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Dietary *Bordão-De-Velho* (*Samanea tubulosa*) Fruit Improves Grazing Beef Cattle Performance

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ABSTRACT

Integrated grass-tree systems have been proposed to address socio-ecological challenges in tropical cattle production. *Bordão-de-velho* (*Samanea tubulosa*), a legume tree native to the Amazon, is commonly found in degraded pastures and valued by farmers for its soil, forage, and livestock benefits. The present study aimed to evaluate the effects of the dietary addition of *bordão-de-velho* fruit supplementation on intake, digestibility, feeding behaviour, and performance of grazing Nellore heifers. Twenty-six Nellore heifers (148 ± 25.5 kg of body weight, mean ± SD) were used in two treatments: 1) control (CON): Mombasa grass (*Megathirsus maximus*) pasture without supplementation; and 2) *Bordão-de-velho* (BORD): Mombasa grass pasture plus 5 g dry matter BORD fruits/kg of body weight per day. The trial lasted 63 days (three 21-day periods). *Bordão-de-velho* did not affect dry matter (DM), organic matter (OM), or crude protein (CP) intake ($p \geq 0.710$). However, BORD improved ($p \leq 0.050$) total tract digestibility of DM, OM, and CP and reduced ($p = 0.017$) animal activity levels. Additionally, average daily gain increased ($p = 0.003$) from 326 to 548 g/day. Thus, BORD enhances nutrient digestibility and growth performance without compromising intake. The findings support using native species to align livestock production with local ecosystems.

1 | Introduction

The conversion of natural vegetation into pastureland, especially in tropical regions, is a key contributor to socio-environmental degradation, intensifying sustainability challenges for livestock production in environmental, social, and governance terms (Brice et al. 2022). Given that pasture-based systems supply 90% of global cattle production (Terry et al. 2020), livestock farming has long been linked to deforestation and biodiversity loss. Climate change and increasingly unpredictable rainfall further threaten pasture resilience, exacerbating these pressures (Agethen et al. 2024). These challenges are particularly acute in the Amazon, where cattle production plays a vital economic role while the biome itself is critical for regional rainfall regulation. At the same time, similar pressures are faced in other tropical and subtropical livestock systems worldwide, where pasture degradation, climate variability, and feed scarcity demand innovative and locally adapted solutions.

To address these challenges, innovative strategies are needed, particularly those that harness biodiversity to tailor production systems to local conditions instead of standardised methods (Olival et al. 2022). One promising approach is integrating native species into livestock systems, which can improve animal nutrition and welfare while reducing greenhouse gas emissions (Andrade et al. 2012; Roa-Fuentes et al. 2015). For example, fruits from native trees can replace traditional feed ingredients (Olival et al. 2021). Such approaches not only serve regional needs but also provide transferable models for other parts of the world, showing how under-utilised native resources can strengthen global efforts to reconcile livestock production with biodiversity conservation and climate mitigation.

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A key species with such potential is *bordão-de-velho* (BORD; *Samanea tubulosa*), a Fabaceae (legume) tree widely distributed across tropical regions, especially in the seasonal climates of the western Amazon (Brazil, Bolivia, and Ecuador) (KEW 2024). Commonly found in degraded pastures and regeneration areas, farmers in Brazil have observed its benefits, including the use of its fruit as supplemental livestock feed during dry seasons (Olival et al. 2022). Local farmers report that BORD fruits are consumed by diverse livestock, including cattle, goats, sheep, horses, donkeys, pigs, and birds. Notably, these fruits are produced during the dry season, a critical period when forage scarcity and declining nutritional quality reduce feed intake, nutrient digestibility, and overall animal performance (Tambara et al. 2021; Feitosa et al. 2021). Nutritional analyses of *S. saman* (a closely related species) fruits reveal promising attributes, with crude protein (CP) levels ranging from 102 to 245 g/kg and neutral detergent fibre (NDF) from 292 to 530 g/kg (Delgado et al. 2014).

