Nigerian J. Anim. Sci. 2026, 28 (1): 110-125

Evaluation of chemical compositions of grass-legume silages produced in Umudike, rainforest zone of South-Eastern Nigeria

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Targeted audience: Livestock farmers, forage scientists, ruminant researchers, and dairy enterprise

Abstract

Livestock productivity in tropical regions is frequently hindered by limited availability of high-quality forage during dry seasons, leading to nutritional stress and reduced animal performance. This study evaluated the proximate composition, fibre fractions, mineral profile and anti-nutritional characteristics of grass–legume silages produced in Umudike, south-eastern Nigeria. Four forage compositions were arranged in a completely randomized design (CRD) with three replicates: sole Cenchrus purpureus (CP), C. purpureus + Calopogonium mucunoides (CPC), C. purpureus + Gliricidia sepium (CPG), and C. purpureus + Moringa oleifera (CPM), each at 50:50 except the sole grass. Samples were analysed after six weeks of ensiling for proximate composition, fibre fractions, minerals and anti-nutritional factors. Legume inclusion improved crude protein, mineral content and selected fibre characteristics compared with sole grass silage. At six weeks, CPM recorded the highest crude protein and mineral concentrations, with lower neutral detergent fibre and acid detergent fibre than most treatments. Anti-nutritional factors declined with longer ensiling and remained within levels considered tolerable for ruminants. The study concludes that inclusion of Moringa oleifera or Calopogonium mucunoides can improve the feeding value of Elephant grass silage. The study recommends grass–legume silage, particularly CPM, for dry-season ruminant feeding in the rainforest zone of Nigeria.

Keywords: *Cenchrus purpureus*; grass–legume silage; *Moringa oleifera*; forage conservation; anti-nutritional factors; dry-season feeding

Description of the Problem

In the tropical regions, livestock farmers face persistent challenges in maintaining a steady supply of high-quality feed throughout the year due to the rapid decline of forage in both quantity and quality during the dry season (1). During the rainy season, grasses and legumes are usually abundant as a result of adequate moisture content in the soil for plant nutrient uptake, however, much of these forage materials that could have been preserved instead of being wasted. This is due to poor conservation techniques, leading to acute shortages of feed resources during the dry season. This ugly situation has a direct impact on livestock health and productivity by causing declines in growth rates, milk production, and overall animal performance during critical periods when feed is limited (2, 3,4). This problem is particularly pressing in Nigeria, where seasonal fluctuations significantly impact feed availability, and it has been addressed through many approaches, such as the use of concentrates as feed supplementation and agro-industrial by-products. However, these agro-industrial by-products are generally characterized with low nutritive value and poor digestibility, and in order to enhance their nutrient content and digestibility, further processing is usually required. This consequently increases the cost of production where it is adopted.

Due to limited use of agro-industrial by-products as a feed resource during the dry season, forage conservation is perceived to be the sustainable approach to all year round availability of forage material for ruminant production in Nigeria and other Sub-Sharan region. This method allows farmers to conserve forage when it is most abundant in desirable nutritive value, ensuring a more consistent supply of quality feed throughout the year (5).

Conserved forages can take the form of hay, haylage and silage. Among all these, silage is best adapted to the rainforest zone of Nigeria due to high relative humidity and inadequate sunlight during the rainy season which could negatively affect hay making. Ensiling is a technique that involves fermenting green forage to maintain its nutritional value, and it has been identified as a promising strategy to combat feed scarcity, particularly in regions with pronounced seasonal weather changes, as it enables farmers to utilize stored forage during the dry season. However, ensiling in tropical climates presents unique challenges, especially in humid zones like Umudike in south-eastern Nigeria. Here, the high moisture content in forage coupled with elevated humidity levels can increase the risk of nutrient loss and spoilage, making effective management of the ensiling process essential to preserving feed quality (6).

Cenchrus purpureus, (formerly known as *Pennisetum purpureum*) known for its high biomass yield and digestibility, serves as an excellent complement to leguminous forages, offering a well-rounded nutritional profile (7). It is a common grass specie used to produce silage and it can be enhanced with inclusion of herbaceous legumes (8). Ensiling grass-legume mixtures may be considered to be advantageous in tropical areas, where grasses quality declines rapidly during dry season. According to (9), grass-legume mixtures have long been recognized for their potential to improve the quality of livestock diets. Combining high-fibre grass with protein-rich legumes provides a more balanced feed that enhances both digestion and animal growth (10). Grasses contribute to the high levels of neutral detergent fiber (NDF) and acid detergent fibre (ADF). Legumes, on the other hand, increase the protein content of the forage, making it more palatable and encouraging higher feed intake.

