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Nutrient composition of some important Brazilian savanna trees and their potential for animal feed

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Abstract

Brazilian savanna (Cerrado) trees present high diversity, whether they are being used by fauna and traditional populations as food or medicine. However, little research has been done to evaluate the nutrient composition of different species relevant to society, which may highlight new uses of these species. The objective of this study was to characterize nutritional aspects of the leaves of different Cerrado native species. Bromatological analyses (i.e. dry matter (DM), total digestible nutrients (TDN), crude protein (CP), ether extract (EE), crude fiber (CF), mineral matter (MM), and nutrient concentration were performed on five native tree species (*Inga cylindrica*; *Platymiscium floribundum*, *Piptadenia gonoacantha*, *Anadenanthera macrocarpa*, and *Dipteryx alata*) that presented potential for animal feed, according to farmer's reports. The chemical characteristics of the leaves of Cerrado trees were characterized and compared between them. All five species evaluated in this study showed nutritional characteristics that suggest their potential use for animal feed, especially the *P. floribundum, I. cylindrica,* and *P. gonoacantha* for their high protein value.

Keywords: Family farm; forage; protein; dry season, Fabaceae.

Introduction

Brazil has unparallel biodiversity in its territory, with approximately 24% of the total superior plants on Earth. The majority of the Brazil's biodiversity is found in the Cerrado (the Brazilian Savanna), which has a promising vegetation for animal feed despite its soils containing high acidity, low fertility, and elevated concentrations of iron and aluminum (Botelho et al., 2018).

The decline in biomass production from forage grasses introduced to the biome, which are characterized by low precipitation and mild temperatures during the winter months, highlights the need to evaluate forage potential of the diverse species within the Cerrado (Cardoso et al., 2014). Most of the forage grasses have not adapted to the edaphoclimatic conditions of the region and are often mismanaged, resulting in grazing degradation that limits the production and profitability of the system (Torres et al., 2018; Pereira et al., 2018). It is estimated that more than 70% of pastures in Brazil show some degree of degradation, whereas in the Cerrado region alone, degraded pastures can be as high as 80% (Galdino et al., 2015).

In this context, the tree/shrub species can be used for the recovery of soil and pastures due to their continuous deposition of plant residues in the soil surface, thereby increasing levels of organic matter and macro and micronutrients in the soil (Oelbermann et al., 2006; Nogroveet al., 2009; Vega et al., 2013; Pinto et al., 2014). In addition, tree/shrub species can contribute to the maintenance of animal thermal comfort, which in turn improves the productivity and reproductivity levels of the herd (Filho Curado 2007; Calil et al., 2016).

Thus, the use of native Cerrado tree/shrub species could be an alternative to complement the animal diet during drought periods. For instance, 70% of dairy farmers in Jamaica massively use trees and shrubs for animal feed (Alonzo et al.,

2001). In semi-arid regions in Brazil, mesquite (*Prosopis juliflora*) and prickly pear (*Opuntia* sp.) are used in family farms to feed cattle and sheep (Andrade-Montemayor et al., 2011).
According to Nicodemo et al. (2004), some trees and forage shrubs of the genus *Calliandra Erythrina, Leucaena* present high levels of crude protein, ranging from 22% to 26% during the drought season. However, they are considered exotic species in the context of the Cerrado; therefore, their introduction into pastures would result in higher production costs. In this sense, there is the challenge to advance the studies of Cerrado native species that have potential for animal feed; the determination of the nutritional value, based on chemical-bromatological parameters, is a basic premise (Silva et al., 2021). Therefore, the objective of this study was to evaluate the forage potential of Cerrado native species based on chemical-bromatological analysis.

