeh MS, Abdullah AY, Muwalla MM, Ishmais MA, Telfah BT (2011). Effect of feeding broiler litter on performance of Awassi lambs fed finishing diets. Animal Feed Science and Technology 165:15-22.

Reddy PB, Reddy TJ, Reddy YR (2012). Growth and nutrient utilization in ids fed expander-extruded complete feed pellets containing Red Gram (*Cajanus cajan*) straw. Asian-Australian Journal of Animal Science 25:1721-1725.

Santra A, Karim SA (2003). Rumen manipulation to improve animal productivity. Asian Australian Journal of Animal Science 16:748-763.

SAS (2013). Users Guide: Statistics. Version 9.3. SAS Institute, Cary, NC: USA.

Sutton JD, Dhanoa MS, Morant SV, France J, Napper DJ, Schuller E (2003). Rates of production of acetate, propionate, and butyrate in the rumen of lactating dairy cows given normal and low-roughage diets. Journal of Dairy Science 86:3620-3633.

Talib NH, Ahmed FA (2008). Performance and carcass characteristics of intact Zebu bulls fed different levels of deep stacked poultry litter. Journal of Animal and Veterinary Advances 7:1467-1473.

Tilley JMA, Terry RA (1963). A two-stage technique for the in vitro digestion of forage crops. Journal of British Grassland Society 18:104-111.

Washaya S, Mupangwa JF, Muchenje V (2017). Chemical composition of *Lablab purpureus* and *Vigna unguiculata* and their subsequent effects on methane production in Xhosa goats. South African Journal of Animal Science 48(3):445-458.

Xie Z, Jiang X, Ye P, Zhang Y, Ni Y, Zhuang S, Shen X (2015). Relationship between liver and low rumen pH in goat. Genetics and Molecular Research 14:209-221.