CHARACTERIZATION OF CASSAVA (MANIHOT SCULENTA CRANTZ) AERIAL PARTS FOR RUMINANT FEEDING

CARACTERIZAÇÃO DA PARTE AÉREA DE MANDIOCA PARA ALIMENTAÇÃO ANIMAL

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SUMMARY

The objective of this research was to characterize the chemical composition and digestibility of aerial part and cuttings of four cassava cultivars grown in five different levels of soil fertilization and three plant densities, in order to use the residues for ruminant feeding. The experiment was conducted using a randomized complete block design, in strip-split-plot scheme, with four replicates. The plots were composed of IAC14, IAC15, IAC90, and Cascuda cultivars; the subplots consisted of five fertilization categories, one fertilization with poultry litter (3000 kg.ha^{-1}) and four chemical fertilization rates (0, 150, 450, 900 kg.ha^{-1}) with NPK 4-20-20; and with the sub-subplots consisted of three plant densities (7,500, 12,500, 17,500 plants.ha^{-1}). During the experiment, aerial part and cuttings were sampled for chemical and *in vitro* digestibility analyzes. There were differences between the varieties of cassava and fertilization rates on fiber fractions, chemical composition, in vitro digestibility, total digestible nutrients (TDN), and dry matter yield (kg / ha) of aerial part (P<0.05) and cuttings (P<0.05). Cassava aerial part and cuttings have considerable amounts of nutrients that can be used for ruminant feeding on small farms and for animal categories with low nutritional requirements. From all treatments, variety IAC15, with chemical fertilization of 900 kg.ha^{-1}, as well as fertilization with poultry litter, with the highest plant density, were those with better nutritional composition and greater amount of available nutrients.

KEY-WORDS: Digestibility. Neutral detergent fiber. Nutrient. Residue. Ruminants.

Abbreviations: crude protein (CP), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare (DM.ha^{-1})

RESUMO

O objetivo desta pesquisa foi quantificar e estudar a composição química e a digestibilidade da parte aérea e da maniva-mãe de quatro cultivares de mandioca, cultivadas sob cinco diferentes níveis de adubações e três densidades de plantio, com a finalidade de utilização destes coprodutos na alimentação de ruminantes. O experimento foi realizado no Pólo Regional de Desenvolvimento do Médio Paranapanema utilizando o delineamento experimental em blocos casualizados, em esquema de parcelas sub-subdivididas, com quatro repetições. As parcelas foram compostas pelas cultivares IAC 14, IAC 15, IAC 90 e Cascuda; as subparcelas compostas por doses de 4-20-20 (0, 150, 450, 900 kg/ha) ou adubação com cama de frango (3.000 kg/ha de cama de frango) e as sub-subparcelas compostas por densidades de plantio de 7.500, 12.500, 17.500 plantas/ha. Foram feitas amostragens de parte aérea e maniva-mãe e realizadas análises químicas para determinação dos nutrientes e digestibilidade *in vitro*. Houve diferença entre as variedades de mandioca e níveis de fertilização sobre as frações da fibra; composição química; digestibilidade in vitro; nutrientes digestíveis totais (NDT), e rendimento de matéria seca (kg/ha) da parte aérea (P<0,05) e da maniva-mãe (P<0,05). A parte aérea e a maniva-mãe oriundas das sobras da colheita de variedades de mandiocas selecionadas para a produção de raiz possuem consideráveis quantidades de nutrientes que podem ser aproveitados para a alimentação animal em pequenas propriedades. Dentre tratamentos estudados, a variedade IAC15, a adubação química de 900 kg/ha, bem como adubação com cama de frango e a maior densidade populacional/ha foram os que apresentaram melhor composição nutricional e maior quantidade de nutrientes por hectare.

PALAVRAS-CHAVE: Digestibilidade. Fibra detergente neutro. Nutriente. Resíduo. Ruminantes.

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INTRODUCTION

Cassava production has an important role in food security especially for populations located in the tropics, such as in some countries in Africa, America, and Asia. According to Faostat (2014), the world production of cassava in 2012 was greaer than 269 million tons of roots. The cassava production area is concentrated in Africa (56.3%), Asia (32.5%), and America (11.1%). Among the main producers, Brazil occupies the fourth position with the production of 23 million tons of roots (FAOSTAT, 2014).

In Brazil, cassava is produced throughout the country, but the states of São Paulo, Paraná, and Mato Grosso do Sul are the largest cassava production centers, and the roots are used for the production of starch and flour. The cassava production generates some residues in the crop field after the harvest, consisting of leaves, stems, and cuttings (cassava foliage). From all cassava cuttings produced, only 20% are used for replanting, leaving the rest on the field, which can be considered as a product of great value for ruminant feeding (LEONEL, 2002). The lack of knowledge about the importance of its use in animal feeding has contributed to the low utilization of this nutrient source by farmers, especially during the dry season (MARQUES et al., 2000; MOURA and COSTA, 2001).

