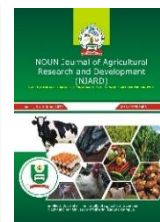




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**Original Article**

## Nutritional Evaluation of Maize Stover Silage Enriched with Selected Browse Fodder Species for Ruminant Feeding



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### Abstract

In tropical regions, climatic variations significantly affect both the availability and nutritional quality of forages for ruminant production. Consequently, the utilization of maize (*Zea mays* L.) stover silage has been suggested as an alternative feed source. However, the inherently low protein content of maize stover necessitates its combination with browse legumes to enhance its nutritional value. This research was conducted to assess the proximate composition and mineral profile of maize stover residues (MSR) ensiled with selected browses (*Gliricidia sepium* (GS), *Ficus thonningii* (FT), and *Gmelina arborea* (GA) using four dietary treatments - T<sub>1</sub> (100% MSR), T<sub>2</sub> (MSR70GS30), T<sub>3</sub> (MSR70FT30), and T<sub>4</sub> (MSR70GA30) after stored for 21 days. The inclusion of browse species significantly ( $P < 0.05$ ) affected proximate composition of the silage as T<sub>1</sub> has the highest dry matter, crude fibre, neutral detergent fibre, acid detergent fibre, and acid detergent lignin of 35.06, 37.82, 64.51, 32.62, 13.54% respectively compared to other dietary treatments, while T<sub>3</sub> had the highest crude protein (16.50%) and ash content (10.12%). The silage pH and temperature ranges between 4.30 – 4.60 and 27.53 – 28.30 °C, respectively. Mineral composition analysis revealed significant differences ( $P < 0.05$ ) among treatments, with T<sub>3</sub> having the highest concentrations of phosphorus (0.35%), potassium (0.86%), calcium (0.27%), magnesium (0.21%), iron (191.50 mg/kg), and zinc (51.94 mg/kg). The findings suggest that ensiling maize stover residues with browse species mixtures can serve as a valuable supplementary feed for ruminants.

**Keywords:** Proximate composition, Mineral content, Maize stover residue, Browse fodders, Silage.

### INTRODUCTION

In recent decades, climate change has resulted in recurring droughts, heat stress, and feed shortages, posing serious challenges to sustainable ruminant production and has intensified the scarcity of quality feed resources among the smallholder livestock producers (FAO, 2014). To mitigate

these constraints, the adoption of conservation techniques that preserve surplus forage and crop residues during the rainy season has become increasingly important towards sustaining livestock productivity (Wong, 2000). Feed inputs constitute over half of total livestock production costs, and the availability of high-quality forage is crucial for maintaining optimal animal



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performance (Kara *et al.*, 2021). In Nigeria, the growing disparity between the rising cost of animal feeds (45 – 55%) and food inflation (24.1%) has underscored the urgent need to explore alternative feed resources (Negash, 2022). Grasses, which are widely used as basal feeds, are typically low in protein (Kebede *et al.*, 2016) as solely grass diets often fail to meet the protein requirements of small ruminants, hence, necessitating the supplementation with fermentable nitrogen and energy sources (Ofori and Nartey, 2018). The nutritive quality of forages depends on several factors, including plant species, climatic conditions, soil fertility, and growth environment. Tropical browse plants and maize stover residues (MSR) represent promising feed resources that can be ensiled to serve as viable alternatives to fresh forages. Research have demonstrated that incorporating tropical browse species into silage can enhance nutrient density and palatability (Moges *et al.*, 2016; Osei *et al.*, 2020), and nutrient intake and digestibility (Adebisi *et al.* 2025). Maize stover, a major agricultural by-product, is abundant, largely underutilised, and nutritionally inadequate as a standalone feed which limits its value in ruminant production systems where feed scarcity is a recurring constraint. Despite this, maize stover has been identified as an important source of fibre and energy for ruminants when utilized in silage form (Akinmoladun *et al.*, 2021), and its nutritional limitations can be improved through inclusion of selected browse or legume fodders (Hawu *et al.*, 2022). Hence, this study aimed to evaluate the proximate composition, physicochemical characteristics, and mineral content of maize stover residues ensiled with selected browse fodder species to determine their suitability as supplementary feed for ruminant production.