Results

All species surveyed by the farmers were from the Fabaceae family, which is commonly found in the Cerrado of Goiás and even Brazil. Table 1 shows more details about each species (Farmers' reports; Lorenzi 1992 and 1998; Silva Júnior 2012; Gomes 2018; Carvalho 2004; and Silva 2011) (Table 1).
The average dry matter content was different among the species evaluated in this study, with the highest value for *A. macrocarpa*, followed by *P. gonoacantha*, *I. cylindrica*, *D. alata*, and *P. floribundum*, as shown in Table 2. High concentrations of CD were found in *I. cylindrica* (20.90%) and *P. floribundum* (21.43%), whereas *A. macrocarpa* (13.3%) and *D. alata* (13.1%) showed low concentrations. As expected, these results were similar for the average percentage of N, since it also reflects the protein percentage of the leaves.
The highest averages of CF and ADF were found in *I. cylindrica*, followed by *D. alata*, *P. floribundum*, *A. macrocarpa*, and finally *P. gonoacantha*. Consequently, the decreasing order of the for the DMD, TDN, DE, and ME variable averages were inversely proportional to those observed for CF and ADF. The EE varied between 1.35 (*D. alata*) and 1.83% (*P. floribundum*), whereas the MM ranged from 3.05 (*D. alata*) to 4.0% (*I. cylindrica*).
The average P concentration varied among species, ranging from 0.10 (*A. macrocarpa*) to 0.32 dag kg^{-1} (*P. floribundum*), resulting in 68.75% of variation among species. Table 2 shows the average concentration of the remaining nutrients. The average levels of MM, CP, P, N, and K formed two groups. The first group was comprised of species with the highest levels (*I. cylindrica* and *P. floribundum*), whereas the second group comprised species with lowest average levels (*P. gonoacantha*, *A. macrocarpa*, and *D. alata*). In contrast, a distinct distribution for Ca was found compared to the other variables, with *A. macrocarpa* and *D. alata* showing the highest levels, *P. gonoacantha* with medium levels, and *P. floribundum* and *I. cylindrical* with the lowest levels (Fig. 1).
For the variables CP, P, and N, larger standard deviations were found in *P. floribundum*. For *P. floribundum* and *A. macrocarpa*, the standard deviation for MM was higher. The largest standard deviations were found for K in *P. floribundum* and *D. alata* and for Ca in *A. macrocarpa*. As expected, these results (Table 2) indicate that there are varying nutrient concentrations among the five native species. However, the average levels of macronutrients were higher in *I. cylindrica* and *P. floribundum*, with the exception of Mg for *I. cylindrica* and Ca for both species. In contrast, the *A. macrocarpa* showed high levels of micronutrients, especially in Fe, Na, Mn, and Cu (PC1:43.35%; PC2 18.89%). Fig 2 shows that the species *I. cylindrica* and *P. floribundum* were close to each other, and correlated to the means of CP, CF, MM, Cu, Zn, P, K, N, S, and EE. In contrast, *P. gonoacantha*, *A. macrocarpa*, and *D. alata* were more correlated to Ca, Mn, Fe, Mg, Na, and TDN.
The mean value of CF was directly related to Mo; both CF and Mo were inversely related to TDN. The variables that most correlated with *P. gonoacantha*, *A. macrocarpa,* and *D. alata* were also highly correlated with each other when compared to the other variables. CP and N were among the variables most correlated with each other ($R=0.999$; $p<0.000$), which is expected by their chemical characteristics; however, EE and CP also showed similar correlations ($R=0.93$; $p<0.000$). Regarding the macro and micronutrients, results showed that Ca, Fe, Mg, Mn, and Na were in opposition to K, Co, S, and Zn (other chemical attributes and their relationships can be seen in table 03). Exception of Na and Mo, all components of the multivariate analysis showed proportional sizes, demonstrating that the definition of leaf nutritional parameters is influenced by several aspects.

Discussion

Overall, all the native species showed an average DM concentration above the ideal range for the ensiling process at 30 to 35% (Embrapa 1991). Dry matter concentration above 35% hinders compaction and increases oxygen levels in the silage mass, favoring the development of aerobic microorganisms and, consequently, the reduction in silage nutrient concentration. Values above 60% of DM do not allow for adequate compaction (Tomich 2012); only *P. floribundum* showed DM below this threshold (45.67%). Therefore, all the species evaluated are not recommended for silage. However, they can be preserved and used in other ways, such as hay or offered *in natura* to animals.
Another important result from this study was the high average concentration of CP found in *P. floribundum* (21.43%) and *I. cylindrica* (20.90%). Even though the CP concentration was lower for both *A. macrocarpa* (13.3%) and *D. alata*, (13%) when compared to the other species, they cannot necessarily be considered low overall since they satisfy the minimum condition for the proper functioning of the rumen, which ranges from 6 to 8% CP (Van Soest 1994).
These results are similar or superior to those found in forage grasses grown in Cerrado soils. Echeverria et al. (2016) found protein concentration between 11.9 and 13.8% for the hybrid *Urochloa* BRS RB331 Ipyporã when submitted to different combinations of grazing frequencies and intensities in the Cerrado (Campo Grande, MS, Brazil). Fontaneli et al. (2012) found CP ranging from 10 to 15% in Napier grass (*Pennisetum purpureum* Schum.), obtained from cutting intervals of 20 to 40 days and rapidly decreasing the nutritional value after six weeks. In the same study, the authors found CP close to 8.4% in Guinea grass (*Panicum maximum* Jacq.).
In a study evaluating the bromatological composition of *Brachiaria brizantha* cv. Marandu under the seasonality effect, Costa et al. (2005) found CP ranging from 7% in the dry season and 11.98% in the wet season. For *Brachiaria humidicola,* when

