

# **Nutritional quality of grasses and forages in different agroecological zones and their relationship with milk production in dual-purpose cattle systems in the department of Huila, Colombia\***

## **Calidad nutricional de pastos y forrajes en diferentes zonas agroecológicas y su relación con la producción de leche en sistemas de bovinos doble propósito en el departamento del Huila, Colombia**

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## ABSTRACT

*In the Andean tropics of Colombia, dual-purpose cattle systems rely predominantly on native and introduced grasses and forages as the primary nutritional resource. However, the diverse agroecological conditions of regions such as the department of Huila result in substantial variation in grasses and forages quality, which is not always adequately characterized. This study aimed to evaluate the nutritional quality of key grasses, forages species and analyze their relationship with milk production across different agroecological zones (central, northern, and western) of the department of Huila. Representative samples of three grass species (*Hyparrhenia rufa*, *Cynodon nlemfuensis*, *Brachiaria decumbens*) and one leguminous tree (*Gliricidia sepium*) were collected from dual-purpose cattle farms and subjected to proximate chemical (bromatological) analysis to determine moisture, crude protein, crude fiber, ash, and ether extract content. Statistically significant differences ( $p \leq 0.01$ ) were found between zones in protein, crude fiber, and ash content for *H. rufa* and *C. nlemfuensis*. In *B. decumbens*, significant variation was observed in moisture, fiber, ash, and lipid content among zones ( $p \leq 0.01$ ). Additionally, cutting age had a significant and negative effect ( $p < 0.01$ ) on daily milk yield. *G. sepium* maintained a consistently high protein content across all zones ( $p > 0.05$ ), highlighting its adaptive potential during dry seasons. The findings demonstrate that grasses and forages nutritional composition is strongly influenced by agroecological zone and management practices. This study emphasizes the importance of integrating bromatological assessments and milk production data as a basis for strategic decision-making, with the goal of improving productivity and sustainability in dual-purpose cattle systems in the department of Huila.*

## KEYWORDS:

Daily milk production; Feeding; Gramineous; Arboreal; Forage nutritional quality; Crude protein; Crude fiber; As; Ether extract; Sustainability.

## RESUMEN

*En los trópicos andinos de Colombia, los sistemas de ganado de doble propósito dependen predominantemente de pastos y forrajes, tanto nativos como introducidos, como principal recurso nutricional. Sin embargo, las diversas condiciones agroecológicas de regiones como el departamento del Huila generan una variación sustancial en la calidad de los pastos y forrajes, la cual no siempre es caracterizada de manera adecuada. Este estudio tuvo como objetivo evaluar la calidad nutricional de especies forrajeras clave y analizar su relación con la producción de leche en diferentes zonas agroecológicas (centro, norte y occidente) del departamento del Huila. Se recolectaron muestras representativas de tres especies de gramíneas (*Hyparrhenia rufa*, *Cynodon nlemfuensis*, *Brachiaria decumbens*) y una especie arbórea leguminosa (*Gliri-**

## PALABRAS CLAVE:

Producción diaria de leche; Alimentación; Gramíneas; Arbórea; Calidad nutricional del forraje; Proteína cruda; Fibra cruda; Cenizas; Extracto etéreo; Sustentabilidad.

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*cidia sepium*) en fincas con sistemas de ganado doble propósito, las cuales fueron sometidas a análisis químico proximal (bromatológico) para determinar los contenidos de humedad, proteína cruda, fibra cruda, cenizas y extracto etéreo. Se encontraron diferencias estadísticamente significativas ( $p \leq 0.01$ ) entre zonas en el contenido de proteína, fibra cruda y cenizas en *H. rufa* y *C. nlemfuensis*. En *B. decumbens*, se observó una variación significativa en humedad, fibra, cenizas y lípidos entre zonas ( $p \leq 0.01$ ). Además, la edad de corte tuvo un efecto significativo y negativo ( $p < 0.01$ ) sobre la producción diaria de leche. *G. sepium* mantuvo un contenido de proteína consistentemente alto en todas las zonas ( $p > 0.05$ ), lo que resalta su potencial adaptativo durante las épocas secas. Los hallazgos demuestran que la composición nutricional de los pastos y forrajes está fuertemente influenciada por la zona agroecológica y las prácticas de manejo. Este estudio enfatiza la importancia de integrar los análisis bromatológicos y los datos de producción lechera como base para la toma de decisiones estratégicas, con el objetivo de mejorar la productividad y sostenibilidad de los sistemas de ganado de doble propósito en el departamento del Huila.

## INTRODUCTION

In Colombia, the cattle sector contributes 1,4% of the national gross domestic product GDP (Federación Colombiana de Ganaderos, 2024). By 2023, the bovine population increased by 1,2% compared to 2022, where it was distributed on 620.807 herds, totaling 29.642.539 animals of which 9.485.612 are classified in dual-purpose (DP) system (ICA, 2022). The DP systems are dedicated to the production of milk and meat, using generally mixed breed animals obtained from crosses of *Bos taurus* x *Bos indicus* (Cadenas-Soberanis *et al.*, 2021; Kelly *et al.*, 2021), and their diet is especially based on the use of grasses and forages through cattle grazing systems (Santana Rodriguez *et al.*, 2022). Therefore, the quality and availability of grasses is closely related to the production of meat and milk that can be reached from cattle under these production systems in the Colombian tropic (Santana Rodriguez *et al.*, 2022).

Thus, a wide diversity of grass and forages sources is used to feed livestock in the tropic (Fraser *et al.*, 2022; Jaurena *et al.*, 2021); among which we have traditional grasses, the foliage of leguminous trees and shrubs, as well as creeping legumes (Triana *et al.*, 2017). The compositional structure of forages is determined by specific factors of the plant such as species, age, morphology, among others; and, to environmental factors such as temperature, solar radiation, precipitation, fertility, and soil type (Brown *et al.*, 2022; Rengel *et al.*, 2022). These factors significantly influence the nutritional contribution provided to the animal at the time of consumption (Chand *et al.*, 2022). For example, reports that legumes have a better accumulation of nitrogen in their tissues and therefore contain a greater amount of protein (de Mello Prado, 2021; Islam *et al.*, 2021); on the other hand, forage with high cell wall content can have an impact on the digestibility and availability of energy in the animal (Ferrufino-Suárez *et al.*, 2022).

Despite the great variety of grasses and forages available in the tropics its nutritional value is not always recognized or adjusted to cover the animal nutrition requirements, which is extremely important to ensure their proper use and achieve sustainable animal production (Lizarazo-Ortega *et al.*, 2024; Triana *et al.*, 2017). This research aimed to assess the nutritional quality of these forage species, which are integral to livestock feeding systems in the region. The study not only focused on determining the chemical composition, such as crude protein, fiber, ash, and lipids, but also examined how these factors influence the productivity of dairy cattle. By considering the distinct geographical and productive zones of the Huila department each with its unique agroecological conditions, such as variations in altitude, climate, and soil types this study sought to understand the regional differences in forage quality and their direct impact on milk production. In particular, the analysis aimed to provide insights into how the nutritional properties of forages from different zones contribute to the health and productivity of dual-purpose cattle, with the goal of offering region-specific recommendations for improving cattle nutrition and milk yield.

