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PEJIBAYE HEART-OF-PALM RESIDUE SILAGE AS AN OPTION FOR RUMINANTS ROUGHAGE

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Abstract

It was aimed in this study to evaluate the ensiled pejibaye residue in the feeding of ruminants as roughage. For the *in vitro* digestibility assay, a randomized block design was used, with four treatments (pejibaye residue without additives; pejibaye residue + banana residue; pejibaye residue + rice residue and pejibaye residue + citrus pulp), with four replications. The variables studied were: chemical composition, specific mass, pH, average particle size, fermentation temperature and fermentative losses. Apparent digestibility was performed with sheep in a completely randomized design, to evaluate the same treatments mentioned above, using five replications. Heart-of-palm pejibaye residue silages showed average particle size, pH and density values within the range appropriate for their manufacture. Among the additives used in this study, silage with 15 g/100g of rice provided improvements in several nutritional parameters, such as DM, NDF, ADF, CF and NDF/NFC. High moisture content impairs the ensiling process, but it was solved with high dry matter content ingredients addition to promote the material stability.

Keywords

Bactris gasipaes, digestibility, animal nutrition, sustainability.

ENSILAGEM DE RESÍDUOS DE PALMITO DE PUPUNHA COMO OPÇÃO DE FORRAGEM PARA RUMINANTES

Resumo

Objetivou-se com este estudo avaliar o resíduo de pupunha ensilada na alimentação de ruminantes como volumoso. Para o ensaio de digestibilidade *in vitro*, foi utilizado o delineamento em blocos casualizados, com quatro tratamentos (resíduo de pupunha sem aditivos; resíduo de pupunha + resíduo de banana; resíduo de pupunha + resíduo de arroz e resíduo de pupunha + polpa cítrica), com quatro repetições. As variáveis estudadas foram: composição bromatológica, massa específica, pH, tamanho médio de partícula, temperatura de fermentação e perdas fermentativas. A digestibilidade aparente foi realizada com ovinos em delineamento inteiramente casualizado, para avaliar os quatro tratamentos mencionados acima, usando cinco repetições. As silagens apresentaram valores adequados para matéria seca, fibra em detergente neutro, fibra em detergente ácido, proteína bruta e fibra em detergente neutro/carboidratos não fibrosos. Os resultados obtidos demonstram a eficiência do uso de silagens de resíduo de pupunha como volumoso na alimentação de ruminantes, o que pode servir como ferramenta para a sustentabilidade da cadeia de produção de pupunha e animal nas regiões onde os negócios coexistem.

Palavras-chave

Bactris gasipaes, *Bubalus bubalis*, digestibilidade, nutrição animal, sustentabilidade.

INTRODUCTION

Pejibaye (*Bactris gasipaes*) Khunt is a palm widely cultivated in Brazil for the production of heart-of-palm and flour for human consumption, mainly in the States of Bahia, Espírito Santo, Rio de Janeiro, São Paulo, Santa Catarina and Paraná (OLIVEIRA et al., 2010). This species presents advantages over other palms, such as cutting earliness, genetic plasticity, abundant tillering, good palatability of its fruit, absence of oxidation of the heart-of-palm produced (browning) and high yield (OLIVEIRA et al., 2010).

The heart-of-palm is enveloped by husks (sheaths), which are not utilized industrially, being discarded, generating a large amount of residues (OLIVEIRA et al., 2010), and which has a high variation in its composition, not presenting, therefore, a defined pattern. However, it can become a by-product (or co-product), being fundamental in reducing animal production costs, among other benefits as an alternative to minimize the negative environmental impacts generated by disposal in the environment (SILVA et al., 2014).

The pejibaye residue possesses nutritional value that gives its potential use in the ruminants feeding with the possibility to reduce the production costs. However, there are few studies about the use of this agro-industrial residue and the levels to be used, digestive behavior or on the silage fermentation, to be able to incorporate them in animal production (OLIVEIRA et al., 2010; PAULA and FARIA JÚNIOR, 2019).