lower quality species are compared to other *Brachiaria*, CP ranges from 3 to 6% (Crispim and Branco, 2002).

Thus, the results of this study demonstrate the potential of these native plants to be used in animal feed, since animals are sensitive to protein deficiency and, therefore, tend to select plants that have higher CP concentration (Hirata et al., 2012). Moreover, CP is one of the most relevant nutritional components in pasture production systems, as it is one of the most variable and limiting constituents in tropical grasses (Hughes et al., 2016).

In addition to the potential use of these five native species in pastures and forage grasses, there is also the possibility to form these so-called forage banks or protein banks. These are areas cultivated exclusively with legumes or in consortium with annual row crops and/or pastures with the basic purpose of providing forage with high nutritional value, especially protein; this would supplement ruminant as a viable strategy to control grazing of foliage.

The average CP concentration varies according to plant species, age, the plant section evaluated, fertilization, and time of year. In this sense, tropical pastures have low productivity during the dry season when CP concentration is below 7%, resulting in low fiber degradation in the rumen and, in turn, a low consumption of DM (Nicodemo et al., 2004); this was the same season in which the samples were collected for this study.

Regarding CF and ADF, *P. gonoacantha* had a lower concentration of 19.67 and 23.82%, respectively. Thus, this latter species was the one that showed the highest DMS at 70.34%. It is possible that this species could provide better results in an animal performance test, since the low CF amount is directly related to the quality of the food offered to the animals. Additionally, the AFD consists almost entirely of cellulose and lignin, which in turn has a negative impact on the digestibility of other nutrients (Silva 2002).

In addition to being more digestible, plants with lower fiber content emit less greenhouse gases to the atmosphere, which is key to create a more sustainable production system. Along with presenting the second highest CP, the *I. cylindrical* showed the highest levels of CF (32.3%) and ADF (40.01%), which influenced the DMD (57.73%) being the lowest among the five native species evaluated. In a study evaluating different species of the *Inga* genus, Souza (2018) found high levels of ADF, ranging from 37.47% (*Inga macrophylla)* and 58.16% (*Inga nobilis*), and consequently, low values of digestibility compared to other species used in the ruminant feedings.

While presenting the highest CP concentration, the *P. floribundum* had 26.3% of CF, 32.49% of ADF, and 63.59% of DMD. In contrast, although the *A. macrocarpa* had the second highest CP concentration, it also had relatively low levels of CF (22.53%), ADF (27.06%), and DMD (67.82%) in relation to the other species, which contributed to the forage potential of the species. However, *D. alata* had the lowest CP, the second highest ADF (34.27%), and the second lowest DMD in comparison to the other species. Therefore, these results indicate that even the native species evaluated in this study with the highest concentration of CF, ADF, and DMD, have potential to feed ruminants when compared to common forages grown in the Cerrado.

Almeida et al. (2009) evaluated species with forage potential in the Caatinga region in Brazil and found the values of DM (44.37%) and ADF (33.99%), which are similar to those reported here during the dry and wet season. However, the CP had a low average of 13.75% which is likely related to lower annual rainfall (600 mm) in the areas where plants were sampled. Forages with an ADF of approximately 30% are consumed in high quantities versus those with values greater than 40% (Simon et al., 2009). In this sense, *I. cylindrica, P. floribundum,* and *D. alata* would be the least interesting species for ruminants; only the first species has a percentage slightly above 40%.