## MATERIALS AND METHODS

### Experimental Site

The experiment was conducted at the Pasture Demonstration Plot, Teaching and Research Farm, Oyo State College of Agriculture and Technology, Igbo-Ora, Nigeria. The study area lies on latitude 7°43' N and longitude 3°29' E, with an elevation of approximately 17 meters above sea level (World Atlas, 2015).

### Collection of Maize Stover Residues and Browse Fodder Plants

Fresh forages consisting of leaves and twigs of *Gliricidia sepium*, *Ficus thonningii*, and *Gmelina*

*arborea* were manually harvested from mature woodlots located within the College farm while the maize stover residues were collected immediately after harvesting of green maize cob from the College's maize production plots.

### Silage Production, Chemical Analysis, and Quality Assessment

All forages were chopped into 2–3 cm lengths using a sharp cutlass to facilitate compaction, wilted for six hours to reduce moisture content, and then thoroughly mixed at varying inclusion levels with the browse species. The dietary treatment combinations were:

- T<sub>1</sub> = 100% Maize Stover Residue Silage (100MSRS),
- T<sub>2</sub> = 70% Maize Stover Residue + 30% *Gliricidia sepium* (70MSR30GS)
- T<sub>3</sub> = 70% Maize Stover Residue + 30% *Ficus thonningii* (70MSR30FT) and
- T<sub>4</sub> = 70% Maize Stover Residue + 30% *Gmelina arborea* (70MSR30GA).

Before ensiling, 200 g of molasses were diluted in 4 litres of water and evenly sprayed over each mixture to enhance fermentation. The mixtures were packed in triplicate into 4L plastic silos for laboratory analysis, and each silage sample was manually compacted and sealed in a thick polythene bag to create anaerobic conditions needed for proper fermentation and then kept in 120L plastic drums for storage. After 21 days of fermentation, the mini silos were opened, and the following parameters were evaluated: silage colour by using a standardized colour chart, smell and texture by a six-member sensory panel, and pH using a calibrated digital pH meter (Hanna Instruments pH210).

Proximate composition analyses were carried out according to AOAC procedure (2005), and the following parameters were estimated: Dry Matter (DM) content using a forced-draught oven at 65 °C, with applied volatile compound loss correction using a factor of 1.056 (Fox and Fenderson, 1978), crude fibre fractions - Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Hemicellulose (HC), Cellulose, and Acid Detergent Lignin (ADL) were determined following the method of Van Soest *et al.* (1991). Mineral elements such as sodium (Na), calcium (Ca), potassium (K), magnesium (Mg), and phosphorus (P) using an atomic absorption spectrophotometer.



### Statistical Design and Analysis

All collected data were arranged in a completely randomised design (CRD) and subjected to Analysis of Variance (ANOVA) using SAS v9.4 software (SAS, 2013). Mean differences among treatment groups were considered significant at  $P < 0.05$  and were separated using Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

### Proximate Composition and Fibre Fractions of Silages

The proximate composition and fibre fractions of silages produced from maize stover residues (MSR) ensiled with different browse fodders are presented in Table 1. Silage from treatment T<sub>1</sub> (100% MSR) recorded the highest dry matter (DM) content (35.06%) and lowest crude protein of 5.34%, while the lowest DM (31.02%) and highest CP (16.50 %) were recorded in T<sub>3</sub>. The observed mean DM (32.34%) of this study was higher than 23% and 21.2% reported for maize silages by Moran (2005) and Ashbell *et al.* (2002) respectively, but lower than 37.02% reported by Elkholy *et al.* (2009). These variations may be attributed to differences in the morphological composition (leaf to stem ratio) of the ensiled materials. According to Smith (1993), ruminants require a minimum CP content of 6 – 7% for maintenance, while Leng (1990) classified forages containing less than 8% CP as low-quality as low-protein forages negatively affect rumen microbial efficiency (Van Soest, 1982). The inclusion of browse species in maize stover silage (T<sub>2</sub> - T<sub>4</sub>) supplied sufficient protein to meet ruminant maintenance requirements. Crude protein (CP) in the mixed silages ranged from 14.89 to 16.50% DM, exceeding the 11.3% threshold for growth proposed by ARC (1984). The lower CP observed in the sole maize stover silage (T<sub>1</sub>) was anticipated, reflecting the advanced maturity of the material at ensiling. CP concentrations in the combined silages also surpassed the minimum 6 - 7% required to sustain adequate rumen ammonia production (Minson, 1982) and met the 11 - 12% recommendation for lactating animals (ARC, 1984; Gatenby, 2002). McDonald *et al.* (1995) similarly noted that CP levels of 7 - 8% are necessary for efficient feed utilization.