## METHOD

This study was carried out on the approval from the ethics, bioethics and scientific integrity committee of the Corporación Colombiana de Investigación Agropecuaria-AGROSAVIA, through Act N.2 of 2021.

### Location, plant material sampling and milk production record

The study was carried out in 12 municipalities distributed in the central, northern, and western zone of the Huila department (Colombia).

### Agroecological characteristics of the northern, central, and western zones of the huila department

The Huila department presents notable agroecological heterogeneity, resulting from its geographical location, diverse topography, and the influence of various thermal floors. These conditions directly impact the dynamics of productive systems, particularly the nutritional quality of grasses and forages, as well as livestock productivity levels. The northern, central, and western regions of the department reflect significant contrasts in terms of climate, soil conditions, and management practices, which must be considered when designing intervention and productivity improvement strategies.

#### Northern zone:

This region is located in the Magdalena Valley and features a hot semi-arid climate, with temperatures ranging from 28°C to 40°C, and an average annual rainfall between 900 and 1.200 mm, concentrated in short periods of the year.

The soils, mostly of alluvial origin, tend to have low water retention capacity and poor natural fertility, with limitations in organic matter and the availability of essential nutrients. These edaphoclimatic conditions restrict the optimal development of high-nutritional-value forage species, favoring the presence of rustic grasses or legumes, which are highly tolerant to water stress but have low crude protein content and high lignification, thus reducing digestibility.

Additionally, livestock management in this region is often characterized by extensive resource use, limited pasture rotation, scarce supplementation, and low adoption of forage conservation technologies, which exacerbates feed availability issues for dual-purpose cattle, especially during dry or rainy seasons.

#### Central zone:

This region presents intermediate agroecological conditions, both in altitude (between 500 and 1,200 meters above sea level) and average annual temperature (between 22°C and 34°C). Rainfall is more evenly distributed throughout the year (1.200 to 1.800 mm/year), which favors better vegetative growth of grasses.

Soils in this region are of medium fertility, with loam or sandy loam textures and better water retention capacity, although acidity issues are present in some areas. These characteristics allow for the establishment of higher nutritional value forage species, including both improved grasses and legumes, particularly in farms that have adopted agroecological and sustainable practices.

There has been progress in production system technification, including rational grazing management, use of electric fencing, establishment of protein banks, and strategic supplementation, which has led to more stable milk production throughout the year. The central region represents an area with great potential for implementing sustainable livestock models and silvopastoral systems.

## Western zone:

This region is located in a higher altitude band (between 1.200 and 2.200 meters above sea level), on the eastern slope of the Central Andes range. It has a more temperate climate, with average temperatures between 16°C and 22°C, and a higher and more evenly distributed annual rainfall (1.800 to 2.500 mm), which provides favorable conditions for the development of high-quality forages.

The soils in this region are generally richer in organic matter, with better physical and chemical properties, although sloping terrain may pose erosion risks that require appropriate management. These conditions support the establishment of high-yield, high-nutritional-quality forage species.

Moreover, livestock systems in this area have shown a more advanced level of management, with the adoption of forage conservation technologies such as silage and haymaking, contributing to more stable and efficient milk production. Altitude and climate also influence the natural botanical composition of the grasses, promoting a greater diversity of nutritionally valuable species.

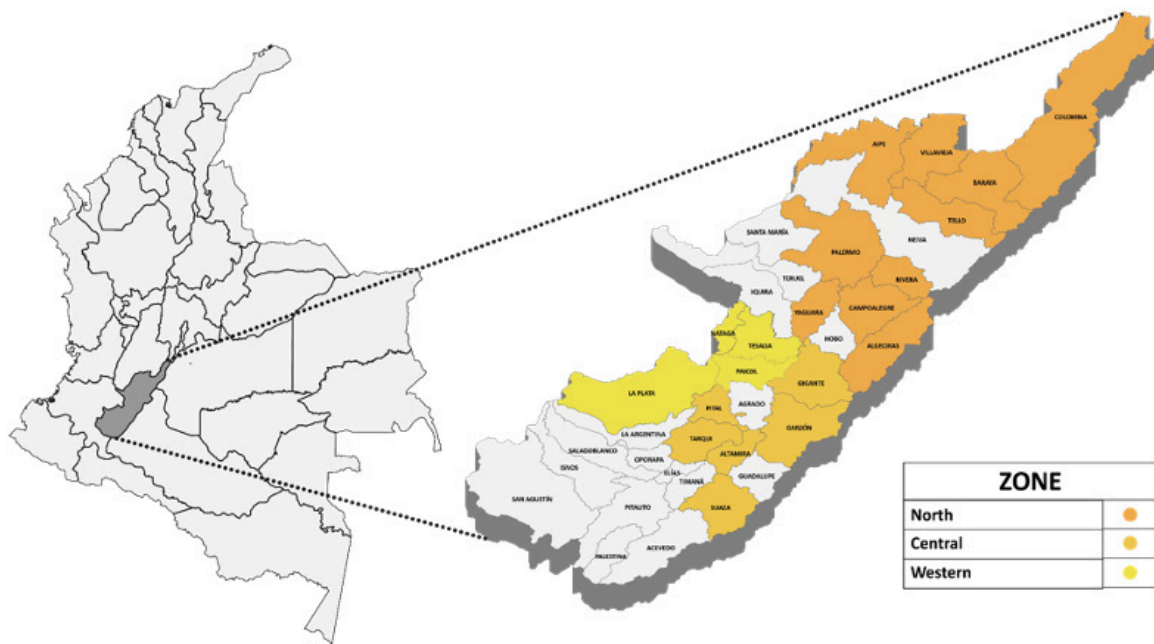


Figure 1. Sampling location by zones in the Huila department, Colombia.

For plant species selection, firstly 260 cattle breeders were surveyed to identify grasses and forages species used for animal feeding (Table 1). Four species were selected: three grasses and one legume, with the highest number of responses were chosen: Jaragua grass (*Hyparrhenia rufa*), stargrass (*Cynodon nlemfuensis*), the Brachiaria grass (*Brachiaria decumbens*), and the “mataraton” legumen (*Gliricidia sepium*).

Samples from selected grasses and forages were collected between August and September 2023. Fresh biomass (300 g) was collected from 32 herds in the central, northern and western zones of the Huila department. For each herd, three representative areas of the pasture were randomly selected to account for terrain and vegetation variability. The cutting age of grass and forages was considered according to the time of consumption by the animal when sampling. Then, samples were dried at 60 °C for 48 hours in a hot air oven; after that they were ground to a particle size of 1 mm in a Wiley mill.

**Table 1.** plant species used for the DP bovine feeding in herds of the department of Huila - Andean region (Colombia).

