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Nutritive value and in situ rumen degradability of Marandu palisade grass at different locations within the pasture in a silvo-pastoral system with different babassu palm densities

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Abstract

The objective of this study was to evaluate the nutritive value and in situ rumen degradability of grass collected from different locations within the pasture in a silvopastoral system with different densities of trees. The silvopastoral system consisted of *Urochloa* (syn. *Brachiaria*) *brizantha* cv. Marandu and the babassu palm, *Orbignya* sp. (now: *Attaleia speciosa*). We used a completely randomized design with a 3 x 3 factorial arrangement for nutritional value (3 differently shaded locations and 3 palm tree densities) and a 3 x 3 x 3 factorial arrangement for dry matter (DM) disappearance (3 locations, 3 palm densities and 3 incubation times). There was no effect of location within the pasture nor of palm tree density on the concentrations of NDF, ADF, lignin, cellulose and hemicellulose. However, location influenced the concentrations of crude protein (CP) and DM, with highest CP in material grown in full sunlight. At all densities, DM disappearance at 96 h for pasture grown in full sunlight exceeded that for pasture grown in full shade. These factors need to be compounded with the possible depressant effect of trees on DM production of pasture when considering the benefits of silvopastoral systems.

Resumen

En el estudio se evaluó el valor nutritivo y la degradabilidad ruminal (digestibilidad) in situ de *Urochloa brizantha* (sin. *Brachiaria brizantha*) cv. Marandu en un sistema silvopastoril con diferentes densidades de árboles de la palma babasú (*Orbignya* sp., ahora: *Attaleia speciosa*). El diseño experimental para el valor nutritivo de la gramínea fue completamente al azar con arreglo factorial 3 x 3 [3 ubicaciones (sitios de muestreo) dentro del sistema: pleno sol, parcialmente sombreado y sombra total; y 3 densidades de palma]; y un arreglo factorial 3 x 3 x 3 para degradabilidad de la materia seca (3 ubicaciones, 3 densidades y 3 tiempos de incubación: 6, 24 y 96 horas). No se encontraron efectos del sitio de muestreo dentro del sistema ni de la densidad de las palmas en los porcentajes de NDF (fibra detergente neutro), ADF (fibra detergente ácido), lignina, celulosa y hemicelulosa. No obstante el sitio de muestreo dentro del sistema influyó en las concentraciones de proteína cruda (PC) y materia seca (MS), siendo más alta la PC en la gramínea que creció a pleno sol. En todas las densidades, la degradabilidad de la MS a 96 horas para la gramínea a plena luz fue más alta que a la sombra total. Al considerarse los beneficios de los sistemas silvopastoriles, estos aspectos de valor nutritivo deben ser tenidos en cuenta, junto con un posible efecto negativo de los árboles en la producción de MS del pasto.

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Introduction

In Brazil, pasture consisting mostly of tropical grasses, is the main inexpensive feed source for ruminants that are able to convert fibrous biomass, which is of no nutritional value to humans, into valuable animal protein. Whereas livestock production takes place mainly in pasture-only systems, there is increasing interest in systems that include a crop and/or tree component (Paciullo et al. 2007).

Maranhão State, particularly, has a huge diversity of vegetation, ranging from Cerrado (center, south and east of the state) to Amazonian vegetation in the west. Despite this variability of vegetation, the native palm tree, babassu (*Orbignya* sp., now *Attaleia speciosa*), occurs in 80% of the state and has immense economic and social importance through the byproducts it yields (Matos et al. 2010).

Silvopastoral systems are common, where there is the intentional combination of trees, pasture and cattle, all managed in an integrated manner (Embrapa 2011). In this system, it is essential to understand the interactions of animals, forage plants and trees, aiming to plan intercropping to minimize the negative effects and enhance the gains related to the specific interactions of the various factors in the system (Andrade et al. 2001, 2004; Araújo et al. 2013). With respect to grazing in silvopastoral systems, Castro et al. (1999) emphasized the need for more information on the main tropical grasses such as *Brachiaria*, as chemical composition and digestibility are affected by low light.

