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Regrowth age and climate effects on chemical composition and fermentability of *Teramnus labialis*

Efecto de la edad de rebrote y clima en la composición química y fermentabilidad de *Teramnus labialis*

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ABSTRACT

Tropical legumes optimize sustainable animal protein in tropical regions. *Teramnus labialis* (L.f.) Spreng represents a promising legume whose nutritive value varies with regrowth age and climatic conditions. This study evaluated how chemical composition and fermentability influence this value in established pastures at five regrowth ages (30, 45, 60, 75, and 90 days) during the dry and rainy seasons through standard chemical assays, *in vitro*, *in situ* digestibility tests and *in vitro* gas production kinetics. Crude protein decreased from 19.8% (30 days, rainy season) to 14.2% (90 days, dry season), while neutral detergent fiber increased from 50.7 to 56.9%. Digestibility declined from 61.4 to 57.8%, and gas production rate showed significant variation, with *lag* time shortening during the dry season. Multivariate analysis confirmed significant differentiation by regrowth age and climate (P<0.0001). These finds indicate that early harvesting ($\leq$60 days), particularly during the rainy season, maximizes the nutritive value of *Teramnus labialis*, and supports tailored management strategies for sustainable livestock systems in tropical environments.

RESUMEN

Palabras clave:
Nutrición animal
Cultivos forrajeros
Fecha de cosecha
Manejo de pastizales
Compuestos fenólicos
Degradación ruminal

Las leguminosas tropicales optimizan fuentes sostenibles de proteína animal en regiones tropicales. *Teramnus labialis* (L.f.) Spreng representa una leguminosa prometedora cuyo valor nutritivo varía con la edad de rebrote y las condiciones climáticas. Este estudio evaluó cómo la composición química y la fermentabilidad influyen en este valor en pasturas establecidas a cinco edades de rebrote (30, 45, 60, 75 y 90 días) durante las estaciones seca y lluviosa, mediante ensayos químicos estándar, pruebas de digestibilidad *in vitro* e *in situ*, y la cinética de producción de gas *in vitro*. Los resultados mostraron que la proteína bruta disminuyó de 19,8% (30 días, lluviosa) a 14,2% (90 días, seca), mientras que la fibra detergente neutra aumentó de 50,7 a 56,9%. La digestibilidad descendió de 61,4 a 57,8%, y las tasas de producción de gas mostraron variación significativa, con acortamiento del tiempo *lag* en condiciones secas. El análisis multivariado confirmó una diferenciación significativa según edad y clima (P<0,0001). Estos hallazgos indican que el corte temprano ($\leq$60 días), especialmente en la estación lluviosa, maximiza el valor nutritivo de *Teramnus labialis* y respalda estrategias de manejo adaptadas para sistemas ganaderos sostenibles en ambientes tropicales.

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Global demand for animal protein continues to rise, which drives the need for sustainable livestock systems that rely on high-quality forage legumes. These species improve animal nutrition and enhance soil fertility through biological nitrogen fixation (Rauw et al. 2023). Tropical forage legumes play a central role in sustainable livestock systems by providing high protein biomass under marginal environmental conditions. Among these species, *Teramnus labialis* (L.f.) Spreng, commonly known as ´blue wiss´, offers high biomass production and strong adaptability to marginal soils and variable rainfall (Acosta et al. 2024). This legume occurs naturally in the Caribbean basin and shows successful establishment in southeastern Cuba, particularly in the Cauto Valley where calcic brown predominate, *T. labialis* establishes well in mixed pastures and supports forage availability during the dry season.

Despite its agronomic advantages, the nutritional value of *T. labialis* changes with regrowth age and climatic conditions, which directly affects animal intake and performance (Verdecia et al. 2020). This species occurs naturally across the Caribbean basin and Central America, with successful establishment in marginal soils of southeastern Cuba. Its forage value derives from high biomass production and drought tolerance, which support livestock feeding during dry periods. Younger plants typically contain more crude protein and fewer structural carbohydrates, whereas older regrowth shows higher fiber, lignin, and secondary metabolites such as phenolic compounds that reduce palatability and microbial degradability (Dixon and Mayer 2020). Fermentation traits, including gas production rate, lag time, and asymptotic gas volume, reflect ruminal degradability and help predict the energy yield of forages (Singh et al. 2023).