Despite this potential, no studies have evaluated BORD impact on grazing animals' digestion or performance. We hypothesised that supplementing with BORD would enhance feed intake, nutrient digestibility, and performance without altering feeding behaviour. This study aimed to test these effects in grazing heifers. Aligned to develop region-specific livestock solutions, this work underscores the importance of identifying social technologies that boost productivity and system resilience while promoting environmental sustainability and equitable value chains. Although the research is region-specific, it exemplifies how the valorisation of native biodiversity can inspire sustainable livestock feeding strategies across different regions of the world. By situating BORD within the wider context of global sustainability pathways, this work underscores the potential of under-utilised native feed resources to improve animal performance, reduce environmental impacts, and promote resilient value chains.

2 | Material and Methods

The trial was conducted at the Centro de Ciências Agrárias (CCA) of the Universidade Federal de São Carlos (UFSCar) between October and December 2022. All animal procedures were approved by the UFSCar Committee on Animal Research and Ethics (Protocol No. 2 806 280 923).

2.1 | Animals, Treatments, and Pasture Management

Twenty-six Nellore heifers (148 ± 25.5 kg of body weight, mean ± SD) were randomly assigned to evaluate two treatments: 1) control (CON): Mombasa grass (*Megathirsus maximus*) pasture without supplementation; and 2) *Bordão-de-velho* (BORD): Mombasa grass pasture and 5 g/kg BW of BORD fruits. The supplementation rate (5 g dry matter of BORD fruits per kg BW per day) was chosen to prevent nutritional disorders, as starch-rich diets exceeding 7 g/kg BW may induce acidosis (NASEM 2016) and reduce pasture intake. Fruits were individually offered to each heifer in separate feeding places to ensure accurate dosing. *Bordão-de-velho* fruits were sourced from Mato Grosso State through the *Rede de Coletores de Sementes do Portal da Amazônia* (Amazon Portal Seed Collectors Network) and sun-dried prior to the experiment. The fruits were sun-dried prior to feeding to standardise their dry matter content and composition, ensuring uniformity among samples. This procedure also reflects the natural condition in which animals commonly consume BORD fruits, as they typically feed on them at the end of the fruiting cycle, when the fruits are naturally dry.

The animals were maintained in a 2.7-ha Mombasa grass (*Megathyrsus maximus*) pasture divided into two paddocks, with each experimental group assigned to one paddock. The trial consisted of three consecutive 21-day evaluation periods. To ensure uniform pasture utilisation, the groups were rotated between paddocks every 16 days during the experimental period. On the same 16-day interval, pasture samples were collected from vegetation above 35 cm in height for chemical composition analysis (Table 1). Body weight measurements were taken on days 0, 21, 42, and 63 following treatment supply. Faecal and urine samples were collected concurrently with weighing. Faecal samples were obtained via rectal retrieval, while urine samples were collected through vulvar stimulation.

2.2 | Chemical Analysis

Pasture and BORD fruit samples were ground to pass through a 1-mm sieve using a knife mill. Samples were then analysed for dry matter (DM; AOAC method 950.15); organic matter (OM; calculated as 1000-crude ash; AOAC method 942.05); crude protein (CP; determined as N × 6.25 using the Kjeldahl method; AOAC method 984.13); and ether extract (EE; AOAC method 920.39) (AOAC 2000). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed according to Van Soest et al. (1991). Non-fibre carbohydrates (NFC) were calculated as: NFC = 1000−(NDF + CP + EE + ash).

Urine samples were analysed for creatinine (Chen and Gomes 1992) and allantoin (Fujihara and Yamaguchi 1978). Indigestible neutral detergent fibre (NDF) was determined after 240 h of in vitro incubation (Huhtanen et al. 1994). Faecal and feed samples were ground to 2 mm using a knife mill and placed into non-woven tissue bags (100 g/m^2; Casali et al. 2008). Each bag measured 5 × 5 cm internally, with a sample weight below 20 mg dry matter (DM)/cm^2 (Nocek 1988). Triplicate bags per sample were incubated for 240 h at 39°C in an in vitro incubator

TABLE 1 | Chemical composition of Mombasa grass and *bordão-de-velho*.

