Preliminary evaluation of ruminal degradation kinetics of diets containing *Bursera simaruba* foliage flour †

[Evaluación preliminar de la cinética de degradación ruminal de dietas con harina de follaje de *Bursera simaruba*]

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SUMMARY

Background. The search for alternative forage sources has become increasingly important due to seasonal feed scarcity and the need for sustainable livestock production systems. *Bursera simaruba* (Sarg.) represents a promising native forage species with potential nutritional value for ruminants, but its ruminal degradation characteristics remain poorly understood. **Objective.** The objective of this preliminary study was to evaluate the ruminal degradation of diets with different inclusion levels of *Bursera simaruba* foliage flour in cattle. **Methodology.** Three rumen-cannulated cows (380 ± 10 kg live weight) were used to evaluate four treatments: Bs0) control diet without inclusion; Bs15) diet with 15% inclusion; Bs30) diet with 30% inclusion; and Bs45) diet with 45% inclusion. *B. simaruba* foliage with 90 days of regrowth was used. Ruminal degradability was evaluated using the nylon bag technique incubated at 0, 6, 12, 24, 48, 72, and 96 h. Data were fitted with the equation $p = a + b (1 - Exp^{(-ct)})$. **Results.** The rapidly soluble fraction (a) of dry matter and crude protein was higher in Bs15 ($p < 0.05$). The effective degradability of dry matter and crude protein at a passage rate of 0.02 h^{-1} was similar between Bs0 and Bs15 ($p > 0.05$), both being higher than Bs30 and Bs45. **Implications.** The 15% inclusion level of *B. simaruba* maintained ruminal degradation parameters similar to the control diet, suggesting potential applicability in tropical cattle feeding systems. However, this preliminary study has significant methodological limitations including confounding effects between *B. simaruba* inclusion and forage:concentrate ratios that limit definitive conclusions. **Conclusion.** The findings suggest that moderate inclusion (15%) of *B. simaruba* might maintain ruminal degradation parameters similar to a control diet, but additional studies with more robust experimental designs are needed to validate these results.
Key words: tropical tree; ruminal degradation; forage; preliminary study; experimental limitations.

RESUMEN

Antecedentes. La búsqueda de fuentes alternativas de forraje ha cobrado cada vez mayor importancia debido a la escasez estacional de alimento y a la necesidad de sistemas de producción ganadera sostenibles. *Bursera simaruba* (Sarg.) representa una especie forrajera nativa prometedora con potencial valor nutricional para rumiantes, pero sus características de degradación ruminal aún son poco conocidas. **Objetivo.** El objetivo de este estudio preliminar fue evaluar la degradación ruminal de dietas con diferentes niveles de inclusión de harina

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de follaje de *Bursera simaruba* en ganado bovino. **Metodología.** Se utilizaron tres vacas canuladas (380 ± 10 kg de peso vivo) para evaluar cuatro tratamientos: Bs0) dieta control sin inclusión; Bs15) dieta con 15% de inclusión; Bs30) dieta con 30% de inclusión; y Bs45) dieta con 45% de inclusión. Se utilizó follaje de *B. simaruba* de 90 días de rebrote. La degradabilidad ruminal se evaluó mediante la técnica de bolsas de nailon incubadas a las 0, 6, 12, 24, 48, 72 y 96 h. Los datos se ajustaron con la ecuación $p = a + b (1 - Exp^{(-ct)})$. **Resultados.** La fracción rápidamente soluble (a) de materia seca y proteína cruda fue mayor en Bs15 ($p < 0.05$). La degradabilidad efectiva de materia seca y proteína cruda a una tasa de paso de 0.02 h^{-1} fue similar entre Bs0 y Bs15 ($p > 0.05$), siendo ambas mayores que Bs30 y Bs45. **Implicaciones.** La inclusión de *B. simaruba* al 15% mantuvo parámetros de degradación ruminal similares a los de la dieta control, lo que sugiere su posible aplicabilidad en sistemas de alimentación de ganado tropical. Sin embargo, este estudio preliminar presenta limitaciones metodológicas significativas, incluyendo efectos de confusión entre la inclusión de *B. simaruba* y las proporciones forraje:concentrado, lo que limita la posibilidad de obtener conclusiones definitivas. **Conclusión.** Los hallazgos sugieren que la inclusión moderada (15%) de *B. simaruba* podría mantener parámetros de degradación ruminal similares a una dieta control, pero se requieren estudios adicionales con diseños experimentales más robustos para validar estos resultados.
Palabras clave: árbol tropical; degradación ruminal; forraje; estudio preliminar; limitaciones experimentales.