Most studies on tropical legumes examine chemical composition or fermentability in isolation, with few integrating both aspects for *T. labialis* across seasons (Sales-Silva et al. 2023). However, the joint evaluation of chemical composition and fermentability provides a more accurate prediction of nutritive value because chemical constituents determine substrate availability and anti-nutritional constraints, while fermentation kinetics reflect microbial accessibility and degradation rate. In the Caribbean, marked rainfall seasonality induces physiological stress that alters plant biochemistry and forage quality (Pitman and Vendramini 2020). Delaying harvest beyond optimal regrowth stages accelerates lignification and diminishes digestibility, yet practical harvest guidelines remain limited for this species under Cuban agroecological conditions (Rauw et al. 2023).

It is hypothesized that regrowth age and climate period interact to modulate the chemical composition and fermentability of *T. labialis*, thereby influencing its overall nutritive value. Based on this hypothesis, the present study evaluates how chemical composition and fermentability determine the nutritional quality of *Teramnus labialis* across five regrowth ages and two climatic periods in southeastern Cuba, with the aim of generating science-based recommendations for forage management.

MATERIALS AND METHODS

Study area

The experiment took place at the animal production facilities of the University of Granma, located 17.5 km from Bayamo in southeastern Granma Province, Cuba (coordinates 20°22´N, 76°38´W). The site features calcic brown (Hernández-Jiménez et al. 2019) with pH=6.2, 3.6% of organic matter, and soil nutrient concentrations of 24 mg kg^{-1} of P_2O_5, 334.2 mg kg^{-1} of K_2O, and 30 mg kg^{-1} of total nitrogen. The study evaluated established pastures of *Teramnus labialis* (L.f.) Spreng without cv. Mayor with 98% species purity, two years after sowing. Two climatic periods were defined to represent regional seasonality (Verdecia et al. 2020): the dry season (January–March), characterized by 83.7 mm of rainfall, a mean temperature of 23.89 °C, and relative humidity of 76.71%; and the rainy season (May–July), with 309.88 mm of rainfall, a mean temperature of 27.22 °C, and relative humidity of 79.25%.

Experimental design

The study was conducted using a completely randomized design with 5x2 factorial arrangement, consisting of five regrowth ages (30, 45, 60, 75, and 90 days) and two climatic periods (dry and rainy seasons), with six replicates per treatment. At the onset of each season (January and May), the pasture was uniformly cut to 5 cm above ground level to standardize initial conditions. Experimental plots of 25 m^2 were established, separated by 50 cm buffer zones, and each plot was assigned to a specific regrowth age to ensure statistical independence.

No irrigation or fertilization was applied throughout the experimental period in order to maintain natural growth conditions.

Sample collection and preparation

At each harvest date, all aboveground biomass within each plot was cut, excluding a 50-cm border to minimize edge effects. A 200 g subsample per plot was collected and homogenized, then ground to a particle size 1 mm and re-homogenized. Samples were subsequently dried in a forced-air oven at 65 °C for 72 h (Herrera-Herrera et al. 2022) to determine dry matter (DM) content. In total, 60 samples were analyses (30 per climatic period).

Chemical analysis

Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined according to Weiss and Hall (2020). Crude protein (CP), ash, organic matter (OM), and mineral concentrations (Ca, P, Mg, Si) were analyzed following AOAC (2005) protocols.

Total extractable phenols (TP) and total tannins (TT) were quantified using the Folin–Ciocalteu reagent with tannic acid as the standard, according to Makkar (2003). Free condensed tannins (FCT) were determined using the butanol–HCl method (Porter et al. 1986) with modifications described by Makkar (2003). Total condensed tannins (TCT) were calculated as the sum of FCT and bound condensed tannins (TBCT). All phenolic compounds were expressed as g tannic acid equivalents kg^{-1} DM.

Determination of flavonoids was performed according to Meesakul et al. (2023), saponins according to Adepoju et al. (2025), and triterpenes, steroids, and alkaloids following the methods described by Hawu et al. (2025).