Species	Herds	Percentage
Cuba 22 ( <i>Pennisetum purpureum</i> x <i>Pennisetum glaucum</i> )	13	5
Puntero grass ( <i>Hyparrhenia rufa</i> )	44	16,9
Estrella grass ( <i>Cynodon nlemfuensis</i> )	69	26,5
Brachiaria grass ( <i>Brachiaria</i> híbrido)	76	29,2
Saboya ( <i>Megathyrsus maximus</i> Jacq.)	17	6,5
Kikuyo ( <i>Pennisetum clandestinum</i> )	2	0,76
Angleton ( <i>Dichantium aristatum</i> )	11	4,2
Bombaza ( <i>Megathyrsus maximus</i> )	3	1,15
Matarratón ( <i>Gliricidia sepium</i> )	19	7,30
Iguá ( <i>Albizia guachapele</i> )	2	0,76
Guácimo ( <i>Guazuma ulmifolia</i> )	4	1,53

Herds with forage evaluation were included in a productive performance recording program. Milk yield recording method AE44 1x were used following the Guidelines for Dairy Cattle Milk from ICAR (<https://www.icar.org>). At least three milk records per animal for each herd were considered for the analysis.

### Chemical analysis

The proximate analysis was carried out in the analytical chemistry laboratory at the Centro de Investigación Turipaná of the Corporación Colombiana de Investigación Agropecuaria-AGROSAVIA. Each of the samples was analyzed by three times by NTC 4888:2000; Ash (Ash) by AOAC 942,05 (2019); ether extract (EE) by AOAC 2003,06 (2019); crude protein (CP) by AOAC 960,52 (2019).

### Statistical analysis

A completely random design was used, where the zone and herds were considered. The analysis of variance (ANOVA) was carried out with a significance level of 0,05 comparing the results obtained in the proximate analyses of the species collected in each of the three zones. Mean comparisons were performed using the least mean squares and the Tukey Kramer test. A linear model was used to estimate the effect of zone and forage cut age on the daily milk yield. The statistical analysis was carried out using R software (<https://www.R-project.org>).

## RESULTS

From the survey of livestock producers, eight different forage sources were identified. The most used species were the genus *Brachiaria* (Table 1). On the other hand, the *G. sepium* showed to be the most used tree species by the producers. The proximate analyses carried out on the species *H. rufa* showed significant differences ( $p \leq 0,05$ ) between the zones evaluated (Table 2). The species taken from the northern zone obtained the highest percentage of protein (7,05%), while the central zone had the lowest percentage (3,35%). Compared to crude fiber, the species of the western zone had the highest value (36,93%). Finally, there were no statistically significant differences for the moisture.

**Table 2.** Proximate analysis of the species *Hyparrhenia rufa* used in the feeding of ruminants in three zones of the department of Huila - Andean region (Colombia).

	Zones			MSE	P-value
	Central	Northern	Western		
MOI (%)	4,64a	5,08a	4,73a	0,19	0,2264
CP (%)	3,35b	7,05a	4,02b	0,67	0,0032
CF (%)	33,92a	29,62b	36,93a	1,00	0,0004
Ash (%)	13,71a	11,44b	12,47b	0,41	0,0043
EE (%)	1,55a	1,89a	1,34a	0,16	0,0751
MOI: moisture, CP: crude protein, CF: crude fiber, Ash: Ashes, EE: ether Extract. MSE: mean standard error. Averages followed by letters, in the lines, differ by the Tukey test ( $P \leq 0,05$ ).					

Likewise, the analysis carried out on the species *C. nlemfuensis* showed statistically significant differences ( $p \leq 0,05$ ) between zones (Table 3). The crude protein reached values of 10,38% in the western zone and differentiated from the central and northern zones. As for the ash parameter found in the northern zone, it was higher than 11,61% when making the comparison with the central and western zone. On the other hand, no differences were observed between the averages obtained for the moisture and fiber results in the three zones evaluated.

**Table 3.** Proximate analysis of the species *Cynodon nlemfuensis* used in the feeding of ruminants in three zones of the department of Huila - Andean region (Colombia).

	Zones			MSE	P-value
	Central	Northern	Western		
MOI (%)	5,01a	6,45a	3,93a	0,80	0,1158
CP (%)	5,98b	6,64b	10,38a	0,57	0,0001
CF (%)	32,60a	33,99a	31,22a	1,03	0,2000
Ash (%)	9,34b	11,61a	9,09b	0,34	0,0002
EE (%)	1,35a	1,46a	1,63a	0,10	0,1511
MOI: moisture, CP: crude protein, CF: crude fiber, Ash: Ashes, EE: ether Extract. MSE: mean standard error. Averages followed by letters, in the lines, differ by the Tukey test ( $P \leq 0,05$ ).					

For the species *B. decumbens* (Table 4), crude fiber and ash show significant differences ( $p > 0,05$ ) between zones, where the western zone had the highest fiber content (32,96%) and the north and western zones had a lower ash content. As for the analysis of moisture in the three zones, there were differences between the zones evaluated.

**Table 4.** Proximate analysis of the species *Brachiaria decumbens* used in the feeding of ruminants in three zones of the Huila department - Andean region (Colombia).

	Zones			MSE	P-value
	Central	Northern	Western		
MOI (%)	7,70a	5,67b	4,25c	0,26	<0,0001
CP (%)	7,82a	7,55a	6,54a	0,70	0,4196
CF (%)	30,34ab	27,31b	32,96a	1,50	0,0547
Ash (%)	11,00a	8,49b	9,17b	0,24	<0,0001
EE (%)	1,55ab	2,03a	1,33b	0,14	0,0094
MOI: moisture, CP: crude protein, CF: crude fiber, Ash: Ashes, EE: ether extract. MSE: mean standard error. Averages followed by letters, in the lines, differ by the Tukey test ( $P \leq 0,05$ ).					

The tree species *G. sepium* evaluated in the three zones of the department did not show statistically significant differences for the variables of ash, ether extract, crude protein or crude fiber, but it showed for the moisture variable that was higher in the central zone 11,61% (Table 5).

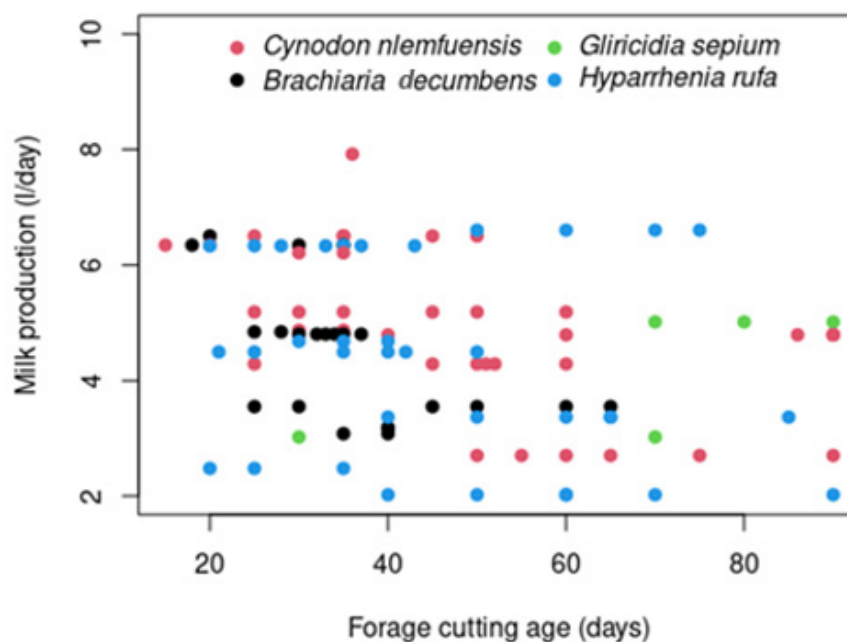
**Table 5.** Bromatological analysis of the species *Gliricidia sepium* used in the feeding of ruminants in three zones of the department of Huila - Andean region (Colombia).