The highest concentrations of TDN, DE, and ME were found in *P. gonoacantha* (71.17%, 3.14%, and 2.57%, respectively), followed by *A. macrocarpa* (68.9%, 3.04%, and 2.49%, respectively) and *P. floribundum* (65.10%, 2.87%, and 2.35%, respectively). The *Inga cylindrica* and *Dipteryx alata* showed lower concentrations of TDN, DE, and ME in this study. It is believed that all food, with the exception of lignin, has full potential for degradability; however, the digestion never entirely occurs due to small portions of lignin that are inserted in cellulose and hemicellulose. In turn, this acts as a barrier against the degrading action of ruminal microorganisms (Salman et al., 2010). High values of CF and ADF directly influence the digestibility of the food and, consequently, the results of TDN, DE, and ME in this study.

All the five native species showed lower values of MM when compared to other common forages. Moraes et al. (2005) found 6.9% for *Brachiaria decumbens*. Minerals are crucial for the proper functioning of the organisms; in their absence, the animal's performance drops, leading to health problems and low productivity (Cassuce 2012). Souza (2018) found MM of 4.68% in *Inga* genus.

The low MM values observed here are likely related to the low availability of minerals in the soil, since none of the areas where the samples were taken were fertilized and/or limed (to increase pH) in the last five years. In addition, these areas correspond to semi-intensive pastures without many divisions, which tend to export more nutrients from the system and reduce fertility over time (Machado 2013).

Generally, the forages had low EE concentrations (between 1 and 4% of DM), in which higher levels can be obtained by adding lipids or oilseeds to the diet (Silva 2011). Therefore, the total diet of the ruminants cannot contain more than 5% fat (EE) in order to avoid compromising food storage and influencing the palatability and consumption (Genro 2008). All the species evaluated showed an average EE concentration below 5%, ranging from 1.35% in *D. alata* to 1.83% in *P. floribundum.*

Silva (2012) evaluated species with forage potential in the semi-arid area of the Bahia state and reported that *A. macrocarpa* showed higher levels of CP and EE than those reported here at 17.54% and 1.72% respectively; however, the values for DM (47.22%) and ADF (24.77%) were different.

Despite the variation in the P levels among species, it is important to highlight that the P concentration in *P. floribundum* was 0.32 dag kg^{-1}, which is similar to those found by Ribeiro et al. (2017) when evaluating the litter (accumulated vegetal material) in typical Cerrado area. Although the natural P levels in the Cerrado region are low, the plants have adapted and can accumulate large concentrations of this and other nutrients (Valadares et al., 2015).

Table 1. Scientific and popular names, subfamily, and uses of the five native species.

Scientific name	Popular name in Brazil	Subfamily of Fabaceae	Useage↑
Dipteryx alata Vog	Baru	Caesalpinioideae	A, B, D, E, F, G, H, I
Piptadenia gonoacantha (Mart.) J. F. Macbr	Pau-jacaré	Caesalpinioideae	A, B, C, D, E, F
Inga cylindrica (Vell.) Mart.	Inga	Mimosoideae	A, B, E, F, G, J
Anadenanthera macrocarpa (Benth.) Brenan	Angico	Mimosoideae	A, B, C, D, F, G, H
Platymiscium floribundum Vogel	Feijão-cru	Papilionoideae	A, B, E, F

↑A = recovery of degraded areas; B = wood is used for energy/firewood; C = use for obtaining tannin; D = wood is used for sawmill; E = beekeeping; F = forage (cattle); G = human food; H = medicinal; I = natural fence; J = nitrogen fixation (symbiosis with *Rhizobium* sp.)