INTRODUCTION

Meat and milk production in tropical regions faces significant challenges related to forage availability and quality throughout the year (Aguilar-Pérez *et al*., 2011; Absalón-Medina *et al*., 2012). The seasonal variations in rainfall patterns typical of tropical regions result in periods of forage scarcity that limit livestock productivity and economic sustainability of production systems. One promising approach to address this challenge is the strategic use of local tree resources as supplementary feed sources, which can be integrated into livestock production systems through silvopastoral approaches.

In the Yucatan Peninsula of Mexico, several tree species have been identified as potential feed resources for ruminants, including *Leucaena leucocephala*, *Gliricidia sepium*, *Enterolobium cyclocarpum*, and others (Canul-Solis *et al*., 2020). Among these species, *Bursera simaruba* (locally known as "chaca") represents an interesting alternative due to its wide distribution throughout Mexico, particularly in areas up to 1000 m above sea level (Alfaro-Reyna *et al*., 2023), and its remarkable resilience during drought conditions, maintaining green foliage when other species have shed their leaves. This characteristic makes it particularly valuable during the dry season when conventional forages are scarce or of poor quality.

The integration of tree species into livestock production systems represents a sustainable intensification strategy that can address multiple objectives simultaneously: providing supplementary feed resources during critical periods, improving soil fertility through nitrogen fixation and organic matter inputs, sequestering carbon in above- and below-ground biomass, and enhancing biodiversity conservation (Murgueitio *et al*., 2011). Research in Latin American silvopastoral systems has demonstrated that strategic integration of fodder trees can increase farm productivity by 50-100% while maintaining or improving ecosystem services (Chará *et al*., 2019). The sustainability of these systems depends on appropriate management practices that balance forage extraction with plant regeneration capacity. For *B. simaruba* specifically, the use of 90-day regrowth material represents a compromise between biomass availability and nutrient quality, allowing periodic harvesting without compromising plant survival or long-term productivity (Verdecia *et al*., 2013).

The form of presentation and processing of tree foliage can significantly influence its nutritional value and utilization by ruminants. Fresh foliage typically has a high moisture content (70-80%), which limits voluntary intake and complicates storage and transportation (Salem *et al*., 2006). Processing methods such as drying and grinding into flour or meal form offer several advantages: (1) reduction of moisture content improves storage stability and prevents microbial spoilage; (2) grinding increases surface area for microbial attachment, potentially enhancing degradation rates; (3) flour form facilitates incorporation into balanced diets and allows for more precise supplementation strategies (Mapiye *et al*., 2011). However, drying processes may also alter the chemical composition and bioavailability of nutrients, particularly affecting heat-labile vitamins and potentially modifying the structure of secondary metabolites such as tannins (Ramsumair *et al*., 2014). Pelletization can further improve handling characteristics and reduce dustiness, though it may increase processing costs. The choice of processing method should strike a balance between nutritional preservation, practical

applicability, and economic feasibility within the target production system.

Previous research has characterized the chemical composition of *B. simaruba* foliage, reporting approximately 26% dry matter (DM), 88-92% organic matter (OM), 11.5-11.6% crude protein (CP), 44-45.2% neutral detergent fiber (NDF), 34-44% acid detergent fiber (ADF), 3.30% ethereal extract (EE), 4.62% condensed tannins (CT), and 3.90% saponins (Ascencio-Rojas *et al.*, 2019). The presence of condensed tannins is particularly noteworthy, as these secondary compounds can have significant effects on ruminal protein degradation. Research has shown that moderate levels of condensed tannins (2-4% of DM) can reduce ruminal protein degradation, decrease ammonia production, and increase the flow of undegradable protein to the small intestine, potentially improving nitrogen utilization efficiency (Patra and Saxena, 2011; Barry and McNabb, 1999).