	Zones			MSE	P-value
	Central	Northern	Western		
MOI (%)	11,61a	7,50b	7,39b	1,08	0,0217
CP (%)	22,52a	24,25 <sup>a</sup>	18,79 <sup>a</sup>	1,57	0,0713
CF (%)	19,25a	17,53a	23,08a	2,33	0,2588
Ash (%)	8,99a	10,13 <sup>a</sup>	8,66a	0,51	0,1288
EE (%)	2,38a	3,18a	2,53a	1,23	0,0538

MOI: moisture, CP: crude protein, CF: crude fiber, Ash: Ashes, EE: ether extract. MSE: mean standard error. Averages followed by letters, in the lines, differ by the Tukey test (P<0,05).

Finally, a total of 4.732 daily milk records were collected in the herds. The daily milk yield was  $4,07 \pm 2,35$  l, with records ranged from 1 to 15,7 l. Differences were observed ( $p < 0,01$ ) in the average milk production between zones. Northern zone showed the higher milk production ( $5,843 \pm 0,05$  l) followed by Eastern ( $5,787 \pm 0,07$  l) and Central ( $3,976 \pm 0,04$  l) zones.

When forage source information was included in the model, a highly significant effect ( $p < 0,05$ ) for species and forage cutting age in the milk yield records in herd were observed. Herds with *C. nlemfuensis* showed the higher average daily milk production ( $5,879 \pm 0,359$  l), followed by *G. sepium* ( $5,545 \pm 0,704$  l), *B. decumbens* ( $5,266 \pm 0,389$  l) and *H. rufa* ( $5,192 \pm 0,355$ ). Additionally, when forage cutting age increased from 15 to 90 days, the average daily milk production decreased by  $-0,020 \pm 0,007$  ( $p\text{-value} = 0,00839$  l) (Figure 2).



**Figure 2.** Milk production records and forage cutting age regarding forages species evaluated.

A total of 71% of Huila department soils are used for the planting of grasses and forages ( PECTIA, 2016), additional it has 11 of the 24 areas of life recorded ideal for this type of productive system (PECTIA, 2016), developed in the low (>1.200 m a.s.l.) and medium (1.200 to 2.000 m a.s.l.) (Carulla & Ortega, 2016).

Meanwhile, of the species identified for the feeding of cattle under DP systems, the “mataratón” and “guácimo” the most used tree species in the departament of Huila, are used by farmers due to the empirical knowledge they have about the nutritional quality and the indicators such as increase in the amount of milk and/or weight gain they observed (Pérez-Almario *et al.*, 2021) whereas the use of Gramineae municipalities in the northern and western zones of the department are characterized by having traditional grasses of the genus *Brachiaria*, especially *B. decumbens*, *B. brizantha* and *C. nlemfuensis* (Zuluaga, 2021).

Compared to the evaluated Gramineae, *H. rufa* showed the lowest percentage of crude protein showing differences in the central and western zones. Ramírez reported values ranging from 7,8% to 10,1%, a result obtained in the northern zone (Ramírez, 2018) and González *et al.* (2017) reported that at two different times of the year, that the CP content of the *H. rufa* grass decreased in the dry season between 5,3 to 4,1 (González *et al.*, 2017) while in the rainy season from 8,7 to 8,5, which could be affecting the CP found in this grass in the central and western zone, since in dry seasons it can decrease up to 1,4% (Quiroz, 2017).

The highest percentage of crude protein in *C. nlemfuensis* was observed in the western zone, similar to previous reports around 12,01 (Mahecha *et al.*, 2022). The highest proportion of protein in this species was observed at 45 days after cutting proteins of 15,08%, but at the age of 55 days the protein was below 13,12 (Lopez & Villalobos, 2024). On the other hand, it has been reported that in dry season the nutritional content of the *C. nlemfuensis* decays due to the high temperatures and water stress presented by the plant (Martínez *et al.*, 2016) as lower as 16% in drought (Villalobos & Arce, 2014).

The same trend could be observed with the protein thrown in the *B. decumbens* that although no differences were found between the evaluated zones, the ages of cuts of that species could be affecting their nutritional quality. For this species, the optimal nutrient composition has been found at 60 days and significantly decreases over this maturity time frame (Osafó *et al.*, 2023). In this study, cutting age of *B. decumbens* was above 60 days, negatively influencing the protein content.

However, the percentage of protein identified in the Gramineae can be potentially aligned with the amount of protein recommended by the National Research Institute (NRC) Council (Nutrient Requirements of Dairy Cattle, 2021). The NRC suggests that the minimum requirement of protein for dairy cows is of the order of 8,8% and this for cows that require to produce 7,1 liters / day on average, with 450 kg of live weight, offering amino acids and continuous ammonium, which favor biological needs at the cellular level (Uzcátegui-Varela *et al.*, 2022).

A similar value for crude protein content in *G. sepium* has been reported with 26,26% (Alcívar *et al.*, 2023). This result could be related to the ability of legumes to adapt and use soil nutrients in dry seasons (Barros *et al.*, 2021), resulting in a greater production of essential amino acids and free amino acids (Islam *et al.*, 2021).

The crude fiber in *C. nlemfuensis* was higher compared to 24,24% (Azania *et al.*, 2021) and 25,3% (Martinez, 2022). In the case of *H. rufa* Lemus *et al.*, reported values of 36,5% of fiber in matured grass, a data that resembles that thrown in this species in the western zone and similar to the observed for the north and central zones (Lemus *et al.*, 2021). The variation of results found in this study may be due to the ages of regrowth. The forage age influences the nutritional quality of forage, according to the mature plant the leaf-stem ratio decreases (Maldonado *et al.*, 2020). An increase in the age of regrowth of the *C. nlemfuensis* grass increases in the fiber content can be observed (Ferrufino-Suárez *et al.*, 2022).

The crude fiber found in the *G. sepium* showed values below those obtained with the grasses, even so, authors have reported values even lower 16,17% (Ferrufino-Suárez *et al.*, 2022) and 15,5 (Swastika *et al.*, 2024). Likewise, these results could be related to factors such as cutting age, soil characteristics and climatic conditions. For example, in the dry season, 24,3% crude fiber has been reported, like those obtained in the western zone. Despite this, tree forage plays an important role in the ruminants feeding due to its quickly degradable fiber for animals that consume poor quality forages (Edwards *et al.*, 2024). Meanwhile, fiber is the fraction of food that determines the consumption in cattle, since the higher the value, the lower the consumption given the slow degradation in the rumen and the filling effect it generates (Niwa *et al.*, 2023).