	Mombasa Grass		*Bordão-de-velho*	
Item	**Mean**	**SD[a]**	**Mean**	**SD[a]**
Chemical composition, g/kg DM unless stated				
Dry matter, g/kg as-fed	263	45.8	820	19.8
Organic matter	899	8.8	966	0.9
Neutral detergent fibre (NDF)	748	17.9	258	22.4
Indigestible NDF	176	47.9	188	28.6
Crude protein	126	21.5	143	7.2
Ether extract	26.0	11.41	10.1	4.30
Non-fibre carbohydrates	109	288.7	558	13.1

[a]Standard deviation.

(NL162, New Lab, Piracicaba, Brazil). Each incubation vial contained 2.0 L of ruminal inoculum, 1.6 L of McDougall's buffer (1948), and 0.4 L of fresh ruminal fluid. The ruminal fluid was collected from two Holstein heifers (600 kg body weight) grazing on Mombasa grass pasture without concentrate supplementation. After incubation, the bags were rinsed under running tap water and analysed for NDF as previously described.

Throughout the trial, animal behaviour was monitored hourly using the Chip Inside S.A. system (Santa Maria, Brazil). Behavioural data were recorded at hourly intervals to capture diurnal patterns of grazing, rumination, and resting. This frequency enables the detection of short-term behavioural fluctuations associated with feeding motivation and circadian regulation (Sheahan et al. 2013).

2.3 | Calculations and Statistical Analysis

Dry matter intake was calculated using the equation from Dorea et al. (2017), which incorporates urinary allantoin, creatinine concentrations, and body weight. These variables were then used to calculate the PDC index and dry matter intake (DMI) using the following equations:

$$\mathrm{PDC}_{\mathrm{index}} = \left[\frac{\text{allantoin} + \text{uric acid}}{\text{creatinine}}\right] \times \mathrm{BW}^{0.75} \quad (1)$$

$$\mathrm{DMI}\left(\frac{\mathrm{kg}}{\mathrm{d}}\right) = 0.24 + 0.046 \times \mathrm{PDC}_{\mathrm{index}} \quad (2)$$

Nutrient intake was calculated from the estimated dry matter intake, partitioned between pasture and supplement. Faecal excretion and total-tract apparent digestibility of nutrients were determined assuming 100% recovery of indigestible NDF in faeces. Average daily gain was derived from the linear regression slope of body weight over time.

Statistical analysis for nutrient intake, digestibility, and behaviour data was performed using PROC MIXED in SAS (version 9.4, SAS Institute Inc., Cary, NC) with the following mixed model

$$Y_{ijk} = \mu + B_i + \omega_{j:i} + T_k + B \times T_{ik} + e_{ijk} \quad (3)$$

where: Y_{ijk} is the observed value; μ is the overall mean; B_i is the fixed effect of treatment/*Bodrão-de-velho* ($i = 1$ and 2); $\omega_{j:i}$ is the random animal effect ($j = 1$ to 26), assumed $\omega_{j:i} \approx N(0, \sigma^2_\omega)$; T_k is the fixed effect of the period/time ($k = 1$ to 3 for intake and digestibility and $k = 1$ to 24 for behaviour); e_{ijk} is the residual error, assumed multivariate normal (0, R), N stands for Gaussian distribution; σ^2_ω is the variance associated with animal effect; R is a variance and covariance matrix due to repeated measures. Matrices (CS, CSH, AR, ARH, TOEP, TOEPH, FA, UN, ANTE) were evaluated using the Bayesian method. The covariance structures used were ARH for intake variables (DM, OM, NDF, and CP), AR or ARH for digestibility variables, and ANTE or TOEPH for behavioural variables.

For animal performance (ADG), the model was simplified to

$$Y_{ij} = \mu + B_i + e_{ij} \quad (4)$$

where: Y_{ij} is the observed value of the dependent variable; μ, B_i, and N were previously described; e_{ij} is the random residual error, assumed with $e_{ij} \approx N(0, \sigma^2_e)$; σ^2_e is the variance associated with the random residual effect. A 5% significance level was applied to all analyses.

3 | Results and Discussion

The inclusion of BORD in heifer diets significantly reduced NDF intake ($p = 0.020$) but did not affect DM, OM, or CP intake ($p \geq 0.710$; Table 2). This aligns with the typical high-fibre composition of tropical pastures, which physiologically limits voluntary intake (Forbes 2007). The reduction in NDF intake can be attributed to BORD's substantially lower NDF content compared to the pasture (258 *vs.* 748 g/kg NDF; Table 1). Notably, the absence of a negative effect on DM intake is advantageous, as it suggests potential for increased pasture stocking rates without compromising feed intake. However, intake regulation in grazing ruminants involves complex mechanisms, including osmotic balance and metabolic feedback (Allen 2020).