In regions with cassava-processing industries, the harvest usually occurs during the dry periods, because that is when the roots present desirable traits for processing. The most favorable harvest season occurs when the cassava plants are at the dormancy period, or when weather conditions and growth stage have decreased the number and size of leaves and leaf lobes, indicating maximum production of roots with high starch concentration (FUKUDA & OTSUBO, 2003). However, greater percentage of leaf retention may occur in different environmental conditions, indicating better nutritional characteristics of the residue. In addition, the harvest of cassava can be extended depending on the demands from the processing industries and on selling price. Thus, the harvest of cassava coincides with the period of lower nutritional value of pastures, when supplementation is needed to avoid a decrease in animal performance. These factors indicate that the aerial part of cassava plant, after harvesting the roots, might be a good alternative to reduce the costs of ruminant feed during this critical period, and according ANJOS et al. (2014) a valuable source of dietary energy for dairy cows.

Cultivars, plant density, fertilization, and harvest season are characteristics that may influence the amount and chemical composition of cassava crop residues. Although research indicates the viability of using cassava aerial parts for ruminant nutrition due to great value of protein and vitamins, this residue has been poorly exploited, usually being wasted in the crop field (CARVALHO, 1983, cited by MOURA & COSTA, 2001).

Therefore, the objective in this research was to quantify the chemical composition and in vitro digestibility of the aerial part and cuttings of four cassava cultivars grown under five levels of fertilization and three planting densities, with the purpose of utilization in ruminant animals feeding.

MATERIAL AND METHODS

Location

The experiment was conducted at the Agência Paulista de Tecnologia dos Agronegócios (APTA), Polo Regional Médio Paranapanema (22°40'S and 50°26'W, altitude of 563 m and humid subtropical climate Cwa) in the city of Assis, São Paulo state, Brazil, in dark Haplorthox soils of medium texture. The results from the chemical analysis in soil samples (0-20 cm) showed OM (g dm^{-3}) = 18; P (Resin, mg dm^{-3}) = 9; pH ($CaCl_2$) = 4.6; K, Ca, Mg, H + Al, BSR and CEC (mmol dm^{-3}) = 2.8; 11; 8; 31; 13.8 and 50.8, respectively, and V (%) = 39. Before the experiment, 2 $t.ha^{-1}$ of dolomitic limestone was applied and *incorporated by harrowing*.

Experimental design and treatments

The experimental design was a randomized complete block, in a strip-split-plot scheme, with four replicates. The plots were composed of cultivars, the subplots consisted of five fertilization rates, and the sub-subplots consisted of three plant densities (Figure 1).

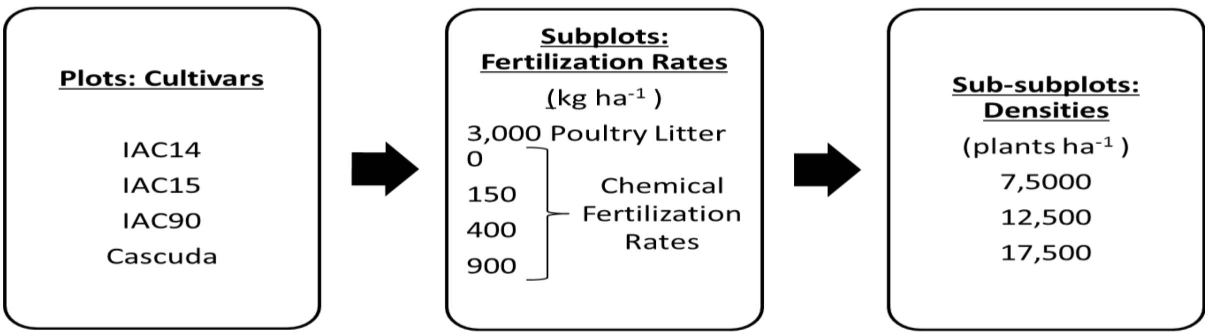

Figure 1 - Distribution of experimental treatments.

Chemical analysis of poultry litter revealed 24.4% of humidity; N, P, K, Ca, Mg, and S ($g.kg^{-1}$) of 22.7, 21.9, 28.6, 91.0, 6.2, and 4.2, respectively; Zn, Cu, Fe, Mn, and B ($mg.dm^{-3}$) of 340.0, 505.0, 8150.0, 536.0, and 32.7, respectively. The planting was done with 18 cm stem cuttings in minimum tillage system, on intercropping with oats as the stage of pinnacle emergence began, after the use of glyphosate as a desiccant. The fertilizers were distributed at planting time and mixed with soil. The sampling of the aerial part and the cuttings were made 12 months after planting.

The aerial parts of each experimental unit were harvested at 20 cm above the ground and weighed. Samples of approximately 5 kg were collected, wrapped in plastic bags, and subsequently taken to the laboratory for processing. In addition, the cuttings from each experimental unit were weighed and three cuttings were collected for later processing. In the laboratory, the samples of the aerial parts and the cuttings were chopped, homogenized, and sub-sampled. The final sub-samples of the aerial parts contained approximately 1 kg whereas the cuttings sub-samples contained approximately 500 g.

