

# Assessment of Stovers of Dual-Purpose Pearl Millet Varieties as Feed for Goats in the West African Sahel

Clarisse Umutoni<sup>1\*</sup>, Vincent Bado<sup>1</sup>, Anthony Whitbread<sup>2</sup> and Augustine Ayantunde<sup>3</sup>

<sup>1</sup>The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), P O Box 12404 Niamey, NIGER

<sup>2</sup>The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), C/O- IITA East Africa Hub, Dar es Salaam, TANZANIA

<sup>3</sup>International Livestock Research Institute (ILRI), Ouagadougou, BURKINA FASO

\*Corresponding Author: [c.umutoni@cgiar.org](mailto:c.umutoni@cgiar.org)

## How to cite this paper:

Umutoni, C., Bado, V., Whitbread, A., & Ayantunde, A. (2021). Assessment of Stovers of Dual-Purpose Pearl Millet Varieties as Feed for Goats in the West African Sahel. *International Journal of Livestock Research*, 11(12), 37-43. <https://dx.doi.org/10.5455/ijlr.20210712082123>

**Received** : Jul 12, 2021

**Accepted** : Oct 13, 2021

**Published** : Dec 31, 2021

Copyright © Umutoni *et al.*, 2021

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0). <http://creativecommons.org/licenses/by/4.0/>



## Abstract

*The purpose of this study was to assess the chemical composition of dual-purpose pearl millet stover and to evaluate its effects on the productive performance of goats. Thirty-six goats aged 18 – 24 months, with an average initial live weight of 23.8 kg, were randomly assigned to six treatments, defined by the type of variety of pearl millet stover fed as basal diet. In each treatment, goats were fed ad libitum for 90 days with the pearl millet stover complemented with cowpea hay (600 g/day/individual). There were significant variations in the crude protein and neutral detergent fiber contents of stover of the pearl millet varieties. The animals fed Chakti and ICMV167005 had the highest average daily live weight gains, compared with the other treatments ( $p = 0.07$ ). Daily fecal output (wet basis) ranged from 666 – 751 g/day/goat. These results indicate that Chakti and ICMV167005 stover varieties may be suitable goat feeds.*

**Keywords:** Crop-Livestock System, Dry Matter Intake, Fecal Output, Growth Performance, Pearl Millet Stover, Weight Gain

## Introduction

Crop residues are becoming a dominant alternative feed resource for ruminants during the dry season in the West African Sahel. The reliance on crop residues to sustain ruminants, however, can be problematic due to their limited availability and low nutritive value. Nevertheless, many studies (Ayantunde *et al.*, 2007; Etala and Dung, 2011; Ansah *et al.*, 2017) have shown scope to improve ruminant livestock production by utilizing crop residues, when appropriate feeding strategies are applied.

Generally, in the West African Sahel, crop residues mainly originate from cereals such as millet and sorghum stover and from legumes, such as cowpea and groundnut haulms. Due to the importance of pearl millet crops in the Sahel, pearl millet stover is widely available and mainly used for feeding ruminants. However, while it has a relatively poor nutritive value (N concentration 0.46–0.84%; digestibility: 39–42%; Nantoumé *et al.*, 2000; Blümmel *et al.*, 2007), it is commonly considered a basal diet among ruminant feeds, especially when other feeds are unavailable towards the end of the dry season. Given the importance of pearl millet stover as a ruminant feed, research by millet improvement programs on dual-purpose varieties to increase their grain and feed quality is ongoing. However, besides that provided by Hiernaux and Ayantunde (2004), Fernandez-Rivera *et al.* (2005), and Abdou *et al.* (2011), reliable information on millet stover as a ruminant feed, and especially as a goat feed, is currently lacking. Varieties of stover that provide optimal gains must be investigated further. We hypothesized that the production performance of goats is influenced by the variety of pearl millet stover used as a basal feed in the goats' diet. The objective was to assess the chemical composition of six stover pearl millet varieties, and to evaluate the effects of pearl millet stover on feed intake, growth, and fecal output in goats.

## Materials and Methods

### Description of the Study Area

The experiment was conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) research station at Sadoré (13°14'N, 2°16'E), Niger. The climate of Sadoré has a unimodal rainfall pattern that begins in late June and ends in early October. The dry season extends from November to late May, with a period of warm dry conditions from March to May. The mean annual rainfall is 562 mm, and temperatures generally range from 12 to 44 °C, with a mean temperature of 29.4 °C.