Therefore, despite variable nutritional value of this residue which change because of industries process, fruit quality, differences residues constitution and especially, husks seeds relation, it should be considered as an alternative ingredient (PENTEADO JÚNIOR et al., 2014).

The pejibaye residue has a large amount of water, which causes its early deterioration, and thus, for better conservation, ensilaging is proposed as an alternative to maintain the amount of dry matter and soluble carbohydrates. (PAULA and FARIA JÚNIOR, 2019). But, ensiled pejibaye residue with additives may be a cheap supplementation solution in times of drought for ruminants (OLIVEIRA et al., 2010).

Additives can be included to stimulate fermentation, adding nutrients and absorbing moisture, preventing aerobic deterioration, making ensiling process efficient. For that, the additives must be available and easy to acquire, manipulate, inexpensive, absorbent and assist in reducing effluent production, improving the nutritional value of silages (PAULA and FARIA JÚNIOR, 2019).

Additive moisture-holding capacity may vary according its chemical composition and higher lignification degrees improve moisture-holding capacity, but also reduce the silage nutritional value (McDONALD et al., 1991), on the other hand, nutritional additives, when added to the ensiled material, improve nutrients supply to meet the animal needs, improving the fermentation process by greater original material quality maintenance and, consequently, silage nutritional value (SCHMIDT et al, 2014).

The additives choice happened because considerable volumes of residues are produced where the experiment was carried out, and they are already used in animal feeding, such as pejibaye, rice processing (unrated rice) by-products and whole banana bunches of Nanicão variety, as small green bunches, commercially unaccepted. The citrus pulp was used as a standard of silage-improving additive that contains ingredients with a high moisture content.

In view of the above exposed, it was intended by this study to evaluate the fermentative parameters, chemical composition, *in vitro* digestibility and apparent digestibility of pejibaye residue silages with or without the inclusion of rice bran, banana residue and citrus pulp as silage additives.

MATERIAL AND METHODS

The experiment was conducted in Vale do Ribeira Regional Pole, Registro - SP and Animal Science Institute, Nova Odessa – SP, both part of the São Paulo Agribusiness Technology Agency (APTA).

The agro-industrial residue from the extraction of pejibaye heart-of-palm, constituted by the sheath (Table 1), was provided by Agroindustry Palmitos Selva SA, in Registro city, São Paulo.

Table 1 - Chemical-bromatological (g/kg) composition of the pejibaye residue (*Bactris gasipaes*)

Resíduos da pupunha	DM[1]	CP[2]	CF[3]	EE[4]	NNE[5]	ASH[6]	TDN[7]	NDF[8]
	129.6	93.1	375.3	11,8	441.9	78.1	578.3	600.0

[1]Dry matter; [2]Crude protein; [3]Fibrous carbohydrate; [4]Ether extract; [5]Non-nitrogenous extract; [7]Total digestible nutrients; [8]Neutral detergent fiber.

The additives used were banana bunches collected in the experimental area belonging to the Ribeira Valley Pole; rice residue donated by Pariquera-Açú rice-processing company rice, located at Regis Bittencourt Highway, Km 462 (southbound), SP; and citrus pulp acquired from the COALMA Company - Com. Prod. for Animal Nutrition, Paulínia, SP.

The material was ground in a stationary forage grinder regulated to generate particles with an approximate of 20 mm, according to the methodology proposed by Lammers et al. (1996). Three sieves with 38, 19 and 08 mm mesh were used. The tare weights of the screens and bottoms were written down. A 250 g fresh material of the silages sample was placed in the upper sieve, on a flat surface, and vigorously shaken in eight series of five shakes, amounting to 40 movements. Subsequently, the weight of each sieve was recorded with the retained material and, with a ruler; the average size of the particles retained in the sieves was obtained.

The silages were made in experimental silos (barrels) with 60 liters capacity with lids that have locks to ensure sealing. At the barrels bottom, 6 kg of dried sand were deposited and covered with a thin-meshed plastic screen and two layers of cotton fabric to avoid direct contact between dry sand and the ensiled material and to allow draining the effluent into the sand, making possible to quantify it by the weight difference, before and after opening the experimental silo. Each barrel was drilled in the center of its respective lid and received a plastic pipe (model adopted in irrigation systems), forming a *Bunsen*-type valve, for gas escape during storage.