Chemical analyses

The samples were pre-dried using an oven with forced air circulation at 65 °C for 72 hours and placed in paper bags. Then, the samples were dried in an oven with forced air circulation at 105 °C degrees for 16 hours, and analyzed for their chemical composition. Chemical analysis of the concentrate was performed according to the AOAC (1995) for dry matter (DM; method n° 930.15), crude protein (CP; method n° 984.13), mineral matter (MM; method n° 42.05), and ether extract (EE; method n° 920.39). Acid detergent fiber (ADF) was analyzed following the AOAC (1990) method n° 973.18. Neutral detergent fiber (NDF) was analyzed with sodium sulfite and heat-stable alpha-amylase according to Van Soest et al., 1991. Lignin (LIG) was determined from the residue of the acid cleaner by using potassium permanganate as cited by Silva (1998). The cellulose (CEL) content was calculated by the equation CEL = ADF – lignin, hemicellulose (HEM) content was calculated by the equation HEM = NDF – ADF, and nitrogen-free extract (NFE) was calculated by the equation NFE = 100 – (CF+EE+CP+MM). The total digestible nutrients (TDN) were obtained according to Kearl (1982). Total carbohydrates (CHT) were calculated by the equation CHT = 100-(CP+EE+MM) as proposed by Hall (1997).In vitro dry matter digestibility (IVDDM) was determined using the two-stage procedure of "Tilley-Terry" (using 0.5 g dry samples and 10 mL of ruminal fluid) as described by Campos et al. (2004).

Statistical analyses

The experimental design was a randomized block, in a strip-split-plot with four replicates, in a trapezoidal model totaling 240 experimental units. Due to non-randomization of the sub-subplots, the results were adjusted by the model: $y = a * x^b$, selected for being the closest to the biological behavior of cassava production, where y is transformed variable, a and b are the power fit coefficients and x the original variable, in this case plant density. After the adjustment, all data were subjected to analysis of variance using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). First, the contrast between the control (no fertilizer) and fertilized treatments was performed, followed by the contrast between chemical and organic fertilizers. Afterwards, a new analysis of variance was performed without including the organic fertilization treatment. On this second analysis, cultivars means were compared trough Student's t test at 5% probability. Fertilization rates and plant densities were submitted to regression analysis.

RESULTS AND DISCUSSION

The cassava aerial part used in animal feed can be defined as the last third of the plant, including stems and leaves, and its composition depends on plant age, cultivar, fertilization, and environment (CAMPOS NETO et al., 1995). Leonel (2002) described that the chemical composition and nutritional value of the aerial part were influenced by the harvest season. As a result of some of his experiments, the best harvest season is obtained from plants aged 12 to 18 months, and even so, there is variation among cultivars.

Differences among cassava cultivars were found for CP, EE, NFE, MM, TDN, ADF, NDF, CEL, LIG, IVDDM, CHT, DM and $DM.ha^{-1}$ ($P< 0.05$, Table 1). Among the fertilization rates, there were differences in NFE, MM, TDN, ADF, CEL, LIG, IVDDM, CHT, DM, and $DM.ha^{-1}$ in the aerial part samples ($P<0.05$, Table 2). Mineral matter ($P<0.05$) and $DM.ha^{-1}$ ($P<0.01$) increased linearly, whereas total DM decreased linearly ($P<0.01$) in the aerial parts as fertilization rates increased (Table 3).

In this study with cassava cultivars (CASCUDA, IAC14, IAC15 and IAC90) in different densities and fertilization rates, the IAC14 cultivar had the greatest productivity ($DM.ha^{-1}$), and the greatest values of DM, CHT, CEL, NDF, ADF, and LIG. Increasing fiber components and lignin resulted in reduced IVDDM and TDN. The cultivar with the greatest IVDDM and TDN was IAC90, but it also presented lower production rates ($DM.ha^{-1}$). The CASCUDA and IAC15 cultivars had greater CP and EE. The ratio between the production of $DM.ha^{-1}$ and TDN were 3.64, 2.83, 1.6, and 1.44 $NDT.ha^{-1}$ for the IAC14, IAC15, IAC90, and CASCUDA cultivar, respectively.

Modesto et al. (2002) studied the chemical composition of five cassava cultivars leaves in different harvest times, and found that earlier harvest (at 12 months) promoted greater digestibility of the cell wall (90%) due to the decreased lignification of leaves. The leaves showed decreased digestibility of 77%, as well as decreased CP content when harvested at 21 months of age. In the present experiment, all of the cassava cultivars were harvested at 12 months of age and showed satisfactory average values for IVDDM (54.90, 52.24, 51.24, and 44.12% for IAC90, IAC15, CASCUDA, and IAC14, respectively).

Table 1 - Values expressed as percentage of crude protein (CP), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare (DM.ha^{-1}) for aerial part and cuttings samples after harvest due to cultivars treatment.

