Rev. Bras. Saúde Prod. Anim., Salvador, v.19, n.2, p.166-177 abr./jun., 2018 ISSN 1519 9940
http://dx.doi.org/10.1590/S1519-99402018000200003

Quantitative anatomy and in situ ruminal degradation parameters of elephant grass under different defoliation frequencies

Anatomia quantitativa e parâmetros de degradação ruminal in situ do capim-elefante sob diferentes frequências de desfolhação

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SUMMARY

This study aimed to determine the area occupied by different tissues present in the leaf blade and the *in situ* degradability of leaf and stem of elephant grass (*Pennisetum purpureum* Schum.) under different defoliation frequencies (30, 45, 60, 75 and 90 days). Plants were classified into three levels of insertion in the tiller (apical, medial and basal). The results were presented as a proportion of the area of each tissue in relation to the total area of the leaf blade, namely, parenchyma tissue (PT), lignified vascular tissue (LVT) and non-lignified vascular tissue (NLVT). The proportion of tissue in the leaf blade is altered in accordance with the insertion in the tiller and increase in cutting age of the plant. PT has greater proportion at lower cutting ages, LVT increases with frequency and NLVT is higher at 60 days. The parameters of DM degradation in the two fractions evaluated decreased significantly with increasing maturity of the plant. The effective degradability of CP in leaf and stem decreased with the increase in the rate of passage (2, 5, and 8% h^{-1}). The highest rate (c) of CP degradation for the leaf fraction was obtained with a frequency of 60 days, for the stem, with 45 days. The advance in plant maturity increases the proportion of lignified vascular tissue, thus influencing the ruminal degradation parameters of elephant grass. The defoliation frequency of 60 days offers an optimal point regarding the proportion of anatomical tissues correlated with the degradation of elephant grass.

Key words: degradation potential, degradation rate, lignin, plant anatomy

RESUMO

Objetivou-se determinar a área ocupada pelos diferentes tecidos presentes na lâmina foliar e a degradabilidade *in situ* das frações folha e colmo do capim-elefante (*Pennisetum purpureum* Schum.) sob diferentes frequências de desfolhação (30, 45, 60, 75 e 90 dias). As plantas foram segmentadas em três níveis de inserção no perfilho (apical, medial e basal). Os resultados foram apresentados como proporção da área de cada tecido em relação à área total da lâmina foliar, sendo estes, tecido parenquimático (TP) tecido vascular lignificado (TVL) e tecido vascular não lignificado (TVNL). Observou-se que a proporção de tecido na lâmina foliar é alterada de acordo com a inserção no perfilho e com a diminuição da frequência de desfolhação. O TP tem maior proporção nas maiores frequências de desfolhação, TVL aumenta com a frequência e o TVNL é maior aos 60 dias. Os parâmetros de degradação da MS nas duas frações avaliadas diminuíram significamente com o aumento na maturidade da planta. A degradabilidade efetiva da PB nas frações folha e colmo diminuíram com o aumento na taxa de passagem (2, 5 e 8% h^{-1}). A maior taxa de degradação (c) da PB para fração folha foi obtida com a frequência de 60 dias, já o colmo aos 45 dias. Com o avanço na maturidade da planta aumenta a proporção de tecido vascular lignificado influenciando nos parâmetros de degradação ruminal do capim-elefante. A frequência de desfolhação de 60 dias apresenta um ponto ótimo quanto à proporção de tecidos anatômicos correlacionados com a degradação do capim-elefante.

Palavras-chave: potencial de degradação, taxa de degradação, lignina, anatomia vegetal

INTRODUCTION

The anatomical structure of leaf blades, as well as their specific tissues, individually or by the combination of these, have a strong influence on the nutritional value of forages. The relationship between the anatomy of plant organs and their tissues has been reported in histological studies, which may be indicative of the qualitative value of the forage because of the proportion of rapidly digestible and indigestible tissues (BATISTOTI, 2006).

In this sense, the factors that interfere with the quality of forage grasses can be of anatomical, physical and chemical origin, besides those related to the structure of the vegetation. The forage cutting management is a factor that modifies both the production and the quality of the forage. Elephant grass, for example, has the capacity for easy adaptation to the various ecosystems and a very important characteristic that is the acceptance by the animals. Most frequent cuts result in lower dry matter production, however, with higher nutritional value than less frequent cuts, which provide higher yields of dry matter, but of lower quality (VERAS et al., 2010), therefore, the correlation of the cutting interval with the light interception can define a more efficient management method in harvesting this forage.

According to Brito et al. (1997), the tissue digestion potential is related to the proportion of tissues, the type and characteristics of the tissues and the stage of growth of the plant, making possible the nutritional characterization of species and cultivars. Thus, studies that make possible the understanding of the tissues and structures of the plants and how they affect the mechanism of digestion and nutrient utilization by the ruminal microorganisms becomes important, always seeking adoption of management strategies that aim at the efficient use of forage grasses.