### Animals

Thirty-six male Sahel goats that were 18–24 months of age, with an average initial live weight of  $23.8 \pm 0.29$  kg ( $p > 0.001$ ), were used. The goats were acquired locally at a livestock market. The animals were housed indoors in individual cages for the entire experimental period. Animals were ear tagged and randomly assigned to six treatments, with six replications per treatment (i.e., six goats per treatment). All animals were de-wormed and vaccinated against three common small ruminant diseases in the study area, namely, Pasteurellosis, small ruminant plague, and sheep and goat pox. In addition, at the beginning of the experiment, the animals received multivitamins ALFASAN (5 mL/goat).

### Feeding Treatments

The experiment was conducted during the dry season (January to April 2020) for 76 days, which were preceded by a 14-day period of adjustment to the environment, management, and diets. The goats were fed stover residues from pearl millet (Chakti, ICMV167005, ICMV167006, ICMV167111, ICMV167002 and the local landrace - Somno) as basal diet. Cowpea hay (variety TN578) was provided to complement the diet. Six treatments corresponding to the six varieties of stover were defined (T0 = stover of local variety + cowpea hay; T1 = stover of Chakti + cowpea hay; T2 = stover of ICMV167005 + cowpea hay, T3 = stover of ICMV167006 + cowpea hay; T4 = stover of ICMV167111 + cowpea hay; T5 = stover of ICMV167002 + cowpea hay).

Stover residues were manually cut using a machete into approximately 5 cm pieces to increase intake and were offered to the goats *ad libitum* (approximately 200% of the fresh intake of the previous day). Stover was supplied twice daily (at 8:00 am and 4:00 pm), and cowpea hay was distributed separately in the afternoon (at approximately 1:00 pm). All animals received the same amount of cowpea hay, approximately 600 g/animal/day, and the portions

were completely consumed with no leftovers recorded during the experiment. Clean drinking water and mineral licks (Intromin block) were provided *ad libitum* to each animal throughout the experiment.

### Data Collection and Sampling

The animals were weighed on the first day of the experiment (day 15), after the adaptation period, and thereafter in the morning for three consecutive days at two-week intervals. To determine total weight gain, the animals were also weighed on the last day of the experiment (day 91).

Pearl millet stover and fecal data were collected over two seven-day periods. The first period commenced after two weeks of adjustment to the feed, and the second started during the 8<sup>th</sup> week of the experiment. Pearl millet stover offered to each goat was weighed individually every morning at 8:00 am before offering to the animal. The leftovers were quantified and removed after 24 hours to determine the individual intake. Daily feed samples were collected to obtain pooled samples for each animal for each data collection period. All samples were ground through 1 mm screens for laboratory analysis.

Feces were collected directly from the animals' rectum twice daily and were weighted before goats were fed. Each goat was fitted with a fecal collection bag three days before each collection period. During the collection period, the bags were removed two times per day, in the morning at 7:00 am and again in the evening at 5:00 pm to collect fresh feces. Fresh feces were immediately weighed after harvesting. A composite sample of 100 g per goat of fecal material was removed, packed in a labeled bag, and was sun-dried for seven days to estimate the quantity of dry fecal matter. At the end of the experiment, daily dried fecal samples from each goat were pooled and were ground for chemical analyses.

### Laboratory Analyses

Feed samples were analyzed using near infrared reflectance spectroscopy (NIRS; Corson *et al.*, 1999; Bidinger and Blümmel, 2007) for dry matter (DM), total nitrogen (N) content, neutral detergent fiber (NDF). Crude protein (CP) was estimated from the N content ( $N \% \times 6.25$ ). Fecal samples were analyzed for DM, Organic Matter (OM), C, N and P.

### Evaluation of Intake and Performance

Daily voluntary feed intake was determined as the difference between the amount of feed offered per day and the amount refused. The average daily gain (ADG) was estimated by dividing the total weight gain (TWG) of each animal by the duration of the experiment ( $ADG = TWG (g) / 76 \text{ days}$ ). The feed conversion ratio (FCR) was estimated as the daily feed DM intake divided by the daily weight gain of each animal.

### Statistical Analyses

Data analysis was performed using Genstat 20 software (VSN International, UK). Treatment effects were assessed using an analysis of variance. Bonferroni tests were used to compare treatment means. Unless otherwise specified, statistical significance is reported at  $p < 0.05$ .