Cultivar	**CP**	**EE**	**NFE**	**MM**	**TDN**	**ADF**	**NDF**	**CEL**	**LIG**	**IVDDM**	**CHT**	**HEM**	**DM**	**DM.ha^{-1}**
							Aerial part							
							%							**t ha^{-1}**
CASCUDA	8.62^{a}	0.89^{ab}	49.68^{b}	5.27^{a}	59.29^{b}	47.12^{b}	65.82^{b}	28.92^{c}	18.40^{a}	51.24^{b}	85.23^{c}	18.63	29.07^{b}	2.44^{d}
IAC14	5.70^{d}	0.82^{bc}	47.23^{c}	3.61^{d}	56.72^{c}	51.93^{a}	71.90^{a}	34.11^{a}	17.93^{a}	44.12^{c}	89.87^{a}	19.93	34.13^{a}	6.42^{a}
IAC15	8.11^{b}	0.97^{a}	49.71^{b}	4.33^{c}	59.00^{b}	46.52^{b}	65.56^{b}	30.06^{b}	16.40^{b}	52.24^{b}	86.60^{b}	19.01	29.80^{b}	4.80^{b}
IAC90	7.53^{c}	0.77^{c}	52.97^{a}	4.89^{b}	60.52^{a}	44.92^{c}	64.49^{b}	29.61^{b}c	15.45^{c}	54.90^{a}	86.81^{b}	19.56	27.23^{c}	2.78^{c}
SEM	0.085	0.018	0.0207	0.047	0.0398	0.260	0.326	0.186	0.143	0.359	0.122	0.240	0.214	0.125
Probability	<0.0001	0.0205	0.0005	<0.0001	0.0049	0.0031	0.0050	0.0001	0.0170	0.0003	<0.0001	0.4901	<0.0001	<0.0001
							Cuttings							
							%							**t ha^{-1}**
CASCUDA	9.35^{b}	0.73	52.62^{b}	4.67^{a}	60.70^{b}	43.19^{b}	63.47^{bc}	27.57^{bc}	14.85^{b}	52.18^{b}	85.25^{c}	20.27^{c}	37.97^{b}	1.47^{d}
IAC14	7.26^{c}	0.64	48.18^{c}	4.02^{bc}	57.39^{c}	49.87^{a}	72.09^{a}	33.25^{a}	15.84^{a}	44.17^{c}	88.08^{a}	22.23^{a}b	39.85^{a}	1.94^{b}
IAC15	9.62^{a}	0.67	54.23^{a}	3.82^{c}	61.69^{a}	40.66^{c}	61.50^{c}	26.80^{c}	13.12^{c}	54.41^{a}	85.90^{b}	20.84^{b}c	37.82^{b}	2.59^{a}
IAC90	9.17^{b}	0.71	53.46^{ab}	4.23^{b}	61.08^{b}	41.39^{c}	65.30^{b}	27.98^{b}	12.85^{c}	54.44^{a}	85.89^{b}	23.91^{a}	37.15^{c}	1.78^{c}
SEM	0.075	0.017	0.225	0.044	0.144	0.311	0.447	0.227	0.107	0.378	0.097	0.341	0.137	0.039
Probability	<0.0001	0.7658	<0.0001	<0.0001	<0.0001	<0.0001	0.0037	<0.0001	<0.0001	<0.0001	<0.0001	0.2257	0.0026	<0.0001

Table 2 - Values expressed as percentage of crude protein (CP), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for aerial part and cuttings samples after harvest due to fertilization treatment.

Fertilization	**CP**	**EE**	**NFE**	**MM**	**TDN**	**ADF**	**NDF**	**CEL**	**LIG**	**IVDDM**	**CHT**	**HEM**	**DM**	**$DM.ha^{-1}$**
							Areal part							
							%							**$t\ ha^{-1}$**
0	7.41	0.83	49.98^{abc}	4.38^{b}	58.85^{ab}	48.17^{a}	67.42	30.95^{a}	17.45^{a}	50.13^{b}	87.39^{a}	19.21	30.57^{a}	3.87^{bc}
150 kg ha^{-1} (4-20-20)	7.55	0.86	50.49^{ab}	4.58^{a}	59.04^{ab}	47.18^{ab}	66.83	30.09^{b}	17.05^{ab}	51.10^{ab}	87.01^{b}	19.63	30.70^{a}	3.70^{c}
450 kg ha^{-1} (4-20-20)	7.48	0.90	49.50^{c}	4.55^{a}	59.15^{ab}	47.49^{ab}	66.65	30.83^{ab}	16.76^{b}	50.58^{b}	87.07^{ab}	19.07	30.20^{ab}	4.16^{ab}
900 kg ha^{-1} (4-20-20)	7.53	0.85	49.60^{bc}	4.59^{a}	58.50^{b}	47.65^{ab}	66.88	30.84^{ab}	16.94^{ab}	50.70^{ab}	87.04^{b}	19.21	29.49^{bc}	4.43^{a}
3,000 kg ha^{-1} (poultry litter)	7.46	0.89	50.78^{a}	4.53^{ab}	59.37^{a}	47.03^{b}	66.04	30.27^{ab}	16.72^{b}	52.12^{a}	87.13^{ab}	19.01	29.34^{c}	4.32^{a}
SEM	0.081	0.018	0.208	0.047	0.398	0.260	0.326	0.185	0.143	0.359	0.122	0.240	0.214	0.125
Probability	0.8792	0.7755	0.0918	0.0977	0.2530	0.4292	0.5866	0.1666	0.2673	0.1458	0.3257	0.8999	0.0037	0.0008
							Cuttings							
							%							**$t\ ha^{-1}$**
0 (control)	8.69^{b}	0.70^{a}	53.08^{a}	4.08	60.68^{a}	42.69^{c}	65.06	28.08^{c}	13.96^{b}	51.73^{a}	86.55^{a}	22.38	38.58^{a}	1.94^{b}
150 kg ha^{-1} (4-20-20)	8.75^{b}	0.66^{ab}	51.85^{bc}	4.13	59.94^{b}	44.53^{ab}	65.99	29.41^{ab}	14.36^{a}	51.48^{ab}	86.45^{a}	21.46	38.17^{ab}	1.89^{b}
450 kg ha^{-1} (4-20-20)	9.07^{a}	0.72^{a}	52.15^{abc}	4.32	60.37^{ab}	42.89^{c}	65.01	28.21^{c}	14.03^{ab}	52.02^{a}	85.89^{b}	22.11	38.25^{ab}	1.99^{b}
900 kg ha^{-1} (4-20-20)	8.88^{ab}	0.67^{ab}	51.42^{c}	4.22	59.87^{b}	45.00^{a}	66.30	29.89^{a}	14.32^{ab}	49.97^{b}	86.23^{ab}	21.30	38.80^{b}	1.96^{b}
3,000 kg ha^{-1} (poultry litter)	8.70^{b}	0.59^{b}	52.65^{ab}	4.26	60.28^{ab}	43.54^{bc}	65.26	28.71^{bc}	13.96^{ab}	51.80^{a}	86.46^{a}	21.71	38.45^{a}	2.14^{a}
SEM	0.075	0.017	0.225	0.044	0.144	0.311	0.447	0.227	0.107	0.378	0.097	0.341	0.137	0.039
Probability	0.0050	0.2431	0.0139	0.2048	0.0630	0.0060	0.6367	0.0030	0.3552	0.0129	0.0029	0.8603	0.0196	0.0042