Compared with previous reports, CP in T<sub>2</sub> - T<sub>4</sub> was higher than values reported by Binuomote *et al.*

(2019) for elephant grass silage blended with cassava peels and poultry droppings (8.46 - 10.72%), yet lower than the concentrations recorded by Silva *et al.* (2014) for elephant grass ensiled with wheat bran (23.63 - 31.46 g/kg). Overall, incorporating browse legumes improved fermentation quality as the mixed silages showed a significant ( $P < 0.05$ ) increase in CP and ash content, and a concurrent reduction in fibre fractions (NDF, ADF, ADL) relative to the maize stover-only treatment (T<sub>1</sub>).

The inclusion of browse legume increased the ash content across silage treatments, consistent with high mineral density typical of browse species (Kebede *et al.*, 2016). Ash content values of 8.96 -10.12% are comparable to those reported by Nurhayu *et al.* (2021) and Tesfaye *et al.* (2019) for silage. This variability is expected as ash concentration in forages responds to plant maturity, the plant parts used, soil fertility, climate, and management practices, and they can shift considerably across production systems (Zewdu, 2007). The slight decline in T<sub>4</sub> is difficult to explain through mineral dynamics alone as differences in fermentation trajectory are a plausible contributor and merit dedicated investigation, as suggested by analogous observations in Xue *et al.* (2020) and Nurhayu *et al.* (2021).

Fibre fractions followed a clearer pattern. Because legumes inherently contain less structural fibre than grasses (Albayrak and Turk, 2013), the reduction in NDF and ADF with rising browse inclusion is unsurprising. Hydrolysis of NDF-bound nitrogen during fermentation may have amplified this effect (Jaakkola *et al.*, 2006). Either way, the resulting decrease in fibre fractions points to improved silage quality because lower NDF and ADF are widely acceptable indicators of enhanced nutritive value (Senjaya *et al.*, 2010), and Xue *et al.* (2020) and Nurhayu *et al.* (2021) reported a decrease in fibre fractions in maize stover silages enriched with browse legumes except lignin which was observed to increase slightly with legume inclusion. Given that lignin directly limits fibre digestibility (Moore and Jung, 2001), this increased value partially offsets the gains in NDF and ADF, and aligns with the same countertrend observed by Xue *et al.* (2020) and Nurhayu *et al.* (2021).



**Table 1: Proximate composition and fibre fractions (%) of maize stover residues ensiled with inclusion levels of selected browse fodder species**

Parameters (%)	T1 100MSRS	T2 MSR70GS30	T3 MSR70FT30	T4 MSR70GA30	SEM (±)
DM	35.06 <sup>a</sup>	31.72 <sup>b</sup>	31.02 <sup>d</sup>	31.57 <sup>c</sup>	1.12
CP	5.34 <sup>d</sup>	15.26 <sup>b</sup>	16.50 <sup>a</sup>	14.89 <sup>c</sup>	0.56
CF	37.82 <sup>a</sup>	16.30 <sup>c</sup>	14.38 <sup>d</sup>	18.40 <sup>b</sup>	0.83
EE	3.24 <sup>c</sup>	3.07 <sup>d</sup>	3.32 <sup>b</sup>	3.43 <sup>a</sup>	0.24
Ash	9.27 <sup>bc</sup>	9.38 <sup>b</sup>	10.12 <sup>a</sup>	8.96 <sup>c</sup>	0.16
NFE	30.04 <sup>a</sup>	27.46 <sup>d</sup>	28.11 <sup>b</sup>	27.82 <sup>c</sup>	0.70
NDF	64.51 <sup>a</sup>	52.89 <sup>c</sup>	48.85 <sup>d</sup>	54.79 <sup>b</sup>	1.30
ADF	32.62 <sup>a</sup>	31.75 <sup>bc</sup>	30.56 <sup>c</sup>	31.90 <sup>b</sup>	1.06
ADL	13.54 <sup>a</sup>	13.06 <sup>c</sup>	12.35 <sup>d</sup>	13.10 <sup>b</sup>	0.37

