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RESEARCH PAPER

Effect of cutting frequency on the yield and properties of elephant grass biomass for bioenergy and animal feed

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Abstract

F.G. da S. Alves, M.S. de S. Carneiro, R.L. Edvan, P.G. Pimentel, M.X. Ribeiro, L.R. Bezerra, B.S.L. de Lima, and M.C.C. Vieira. 2020. Effect of cutting frequency on the yield and properties of elephant grass biomass for bioenergy and animal feed. Int. J. Agric. Nat. Resour. The objective of this study was to evaluate the biomass production and the potential use of the elephant grass hybrid Carajas for animal feeding and bioenergy production under different cutting frequencies. A randomized block design with a 3×3 factorial arrangement was used to evaluate the potential of the grass as animal feed (*in natura*, silage and hay form; cutting at 60, 75 and 90 days). A randomized block design with three treatments (three cutting intervals, 60, 75 and 90 days) was also used to evaluate the grass for biomass production and its potential use as an energy source in briquette form. The total forage biomass, leaf blade and stem biomass, dry matter, neutral and acid detergent fiber contents, mass and higher heating value increased with cutting interval, whereas the crude protein, ash and moisture contents decreased with cutting interval. Regardless of the cutting interval, the *in natura* material presented higher values of all content parameters than silage and hay. The Carajas hybrid can be used as animal feed in *in natura*, silage and hay form, and the recommended cutting interval for use as animal feed is 60 days. The Carajas hybrid also shows potential for use in bioenergy production in briquette form, with a suggested cutting interval of 90 days.

Keywords: Briquette, chemical composition, energy, *Pennisetum purpureum*

Introduction

Elephant grass is a very important tropical forage due to its high potential for biomass production.

Its high tolerance for and adaptation to diverse environmental conditions makes it an important forage plant in the production of roughage for livestock in the semi-arid region of Brazil. It is traditionally fed to livestock herds in its fresh chopped form (*in natura*) as well as being

preserved in the form of silage or hay (Pereira *et al.*, 2010).

In recent years, techniques have been developed for the use of grass biomass as an alternative energy source, providing a new course for grass development in terms of the desired target characteristics. For this purpose, plants richer in fiber and lignin with high biomass production started to be developed for use in energy production (Mourad & Walter, 2011). These desired traits are different from what is desired in animal production, which are species that present lower contents of fiber and acid detergent lignin.

Elephant grass still does not have the same range as an energy source as other crops, such as sugarcane (*Saccharum officinarum*). However, Silva and Rocha (2010) in a literature review reported that elephant grass has higher energetic potential than sugarcane; the dry biomass of elephant grass can generate 25 units of energy per fossil resource consumed in its production, whereas sugarcane converted into ethanol reaches a ratio of only nine to one.

Elephant grass biomass can be used as a source of bioenergy through the production of briquettes. Briquettes are the result of a chopped biomass compaction process in which the elasticity of the fibers is destroyed due to the high temperature and pressure (Quirino *et al.*, 2012). The same authors report that briquettes provide higher energy production per unit of volume, reducing the expenses of transportation and storage.

The cutting interval of a grass influences its chemical composition and potential to produce energy, especially the calorific power of the material. Young grasses tend to have fewer energetic compounds in their chemical composition (Silva *et al.*, 2011).

Thus, we hypothesized that the Carajas hybrid, when managed with a longer cutting interval, would have high biomass production, associated

with a worse chemical composition as animal feed and better characteristics for bioenergy production. Therefore, the objective of this study was to evaluate the biomass production of the Carajas hybrid, the potential for its use in *in natura*, silage and hay forms for animal feed and as a briquette for energy production, and the changes in its potential at different cutting intervals.