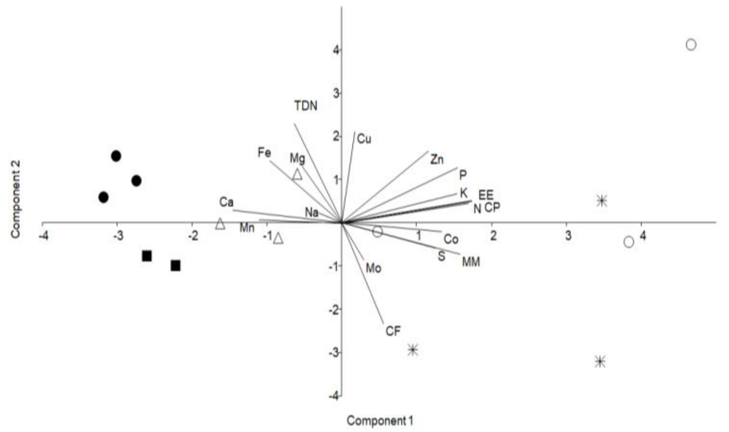

Fig 1. Principal Components Analysis of the chemical-bromatological analysis of the five native species (PC1:43.35%; PC2 18.89%; TDN, total digestible nutrients; CP, crude protein; EE, ether extract; CF, crude fiber; MM, mineral matter; N, nitrogen; P, phosphorus; K, potassium; Mg, magnesium; Ca, calcium; S, sulfur; Fe, iron; Na, sodium; Mn, manganese; Zn, zinc; Cu, copper; Mo, molybdenum; and Co, cobalt). (Black ball – *A. macrocarpa*; Square – *D. alata*, Triangule – *P. gonoacantha*; Asterisk - *I. cylindrica* and Circle – *P. floribundum*).

Table 2. Average concentration of dry matter (DM), crude protein (CP), crude fiber (CF), acid detergent fiber (ADF), digestible dry matter (DMD), total digestible nutrients (TDN), digestible energy (DE), metabolizable energy (ME), ether extract (EE), mineral matter (MM), nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), iron (Fe), sodium (Na), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and cobalt (Co) for each native species of the Cerrado.

	Species				
	Inga cylindrica	*Platymiscium floribundum*	*Piptadenia gonoacantha*	*Anadenanthera macrocarpa*	*Dipteryx alata*
DM (%)	70.00	45.67	75.33	84.00	67.5
CP (%)	20.90	21.43	17.03	13.3	13.1
CF (%)	32.30	26.30	19.67	22.53	28.5
ADF (%)	40.01	32.49	23.82	27.06	34.27
DMD (%)	57.73	63.59	70.34	67.82	62.20
TDN (%)	59.83	65.10	71.17	68.9	63.85
DE (%)	2.64	2.87	3.14	3.04	2.82
ME (%)	2.16	2.35	2.57	2.49	2.31
EE (%)	1.73	1.83	1.47	1.40	1.35
MM (%)	4.00	3.93	3.17	3.13	3.05
N (%)	3.35	3.43	2.73	2.13	2.1
P (dag kg^{-1})	0.19	0.32	0.12	0.10	0.11
K (dag kg^{-1})	1.02	1.48	0.66	0.49	0.75
Mg (dag kg^{-1})	0.13	0.25	0.12	0.31	0.19
Ca (dag kg^{-1})	0.49	0.54	1.05	1.93	1.85
S (dag kg^{-1})	0.16	0.13	0.13	0.12	0.12
Fe (mg kg^{-1})	180.33	231.67	260.33	297.33	245.5
Na (mg kg^{-1})	101.67	101.33	98.67	108.67	104
Mn (mg kg^{-1})	100.67	65.00	152.67	260.67	332.5
Zn (mg kg^{-1})	30.00	44.67	22.33	26.67	28.5
Cu (mg kg^{-1})	7.67	8.67	8.00	8.67	7.5
Mo (mg kg^{-1})	0.54	0.49	0.51	0.46	0.52
Co (mg kg^{-1})	0.14	0.14	0.13	0.11	0.12

Table 3. Correlation coefficient and statistical significance between chemical attributes of Cerrado trees (Attributes that do not appear in the table were not correlated - dry matter (DM), crude protein (CP), crude fiber (CF), acid detergent fiber (ADF), digestible dry matter (DMD), total digestible nutrients (TDN), digestible energy (DE), metabolizable energy (ME), ether extract (EE), mineral matter (MM), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and cobalt (Co).