DM= Dry Matter, CP= Crude Protein, CF= Crude Fibre, EE= Ether Extract, NFE= Nitrogen Free Extract, NDF= Neutral detergent fibre, ADF= Acid detergent fibre, ADL= Acid detergent lignin, MSRS=Maize stover residue silage, GS= *Gliricidia sepium*, FT=*Ficus thonningii*, GA=*Gmelina arborea*

### Physio-Chemical Parameters of Silages

The physicochemical parameters across treatments are summarised in Table 2. The colour differences between sole maize stover silage and mixed silages were directly attribute of browse legume inclusion. Despite these visual differences, colour, odour, and texture remained within acceptable limits for high-quality silage across all treatments, in agreement with Khota *et al.* (2018) and Dongxia *et al.* (2019). The pH values ranged from 4.30 to 4.60, all below the 4.80 threshold considered appropriate for high-quality silage production (Matlabe *et al.*, 2022), suggesting satisfactorily fermentation as lower pH generally reflects effective preservation and better ensiled stability (Jusoh *et al.*, 2016). The slight increase in pH with browse inclusion is not unexpected because legumes carry a higher

buffering capacity than grasses which is attributed to elevated concentrations of cations, such as K<sup>+</sup>, Ca<sup>2+</sup>, and Mg<sup>2+</sup>, during fermentation (Wang *et al.*, 2017; Da Silva Brito *et al.*, 2020). Silage temperatures ranged from 27.53 to 28.30°C which exceed the 16.62 - 19.52 °C range reported for the Arganie variety of maize stover silage (Abebaye *et al.*, 2020) but fall well below the 29 - 40 °C recorded by Naeini *et al.* (2014). The distinction matters because elevated temperatures during ensiling can accelerate protein degradation and slow the rate of pH decline, both of which undermine fermentation quality (Rahjerdi *et al.*, 2015). Ambient and climatic conditions at the time of ensiling influenced the inter-study differences, though production-system differences cannot be ruled out.

**Table 2: Physico-chemical parameters, pH and temperature of maize stover residues ensiled with selected browse fodder mixtures**

Parameters	T1 100MSRS	T2 MSR70GS30	T3 MSR70FT30	T4 MSR70GA30
Colour	Pale yellow	Olive-green	Yellow-green	Yellowish-green
Smell	Pleasant	Nice	Pleasant	Sweet-sour
Taste	Sour	Vinegar	Vinegar	Sour
pH	4.30	4.50	4.60	4.40
Temp (°C)	28.30	27.53	27.82	27.60

MSRS=Maize stover residue silage, GS= *Gliricidia sepium*, FT=*Ficus thonningii*, GA=*Gmelina arborea*, Temp=Temperature

### Mineral Composition of Silages

The mineral composition across silage treatments is presented in Table 3, with significant differences detected among treatments (P < 0.05). Phosphorus concentrations ranged from 0.30 to

0.35% which are comfortably above the NRC (1985) maintenance threshold of 0.20% and the broader recommended level of 0.15%. This is noteworthy because phosphorus is not a passive nutrient; it underpins carbohydrate and amino acid

metabolism, bone mineralisation, and blood coagulation, and deficiencies can have cascading consequences for animal performance (Underwood, 1981). Calcium (0.24 – 0.27%) exceeded the 0.21% reported by Lockett *et al.* (2000) and appears adequate to support bone and muscle development in ruminants (Margaret and Vickery, 1997), though it fell short of the 0.30% level recommended by ARC (1980), and this gap worth noting in ration formulation. Magnesium (0.15 – 0.21%) tracked within and slightly above the NRC (1985) recommended range of 0.12 - 0.20%, which is sufficient to meet requirements for circulatory function and calcium metabolism (Ishida *et al.*, 2000). The observed difference in Ca, Mg, and P concentrations across treatments