The material was compacted in the silos by trampling, trying to reach a specific mass of 600 kg/m^3. The lid + barrel + sand + cloth + screen set was weighed at the beginning and after the pejibaye residue was introduced into as their respective treatments. After 90 days of storage, the silos were again weighed and opened. The losses of dry matter, in the form of gases in dry matter (DM) and effluents (kg/t) as fed basis were quantified gravimetrically, according to the methodology described by Schmidt et al. (2010).

The experimental design was in randomized blocks with four treatments and four replications, considering each silo as an experimental unit, where the silages were made according to the following treatments: pejibaye residue without additives (P); pejibaye residue with 150 g/kg of the whole dwarf banana residue (bunches); (P+B); pejibaye residue with 150 g/kg of rice -processing residue as fed basis (P+R) and pejibaye residue with 150 g/kg of pelleted citrus pulp as fed basis (P+CP). The additives were added to the pejibaye residue before ensiling and after wilting the residue spread evenly over the concrete floor for a period of 4 hours.

The inclusion of 150 g/kg of as fed was limited because of the use of citrus pulp, which use should not exceed 300 g/kg of the DM of the diet (LANA, 2000).

The temperature was measured with the aid of a digital food thermometer with an extension cables attached to experimental silos every 12 hours.

Homogenized samples for analysis was obtained from four collections at different silo points before closing and another four after open silos. This procedure was performed due to the uniformity lack which is usually observed in ensiled materials (CAMPOS et al., 2010).

The specific mass (SM) was defined as kg of dry matter (DM)/m^3 and its measurement was performed by weighing each component of experimental unit, lid + barrel + sand + cloth + screen + silage (SCHMIDT et al., 2010).

The pH determination was carried out by the method proposed by Wilson and Wilkins (1972) consisting of extracting silage juice in a hydraulic press and performing the acidity measurement directly with a potentiometer calibrated for acid.

The measures of total dry matter losses, gas losses and losses due to silage effluents were calculated according to the methodology described by Schmidt et al. (2010).

The determinations of percentages of dry matter (DM), mineral matter (MM) and ether extract were made according to AOAC (1995), the total digestible nutrients (TDN) according to the Kearl equation (KEARL, 1982), the crude protein (CP) according to the methodology de Kjeldahl and neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose and lignin according to Van Soest et al. (1991). *In vitro* dry matter digestibility was carried out using the method described by Tilley and Terry (1963).

The apparent digestibility assay, carried out on sheep, crossbred Texel lambs of similar age and average weight (one year old and 38.67 kg, respectively) and was approved by the Animal Use Ethics Committee of the Animal Science Institute (Instituto de Zootecnia /APTA/SAA - Protocol number 134-10).

The animals were housed individually in metabolism cages, where each unit contained separator of feces and urine. A completely randomized design with four treatments was used (the same ones previously used) and five replications, being one animal per replication.

For urine collection samples, appropriate containers were used with the addition of 6N HCl (hydrochloric acid), in the amount necessary to maintain the pH below 3.0, thus avoiding the loss of nitrogen by volatilization. The daily volume was measured and an aliquot of 100 mL/L collected and stored under refrigeration for later analysis of urinary nitrogen by the Kjeldahl method, according to Silva and Queiroz (2009).

The experimental diets were provided twice a day (7:00 am and 4:00 pm) and adjusted daily, according to the consumption of the previous day, to ensure surplus of approximately 100 g/kg of the total fed and voluntary intake. Water and mineral salt were given at will intake.

The proposal was that the assay should be developed in three periods, the first being intended for the adaptation of the animals to cages and to feed for seven days; the second, also with seven days, was to assess voluntary intake and the third period was for the collection of samples and feed surplus, feces and urine, lasting 5 days (SILVA and LEÃO, 1979). However, it was found in practice that 11 days were necessary to pass to the second phase during the adaptation period. In the third period of sample collection, the animals were given 900 g/kg of the voluntary consumption determined in the previous phase.