In this context, knowledge of the nutritive value and digestibility of the forage at different locations within the pasture in silvopastoral systems with babassu palm can provide the basis for developing management strategies to increase animal production. Thus, the present study aimed to evaluate the nutritive value and in situ digestibility of Marandu grass at different locations within the pasture in a silvopastoral system. Given the economic and social importance of the native babassu palm in the region (Matos et al. 2010), we took advantage of availability of experimental paddocks with different tree densities to furthermore consider any additional effects, such as from competition for nutrients, soil moisture etc., on pasture quality.

Materials and Methods

Study site

The study was conducted at the Água Viva Farm, in the municipality of Matinha, Maranhão State (02º59'35" S, 45°06'25" W). The pasture species was *Brachiaria brizantha* (now: *Urochloa brizantha*) cv. Marandu and the tree species was the babassu palm, *Orbignya* sp. (now: *Attaleia speciosa*). This grass-tree system was already established on the property and was under grazing. The grass was collected from exclusion cages.

In the rainy period of 2012 (March–July), the pasture was mowed before application of dolomitic limestone (1 t/ha) and fertilization with nitrogen as urea (60 kg N/ha) and phosphorus as superphosphate (12 kg P/ha).

Experimental setup

Treatments consisted of 3 densities of babassu palm per hectare (low, medium and high; LDP, MDP and HDP) corresponding with 39, 72 and 92 trees per hectare, respectively, and 3 locations within the pasture: no interference from palm tree shade (full sunlight, WIS), intermediate positioning between unshaded and shaded locations (partial sun, MID) and under the palm trees in full shade (full shade, IWS), in a 3 x 3 factorial arrangement with 3 replications in a randomized design. For dry matter disappearance (DDM), we used a completely randomized design with a 3 x 3 x 3 factorial arrangement (3 densities of palm trees, 3 sampling sites and 3 incubation times).

The shaded (IWS) area was the area around the palm tree, i.e. the exclusion cage (0.5 x 0.5 m) was placed next to the base of the palm tree; in the MID area, at some point in the day the palm tree shadow was projected onto the exclusion cage; and at full sun (WIS), at no time was the palm tree shadow projected onto the exclusion cage.

Measurements

At the beginning of the experiment, pastures had an average height of 60 cm. Samples were collected from 28-day-old regrowth by cutting the grass to 5 cm above ground level, within exclusion cages placed at 28-day intervals in the paddocks according to the particular treatment, when the cages were relocated to a new spot. Samples were collected during the dry period of 2012 (November 2012–January 2013). Samples of each treatment were mixed and chemical analyses conducted. Data presented result from the average of the experimental period.

Samples were pooled in their respective treatments for chemical analysis. In the laboratory, samples were weighed and oven-dried at 55 °C to constant weight. Afterwards, samples were ground in a Wiley mill for determination of concentration of dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, crude protein (CP), cellulose and hemicellulose, according to Silva and Queiroz (2002).

For in situ degradability, and following the suggestions of Tomich and Sampaio (2004), one male sheep, castrated and cannulated in the rumen, with an average body weight of 60 kg, was fed the forage and mineral salt, with water ad libitum. Incubation times used were: 6, 24 and 96 hours, according to the methodology of Sampaio et al. (1995). For each incubation time, 18 nylon bags (each with 5 g of ground sample material) were inserted in the rumen, representing the 3 tree densities x 3 locations x 2 replications. Bags for the various incubation times were inserted progressively at the appropriate times and all were removed at the same time. Bags were 14 x 19 cm, with 50 μm porosity. After the incubation periods, bags were removed and immediately washed, oven-dried at 50 °C for 48 h, weighed and the residue analyzed for DM, CP, NDF and ADF (Silva and Queiroz 2002).

In order to determine the loss of material at time zero, bags containing samples were washed in cold water. After washing, the bags were subjected to the same procedures as incubated bags. In situ rumen degradability (“digestibility”) was measured as percentage of dry matter disappearance (DDM), calculated over each time interval by the proportion of forage that disappeared from the bags after incubation in the rumen.