TABLE 2 | Effects of *Bordão-de-velho* (*S. tubulosa*) dietary supply on grazing Nellore heifers' nutrient intake and digestibility.

	Treatments[a]			Probabilities[c]		
Item	**CON**	**BORD**	**SEM[b]**	**Treat**	**Time**	**Treat. × Time**
Intake, kg/d						
Dry matter	3.75	3.70	0.103	0.816	<0.001	0.789
Organic matter	3.37	3.38	0.093	0.959	<0.001	0.773
Neutral detergent fibre	2.91	2.48	0.085	0.020	<0.001	0.792
Crude protein	0.470	0.479	0.0124	0.710	<0.001	0.916
Apparent digestibility						
Dry matter	0.476	0.529	0.0091	0.008	<0.001	0.020
Organic matter	0.561	0.596	0.0084	0.050	<0.001	0.156
Neutral detergent fibre	0.595	0.567	0.0071	0.056	<0.001	0.039
Crude protein	0.517	0.600	0.0177	0.033	0.154	0.030

[a]Treatments: control (CON): mombasa grass (*Megathirsus maximus*) pasture without supplementation; and *Bordão-de-velho* (BORD): mombasa grass pasture and 5 g/kg BW of *S. tubulosa* fruits.
[b]Standard error of mean.
[c]Probabilities: Treat.: treatment effect (Con. vs. Bord.); Time: evaluation period effect; Treat×time: treatment and evaluation period interaction effect.

Overall, BORD supplementation significantly increased ($p \leq 0.05$) the total-tract digestibility of DM, OM, and CP. It also tended to improve ($p = 0.056$) NDF digestibility. As noted earlier, BORD reduced the dietary fibre content, which aligns with the well-established inverse relationship between fibre and energy content in ruminant feeds (NASEM 2016, 2021). The higher CP digestibility may be attributed to a reduction in acid-detergent insoluble protein, as lower fibre content (due to BORD) is known