The ash content of the *C. nlemfuensis* was slightly lower in the north and west zone than previous reports of 10,98% (Mahecha *et al.*, 2022); but even lower contents has been reported such as 6,83% at 30 days of regrowth, 7,93% at 45 days, and 8,74% at 60 days (Herrera-Pérez *et al.*, 2023). The grasses collected in the western zone where the ash content was less affected compared to the dry season. The response of the *C. nlemfuensis* could be explained by the scarcity of mineral nutrient absorption from the soil in this pasture under conditions of water restriction. This scarcity may be related to the decreasing vapor pressure deficit (VPD) that has been shown to affect the nutrient absorption of plants (Ding *et al.*, 2022); conversely, the ash contents of *H. rufa* were greater than 11%.

Regarding the *B. decumbens*, observed that the ash content of 7,62 before ensiling (Mugoti *et al.*, 2023). Here, they were below 8%, likely associated to the maturity of the grasses. Since it has been observed that the leaves have a higher concentration of minerals, and as the plant matures, the proportion of leaves decreases relative to the stem. Consequently, the mineral content in the leaves diminishes as a result (Oyedele *et al.*, 2016). Regarding *G. sepium*, have been reported an ash content of 13,8% (Swastika *et al.*, 2024), higher than the one obtained in this study, but that is close to that found in the northern zone and previous report of 7,71% (Combatt *et al.*, 2008). As previously indicated, the mineral content in plants can vary according to the cutting period and its vegetative stage or low precipitation (Ding *et al.*, 2022).

The ether extract (EE) is considered the fraction of fat found in plant pigments and sterols. In the forage, EE is in both the seeds and the leaves and important for estimating the energy contribution (Katoch, 2023). For EE in the *C. nlemfuensis* pasture, other studies reported values of 1,97% (Mahecha *et al.*, 2022). This value for *C. nlemfuensis* has been also evaluated for wet and dry seasons, and regrowth maturity without finding differences between them, and the results were higher than the value observed in this study (Núñez-Arroyo *et al.*, 2022).

Regarding species within the genus *Brachiaria*, regrowth ages of 45 and 55 days exhibited EE greater than 3%. Additionally, the fat content of *B. decumbens* reached 4,2% during the dry season (Núñez-Arroyo *et al.*, 2022), contrasting with the findings of this study. The percentage content and composition of fatty acids can vary depending on the species and drought conditions (Núñez-Arroyo *et al.*, 2022).

The species *G. sepium* showed an EE of 2,69%, similar to other reports. However, evaluations of EE at different cutting heights showed that EE at lowest height (70 cm) was 4,49% whereas at the highest height (110 cm) was 5,69% (Ferrufino-Suárez *et al.*, 2022). The differences in the chemical composition of legumes are related to the genetic characteristics of each plant, such as the differential absorption of nutrients and the conversion of photosynthetic metabolites, climatic and soil conditions, or even different states of maturity of the leaves.

In terms of climatic conditions, studies indicate that an increase in average temperature can lead to forage crops becoming more fibrous and less protein-rich. The projected increase in average temperatures, estimated at least 2°C, implies that cattle will require more feed volume to reach the expected productivity. Additionally, the climate change will cause a reduction in the quality of grasses, resulting in lower protein content, increased fibrousness, and consequently, longer digestion times.

The cutting age is directly related to the fiber content in the plant as well as the leaf/stem ratio, leading to decrease the forage source quality and digestibility. The *Brachiaria* spp. and *C. nlemfuensis* were the most used forages sources between herds, with  $39,14 \pm 15,98$  and  $49,17 \pm 21,14$  average cut days respectively. However, the observed high variability in the forage cut days reflected the diverse climatic conditions and the limited soil management. Either early or late forage cut interact with several environmental factors, but, if traditional extensive livestock farming is also considered, the application of improvement strategies to enhance productivity will be limited. Therefore, initial efforts to evaluate the forage sources quality and the continuous daily milk record will be relevant decision-making tools for farmers in this region of Colombia.

## CONCLUSIONS

The species *Hyparrhenia rufa*, *Cynodon nlemfuensis*, *Brachiaria decumbens*, and *Gliricidia sepium* were identified as the most commonly used forage species for feeding dual-purpose cattle in the central, northern, and western zones of the Huila Department. This selection is based on their availability, adaptability to local agroecological conditions, and acceptable nutritional value, making them a fundamental component for the sustainability of livestock systems in these regions.

It was found that the nutritional composition of these grasses and forages is strongly influenced by cutting management in the herds, particularly the frequency and regrowth age at which cutting is performed. Inadequate cutting management can reduce nutritional quality, affecting parameters such as crude protein content, neutral detergent fiber (NDF), and digestibility, which directly impacts herd productivity efficiency.

The species *G. sepium*, in particular, showed a high protein content in the three evaluated zones ( $p > 0.05$ ), suggesting good adaptation to the region's edaphoclimatic conditions, as well as a remarkable ability to maintain its nutritional value even during the dry season. This positions it as a strategic alternative for protein supplementation during periods of low forage quality availability.

Furthermore, it was observed that an increase in forage cutting age had a significant negative effect ( $p < 0.01$ ) on daily milk production, highlighting the importance of implementing more frequent and species-specific cutting schedules to preserve nutritional quality. This finding reinforces the need for producers to adopt more efficient management practices based on technical criteria, enabling them to maximize system productivity without compromising animal health or the sustainability of the production system.

The study emphasizes the need to integrate planned forage management strategies and proper selection of species adapted to each agroecological zone, in order to optimize milk production in dual-purpose cattle systems in the Huila Department.