To evaluate the parameters of DDM, we used the Brody model according to the equation of Orskov and McDonald (1979), modified by Sampaio (1988):

$$\%\mathrm{Deg\ DM} = A - B\exp(-c*\mathrm{Time})$$

where:

A = potential degradability of the forage, without time for colonization, i.e. if the Deg% at time zero was 0%;
B = percentage of degraded material deposited in the rumen without time for colonization; and
c = degradation rate constant of the material remaining in the rumen at any incubation time.

Effective DM degradability (DE) was calculated assuming 3 ruminal passage rates (2, 5 and 8%/h) through the equation described by Orskov and McDonald (1979):

$$DE = a' + (b'*c/c+k)$$

where:

a' = % disappearance at time zero (mean);
b' = A - a';
c = degradation rate constant; and k = passage rate.

Statistical analysis

Data were first subjected to normality (Cramér-von Mises test) and homogeneity of variances (Levene test). Data met the assumptions and were subjected to analysis of variance. Statistical analyses were run considering a significance level of 5%, using the GLM procedure of SAS 9.0 (2002).

Results

The chemical composition of forage samples is shown in Table 1. Location within the pasture and palm density had no significant ($P>0.05$) effects on NDF, ADF, lignin, cellulose and hemicellulose concentrations in the forage. Regarding CP, the only significant effect was that of location ($P<0.05$): regardless of palm tree density, pasture grown in full sunlight (WIS) showed the highest CP concentration and that in full shade (IWS) the lowest.

Significant interactions were detected between density of palm trees and location within the pasture ($P<0.05$) for DM percentage in forage. In general, pasture grown in full shade had higher DM concentration than that grown in either partial sun or full sunlight ($P<0.05$). For pasture grown in partial sun, the DM concentration was higher at the highest palm density ($P<0.05$).

At all densities of palm trees in the pasture and locations within the pasture, DDM increased progressively with time ($P<0.05$) (Table 2). This result is associated with the time necessary for the attachment of ruminal microorganisms to fiber particles in the rumen and for digestion to commence.

At each time of incubation and for each location in the pasture, DDM increased as the density of trees increased. However, the differences were inconsistent across treatments, being significant ($P<0.05$) only for WIS at 6 h incubation, IWS at 24 h and MID at 96 h (Table 2). In situ rumen degradability (Table 3) of all variables had a coefficient of determination (R^2) above 93%, which indicates that the non-linear model used by Sampaio et al. (1995) has satisfactorily fitted the data for DDM.

Table 1. Chemical composition (% DM) of Marandu palisade grass grown at different locations (WIS – full sunlight; MID − intermediate location between shade and sun; and IWS – full shade) within the pasture in silvopastoral systems with different densities of babassu palm (LDP – low; MDP – medium; and HDP – high).

Nutritive value	Location	Density of babassu palms LDP	MDP	HDP	CV (%)	P-value Location	P-value Density	P-value Location x Density
Neutral detergent fiber (NDF)					2.97	0.62	0.23	0.29
	WIS	75.5	71.1	75.0				
	MID	74.4	72.6	73.1				
	IWS	72.4	73.3	72.9				
Acid detergent fiber (ADF)					4.69	0.59	0.44	0.92
	WIS	61.3	59.2	59.9				
	MID	60.8	57.8	58.9				
	IWS	58.9	58.9	58.7				
Lignin					17.70	0.91	0.25	0.55
	WIS	7.83	6.60	8.21				
	MID	7.84	6.63	8.18				
	IWS	7.94	7.91	7.30				
Cellulose					5.23	0.82	0.40	0.99
	WIS	53.4	51.8	51.7				
	MID	53.0	51.5	51.4				
	IWS	52.3	50.9	50.7				
Hemicellulose					11.58	0.86	0.57	0.24
	WIS	14.3	12.0	15.0				
	MID	13.6	14.8	14.2				
	IWS	13.5	14.4	14.8				
Crude protein					11.08	<0.0001	0.14	0.99
	WIS	5.54Aa[1]	5.98Aa	5.83Aa				
	MID	4.67Aab	5.25Aab	4.96Aab				
	IWS	3.94Ab	4.52Ab	4.08Ab				
Dry matter (% fresh weight)					16.28	<0.0001	0.04	0.02
	WIS	34.8Ab	30.8Ab	37.9Ab				
	MID	38.7Bb	31.2Bb	52.4Aa				
	IWS	58.4Aa	56.9Aa	56.9Aa				

