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ANIMAL PRODUCTION

The nutritional value of gliricidia in different fed forms: a systematic review

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ABSTRACT: Different types of supplied roughage may cause losses in the chemical composition and digestibility of gliricidia (*Gliricidia sepium* [Jacq.] Kunth ex Walp.) depending on their making and fed-out management. This study has summarized data from scientific studies on gliricidia and compared its nutritional value in various fed forms using a systematic review approach and principal component analysis (PCA). A robust survey of scientific papers was realized on web indexes of periodicals and databases from 1990 to 2023. Data from 100 scientific researches has been compiled and analyzed. In 40% of the trials, the gliricidia nutritional value was determined as fresh leaves, while 30% was in the form of 'leaves + thin stems'. Gliricidia was evaluated as silage in 11% of the opportunities, followed by 10% as leaf meal and 9% as hay. Non-fiber carbohydrates, crude protein (CP), and organic matter digestibility (OM) had negative correlations with neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin. Only NDF, ADF, and CP contents could explain 71% of the total data variation (PC1 and PC2). There was no discrimination among fed forms, so they showed similar nutrient compositions. Eventual nutrient losses reported in the scientific researches owing to ensilage, haymaking, and leaf meal-making processes do not mischaracterize the gliricidia nutritional value. The assorted manners of roughage making, and fed-out management traditionally performed by farmers can conserve the excellent nutritional quality of gliricidia.
Key words: digestibility, hay, secondary metabolites, silage, tropical legume.

O valor nutricional da gliricídia em diferentes formas de alimentação: uma revisão sistemática

RESUMO: Diferentes tipos de volumosos podem causar perdas na composição química e digestibilidade da gliricídia (*Gliricidia sepium* [Jacq.] Kunth ex Walp.) dependendo de sua confecção e do manejo da alimentação. O objetivo deste estudo foi sumarizar dados de trabalhos científicos com gliricídia e comparar seu valor nutritivo em diferentes formas de alimentação, sob uma abordagem de revisão sistemática e análise de componentes principais (ACP). Realizou-se um levantamento robusto de trabalhos científicos em *web* indexadores de periódicos, e em base de dados, de 1990 a 2023. Dados de 100 trabalhos foram sumarizados e analisados. Em 40% dos trabalhos, o valor nutricional da gliricídia foi determinado como folhas *in natura*, enquanto 30% foi na forma de 'folhas + caules finos', em 11% das oportunidades, a gliricídia foi avaliada na forma de silagem, seguido por 10% como farelo de folhas, e 9% como feno. Carboidratos não-fibrosos, proteína bruta (PB) e digestibilidade da matéria orgânica (MO) tiveram correlações negativas com fibra em detergente neutro (FDN), fibra em detergente ácido (FDA) e lignina. Os teores de FDN, FDA e PB foram capazes de explicar 71,00% da variação total dos dados no CP 1 e 2. Além disso, não houve discriminação entre as formas de alimentação, que tiveram composições semelhantes. Eventuais perdas de nutrientes relatadas em trabalhos científicos devido aos processos de ensilagem, fenação ou fabricação de farelo de folhas não descaracterizam o valor nutritivo da gliricídia. As diversas maneiras de confecção de volumosos e manejo da alimentação tradicionalmente utilizadas por agricultores são capazes de conservar a excelente qualidade nutricional da gliricídia.
Palavras-chave: compostos secundários, digestibilidade, leguminosa tropical, feno, silagem.

INTRODUCTION

Gliricidia (*Gliricidia sepium* [Jacq.] Kunth ex Walp.) is an arboreal legume native to Mexico and Central America, and its use in forage production systems for animal feeding has enhanced in recent decades (CASTRO FILHO et al., 2016; RANGEL et al., 2019; ALAMU et al., 2023). This forage source is naturalized in tropical regions worldwide (e.g., South America, Africa, and Southeast Asia) and adapted to limited rainfall conditions (from 365 to 800 mm per year). In such conditions, the gliricidia forage yield may vary from 70 to 105 t ha^{-1} year^{-1} of biomass, and the leaf crude protein (CP) can reach 230 g kg^{-1} of DM. Gliricidia can reduce costs with protein concentrates such as soybean meal (GURGEL et al., 2021).