The inclusion of leguminous plants such as *Moringa oleifera, Gliricidia sepium, and Calopogonium mucunoides* is considered important for improving the overall quality of grass-legume silages. These plants offer a balanced nutrient profile that supports the nutritional needs of ruminants, providing essential fibres, proteins, and minerals (11). Meanwhile, legumes such as *G. sepium and M. oleifera* have been observed to enhance the protein content of the feed, which is critical for muscle growth and milk production in livestock (5, 12). The inclusion of *M. oleifera* in silage-making has been reported to improve both the fermentation quality and the nutrient composition of the silage (13). According to a study by (14), mixing *C. purpureus* with *M. oleifera* leaves resulted in silage with significantly higher crude protein content, improved digestibility, and a more favourable pH level. In another study reported by (15), the inclusion of *C. mucunoides* and *M. oleifera* in silage boosts the protein levels and makes the feed more attractive to livestock, ultimately resulting in better performance. Although several studies have evaluated grass–legume mixtures for ruminant feeding, limited information is available on the comparative effects of *Calopogonium mucunoides*, *Gliricidia sepium* and *Moringa oleifera* inclusion on the nutrient, mineral and anti-nutritional profiles of *Cenchrus purpureus* silage under the humid rainforest conditions of Umudike. This study was therefore designed to evaluate the chemical quality of these grass–legume silages at six weeks of ensiling.

Materials and Methods

Experimental Site

This study was conducted at the Pasture Unit of Teaching and Research farm, College of Animal Science and Animal Production, Michael Okpara University of Agriculture Umudike, Abia State. The site is located in South-Eastern part of Nigeria with coordinates of 5° 27' N and 7° 32' E, and an elevation of 123m above sea level. The region has an annual rainfall of 2177mm, temperature variations from 22°C to 36°C, and relative humidity ranging from 50-90%. The humid rainforest zone of West Africa is the climatic zone of this location, which has a long rainy season (March-October) and a short dry season (November-February). The Meteorological Center of the National Root Crop Research Institute in Umudike, Abia State (16) provided the climatic data. The laboratory analyses were carried out at Biochemistry Laboratory of Department of Animal Nutrition and Forage Science, College of Animal Science and Animal Production, Michael Okpara University of Agriculture, Umudike, Abia State and Department of Pasture and Range Management, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta, Ogun State.

Source of forage materials

In October 2024, marked commencement of dry season in Umudike, *Cenchrus purpureus*, *M. oleifera*, *Calopogonium mucunoides,* and *G. sepium* were harvested at about 15-20 cm stubble height above the ground level during vegetative stage, within the University environment. The leaves components with some succulent stem part of the forage materials were allowed to wilt by air-drying for 2 hours to reduce the moisture content before proceeding to the ensiling.

Procedure of Ensiling

The plant materials (*Moringa oleifera*, *Calopogonium mucunoides*, *Gliricidia sepium* and *Cenchrus purpureus*) were chopped into smaller pieces (approximately 1-2 cm in length) using a cutlass in order to ease the filling and compaction of the forage materials inside the silos (bottle silos) which would consequently facilitate better fermentation during the ensiling process. Bottle silos weighed 500g were used, and silos were filled with only plant materials without any silage additives. After filling and compaction, the silos were covered with black polytene bag, and small sands particles were added at the top to prevent air space. The silos were properly covered and sealed using paper tape to prevent further air entry. Thereafter, they were then grouped into treatments where T_1 was the control and had sole *Cenchrus purpureus*, T_2 was a mixture of *Cenchrus purpureus* and *Calopogonium mucunoides* at 50:50, T_3 was *Cenchrus purpureus* and *Gliricidia sepium* at 50:50 and T_4 *Cenchrus purpureus* and *Moringa oleifera* at 50:50. Each treatment group was replicated three (3) times, and each treatment weighed

1000g each. The silos were well arranged and stored at room temperature of an average 27℃. At the beginning of ensiling, the P^H of the ensiling materials were not measured.

Duration of Ensiling

The silos were kept under favourable environmental conditions at room temperature of an average 27℃ for a period of 6 weeks. After six weeks of ensiling, the silos were opened and samples were taken to determine the chemical quality of silages produced.

Data collection

Sampling and Chemical analyses

At the end of six weeks ensiling duration, silages were open and samples were taken from each bottle. Sub samples of the silage were taken oven dried at 60°C to about 20% moisture for 48 hours using oven drying machine. The dried samples were ground through a 1 mm sieve for determination of chemical analysis.

Determination of Proximate composition and Fibre fractions

The proximate composition (dry matter, crude protein, ether extract, crude fibre, and ash) was determined using the methods outlined by (17). Nitrogen-free extract was calculated as: NFE= 100 – CP – Ash – EE – CF. The fibre fraction analysis (NDF, ADF and ADL) was determined according to the procedure of (18). Cellulose was estimated as difference between ADF and ADL, while, Hemicellulose was calculated as the difference between NDF and ADF.