[1]Means within rows followed by the same upper-case letter, and within columns followed by the same lower-case letter are not significantly different by Duncan's test at 5% probability.

Table 2. Mean values for dry matter disappearance (%) of Marandu palisade grass grown at different locations (WIS – full sunlight; MID − intermediate location between shade and sun; and IWS – full shade) within the pasture in silvopastoral systems with different densities of babassu palm (LDP – low; MDP – medium; and HDP − high). CV (%) = 7.78.

Location	Density of babassu palms	Incubation time 6 h	24 h	96 h
WIS	LDP	29.2Cβ[1]	47.7Bα	68.8Aα
MID		32.4Cα	48.3Bα	64.8Aβ
IWS		29.2Cα	43.3Bβ	65.0Aα
WIS	MDP	35.2Cαβ	50.7Bα	71.4Aα
MID		32.4Cα	49.4Bα	68.3Aαβ
IWS		31.0Cα	47.5Bαβ	67.4Aα
WIS	HDP	36.9Cα	51.9Bα	72.6Aα
MID		36.2Cα	51.7Bα	72.6Aα
IWS		32.8Cα	51.3Bα	69.1Aα

[1]Means within rows followed by the same upper-case letter (comparing times of incubation) and within columns followed by the same Greek letter (comparing densities within location and time of incubation) are not significantly different by Duncan's test at 5% probability.

Table 3. Parameters of in situ rumen degradability of dry matter of Marandu palisade grass grown at different locations (WIS – full sunlight; MID – intermediate location between shade and sun; and IWS – full shade) within the pasture in silvopastoral systems with different densities of babassu palm (LDP – low; MDP – medium; and HDP – high).

Location	Density of babassu palms	Potential degradability (A)	Rumen degradable fraction (B)	Degradation rate constant (c)	R^2	Effective dry matter degradability (DE) for passage rates (%/h) of:		
						2%	5%	8%
WIS	LDP	71.4	78.5	3.8	98.8	52.5	40.2	34.2
MID		66.7	73.0	4.7	98.3	51.3	40.1	34.2
IWS		70.3	72.7	2.7	98.6	50.4	40.0	35.4
WIS	MDP	71.8	56.4	2.5	97.8	46.4	33.7	28.2
MID		75.2	62.0	2.4	98.4	57.1	50.0	47.2
IWS		74.3	63.2	1.9	98.4	47.2	33.6	27.8
WIS	HDP	74.6	60.2	2.9	98.3	49.0	34.9	28.5
MID		72.8	60.9	3.2	98.2	51.5	39.0	33.2
IWS		71.4	64.6	3.6	98.2	50.8	37.9	31.7

Discussion

Location (sampling site) within the silvopastoral systems containing different densities of palm trees showed little influence on the nutritive value of Marandu palisade grass, except for crude protein concentration. In spite of the young age of the samples (28 d), all pasture produced had unexpectedly low CP concentration (3.9−6.0%) which was possibly influenced by the dry season. Pasture grown in full sunlight was of higher quality than that grown in full shade (5.8 vs. 4.2% CP, P<0.05). These values are lower than the level of 7% recommended for appropriate rumen fermentation. Azar (2011) evaluated the nutritional value of Marandu palisade grass in a silvopastoral system and observed a higher CP concentration in pasture in full sunlight grown in association with trees than in grass grown in a monoculture, in both rainy and dry periods. The pastures in that study were irrigated during the dry season. This suggests that recycling of nutrients by the trees might have made more nutrients available to the pasture. However, Paciullo et al. (2007), working with *B. decumbens,* in conditions of full sun and shade, found no interaction between light condition and the chemical composition of the plant.