Gliricidia is a moderate-sized tree that can reach 10 to 15 m of height and 30 to 40 cm in stem diameter (ALAMU et al., 2023). The legume can be grown with seeds or stakes, and smallholder farmers often harvest it in cut-and-carry systems and supply it fresh for the animals. Haymaking and ensilage

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are adequate fed forms of gliricidia, mainly when animals display low acceptability owing to secondary metabolites such as polyphenols, condensed tannins, alkaloids, flavonoids, and especially the coumarin (PURBA et al., 2023a; SUONG et al., 2022). Bovines are more susceptible to fresh gliricidia, while sheep and goats adapt better to this fed form roughage (RUSDY et al., 2019).

Gliricidia has also been utilized in integrated production systems like silvopastoral systems (RANGEL et al., 2019; SILVA et al., 2022; PARRA et al., 2022). This arboreal legume is an efficient carbon sink due to its grand biomass production and high photosynthetic rates (LEMAIRE et al., 2011; PARRA et al., 2023). Moreover, the species provide economic gains because of the N_2 fixing that diminishes considerably the use of inorganic nitrogen fertilizers (SILVA et al., 2023).

Despite the viable use of gliricidia in diverse forage production systems, fluctuations in nutritional value have been reported in the literature (CARVALHO et al., 2017; RUSDY et al., 2019; SOBRAL et al., 2022). Multiple factors can affect the chemical-bromatological composition and digestibility of forage plants, especially tropical legumes since they display various growth habits and secondary metabolites (SALES-SILVA et al., 2023). Besides fertilization and irrigation, harvest frequency and intensity often alter the forage plant's nutritional value. Different forage production systems (e.g., fodder banks, grass-legume intercrops, cacti-legume intercrops, or silvopastoral systems) influence harvest management. In addition, haymaking and ensilage may generate nutrient losses and accumulation of compounds that decline digestibility, such as the acid detergent insoluble protein (ADIP), condensed tannins, and total phenols (CASTRO-MONTOYA & DICKHOEFER, 2018). In addition, gliricidia has been studied as a protein concentrate source in the form of dehydrated foliage (ASAOLU et al., 2012; WINART et al., 2022). Some review manuscripts on gliricidia nutritive value were published (SMITH & VAN HOUTERT, 1987; RANGEL et al., 2019), but a robust survey of information can point out the gliricidia state of the art in animal feeding (e.g., countries where the plant is more used or which technologies are adopted for feeding).

Considering this background, this study summarized data from 100 scientific studies on gliricidia and compare its nutritional value in various fed forms using a systematic review approach besides principal component analysis (PCA).

MATERIALS AND METHODS

Systematic review

Data for this study was obtained from a survey of scientific papers, abstracts, thesis, and dissertations in web indexers of journals and databases. Google Scholar, Web of Science, Periódicos da Capes, CABI Direct, Scielo, Springer, and Science Direct were the platforms used in this review. The searched keywords were 'gliricidia nutritive value', 'secondary compounds/metabolites', 'condensed tannins', 'hay', 'silage', 'leaf meal', 'fodder banks', and 'silvopastoral systems'. Manuscripts published in English, Portuguese, and Spanish languages were considered in the survey. The keyword searched was altered every five manuscripts (e.g., from 'gliricidia nutritive value' to 'gliricidia nutritive value secondary metabolites', then to 'gliricidia nutritive value condensed tannins' and so on). In parallel, the used indexer was switched every ten manuscripts (e.g., from 'Google Scholar' to 'Periódicos da Capes', then to 'Web of Science', and so on). Based on these criteria, 100 scientific researches (90 manuscripts published in journals, five abstracts, and five thesis or dissertations) were selected and identified regarding year and country of publication. In addition, the articles published in journals were ranked based on the quartiles' system from Web of Science (Q1, Q2, Q3, and Q4 in Agriculture, Agronomy, Veterinary Medicine, Animal Science, or Multidisciplinary) (*Supplementary file*).

Gliricidia was identified by the forage production system that originated it: (i) fodder banks, (ii) free-growing trees, (iii) intercrop system, and (iv) silvopastoral system. The fed form also classified the arboreal legume: (i) fresh leaves, (ii) leaves + thin stems, (iii) silage, (iv) hay, and (v) leaf meal.