The objective of this study was to evaluate the quantitative anatomy and in situ ruminal degradation parameters of elephant grass under different defoliation frequencies.

MATERIAL AND METHODS

The experiment was conducted in forage of the grassland scan UFMA, region of Low Parnaiba situated 03º44'33" South, 43º21'21" west. The climate, according to the classification of Köppen, type is tropical, hot and humid (AW), with annual average temperature above 27 °C and an average annual rainfall of 1,835 mm, with periods of rain between the months of January and June and drought from july to december. The data of

Rev. Bras. Saúde Prod. Anim., Salvador, v.19, n.2, p.166-177 abr./jun., 2018 ISSN 1519 9940
http://dx.doi.org/10.1590/S1519-99402018000200003

rainfall and temperature occurred in the experimental period is shown in Figure 1. The soil of the experimental site was classified as yellow latosol (EMBRAPA, 1999). Presenting the following chemical characteristics: pH in $CaCl_2$ = 4.2; O.M.= 19 g/dm³; P = 5 and S = 9 mg/dm³, respectively; K = 0.4, Ca = 5, Mg = 2, H+Al = 29, Al = 8, CTC = 36, SB = 7.4 mmolc/dm³, respectively; V = 20 and m = 52%; and b = 1.43, Cu = 0.2 = 55, Fe,Mn and Zn = 0.4 = 0.3mg/dm³, respectively. The liming was performed by the method of lifting the base saturation (V%), raising V% of 20 to 60%.

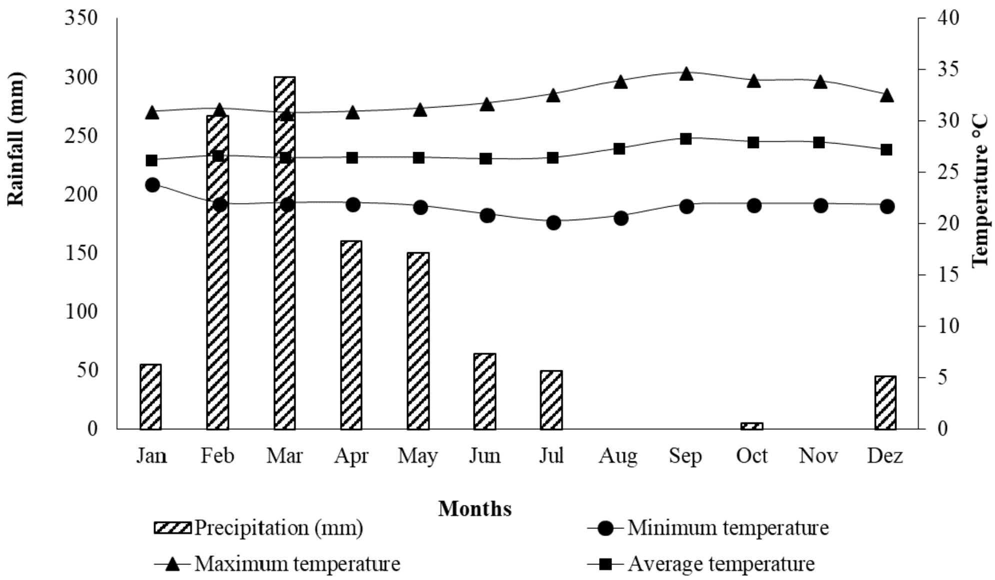

Figure 1. Average rainfall during the experiment (Source: INMET, 2015)

The experimental design was completely randomized with five treatments and five replications. The treatments consisted in the following defoliation frequencies: 30, 45, 60, 75 and 90 days. The forage species used was the elephant grass (*Pennisetum purpureum* Schum.). The experiment was carried out in capineira already pre-established. The total area used in the experiment was 784 m^2, being subdivided into 25 plots of 31.36 m^2 each (experimental units).

In each defoliation frequency were collected samples of elephant grass in experimental units for determining the chemical-bromatological composition (Table 1), evaluation of the anatomy of the leaf blade and in situ degradability of DM and CP fraction of leaf and stem.

For the anatomic study, 10 plants were collected in each experimental plot, totaling 50 plants per treatment, these five plants per experimental unit were selected, 25 plants were analyzed per treatment. The plants were collected at each cutting of evaluation in the height of the residue of 25 cm.

The leaf blade was collected in three levels of insertion in the vegetative tiller called apical, medial and basal. For the establishment of limits in these regions, took the stem as a reference, thus the lower fraction of basal, the medial portion of median and upper portion of apical segments. The dead leaves, present in the basal region, were not used for the anatomical study.