Material and Methods

Location and statistical design

The experiment was conducted at the Experimental Farm of the Federal University of Piauí (UFPI), located in Alvorada do Gurgueia, Brazil. The town is at latitude 8° 22' 30" south, longitude 43° 50' 48" west at an altitude of 239 m. The annual rainfall accumulation is 900 to 1200 mm, and the annual mean temperature is 26.6 °C. The experiment was carried out from October 2015 to March 2016. The climatic data observed during the experimental period were obtained at a meteorological station located in that region (Figure 1).

For the evaluation of the Carajas hybrid (*Pennisetum purpureum* × *Pennisetum glaucum*) as animal feed, the experimental design adopted was randomized blocks in a 3×3 factorial arrangement. The treatments were three forms used for animal feeding (*in natura*, silage and hay) and the three cutting intervals (60, 75 and 90 days), with four blocks and two cuts per age, totaling eight replicates. In the briquette evaluation for energy production, a randomized block design with three treatments (three cutting intervals, 60, 75 and 90 days) and eight replicates (four blocks and two cuts) was adopted.

Grass planting and experimental area

Before the implementation of the experiment, a representative soil sample for the area was col-

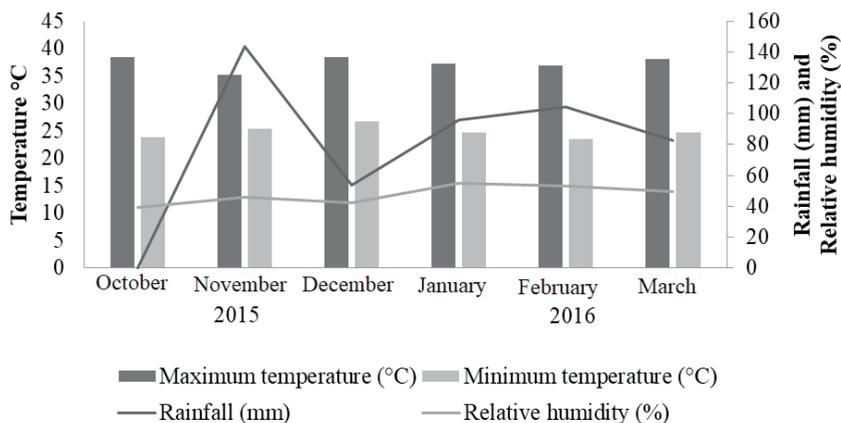


Figure 1. Climate data observed during the experimental period.

lected for analysis and chemical characterization. The sample was sent to the Laboratory of Soils of the Federal University of Piauí (UFPI) campus Professor Cinobelina Elvas (CPCE), in Bom Jesus, Piauí, Brazil. The soil nutrient concentrations were as follows: 9.6 mg dm⁻³ phosphorus, 21.19 mg dm⁻³ potassium, 0.0 cmol dm⁻³ aluminum, 2.4 cmol dm⁻³ calcium, 1 cmol dm⁻³ magnesium, 3.1 cmol dm⁻³ base sum, 6.5 cmol dm⁻³ cation exchange capacity at pH 7.0, 46.8% base saturation and pH 5.4. Based on the results, soil amendment and fertilization were performed. Dolomitic limestone (PRNT 80%) was applied to bring the soil saturation levels to 60%. At planting, 20.8 g of phosphorus per linear meter (of simple superphosphate, 18% of P₂O₅) and 3.44 g of potassium per linear meter (in the form of potassium chloride, 48% of K₂O) were applied.

The experimental area was a forage area growing the elephant grass hybrid Carajas established in 2013. The seeding was performed in rows, and the distance between rows was one linear meter. For each linear meter, 0.64 g of grass seed was used, according to the recommendations of MATSUDA® Seeds. In October 2015, a uniform cut was performed at 20 cm above the soil when the treatments were applied, and irrigation was performed with an irrigation water depth of ten millimeters every three days in each plot by sprinkling.

The experimental area had four blocks with three plots in each block. Each experimental plot was 4 m² (4 m long and 1 m wide), with five rows of plants per plot. For data collection, only the plants in the central line were used. The plots were separated by uncultivated spaces of one meter between plots of each block and two meters between blocks.