Variables recorded were the contents of mineral matter (MM), organic matter (OM), crude protein (CP), calcium (Ca), phosphorous (P), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude fiber (CF), non-fiber carbohydrates (NFC), lignin, ether extract (EE), total phenolic compounds (TPC) and condensed tannins (CT). The digestibility of dry and organic matter assayed *in vitro*, *in situ*, or *in vivo* was also registered. The measurement unit was g kg^{-1}, and percentage values were converted by multiplying by ten times the respective value. OM concentrations were calculated by subtracting the MM content from 1000 g kg^{-1} when necessary. Eventual nitrogen concentrations reported were transformed into CP contents by multiplying the value by the 6.25 conversion factor (HORWITZ, 2005; DETMANN et al., 2021). In addition, the NFC contents were calculated using the following formula: NFC = 1000 – (NDF + CP + MM + EE) (SNIFFEN et al., 1992).

Statistical analysis

Information about the year and classification of the manuscripts, besides the forage production systems and fed forms, was subjected to frequency analysis using the PROC FREQ from SAS® OnDemand for Academics. The results were expressed as percentages. All observations regarding the countries producing data about gliricidia were grouped in sheets of Microsoft Excel® 2013 (Supplementary file). Then, a word cloud was elaborated from this data using algorithms from the https://www.wordclouds.com/ webpage. An inductive interpretation was used from the mentioned words by capturing the observation appearances.

Chemical-bromatological and digestibility data was subjected to descriptive statistics (mean, standard deviation, plus minimum and maximum value) and Pearson linear correlation analyses using the PROC CORR, a procedure from SAS® OnDemand for Academics. The probability of error was 5% ($P < 0.05$).

The principal components' relative importance was evaluated using eigenvalues (MARDIA, 1978), thus defining the factors to be extracted by the Varimax rotation method for better interpretability. Therefore, only components with eigenvalues over 1.0 were included in the principal components analysis (PCA), performed using Statistica 8.0.

RESULTS AND DISCUSSION

Scientific publications with gliricidia

One hundred thirty-nine chemical analyses were performed within the 100 scientific works selected based on the search criteria. Of the 90 manuscripts, 32% were published in journals without classification on the Web of Science (Figure 1A). Conversely, 29% of the articles had the best qualification (Q1), while 19% of the works were classified as Q2, 11% as Q3, and 9% as Q4.

The oldest manuscript was from 1990. A graduate increase in studies and analyses of gliricidia nutritive value was noted from that year to 2023. From researches searched in the indexers, 9% were published in 2019, percentage repeated in 2022 (Figure 1B). Conversely, only 1% of the total was published in 1990, 1994, and 1996, years from the first decade of observation.

Regarding the country classification, Brazil had the largest percentage of publications (34.6%) whose chemical-bromatological and digestibility analyses were performed in gliricidia (Figure 2). Mexico and Nigeria occupied the second place, with 9.9% of the studies assessed, followed by Indonesia and Cuba (5.9%). Kenya and Sri Lanka taken the fifth position with 3.0%. Other results were registered in countries from the Americas (e.g., Colombia, Venezuela, and Trinidad and Tobago), Africa (e.g., Tanzania, Ethiopia, and Ghana), and Southeast Asia (e.g., Samoa, Bhutan, and Laos).

These results showed increased relevance in using gliricidia in scientific research, with a more expressive utilization in animal feeding trials in recent decades. The studies concentrated primarily on tropical countries. CASTRO-MONTOYA & DICKHOEFER (2020) realized a systematic review of tropical forage legumes and pointed out that most data were derived from tropical countries such as Brazil, Ethiopia, Nigeria, Zimbabwe, India and Laos. Interest in growing gliricidia is high in tropical or semiarid countries owing to desirable traits like drought tolerance, good regrowth capability, perenniality, high CP concentrations, and cutting management adaptation in fodder banks (RAMOS-TREJO et al.,

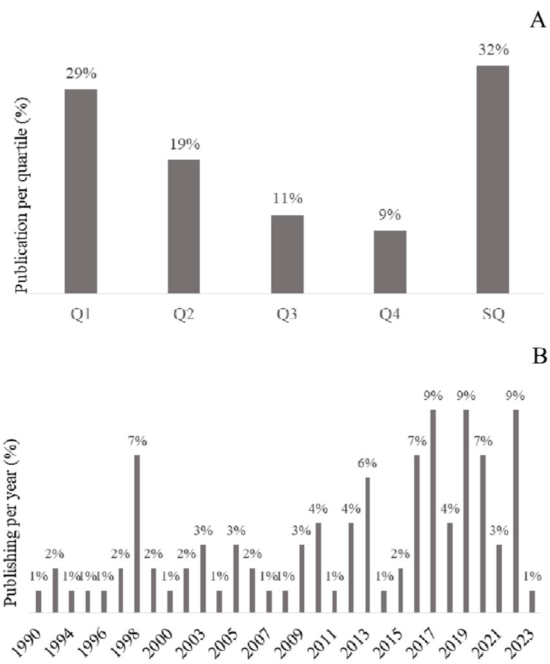

Figure 1 - Percentages of publications in scientific journals containing information on the nutritive value of gliricidia (*Gliricidia sepium* [Jacq.] Kunth ex Walp.), by (A) classification of the Web of Science (Q1, Q2, Q3 and Q4), and (B) per year, from 1990 to 2023. NQ = no qualification.