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Table 1. Chemical-bromatological composition of leaf and stem fractions of elephant grass under different defoliation frequencies

Defoliation frequencies (days)	Chemical-bromatological composition (%)							
	Leaf							
	DM	CP	NDF	NDA	LIG	CEL	HEM	Ash
30	15,53	19,88	66,16	44,57	6,36	38,2	21,59	5,23
45	17,57	18,39	70,54	49,17	8,55	40,62	21,37	5,55
60	18,87	13,26	72,82	52,65	10,54	42,11	20,16	5,48
75	19,82	12,87	75,75	55,59	12,37	43,23	20,15	9,08
90	20,73	11,96	79,57	58,46	14,83	43,63	21,11	9,36
	Stem							
30	16,55	12,94	67,35	52,02	9,18	42,84	15,33	5,43
45	17,19	11,55	73,26	57,76	12,57	45,19	15,5	7,85
60	20,44	11,05	76,24	65,06	14,77	50,29	11,18	8,55
75	22,04	10,95	80,66	69,23	16,63	52,6	11,43	11,23
90	23,33	9,45	84,28	75,54	21,05	54,49	8,74	14,68

The cuts were made free hand with steel blade and examined under an optical microscope BELL fhotonics. All analyzes were made in digital images, using an image analysis program BELL Views. After the sampling of fragments, the measurement was performed of the leaf area of each leaf by means of a scanner. To estimate the proportion of each tissue in the leaf, it was used the system image analyzer (BELL Views), coupled to the binocular optical microscope. Initially, measured throughout the area of the cross section designed in the video, and then was given to the area occupied by the tissues.

Tissue types were separated according to the nature of the cell walls, considering the following division: parenchymal tissue (PT): including buliform cells and parenchymal sheath of the vascular bundle; lignified vascular tissue + sclerenchyma (LVT): including xylem, sclerenchymatic sheaths and other cells present in vascular bundles presenting lignified cell wall and non-lignified vascular tissue (NLVT): including phloem and other cells present in vascular bundles presenting cell wall of a cellulosic nature. The results were presented as proportion of the area of each tissue in relation to the total area of the leaf blade, in a 3x5 factorial arrangement (three anatomical tissues and five defoliation frequencies).

For analysis of in situ degradability samples of stem and leaf fractions were weighed and conditioned in a forced air circulation oven for 72 hours at 55 °C. Afterwards, they were weighed to obtain the DM content and milled with Willey-type knives to carry out chemical analysis and in situ degradability of DM and CP. The degradability was estimated by the in situ technique, using a mestizo sheep weighing 60 kg, a procedure suggested by Tomich & Sampaio (2004). It was weighed and placed 4g of the sample milled in nylon bags measuring 12x8 cm and with 50 µm pores (NOCEK, 1988). In a 5x5 factorial arrangement (five incubation times and five defoliation frequencies). The incubation times used were 6, 12, 24, 72 and 96 hours.

After the incubation period, the bags were removed for washing and dried in a forced-circulation oven at 55 °C for 48 hours. To determine the disappearance of the material at time zero the bags were kept in a water bath for one hour at a temperature equal to 39 °C. After this time, the bags received the same procedures from the bags that were incubated.

The percent disappearance of DM and CP at each time point was calculated by the proportion of food that disappeared in the bags after incubation in the rumen. To evaluate the parameters, the Orskov & McDonald model (1979), adapted by Sampaio (1988): Deg = A - B (- ct) was used. Where: A = corresponds the potential degradation of the incubated material when time is not a limiting factor; B = parameter without biological value, that is, if there were no colonization time, it would correspond to the total to be degraded by the microbial action; c = rate of degradation per fermentative action of B; t = rumen incubation time, in hours.

Once the coefficients A, B and c were calculated, they were applied to the equation proposed by Ørskov & McDonald (1979) for the calculation of the effective degradability:

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

where: a '=% disappearance at time zero (Mean); b '= A-a'; C = constant rate of degradation; K = food passage rate, a rate of passage from the digesta to the duodenum of 2, 5 and 8% per hour was assumed.

The data were submitted to analysis of variance and the statistical analyzes were performed using the GLM procedure of the software SAS 9.0 (2002), using the Duncan test at 5% probability for the degradability test of DM and CP and quantitative anatomy study.

RESULTS AND DISCUSSION

There was interaction (P <0.001) between the evaluated tissues and the defoliation frequencies of elephant grass in the three levels of insertion of the leaf blade in the vegetative tiller (Table 2). The parenchyma tissue (PT) presented a higher proportion at the highest frequencies of defoliation (30 and 45) at the different levels of insertion in the plant (apical, medial and basal), and decreased with the reduction in the frequency of defoliation, and at 90 days, it has a lower proportion of PT in the leaf. This phenomenon is due to the growth of vascular bundles, both in number and in size, thus occupying a larger area in the leaf region with advancing age, mainly of lignified tissue (sclerenchyma).