Soluble sugars (glucose, fructose, sucrose) and oligosaccharides (raffinose, verbascose, and stachyose) were extracted using 70% methanol, followed by high-performance liquid chromatography (HPLC) analysis using an HPX-87M column at 50 °C with refractive index detection. All analyses were performed in duplicate.

Digestibility assays

***In vitro* digestibility**

The study determined *in vitro* dry matter digestibility (IVDMD) with the ANKOM Daisy II® incubator (ANKOM Technology, Fairport, NY, USA) for García-Rodríguez et al. (2019). Collection of rumen fluid came from four rumen-cannulated Merino sheep (53.8±4.08 kg body weight) fed *Medicago sativa* and *Erica arborea*. After morning fasting, filtration of rumen fluid passed through four layers of gauze, the team weighed 250±10 mg of sample into F57 Ankom bags (25 µm pore size) and incubated them in digestion jars at 39 °C for 48 h under constant agitation. After incubation, they rinsed, dried at 105 °C, and analyzed residues for NDF to estimate true digestibility (TD). All animal procedures complied with ethical standards approved by the University of Granma Ethics Committee (Protocol No. 2023-045).

***In situ* digestibility**

The application of the nylon bag technique followed Pagella et al. (2018). Placement of 4 g of ground sample (2 mm screen) occurred into nylon bags (12×10 cm, 40 µm pore size) and incubation duplicate bags per treatment in each sheep for 72 h. After removal, they soaked bags in cold water for 15 min, froze them at –30 °C for 24 h, thawed at 4 °C, rinsed, dried at 60 °C for 48 h, and weighed residues. They analyzed residues for NDF, ADF, and CP allowed calculation of dry matter (DMD), organic matter (OMD), and crude protein digestibility (CPD). Metabolizable energy (ME) and net energy for lactation (NEL) followed Caceres and García (2000).

***In vitro* gas production**

The study measured gas production with the pressure transducer method (Cabral et al. 2020). The team weighed 500±10 mg of sample into 120 mL serum bottles containing 50 mL of rumen fluid diluted 1:4 (v/v) with culture medium (Njidda 2020). After sealing under CO_2, incubation of bottles at 39 °C happened and recording of gas pressure at 3, 6, 9, 12, 16, 21, 26, 31, 36, 48, 60, 72, 96, 120, and 144 h post-inoculation followed. The calculation of gas volume (mL g^{-1} DM) used the equation of Dhanoa et al. (2023). The experiment Researchers fitted data to the exponential model (Equation 1) of Powell et al. (2020):

$$G = A\,[1 - e - c(t - L)] \quad (1)$$

Where G is the cumulative gas production (mL g^{-1} DM), A is the asymptotic gas production (mL g^{-1} DM), c is the fractional fermentation rate (h^{-1}), and L is the lag time (h). The average fermentation rate R (mL g^{-1} DM h^{-1}) used

(Equation 2):

$$R = Ac / [2 (\ln 2 + cL)] \quad (2)$$

Statistical analysis

The analysis began with a significance level of $P<0.05$. The study conducted a two-way bidirectional ANOVA with the factorial model (Equation 3):

$$Yijk= \mu + \alpha i + \beta j + (\alpha\beta)ij + \varepsilon ijk \quad (3)$$

Where Yijk is the observed value, μ is the overall mean, αi is the effect of regrowth age (i=1 to 5), βj = effect of climatic period (j=1,2), (αβ)ij = interaction, and εijk = random error. Verification of normality (Kolmogorov–Smirnov test) and homoscedasticity (Bartlett's test) preceded analysis. When ANOVA showed significance ($P<0.05$), application of Tukey's honest significant difference (HSD) test for post hoc comparisons occurred.