Figure 2 - Word cloud of countries publishing scientific works containing information on nutritive value of gliricidia (*Gliricidia sepium* [Jacq.] Kunth ex Walp.) from 1990 to 2023. Brazil – 34.6%; Mexico – 9.9%; Nigeria – 9.9%; Indonesia – 5.9%; Cuba – 3.4%; Kenya – 3.4%; Sri Lanka – 3.0%; Tanzania – 3.0%; Colombia – 2.0%; French West Indies –2.0%; Samoa – 2.0%; Trinidad and Tobago – 2.0%; Venezuela – 2.0%; Bhutan – 1.0%; Costa Rica – 1.0%; Ethiopia – 1.0%; Ghana – 1.0%; Guadalupe – 1.0%; Jamaica – 1.0%; Laos – 1.0%; Malaysia – 1.0%; Mozambique – 1.0%; Philippines – 1.0%; Uganda – 1.0%; Vietnam – 1.0%.

2020; BAYALA et al., 2022). The great potential of gliricidia for forage production is probably the key reason why this tree legume is so used in tropical regions (SILVA et al., 2017). Smallholder farmers want to use gliricidia in animal feeding for ensilaging, haymaking, and mixing this legume with other roughage sources to increment the dietary protein (e.g., mixture with forage cactus) (BRITO et al., 2020).

Forage production systems with gliricidia

Gliricidia was harvested in fodder banks in 56% of the studies (Figure 3A). In addition, the gliricidia forage originated from free-growing trees in 40% of the selected works. Only 3.0% of the forage was from silvopastoral systems, even lower from intercrops (1%).

Fodder banks composed of arboreal legumes demand less area than silvopastoral systems or other intercrops. Furthermore, introducing gliricidia trees into integrated production systems is unusual and recent (HERRERA et al., 2021) because, for a long time, there was a preference for growing wood species like eucalyptus (CARVALHO et al., 2022). Harvesting gliricidia leaves in free-growing trees was significant and a simple resolution to feed small herds or confect gliricidia leaf meal, with no labor related to the grow and tillage of this legume (AHMED et al., 2018; WINARTI et al., 2022).

Fed forms and nutritive value of gliricidia

Gliricidia nutritive value was determined in fresh leaves (without branches or stems) in 40% of the publications. ‘Leaves + thin stems’ was the fed form 30% of the time, whereas gliricidia silage was observed in 11%, the gliricidia hay in 10%, and the gliricidia leaf meal in 9% of the selected works (Figure 3B).

Gliricidia hay and leaf meal had higher concentrations of MM and lower OM than fresh leaves, silage, or ‘leaves + thin stems’ (Table 1). Within fed forms, the lower CP content was recorded in the silage (169 g kg^{-1}), followed by the hay (194 g kg^{-1}) and the leaf meal (226 g kg^{-1}). The fresh forages (leaves or ‘leaves + thin stems’) displayed CP contents over 200 g kg^{-1}. Higher NDF and ADF concentrations were recorded in silage and ‘leaves + thin stems’ than in other roughage sources. The lowest EE content was observed in the gliricidia

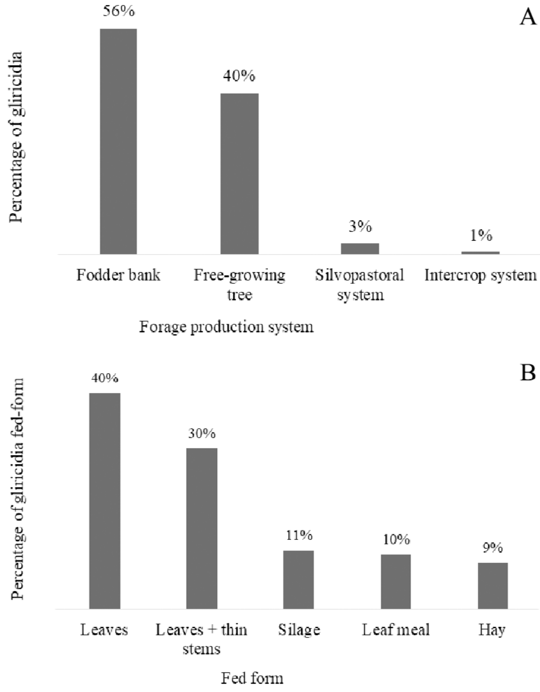

Figure 3 - Percentages of publications in scientific journals containing information on the nutritive value of gliricidia (*Gliricidia sepium* [Jacq.] Kunth ex Walp.), according to (A) the forage production system and (B) the fed form.