In this sense, lignin seems to be the main chemical limitation to the digestion of these cells, which can hinder the access of the microorganisms to the cellular content (AKIN & CHESSON, 1989). According to Brito et al. (2001), the parenchyma tissue presents high degradation rates and occupies a large part of the area in the different organs and fractions, being therefore very important in forage quality. Data that can be observed in table 4, in which, the decrease in the frequency of defoliation significantly decreases the potential degradability of DM (A). In contrast, lignified vascular tissue (LVT) increased considerably from 30 to 90 days, a similar behavior observed in the three levels of leaf insertion (Table 2).

The lignified vascular tissue is basically composed of xylem and sclerenchyma; Paciullo et al. (2001) verified that the cell wall thickness of sclerenchyma and xylem showed a negative correlation with digestibility, and concluded that estimates of the proportions of mesophyll, xylem and sclerenchyma with cell wall thickness can be combined with the chemical composition to improve the estimation of the nutritive value of the forage. In this sense, this negative correlation can be found in Tables 3 and 5, where the degradability parameters of DM and CP are significantly affected by defoliation frequencies.

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http://dx.doi.org/10.1590/S1519-99402018000200003

Table 2. Proportion (%) occupied in the leaf blade by the parenchymatic tissue (PT), vascular lignified tissue (LVT) and non-lignified vascular tissue (NLVT) at three levels of plant insertion (apical, medial and basal) of elephantgrass under different frequencies of defoliation

Tissue	Frequencies of defoliation (days)					Mean	I x T
	30	45	60	75	90		
			Insertion apical				
PT	60,3^{Aa}	56,72^{Aa}	48,51^{Ab}	43,13^{Ac}	36,99^{Bd}	49,13	
LVT	29,07^{Bb}	30,32^{Bb}	31,16^{Bb}	39,38^{Ab}	52,69^{Aa}	36,52	
NLVT	10,3^{Cc}	12,21^{Cc}	24,24^{Ca}	16,91^{Bb}	12,1^{Cc}	15.15	<0,0001
Mean	33,23	33,08	34,64	33,14	33,93	-	
			Insertion medial				
PT	57,1^{Aa}	53,57^{Aab}	44,24^{Abc}	45,41^{Abc}	40,95^{Ac}	48,25	
LVT	31,16^{Bb}	32,99^{Bb}	32,99^{Bb}	37,24^{Bab}	42,83^{Aa}	35,44	
NLVT	11,73^{Cc}	13,52^{Cc}	22,47^{Ca}	17,33^{Cb}	16,63^{Ab}	16.34	0,0001
Mean	33,33	33,36	33,23	33,73	33,47	-	
			Insertion basal				
PT	66,74^{Aa}	61,55^{Aa}	46,03^{Ab}	44,68^{Ab}	41,12^{Bb}	52,02	
LVT	24,13^{Bc}	29,73^{Bbc}	35,04^{Bb}	37,75^{Aab}	45,46^{Aa}	34,42	
NLVT	9,11^{Cc}	12,2^{Cbc}	20,82^{Ca}	14,04^{Bb}	12,91^{Cb}	13.82	<0,0001
Mean	33.33	34,49	33,97	32,16	33,16	-	

Averages followed by uppercase letters in the columns and lower case letters in the lines do not differ by Duncan's test.

Sclerenchyma is a supporting tissue present in the periphery or in the inner layers of the organ. The sclerenchyma cells of grasses develop a thick secondary wall of 2 to 5 µm that lignifies with the age of the tissue (GLÓRIA & GUERREIRO, 2006). Analyzing the chemical composition of elephant grass (Table 1), it is evident this lignification effect in function of the different defoliation frequencies.

Paciullo et al. (2002) observed that the proportion of tissues did not vary with age nor with the growing season, except for the highest proportion of xylem in blades harvested in summer (6.4%), when compared to fall (5.1%). The digestion resistant tissues represented 28.9% of the cross-section of the stem, considering the average values of the proportions of epidermis (2.8%), xylem (18.7%) and sclerenchyma (7.4%). The results showed a significant alteration in the proportion of tissues with different frequencies of defoliation, and an increase in tissues more resistant to digestion (Table 2).

The non-lignified vascular tissue (NLVT) had a lower proportion at the lower and higher frequencies (30, 45 and 90 days), the greater amount present in the leaf was observed at 60 days. The effect observed in the development of this tissue is similar in the three evaluated levels; it is understood that at the higher frequencies of defoliation this tissue, composed basically by the phloem, is still in developmental stage, and along the frequencies of defoliation, there is an increase in the proportion of this tissue, to a certain extent (60 days), where the differentiation of this tissue is already made up of tissue for higher support of the plant, in this case the highly lignified sclerenchyma, thus reducing the proportion of NLVT and increasing the proportion of LVT.