Table 3 - Values expressed as percentage of crude protein (CP), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for aerial part samples after harvest due to chemical fertilization.

	CP	**EE**	**NFE**	**MM**	**TDN**	**ADF**	**NDF**	**CEL**	**LIG**	**IVDDM**	**CHT**	**HEM**	**DM**	**$DM.ha^{-1}$**
Fertilization						**%**								**$t\ ha^{-1}$**
0 (control)	7.40	0.83	49.98	4.38	58.85	48.17	67.42	30.95	17.45	50.13	87.39	19.22	30.60	3.87
150 $kg\ ha^{-1}$ (4-20-20)	7.55	0.86	50.50	4.58	59.04	47.18	66.83	30.09	17.05	51.10	87.01	19.63	30.70	3.71
450 $kg\ ha^{-1}$ (4-20-20)	7.49	0.90	49.50	4.55	59.15	47.49	66.65	30.83	16.76	50.58	87.07	19.08	30.20	4.16
900 $kg\ ha^{-1}$ (4-20-20)	7.53	0.85	49.60	4.59	58.50	47.65	66.88	30.84	16.94	50.70	87.04	19.21	29.43	4.43
SEM	0.093	0.019	0.232	0.053	0.492	0.296	0.374	0.216	0.156	0.408	0.140	0.278	0.236	0.148
Probability														
Linear	0.621	0.693	0.174	0.044*	0.263	0.743	0.585	0.547	0.165	0.745	0.213	0.747	0.002**	0.0007**
Quadratic	0.741	0.210	0.753	0.166	0.137	0.294	0.406	0.534	0.121	0.589	0.259	0.948	0.509	0.775

Regression equations		**R^2**
MM	$Y = 0.0002X_A + 4.4631$	0.45*
DM	$Y = -0.0014 X_A + 30.762$	0.94**
$DM.ha^{-1}$	$Y = 0.0007 X_A + 3.7633$	0.87**

** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

Y = correspondent variable; X_A = fertilization rate

Wanapat et al. (1997) showed the viability of using the cassava aerial part as good quality forage for ruminants due to its availability during the dry season of the year, which is the most critical in terms of pasture availability. The main advantage, according to the authors, is related to production of 20,400 kg ha^{-1} (fresh) or 10,200 kg/ha (dried) from the first cut after three months planted and estimated combined yield of second and third cut of 40,820 kg ha^{-1} (fresh) or 20,400 kg/ha (dried) or 5,102 kg crude protein/ha. According to Vidigal Filho et al. (2000), cultivars IAC12, IAC13, and IAC14 can produce 11.91 to 31.65 $t.ha^{-1}$ of the aerial part, and can reach a height of up to 2.47 m. In the current experiment, the cultivar with the greatest production rates was IAC14 (6,420 kg ha^{-1}), however, it was also the one with the lowest protein content. From all of the studied cultivars, IAC15 showed the highest protein production, followed by IAC14, CASCUDA, IAC90 (389.28, 365.94, 210.32 and 209.33 kg of $protein.ha^{-1}$, respectively).

Wanapat et al. (1997) aimed to study cassava cultivars with high aerial part production for use in animal feeding in Thailand, and they reported greater values of protein content in comparison to those observed in the current experiment (24.9 vs. 7.49% CP in the DM, respectively). It is important to mention that the cultivars used in the current experiment were selected for root production, therefore the harvest was done when the plants showed a small amount of leaves and theoretically the maximum starch accumulation in roots, which explains their decreased nutrient concentrations in the aerial part. The cassava crops produced for animal feeding purposes are harvested when the plants have maximum quantity of leaves, which explains the greater protein accumulation in the aerial part reported by Wanapat et al. (1997).