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## REFERENCES

- ALCÍVAR-ACOSTA, EUSTER-HERWINTON; ROMAY-FERNANDO, YULIEN-FERNÁNDEZ; VIVAS, FERNANDO-WATER; CUSME-RIVAS, KARINA-ELIZABETH; VERDUGA-LÓPEZ, CRISTIAN-DARIO; HEREDIA-MENDOZA, JOFFRE-DANILO. Evaluación del potencial nutritivo de especies arbustivas tropicales para la alimentación de cerdos de traspatio. *Ciencia y Tecnología Agropecuaria*, v. 24, n. 3, 2023, e2991  
[https://doi.org/10.21930/rcta.vol24\\_num3\\_art:2991](https://doi.org/10.21930/rcta.vol24_num3_art:2991)
- AZANIA, ROLANDO; ACOSTA, LUIS. T; RODRÍGUEZ, ANIBAL. R; LÓPEZ, GILMAR. H. Rendimiento y composición bromatológica de *Setaria sphacelata* cv Nandi, en tres edades de rebrote. *Revista de Investigación Agropecuaria Science and Biotechnology*, v.1, n. 3, 2021, p. 44–52.  
<https://doi.org/10.25127/riagrop.20213.702>
- BARROS, FELIPE-MARTINS; CURY-FRACETTO, FELIPE-JOSÉ; JUNIO-LIRA, MARIO-ANDRADE; BRAGA-BERTINI, SIMONE-CRISTINA; MONTEIRO-FRACETTO, GISELLE-GOMES. Spatial and seasonal responses of diazotrophs and ammonium-oxidizing bacteria to legume-based silvopastoral systems. *Applied Soil Ecology*, v. 158, p. 103797.  
<https://doi.org/10.1016/j.apsoil.2020.103797>
- BROWN, PATRICK. H; ZHAO, FANG-JIE; DOBERMANN, ACHIM. What is a plant nutrient? Changing definitions to advance science and innovation in plant nutrition. *Plant and Soil*, v. 476, n. 1, 2022, e05171  
<https://doi.org/10.1007/s11104-021-05171-w>
- CADENAS-SOBERANIS, ANDRÉS; JIMÉNEZ-OCAMPO, RAFAEL; ARCEO-CASTILLO, JEYER. I; LÓPEZ-ZAPATA, CINTHYA. P; AGUILAR-PÉREZ, CARLOS. F; KU-VERA, JUAN. C. Net energy requirement for maintenance of crossbred beef heifers (*Bos taurus* x *Bos indicus*) as measured with the washed-rumen technique and indirect calorimetry. *Livestock Science*, v. 251, 2021, e104612  
<https://doi.org/10.1016/j.livsci.2021.104612>
- CARULLA, JUAN. E; ORTEGA, ENRIQUE. Sistemas de producción lechera en Colombia: Retos y oportunidades. *Archivos Latinoamericanos de Producción Animal*, v. 24, n. 2, 2016. [https://ojs.alpa.uy/index.php/ojs\\_files/article/view/2526](https://ojs.alpa.uy/index.php/ojs_files/article/view/2526)
- CHAND, SUBHASH-INDU; SINGHAL, RAJESH KUMAR; GOVINDASAMY, PRABHU. Agronomical and breeding approaches to improve the nutritional status of forage crops for better livestock productivity. *Grass and Forage Science*, v. 77, n. 1, 2022, e12557  
<https://doi.org/10.1111/gfs.12557>
- COMBATT, ENRIQUE; JARMA, AFREDO; MAZA, LIBARDO. Crecimiento de *Brachiaria decumbens* Stapf y *Cynodon nlemfuensis* Vanderyst en suelos sulfatados ácidos de Córdoba. *Revista MVZ Córdoba*, v.13, n. 2, 2008, p. 1380–1392.  
[http://www.scielo.org.co/scielo.php?pid=s0122-02682008000200014&script=sci\\_arttext](http://www.scielo.org.co/scielo.php?pid=s0122-02682008000200014&script=sci_arttext)
- DE MELLO PRADO, RENATO. Nitrogen. In R. de Mello Prado (Ed.), *Mineral nutrition of tropical plants*. Springer International Publishing, 2021, p. 69–98.  
[https://doi.org/10.1007/978-3-030-71262-4\\_4](https://doi.org/10.1007/978-3-030-71262-4_4)
- DING, JUPING; JIAO, XIAOCONG; BAI, PING; HU, YIAYU; ZHANG, JIAYU; LI, JIANMING Effect of vapor pressure deficit on the photosynthesis, growth, and nutrient absorption of tomato seedlings. *Scientia Horticulture*, v. 293, 2022, p. 110736. <https://doi.org/10.1016/j.scienta.2021.110736>
- EDWARDS, ANDELL; MLAMBO, VICTOR; MNISI, C. MNISI; HUGHES, P. HUGHES. Mature fruits of *Gliricidia sepium* and *Leucaena leucocephala* plants have potential as inexpensive protein and mineral supplements for ruminants. *Agroforestry Systems*, v. 98, 2024, p. 2951–2960  
<https://doi.org/10.1007/s10457-024-01066-8>
- FEDERACIÓN COLOMBIANA DE GANADEROS. Cifras de referencia del sector ganadero colombiano. 2024. <https://www.fedegan.org.co/estadisticas/documentos-de-estadistica> [Consultado octubre 10 de 2024].
- FERRUFINO-SUÁREZ, ADRIEL-JACOC; MORA-VALVERDE, DAVID; VILLALOBOS-VILLALOBOS, LUIS-A. Biomass and bromatology of African Stargrass (*Cynodon nlemfuensis* Vanderyst) with five regrowth stages. *Agronomía Mesoamericana*, v. 33, n. 2, 2022, e47746.  
<http://dx.doi.org/10.15517/am.v33i2.47746>