Determination of Macro and micro mineral contents

The well-ground samples of the silages were taken to analytical laboratory at IAR&T Moor Plantation, Ibadan for the determination of minerals. Macro minerals such as Calcium, Potassium and Magnesium and some micro minerals such as Zinc, Iron, Manganese, Copper and Chromium were determined using Atomic Absorption Spectrophotometer (AAS) according to the procedure described by Fritz and Schenk (19). Phosphorus and sodium were determined using Flame photometer after wet digestion in Nitric and per chloric acid.

Determination of anti- nutrients quality

The well ground samples of the silages produced were prepared and packaged at the Biochemistry laboratory of Animal Nutrition and Forage Science, Michael Okpara University of Agriculture, Umudike, Abia State. The samples were sent to Analytical Laboratory of the Institute of Agricultural Research and Training (IAR&T), Ibadan for the determination of some selected anti nutrients parameters to include Trypsin inhibitor, Phytate, Saponin, Tannins and Oxalate**.** Samples were analysed chemically by alkaline titration method according to the official methods of analysis described by the Association of Official Analytical Chemist (20). Trypsin inhibitor was determined using Spectrophotometric method as described by (21). Phytate analysis was done using the method described by (22). The method of (23) was used to determine tannin content, while the optical density (absorbance) readings were taken at 500nm wavelength. Oxalate was determined using the method of (24).

Statistical analysis

The data collected were analyzed using one-way analysis of variance (ANOVA) at 5% probability level. Significant differences between mean were separated using Duncan's Multiple Range Test (DMRT) as described by (25).

Experimental model

The statistical model is shown below:

$Y_{ij}= \mu + T_i + \varepsilon_{ij}$

Where:

Y_{ij} = j^{th} observation of the i^{th} treatment

μ = Overall mean

T_i = Effect of the i^{th}treatment

ε_{ij}= Random error, assumed to be independent, identically and normally distributed with zero means and constant variance

Results and Discussion

Table presents the proximate composition of fresh forage materials before ensiling. The values here indicated that crude protein of all the mixtures were higher than sole grass. But the crude fibre and ash of sole grass were higher than grass-legume mixtures. This suggests that legumes have tendency to increase the buffering capacity of mixed forage during the ensiling period.

Table 1: Proximate composition (%) of fresh forage materials before ensiling

Sample	Dry matter (%)	Crude protein (%)	Ether extract (%)	Crude fibre (%)	Ash (%)	NFE (%)
PP	87.87	13.84	3.91	28.74	10.53	30.85
CPC	88.14	26.64	5.80	14.60	8.19	32.91
CPG	88.44	28.74	5.93	13.80	7.90	32.07
CPM	87 .96	24.43	5.61	15.95	9.84	32.13

PP= *Cenchrus purpureus* (Sole), CPC = *Cenchrus purpureus* and *Calopogonuim mucunoides* (50% by 50%) CPG = *Cenchrus purpureus* and *Gliricidia sepium* (50% by 50%), CPM = *Cenchrus purpureus* and *Moringa oleifera* (50% by 50%).

Table 3 shows that forage composition significantly (P<0.05) influenced proximate composition and fibre fractions of silages after six weeks of ensiling. The mean values of crude protein (CP %) content, however, was affected (P<0.05), where the sole grass silage (PP) had the lowest CP (7.00%), while inclusion of legumes especially *Moringa oleifera* (CPM) and *Calopogonium mucunoides* (CPC) had the highest values (11.67%) and 10.80%, respectively) indicating an improved protein content of the silage. This reflects the well-established role of legumes in enhancing nitrogen content due to their higher protein concentration and biological nitrogen fixation capacity.

The improved CP in mixed silages against sole grass silage as revealed above, suggests that the combination of legumes, especially *M. oleifera* with grass has synergistic effect by enhancing it low level of fermentable carbohydrates which limit its use as a silage material, thereby benefiting from its high protein content (10). This align with the report by (26) that the inclusion of 30% boiled *Enterolobium cyclocarpum* seeds + 70% *Cenchrus purpureus* grass ensiled for 60 days improved the quality of silage over the sole grass. Although, the values of CP obtained in the mixed silages ranges from 9.63% to 11.69% in this study, was lower than the values (15.47%) reported in their study. This variation could be attributed to the part of the legume used. This suggests that high CP content of *E. cyclocarpum* seeds improved the silage nutritive quality more than thus by the vegetative parts as observed in this finding. Conversely, the CP values was slightly higher than that observed by (13), where *M. oleifera* was mixed Panicum in equal proportion in silage produced during dry season. This finding suggests that incorporating protein-rich forages like *M. oleifera* and *C. mucunoides* (CPC) in sole grass silage can reduce the need for costly protein supplements when such materials are fed to ruminants. Feeding silages with higher

CP content can be beneficial to animal by meeting rumen microbial requirements, thereby improving microbial protein synthesis and overall animal performance (27).