The variability in the results recorded for the measured variables (weight gain, fecal output, and nutrients in the feces) was attributed to the variability of the stover among the different pearl millet varieties, as all animals received the same amount of cowpea hay every day, which was completely consumed; thus, this part of the daily feed (cowpea hay) was considered invariable.

## Results and Discussion

### CP and NDF Composition of Pearl Millet Stover

There were significant variations among the pearl millet varieties for stover CP and NDF ( $p = 0.035$  and  $0.023$  for CP and NDF, respectively). CP was highest in Chakti (5.63%) and lowest in ICMV167111\_Hybrid (3.31%), while NDF was highest in ICMV167111 and lowest in Chakti (Table 1).

**Table 1:** DM, CP and NDF of the different pearl millet stover varieties and cowpea hay used in the feeding experiment at Sadoré

Parameter	Pearl Millet Stover Varieties							Cowpea	
	Somno	Chakti	ICMV	ICMV	ICMV	ICMV	SEM	p-Value	Cowpea Hay
			167005	167006	167111 (Hybrid)	167002			
DM (%)	92.91 <sup>a</sup>	92.91 <sup>a</sup>	92.86 <sup>a</sup>	92.65 <sup>a</sup>	92.95 <sup>a</sup>	92.61 <sup>a</sup>	0.193	0.421	90.74
CP (%)	4.63 <sup>ab</sup>	5.63 <sup>c</sup>	4.75 <sup>ab</sup>	3.94 <sup>b</sup>	3.31 <sup>a</sup>	4.81 <sup>ab</sup>	0.488	0.035	14.38
NDF (%)	78.16 <sup>ab</sup>	74.98 <sup>a</sup>	76.38 <sup>ab</sup>	77.21 <sup>ab</sup>	79.13 <sup>b</sup>	77.46 <sup>ab</sup>	0.817	0.023	46.93

CP= Crude protein, DM=Dry matter, NDF = Neutral detergent fiber, SEM= Standard error of means. Means with different superscripts in each row are significantly different at  $p < 0.05$ ; values presented are means ( $n = 12$ )

The observed variations in CP and NDF content in stover from different pearl millet varieties was mainly due to genetic variability and growth duration. Madibela and Modiakgotla (2004) and Blümmel *et al.* (2007) also found variations in chemical composition of stover of different pearl millet varieties. Blümmel *et al.* (2007) reported CP concentrations of 4.94–5.81%, while Madibela and Modiakgotla (2004) found NDF values of 68.9%, 70.1%, and 72.6% for three different varieties. The highest CP concentration was found in Chakti, which may be an indication of its high nutritional value, thus explaining the advantage in growth performance for goats fed this variety.

The CP concentration values reported in this study were lower than those reported by Madibela and Modiakgotla (2004), as they reported CP concentrations of 7.63–7.94%. However, the concentrations observed in the current study were within the range reported in other studies for pearl millet varieties grown in arid and semi-arid cropping regions of Africa and India (Blümmel *et al.*, 2007; Blümmel *et al.*, 2010; Abdou *et al.*, 2011). Furthermore, these values were lower than those of wheat and sorghum as reported by Tan *et al.* (1995) and Fadel Elseed *et al.* (2007) but higher than those in other cereals such as maize and rice (Singh *et al.*, 1977; Vadiveloo, 2000; Korlagama *et al.*, 2008).

The NDF values in the stover were all higher than those reported by Singh *et al.* (1977; 67.9%) and Madibela and Modiakgotla (2004; 70.1–72.6%), but lower than those reported by Abdou *et al.* (2011; 53.2%).

### Feed Dry Matter Intake and Live Weight Gain

Overall daily DM intake ranged from 723 to 789 g, and stover intake by goat ranged from 181 to 244 g/day/animal; and there were significant differences in stover intake among varieties (Table 2). This may suggest that concentrations of structural carbohydrates in stover affected voluntary intake. The high daily stover intake recorded in goats fed ICMV167111 and Chakti indicates higher digestibility.