	DM	CP	CF	ADF	DMD	TDN	DE	ME	EE	MM	N	P	K	Ca	Mn	Zn	Co
DM	-	-	-	-	-	-	-	-	-	-	-	0.032	0.013	-	-	0.033	-
CP	-	0	-	-	-	-	-	-	0.0069	0.0177	0.000	-	-	0.0013	0	-	0.0128
CF	-	-	0	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	-	-
ADF	-	-	0.997	0	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	-	-
DMD	-	-	-0.99	-1	0	0.000	0.000	0.000	-	-	-	-	-	-	-	-	-
TDN	-	-	-0.99	-1	1	0	0.000	0.000	-	-	-	-	-	-	-	-	-
DE	-	-	-0.99	-0.999	0.999	0.999	0	0.000	-	-	-	-	-	-	-	-	-
ME	-	-	-0.99	-0.999	0.999	0.999	0.99	0	-	-	-	-	-	-	-	-	-
EE	-	0.967	-	-	-	-	-	-	0	0.006	0.007	-	-	0.026	0.027	-	-
MM	-	0.939	-	-	-	-	-	-	0.96	0	0.017	-	-	0.03	0.06	-	
N	-	0.999	-	-	-	-	-	-	0.96	0.93	0	-	-	0.001	0.009	-	0.012
P	-0.90	-	-	-	-	-	-	-	-	-	-	0	0.00	-	-	0.019	-
K	-0.94	0.835	-	-	-	-	-	-	-	-	-	0.976	0	-	-	0.028	-
Ca	-	-0.98	-	-	-	-	-	-	-0.92	-0.89	-0.989	-0.770	-	0	0.012	-	0.005
Mn	-	-0.96	-	-	-	-	-	-	-0.91	-	-	-	-	-	0	-	-
Zn	-0.90	-	-	-	-	-	-	-	-	-	-	0.934	-	-	-	0	-
Co	-	0.95	-	-	-	-	-	-	-	-	0.951	-	-	-0.972	-	-	0

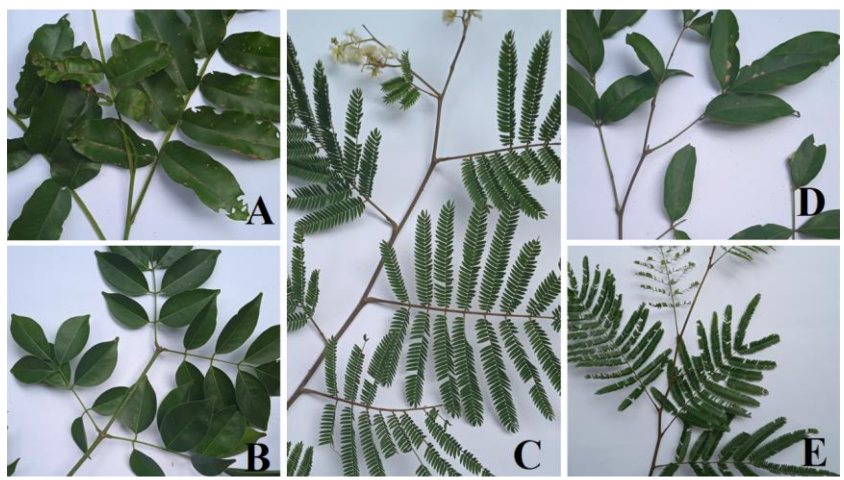

Fig 2. A. Leaves of *Dipteryx alata*, alternate phyllotaxis, compound leaves, winged rachis. B. Leaves of *Platymiscium floribundum*, phyllotaxis opposite, leaves compound. C. *Piptadenia gonoacantha*, alternate phyllotaxis, recomposed leaves, presence of thorns and extrafloral nectaries. D. *Inga cylindrica*, alternate phyllotaxis, compound leaves, extrafloral nectaries. e. *Anadenanthera macrocarpa*, alternate phyllotaxis, recomposed leaves, extrafloral nectaries.

In all five native species, the Ca concentration was greater than those found in the literature for *Brachiaria brizantha* (0.17 and 0.21dag kg^{-1}) and *B. humidicola* (0.13 and 0.16 dag kg^{-1}, respectively).

The presence of trees in production systems tends to increase organic matter content in the soil, which reduces P adsorption in the soil and increases its availability for plant uptake (Silva et al., 2012); this also increases the availability of Ca, Mg, and K through organic matter decomposition (Diehl et al., 2008). Thus, the deposition of organic matter from trees/shrubs species can improve soil quality. When evaluating different agroforestry systems (intercropping of row crops with trees) in the transitioning biome of Cerrado/secondary forest, Iwata et al. (2012) reported that the deposition of organic matter decreases the aluminum saturation and increases the levels of macro and micronutrients in the soil. Other advantages such as increased carbon content and improved soil microbial activity were also described in the literature (Norato et al., 2014).