Crude fibre (CF) content of the silages showed (P<0.05) differences as a result of legumes used, with the CPG recorded (27.35%) being notably higher than the other treatments. Elevated CF often indicates increased structural carbohydrates, which can reduce digestibility if excessive. This suggests that inclusion of *Gliricidia sepium* may increase fibre bulk, potentially limiting voluntary intake if not balanced properly. In contrast, lower CF values in CPC, and CPM may favour better digestibility and intake (28). Neutral detergent fibre (NDF) content recorded in CPM (60.4%) was lower (P<0.05) compared to other treatments. This lower NDF is advantageous because the silage might have higher voluntary intake and better animal performance over other silages. Similarly, Acid detergent fibre (ADF), which inversely relates to digestibility, was also lowest (P<0.05) in CPM with (31.77%,). This indicates that CPM likely produced the most digestible silage among treatments. Moreover, Acid detergent lignin (ADL), a major component limiting fibre degradation in the rumen, was significantly lower in CPG and CPM. Lower lignin content of these two silages enhances rumen degradability of fibre, improving energy availability. The relatively high ADL in CPC suggests that although protein content improved, digestibility may be somewhat constrained when compared to CPM.

In the case of Cellulose content of the silages, CPC and CPG having higher (P<0.05) values (29.61% and 28.61%, respectively), while CPM recorded the lowest value (20.90%), but statistically similar to that of PP. Indicates that CPM silage have more digestible fibre constituent than other silages. Since cellulose is digestible to an extent in the rumen, moderate levels are beneficial; however, excessive amounts, especially when associated with lignin, can limit nutrient availability. The lower cellulose in CPM, combined with reduced lignin, reinforces its superiority in terms of digestibility, thereby making it best for feeding ruminants.

Table 2: Effect of forage composition on proximate composition and fibre fractions of silages sampled after six weeks of ensiling

PARAMETERS %	PP	CPC	CPG	CPM	SEM	P- Value
Dry matter	83.71	83.49	82.99	82.33	0.293	0.379
Crude protein	7.00^{b}	10.80^{a}	9.63^{a}	11.67^{a}	0.627	0.014
Ether extract	24.75	21.92	24.18	23.44	0.702	0.559
Crude fibre	16.66^{b}	18.07^{b}	27.35^{a}	16.53^{b}	1.184	0.000
Ash	15.51	11.30	10.37	11.90	0.894	0.191
NFE	37.83	40.61	30.88	39.37	2.082	0.381
NDF	71.06^{a}	72.57^{a}	67.28^{a}	60.4^{b}	1.499	0.004
ADF	40.25^{a}	43.16^{a}	39.30^{a}	31.77^{b}	1.408	0.011
ADL	12.86^{b}	13.55^{a}	10.69^{c}	10.88^{c}	0.333	0.000
Hemicellulose	30.81	29.41	27.98	28.63	1.405	0.924
Cellulose	27.39^{b}	29.61^{a}	28.61^{a}	20.90^{b}	1.286	0.050

a, b, c: means the same row with different superscripts are significantly different (p<0.05), SEM = Standard error of mean, NFE= Nitrogen free extract, NDF= Neutral detergent fibre, ADL= Acid detergent lignin.
PP= *Cenchrus purpureus* (100%), CPC = *Cenchrus purpureus* and *Calopogonuim mucunoides* (50% by 50%) CPG = *Cenchrus purpureus* and *Gliricidia sepium* (50%by50%) CPM = *Cenchrus purpureus* and *Moringa oleifera* (50%by50%)

The effect of forage composition on mineral contents of silages produced from mixtures of M*oringa oleifera, Calopogonium mucunoides, Gliricidia sepium and Cenchrus purpureus* after six weeks of ensiling period (Table 3). The results reveal that forage composition (P<0.05) affected mineral contents of the silages. Across both macro- and micro-minerals, a consistent pattern observed, in which mineral concentrations increased from the sole *Cenchrus purpureus* (PP) silage to the mixed silages, with the *M. oleifera*-based mixture (CPM) maintaining the highest values. For macro minerals, sodium, potassium, calcium, phosphorus, and magnesium all showed progressive increases across treatments. The calcium content of silages rose from 0.25% in PP to 0.31% in CPM, while phosphorus increased from 0.34% to 0.41%. Potassium and sodium also increased (P<0.05), with CPM again recording the highest levels (0.72% and 0.28%, respectively). Magnesium followed a similar trend, with the highest value recorded in CPM (0.32%).