Additionally, *B. simaruba* has demonstrated potentially degradable dry matter fractions in the rumen of 16.7%, 21.7%, 25.9%, 32.6%, 38.6%, and 64.6% at incubation times of 6, 12, 24, 48, 72, and 96 hours, respectively (Ángeles-Mayorga *et al.*, 2022). These degradation characteristics suggest that *B. simaruba* could be a valuable feed resource for ruminants in tropical regions, particularly when incorporated strategically into feeding systems.

However, there is limited information on the effects of varying levels of *B. simaruba* in ruminant diets on ruminal degradation parameters, particularly when formulated as complete diets rather than as standalone ingredients. The interaction between *B. simaruba* and other dietary components, as well as the effects of varying inclusion levels on overall diet digestibility, remains largely unexplored.

It was hypothesized that moderate inclusion levels of *B. simaruba* foliage (15-30%) could maintain ruminal degradation parameters similar to a conventional diet, while higher inclusion levels (45%) might negatively affect degradation due to increased fiber content and the influence of secondary compounds such as condensed tannins. Therefore, the objective of this preliminary study was to evaluate the effect of increasing levels of *B. simaruba* foliage inclusion on the ruminal degradation kinetics of diets potentially suitable for cattle feeding, while acknowledging the methodological limitations inherent in the experimental design employed.

MATERIALS AND METHODS

Study area and ethical approval

This preliminary study was conducted at the Instituto Tecnológico de Tizimín, Yucatán, Mexico, located at 21° 09' 29" north latitude and 88° 10' 21" west longitude. The climate in this region is classified as warm subhumid with summer rains (Aw0) according to García (2004), with an average annual precipitation of 1167 mm, mean temperature of 27°C, and relative humidity of 68.5-86.3%.

All experimental procedures involving animals were conducted following guidelines established by Tucker *et al*. (2020) for the care and use of agricultural animals in research.

Experimental animals and housing

Three crossbred cows (Cebu×Swiss) with an average body weight of 380 ± 10 kg, fitted with permanent ruminal cannula (Bar Diamond, Parma, Idaho, USA), were used in this study. The animals were individually housed in pens with free access to fresh water and fed twice daily (09:00 and 16:00 h) with chopped *Pennisetum purpureum* (70 days of growth) supplemented with 20% of a balanced feed (70% non-protein nitrogen and 30% ground corn) to meet maintenance requirements according to AFRC (1993). Animals were adapted to the basal diet for 14 days before the start of the experimental period. The total study duration was 35 days, comprising 14 days of adaptation followed by 21 days of experimental measurements (7 days per incubation run, with three complete runs to evaluate all treatment combinations).

Plant material collection and identification

B. simaruba foliage with 90 days of regrowth was manually harvested from a cattle ranch located in Calotmul, near Tizimín, in eastern Yucatan. The plant material was collected from a *B. simaruba* plantation used to support the cultivation of pitahaya (*Hylocereus undatus*). The harvested material (leaves and small stems < 5 mm diameter) was air-dried for seven days at ambient temperature, followed by oven-drying at 60°C for 48 h. The dried material was then ground through a 2 mm screen in a Wiley mill to produce *B. simaruba* foliage flour.

Experimental diets and compositional limitations

Four experimental diets were formulated with increasing levels of *B. simaruba* foliage: Bs0 (0%),

Bs15 (15%), Bs30 (30%), and Bs45 (45%). As the inclusion level of *B. simaruba* increased, the total forage content also increased substantially (20% in Bs0, 34.2% in Bs15, 47.3% in Bs30, and 65.1% in Bs45), while the concentrate content (particularly ground corn) decreased proportionally (Table 1). This compositional difference represents a critical confounding factor, as differences in the forage:concentrate ratio can influence ruminal degradation parameters independently of *B. simaruba* effects. Therefore, the observed differences cannot be attributed solely to *B. simaruba* inclusion but likely reflect the combined effect of changing *B. simaruba* levels and varying forage:concentrate ratios.

In situ ruminal degradation

The ruminal degradability of experimental diets was determined using the nylon bag technique as described by Mehrez and Ørskov (1977). Samples of each diet (approximately 5 g, ground to pass through a 2 mm screen) were placed in nylon bags (ANKOM Co, Fairport, NY, USA) with a pore size of 50 ± 3 μm and dimensions of 10×20 cm, providing a sample size to surface area ratio of approximately 25 mg/cm², which is within the recommended range for concentrate-type diets as suggested by recent research (Vanzant *et al*., 1996).