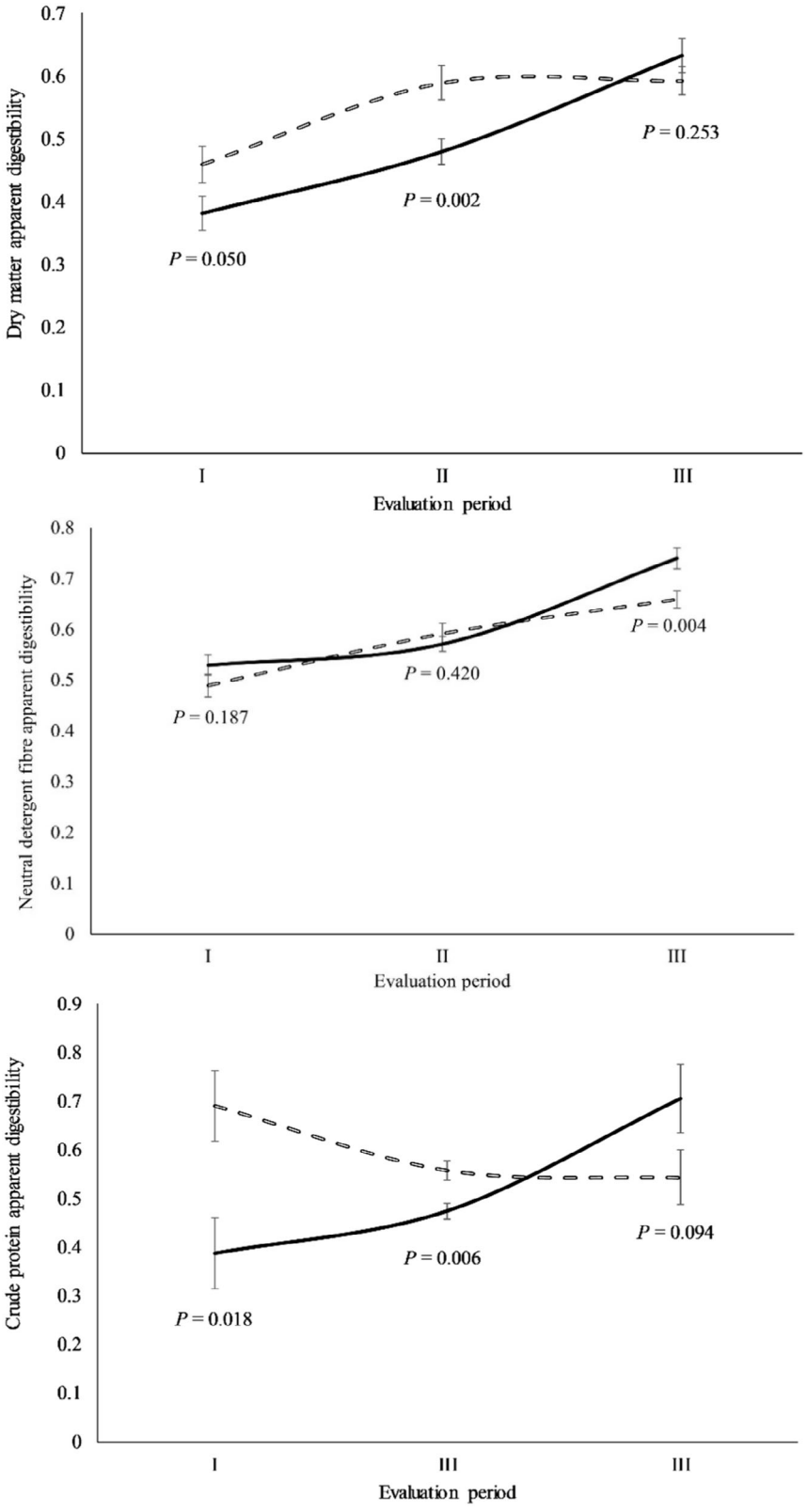


FIGURE 1 | Effects of *Bordão-de-velho* (*S. tubulosa*) dietary supply on grazing Nellore heifers' dry matter, neutral detergent fibre, and crude protein total-tract apparent digestibility. Legends: CON (▬▬) BORD (▭ ▭).

to decrease acid-detergent insoluble protein (Sniffen et al. 1993). Additionally, the trend toward improved NDF digestibility further supports the beneficial effects of BORD on fibre utilisation.

During grazing, cattle had access to different pasture pools (Freer et al. 2007). In this study, we observed a significant BORD by period interaction ($p \leq 0.039$) affecting the digestibility of DM, OM, and NDF. Improved pasture management during the trial enhanced NDF digestibility, particularly in the CON treatment (Figure 1). As a result, BORD supplementation led to higher nutrient digestibility compared to CON, especially in short-term assessments. Over the entire trial period, animals grazing on pasture without BORD consumed lower-quality forage than those receiving BORD supplementation. This improvement may also be attributed to the higher CP content of BORD fruits, which likely enhanced rumen microbial activity and thereby favoured the degradation of fibre fractions (Reis et al. 2016). Moreover, BORD supplementation reduced the overall fibre challenge of the diet, improving ruminal fermentability and nutrient availability (NASEM 2016). Over the entire trial period, animals grazing on pasture without BORD consumed lower-quality forage than those receiving BORD supplementation.

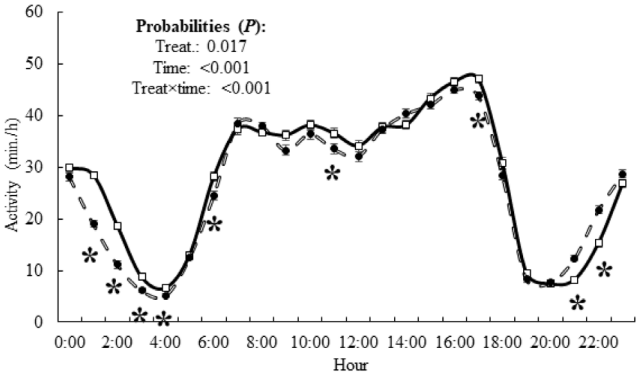


FIGURE 2 | Effects of *Bordão-de-velho* (*S. tubulosa*) dietary supply on grazing Nellore heifers' activity level. Legends: CON (▬▬) BORD (▭ ▭).