The observation in this study conforms with the report of (29) that *M. oleifera* contain high mineral value and high yield potential. This corroborates earlier finding by (11) that the inclusion of *Centrosema pubescens* influenced the mineral contents of grass-legume silage in Umudike, rainforest zone of South-eastern Nigeria. Similar findings have been reported by (30 and 31), where legume inclusion consistently improved mineral profiles of silage irrespective of fermentation length. The *M. oleifera* has advantage over other legumes having significantly improved Calcium and Phosphorus contents, since these two minerals are critical for skeletal integrity, milk production, and metabolic functions in ruminants. Diets deficient in these minerals can limit animal performance, particularly in tropical systems where basal forages are often mineral-poor (32, 33). Potassium is essential for maintaining osmotic balance and muscle function, while sodium plays a key role in nutrient absorption and nerve transmission. Adequate supply of these minerals improves feed utilization and animal productivity (34). The elevated levels of Potassium and sodium in legume-based silages suggest improved electrolyte balance, which is especially beneficial under heat stress conditions common in tropical environments. The enhanced magnesium content of CPM is very imperative because magnesium deficiency in animal feed can lead to metabolic disorders such as hypomagnesaemia (grass tetany). The improved magnesium concentration in mixed silages therefore enhances their safety and nutritional adequacy for ruminants as reported by (33).

The micro-mineral concentrations revealed that mixed silages had significant higher values than sole grass silages, While *Calopogonium mucunoides* (CPC) and *Gliricidia sepium* (CPG) improved mineral content compared to PP, their values were consistently lower than those of CPM. This highlights the exceptional nutrient density of *Moringa oleifera*, which has been widely reported to contain high levels of essential minerals and to serve as a valuable feed supplement in livestock diets (35, 36). Iron concentration increased from 118.24 mg/kg in PP to 129.79 mg/kg in CPM, while zinc rose from 56.81 mg/kg to 71.04 mg/kg. Copper, manganese, and chromium followed similar patterns, all peaking in CPM. These trace elements are indispensable for numerous biological processes, including enzyme activation, immune response, antioxidant defense, and reproductive performance (37, 38). Zinc and copper, for example, are closely linked to immune competence and growth, while manganese is essential for bone formation and reproductive efficiency. Chromium, though required in trace amounts, plays a role in glucose metabolism and may improve feed efficiency and stress tolerance in livestock (39). The significantly higher concentrations of these elements in CPM suggest that feeding CPM silage to the ruminant can substantially enhance micronutrient supply, potentially reducing the need for mineral premixes.

Table 3: Mineral composition of silage produced from mixtures of M*oringa oleifera, Calopogonium mucunoides, Gliricidia sepium and Cenchrus purpureus* silage after six weeks of ensiling period

Parameters	PP	CPC	CPG	CPM	SEM	P value
Macro mineral						
Sodium (%)	0.24^{d}	0.26^{c}	0.27^{b}	0.28^{a}	0.005	0.000
Potassium (%)	0.65^{d}	0.68^{c}	0.69^{b}	0.72^{a}	0.009	0.000
Calcium (%)	0.25^{d}	0.27^{c}	0.29^{b}	0.31^{a}	0.008	0.000
Phosphorus (%)	0.34^{d}	0.37^{c}	0.39^{b}	0.41^{a}	0.011	0.000
Magnesium (%)	0.27^{c}	0.29^{b}	0.30^{b}	0.32^{a}	0.006	0.000
Micro mineral						
Iron (mg/kg)	118.24^{d}	127.52^{b}	125.89^{c}	129.79^{a}	1.639	0.000
Zinc (mg/kg)	56.81^{d}	68.78^{b}	67.94^{c}	71.04^{a}	2.081	0.000
Copper (mg/kg)	13.51^{d}	17.00^{b}	15.91^{c}	18.36^{a}	0.672	0.000
Manganese(mg/kg)	31.41^{d}	34.61^{b}	33.82^{c}	35.11^{a}	0.537	0.000
Chromium (mg/kg)	5.28^{d}	8.23^{b}	7.99^{c}	11.23^{a}	0.796	0.000

$^{a, b, c, d:}$ means on the same row with different superscript are significantly ($p<0.05$)
SEM: Standard error of mean
PP= *Cenchrus purpureus* (100%), CPC = *Cenchrus purpureus* and *Calopogonuim mucunoides* (50% by 50%) CPG = *Cenchrus purpureus* and *Gliricidia sepium* (50%by50%) CPM = *Cenchrus purpureus* and *Moringa oleifera* (50%by50%)

Table 4 shows that forage composition significant ($P<0.05$) influenced the anti-nutritional profile of silages after six weeks of ensiling. Phytate content recorded the highest value (0.26%) in CPM and the lowest in CPC (0.22%). This aligns with reports that microbial phytases produced during ensiling can hydrolyze phytate, thereby improving mineral bioavailability (40, 41). Oxalate content also showed variation ($P<0.05$), with PP and CPM recording the highest values (0.18%) and CPC the lowest (0.16%). However, the relatively low levels observed across treatments remain within safe limits for ruminants, which can metabolize oxalates through rumen microbial activity (42). Saponin content decreased significantly with legume inclusion ($P<0.05$), with CPC and CPM showing the lowest values (0.26%) compared to PP (0.29%). At the same time, maintaining moderate levels may still confer benefits such as reduced rumen protozoa and improved nitrogen utilization (43).