**Table 2:** Feed intake for the goats fed the stover of the local or five dual-purpose millet varieties and the cowpea hay

Parameter	Pearl Millet Stover Varieties							Cowpea	
	Somno	Chakti	ICMV	ICMV	ICMV	ICMV	SEM	p-Value	Cowpea hay
			167005	167006	167111 (Hybrid)	167002			
<b>DM Intake (g/goat/day)</b>									
Leaves	199.13 <sup>b</sup>	214.06 <sup>b</sup>	189.10 <sup>ab</sup>	156.31 <sup>a</sup>	210.59 <sup>b</sup>	186.42 <sup>ab</sup>	11.99	<.001	-
Stems	30.62 <sup>ab</sup>	25.92 <sup>ab</sup>	27.84 <sup>ab</sup>	24.14 <sup>a</sup>	34.91 <sup>b</sup>	30.28 <sup>ab</sup>	3.33	0.043	-
Total DM stover intake	229.01 <sup>b</sup>	239.84 <sup>b</sup>	215.92 <sup>ab</sup>	179.42 <sup>a</sup>	244.87 <sup>b</sup>	215.42 <sup>ab</sup>	13	<.001	544.44
DM stover intake g/ kg-1 BW	9.14 <sup>b</sup>	9.27 <sup>b</sup>	8.43 <sup>ab</sup>	6.98 <sup>a</sup>	9.66 <sup>b</sup>	8.52 <sup>b</sup>	0.454	<.001	-
Total feed DM intake	773.49 <sup>b</sup>	784.27 <sup>b</sup>	760.35 <sup>ab</sup>	723.85 <sup>a</sup>	789.25 <sup>b</sup>	759.85 <sup>ab</sup>	13	<.001	-

BW= Body weight, DM= Dry matter, SEM: standard error of mean. Means with different superscripts in each row are significantly different at  $p < 0.05$

Growth performances are presented in Table 3. The average daily liveweight gains were significantly different at the 10% level among treatments ( $p = 0.07$ ). Goats fed the Chakti (T1) and ICMV167005 (T2) stovers had the highest ADG, compared with those fed ICMV167006 (T3), ICMV167111 (T4), ICMV167002 (T5), and Somno (T0). The higher LWG observed in goats fed Chakti and ICMV167005 stover was a consequence of the higher CP and digestibility. Normally, animal performance and production efficiency are affected by feed digestibility, both of which are positively correlated with feed intake and quality (Peripolli *et al.*, 2011).

**Table 3:** Growth performance, daily fecal output, and characteristics of goats feces fed pearl millet stover as a basal diet supplemented with cowpea hay

Parameters	Pearl millet stover varieties +cowpea hay						SEM	P-Value
	Somno	Chakti + CH	ICMV	ICMV	ICMV	ICMV		
	+ CH		167005 + CH	167006+CH	167111 + CH	167002 + CH		
<b>Live weight gain</b>								
Initial weight (kg)	23.40 <sup>a</sup>	23.55 <sup>a</sup>	23.14 <sup>a</sup>	24.05 <sup>a</sup>	24.06 <sup>a</sup>	24.31 <sup>a</sup>	1.071	0.876
Final weight (kg)	26.10 <sup>a</sup>	27.10 <sup>a</sup>	27.04 <sup>a</sup>	26.52 <sup>a</sup>	26.47 <sup>a</sup>	26.21 <sup>a</sup>	1.044	0.902
Weight gain (kg)	2.60 <sup>ab</sup>	3.74 <sup>b</sup>	3.64 <sup>b</sup>	2.45 <sup>ab</sup>	2.15 <sup>a</sup>	1.82 <sup>a</sup>	0.714	0.042
Daily weight gain (g)	28.89 <sup>ab</sup>	40.74 <sup>b</sup>	40.44 <sup>b</sup>	27.22 <sup>ab</sup>	23.89 <sup>a</sup>	20.19 <sup>a</sup>	7.931	0.042
Feed Conversion Ratio	32.37 <sup>b</sup>	20.35 <sup>a</sup>	20.34 <sup>a</sup>	26.75 <sup>ab</sup>	44.13 <sup>c</sup>	51.66 <sup>c</sup>	10.46	0.023
<b>Feces output /(g/animal/day)</b>								
Fresh feces (wet)	713.60 <sup>a</sup>	743.10 <sup>a</sup>	751.30 <sup>a</sup>	666.70 <sup>a</sup>	768.30 <sup>a</sup>	703.20 <sup>a</sup>	46.4	0.299
Dry feces (dung)	319.00 <sup>a</sup>	330.60 <sup>a</sup>	325.30 <sup>a</sup>	303.30 <sup>a</sup>	334.80 <sup>a</sup>	319.10 <sup>a</sup>	15.22	0.4
Fecal DM output	80.90 <sup>a</sup>	84.90 <sup>a</sup>	87.50 <sup>a</sup>	75.80 <sup>a</sup>	84.60 <sup>a</sup>	85.00 <sup>a</sup>	6.45	0.538
<b>Feces composition</b>								
OM (%)	78.37 <sup>ab</sup>	80.71 <sup>b</sup>	78.46 <sup>ab</sup>	78.23 <sup>ab</sup>	77.21 <sup>a</sup>	77.18 <sup>a</sup>	0.86	0.004
Carbon (%)	45.57 <sup>ab</sup>	46.93 <sup>b</sup>	45.62 <sup>ab</sup>	45.48 <sup>ab</sup>	44.89 <sup>a</sup>	44.87 <sup>a</sup>	0.5	0.004
Nitrogen (%)	2.96 <sup>a</sup>	2.95 <sup>a</sup>	3.04 <sup>a</sup>	3.00 <sup>a</sup>	3.03 <sup>a</sup>	2.99 <sup>a</sup>	0.044	0.4
Carbon: Nitrogen	15.40 <sup>ab</sup>	15.88 <sup>b</sup>	15.06 <sup>a</sup>	15.12 <sup>ab</sup>	14.85 <sup>a</sup>	15.01 <sup>a</sup>	0.252	0.004
Phosphorus (%)	0.42 <sup>a</sup>	0.44 <sup>a</sup>	0.43 <sup>a</sup>	0.48 <sup>a</sup>	0.45 <sup>a</sup>	0.44 <sup>a</sup>	0.022	0.283