In most of the research involving the use of the cassava aerial part for ruminant feeding, the last third part of the plant is used, due to the larger amounts of leaves and smaller amounts of stems, and consequently it also has greater concentrations of protein and greater digestibility. According to Leonel (2002), the cassava aerial part has high nutritional value and favorable acceptability by the animals, and its nutritional value can vary due to the ratio between leaves and stems, in which plants containing greater amount of leaves provide greater nutritional value to the animal feed. Even so, the aerial part shows satisfactory chemical composition as forage, with the following values of nutrient amounts: 25.95% DM, 14.99% CP, 42.53% NDF, and 2.66% of EE for the fresh aerial part. In the current study, the composition of the whole aerial part was analyzed, showing values of 30.06% DM, 7.49% CP, NDF 66.76%, and 0.87% of EE. Thus, due to the lower percentage of CP and greater NDF, it can be concluded that the material sampled had proportionally greater amount of stems than leaves. This was expected because the whole plant was used, and not only the last third of the cassava aerial part.

Modesto et al. (2004) performed chemical analyses in the silage from the last third of the cassava aerial part and concluded that it has good nutritional qualities, with adequate protein levels, moderate NDF content (50.75%), satisfactory fractions of non-protein nitrogen and acid detergent insoluble protein. Moreover, the authors observed high lignin content and low tannin, which suggests the need for further studies on the use of this silage for animal feeding. It has been demonstrated that the condensed tannins contained in cassava foliage hay have an important role as a tannin-protein complex to increase protein bypass in the rumen and to reduce nematode egg counts in the gastrointestinal tract (WANAPAT, 2003). Branco et al. (2006), when evaluating protein digestibility of various feedstuffs, reported that cassava foliage silage showed high ruminal degradation (50.51%) and low true intestinal digestibility (39.94%) when compared with other roughages.

Wanapat et al. (1997) described a digestibility of 71% DM of the cassava hay, and the experiment was conducted and analyzed with plants up to three months of age. In the current experiment, average values of 50.94% for IVDDM were observed, but the plants were harvested at 12 months of age and had high lignin percentages (average of 16.98%). Oni et al. (2011) studied the nutritional value of the leaves from four cultivars of cassava in Nigeria and observed average values of 17.7 to 24.0% CP, 59.6 to 66.2% NDF, 41.8 to 54.6% ADF, and 58.5 to 86.7% DM. Those authors also observed in vitro total volatile fatty acids production of up to 50.5 mL/200mg DM, demonstrating that the cassava aerial part can be used as a supplement for ruminants fed poor quality roughages.

There was a slight variation in nutrients of the cassava aerial part due to different fertilization levels. The results showed that treatments with higher values of $DM.ha^{-1}$, IVDDM, and lower lignin percentage were associated with the highest mineral fertilizer level (900 $kg.ha^{-1}$) and with poultry litter (Table 2). According to Souza and Fialho (2003), cassava plants present satisfactory response to the application of organic fertilizers (manure, cakes, organic compounds, green manure, etc), which should be preferred as nitrogen sources over inorganic fertilizers.

Crude Protein, NFE, MM, CEL, and $DM.ha^{-1}$ from the cassava aerial part showed quadratic responses to planting densities ($P<0.05$). Dry matter increased linearly as plant density per hectare was increased ($P<0.05$, Table 4). The regression equations are presented in Table 4 with their respective R^2.

Regarding the chemical fertilizer levels, a linear increase in the amount of mineral matter and $DM.ha^{-1}$, as well as a linear decrease in DM were observed due to the increase in the fertilizer levels. Thus, it is possible to observe that the greatest fertilization level produced a greater amount of material available to be used as ruminant feed. It was also observed that as the plant density per hectare was increased, an increase in the production of dry matter was observed, with an average value of 810 kg $DM.ha^{-1}$ (Table 3).

Souza and Fialho (2003) reported that the spacing of the cassava depends on soil fertility, size of cultivar, aim of production (roots or foliage), management practices, and harvesting type (manual or mechanized). In the current study, the largest production of $DM.ha^{-1}$ is related to treatments with a higher level of chemical fertilizer (900 kg ha^{-1}), organic fertilization by poultry litter, and higher density of plants per ha (17,500). The cassava absorbs large amounts of nutrients and exports most of what is absorbed, with only small amounts of nutrients returning to the soil through crop residue. As examples of nutrient export, the tuberous roots are used for flour production, starch, and other products for human and animal consumption; the aerial part (leaves and cuttings) is used for new plantings, and human and animal nutrition (SOUZA & FIALHO, 2003).

The IAC15 cultivar showed greater production of cuttings (DM.ha^{-1}), greater values of IVDDM, NFE, and CP, with greater percentage of TDN and lower percentage of lignin (Table 1). However, the cultivar IAC14 had greater amounts of CHT due to the higher levels of structural carbohydrates (NDF, ADF, and cellulose) and lignin in comparison the other cultivars. There were differences among the cassava cultivars on CP, NFE, MM, TDN, ADF, NDF, CEL, LIG, IVDDM, CHT, HEM, DM, and DM.ha^{-1} for cuttings samples ($P<0.05$, Table 1).