This study employed a completely randomized design where each diet and incubation time combination was represented by three bags (technical replicates) incubated in each of the three cannulated cows, for a total of nine observations per treatment per time point. Multiple treatments were incubated simultaneously within each animal and the use of nylon bags as experimental units rather than animals were pseudoreplication.

Table 1. Ingredient composition (% as-fed basis) and calculated forage to concentrate ratios of experimental diets containing increasing levels of *Bursera simaruba* foliage flour.

Ingredient (%)	Bs0	Bs15	Bs30	Bs45
Bursera simaruba	0.00	15.02	30.03	45.12
Cane molasses	8.44	6.14	5.54	5.88
Ground corn	66.83	56.57	42.94	21.35
Soya flour	0.42	3.07	4.16	7.65
Urea	0.08	0.00	0.00	0.00
Malt flour	4.18	0.00	0.00	0.00
Pennisetum purpureum	20.05	19.20	17.33	20.00
Total forage content	20.05	34.22	47.36	65.12
Total concentrate content	79.95	65.78	52.64	34.88

Table 2. Chemical composition (% dry matter basis) of experimental diets containing increasing levels of *Bursera simaruba* foliage flour (NDF and ADF values were calculated based on ingredient composition using published values).

Parameters (%)	Bs0	Bs15	Bs30	Bs45
DM	85.88	84.76	80.15	82.07
OM	67.01	73.53	79.40	83.73
CP	11.64	12.27	12.55	14.96
NDF†	28.42	32.18	36.94	41.72
ADF†	16.87	21.56	26.25	30.94

DM: Dry matter; OM: Organic matter; CP: Crude protein; NDF: Neutral detergent fiber; ADF: Acid detergent fiber. *Estimated values based on ingredient composition using published values for individual ingredients.
†NDF and ADF values were estimated using the following equation: Nutrient_diet = Σ(Nutrient_ingredient × Proportion_ingredient). Values for individual ingredients were obtained from: *Pennisetum purpureum* hay at 70 days of regrowth (NDF: 67.0%, ADF: 37.0%; Kozloski *et al*., 2005), *B. simaruba* foliage (NDF: 44.0%, ADF: 34.0%; Ascencio-Rojas *et al*., 2019), ground corn (NDF: 9.5%, ADF: 2.9%; NRC, 2001), soybean meal (NDF: 8.7%, ADF: 5.4%; NRC, 2001), and cane molasses (NDF: 0%, ADF: 0%; assumed negligible fiber content).

The bags were incubated according to the reverse sequence method, where bags for longer incubation times were introduced first, starting with the 96 h incubation and ending with the 6 h incubation, so that all bags could be removed simultaneously as described by Nocek and Russell (1988). This approach helps minimize handling stress and ensures consistent removal conditions. Incubation times were 0, 6, 12, 24, 48, 72, and 96 h. The 0 h bags were not incubated in the rumen and were only subjected to the washing procedure to determine the immediately soluble fraction.

After removal, all bags were rinsed under cold running tap water until the rinse water was clear, gently manipulating the bags to ensure thorough washing without excessive force. The washed bags were then dried at 60°C for 48 h in a forced-air oven, and residues were weighed to determine DM disappearance. The residues from the three bags per cow at each incubation time were pooled for subsequent chemical analysis.

Chemical analysis

Dry matter content was determined by drying samples at 105°C for 24 h according to AOAC (2016) procedures. Ash content was determined by incineration at 550°C for 4 h. Crude protein was determined by the Kjeldahl method ($N \times 6.25$) following AOAC (2016) procedures. All chemical analyses were performed in triplicate.

Calculations and statistical analysis

The DM and CP disappearance data were fitted to the exponential model of Ørskov and McDonald (1979):

$$p = a + b (1 - Exp^{(-ct)})$$

where p is the actual degradation at time t, a is the rapidly soluble fraction, b is the potentially degradable fraction, c is the rate of degradation of fraction b, and t is time in hours.

The effective degradability (ED) was calculated using the equation:

$$ED = a + [b \times c / (c + k)]$$

where k is the estimated rate of passage from the rumen. Values of 0.02, 0.05, and 0.08 h^{-1} were used to represent slow, medium, and fast passage rates, respectively (AFRC, 1993).