CH= Cowpea hay, DM= Dry matter, OM= Organic matter, SEM= Standard error of mean. Means with different superscripts in each row are significantly different at  $p < 0.05$

The lower LWG observed in goats fed ICMV167002 stover may be an indicator of a lower rate of nutrient utilization from the residues of this variety and of its lower digestibility. This suggests that ICMV167002 may be used as fodder in combination with supplements of higher nutritional value. Indeed, several studies reported the benefits of complementing cereal stover with cowpea hay or groundnut haulm (Ayantunde *et al.*, 2007; Abdou *et al.*, 2011; Etela and Dung, 2011; Ansah *et al.*, 2017).

Treatment type significantly influenced FCR, with FCR values ranging from 20.3 to 51.7 and the highest FCR values in goats fed ICMV167002 (T3) stover and the lowest in the Chakti (T1) and ICMV167005 (T2) treatments. Lower FCR indicates more efficient conversion of ingested feed to body mass, while a high FCR suggests that animals do not efficiently utilize the ingested feed. In fact, the high FCR in goats fed ICMV167002 stover may be attributed to its low nutritive value, which means that the goats need to ingest more feed to meet their requirements. The low FCR in goats fed Chakti and ICMV167005 stover might explain their highest weight gain.

### Fecal Output and Characteristics of Feces

Fresh fecal output ranged from 666 to 751 g/animal/day with no significant differences among varieties (Table 3). Likewise, there were no differences among varieties regarding DM fecal output. Fecal output was higher in the current study than that observed by Ansah *et al.* (2019) in Ghana. The proportion of N excreted in the feces ranged from 2.9–3%, whereas that of P ranged from 0.42–0.48% (Table 3). There was a negative linear correlation ( $p < 0.001$ ;  $R^2 = 38.9$ ) between pearl millet stover intake and fecal P excretion. In contrast, there was no relationship between fecal N content and stover intake. Carbon content and C:N ratios of goat feces were higher in goats fed Chakti (T1) stover than in goats of the other treatments.

The characteristics of feces indicated that pearl millet stover affected the proportion of carbon and the C:N ratios. Stover varieties, however, did not affect the proportion of N and P in feces; this might indicate that the level of N and P assimilation is not affected by pearl millet varieties. The range of total N and C in goat feces was larger than observed by Moral *et al.* (2005) and Ansah *et al.* (2019). The C:N ratio in feces was below 20%, which indicates a potential or likely net N mineralization if applied directly to soil. This is considered an important additional benefit of using feces from goats as a soil amendment. High quality manure has been defined as containing more than 1.6% N or with a C:N ratio less than 10, while low-quality feces contain less than 0.6% N and have a C:N ratio higher than 17 (Bationo *et al.*, 2004). A general remark from this study is that even though all C:N ratios were higher than 10, they were all below 17 and below the critical level of 20 as reported by Saha *et al.* (2008), and the N content was higher than 1.6%, indicating the quality of manure. From our results, it was estimated that a goat of an average weight of 23 kg may produce as much as 117.53 kg feces per year, which could be considered a potential input contribution for soil fertility in crop-livestock systems.