This differentiation and growth of phloem cells occurs mainly in the apical region,

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http://dx.doi.org/10.1590/S1519-99402018000200003

where these cells are young and still at the differentiation stage. According to Paciullo et al. (2002), in a same plant, there is a gradient of anatomical and nutritional characteristics, according to the level of insertion, when comparing leaves at the same stage of development, in which the blades of the upper position in the tiller showed a greater proportion of xylem, regardless of frequency, species and season. The leaf blades at the top of the tiller are longer, therefore they require strong structural support to keep erect, being this support formed mainly by xylem and sclerenchyma (CABRAL et al., 2011).

In relation to the data of the soluble fraction (*a*) (Table 3), there is a reduction in the soluble fraction according to the increase in the cutting age, which was expected, since, with the advancement in maturity, the plant has the tendency in accumulating supporting structures that collaborate with greater cell densification and, consequently, in the decrease in their degradability.

Table 3. Estimation of dry matter (DM) degradation parameters of leaf and stem fractions of elephantgrass under different frequencies of defoliation

Frequencies of defoliation (days)	Leaf blade							
	a (%)	*b* (%)	*c* (%/h)	A	R^2	Effective degradation (%) 2 % h^{-1}	5 % h^{-1}	8 % h^{-1}
30	23,30	71,93	2,88	87,53	97,94	65,75	49,59	42,34
45	15,90	68,95	2,74	81,35	96,67	55,76	40,31	33,49
60	14,20	72,12	2,05	84,22	95,15	50,71	35,17	28,91
75	13,10	69,43	2,07	81,23	94,98	48,41	33,43	27,37
90	12,40	55,99	2,50	66,99	91,40	43,51	31,06	25,73
	Stem							
30	15,60	64,03	2,38	87,33	98,15	54,58	38,73	32,05
45	12,40	75,33	1,85	91,23	98,13	50,28	33,69	27,21
60	12,10	41,56	1,51	77,81	94,12	40,37	27,34	22,53
75	11,80	53,99	1,63	67,09	93,61	36,63	25,39	21,16
90	11,00	39,25	2,47	51,65	96,55	33,46	24,44	20,59

Soluble fraction (a), insoluble fraction potentially degradable (b), degradation rate of fraction b (c), potential degradability (A), coefficient of determination (R^2) and effective degradability (for passage rates of 2, 5 and 8 % h^{-1}), relative to the degradation models of DM according to the defoliation frequencies.

The leaf fraction showed a higher amount of "*a*", and at 30 days it presented 23.30% solubility in water, a highly soluble fraction, and because it is a new plant and still in development, most of its carbohydrates are readily available for the ruminal microbiota. Regarding the frequencies of defoliation of 45 and 60 days, the difference was 10.69%, as they obtained 15.90 and 14.20% of "*a*", respectively. At 90 days, the leaf fraction presented a 12.40% "*a*", a drop of 46.78%, almost half of the soluble fraction at 30 days, however, despite this sharp drop, these values were very pronounced in relation to the stem fraction. These values are in agreement with the results of the chemical composition of the elephant grass in Table 1, in which this one presents high protein content, even at 90 days, the CP content is still considered medium.

The stem fraction had lower "*a*" values, results influenced by the large presence of

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http://dx.doi.org/10.1590/S1519-99402018000200003

lignified material. At 30 days, this presented 15.60% "*a*", with a drop in the frequency, these values were falling significantly, reaching 11.0% in the last frequency evaluated, a decrease of 29.48%. According to Carvalho et al. (2007), the dry matter fraction "*a*" represents the portion of the food that is readily available to ruminal microorganisms. Rêgo et al. (2011) evaluated the DM degradation parameters in elephant grass silages at different cutting ages with different inclusion levels of mesquite pods, and observed that the soluble fraction (*a*) decreased with age of elephant grass after regrowth and increased with the inclusion of mesquite pod.

The degradable fraction in the rumen (*b*) presented lower values at the lower frequencies of defoliation (75 and 90 days). At 60 days, the elephant grass presented the highest amount of degradable material in the rumen, with 72.12% next to that of 30 days (71.93%), at 60 days the grass still presents a significant quality (Table 1), correlated with its production, its nutritive value contributes to positive degradation results (Table 3). As for the stem fraction, higher "*b*" values were observed for the two higher defoliation frequencies (30 and 45 days). At 90 days, the elephant grass presented only 39.25% of the variable "*b*", a fall of 47.89% in relation to the frequency of 45 days, a significant reduction.