Data for ruminal degradation parameters (a, b, c, a+b, and ED) were analyzed using a general linear model with treatment as the fixed effect and cow as a random effect. Prior to analysis, the assumptions of normality of residuals and homogeneity of variance were verified using the Shapiro-Wilk and Levene's tests, respectively. When significant differences were observed ($p < 0.05$), means were compared using Tukey's test. Statistical analyses were performed using InfoStat 2020 software (Di Rienzo *et al.*, 2018). The goodness of fit was evaluated using the coefficient of determination (R^2)

RESULTS

Ruminal degradation of dry matter

The rapidly soluble fraction (a) of DM showed significant differences among treatments (p = 0.009), with Bs15 showing the highest value and Bs30 the lowest. The potentially degradable fraction (b) did not differ significantly among treatments (p = 0.19), while the degradation rate (c) decreased significantly with increasing *B. simaruba* inclusion (p < 0.001), with Bs0 and Bs15 maintaining higher rates than Bs30 and Bs45. However, the potential degradability (a+b) showed a significant reduction (p = 0.05) in treatments with high inclusion of *B. simaruba*, observing the highest extent in Bs0 (52.63%) and the lowest in Bs30 (32.83%). The effective degradability (ED) of DM at passage rate k = 0.02 h^{-1} demonstrated a clear pattern: Bs0 and Bs15 achieved significantly higher values (40.11% and 35.87%, respectively; p < 0.001) compared to Bs30 and Bs45 (18.50% and 22.90%, respectively). This pattern persisted across all passage rates evaluated (Table 3).

Ruminal degradation of crude protein

Crude protein degradation parameters showed similar patterns to DM. The rapidly soluble fraction (a) was highest in Bs15 (12.12%), while Bs30 showed the lowest value (1.5%; p = 0.01). The potentially degradable fraction (b) was significantly reduced only in Bs45 (26.09%) compared to other treatments (33.44-35.27%; p = 0.01). The degradation rate of CP was significantly higher in Bs0 (0.07 h^{-1}) compared to all other treatments (0.02-0.03 h^{-1}; p = 0.01). Effective degradability at k = 0.02 h^{-1} followed the established pattern, with Bs0 and Bs15 showing superior values (32.60% and 28.94%, respectively) compared to Bs30 and Bs45 (20.47% and 23.00%, respectively; p = 0.01) (Table 4).

Table 3. Effect of *Bursera simaruba* foliage inclusion level on the ruminal degradation parameters of dry matter in experimental diets.

Variable	Level of *B. simaruba* (%)				SEM	p-value
	Bs0	Bs15	Bs30	Bs45		
Dry matter degradation (%)						
Rapidly soluble fraction (a)	7.86[ab]	10.92[a]	2.98[b]	6.59[ab]	1.89	0.009
Potentially degradable fraction (b)	44.77	35.22	29.84	36.42	4.39	0.190
Degradation rate (c)	0.05[a]	0.04[a]	0.02[b]	0.01[b]	0.004	< 0.001
Potential degradability (a+b)	52.63[a]	46.15[ab]	32.83[c]	43.02[b]	4.25	0.050
Effective degradability (%)						
$k = 0.02$ h^{-1}	40.11[a]	35.87[a]	18.50[b]	22.90[b]	2.61	< 0.001
$k = 0.05$ h^{-1}	30.69[a]	28.31[a]	12.05[b]	15.56[b]	1.85	< 0.001
$k = 0.08$ h^{-1}	25.56[a]	24.27[a]	9.39[b]	12.78[b]	1.54	< 0.001

[a,b,c] Means in the same row with different superscripts differ significantly according to Tukey's test (p < 0.05). SEM: standard error of the mean.

Table 4. Effect of *Bursera simaruba* foliage inclusion level on the ruminal degradation parameters of crude protein in experimental diets.