## Conclusion

This study demonstrated that stover of the Chakti and ICMV167005 pearl millet varieties have higher CP and lower NDF. The stover of the two varieties increased the final weight and daily weight gain of goats. When supplemented with cowpea hay, they showed a low FCR, which suggested efficient conversion of the ingested feed to body mass. Based on productive performance, we recommend that the Chakti and ICMV167005 dual-purpose pearl millet varieties should be introduced into crop-livestock farming to improve goat productivity and soil fertility in the West African Sahel. Furthermore, it was concluded that not all so-called "*improved dual-purpose pearl millet varieties*" show improved performance when compared with the local landraces used by the farmers in the region.

## Acknowledgments

This research was funded by the United States Agency for International Development (USAID) via the Feed the Future Innovation Lab on Livestock Systems program [PTE Federal Award No: AID-OM-L-15-00003] and the CGIAR research program, Grain Legumes and Dryland Cereals, conducted with support from the CGIAR Trust Fund and through bilateral funding agreements. The funders did not influence the design of the study, the collection, analysis, or interpretation of data, the writing of the article, or the decision to submit the article for publication

## Conflict of Interests

There is no conflict of interest.

## Publisher Disclaimer

IJLR remains neutral concerning jurisdictional claims in published institutional affiliation.

## References

1. Abdou, N., Nsahlai, I.V. and Chimonyo, M. (2011). Effects of groundnut haulms supplementation on millet stover intake, digestibility and growth performance of lambs. *Animal Feed Science and Technology*, 160 (3-4), 176-184.
2. Ansah, K.O., Antwi, C., Osafo, E.L.K., Enning, S. and Adu-dapaah, H. (2019). Manure characteristics of small ruminants fed agrobyproducts in the guinea savannah agro-ecological zone of Ghana. *The Ghana Journal of Agricultural Science*, 54 (1), 67-76.
3. Ansah, T., Zanamongo, I.Y. and Nurudeen, A.R. (2017). Growth performance and hematology of Djallonké rams fed haulms of four varieties of groundnut (*Arachis hypogaea* L.). *Animal Nutrition*, 3 (4), 406-410.
4. Ayantunde, A.A., Delfosse, P., Fernandez-Rivera, S., Gerard, B. and Dan-Gomma, A. (2007). Supplementation with groundnut haulms for sheep fattening in the West African Sahel. *Tropical Animal Health and Production*, 39, 207-216.
5. Bationo, A., Nandwa, S.M., Kimetu, J.M., Kinyangi, J.M., Bado, B.V., Lompo, F., Kimani, S., Kihanda, F. and Koala, S. (2004). Sustainable intensification of crop-livestock systems through manure management in eastern and western Africa: lessons learned and emerging research opportunities. In: Proceedings of the International Conference on Sustainable Crop-livestock Production for Improved Livelihoods and Natural