The cuts were performed according to the evaluated cutting frequencies. For each frequency evaluated, it was possible to make two cuts in the dry season (October, November and December) and two in the rainy season (January, February and March) during the evaluation period. After cutting, the grass was fertilized with a dose of nitrogen equivalent to 200 kg N ha⁻¹ year⁻¹, with conventional urea as the source of nitrogen (45% of N). The fertilization was in installments according to the number of cuts per year, which varied with the cutting interval of the grass. The cuts were performed at a height of 20 cm above the soil, according to the recommendations of the MATSUDA® company for the Carajas hybrid.

Grass biomass determination

After cutting the elephant grass in the field, the total forage biomass (TFB), leaf blade biomass (LBB), and stem biomass (STB) were estimated from samples collected in one linear meter. The

collected material was separated into leaf blades and stems. Those samples were packed in paper bags, weighed, placed in a forced ventilation oven at 55 °C until constant weight and weighed again. The biomasses (tDM ha⁻¹) were calculated from the total fresh weight and dry weight.

Determination of the potential of the grass as animal feed

The material collected in each 4 m² plot was taken to a DPM-2 c/VPB chopper and chopped into 2 cm × 2 cm particles. From the chopped material, samples were collected *in natura* and to produce hay, silage and briquettes.

For hay production, the chopped material was exposed to the sun on a plastic canvas until reaching the hay point (±80% of DM). The nail method was used to evaluate the hay point. This method consists of inserting a nail into the stem node and observing whether it is wet. If there is moisture, the material is not ready. After the material reached the hay point, samples were collected to determine its nutritional value.

The silage was prepared in mini silos at a density of 600 kg m⁻³. For each age, three miniature PVC silos were made, with 50 cm in length and 10 cm in diameter per treatment. After 28 days, the miniature silos were opened, and samples were collected to determine the nutritional value of the silage.

Samples collected from the *in natura* grass and the preserved material were packed in paper bags, weighed, placed in a forced ventilation oven at 55 °C for 72 hours and weighed again. The samples were milled in a Wiley mill using a one-millimeter sieve for further analysis of their chemical composition. The samples were stored in plastic jars with lids, labeled, and subjected to analyses to determine their dry matter (DM; method 967.03), ash (method 942.05) and crude protein (CP; method 981.10) contents according

to Association of Official Analytical Chemists (AOAC, 1990). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the Van Soest *et al.* (1991) method. The CP content was obtained by multiplying the total nitrogen content by 6.25.

Determination of the energetic potential of the grass

The biomass to produce the briquettes came from the material collected after being chopped. The collected material was packed in paper bags and placed in a 55 °C oven for 72 hours. Due to the dimensions of the iron cylinder used in briquetting, 50 grams of biomass were used to make each briquette. The biomass to produce the briquettes was weighed on a scale with a precision of 0.0001 g. For the manufacturing of briquettes, a hydraulic press (15 t) fitted with a gas cylinder, three hollow iron cylinders (30 mm × 250 mm), two solid iron cylinders (29 mm × 250 mm and 29 mm × 150 mm), two holders for the hollow iron cylinders (one for compacting and another for briquette removal), an appliance flame launcher and a universal holder were used.

After weighing, the biomass was placed in a hollow iron cylinder to be pressed. In the lower part of the cylinder, a support was attached to prevent the biomass from falling out and to provide stability during the briquetting process. The solid iron cylinders were placed in the upper part in order to ease the pressing of the residue, given that the hydraulic course of the press was only 12.5 cm. Subsequently, the hollow cylinder was carried with the support and the solid iron cylinder to the hydraulic press. Finally, the biomass was compacted for eight minutes at a pressure of 250.45 kgf cm⁻² and a temperature of approximately 129 °C.