Tannin content exhibited a clear and significant increase with legume inclusion ($P<0.05$), with CPM recording the highest value (0.06%) and PP the lowest (0.02%). This suggests that while ensiling reduces absolute concentrations, the relative contribution of tannin-rich legumes persists. Importantly, the levels reported are still within a range considered beneficial for ruminants, where tannins can protect proteins from excessive ruminal degradation and enhance amino acid flow to the intestine (44, 45).

Trypsin inhibitor activity followed a similar pattern to earlier observations, increasing significantly with legume inclusion ($P<0.05$) and peaking in CPM (5.29 mg/g). Ensiling is known to reduce protease inhibitors through microbial and enzymatic action, thereby improving protein digestibility (46, 47). Despite this reduction, the higher levels in legume-based silages indicate that inclusion rates should be balanced, particularly if silage constitutes a large proportion of the diet.

Forage composition remains the dominant factor determining ANF levels, as evidenced by the consistently higher values in CPM and CPG compared to PP and CPC. Importantly, the coexistence of higher nutrient density and moderately elevated ANFs in legume-based silages reflects a common trade-off in forage nutrition. However, in ruminants, this balance is often favourable because rumen microbes can detoxify many anti-nutritional compounds. Moreover, low to moderate levels of tannins and saponins may actually improve protein utilization efficiency and reduce methane emissions, contributing to more sustainable livestock production (45, 43).

Table 4: Effect of forage composition on anti-nutritional parameters of grass legume silage after six weeks of ensiling

Parameters %	PP	CPC	CPG	CPM	SEM	P-value
Phytate%	0.25^{b}	0.22^{d}	0.24^{c}	0.26^{a}	0.004	0.000
Oxalate%	0.18^{a}	0.16^{c}	0.17^{b}	0.18^{a}	0.002	0.000
Saponin%	0.29^{a}	0.26^{c}	0.27^{b}	0.26^{c}	0.003	0.000
Tannin%	0.02^{d}	0.04^{c}	0.05^{b}	0.06^{a}	0.004	0.000
Trypsin inhibitor (mg/g	2.19^{d}	3.45^{c}	4.94^{b}	5.29^{a}	0.373	0.000

a, b, c, d: means the same row with different superscripts are significantly different ($p<0.05$), SEM = Standard error of mean

PP= *Cenchrus purpureus* (100%), CPC = *Cenchrus purpureus* and *Calopogonuim mucunoides* (50%by50%) CPG = *Cenchrus purpureus* and *Gliricidia sepium* (50%by50%) CPM = *Cenchrus purpureus* and *Moringa oleifera* (50%by50%)

Conclusion and Recommendation

The inclusion of legumes improved the chemical quality of *Cenchrus purpureus* mixed silage compared with sole grass silage. *C. purpureus* mixed with *M. oleifera* at 50:50 (CPM) recorded the highest crude protein and mineral concentrations after six weeks of ensiling. In addition, CPM had lower NDF and ADF, suggesting better potential intake and digestibility. Anti-nutritional factors declined with ensiling, indicating that six weeks of ensiling improved silage safety and feeding value. *Cenchrus purpureus* mixed with *Calopogonium mucunoides* (CPC) silage had relatively lower anti-nutritional factor concentrations and may be useful where anti-nutrient reduction is a priority. Therefore, *C. purpureus* mixed with *M. oleifera* at 50:50 is recommended for improving silage nutrient quality in the rainforest zone of south-eastern Nigeria, while further animal feeding trials are suggested to evaluate intake, digestibility and performance responses.

References

1. Tulu, D., Gadissa, S., Hundessa, F. and Kebede, E. (2023). Contribution of climate-smart forage and fodder production for sustainable livestock production and environment: Lessons and challenges from Ethiopia. Environmental Sustainability, 2023, Article 8067776.

https://doi.org/10.1155/2023/8067776

2. Muzzo, B. I., Ramsey, R. D. and Villalba, J. J. (2024). Changes in climate and their implications for cattle nutrition and management. *Climate*, 13 (1), 1. https://doi.org/10.3390/cli13010001.

3. Duguma, B. and Janssens, G. P. J. (2021). Assessment of livestock feed resources and coping strategies with dry season feed scarcity in mixed crop-livestock farming systems around the Gilgel Gibe catchment, Southwest Ethiopia. Sustainability, 13(19), 10713. https://doi.org/10.3390/su131910713

4. Maleko, D., Ng, W. T., Msalya, G., Mwilawa, A., Pasape, L. and Mtei, K. (2018). Seasonal variations in the availability of fodder resources and practices of dairy cattle feeding among the smallholder farmers in Western Usambara Highlands, Tanzania. *Tropical Animal Health and Production*, 50 (7), 1653-1664.

5. Aduku, A.O. (2004). Animal Nutrition in the tropics feeds and feeding, pastures management, Monogastric and ruminant nutrition. Davicom, Zaria, Kaduna, Nigeria. Pp. 17.