- Resource Management in West Africa (Eds. TO Williams, S Tarawali, P Hiernaux and S Fernandez- Rivera). Addis Ababa, Ethiopia: International Livestock Research Institute (ILRI). pp.173-198.
6. Bidinger, F.R. and Blümmel, M. (2007). Determinants of ruminant nutritional quality of pearl millet [*Pennisetum glaucum* (L.) R. Br.] stover: I. Effects of management alternatives on stover quality and productivity. *Field Crops Research*, 103 (2), 119-128.
  7. Blümmel, M., Bidinger, F.R. and Hash, C.T. (2007). Management and cultivar effects on ruminant nutritional quality of pearl millet (*Pennisetum glaucum* (L.) R.Br.) stover: II. Effects of cultivar choice on stover quality and productivity. *Field Crops Research*, 103 (2), 129-139.
  8. Blümmel, M., Khan, A. A., Vadez, V., Hash, C.T. and Rai, K.N. (2010). Variability in stover quality traits in commercial hybrids of pearl millet (*Pennisetum glaucum* (L.) R. Br.) and grain-stover trait relationships. *Animal Feed Science and Technology*, 10, 29-38.
  9. Corson, D.C., Waghorn, G.C., Ulyat, M.J. and Lee, J. (1999). NIRS: Forage analysis and livestock feeding. *Proceedings of the New Zealand Grassland Association*, 61, 127–132.
  10. Etela, I. and Dung, D.D. (2011). Utilization of stover from six improved dual-purpose groundnuts (*Arachis hypogaea* l.) cultivars by west African dwarf sheep. *The African Journal of Food, Agriculture, Nutrition and Development*, 11 (1), 4538-4545.
  11. Fadel Elseed, A.M.A., Nor Eldaim Niemat, I. and Amasaib, E.O. (2007). Chemical composition and in situ dry matter degradability of stover fractions of five sorghum varieties. *Research Journal of Applied Sciences*, 3 (10), 1141-1145.
  12. Fernandez-Rivera, S., Hiernaux, P., Williams, T.O., Turner, M.D., Schlecht, E., Salla, A., Ayantunde, A.A. and Sangare, M. (2005). Nutritional constraints to grazing ruminants in the millet-cowpea livestock farming system of the Sahel. In: Coping with feed scarcity in smallholder livestock systems in developing countries (Eds. A.A. Ayantunde, S. Fernández Rivera and G. McCrabb). Nairobi, Kenya: International Livestock Research Institute (ILRI). pp.157- 182.
  13. Hiernaux, P. and Ayantunde, A.A. (2004). *The Fakara: a semi-arid agro-ecosystem under Stress. Report of research activities, first phase of the Desert Margins Programme* (Research Report, the International Crops Research Institute for the Semi-Arid Tropics). Retrieved from [https://www.jircas.affrc.go.jp/project/africa\\_dojo/Metadata/grad\\_research/15.pdf](https://www.jircas.affrc.go.jp/project/africa_dojo/Metadata/grad_research/15.pdf).
  14. Koralagama, K.D.N., Mould, F.L., Fernandez-Rivera, S. and Hanson, J. (2008). The effect of supplementing maize stover with cowpea (*Vigna unguiculata*) haulms on the intake and growth performance of Ethiopian sheep. *Animal*, 2 (6), 954-961.
  15. Madibela, O.R. and Modiakgotla, E. (2004, February 8). Chemical composition and in vitro dry matter digestibility of indigenous finger millet (*Eleusine coracana*) in Botswana. *Livestock Research for Rural Development*, 16 (4). Retrieved from <http://www.lrrd.org/lrrd16/4/madi16026.htm>
  16. Moral, R., Moreno-Caselles, J., Perez-Murcia, M.D., Perez-Espinosa, A., Rufete, B. and Paredes, C. (2005). Characterisation of the OM pool in manures. *Bioresource Technology*, 96 (2), 153-158.
  17. Nantoumé, H., Kouriba, A., Togola, D. and Ouologuem, B. (2000). Evaluation of the feeding value of forages and byproducts used for feeding small ruminants (in French). *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, 53 (3), 279-284.
  18. Peripolli, V., Prates, E.R., Barcellos, J.O. and Braccini Neto, J. (2011). Fecal nitrogen to estimate intake and digestibility in grazing ruminants. *Animal Feed Science and Technology*, 163 (2-4), 170-176.
  19. Saha, H.M., Kahindi, R.K. and Muinga, R.W. (2008). Evaluation of manure from goats fed Panicum basal diet and supplemented with Madras thorn, Leucaena or Gliricidia. *Tropical and Subtropical Agroecosystems*, 8 (3), 251-257.
  20. Singh, R., Gupta, P.C., Singh, K. and Pradhan, K. (1977). Chemical composition of forages in relation to their nutritive value. *The Indian Journal of Genetics and Plant Breeding*, 37 (1), 268-279.
  21. Tan, Z.L., Chen, H.P., He, L.H., Fang, R.J. and Xing, T.X. (1995). Variation in the nutritional characteristics of wheat straw. *Animal Feed Science and Technology*, 53 (3-4), 337-344.
  22. Vadiveloo, J. (2000). Nutritional properties of the leaf and stem of rice straw. *Animal Feed Science and Technology*, 83 (1), 57-65.

\*\*\*\*\*