In addition, experiments exploring multivariate analyses such as canonical correlation and discriminant analysis to identify patterns among chemical, digestibility, and fermentability variables across treatments. Justification multivariate analysis relied on need to integrate multiple variables for comprehensive quality assessment. The test of Multivariate significance used Wilks' Lambda test with $P<0.05$ as the threshold. All analyses used SPSS v.22 (IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSION

The results summarized in Table 1 demonstrate distinct associations between the chemical composition, nutritive quality, and fermentability variables of *Teramnus labialis* according to regrowth age and climate period. Specifically, the canonical coefficients reveal that the first set, which encompasses chemical composition traits, shows positive correlations for dry matter (DM, 0.46), neutral detergent fiber (NDF, 0.59), acid detergent fiber (ADF, 0.50), and lignin (0.42), while crude protein (CP) presents a negative correlation (-0.55). The second set, which includes nutritive and fermentability factors, shows moderate positive correlations with *in vitro* dry matter digestibility (IVDMD,), dry matter digestibility (DMD), organic matter digestibility (OMD), and metabolizable energy (ME). Gas production rate (S) correlates positively (0.31), whereas maximum gas volume (Vm) and lag time (λ) correlate negatively (-0.29 and -0.25, respectively).

Table 1. Standardized canonical coefficients of chemical composition, nutritive quality, and fermentability variables in *Teramnus labialis* according to regrowth age and climate period.

Variables	Set	
	Chemical Composition	Nutritive Quality and Fermentability
Dry matter (DM)	0.46	–
Crude protein (CP)	-0.55	–
Calcium (Ca)	0.11	–
Phosphorus (P)	0.08	–
Magnesium (Mg)	0.17	–
Silica (Si)	0.20	–
Neutral detergent fiber (NDF)	0.59	–
Acid detergent fiber (ADF)	0.50	–
Lignin	0.42	–
Cellulose (Cel)	0.38	–
Hemicellulose (Hcel)	0.25	–
Cell content (CC)	0.30	–
Ash	-0.10	–
Organic matter (OM)	-0.15	–

Table 1

Variables	Set	
	Chemical Composition	Nutritive Quality and Fermentability
***In vitro* dry matter digestibility (IVDMD)**	–	0.65
Dry matter digestibility (DMD)	–	0.54
Organic matter digestibility (OMD)	–	0.63
***In situ* dry matter digestibility (ISDMD)**	–	0.60
Metabolizable energy (ME)	–	0.57
Net energy for lactation (NEL)	–	0.53
Total tannins (TT)	0.51	–
Total phenols (TP)	0.48	–
Total condensed tannins (TCT)	0.45	–
Total bound condensed tannins (TBCT)	0.40	–
Free condensed tannins (FCT)	0.38	–
Crude protein digestibility (CPD)	–	0.54
Neutral detergent fiber digestibility (NDFD)	–	0.49
Acid detergent fiber digestibility (ADFD)	–	0.47
Verbascose	0.31	–
Stachyose	0.33	–
Raffinose	0.29	–
Glucose	-0.30	–
Fructose	-0.28	–
Sucrose	-0.26	–
Total flavonoids	0.43	–
Total alkaloids	0.34	–
Total saponins	0.36	–
Total triterpenes	0.32	–
Total steroids	0.30	–
Maximum gas volume (Vm)	–	-0.29
Gas production rate (S)	–	0.31
Lag time (λ)	–	-0.25

These findings align with studies conducted under semi-arid and tropical conditions of Marius et al. (2021) and Acosta et al. (2024), which report that the fiber content, especially NDF and ADF, strongly influences forage quality because limits digestibility as plants mature. High fiber correlates with lower crude protein and digestibility, as observed here by the inverse relationship between CP and fiber components. This biological phenomenon occurs because cell wall thicken dilutes cellular contents. Similar behavior appears in the phenolic compounds such as total tannins and condensed tannins, which relate positively with chemical composition variables but often exert inhibitory effects on fermentability (Verdecía et al. 2021). This dual role of tannins agrees with previous observations that moderate tannin levels can protect dietary protein from ruminal degradation but excessive concentrations reduce microbial fermentation (Milera-Rodríguez et al. 2019).

Climatic influence on forage quality emerges as a key factor, since seasonal variations impact plant growth and secondary metabolite accumulation (Marius et al. 2021). The current data support this notion, as digestibility and

energy show higher values in the rainy season, whereas fiber and phenolic compounds tend to increase during drier periods, possibly as an adaptation to environmental stress (Acosta et al. 2024). The negative correlations of maximum gas volume and lag time with nutritive quality confirm that more degradable forages produce greater gas amounts faster, which reflect enhanced fermentability (Strafella et al. 2020).