6. Frontiers. (2021). Tapping into the environmental Co-benefits of improved tropical forages for an agroecological transformation of livestock production *systems*. https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2021.742842/full

7. Omoniyi, L. A., Akinbode, R. M. Isah, O. A. and Onwuka, C. F. I. (2021). Mineral profile of four selected tree forage species consumed by small ruminants in the South-Western Nigeria. Nigeria. Proceeding of 46th Annual Conference Nigerian Society for Animal Production (NSAP), held on 13th-17th March, 2021, at Federal University Dutsin-Ma, Kastina State, Nigeria. Page560-563.

8. Ewetola, I. A. and Nzeaghara, M. J. 2025. Proximate composition of grass-legume silages as affected by wilting periods, produced in Umudike, rainforest zone of South-east, Nigeria. Proceedings of the 6th Biennial Conference of the Society for Grassland Research and Development in Nigeria (SOGREDEN) held on 11th- 14th, November, 2025, at Ebonyi State University, Abakaliki, page 159-164.

9. Singh, N., Jain, P., Ujinwal, M. and Langyan, S. (2022). Escalate protein plates from legumes for sustainable human nutrition. *Frontiers in Nutrition*, 9, 977986. https://doi.org/10.3389/fnut.2022.977986.

10. Odeyinka, S. M., Abegunde, T. O., Ofoegbu, M. O. and Apanisile, J. O. 2021. Silage quality, growth performance and haematology of West African dwarf goats fed *Moringa oleifera* leaves ensiled with cassava peels. *Nigerian Journal of Animal Production*, 48(2):183-190.

11. Ewetola, I. A., Onabanjo, S. R., Francis, N. P. and Ojewola, G. S. 2023. Influence of wilting period on mineral contents of grass-legume silage mixtures in Umudike, South

east, Nigeria. *Nigerian Journal of Animal Production* 49 (2): 182-190.

12. Gulwa, U., Mgujulwa, N. and Beyene, S. T. (2018). Benefits of grass-legume inter-cropping in livestock systems. *African Journal of Agricultural Research*. https://academicjournals.org/journal/AJAR/article-full-text-pdf/5D6BF5057582

13. V. O. A. Ojo, E. D. Oyebanjo, O. T. Opayemi, S. O. Mustapha, O. O. Adelusi, S. A. Adeoye, U. Y. Anele, A. O. Ogunsakin, A. O. Jolaosho, O. S. Onifade. 2016. Effects of seasonal changes on the nutritive quality of Moringa and Panicum silage. *Slovak Journal Animal Science*, 49(2): 76-84.

14. Asaolu, V. O., Akinlade, J. A., Ojebiyi, O. O., Rafiu, T. A. and Babayemi, O. J. (2012). Performance of West African Dwarf goats fed *Moringa oleifera* and *Gliricidia sepium* supplemented diets. *Agriculture and Biology Journal of North America*, 3(1): 24-30.

15. Stagnari, F., Maggio, A., Galieni, A. and Pisante, M. (2017, February 2). Multiple benefits of legumes for agriculture sustainability: An overview. SpringerOpen. https://chembioagro.springeropen.com/articles/10.1186/s40538-016-0085-1

16. NRCRI. (2021). Meteorological data report for Umudike Station. National Root Crops Research Institute, Umudike, Abia State, Nigeria. https://nrcri.gov.ng/agro-meteorology/.

17. AOAC. (2005). Official Methods of Analysis. Association of Official Analytical Chemists, Washington DC.

18. P. J. Van Soest, J. B. Robertson, B. A. Lewis. 1991. Methods for Dietary Fiber, Neutral Detergent Fiber and Non-Starch Polysaccharides in Relation to Animal Nutrition. *Journal of Dairy Science,* 74 (10); 3583-3597.

19. Fritz, J. S. and Schenk, G. H. 1979. Quantitative Analytical Chemistry, 4th Edition. Allyn and Boston, pp 661.

20. AOAC (2004). Official methods of analysis of the association of official analytical chemists, 20th ed.

21. Arntfield, S. D., Ismond, M. A. H. and Murray, E. D. (1985). The fate of anti-nutritional factors during the preparation of the faba beans protein isolate using micellization technique. Canadian Institute of Food Science and Technology Journal, 18(2): 137-143.

22. Reddy, N. R., Sathe, S. K. and Salunkhe, D. K. (1982). Phytates in legumes and cereals. Advances in Food Research, 28: 1-92.

23. Doss, A., Pugalenthi, M., Vadivel, V. G., Subhashini, G. and Subash, R. A. (2011). Effects of processing technique on the nutritional composition and anti-nutrients content of under-utilize food legume *Canavalia ensiformis* LDC. *International Food Research Journal*, 18(3):965-970.