The degradation rate (*c*) in the leaf and stem was higher at the highest evaluated frequency (30 days). This treatment presented younger plants and material readily available for ruminal microbiota, data that are in accordance with table 2, in this sense the rate with which this material is degraded has great influence in relation to its maturity. However, it was observed a 90% degradation rate of 2.5% (leaf) and 2.4% (stem), high values taking into account that at 90 days the plant already has a high lignin content, causing this material to remain for longer in the rumen, consequently the degradation of this material is slow. According to Sampaio (1994), dry matter degradation rates of less than 2% per hour indicate poor quality foods, since they require a long time of permanence in the rumen to be degraded, as for example the majority of the tropical forages.

The high digestibility observed at higher frequencies is also related to the rapid detachment of EPI in the rumen, resulting in greater accessibility of the MES cells to the rumen microbiota. In C4, differences between genotypes are verified regarding digestibility and one of the causes would be the frequency of the girder structure (I and T) and epidermal stegmata.

The highest potential degradability (A) in the leaf fraction was verified at 30 days, influenced by the high rate of degradation and degradable fraction in the rumen, reaching 87.53% of its potential degradability. At 60 days, it presented significant values, with 84.22% of "A", in turn, at 90 days, the effect of plant maturity became pronounced, decreasing significantly. The behavior of the stem fraction was different, where at 45 days, it presented higher "A", and with decrease of the frequency of defoliation, there was a decrease in potential degradability. This behavior can be justified by the increase in the proportion of LVT (Table 2). These results are in agreement with those reported by Araújo et al. (2010), when evaluating the degradability parameters of DM of cultivar Mott at different cutting ages, which observed a decline in "A" values with increasing cutting age. The decrease observed in this study was much more accentuated, since a lower frequency of defoliation was used in this experiment.

It is observed that the DE values (Table 3) tend to decrease with increasing rate of

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passage. This effect is a result of the action of the ruminal microorganisms on the material that reached the rumen, since the lower the rate of passage of this material in the rumen, the longer it stays and the greater the action of the ruminal microbiota, thus influencing the DE of material. According to Araújo et al. (2010), the effective degradability of DM decreased significantly with increasing maturity and increased rate of passage.

The DE reduced significantly with the defoliation frequencies, regardless of the fraction evaluated, the highest values were found for the leaf fraction at 30 days in the three rates of passage. The results obtained for the protein degradability are presented in Table 4. The coefficient of determination (R^2) obtained for the variables at the different cutting times were greater than 93%.

The soluble fraction (*a*) of the protein (CP) present in the leaf and stem was higher than that observed for "*a*" of DM (Table 3). In the leaf fraction, the frequency of 45 days presented higher "a" content. The results obtained for the soluble fraction did not follow a logical sequence, where the variation occurred independent of the cutting frequency and the fraction evaluated (Table 4).

Table 4. Estimation of crude protein degradation (CP) parameters of leaf and stem fractions of elephantgrass under different frequencies of defoliation

Frequencies of defoliation (days)	Leaf blade							
	a (%)	*b (%)*	*c(%/h)*	A	R^2	Effective degradation (%)		
						2 % h^{-1}	5 % h^{-1}	8 % h^{-1}
30	23,99	73,18	6,78	97,17	98,37	80,50	66,11	57,56
45	33,61	63,68	4,59	97,29	97,75	77,96	64,09	56,83
60	20,90	71,35	9,47	92,25	95,81	79,81	67,60	59,58
75	27,83	67,99	4,27	95,82	98,90	74,13	59,15	51,49
90	20,41	71,09	5,83	91,50	96,95	73,34	58,68	50,38
	Stem							
30	25,71	63,35	4,44	89,06	97,47	69,39	55,51	48,32
45	20,70	68,94	6,81	89,64	96,19	73,99	60,45	52,40
60	28,56	67,45	4,14	86,24	96,31	67,45	54,69	48,23
75	22,52	65,38	4,57	87,90	95,38	68,00	53,74	46,29
90	23,38	58,76	3,89	82,14	93,36	62,19	49,09	42,60

Soluble fraction (a), insoluble fraction potentially degradable (b), degradation rate of fraction b (c), potential degradability (A), coefficient of determination (R^2) and effective degradability (for passage rates of 2, 5 and 8 % h^{-1}), relative to the degradation models of CP according to the defoliation frequencies.

A similar behavior was observed for the potentially degradable insoluble fraction (b) of the protein, where, at the 30 and 90 days for the leaf fraction, higher values of "b" were observed, while in the stem fraction the behavior was of decreasing order from 45 to 90 days. The fraction "b" is characterized by the part that is not lost in the washing of the bags under running water, but when it reaches the rumen, it has a great potential to undergo ruminal microbiota action and be degraded. According to Sampaio (1994), the interpretation of "b" does not interfere with the classification of the forage, since it usually indicates how much of the degradation potential was effectively due to the biological chemical action. The undegradable fraction of nutrients may be responsible for the longer retention time and ruminal repletion of the fiber fraction in the rumen. This retention of the feed in the rumen, usually due to ingestion of forage that presents low degradation, decreases dry matter intake and animal performance (PEREIRA et al., 2002).