The mass (g), volume (cm³), density (g cm⁻³), higher heating value (HHV) and moisture contents of the briquettes were determined. The HHV of

each treatment was determined using the IKA C200 calorimetric pump. To obtain the mass, a precision scale (0.0001 g) was used, and a digital caliper was used to determine the volume. The apparent density was obtained from the division of the volume by the mass of the briquette.

Statistical analysis

The results were submitted to analysis of variance, a test of the comparison of the means and regression analysis. An analysis of the interactions was performed by the F test when the interactions were significant ($P < 0.05$). The means were compared by Tukey's test ($P < 0.05$). SISVAR software version 5.0 was used.

Results

Grass biomass determination

The Carajas hybrid showed no interaction effect ($P > 0.05$) between the cutting interval and the evaluation seasons (Table 1) for the total forage biomass (TFB), leaf blade biomass (LBB) and stem biomass (STB). Individual effects were observed for the cutting intervals of 60, 75 and 90 days and the evaluation seasons (dry and rainy seasons) for TFB, LBB and STB.

The cutting interval at 90 days provided higher production than the other cutting times of TFB ($P < 0.0001$), LBB ($P < 0.0001$) and STB ($P < 0.0001$), at 35.86 (± 0.26), 25.75 (± 0.24) and 16.80 (± 0.21) t ha⁻¹, respectively. The grass under irrigation in the rainy season presented higher TFB ($P = 0.0012$), LBB ($P = 0.0039$) and STB ($P = 0.0118$), at 33.70 (± 0.21), 21.98 (± 0.19) and 12.68 (± 0.17) t ha⁻¹, respectively, than the grass in the dry season.

Determination of the potential of the grass as animal feed

Regarding the chemical composition, there was an interaction effect between cutting interval (60, 75 and 90 days) and form of use (*in natura*, silage and hay) for animal feeding of the Carajas hybrid in terms of DM ($P = 0.0464$), CP ($P = 0.0093$), NDF ($P < 0.0001$) and ADF ($P < 0.0001$). For ash, there were only individual effects of cutting interval ($P < 0.0001$) and form of use ($P < 0.0001$) as animal feed (Table 2).

A reduction in the CP content was observed as the grass age increased; 60-day-old plants showed higher CP content for all forms of use than plants cut at higher ages (Table 3). The grass had a higher content of CP in the *in natura* form than in the other animal feed forms, at 90.2 (± 0.11) g kg⁻¹.

Table 1. Characterization of elephant grass hybrid Carajas production at different cutting intervals (60, 75 and 90 days) and evaluation seasons (dry and rainy)

Pr<Fc	Source of Variation						
	Block	Age	Seasons	Age x Season	CV (%)		
DF	3	2	1	2			
TFB (t DM ha ⁻¹)	0.0001	<0.0001*	0.0012*	0.6521 ^{ns}	3.14		
LBB (t DM ha ⁻¹)	0.3505 ^{ns}	<0.0001*	0.0039*	0.4618 ^{ns}	4.51		
STB (t DM ha ⁻¹)	0.0187 ^{ns}	<0.0001*	0.0118*	0.5080 ^{ns}	6.84		
	Cutting interval (days)			Evaluation seasons			
	60	75	90	SEM	Dry	Rainy	SEM
TFB (t DM ha ⁻¹)	30.74 c	32.92 b	35.86 a	0.26	32.64 b	33.70 a	0.21
LBB (t DM ha ⁻¹)	17.67 c	21.22 b	25.75 a	0.24	21.12 b	21.98 a	0.19
STB (t DM ha ⁻¹)	8.57 c	11.70 b	16.80 a	0.21	12.04 b	12.68 a	0.17

DF: degree of freedom; CV: coefficient of variation; SEM: standard error of mean; TFB: total forage biomass; LBB: leaf blade biomass; STB: stem biomass; *: significant at 5%; ^{ns}: non-significant at 5%.

Table 2. Summary of variance analysis of chemical composition of the elephant grass hybrid Carajas at different cutting intervals (60, 75 and 90 days) and form of use for animal feeding (*in natura*, silage and hay).