Overall, BORD supplementation significantly reduced ($p = 0.017$) animal activity levels from 27.6 to 26.4 min/h (Figure 2; Table 3). Under grazing conditions, pasture availability and grazing time are key determinants of feed intake (Freer et al. 2007). The decrease in activity likely occurred because BORD supplementation reduced pasture intake. However, BORD had no effect ($p \geq 0.208$) on resting, ruminating, or panting behaviour. Rumination time is primarily influenced by dietary fibre content and particle size (Beauchemin 2018). Although BORD shortened grazing time, its impact on overall diet composition was minimal, resulting in negligible effects on rumination duration.

A significant BORD by time interaction ($p < 0.001$) was observed for all behaviour variables (Table 3). Animals exhibited greater daytime activity and increased nighttime rumination. Furthermore, BORD supplementation significantly reduced activity ($p \leq 0.05$) during early morning hours (01:00–04:00) and specific afternoon periods. As noted earlier, CON-fed animals required extended grazing time to achieve adequate forage intake (Freer et al. 2007; Missio et al. 2010), explaining their different behavioural patterns compared to BORD-supplemented cattle.

BORD supplementation significantly increased ($p = 0.003$) average daily gain from 326 to 548 g/d. This positive effect on cattle performance aligns with previous findings reporting benefits of Amazonian fruits (Olival et al. 2021). The enhanced growth performance likely results from improved nutrient digestibility in BORD-fed animals. These findings demonstrate the potential of BORD as an effective nutritional supplement for grazing beef cattle.

4 | Conclusion

The inclusion of *Bordão-de-velho* (*S. tubulosa*) fruits in grazing heifer diets enhances nutrient digestibility, reduces physical activity, and significantly improves average daily gain. These findings demonstrate that *Bordão-de-velho* supplementation is an effective nutritional strategy to boost cattle productivity in pasture-based systems.

TABLE 3 | Effects of *Bordão-de-velho* (*S. tubulosa*) dietary supply on grazing Nellore heifers' behaviour and productive performance.

	Treatments[a]			Probabilities[c]		
Item	**CON**	**BORD**	**SEM[b]**	**Treat.**	**Time**	**Treat. × Time**
Behaviour, min/h						
Activity	27.6	26.4	0.54	0.017	<0.001	<0.001
Resting	14.8	15.9	0.92	0.208	<0.001	<0.001
Rumination	10.0	10.1	0.80	0.849	<0.001	<0.001
Panting	7.56	7.57	0.260	0.955	<0.001	<0.001
Initial body weight, kg	147.8	148.5	5.0	0.945	—	—
Final body weight, kg	163.3	183.2	6.3	0.239	—	—
Average daily gain, g/d	332	505	26.0	0.003	—	—

[a]Tratments: control (CON): mombasa grass (*Megathirsus maximus*) pasture without supplementation; and *Bordão-de-velho* (BORD): mombasa grass pasture and 5 g/kg BW of *S. tubulosa* fruits.
[b]Standard error of mean.
[c]Probabilities: Treat.: treatment effect (Con. vs. Bord.); Time: evaluation period effect; Treat×time: treatment and evaluation period interaction effect.

Author Contributions

All authors contributed to the study conception and design. Material preparation and data collection were performed by Vanderson Eliel Meira, Jozivaldo P. de Moraes, Mariana Campana and Alexandre de Azevrdo Olival. Analysis were performed by Tiago Antonio Del Valle. The first draft of the manuscript was written by Alexandre de Azevedo Olival all authors commented on previous versions of the manuscript. Tiago Antonio Del Valle performed reviews. All authors read and approved the final manuscript.

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Ethics Statement

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of UFSCar (approval number 2806280923).

Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

Data Availability Statement

The authors have nothing to report.

References

Agethen, K., R. M. Mauricio, C. Deblitz, M. D. Izquierdo, E. Reyes, and J. Chará. 2024. "Future Perspectives of Brazilian Beef Production: What Is the Role of Silvopastoral Systems?." *Agroforestry Systems* 98: 2179–2196. https://doi.org/10.1007/s10457-024-01005-7.