silage, while the greatest value was registered in fresh leaves. Of the few researches in which CF was analyzed, the highest value was found in the silage (248 g kg^{-1}) and the lowest in the leaf meal (139 g kg^{-1}). Fresh leaves showed the highest NFC content, and leaf meal displayed the lowest value. Ca, P, TF, and CT were not analyzed in silages or hays, and at most in six opportunities in 'leaves + thin stems'. Contrary to CT and TF, Ca and P had no substantial variability (Table 1). The highest DMO value was found in fresh leaves (624 g kg^{-1}), followed by 'leaves + thin stems' (557 g kg^{-1}) and leaf meals (402 g kg^{-1}).

Preference for fresh leaves probably occurred because they are the most nutritive morphological component of the plant, mainly in tropical legumes like gliricidia (BAN et al., 2022; PARRA et al., 2022). In C_3 plants, leaf tissues are composed of great ratios of mesophyll that have high digestibility plus lower proportions of less digestible tissues such as sclerenchyma, vascular bundle, and lignified vessels. Furthermore, the Rubisco enzyme is embedded in the mesophyll, which explains the high CP content (WILSON & MERTENS, 1995). The woody stems of arboreal legumes are quite lignified, so they are not supplied, and the animals do not graze them. Tree legumes like gliricidia and leucena (*Leucaena leucocephala* [Lam.] de Wit.) often have better nutritive value than shrub types because only leaves comprise the allowed forage (LEE, 2018; RUSDY et al., 2019).

Preference for supplying fresh leaves to hay or silage could be explained for some points: (i) the necessity of labor to make silage, hay, or leaf meal; (ii) the necessity of storage room or sheds plus the technological degree to prepare the feedstuffs; and (iii) avoidable and unavoidable nutrient losses during the ensilage or haymaking processes (DANIEL et al., 2019; NERES et al., 2021). Lower contents of CP, NFC, and DM digestibility in silages, hays, and leaf meals represent a nutritional decline related to the original material (KUNG JR. et al., 2018; PURBA et al., 2023b). Proteins, soluble carbohydrates, vitamins, and other organic materials are lost through effluent and gas production over the fermentation during ensilage (BORREANI et al., 2018) or by dehydration during haymaking (BAYÃO et al., 2016; CARVALHO et al., 2017). Losses during the ensilage may be higher in tropical forage plants like gliricidia owing to the elevated moisture content (COSTA et al., 2022). Another factor increasing losses in gliricidia silage is the buffering capacity of legumes, performed by residual amino acids and the presence of cations (K^+, Ca^{2+}, and Mg^{2+}) that neutralize organic acids and stop the sharp reduction of pH (EVANGELISTA et al., 2009).

Regarding secondary metabolites, there was significant variability in results (Table 1), and gliricidia was characterized as a plant with low concentrations of CT and TPC. Coumarin is another secondary compound known as an anti-nutritional factor of gliricidia, which declines the forage acceptability owing to a specific smell produced (AHN et al., 1997; TAHUK et al., 2022). However, coumarin concentration was evaluated in only one of the 100 scientific works. WOOD et al. (1998) analyzed the coumarin concentration in 16 gliricidia genotypes. However, they reported high data variability (from 0.50 to 7.72 g kg^{-1} of DM), plus considerable losses by drying the samples, besides several difficulties in determining the concentrations. These issues likely discouraged other researchers from analyzing coumarin, alkaloids, flavonoids and other secondary metabolites in gliricidia over the years.

Significant effects were observed in 16 of the 105 possible Pearson correlations between variables assessed in all fed forms of gliricidia (Table 2). The higher coefficient was recorded in MM × OM correlation ($r = -0.99$), with a negative association degree. CP correlated negatively with ADF ($r = -0.22$; $n = 113$) and lignin ($r = -0.32$; $n = 64$) but with low degrees

Table 1 - Descriptive statistic of nutritive value of gliricídia(1) (Gliricidia sepium [Jacq.] Kunth ex Walp.) in 135 analyses of 100 scientific researches with different fed forms and published from 1990 to 2023.