Biologically, these relationships reflect the balance between structural carbohydrates that provide physical support but resist microbial breakdown and chemical constituents that modulate microbial efficiency. As the plant ages, cell wall components like lignin increase, which impede microbial access and digestion, which explains the lower digestibility and fermentability seen with higher fiber content (Marius et al. 2021). Concurrently, secondary metabolites such as tannins and phenolics serve defensive roles against herbivory, which influence microbial activity in the rumen and feed utilization (Verdecía et al. 2021).

The multivariate distribution of chemical composition and fermentability variables that influence the nutritive quality of *Teramnus labialis* (Figure 1). The analysis separates variables into two main sets: Set 1, representing chemical composition traits such as dry matter, crude protein, fiber fractions, and secondary metabolites including tannins and phenols; and Set 2, encompassing nutritive quality and fermentability variables, including digestibility measures and fermentation kinetics parameters. Dry matter, neutral detergent fiber, acid detergent fiber, and lignin show strong positive associations within the chemical composition set, while crude protein exhibits a pronounced negative correlation. In contrast, *in vitro* dry matter digestibility, organic matter digestibility, and metabolizable energy load heavily within the nutritive quality and fermentability set. Gas production rate correlates positively with digestibility factors, whereas maximum gas volume and lag time exhibit negative correlations.

These results converge with finds by Kurniawan et al. (2025), who demonstrated that multivariate analysis effectively discriminates legume quality by integrating chemical composition and digestibility values. The inverse relationship between fiber content and crude protein aligns with their classification, what indicates that higher fiber and structural constituents limit digestibility, which reduces overall nutritive value. Additionally, Adebo et al. (2022) emphasized the impact of fermentation processes on improving nutrient bioavailability in legumes, what reflects the positive associations observed here between fermentability parameters and digestibility.

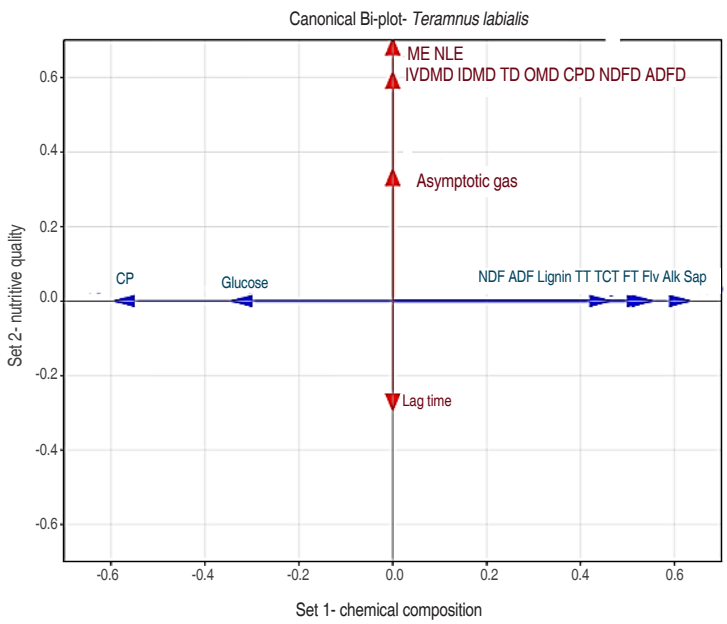


Figure 1. Multivariate distribution of chemical and fermentability variables affecting nutritive quality of *Teramnus labialis*.

Senanayake et al. (2023) further support these observations by demonstrating that microbial fermentation modulates the sensory and nutritional attributes of legumes in response to their biochemical composition. The negative correlation of lag time with nutritive quality parameters indicates that more readily fermentable forages initiate gas production sooner, which enhances energy availability, a pattern consistent with the fermentation kinetics described by Meng et al. (2024).

Moreover, secondary metabolites such as tannins and phenols contribute complex effects. While tannins appear positively correlated with chemical composition variables, their presence can both protect protein from ruminal degradation and inhibit microbial activity when present in excess, as reported by Yakubu et al. (2022). This nuanced biological role explains the moderate correlations observed in this study.