Allen, M. S. 2020. "Review: Control of Feed Intake by Hepatic Oxidation in Ruminant Animals: Integration of Homeostasis and Homeorhesis." *Animal : an International Journal of Animal Bioscience* 14, no. S1: s55–s64. https://doi.org/10.1017/S1751731119003215.

Andrade, C. M. S., A. K. D. Salman, M. M. Bentes-Gama, et al. 2012. *Método De Seleção De Espécies Arbóreas Para Sistemas Silvipastoris. Congresso Latinoamericano De Sistemas Agroflorestais Para a Produção Pecuária Sustentável*. 243–247. Assessed on Januarry, 30, 2026. https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1138690/1/cpafro-18671.pdf.

AOAC. 2000. *Official Methods of Analysis*. 17th edition. Association of Official Analytical Chemists.

Beauchemin, K. A. 2018. "Invited Review: Current Perspectives on Eating and Rumination Activity in Dairy Cows." *Journal of Dairy Science* 101, no. 6: 4762–4784. https://doi.org/10.3168/jds.2017-13706.

Brice, J., G. Cusworth, J. Lorimer, and T. Garnett. 2022. "Immaterial Animals and Financialized Forests: Asset Manager Capitalism, ESG Integration and the Politics of Livestock." *Environment and Planning A* 54: 1551–1568. https://doi.org/10.1177/0308518X221121132.

Casali, A. O., E. Detmann, S. C. Valadares Filho, et al. 2008. "Influence of Incubation Time and Particles Size on Indigestible Compounds Contents in Cattle Feeds and Feces Obtained by In Situ Procedures." *Revista Brasileira de Zootecnia* 37, no. 2: 335–342. https://doi.org/10.1590/s1516-35982008000200021.

Chen, X. B., and M. J. Gomes. 1992. "Estimation of Microbial Protein Supply to Sheep and Cattle Based on Urinary Excretion of Purine Derivatives -an Overview of the Technical Details." In *Occasional Publication*. 19. International Feed Resources Unit, Rowett Research Institute, Bucksburn.

Delgado, D. C., R. Hera, J. Cairo, and Y. Orta. 2014. "*Samanea Saman*, a Multi-Purpose Tree with Potentialities as Alternative Feed for Animals of Productive Interest." *Cuban Journal of Agricultural Science* 48, no. 3: 205–212.

Dorea, J. R. R., M. A. C. Danés, G. I. Zanton, and L. E. Armentano. 2017. "Urinary Purine Derivatives as a Tool to Estimate Dry Matter Intake in Cattle: A Meta-Analysis." *Journal of Dairy Science* 100: 8977–8994. https://doi.org/10.3168/jds.2017-12908.

Feitosa, O. S., R. C. Leite, E. Alexandrino, et al. 2021. "Forage Performance and Cattle Production as a Function of the Seasonality of a Brazilian Tropical Region." *Acta Scientiarum. Animal Sciences* 44: e53779. https://doi.org/10.4025/actascianimsci.v44i1.53779.

Freer, M., H. Dove, and J. Nolan. 2007. *Nutrient Requirements of Domesticated Ruminants*. 270.CSIRO Publishing.

Forbes, J. M. 2007. "A Personal View of How Ruminant Animals Control Their Intake and Choice of Food: Minimal Total Discomfort." *Nutrition Research Reviews* 20: 132–146. https://doi.org/10.1017/S0954422407797834.

Fujihara, S., and M. Yamaguchi. 1978. "Effects of Allopurinol [4-Hydroxypyrazolo(3,4-d)Pyrimidine] on the Metabolism of Allantoin in Soybean Plants." *Plant Phisiology* 62: 134–138. https://doi.org/10.1104/pp.62.1.134.

Huhtanen, P., K. Kaustell, and S. Jaakkola. 1994. "The use of Internal Markers to Predict Total Digestibility and Duodenal Flow of Nutrients in Cattle Given Six Different Diets." *Animal Feed Science and Technology* 48: 211–227. https://doi.org/10.1016/0377-8401(94)90173-2.