- FRASER, M.D.; VALLIN, H.E.; ROBERTS, B.P. Animal board invited review: Grassland-based livestock farming and biodiversity. *Animal*, v. 16. n. 12, 2022. e100671. <https://doi.org/10.1016/j.animal.2022.100671>
- GONZÁLEZ-MARTÍNEZ, ÁLVARO; ROJAS-HERNÁNDEZ, JOEL; CHAVARRÍA-ÑAMENDI, FRANCISCO-JÓSE; MARTIN-JIMÉNEZ, RONALDO. Disponibilidad de Biomasa y contenido de Proteína Cruda de *Hyparrhenia rufa* y *Panicum máximum* cv Tanzania asociados con *Leucaena leucocephala* y *Gliricidia sepium* en sistemas de pasturas de callejones, v. 17, n. 28, 2017, p. 15-20.  
<https://dialnet.unirioja.es/servlet/articulo?codigo=8910473>
- HERRERA-PÉREZ, JERONIMO; HERNÁNDEZ-GONZÁLEZ, DANIEL; SÁNCHEZ-SANTILLÁN, PAULINO; TORRES-SALADO, NICOLÁS; AYALA-MONTER, MARCO-ANTONIO; SAAVEDRA-JIMÉNEZ, LUIS-ANTONIO; ROSALES-MARTÍNEZ, GERARDO-NOÉ. In vitro Chemical and fermentative characteristics of tropical pastures at different ages of regrowth. *Agrociencia*. v, 56, n. 7. 2023. e2738  
<https://doi.org/10.47163/agrociencia.v57i6.2738>
- INSTITUTO COLOMBIANO AGROPECUARIO (ICA). Censos Pecuarios Nacional. (2022). <https://www.ica.gov.co/areas/pecuaria/servicios/epidemiologia-veterinaria/censos-2016/censo-2018>. [Consultado agosto 20 de 2024]
- ISLAM, M MOHAMMAD-SOHIDUL; FAHAD, SHAH; HOSSAIN, AKBAR; CHOWDHURY M., KAIUM; IQBAL, MUHAMMAD-AAMIR; DUBEY, ANAMIKA; KUMAR, ASHWANI; RAJENDRAN, KARTHIKA; DANISH, SUBHAN; RAHMAN, MUHAMMAD-HABIB-UR. Legumes under Drought Stress: Plant Responses, Adaptive Mechanisms, and Management Strategies in Relation to Nitrogen Fixation. In *Engineering Tolerance in Crop Plants Against Abiotic Stress*. 1st Edition, CRC Press 2021, 29 p.
- JAURENA, MARTÍN; DURANTE, MARTÍN; DEVINCENZI, THAIS; SAVIAN, JEAN V.; BENDERSKY, DIEGO; MOOJEN, FERNANDA G.; PEREIRA, MARCELO; SOCA, PABLO; QUADROS, FERNANDO. L.F; PIZZIO, RAFAEL; NABINGER, CARLOS; CARVALHO, PAULO. C.F; LATTANZI, FERNANDO A. Native Grasslands at the Core: A New Paradigm of Intensification for the Campos of Southern South America to Increase Economic and Environmental Sustainability. *Frontiers in Sustainable Food Systems*, v. 5, 2021, e547834  
<https://doi.org/10.3389/fsufs.2021.547834>
- KATOCH, RAJAN. Estimation of Nutritional Components in Forages. En *Techniques in Forage Quality Analysis*. Singapore: Springer Nature Singapore, 2023. p. 69-100.  
[https://doi.org/10.1007/978-981-19-6020-8\\_9](https://doi.org/10.1007/978-981-19-6020-8_9)
- KELLY, L.; BOUGOUIN, A.; KEBREAB, E. Maintenance energy requirement and efficiency of utilisation of metabolisable energy for milk production of *Bos taurus* × *Bos indicus* crossbred tropical dairy cows: A meta-analysis. *Animal Production Science*, v. 61, n.13, 2021, p. 1338-1347.  
<https://doi.org/10.1071/AN20470>
- LEMUS, R.; DER-HOEK, VAN; NEWMAN, Y.C.; MENA, M.; ALBRECHT, K.A. Effects of maturity and drying method on the nutritive value of tropical grasses in Nicaragua. 2021. [https://cgspace.cgiar.org/bitstream/10568/115977/1/13%20IGC-IRC-FullPaper-Lemus%20et.%20al.\\_Final.pdf](https://cgspace.cgiar.org/bitstream/10568/115977/1/13%20IGC-IRC-FullPaper-Lemus%20et.%20al._Final.pdf) [Consultado agosto 20 de 2024].
- LIZARAZO-ORTEGA, CRISTIAN; RODRÍGUEZ-CASTILLEJOS, GUADALUPE; BERNAL-BARRAGÁN, HUGO; GUTIÉRREZ-ORNELAS, ERASMO; OLIVARES-SÁENZ, EMILIO; HERNÁNDEZ-MENDOZA, JOSE-LUIS. Efecto del pastoreo, corte y riego en la producción y valor nutritivo de zacate Buffel. *Revista Mexicana de Ciencias Pecuarias*, v.15, n. 3, 2024, e5702  
<https://doi.org/10.22319/rmcp.v15i3.5702>
- LOPEZ-SOLANO, MARVIN J.; VILLALOBOS- VILLALOBOS, LUIS-ALONSO. Valor nutricional del pasto Estrella Africana con fuentes de fertilización orgánica e inorgánica: *Archivos Latinoamericanos de Producción Animal*, v. 32, n. 2, 2024, e 320205  
<https://doi.org/10.53588/alpa.320205>
- MAHECHA, LILIANA; LONDOÑO, JUAN-DAVID; ANGULO, JOAQUÍN. Agronomic and Nutritional Assessment of an Intensive Silvopastoral System: *Tithonia diversifolia*, *Sambucus nigra*, *Cynodon nlemfuensis*, and *Urochloa plantaginea*. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, v. 92, 2022, p. 37-47.  
<https://doi.org/10.1007/s40011-021-01282-7>

- MALDONADO-PERALTA, MARIA-DE LOS ANGELES; ROJAS-GARCIA, ADELAIDO-RAFAEL; RUÍZ-CLAVEL, JESSICA-LIZBETH; ANIANO-AGUIRRE, HERMINIO; MAGADAN- OLMEDO, FILIBERTO; CASTAÑEDA, LEOPOLDO-JORGE; MONDRAGÓN- CALDERÓN, URIEL. Stem population and tissue replacement of *Urochloa* in different phenological stages. *American Journal of Plant Sciences*, v. 11, n. 8, 2020, p. 1296-1306  
<https://doi.org/10.4236/ajps.2020.118092>
- MARTÍNEZ - MARTÍNEZ, MIGUEL; CRUZ-REYES, ADRIAN; BUENO-LARA, ALEJANDRO; ROMERO-MIRANDA, LUIS-ALEJANDRO; BRAVO, MAXIMILIANO; GÓMEZ-URIBE, MIGUEL. Composición nutricional de leucaena asociada con pasto estrella en la Huasteca Potosina de México. *Revista Mexicana de Ciencias Agrícolas*, v. 16, 2016, p. 3343-3355.  
<https://www.redalyc.org/pdf/2631/263146726015.pdf>
- MARTINEZ, OSCAR-ALEXANDER. Caracterización de las fibras en pastos; estrella africana (*Cynodon nlemfuensis vanderyst*, *brachiaria (urochloa decumbens (stapf) r. D. Webster*) y pasto elefante (*Pennisetum purpureum schum*) y su efecto en la ganancia de peso en bovinos destetos [Tesis Maestría en Salud y producción Animal]. Bucaramanga (Colombia): Universidad Cooperativa de Colombia, Facultad de Medicina Veterinaria y Zootecnia, 2022, 94 p.
- MUGOTI, ALBAN; CHIKUMBA, NATION; MUNENGWA, ANDERSON; DZIWANYIKA, LENIN; MOYO, SIZO; MGUMBA, CHIEDZA. Associative effects of a mixed *Brachiaria decumbens* and *Pennisetum purpureum* grass feed on the ensiling properties. *Biotechnology in Animal Husbandry*, v. 39, n. 1, 2023, p. 103-116.  
<https://doi.org/10.2298/BAH2301103M>
- NIWA-GARCÍA, MARCUS-VINICIUS; ÍTAVO-VINHAS, LUIS-CARLOS; ÍTAVO-FERREIRA, CAMILA-CELESTRE; DIAS-MENEXEZ, ALEXANDRE; DOS SANTOS DIFANTE, GELSON; LONGHINI-ZIRONDI, VANESSA; DA COSTA-GOMES, RODRIGO; VEDOVATTO, MARCELO; GURGEL-GURGEL, ANTONIO-LEONARDO; DE MORAES, GABRIELLA-JORGETTI; DE AQUINO MONTEIRO, GABRIELA. Effect of physically effective neutral detergent fiber on nutrient intake and digestibility, ruminal and blood parameters, and ingestive behavior of confined beef cattle. *Tropical Animal Health and Production*, v. 55, n. 3, 2023, p. 224  
<https://doi.org/10.1007/s11250-023-03633-0>
- NORMA TÉCNICA DE COLOMBIA (NTC). NTC 4888:2000. Alimentos para animales. Determinación del contenido de humedad y materia volátil. Bogotá (Colombia): 2022, 12 p.
- NÚÑEZ-ARROYO, JOSE; JIMÉNEZ-CASTRO, JOSE. P.; TOBÍA-RIVERO, CARLOS M.; ARIAS-GAMBOA, LUIS M.; JIMÉNEZ-ALFARO, ESTEBAN; PADILLA-FALLAS, JOSE. E. Efecto de la edad de rebrote y época del año sobre la biomasa y calidad bromatológica en gramíneas utilizadas en tres zonas agroclimáticas de Costa Rica (I PARTE). *Nutrición Animal Tropical*, v. 16, n. 1, 2022, e50370  
<https://doi.org/10.15517/nat.v16i1.50370>
- Nutrient Requirements of Dairy Cattle: Eighth Revised Edition (with Committee on Nutrient Requirements of Dairy Cattle, Board on Agriculture and Natural Resources, Division on Earth and Life Studies, & National Academies of Sciences, Engineering, and Medicine), 2021. National Academies Press.  
<https://doi.org/10.17226/25806>
- OSAFO-KWAME, EMMANUEL-LARTEY; OSMAN, ALHASSAN; ATTOH-KOTOKU, VICTORIA; ANTWI, CHRISTOPHER; ABDUL AZIZ, YUNUS; IDAN, FRANK. Chemical composition and in vitro gas production of *Brachiaria decumbens* harvested at different stages of growth in the hot humid region. *Online Journal of Animal and Feed Research*, v. 13, n. 4. 2023.  
<https://doi.org/10.51227/ojafr.2023.45>
- OYEDELE, OIUSEGUN-JULIUS; ASAOLU-OLAJIDE, VINCENT; ODEYINKA, SIMISOLA-MERCY. Nutrient digestibility and growth performance of West African Dwarf (WAD) goats fed foliage combinations of *Moringa oleifera* and *Gliricidia sepium* with equal proportions of a low-cost concentrate. *Journal of Natural Sciences Research*, v, 6, n. 18, 2016, p. 20-29.  
<https://core.ac.uk/download/pdf/234656619.pdf>
- PECTIA-Plan Estratégico de Ciencia, Tecnología e Innovación del Sector Agropecuario Colombiano (PECTIA). Cadena agroalimentaria del café. Corporación Colombiana de Investigación Agropecuaria, Departamento Administrativo de Ciencia, Tecnología e Innovación, & Ministerio de Agricultura y Desarrollo Rural, 2016.  
<https://repository.agrosavia.co/handle/20.500.12324/1388> [consultado septiembre de 2024].