The degradation rate of CP (c) presented variation in the different frequencies of plant defoliation. However, for the two fractions and cutting intervals, this rate was higher than 0.025 hour^{-1}, which favors its effective degradability values (RODRIGUES et al., 2004). The leaf fraction at 60 days presented a higher value of "*c*", while in the stem fraction, the highest values were verified for the frequency of defoliation of 45 days. This behavior can be related to the greater amount of non-lignified vascular tissue (NLVT) found at this frequency of defoliation, being this tissue composed mainly of phloem, a tissue of rapid digestion (Table 2).

The highest potential degradability of CP (A) was found at the highest frequencies of defoliation (30 and 45 days) for the two fractions evaluated, and the lowest values of "A" were observed at the lowest frequency of defoliation (90 days), which are expected results, since younger forages present higher protein content and lower NDF content than those with lower defoliation frequency, which allows a more efficient action of ruminal microorganisms on the food. In accordance to Carvalho et al. (2007), with the growth of plants, the cell wall develops and accumulates lignin, therefore, it is believed that the maturity stage has an influence on the potential degradability. Araújo et al. (2016) analyzed the degradability of leaves and stems of marandu palisadegrass and observed the same tendency of this experiment.

The effective degradability (ED) of CP was estimated considering the rates of passage of 2, 5 and 8% h^{-1}. According to Carvalho et al. (2007), the measurement of rumen degradability, without considering different rates of passage, may overestimate the extent of degradation, since the food particles are subjected to passage to the next compartment before being completely degraded. Thus, ED significantly decreased with increasing rates of passage (2, 5 and 8% h^{-1}), values explained by the increase in the rate of passage of food through the gastrointestinal tract of the animal, consequently providing lower action of the ruminal microbiota. Pereira et al. (2005) reported that with the increase in the rate of passage there is a greater escape of carbohydrates and proteins from ruminal fermentation, thus increasing the flow of these nutrients to the small intestine. Regarding the decrease in the frequency of defoliation, there was not much variation in the ED.

As plant maturity advances, the proportion of lignified vascular tissue increases, influencing the rumen degradation parameters of elephantgrass. The frequency of defoliation at 60 days presents an optimum point regarding the proportion of anatomical tissues correlated with a satisfactory degradation.

REFERENCES

ARAÚJO, S.A.C.; VÁSQUEZ, H.M.; COELHO DA SILVA, J.F.; DEMINICIS, B.B.; CAMPOS, P.R.S.S.; LISTA, F.N. Degradação ruminal e estimativa de consumo de genótipos de capim-elefante anão. Revista Brasileira de Zootecnia, v.39, n.1, p.18-24, 2010.

ARAÚJO, R.A.; RODRIGUES, R.C.; COSTA, C.S.; SANTOS, F.N.S.; COSTA, F.O.; LIMA, A.J.T.; SILVA, I.R.; RODRIGUES, M.M. Composição químico-bromatológica e degradabilidade in situ de capim-Marandu em sistemas silvipastoris formados por babaçu e em monocultivo. Revista Brasileira de Saúde e Produção Animal [online], v.17, n.3, p.401-412, 2016.

AKIN, D.E.; CHESSON, A. Lignification as the major factor limiting forage feeding value especially in warm conditions. In: INTERNATIONAL GRASSLAND CONGRESS, 16., 1989, Nice. Proceedings… Nice: Association Française pour la Production Fourragère, 1989. p.1753□1760.

BATISTOTI, C. Quantificação morfoanatômica de lâminas foliares de genótipos de *Panicum maximum*. 2006. 63p. Dissertação (Mestrado) – Universiddae Feaderal de Mato Grosso do Sul, Campo Grande.

BEZERRA, H.F.C.; SANTOS, E.M.; OLIVEIRA, J.S.; CARVALHO, G.G.P.; CASSUCE, M.R.; PERAZZO, A.F.; FREITAS, D.S.S.; SANTOS, V.S. Degradabilidade ruminal in situ de silagens de capim-elefante aditivadas com farelo de milho e inoculante da microbiota autóctone. Revista Brasileira de Saúde e Produção Animal [online], v.16, n.2, p.265-277, 2015.

BRITO, C.J.F.A; DESCHAMPS, F.C. Caracterização Anatômica em Diferentes Frações de Cultivares de Capim-elefante (*Pennisetum purpureum* Schumach.). Revista Brasileira de Zootecnia, v.30, n.5, p.1409-1417, 2001.