Pr<Fc	Source of Variation				
	Block	Age	Forms of use	Age x Forms of use	CV (%)
DL	3	2	2	4	–
DM (%)	0.8190 ^{ns}	<0.0001*	<0.0001*	0.0464*	2.78
Ash (%)	0.1822 ^{ns}	<0.0001*	<0.0001*	0.4249 ^{ns}	4.18
CP (%)	0.5359 ^{ns}	<0.0001*	<0.0001*	0.0093*	4.44
NDF (%)	0.2816 ^{ns}	<0.0001*	<0.0001*	<0.0001*	0.76
ADF (%)	0.5033 ^{ns}	<0.0001*	<0.0001*	<0.0001*	1.24

DL: degree of freedom; DM: dry matter; Ash: mineral matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; CV: coefficient of variation. *: significant at 5%. ^{ns}: non-significant at 5%.

Table 3. Chemical composition of the elephant grass hybrid Carajas at different cutting intervals and forms of use for animal feeding.

Variables	Age (days)			SEM
	60	75	90	
DM (g kg ⁻¹)				
<i>In natura</i>	169.0 ^{cA}	199.9 ^{bA}	214.1 ^{aA}	0.18
Silage	159.4 ^{cB}	187.3 ^{bB}	194.3 ^{aB}	
Hay	154.2 ^{cB}	183.3 ^{bB}	190.2 ^{aB}	
CP (g kg ⁻¹)				
<i>In natura</i>	90.2 ^{aA}	79.0 ^{bA}	62.3 ^{cA}	0.11
Silage	79.6 ^{aB}	71.6 ^{bB}	57.5 ^{cB}	
Hay	74.5 ^{aC}	69.1 ^{bB}	54.8 ^{cB}	
NDF (g kg ⁻¹)				
<i>In natura</i>	663.0 ^{cA}	692.5 ^{bA}	724.3 ^{aA}	0.57
Silage	647.5 ^{cB}	676.2 ^{bB}	690.8 ^{aB}	
Hay	645.8 ^{cB}	670.0 ^{bC}	687.8 ^{aB}	
ADF (g kg ⁻¹)				
<i>In natura</i>	374.5 ^{cA}	403.8 ^{bA}	433.3 ^{aA}	0.17
Silage	367.8 ^{cB}	384.2 ^{bB}	399.3 ^{aB}	
Hay	366.5 ^{cB}	382.1 ^{bB}	393.1 ^{aC}	
Cutting interval (days)				
Ash (g kg ⁻¹)	60	75	90	0.09
	129.7 ^a	99.6 ^b	84.6 ^c	
Forms of use				
<i>In natura</i>	Silage	Hay		0.09
109.1 ^a	104.3 ^b	100.5 ^c		

Lowercase letters in the row and uppercase letters in the column differ by Tukey's test at a 5% significance level. DM: dry matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; Ash: mineral matter. SEM: standard error of the mean.

The values of NDF increased with the increase in the cutting interval and obtained a higher content for the *in natura* form associated with the 90-day cutting time, of 724.3 (±0.57) g kg⁻¹. The content of the ADF presented the same behavior as the NDF, showing an increase in value with the advancement of the cutting interval and

in the *in natura* form, at 433.3 (±0.17) g kg⁻¹. It was observed that the content of ash decreased with the advancement of plant age, with a higher content at 60 days (129.7±0.09 g kg⁻¹) and in *in natura* form (109.1±0.09 g kg⁻¹) than at other cutting times and forms.

Determination of the energetic potential of the grass

In the analysis of the briquettes, the cutting interval the Carajas hybrid had significant effects ($P < 0.05$) only on the mass, moisture and higher heating value (Table 4). The different cutting intervals did not influence ($P = 0.0580$) the volume or density ($P = 0.1487$) of the briquettes produced.