Fed form	MM	OM	CP	NDF	ADF	LIG	EE	CF	NFC	Ca	P	TPC	CT	DMD	OMD
	(g kg-1 DM)														
Leaves	79	921	225	440	2844	109	61	152	245	14	2	28	41	643	624
n	37	38	55	51	49	30	14	3	7	19	19	18	12	24	22
SD	20	24	43	93	76	45	29	7	36	17	1	13	65	113	107
Minimum	28	885	104	240	114	22	23	145	171	4	1	0	0	469	510
Maximum	115	998	300	656	88	176	100	159	276	83	4	50	205	864	789
Leaves + stems	91	909	208	458	337	99	43	182	119	11	2	13	19	510	557
n	31	31	40	39	35	17	15	4	208	4	5	4	6	14	6
SD	25	26	37	91	98	46	29	60	12	5	1	6	21	78	64
Minimum	58	816	130	238	121	16	16	120	85	4	1	6	0	322	455
Maximum	184	942	268	653	506	188	137	264	501	16	3	18	58	709	710
Silage	79	921	169	480	338	99	35	248	226	.	.	.	.	531	.
n	11	11	11	13	13	9	10	1	10	.	.	.	.	5	.
SD	15	15	29	91	85	48	8	.	128	.	.	.	.	69	.
Minimum	62	902	128	280	219	38	25	248	79	.	.	.	.	467	.
Maximum	98	938	232	644	488	174	47	248	471	.	.	.	.	520	.
Hay	101	899	194	425	291	106	57	153	238	.	.	.		704	.
n	11	11	12	11	9	4	7	2	5	.	.	.		2	.
SD	50	50	21	107	72	41	36	59	120	.	.		.	49	.
Minimum	63	764	139	240	164	84	28	111	52	.	.	.	.	670	.
Maximum	236	937	214	639	417	167	123	195	341	.	.	.	.	739	.
Leaf meal	111	889	226	441	323	104	49	139	190	14	2	202	122	607	402
n	13	13	14	10	10	6	8	4	4	2	1	3	5	3	1
SD	53	53	56	98	111	34	20	37	97	7	.	192	150	21	.
Minimum	54	756	163	330	164	52	13	86	57	9	2	6	0	583	402
Maximum	244	946	346	592	567	143	77	170	290	19	2	388	351	624	402

(1)MM – mineral matter; OM – organic matter; CP – crude protein; NDF – neutral detergent fiber; ADF – acid detergent fiber; LIG – lignin; EE – ether extract; CF – crude fiber; NFC – non-fiber carbohydrates; TPC – total phenolic compounds; CT – condensed tannins; Ca – calcium; P – phosphorous; DMD – dry matter digestibility; OMD – organic matter digestibility.

of association. CNF content negatively correlated with NDF (r = -0.90; n = 37) and ADF (r = -0.69; n = 36) concentrations. Ca concentration was positively associated with MM (r = 0.50; n = 17) and ADF (r = 0.39; n = 25), but with moderate degrees. The concentration of total phenols (TP) was negatively associated with the concentration of MM (r = -0.58; n = 22) and DMD (r = -0.49; n = 18) but positively with OM (r = 0.58; n = 22) and CP (r = 0.68; n = 25) levels. OMD had a high and negative correlation with lignin (r = -0.62; n = 23) and P (r = -0.70; n = 13), in addition to a high and positive correlation with DMD (r = 0.74; n = 17).

NFC, CP, and OMD correlated negatively with fiber compounds such as NDF, ADF, and lignin. Plant cell wall thickening enhances cellulose and lignin concentrations in the forage, mainly over the plant maturity, while decreasing the contents of soluble proteins and carbohydrates plus other digestible nutrients (WILSON & MERTENS, 1995). Conversely, TPC and CP had a positive correlation. Tropical forage legumes like gliricidia often present secondary metabolites that bind to proteins, forming complexes. Such complexes reduce OMD if the secondary metabolites are found in large concentrations (MUIR et al., 2019). In addition, lignin may reduce OMD when binding proteins since protein-lignin complexes are indigestible (LICITRA et al., 1996; SALES-SILVA et al., 2023). Lignin decreases digestibility also because it is an indigestible phenolic compound (CHAND et al., 2022). The negative correlation between lignin and forage digestibility could be observed in the present study (Table 2).