BRITO, C.J.F.A.; RODELLA, R.A.; DESCHAMPS, F.C.; ALQUINI, Y. Organização estrutural da lâmina e da bainha foliar de cultivares de capim-elefante (*Pennisetum purpureum* Schum). Arquivos de biologia e tecnologia, v.40, n.1, p.61-71, 1997.

CABRAL, C.H.A.; BAUER, M.O.; CABRAL, C.E.A. Influência das características anatômicas e estruturais em dossel forrageiro no consumo de ruminantes. Enciclopédia Biosfera, v.7, n.13, p.680-693, 2011.

CARVALHO, C.A.B.; ROSSIELLO, R.O.P.; PACIULLO, D.S.C.; SBRISSIA, A.F.; DERESZ, F. Classes de perfilhos na composição do índice de área foliar em pastos de capim-elefante. Pesquisa Agropecuária Brasileira, v.42, n.4, p.557-563, 2007.

GLÓRIA, B.A.; GUERREIRO, S.M.C. Anatomia Vegetal. 2. ed. Viçosa: UFV, 2006. 438p.

PACIULLO, D.S.C.; GOMIDE, J.A.; QUEIROZ, D.S.; SILVA, E.A.M. Composição química e digestibilidade "in vitro" de lâminas foliares e colmos de gramíneas forrageiras, em função do nível de inserção no perfilho, da idade e da estação de crescimento. Revista Brasileira de Zootecnia, v.30, p.964974, 2001.

PACIULLO, D.S.C. Características anatômicas relacionadas ao valor nutritivo de gramíneas forrageiras. Ciência Rural, v.32, p.357364, 2002.

PACIULLO, D.S.C.; GOMIDE, J.A.; SILVA, E.A.M.; QUEIROZ, D.S.; GOMIDE, C.A.M. Características anatômicas da lâmina foliar e do colmo de gramíneas forrageiras tropicais, em função do nível de inserção no perfilho, da idade e da estação de crescimento. Revista Brasileira de Zootecnia, v.31, p.890899, 2002.

PEREIRA, E.S.; ARRUDA, A.M.V.; MIRANDA, L.F.; PINTO, A.P. Importância da inter-relação carboidrato e proteína em dietas de ruminantes. Semina: Ciências Agrárias, v.26, p.125-134, 2005.

PEREIRA, J.C.; ALMEIDA, M.S.; CECON, P.R.; QUEIROZ, A.C. Dinâmica da degradação ruminal por novilhos mantidos em pastagem natural, em diferentes épocas do ano. Revista Brasileira de Zootecnia, v.31, p.740-748, 2002.

RÊGO, A.C.; PAIVA, P.C.A.; MUNIZ, J.A.; CLEEF, H.C.B.V.; NETO, O.R.M. Ruminal degradation of elephant grass silage with mesquite pods. Revista Ciência Agronômica, v.42, p.199-207, 2011.

RODRIGUES, A.L.P.; SAMPAIO, I.B.M.; CARNEIRO, J.C.; TOMICH, T.R.; MARTINS, R.G.R. Degradabilidade in situ da matéria seca de forrageiras tropicais obtidas em diferentes épocas de corte. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, v.56, p.658-664, 2004.

SAMPAIO, I.B.M. Contribuições estatísticas e de técnica experimental para ensaios de degradabilidade de forragens quando avaliada *in situ*. In: REUNIÃO ANUAL DA Sociedade Brasileira de Zootecnia, 31; simpósio internacional de produção de ruminantes, Maringá, 1994. Anais... Maringá: SBZ/EDUEM, 1994. p. 81-88.

VAN SOEST, P. Nutritional ecology of the ruminant. Ithaca: Cornell University Press, 1994. 476p.

VERAS, V.S.; OLIVEIRA, M.E.; LACERDA, M.S.B.; CARVALHO, T.B.; ALVES, A.A. Produção de biomassa e estrutura do pasto de capim andropogon em sistema silvipastoril e monocultura. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, v.61, n.1, p.200-207, 2010.

Receipt date: 27/02/2018
Approval date: 14/05/2018

Rev. Bras. Saúde Prod. Anim., Salvador, v.20, 01 - 01, e0272019, 2019 **ISSN 1519 9940**
http://dx.doi.org/10.1590/S1519-994020 0272019

Errata

No artigo "**Quantitative anatomy and in situ ruminal degradation parameters of elephant grass under different defoliation frequencies**", com número de DOI: 10.1590/S1519-99402018000200003, publicado no periódico Revista Brasileira de Saúde e Produção Animal, v.19, n.2, p. 166-177 abr./jun., 2018, na página 241:

Onde se lia:

"RODRIGUES, Ivone da Silva [4*]"

Leia-se:

"SILVA, Ivone Rodrigues da [4*]".