Comparisons with studies on cowpea germplasm by Deepika et al. (2023) and faba bean research by Guevara Oquendo et al. (2022) reinforce the importance of considering both chemical and fermentability traits for comprehensive forage quality assessments. These studies collectively highlight the significance of integrating multiple variables to guide forage management decisions, optimizing harvest timing relative to regrowth stage and climatic conditions to maximize nutritive value.

The results presented in Table 2 report multivariate statistics for discriminant functions that analyze chemical composition and fermentability variables in *Teramnus labialis*. The first function explains the greatest variance with a high correlation coefficient (R=0.87) and a statistically significant Wilks' Lambda of 0.10 (χ^2=50.2, df=24, *P*<0.0001). This indicates a strong discriminatory power in differentiating groups based on the combined chemical and fermentability variables. The second function shows a moderate correlation and a Wilks' Lambda of 0.37, though it does not reach statistical significance at the conventional level. The third function accounts for less variance and shows a weaker correlation with no statistical significance.

Table 2. Multivariate statistics for discriminant functions of chemical composition and fermentability variables in *Teramnus labialis*.

Function	Correlation (R)	Wilks' Lambda	Chi-square(χ^2)	Degrees of Freedom (df)	P-Value
1	0.87	0.10	50.2	24	<0.0001
2	0.70	0.37	21.5	16	0.085
3	0.50	0.68	10.2	10	0.40

Function 1: represents the primary discriminant axis separating regrowth ages; Function 2 and 3: represent secondary variance components related to climatic periods.

These findings demonstrate clear multivariate differentiation among the *Teramnus labialis* treatments, reflecting the influence of regrowth age and climate period on forage quality. The dominance of the first function aligns with previous studies that successfully employed discriminant analysis to classify legume quality based on chemical fingerprints combined with supervised learning (Pérez-Rodríguez et al. 2019). Similarly, Baath et al. (2020) used near-infrared spectroscopy and machine learning techniques to predict forage quality in warm-season legumes, while corroborate with the effectiveness of multivariate approaches in forage evaluation.

The significant discrimination observed suggests that both chemical composition and fermentability variables collectively impact the nutritive variation in *Teramnus labialis*. Johnson et al. (2004) highlighted the utility of chemometric techniques coupled with spectral data to fingerprint silage fermentations, which echoes the value this integrate diverse chemical and fermentation parameters. Furthermore, Dal Prà et al. (2023) utilized discriminant analysis to classify farm hay quality effectively, with the emphasizes multivariate methods' applicability in forage quality assessments.

Growth stage and environmental conditions modulate the biochemical pathways in forage legumes, this led to variations in fiber content, secondary metabolites, and fermentability attributes (Fu et al. 2023). Takla et al. (2023) reported that roasting and fermentation influence metabolites' concentration in plant materials, which suggest that similar microbial and biochemical processes

may underpin the observed discrimination in *Teramnus labialis*. The integration of multiple fermentation and chemical variables, as shown by Kurniawan et al. (2025), facilitates more precise classification of legume quality, therefore supports informed management decisions.

Table 3 presents mean values of chemical composition, digestibility, and fermentability variables of *Teramnus labialis* grouped by regrowth age and climatic period (rainy and dry seasons). During the rainy season, dry matter content (DM) remains fairly consistent for younger plants, with a slight increase at later stages (75 and 90 days). Crude protein (CP) shows a modest decline from 19.7 to 18.6%, which coincides with a minor increase in fiber fractions, including neutral detergent fiber (NDF) at 50.7–51.6%, and acid detergent fiber (ADF).

Notably, lignin content rises sharply at 75 days (6.47%), which indicates increased cell wall structural complexity. Total tannins (TT) diminish slightly from 0.81 to 0.79. Digestibility indicators, such as *in vitro* dry matter digestibility (IVDMD) decrease from 61.4 to 58.5%, accompanied by modest reductions in metabolizable energy (ME) and net energy for lactation (NEL). Fermentability measurements reveal decreasing maximum gas volume (Vm) in later stages and lowered gas production rate (S) from 0.85 to -0.07, while lag time (λ) shortens from 2.19 to about 1.85–1.87 hours.