can be influenced by soil fertility and local climatic conditions which are well-established drivers of mineral uptake in forage plants, and these varies considerably between production systems (Azevedo *et al.*, 2011; Heuze *et al.*, 2017). For trace minerals, iron content (190.07 – 191.50 mg/kg) was markedly higher than the 50 mg/kg threshold for adequate ruminant performance (Khan *et al.*, 2005) suggesting that the silages could serve as rich sources of dietary iron for pregnant and lactating animals (Anonymous, 1980). Zinc (50.10 – 51.94 mg/kg) exceeded the 30 mg/kg critical threshold across all treatments, indicating concentrations sufficient to support protein synthesis and growth (Melaku *et al.*, 2005).

**Table 3: Mineral composition of maize stover residues ensiled with selected browse fodder mixtures**

Parameters	T1	T2	T3	T4	SEM (±)
	100MSRS	MSR70GS30	MSR70FT30	MSR70GA30	
Phosphorus (%)	0.30 <sup>c</sup>	0.32 <sup>b</sup>	0.35 <sup>a</sup>	0.33 <sup>ab</sup>	0.01
Potassium (%)	0.84 <sup>bc</sup>	0.85 <sup>b</sup>	0.86 <sup>a</sup>	0.85 <sup>b</sup>	0.04
Calcium (%)	0.24 <sup>d</sup>	0.26 <sup>b</sup>	0.27 <sup>a</sup>	0.25 <sup>c</sup>	0.02
Magnesium (%)	0.15 <sup>d</sup>	0.20 <sup>b</sup>	0.21 <sup>a</sup>	0.19 <sup>c</sup>	0.01
Iron (mg/kg)	190.07 <sup>c</sup>	190.20 <sup>b</sup>	191.50 <sup>a</sup>	191.31 <sup>ab</sup>	2.05
Zinc (mg/kg)	50.10 <sup>d</sup>	51.04 <sup>c</sup>	51.94 <sup>a</sup>	51.70 <sup>b</sup>	1.30

MSRS=Maize stover residue silage, GS= *Gliricidia sepium*, FT=*Ficus thonningii*, GA=*Gmelina arborea*

## CONCLUSION

This study demonstrates that ensiling maize stover with browse fodder plants resolves the limitation of maize stover residues as a stand-alone feed by enhancing the nutritional value, mineral content, and overall silage quality. Inclusion of *Gliricidia sepium*, *Ficus thonningii*, or *Gmelina arborea* increased the crude protein and ash concentrations, reduced NDF, ADF, and ADL fractions, and improved mineral composition relative to sole maize stover silage. Hence, collectively shifting the feed from a low-quality roughage to a product that approaches established nutritional thresholds for productive ruminants. Browse-supplemented maize stover silage warrants prioritisation as a feed system intervention beyond controlled settings, and non-farm validation and targeted extension support are needed toward scaling an approach with clear potential to narrow seasonal feed gaps, reduce reliance on purchased concentrates, and strengthen the nutritional requirements of smallholder ruminant enterprises

## RECOMMENDATION

It is recommended that underutilized crop residues, such as maize stover, be ensiled in combination with browse fodders to produce conserved feeds for growing and lactating ruminants as it can enhance animal performance and reduce dependency on expensive commercial feeds. At 30 % mixture ratio, *Ficus thonningii* performed most consistently across nutritional parameters, making it the best browse legume for practical application. Further research should focus on feeding trials to evaluate the in vivo performance, digestibility, and growth response of animals fed these silages.

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## CONFLICT OF INTEREST

There is no conflict of interest to declare

## AUTHORS' CONTRIBUTIONS

Adebisi, I.A: Conceptualized the study, designed the methodology, and wrote the original draft. Ajibike, A.B: Conducted the formal analysis of data, prepared the visualization, and review of the



manuscript. Okunlola, O.O: Original draft of the manuscript. Muraina, T.O: Review and research design. Adeniyi, O.A: Reviewed and edited the manuscript, and validated the results. Oladepo, O: Provide resources for research work. Mustapha, T.B: Investigation and methodology for the research work. Akanmu, O.C: Reviewed and edited the manuscript. Raji, I.O: Supervised the project. Sunday, A.G: Supervised the project work.

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