We analyzed 15 variables in the PCA; the most important were NDF, ADF, CP, and OM. PCA inferred that the first two PCs (PC1 and PC2) could explain 71.00% of the total data variation (Table 3). In PC1, NDF and ADF directly correlated to the PC,

Table 2 - Pearson correlation coefficients (r) between variables of nutritive value of gliricídia(1) (Gliricidia sepium [Jacq.] Kunth ex Walp.) in 135 analyses of 100 scientific researches with different fed forms and published from 1990 to 2023.

	OM	CP	NDF	ADF	LIG	EE	CF	NFC	Ca	P	TPC	CT	DMD	OMD
MM (r)	-0.99	0.02	-0.08	-0.18	0.11	-0.12	-0.24	-0.04	0.50	-0.18	-0.58	-0.38	0.15	-0.25
P-value	<.001	0.874	0.456	0.110	0.402	0.410	0.406	0.795	0.041	0.498	0.004	0.109	0.387	0.192
N	102	102	93	84	55	51	14	39	17	17	22	19	38	28
OM (r)		0.01	0.05	0.14	-0.12	0.12	0.24	0.04	-0.28	0.05	0.58	0.38	-0.14	0.25
P-value		0.937	0.619	0.216	0.398	0.423	0.406	0.799	0.259	0.829	0.004	0.109	0.387	0.192
N		101	92	83	55	49	14	39	18	18	22	19	38	28
CP (r)			-0.05	-0.22	-0.32	-0.04	0.03	-0.15	-0.33	0.25	0.68	0.13	-0.01	0.10
P-value			0.550	0.017	0.009	0.755	0.932	0.367	0.102	0.233	<.001	0.569	0.927	0.607
N			121	113	64	53	13	38	25	25	25	23	46	29
NDF (r)				0.67	0.17	-0.15	-0.56	-0.90	0.06	-0.22	0.17	0.15	-0.12	0.01
P-value				<0.001	0.174	0.320	0.326	<.0001	0.758	0.283	0.438	0.518	0.404	0.977
N				116	66	48	5	37	25	25	23	21	47	29
ADF (r)					-0.01	-0.27	-0.88	-0.69	0.39	0.02	-0.12	0.39	-0.08	0.03
P-value					0.962	0.077	0.117	<.0001	0.053	0.941	0.597	0.091	0.624	0.870
N					66	45	4	36	25	25	22	20	42	29
LIG (r)						-0.14	1.00	-0.21	-0.23	0.41	0.13	-0.13	-0.33	-0.62
P-value						0.486	.	0.298	0.434	0.160	0.594	0.667	0.091	0.002
N						28	2	26	14	13	20	13	27	23
EE (r)							0.07	0.08	0.96	-1.00	-0.52	-0.68	0.15	-0.78
P-value							0.822	0.643	0.175	.	0.650	0.134	0.637	0.121
N							12	37	3	2	3	6	12	5
CF (r)								0.66	.	.	.	.	-1.00	.
P-value								0.158	.	.	.	.	.	.
N								6	1	0	0	1	2	0
NFC (r)									-1.00	.	-1.00	-0.50	0.14	0.81
P-value									.	.	.	0.396	0.690	0.098
N									2	1	2	5	11	5
Ca (r)										0.29	-0.06	1.00	-0.17	-0.16
P-value										0.168	0.869	0.007	0.539	0.592
N										24	11	3	16	13
P (r)											-0.13	-1.00	-0.41	-0.70
P-value											0.708	.	0.112	0.008
N											11	2	16	13
TPC (r)												0.77	-0.49	-0.47
P-value												0.010	0.040	0.122
N												10	18	12
CT (r)													-0.43	-0.45
P-value													0.221	0.370
N													10	6
DMD (r)														0.74
P-value														0.001
N														17

Pearson linear correlation was significant at 5% of probability of error ($P < 0.05$) (highlighted in black). r – Pearson correlation coefficient. (1)MM – mineral matter; OM – organic matter; CP – crude protein; NDF – neutral detergent fiber; ADF – acid detergent fiber; LIG – lignin; EE – ether extract; CF – crude fiber; NFC – non-fiber carbohydrates; TPC – total phenolic compounds; CT – condensed tannins; Ca – calcium; P – phosphorous; DMD – dry matter digestibility; OMD – organic matter digestibility. n = number of intersected observations.