In addition, the fertilization level also affected CP, EE, NFE, TDN, ADF, CEL, LIG, IVDDM, CHT, DM, and DM.ha^{-1} of the cassava cuttings ($P<0.05$, Table 2). Nitrogen-free extract ($P<0.01$) and DM ($P<0.05$) decreased linearly, whereas ADF ($P<0.05$) and CEL ($P<0.01$) increased linearly with the increase of the fertilization level. The levels of CP ($P<0.01$), IVDDM ($P<0.05$), and CHT ($P<0.01$) showed a quadratic response to the fertilization levels (Table 5). There was a linear increase on TDN and amount of DM.ha^{-1} ($P<0.05$), whereas there was a linear decrease on DM content ($P<0.01$) as plant density per hectare was increased (Table 6). The regression equations are presented in Table 6 with their respective R^2.

The fertilization rates had minor effects on the nutrient amounts of the cuttings samples, as observed for the aerial part. The treatments with 450 kg ha^{-1} showed the highest values of CP and IVDDM, but not the greatest DM yield ha^{-1}. However, fertilization with poultry litter promoted the highest values for DM.ha^{-1} and CP.ha^{-1}, even though the values of CP were not the greatest for this treatment. With the increase in chemical fertilization, there was an increase in the amount of protein and structural carbohydrates (cellulose and ADF), and a decrease in the percentages of NFE from cuttings samples (Table 5). The increase in the plant densities increased the concentration of nutrients in the cuttings, as well as the DM yield per ha (Table 6).

The results of CP in this study are noteworthy. The cuttings showed greater average values of CP (8.82%) than the aerial part. The cassava root is classified as an energetic ingredient because of its high energy and low protein concentrations (CARVALHO, 1994). Cuttings showed low concentrations of nutrients, but they were very similar to ground corn for CP and slightly lower for other nutrients. Valadares Filho et al. (2006) reported that ground corn has an average of 8.50% CP, 75.40% NFE, 7.83% NDF, and 64.70% IVDDM. Cuttings from the cultivars evaluated in the present study had an average of 8.82% CP, 52.23% NFE, 65.53% NDF and 51.40% IVDDM (Table 1).

In terms of composition and amount produced, it is not possible to effectively compare the ingredients studied in this work with others commercially produced and used for ruminant feeding. However, it is evident that the cassava root residue, either the shoots or the cuttings, have considerable nutrient amounts and satisfactory digestibility, and can be included as an ingredient in the diet of ruminants on small farms.

The cassava aerial part can be fed to ruminants in fresh, hay, or silage forms, depending on its variety. Cultivars with low content of hydrocyanic acid can be chopped and offered directly to the ruminants, whereas cultivars with high content of hydrocyanic acid should be dried for at least 24 hours, to reduce the level of hydrocyanic acid to non-toxic levels to animals (CAMPOS NETO et al., 1995). Another recommendation of use for the cassava aerial part would be as a mixture with 50% of other roughage for feeding ruminants and with 80% concentrate for feeding monogastric animals (CARVALHO, 1994).

The utilization of the aerial part of cassava as hay or silage for animal feeding has been studied by several authors, who suggest that it should be offered in combination with other ingredients to supply nutrients to the animals, especially for categories with lower nutritional requirements (DUNG et al. 2005; EUCLIDES et al., 1988; PHENGVICHITH & LEDIN, 2006; THANG et al., 2010).

Wanapat (2003) reported that hay from the cassava aerial part is an excellent source of many nutrients for animal nutrition, especially for dairy cattle during the long dry season, and has the potential to increase the productivity and profitability of sustainable livestock production systems in the tropics.

CONCLUSION

The residues of foliage and cuttings derived from cassava root production have nutrients that may be used for ruminant feeding, but the nutritional value is not the same as that of cassava produced for the specific purpose of animal feeding. The cultivars used for animal feeding have greater quality and amount of nutrients than that provided by cassava used for root production.

Cassava for root residue production, composed by foliage and cuttings, have considerable amounts of nutrients that can be used for livestock feeding on small farms and for animal categories with low nutritional requirement. From all studied treatments, the cultivar IAC15, chemically fertilized with 900 kg.ha^{-1}, as well as fertilization with poultry litter, and the highest plant density, showed the best nutritional composition and greater amount of available nutrients.

Table 4 - Values expressed as percentage of crude protein (CP), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for aerial part samples after harvest due to plant density.

	CP	**EE**	**NFE**	**MM**	**TDN**	**ADF**	**NDF**	**CEL**	**LIG**	**IVDDM**	**CHT**	**HEM**	**DM**	**$DM.ha^{-1}$**
Plant Density (D)								**%**						**t ha^{-1}**
7,500 $plants.ha^{-1}$	7.56	0.85	49.58	4.47	58.63	48.01	66.97	31.05	17.04	49.93	87.11	18.93	30.72	3.77
12,500 $plants.ha^{-1}$	7.30	0.83	50.49	4.60	59.11	47.14	66.93	30.14	17.03	51.28	87.27	19.76	29.98	3.77
17,500 $plants.ha^{-1}$	7.61	0.90	49.62	4.50	58.91	47.72	66.93	30.84	17.07	50.66	86.99	19.15	30.02	4.58
SEM	0.081	0.018	0.207	0.047	0.398	0.260	0.326	0.185	0.143	0.359	0.122	0.240	0.214	0.125
Probability														
Linear	0.689	0.282	0.927	0.649	0.402	0.559	0.946	0.566	0.904	0.234	0.445	0.748	0.036*	<0.001**
Quadratic	0.003*	0.204	0.012*	0.040*	0.230	0.092	0.979	0.009*	0.885	0.066	0.123	0.214	0.167	0.003*