The briquette mass from the plants cut at 60 days was lower (34.02 ± 5.91 g) than that of the briquettes from plants cut at other ages. Briquette moisture decreased with advancing grass age, and the briquettes produced from the plants cut at 90 days had the lowest moisture content ($6.81 \pm 3.69\%$). The HHV of the briquette produced with the Carajas hybrid increased with the increase in the cutting interval, and it was observed that the cutting interval of 90 days had the highest value, of $4414.32 (\pm 1.29)$ cal g^{-1} .

Discussion

Grass biomass determination

The high biomass production of the Carajas hybrid (Table 1) justifies its cultivation for both animal feed and bioenergy. According to Moraes *et al.* (2012), certain varieties of elephant grass are being cultivated for those purposes in Brazil. In the Cerrado biome of Brazil, Flores *et al.* (2012) reported that the productivity of elephant grass

corresponds directly to the time of permanence in the field. With a cutting interval of 90 days, it is possible to perform up to 4 cuts per year, and the Carajas hybrid could produce ± 143.44 t ha^{-1} per year of TFB. The advantage of the Carajas hybrid compared to other varieties of elephant grass is that it can be cultivated through seeds. Other varieties are cultivated asexually through seedlings, which are difficult to acquire, and planting them is costly.

The cut at 60 days showed a leaf/stem ratio of 2.06; at 75 and 90 days, this ratio was 1.81 and 1.53, respectively. This result indicates that when the grass is managed with a cutting interval of 60 days, it has more leaves and therefore provides a better quality of grass for animal feeding. The material obtained with a cutting interval of 90 days had a greater amount of stem, a component of the plant that confers more fiber to the material produced. This cutting interval provides grass that is more suitable for energy production.

The Carajas hybrid presented higher production of TFB, LBB and STB in the rainy season than in the dry season. This is probably due to the high temperatures that are common in the dry season (the highest temperature recorded in the dry period was 41.8 °C). Even C4 plant species reduce their production when the optimum temperature of the plant is exceeded. When evaluating different cultivars of elephant grass for energy purposes, Santos *et al.* (2014) reported that there was no significant difference in production among the

Table 4. Volume, density, mass, moisture and higher heating value (per briquette unit) of briquettes produced from the elephant grass hybrid Carajas at different cutting intervals.

Variables	Cutting interval (days)			SEM	Pr<Fc	CV (%)
	60	75	90			
Volume (cm ³)	23.16	23.68	23.87	0.25	0.1487 ^{ns}	1.79
Density (g cm ⁻³)	1.41	1.40	1.40	0.03	0.9974 ^{ns}	2.99
Mass (g)	34.02 ^b	34.85 ^a	34.18 ^a	0.22	0.0058*	5.91
Moisture (%)	9.34 ^a	7.55 ^b	6.81 ^c	0.10	<0.001*	3.69
HHV (cal g ⁻¹)	4181.62 ^c	4329.93 ^b	4414.32 ^a	19.62	<0.001*	1.29

SEM: standard error of the mean. CV: coefficient of variation. HHV: higher heating value. Pr<Fc: *significant at 5%. ^{ns} non-significant at 5%. Means with the same lowercase letter in the row do not differ by Tukey's test at 5% significance.

grasses, but production decreased during the hottest time of the year.

Determination of the potential of the grass as animal feed

The DM contents increased with the increase in the cutting interval, and the cutting interval of 90 days presented higher DM levels for all three forms of feed than the other cutting intervals (Table 2). The *in natura* form had the highest DM content. These results may be because as the plant grows and advances in age, its structural carbohydrate and lignin contents increase because the cell wall becomes more expansive, which contributes to the increase in the DM content (Lima *et al.*, 2010).

When studying the production of the elephant grass genotype Pioneiro harvested at different cutting heights (30, 40, 50 and 60 cm), Figueira *et al.* (2016) observed that DM values varied from 10.45 to 13.34% for the grass cut at 30 cm from the soil in the first and third cuts, respectively. Analyzing elephant grass managed under different cutting intervals (120, 150 and 180 days), Flores *et al.* (2012) observed that with increase in the age, the DM content increased in the whole plant as well as in the leaf and stem fractions.