Variable	Level of *B. simaruba* (%)				SEM	p-value
	Bs0	Bs15	Bs30	Bs45		
Crude protein degradation (%)						
Rapidly soluble fraction (a)	6.24[bc]	12.12[a]	1.5[c]	7.46[ab]	1.07	0.01
Potentially degradable fraction (b)	33.44[ab]	35.27[a]	34.61[a]	26.09[b]	1.63	0.01
Degradation rate (c)	0.07[a]	0.02[b]	0.03[b]	0.03[b]	0.01	0.01
Potential degradability (a+b)	39.68[b]	47.40[a]	36.11[bc]	33.55[c]	1.35	0.01
Effective degradability (%)						
$k = 0.02$ h^{-1}	32.60[a]	28.94[a]	20.47[b]	23.00[b]	0.91	0.01
$k = 0.05$ h^{-1}	26.26[a]	21.56[b]	13.11[c]	17.21[b]	0.99	0.01
$k = 0.08$ h^{-1}	22.39[a]	18.69[ab]	9.91[c]	14.58[b]	0.92	0.01

[a,b,c] Means in the same row with different superscripts differ significantly according to Tukey's test (p < 0.05). SEM: standard error of the mean.

DISCUSSION

This preliminary study evaluated the effect of different inclusion levels of *B. simaruba* foliage on the ruminal degradation kinetics of dry matter and crude protein in experimental diets. The findings suggest that moderate inclusion (15%) of *B. simaruba* foliage maintained ruminal degradation parameters relatively similar to the control diet, while higher inclusion levels (30% and 45%) generally resulted in reduced degradation. However, these results must be interpreted with considerable caution due to significant methodological limitations inherent in the experimental design.

Critical limitations and confounding factors

The most significant limitation of this study is the substantial variation in forage:concentrate ratios across treatments. As *B. simaruba* inclusion increased from 0% to 45%, the total forage content increased from 20% to 65.1%, while concentrate content decreased from approximately 80% to 35%. This compositional difference could independently affect ruminal degradation parameters, as diets with higher concentrate proportions typically exhibit higher degradability due to lower fiber content and more readily available carbohydrates (Mertens, 1997). Therefore, the reduced degradation observed in Bs30 and Bs45 treatments cannot be attributed solely to *B. simaruba* inclusion, but likely reflects the combined effect of increasing *B. simaruba* and decreasing concentrate proportion.

Additionally, the experimental design employed does not follow current best practices for *in situ* degradation studies. The simultaneous incubation of multiple treatments within the same animal may introduce confounding effects, as all treatments share the same ruminal environment. A Latin square design with proper temporal separation of treatments would have been more appropriate for

controlling animal effects and eliminating potential carry-over effects (López *et al*., 1999).

Effects on dry matter degradation

The rapidly soluble fraction (a) of DM was highest in the Bs15 diet, which may be attributed to the combination of a relatively high proportion of readily fermentable carbohydrates from concentrates and the soluble components from *B. simaruba* foliage. The significantly lower values observed in Bs30 could be related to the reduction in concentrate proportion and the increase in fiber content, as evidenced by the estimated higher NDF and ADF values in this diet.

The degradation rate (c) of DM decreased progressively with increasing levels of *B. simaruba*, which is consistent with findings from other studies evaluating tropical forage trees. This reduction may be attributed to several factors how the higher fiber content in diets with greater *B. simaruba* inclusion, and the potential effect of secondary compounds present in *B. simaruba*, particularly condensed tannins, which have been reported at 4.62% in *B. simaruba* foliage (Ascencio-Rojas *et al*., 2019).

Condensed tannins can form complexes with dietary carbohydrates and proteins, reducing their availability for ruminal degradation (Patra and Saxena, 2011). Research has demonstrated that moderate levels of condensed tannins (2-4% of DM) can reduce ruminal protein degradation and alter carbohydrate fermentation patterns, while higher concentrations may negatively affect overall nutrient digestibility (Barry and McNabb, 1999; Min *et al*., 2003). The progressive reduction in degradation rates observed with increasing *B. simaruba* inclusion aligns with this understanding, suggesting that the effects may be dose-dependent.

Effects on crude protein degradation

The pattern of crude protein degradation was more complex than that observed for dry matter. The highest rapidly soluble fraction (a) in Bs15 could be attributed to the higher CP content in this diet combined with a proportion of readily soluble nitrogen compounds from *B. simaruba*. The lower values observed in Bs30, despite its higher total CP content, might be related to the formation of protein-tannin complexes that reduce protein solubility and initial degradation.

The significantly lower potentially degradable fraction (b) in Bs45 might be due to the higher level of tannin-bound proteins that become less accessible to ruminal microorganisms. This aligns with research showing that condensed tannins can form stable complexes with dietary proteins, protecting them from ruminal degradation but potentially making them available for digestion in the small intestine (Min *et al*., 2003; Frutos *et al*., 2004).