Competition for moisture and nutrients between the pasture and palm trees would have played a part in production, especially during the dry season. During this time pasture around the babassu palms had the appearance of standing hay, indicating stress being experienced by the grass. The results point to the great competitive strength of babassu palm, because it occupies the same underground niche, exploring the same resources as the grass, and thus enters into direct competition with pasture. This was evidenced by the highest DM content of pasture in fully shaded positions.

We could find no general consensus in the literature on the effect of shading in relation to the nutritional value of tropical forages. However, some Brazilian reports dealing with Marandu grass agree that there is no major shade effect: Reis et al. (2013) evaluated the influence of nitrogen fertilization and artificial shading on chemical variables of Marandu grass and also found no effect of shading on the NDF concentration. Similar results were achieved by Lacerda et al. (2009) and Reis et al. (2011) in pastures of gamba grass (*Andropogon gayanus*) and Marandu with natural shading, respectively.

According to Van Soest (1965), concentrations of NDF above 55% may negatively influence voluntary intake and thus impair animal performance. Pasture from all locations in our study had NDF levels above 70%, indicating that voluntary intake would be affected and supplements would need to be fed in conjunction with the forage to achieve good animal performance.

Reis et al. (2013) found that shading and nitrogen fertilization caused a reduction in ADF concentration. In contrast, Sousa et al. (2010) registered the opposite result, with values for ADF being higher in shaded areas due to stem elongation and greater height of the canopy.

There is no consensus on the effect of shading on the lignin content in forages. Plants grown in shade tend to have higher lignin content compared with those experiencing no restriction of light, but shaded plants have lower physiological age, which can result in lower levels of lignin (Reis et al. 2013).

It is noteworthy that there was no significant effect of babassu palm density on any of the nutritive value factors analyzed, except for DM %. Apparently there were no major competitive effects.

Moreira et al. (2009) examined the in situ dry matter degradability of Marandu grass harvested from 2 silvopastoral systems containing the trees, *Zeyheria tuberculosa* and *Myracrodruon urundeuva*, in Cerrado and found no difference in DDM between forage grown in the shade of these trees and that grown in grass monoculture. The values we found for DDM at 96 hours digestion were similar to the 75.5 and 74.4% reported by Castro et al. (2009) for *B. brizantha* cv. Marandu harvested at 28 and 56 days of age, respectively. Similarly, Rodrigues et al. (2004) studied 3 accessions of *B. brizantha* aged 21 and 42 days and found average values for DM degradation of 77.4 and 76.3%, respectively.

Furthermore, for all situations the effective degradability values tended to decrease with the increase in passage rate. This would be due to the effects on action of ruminal microorganisms, which is affected by the time spent in the rumen, since the slower the passage rate of this fibrous material through the rumen the greater the action of microorganisms, thereby influencing the effective digestibility.

The effective degradability (DE) values of DM for the passage rate of 2%/h were lower than those reported by Rodrigues et al. (2004), who worked with 3 accessions of *B. brizantha* harvested at 21 days of age and found a DE around 56.7%, similar to the values reported by Moreira et al. (2009) with Marandu palisade grass grown in silvopastoral systems.

For the 5%/h passage rate, DE values of DM registered in our experiment were higher than those obtained by Moreira et al. (2009) for Marandu (34.9−37%) and lower than those reported by Castro et al. (2009) when working with *B. brizantha* harvested at 28 and 56 days of age (46.8 and 43.8%, respectively).

Conclusions

This study has shown that palm density in a silvopastoral system had little influence on nutritive value of the associated Marandu palisade grass, but shade-affected locations within the system had effects on protein concentration in the pasture. Since material grown in full sunlight had higher CP concentrations than that grown in full shade, forage quality could be expected to decline as trees matured and spread more shade over the pasture. This effect would need to be compounded with the reduced DM production of pasture in a silvopastoral system relative to monoculture, when assessing the benefits of these systems.

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