All five tree/shrub species evaluated in this study were from the Fabacea family, which is characterized by its relationship with biological N fixation. Approximately 90% of legume species can establish a symbiotic relationship with diazotrophic bacterias in the roots (Ribeiro-Barros et al., 2017). Therefore, the N assimilated by the symbiotic relationship between different bacteria and legumes and made available to the plant can contribute to its nutritional characteristics; furthermore, the presence of N can increase in the soil by the deposition of organic matter, and later, by its decomposition (Ribeiro-Barros et al., 2017).

Even in this case, in which all species are from the Fabacea family, it is expected that some may have the relationship with N-fixing bacteria; however, this is still unknown. For *D. alata*, it is known that this species does not have a frequent relationship with N-fixing bacteria, a factor that could explain the low concentration of CP and N in the leaves when compared to the other species. Nonetheless, our results showed that *D. alata* had higher levels of protein compared to other common forages. The formation of nodules in *P. gonoacantha* from *Rhizobium spp* has been reported in the Brazilian Cerrado (Barros Gomes 2018), which likely contributed to its high content of CP and N.

Studies across African and South American countries have shown that leguminous trees can supply N to row crops in agroforestry systems. For instance, Akinnifesi et al. (2010) assessed the use of tree and shrub legumes (*Acacia anguistissima, Cajanus cajan, Gliricidia sepium, Leucaena collinsii, Sesbania sesban, Tephrosia* candida, and *Tephrosia vogelii*) as green manure in corn (*Zea mays*) production systems in Zambia, Zimbabwe, Malawi, and Tanzania. The authors reported that legumes contributed to more than 60 kg N ha^{-1}, reducing the N fertilizer need by 75%. In Mexico, Roskoski (1982) showed that leguminous in agroforestry system with coffee plants, especially the *Inga spp.* Genus, supplied at least 40 kg N ha^{-1}, corresponding to approximately 53% of the average N rate applied annually with synthetic fertilizers.

It must be noted that the results obtained in this study are preliminary, and as a result, other analysis are necessary to complement this study, including investigations on *in vitro* digestibility and palatability analysis. Another important issue is the potential of fruits from these species for animal feed as well as anti-nutritional factors such as high concentration of tannins in leaves and fruits that can cause toxicity to the animals, especially for *P. gonoacantha* and *A. macrocarpa*; in previous studies, the potential for the extraction of tannin substances was highlighted. The presence of phenolic compounds (tannins), especially in legumes, has received great attention for its ability to bind food proteins and thus reduce its availability for rumen microorganisms (Naumann et a., 2017).

Future studies should also explore dendrological parameters such as DAP, height, and the regrowth ability of these species when considering the opposite feeding habits of goats and cattle. It is also important to take note of the seasonality of these species, since it is known that plant growth is low during the dry season and there is have been contrasting results in the literature. Almeida et al. (2006) found that the majority of the species evaluated in Caating showed more favorable bromatological conditions during the wet season, but interestingly, the ADF in *P. floribundum* was significantly higher during the dry season.

Other studies also need to be developed in order to better understand the potential of Cerrado native species to be used in animal feeding, considering that there are many studies that address exotic species (*Leucaena* spp.; *Gliricidia* spp.) native to the Atlantic Forest and Caating. Since traditional systems with inadequately managed fertilization techniques accelerate the degradation of pastures and limit the animal production in the country (Souza et al., 2016), studies and experiences that consider the arboreal element in the productive context will help to lay the groundwork for the development of alternative agricultural models.

All the species evaluated are common in the Cerrado, with rapid growth and easily identified by farmers (Lorenzi 1992 and 1998; Silva Junior 2012). In addition, they are considered multifunctional species, an extremely important characteristic particularly for the development of agricultural production models that include biodiversity as a sustainable tool. As a result, these production systems tend to be more stable, balanced, safe, less susceptible to market variations, and especially in relation to input costs (Queda et al., 2009). The multifunctionality of these species provides products for family farms and/or commercialization, including ecosystem services such as CO_2 fixation, gene flow of Cerrado fauna and flora, along with increased organic matter and nutrient content in the soil (Porfírio-da-Silva, 2006; Sanchéz 2001).