The degradation rate of CP was highest in Bs0, which contained primarily conventional protein sources with minimal anti-nutritional factors. The reduced degradation rates in diets containing *B. simaruba* could be attributed to tannin-protein interactions, which have been shown to slow protein degradation in a pH-dependent manner (Jones and Mangan, 1977).

Comparison with other tropical tree species

The effective degradability values obtained in this study are generally lower than those reported for other tropical forage tree species. For instance, Flores *et al*. (1998) reported degradation rates ranging from 0.063 to 0.332 h^{-1} for species such as *Leucaena leucocephala*, *Gliricidia sepium*, and *Moringa alba*. The lower values observed for diets containing *B. simaruba* may reflect both the intrinsic characteristics of this species and the dilution effect of including it in mixed diets rather than evaluating it as a pure feed ingredient.

Similarly, the effective degradability values for crude protein in our study are lower than those reported for *B. simaruba* foliage alone (51.85%; Ascencio-Rojas *et al*., 2019). This difference emphasizes the importance of evaluating tree forages within the context of complete diets rather than as isolated ingredients, as interactions between components can significantly influence overall nutritional value.

Methodological considerations for future research

Based on the limitations identified in this preliminary study, several recommendations can be made for future research. In the future studies should employ a Latin square design with proper temporal separation of treatments to control for animal effects and eliminate carry-over effects, as recommended for in situ degradation studies (López *et al*., 1999; Huntington and Givens, 1995). To isolate the specific effects of *B. simaruba* inclusion, future studies should maintain consistent forage:concentrate ratios across treatments by replacing other forage components rather than concentrates. Similarly, the use of an adequate number of animals (minimum of 4-6 cannulated animals) would provide better statistical power and more reliable estimates of degradation parameters.

In the future research should include comprehensive chemical analysis of experimental diets, including fiber fractions (NDF, ADF), condensed tannin content, and *in vitro* fermentation parameters to better understand the mechanisms underlying the observed effects. Is important to make complementary studies evaluating animal performance, nitrogen utilization, and ruminal fermentation parameters would provide a more complete assessment of *B. simaruba* as a feed resource.

Environmental and practical implications

Despite the limitations of this preliminary study, the results provide initial insights into the potential use of *B. simaruba* as a feed resource in tropical livestock production systems. The maintenance of degradation parameters at the 15% inclusion level suggests that this species could be incorporated into feeding strategies as a supplementary forage source, particularly during periods of conventional forage scarcity.

The environmental benefits of using locally available tree resources like *B. simaruba* include reduced dependence on external feed inputs, potential for carbon sequestration in silvopastoral systems, and improved resilience of production systems to climate variability. However, these potential benefits must be validated through more comprehensive studies addressing the methodological limitations identified in this work.

CONCLUSIONS

The inclusion of *Bursera simaruba* foliage at 15% in the experimental diets maintained ruminal degradation parameters of dry matter comparable to the control diet. However, higher inclusion levels (30% and 45%) resulted in a significant reduction in potentially degradable fractions and effective degradability. These results indicate that the degradation kinetics were negatively affected in the diets with higher foliage inclusion, likely driven by the combined effect of increased fiber from *B. simaruba* and the concurrent reduction in the concentrate proportion. Therefore, under the specific conditions of this preliminary study, *B. simaruba* shows potential for moderate inclusion (up to 15%) in cattle diets without compromising ruminal degradation kinetics.

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Conflict of interest. The authors declare that they have no competing interests.

Compliance with ethical standards. The institution does not have an ethics committee; however, experimental procedures involving animals were carried out following the guidelines established by Tucker *et al*. (2020) for the care and use of agricultural animals in research.

Data availability. Data is available with the corresponding author upon reasonable request.

Author contribution statement (CRediT). A. Barrera-Arias – Conceptualization; Data curation; **G. Pool-Cordero** – Formal analysis; Investigation;**L.E. Castillo Sánchez** – Funding acquisition; Resources; **N.M. Ruz-Febles** – Methodology; **M.J. Campos-Navarrete** – Project administration; Supervision; **A.A. Luna-Mendicuti** – Software; Validation; **A.A. Alayón-Gamboa** – Visualization; **J.R. Canul Solis** – Writing-original draft; Writing-review and editing.

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