24. Leyva, J. A. M., Artiga, M. P. H., Mendez, M. M. A. and Per, J. J. Q. (1990). Atomic absorption and UV-VIS absorption spectrophotometric determination of oxalate in urine by

ligand exchange extraction, *Clinica Chimica Acta*, 195(1-2): 47-56.

25. Gomez, K. A., and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research (2nd ed.). Wiley.

26. V. O. A. Ojo, G. A. Akinade, G. A. Adetokunbo, A. A. Lamidi, A. O. Jolaosho, R. Y. Aderinboye, T. A. Amole, R. M. Akinbode, O. A. Okukenu and O. J. Idowu. 2017. Silage quality of *Pennisetum purpureum* Schumach. Grass mixed with processed *Enterolobium cyclocarpum* (Jacq.) Griseb. Seeds at varying proportions as affected by ensiling periods. *Tropical Agriculture (Trinidad)*, 94 (4): 362-371.

27. Khan, N. A., Yu, P., Ali, M., Cone, J. W. and Hendriks, W. H. (2015). Nutritive value of maize silage in relation to dairy cow performance and methane emission. *Journal of Dairy Science*, 98(9), 6477–6491.

28. Van Soest, P. J. (1994). *Nutritional Ecology of the Ruminant* (2nd ed.). Cornell University Press.

29. Aregheore, E. M. 2002. Intake and digestibility of *Moringa oleifera* Batiki grass mixtures for growing goats. *Small Ruminant Res*, 46: 23-28.

30. Oladosu, Y., Rafii, M. Y., Abdullah, N., Magaji, U., Hussin, G., Ramli, A. and Kareem, I. (2016). Fermentation quality and additives: A review. *BioMed Research International*, 2016, 1–14.

31. Nkosi, B. D., Meeske, R., Van der Merwe, H. J. and Groenewald, I. B. (2011). Effects of ensiling forage soybean and forage sorghum mixture on silage quality and animal performance. *Animal Feed Science and Technology*, 164(3–4), 186–194.

32. McDowell, L. R. (2003). *Minerals in Animal and Human Nutrition* (2nd ed.). Elsevier Science.

33. Suttle, N. F. (2010). *Mineral Nutrition of Livestock* (4th ed.). CABI.

34. NRC (National Research Council). (2016). *Nutrient Requirements of Beef Cattle* (8th rev. ed.). National Academies Press.

35. Moyo, B., Patrick, J. S., Mupangwa, J. F. and Masika, P. J. (2011). Nutritional composition of *Moringa oleifera* leaves and potential uses as feed and food. *Livestock Research for Rural Development*, 23(1).

36. Nouman, W., Basra, S. M. A., Siddiqui, M. T., Yasmeen, A., Gull, T. and Alcayde, M. A. C. (2014). Potential of *Moringa oleifera* L. as livestock fodder crop: A review. *Turkish Journal of Agriculture and Forestry*, 38(1), 1–14.

37. Spears, J. W. and Weiss, W. P. (2014). Role of antioxidants and trace elements in health and immunity of transition dairy cows. *Veterinary Journal*, 176(1), 70–76.

38. Oba, M. and Allen, M. S. (2019). Effects of dietary fibre on feed intake and productivity in ruminants. *Journal of Dairy Science*, 102(6), 4749–4761.

39. Spears, J. W. (2000). Micronutrients and immune function in cattle. *Proceedings of the Nutrition Society*, 59(4), 587–594.

40. Humer, E. and Zebeli, Q. (2015). Phytate in feed ingredients and potentials for improving ruminal phosphorus availability. *Animal Feed Science and Technology*, 209, 1–15.

41. Kung, L., Shaver, R. D., Grant, R. J. and Schmidt, R. J. (2018). Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. *Journal of Dairy Science*, 101(5): 4020-4030.

42. Noonan, S. C. and Savage, G. P. (1999). Oxalate content of foods and its effect on humans. *Asia Pacific Journal of Clinical Nutrition*, 8(1), 64–74.

43. Patra, A. K. and Saxena, J. (2009). The effect and mode of action of saponins on microbial populations and fermentation in the rumen. *Nutrition Research Reviews*, 22(2), 204–219.

44. Mueller-Harvey, I. (2006). Unravelling the conundrum of tannins in animal nutrition. *Journal of the Science of Food and Agriculture*, 86(13), 2010–2037.

45. Min, B. R., Solaiman, S., Waldrip, H. M., Parker, D., Todd, R. W. and Brauer, D. (2020). The role of condensed tannins in ruminant nutrition and methane mitigation. *Animal*, 14(S1), s168–s177.

46. Alonso, R., Aguirre, A. and Marzo, F. (2000). Effects of processing on anti-nutritional factors in legumes. *Food Chemistry*, 68(2), 159–165.

47. Mukherjee, R., Chakraborty, R. and Dutta, A. (2016). Role of fermentation in improving nutritional quality of soybean meal. *Journal of Food Science and Technology*, 53(1), 23–34.