In summary, the five native species of the Cerrado demonstrate forage potential for food supplementation of ruminants in the form of controlled grazing, which can also be supplied *in natura* and/or as hay to animals, especially during the dry season.

Materials and Methods

Study area

Based on key informants linked to technical assistance, rural extension, and the agroecological movement in Goiás and the overall region, three family farms were selected by using the snowball methodology (Thiollent, 2011). Each family farm was located in a different city (Goiás, Itapuranga, and Itaberaí) in the State of Goiás, Brazil.

The region was a mosaic of remnant natural areas in the Cerrado biome (65%) and areas converted to agricultural lands

(35%). Among the remnant natural areas in the region, the most common vegetation are "veredas" (vegetation with *Mauritia flexuosa* palm tree), riparian forest, seasonal forest, and "cerrado sentido restrito"(savanna trees" according to the classification of Ribeiro and Walter (2008). The region has a tropical wet-dry climate (Köppen Climate Classification System: AW), characterized by distinct wet (from October to April) and dry seasons (From May to September), with an average annual precipitation ranging from 1600 to 2000 mm (Cardoso et al., 2014). The altitude varies between 400 and 800 m.

Species tree

A preliminary survey of native species with potential use for ruminant feeding was conducted by using semi-structured interviews and walking through the properties (Trivinõs 2009). Then, the triangulation was performed (Trivinõs 2009) by giving preference to the multifunctional and perennial species that appeared in the all three lists, presenting leaves during the winter/summer (from May to November). The description of the selected species was completed through a literature review and the farmers' reports (*Dipteryx alata*, *Inga cylindrica*, *Piptadenia gonoacantha, Platymiscium floribundum and Anadenanthera macrocarpa – Fig 2*).

The plant samples were collected in August 2019; there was one from each property/municipality in order to cover the natural variability of the species itself. In each location, trees with apparent disease and no physiological signs of reproduction were selected. At least three samples were collected from each tree, with at least three trees per location, and composited. Plant samples consisted of mature leaves collected from the middle third of the branches in each tree. Young leaves or senescent leaves were not collected.

Laboratory analyzes

Plant samples were dried at 65ºC in a forced-air oven for three days and ground to pass a 1-mm screen by using a Wiley mill. The ground samples were submitted to chemical-bromatological analyses in the laboratory. The determination of macro and micronutrients was done by following methodology described by Tedesco et al. (1995) and Miyazawa et al. (1999), which consisted of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), sodium (Na), iron (Fe), copper (Cu), zinc (Zn), cobalt (Co), and molybdenum (Mo).

Bromatological analyses were performed according to methodology described in Silva and Queiroz (2006) and Souza et al. (2013), which consisted of moisture, dry matter (DM), total digestible nutrients (TDN), crude protein (CP), ether extract (EE), crude fiber (CF), and mineral matter (MM). The acid detergent fiber (ADF), digestible dry matter (DMD), digestible energy (DE), and metabolizable energy (ME) were estimated according to the following equations: ADF = (87.84 – TDN)/0.7; DE = TDN × 0.04409; and ME = DE × 0.82.

Statistical Analysis

Data were submitted to the Shapiro-Wilk test (α=0.05) to assess normality. The nutritional parameters did not fulfill the assumptions of normal distribution and were analyzed by the Kruskall-Wallis test (α=0.05). The principal component analysis was used to assess the relationship among variables. The bromatological attributes were not compared between the species for not being a statistically valid comparison, however the attributes were compared among themselves within the multivariate analysis with the correlation between the attributes (correlation coefficient and significance 95%).

Conclusions

Overall, all the parameters evaluated from the five native species were similar to or greater than those of forages usually used in livestock in the Cerrado region, with the exception of MM. These results showed that, even though these species were not managed and were in soils without fertilization and/or pH correction, all the species evaluated here (*Inga cylindrica, Platymiscium floribundum*, *Piptadenia gonoacantha, Anadenanthera macrocarpa* e *Dipteryx alata*) presented nutritional characteristics that suggest its potential for use in animal feed. We highlight *P. floribundum, I. cylindrica,* and *P. gonoacantha* for their high protein concentration, especially the latter for the interesting results considering CF, ADF, TDN, DMD, DE, and ME.

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