Table 3 - Factorial charges, eigenvalues, and accumulated variance of concentrations of organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) of gliricidia (Gliricidia sepium [Jacq.] Kunth ex Walp.) in different fed forms, with scientific research data from 1990 to 2023.

Variable	----------------------PC1----------------------	----------------------PC2----------------------
OM	0.161424	0.496260
CP	0.057430	-0.887807
NDF	0.946607	0.039986
ADF	0.929570	0.148039
Eigenvalue	1.842850	1.004661
Maximum accumulated variance (%)	46.1	71.2

PC1 - principal component 1; PC2 – principal component 2.

explaining 46.07% of the total variation. Conversely, in PC2, the CP showed an inverse correlation with the PC, explaining 24.93% of the variation. No discrimination was observed between gliricidia fed-forms (Figure 4) despite the numerical differences found in means (Table 1).

NDF, ADF, and CP had a substantial discriminatory power, and they are variables of great interest in animal feeding for characterizing the nutritional value of forage plants. The CP was the most analyzed nutrient likely by assuming that gliricidia has a great protein value (over 200 g kg^{-1}), based on the available dataset about the plant (VALADARES FILHO et al., 2016; VALADARES-FILHO et al., 2018). Also, CP, NDF, and ADF analyses are trivial for describing the chemical composition of feedstuffs. The methods to estimate CP, NDF, and ADF are less demanding in terms of infrastructure and technological degree (e.g., apparatus, reagents, and technical knowledge) compared to the analyses of lignin, TPC, CT, Ca, and P) (BEZERRA NETO & BARRETO, 2011; DETMANN et al., 2021). Lack of discrimination in the fed forms validated the gliricidia use as silage, hay, or leaf meal without significant

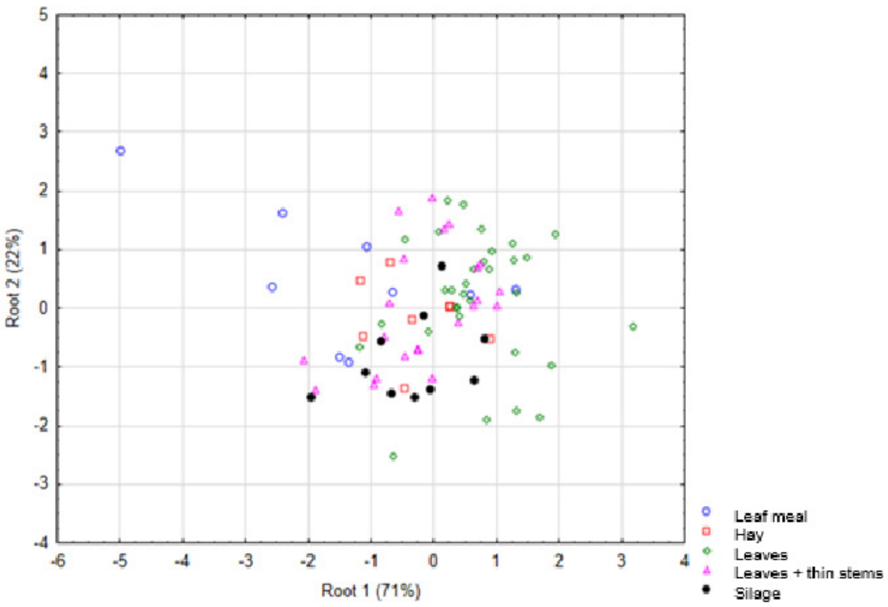

Figure 4 - 2D graphic of distribution of fed forms of gliricidia (*Gliricidia sepium* [Jacq.] Kunth ex Walp.) regarding the nutritive value, with scientific research data from 1990 to 2023.

nutrient losses by fermentation or dehydration processes of the vegetal material.

CONCLUSION

Gliricidia-fed forms do not represent significant differences in the chemical composition and digestibility of the forage plant. Eventual nutrient losses reported in the scientific works owing to ensilage, haymaking, and leaf meal-making processes do not mischaracterize the gliricidia nutritional value.

Findings in this systematic review reinforce the great gliricidia value in animal feeding and nutrition and reveal an interesting fed-form versatility of this legume with no significant nutrient losses. The assorted manners of roughage making, and fed-out management traditionally performed by farmers can conserve the excellent nutritional quality of gliricidia. Mineral nutrients and anti-nutritional variables must be analyzed in further scientific researches to detail the legume's chemical composition better.

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DECLARATION OF CONFLICT OF INTEREST

We have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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