KEW – Royal Botanic Garden. Samanea tubulosa (Benth.) Barneby & J.W.Grimes. On line: Access: Samanea tubulosa (Benth.) Barneby & J.W.Grimes | Plants of the World Online | Kew Science, 2024.

McDougall, E. I. 1948. "Studies on Ruminant Saliva. 1. The Composition and Output of Sheep's Saliva." *The Biochemical Journal* 43, no. 1: 99–109.

Missio, R. L., I. L. Brondani, D. C. Alves Filho, M. F. Silveira, L. S. Freitas, and J. Restle. 2010. "Ingestive Behavior of Feedlot Finished Young Bulls Fed Different Concentrate Levels in the Diet." *Revista Brasileira de Zootecnia* 39: 1571–1578. https://doi.org/10.1590/S1516-35982010000700025.

National Academies of Sciences, Engineering, and Medicine (NASEM). 2016. *Nutrient Requirements of Beef Cattle: Eighth Revised Edition*. 475. National Academies Press. https://doi.org/10.17226/19014.

National Academies of Sciences, Engineering, and Medicine (NASEM). 2021. *Nutrient Requirements of Dairy Cattle: Eighth Revised Edition*. National Academies Press. https://doi.org/10.17226/25806.

Nocek, J. E. 1988. "In Situ and Other Methods to Estimate Ruminal Protein and Energy Digestibility: A Review." *Journal of Dairy Science* 71: 2051–2069. https://doi.org/10.3168/jds.S0022-0302(88)79781-7.

Olival, A. A., S. E. X. F. Souza, J. P. G. Moraes, and M. Campana. 2021. "Effect of Amazonian Tree Species on Soil and Pasture Quality in Silvopastoral Systems." *Acta Amazonica* 51: 281–290. https://doi.org/10.1590/1809-4392202004692.

Olival, A. A., R. E. Oliveira, A. C. Sais, and S. E. X. F. Souza. 2022. "Family Farmers` Local Knowledge about Native Trees on Pastures in Portal DA Amazônia, MT." *Brazil Desenvolvimento e Meio Ambiente* 59: 319–337. https://doi.org/10.5380/dma.v59i0.76867.

Reis, W. L. S., E. Detmann, E. D. Batista, et al. 2016. "Effects of Ruminal and Post-Ruminal Protein Supplementation in Cattle Fed Tropical Forages on Insoluble Fiber Degradation, Activity of Fibrolytic Enzymes, and the Ruminal Microbial Community Profile." *Animal Feed Science and Technology* 218: 1–16. https://doi.org/10.1016/j.anifeedsci.2016.05.001.

Roa-Fuentes, L. L., C. Martínez-Garza, J. Etchevers, and J. Campo. 2015. "Recovery of Soil C and N in a Tropical Pasture: Passive and Active Restoration." *Land Degradation & Development* 26: 201–210. https://doi.org/10.1002/ldr.2197.

Sheahan, A. J., R. C. Boston, and J. R. Roche. 2013. "Diurnal Patterns of Grazing Behavior and Humoral Factors in Supplemented Dairy Cows." *Journal of Dairy Science* 96: 3201–3210. https://doi.org/10.3168/jds.2012-6201.

Sniffen, C. J., J. D. O'Connor, D. G. Fox, et al. 1993. "A Net Carbohydrate and Protein System for Evaluating Cattle Diets: IV. Predicting Amino Acid Adequacy." *Journal of Animal Science* 71: 1298–1311. https://doi.org/10.2527/1993.7151298x.

Tambara, A. A. C., C. J. Härter, C. H. S. Rabelo, and G. V. Kozloski. 2021. "Effects of Supplementation on Production of Beef Cattle Grazing Tropical Pastures in Brazil during the Wet and Dry Seasons: A Meta-Analysis." *Revista Brasileira de Zootecnia* 50, no. 50: e20210020. https://doi.org/10.37496/rbz5020210020.

Terry, S. A., J. A. Basarab, L. L. Guan, and T. A. McAllister. 2021. "Strategies to Improve the Efficiency of Beef Cattle Production." *Canadian Journal of Animal Science* 101: 1–19. https://doi.org/10.1139/cjas-2020-0022.

Van Soest, P., J. Robertson, and B. Lewis. 1991. "Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition." *Journal of Dairy Science* 74, no. 10: 3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2.