Table 3. Mean key variables of chemical composition, digestibility, and fermentability in *Teramnus labialis* by regrowth age and climate period (Rainy vs. Dry).

Age (days)	Season	DM	CP	NDF	ADF	Lignin	TT	IVDMD	ME	NEL	Vm	S	λ
30		17.3	19.7	50.7	30.2	2.11	0.81	61.4	10.1	5.8	5.7	0.85	2.19
45		17.3	19.7	50.7	30.2	2.11	0.82	61.3	10.0	6.0	5.9	0.83	2.19
60	Rainy	17.3	19.8	50.7	30.2	2.12	0.81	61.4	10.6	5.9	6.0	0.80	2.20
75		19.2	18.6	51.6	30.6	6.47	0.78	58.5	9.4	5.6	5.6	-0.07	1.85
90		19.2	18.6	51.6	30.6	6.47	0.79	58.5	9.6	5.7	5.7	-0.07	1.87
30		18.0	16.4	49.2	28.3	3.33	0.89	61.1	9.6	5.8	5.8	0.91	0.91
45		21.4	16.5	51.9	31.7	7.37	1.02	57.8	9.1	5.4	5.6	2.37	1.27
60	Dry	21.4	16.5	51.9	31.7	7.37	1.03	57.9	9.1	5.4	5.7	2.32	1.26
75		21.4	16.5	52.0	31.8	7.37	1.00	57.9	9.1	5.4	5.5	2.28	1.27
90		23.8	14.2	56.9	36.6	8.53	1.13	57.9	9.0	5.3	5.6	2.64	0.92

DM: Dry matter; CP: Crude protein; NDF: Neutral detergent fiber; ADF: Acid detergent fiber, TT: Total tannins; IVDMD: *In vitro* dry matter, ME: Metabolizable energy; NEL: Net energy for lactation, Vm: Maximum gas volume (mL g^{-1} DM); S: Gas production rate (mL h^{-1}); λ: Lag time (h).

In contrast, the dry season exhibits increases in DM with regrowth age, alongside a more pronounced decline in CP. Fiber components exhibit marked increases: NDF ranges from 49.2 up to 56.9%, and ADF from 28.3 to 36.6%. Lignin content similarly rises to at 90 days, so reflect intensified cell wall maturation under drier environmental conditions. Total tannins (TT) increase notably, which likely represent biochemical response to water stress. Digestibility metrics (IVDMD, ME, NEL) steadily decline with plant age. Gas production volume (Vm) shows variations across, and the gas production rate (S) peaks at intermediate regrowth ages, while lag time (λ) decreases slightly from 0.91 to 0.92 hours.

These results align with prior findings indicating that younger forage stages typically maintain higher crude protein and lower fiber contents, thus exhibiting enhanced digestibility (Marius et al. 2021; Kurniawan et al. 2025). The elevated fiber and tannin levels during the dry season corroborate observations of plant adaptation mechanisms to drought stress, which negatively affect nutritive value (Verdecía et al. 2021). Similar declines in digestibility have been documented in other legumes and forage species with face environmental stress (Adebo et al. 2022; Guevara Oquendo et al. 2022). Fermentation parameters mirror these changes in chemical composition and digestibility. Reduced gas

production volume and rate in older, more fibrous plants reflect decreased microbial accessibility and slower ruminal degradation kinetics (Senanayake et al. 2023; Meng et al. 2024). The lag time decrease in the dry season may indicate faster adaptation of rumen microbiota to substrate or variations in substrate composition (Strafella et al. 2020). The peak in S at intermediate ages suggest optimal substrate availability before lignification dominate.

CONCLUSION

Regrowth age and climatic period determine the nutritional profile of *Teramnus labialis* (L.f.) Sprend through chemical and fermentability modulation. Early growth stages during the rainy season maximize forage quality, whereas maturity accelerates lignification and reduces digestibility. Producers should harvest *T. labialis* at $\leq$60 days, preferably during the rainy season, to optimize livestock performance and sustain pasture-based systems. Future studies must validate these guidelines under conditions across diverse agroecological zones.

CONFLICT OF INTERESTS

The authors declare that they have no conflicts of interest in relation to this research study.

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