- PÉREZ-ALMARIO, NELSON; MEDINA-RIO, ELIANA LIZETH; MORA-DELGAD, JAIRO; CRIOLLO-CRUZ, DAGOBERTO; ROBERTO MEJÍA, JULIAN. Criterios de uso y conservación de árboles en potreros basados en el conocimiento local de los ganaderos en una zona de bosque seco tropical en Colombia. *Tropical Grasslands-Forrajés Tropicales*, v. 9, n. 3, 2021, p. 321–336.  
[https://doi.org/10.17138/tgft\(9\)321-336](https://doi.org/10.17138/tgft(9)321-336)
- QUIROZ-MARTINEZ, SALOME. Efecto del dosel de *Vachellia pennatula* en la fisiología, producción y calidad nutritiva de las gramíneas tropicales *Hyparrhenia rufa* y *Megathyrsus maximus*. [Maestría en ciencias]. Veracruz (México): Colegio de postgraduados, 2017, 82 p.
- RCORE TEAM. R. A language and environment for statistical computing. R Foundation for Statistical Computing. <https://www.R-project.org>, 2023.
- RAMÍREZ, PERSIA-DE GANTE. Crecimiento, rendimiento y calidad nutritiva de gramíneas bajo el dosel de árboles leguminosos [Maestría en ciencias]. Veracruz (México): Colegio de postgraduados, 2017, 64 p.
- RENGEL, ZED; CAKMAK, ISMAIL; WHITE, PHILIP JOHN. Marschner's mineral nutrition of plants. Academic Press, 2022.
- SANTANA-RODRIGUEZ, MARTHA-OLIVA; MESTRA-VARGAS, LORENA-INÉS, FLOREZ- DIAZ, HERNANDO. Productive parameters of *dualpurpose cattle* supplemented with unconventional feed in the humid Colombian Caribbean. v. 30, n. 3, 2022, p. 179–190.  
<https://doi.org/10.53588/alpa.300303>
- SWASTIKA-LANANG, I. GUSTI; SURYANI, NI-NYOMAN; DAN, I-WAYAN. Capacity of *Gliricidia sepium* and *Indigofera zollingeriana* plants which were given Rhizobium inoculants as a source of feed for Bali cows on post-mining lands, v. 11, n. 5, 2024, p. 30–33.  
<https://doi.org/10.22271/23940522.2024.v11.i5a.1045>
- THE GLOBAL STANDARDS FOR LIVESTOCK DATA (ICAR). Protocol for evaluation of milk analysers for granting ICAR certification. <https://www.icar.org/guidelines/> [consultado junio 10 de 2023].
- TRIANA-GONZÁLEZ, DELMY; CURBELO- RODRÍGUEZ, LINO; LOYOLA- HERNÁNDEZ, OSCAR. Indicadores bioeconómicos del uso de *Ateleia cubensis* (DC) Dietr. Para la producción con rumiantes en Camagüey. *Revista de Producción Animal*, v. 29, n. 1, 2017, p. 16–20
- UNITED STATES OF AMERICA. AMERICAN SOCIETY FOR TESTING AND MATERIALS (AOAC). ASH 942.05: Determination of Ash in Animal Feed. Rockville, MD: AOAC International, 2019. 27 p.
- UNITED STATES OF AMERICA. AMERICAN SOCIETY FOR TESTING AND MATERIALS (AOAC). AOAC 2003.06: Ether Extract (EE). Rockville, MD: AOAC International, 2019. 15 p.
- UNITED STATES OF AMERICA. AMERICAN SOCIETY FOR TESTING AND MATERIALS (AOAC). AOAC 960.52: Crude Protein (CP). Rockville, MD: AOAC International, 2019. 12 p.
- UZCÁTEGUI-VARELA, JUAN-PABLO; CHOMPRES, KENDRY; CASTILLO, DANIELA; RANGEL, SAIRO; BRICEÑO-RANGEL, ARMANDO; PIÑA, ANDRES. Nutritional assessment of tropical pastures as a sustainability strategy in dual-purpose cattle ranching in the South of Lake Maracaibo, Venezuela. *Journal of the Saudi Society of Agricultural Sciences*, v. 21, n. 7, 2022, p. 432–439.
- VILLALOBOS, LUIS; ARCE, JOSE. Evaluación agronómica y nutricional del pasto estrella africana (*Cynodon nlemfuensis*) en la zona de Monteverde, Puntarenas, Costa Rica. II. Valor nutricional. *Agronomía Costarricense*, v. 38, n. 1, 2014, p. 133–145.
- ZULUAGA-DURANGO, DAVID. Determinación de las reservas de carbono en sistemas bovinos basados en silvopastoreo y praderas sin árboles en bosque seco tropical del Departamento del Huila–Colombia [Tesis Maestría en Desarrollo Sostenible y Medio Ambiente]. Manizales (Colombia): Universidad de Manizales, Facultad de Ciencias Contables Economicas y Administrativas, 2017, 54 p.