The reduction in the CP content with the increase in the cutting interval of the grass may have occurred due to the increase in the proportion of the stem and of senescent material as the plant ages. The senescent and stem fractions have low CP content, which reduces the nutritional value of the grass, regardless of how it is used in animal feeding. Studying the elephant grass genotype Napier and its nutritional value as *in natura* feed at different cutting intervals, Teixeira *et al.* (2015) reported CP values between 5.05 and 17.08% for the ages 112 and 56 days, respectively.

For animal feeding, cutting the elephant grass at 90 days provides a lower-quality material due to the high amount of fiber; however, for energy

production, the higher fiber content indicates better quality. Evaluating the elephant grass genotype Napier managed under different cutting intervals, Teixeira *et al.* (2015) observed an NDF content of 66.76% at 56 days, 71.62% at 84 days and 74.05% at 105 days.

The same trend was observed for ADF content, which increased with the increase in cutting interval. The ADF concentrations of 37.19% at 56 days, 44.77% at 84 days and 44.53% at 112 days were found by Teixeira *et al.* (2015) for the elephant grass genotype Napier when studying the quality of five elephant grass genotypes.

The ash content of the grass decreased with the increasing cutting interval. This may have occurred because as the cutting interval increases, the maturation period of the plant also increases such that the stem production is higher; the stem has a lower mineral content than the leaves. With a cutting interval of 90 days, higher STB production was observed than with a 60-day interval, and the leaf/stem ratio was the highest for the shortest cutting interval. When studying the elephant grass genotype Paraíso managed with different cutting intervals (120, 150 and 180 days), Flores *et al.* (2013) observed levels of mineral matter ranging from 5.7 to 5.0% in stems and 10.4 to 8.9% in leaves at the lowest and highest cutting intervals, respectively. Grass biomass with high ash content may not be suitable for energy purposes because the higher the content of ash, the lower the volatile content; the volatile content indicates the ease of burning of the material (Tavares & Santos, 2013). This indicates that the biomass of the Carajas hybrid produced with a cutting interval of 90 days will have a better quality for energy production.

For all evaluated variables, the *in natura* form showed higher values than silage and hay. This demonstrates that although preservation techniques can preserve the nutritional value of the feed, there will always be nutritional losses in the material and that regardless of the form of use (*in natura*,

hay or silage), shorter cutting intervals provide better material for animal feed.

Determination of the energetic potential of the grass

The volume of the briquettes produced with the grass was the same because the different cutting intervals did not influence volume. The finding in the present study is in accordance with that found by Lima *et al.* (2016), who did not observe a difference in the volume of the briquettes made from the Carajas hybrid at different ages and fertilized with different doses of nitrogen (200 and 400 kg ha⁻¹ year⁻¹).

The response observed for density strengthens the finding of the homogeneity of briquettes produced from the Carajas hybrid. Briquette density is extremely important because the higher the density is, the greater the energy/volume ratio (Dias *et al.*, 2012). Evaluating briquettes from the Carajas hybrid subjected to different cutting intervals and nitrogen doses, Lima *et al.* (2016) did not find significant differences in density. In studying different sources of plant biomass for briquette production, Tavares and Santos (2013) reported density values of 1.36 and 2.22 g mm⁻³ for elephant grass and *Vetiveria zizanioides*, respectively.

The mass values observed at the different cutting intervals were expected, since older, previously cut plants have more structural components. Unlike the results observed in the present study, Lima *et al.* (2016), studying the use of the Carajas hybrid managed under different cutting intervals (60, 75 and 90 days) and nitrogen doses (200 and 400 kg ha⁻¹ year⁻¹) for the production of briquettes, did not find a significant difference in the mass of briquettes between the evaluated cutting intervals.