Regression equations		**R^2**
CP	$Y = 1.14E\text{-}08\ X_B^2 - 0.003X_B + 9.0188$	1.00**
NFE	$Y = -3.56E\text{-}08\ X_B^2 - 0.0009X_B + 44.8775$	1.00**
MM	$Y = -1.36E\text{-}08\ X_B^2 - 0.004X_B + 56.6350$	1.00**
CEL	$Y = 3.224E\text{-}08\ X_B^2 - 0.0008X_B + 35.4338$	1.00**
DM	$Y = -7E\text{-}05\ X_B + 31.099$	0.71*
$DM.ha^{-1}$	$Y = 8E\text{-}05\ X_B + 3.0242$	0.74*

** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

Y = correspondent variable; X_B = plant density

Table 5 - Values expressed as percentage of crude protein (CP), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for cuttings samples after harvest due to chemical fertilization.

	CP	**EE**	**NFE**	**MM**	**TDN**	**ADF**	**NDF**	**CEL**	**LIG**	**IVDDM**	**CHT**	**HEM**	**DM**	**$DM.ha^{-1}$**
Fertilization						**%**								**$t\ ha^{-1}$**
0	8.69	0.70	53.08	4.08	60.68	42.69	65.06	28.08	13.96	51.73	86.55	22.38	38.56	1.94
150 kg ha^{-1} (4-20-20)	8.75	0.66	51.85	4.13	59.94	44.53	65.99	29.41	14.36	51.48	86.45	21.46	38.17	1.89
450 kg ha^{-1} (4-20-20)	9.08	0.72	52.15	4.32	60.37	42.89	65.01	28.21	14.03	52.02	85.89	22.11	38.25	1.99
900 kg ha^{-1} (4-20-20)	8.89	0.67	51.42	4.22	59.87	45.00	66.30	29.89	14.32	49.97	86.23	21.30	37.90	1.96
SEM	0.083	0.020	0.258	0.046	0.166	0.360	0.506	0.262	0.123	0.444	0.105	0.383	0.160	0.044
Probability														
Linear	0.024*	0.843	0.006**	0.072	0.059	0.010*	0.418	0.007**	0.361	0.006**	0.027*	0.514	0.052*	0.412
Quadratic	0.004**	0.606	0.485	0.059	0.885	0.304	0.621	0.237	0.882	0.046*	0.004**	0.931	0.975	0.643

Regression equations		**R^2**
CP	$Y = -1E\text{-}05X_F^2 + 0.0144\ X_F + 86.477$	0.88**
NFE	$Y = -0.0014\ X_F + 52.652$	0.63**
ADF	$Y = 0.0017\ X_F + 43.132$	0.35*
CEL	$Y = 0.0014\ X_F + 28.373$	0.39*
IVDDM	$Y = -5E\text{-}06\ X_F^{2} + 0.003\ X_F + 51.523$	0.91**
CHT	$Y = 2E\text{-}06\ X_F^{2} - 0.0025\ X_F + 86.629$	0.87**
DM	$Y = -0.0007\ X_F + 38.46$	0.81*

** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

Y = correspondent variable; X_F = fertilization rate

Table 6 - Values expressed as percentage of crude protein (CP), ether extract (EE), nitrogen-free extract (NFE), mineral matter (MM), total digestible nutrients (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CEL), lignin (LIG), in vitro digestibility of dry matter (IVDDM), total carbohydrates (CHT), hemicellulose (HEM), dry matter (DM) and dry matter per hectare ($DM.ha^{-1}$) for cuttings samples after harvest due to plant density.

	CP	EE	NFE	MM	TDN	ADF	NDF	CEL	LIG	IVDDM	CHT	HEM	DM	$DM.ha^{-1}$
Plant Density						%								**t ha^{-1}**
7,500 $plants.ha^{-1}$	8.85	0.69	51.67	4.11	59.88	44.01	66.23	29.15	14.10	51.01	86.35	22.27	38.51	1.63
12,500 $plants.ha^{-1}$	8.89	0.63	52.32	4.19	60.30	43.71	65.36	28.85	14.21	51.56	86.29	21.65	38.28	1.89
17,500 $plants.ha^{-1}$	8.81	0.75	52.38	4.25	60.47	43.62	65.18	28.69	14.20	51.32	86.19	21.56	37.81	2.31
SEM	0.074	0.017	0.225	0.044	0.145	0.311	0.447	0.227	0.107	0.379	0.096	0.341	0.137	0.039
Probability														
Linear	0.644	0.197	0.112	0.179	0.013*	0.464	0.256	0.255	0.593	0.708	0.345	0.415	0.009**	<0.0001*
Quadratic	0.488	0.067	0.451	0.895	0.564	0.822	0.667	0.837	0.711	0.577	0.912	0.732	0.594	0.078

Regression equations		R^2
TDN	$Y = 6E\text{-}05\ X_D + 59.479$	0.94*
DM	$Y = -7E\text{-}05\ X_D + 39.075$	0.96**
$DM.ha^{-1}$	$Y = 7E\text{-}05\ X_D + 1.0933$	0.98**

** and * = statistical significance determined by probability of 0.01 and 0.05, respectively

Y = correspondent variable; X_D = plant density

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