The results for briquette moisture can be explained by the fact that as the plant ages, the DM content increases due to structural alterations in

the tissues, reductions in cell contents and the expansion of cell walls. This was observed in the chemical composition, especially in the contents of NDF and ADF, which were higher due to the greater cell wall content with the increase in the cutting interval.

The moisture content is a criterion that must be well controlled. The lower the water content is, the higher the heat production per mass unit, as the presence of water can make combustion difficult (Vale *et al.*, 2000). For the proper burning of briquettes, the moisture content should be between 5–15%; above 15%, the briquettes may break down or degrade biologically during transportation or storage, and below 5%, material losses and breakage can occur during transport and storage (Dias *et al.*, 2012).

All the values for moisture found in this study are within the range of ideal values. Studying the use of different biomass sources to produce briquettes, Tavares and Santos (2013) observed moisture values of 8.89% for *V. zizanioides* and 9.73% for elephant grass. For briquettes made from the Carajas hybrid, Lima *et al.* (2016) observed a moisture content of 6%.

The cutting interval of 90 days led to a higher HHV for the grass due to the increase in lignin and carbon content with aging. These are the two main factors responsible for the elevation of HHV, as confirmed by the increase in ADF in the material. Moreover, the decrease in the moisture content with the increase in the cutting interval may have influenced the HHV increase.

The HHV is an extremely important characteristic for evaluating the viability of using biomass for energy generation. The HHV corresponds to the amount of calories released by the combustion of a mass unit of the material (Tavares & Santos, 2013). Analyzing the elephant grass genotype Purple as raw material for renewable energy production, Saraiva and König (2013) found HHV values ranging from 4000 to 4251 cal g⁻¹.

Evaluating the HHV estimates from crop residues and from the processing of *Pinus taeda*, Souza *et al.* (2012) observed values ranging from 4535 to 4926 kcal kg⁻¹.

The elephant grass hybrid Carajas with a cutting interval of 60 days can be used in animal feed-

ing in its *in natura* form and as hay and silage as it presents a better chemical composition than older grass. For energy production, it is recommended to cut the elephant grass hybrid Carajas at 90 days, as grass cut at this time has higher production value and better energy-production characteristics when it is formed into briquettes.

Resumen

F.G. da S. Alves, M.S. de S. Carneiro, R.L. Edvan, P.G. Pimentel, M.X. Ribeiro, L.R. Bezerra, B.S.L. de Lima, y M.C.C. Vieira. 2020. Hierba elefante sometida a diferentes edades de corte para la producción de biomasa destinada a la bioenergía y a la alimentación animal. Int. J. Agric. Nat. Resour. El objetivo fue evaluar la producción de biomasa y el potencial de uso del híbrido de pasto elefante ‘Carajas’ para la alimentación animal y la producción de bioenergía, en diferentes edades de corte. Se utilizó un diseño de bloques al azar con arreglo factorial 3 × 3 para evaluar el potencial del pasto como alimento para animales (in natura, silo y heno a 60, 75 y 90 días) y un diseño de bloques al azar con tres tratamientos (tres edades de corte) 60, 75 y 90 días para la evaluación de la hierba para la producción de biomasa y el potencial energético de las briquetas. Biomasa forrajera total, biomasa de la lámina foliar y biomasa del tallo, materia seca, contenido de fibra detergente neutro y ácido, masa y aumenta el poder calorífico con el avance de la edad de la planta, mientras que los contenidos de proteína cruda, ceniza y humedad disminuyeron. Independientemente de la edad de corte, el material in natura presentó mayores contenidos que el ensilado y el heno. El híbrido Carajas puede utilizarse como alimento para animales en forma de in natura, silo y heno, con recomendación de corte a los 60 días, y muestra potencial para la producción de bioenergía a través de briquetas, con sugerencia de corte a los 90 días.

Palabras clave: Briquetas, composición química, energía, *Pennisetum purpureum*.

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