DM intake was monitored by average of the difference between the amount of feed given and the surplus. During the collection period, approximately 100 g/kg of the total of each fraction samples of the feed given, surplus and feces were collected daily in the morning, pre-dried in a forced ventilation oven and stored for later analysis. At the end of the experiment, a sample was made up of animals per period.

These daily samples formed, at the end of the collection period, a composite sample for each animal, which was weighed and placed in a regulated oven at 50 – 55 °C, for 72 hours to determine the DM in the air. Then, the samples were ground in a mill, with a 1mm sieve, packed in plastic bags and sent to the laboratory, where DM (105 °C), CP, EE, ashes, CF, NNE, NDF and ADF were determined (SILVA and QUEIROZ, 2009).

Dry matter, neutral detergent fiber and acid detergent fiber apparent digestibility coefficients were determined by the total feces collection method. Dry matter, neutral detergent fiber and acid detergent fiber intake were determined, according to SILVA and LEÃO (1979).

The data for measuring silage quality, *in vitro* digestibility, as well as consumption and apparent digestibility were subjected to analysis of variance using the statistical program SAS (1999). The treatments were compared by the Tukey test at 0.05 probability.

RESULTS

The results of specific mass (SM), pH and average particle size (APS) of pejibaye silages (*Bactris gasipaes*) are shown in Table 2. There was difference ($P<0.05$) between silages SM, with greatest values to silages with rice residue and citrus pulp. Likewise, the pH values differed significantly ($P<0.05$) among silages, with values ranging from 3.27 to 4.00, indicating that the addition of additives raised pH, when compared to the pejibaye residue silage without additives. No differences ($P>0.05$) in the average particle size of the different silages were found.

Table 2 - Specific mass (SM), pH and average particle size (APS) of pejibaye silages (*Bactris gasipaes*) with and without additives

Variables	Treataments[1]				SMD[2]
	P	P+B	P+R	P+CP	
SM - kg(NM)/m³	671.60 b	672.75 b	705.63 a	711.47 a	15.50
pH	3.27 d	4.00 a	3.77 b	3.52 c	0.05
APS (cm²)	1.95	1.90	2.05	2.23	0.47

Average followed by same letters in the rows do not differ from each other by the Tukey test ($P<0.05$)
[1]P = pejibaye silage; P+B = pejibaye with banana silage; P+R = pejibaye with rice silage; P+CP = pejibaye with citrus pulp silage.
[2]Significant minimum difference

Silages fermentation temperature did not vary ($P>0.05$) at time zero and 72h, but differences at the temperatures ($P<0.05$) were observed at 12, 24, 36, 48 and 60 hours (Table 3). And silage fermentation temperature additive with banana was higher than others from 12 until 24 h. At 36 hours, silage plus citrus pulp showed the lowest temperature and at 48 and 60 hours the silage added of banana showed the lowest one. At 72 hours there wasn't difference between silages which established at average of 33 ºC.

Table 3 - Fermentation temperature of the silages with pejibaye residue (*Bactris gasipaes*) with and without additives

Period (hours)	Temperature (°C)/Treataments[1]				SMD[2]	CV (%)
	P	P+B	P+R	P+CP		
0	31	38	33	32	6.52	1.64
12	42 c	54 a	47 b	44 b	2.29	5.40
24	49 c	57 a	51 b	49 c	2.14	7.60
36	56 a	56 a	55 a	52 b	1.86	1.94
48	55 a	49 b	53 a	54 a	2.62	2.66
60	43 b	39 c	49 a	51 a	2.40	3.90
72	33	32	36	35	3.58	1.20
Average	44	46	46	45		

Average followed by same letters on the rows do not differ from each other by the Tukey test (P <0.05).
[1] P = pejibaye silage; P+B = pejibaye with banana silage; P+R = pejibaye with rice silage; P+CP = pejibaye with Citrus pulp silage.
[2]Significant minimum difference

Quadratic effect (P<0.05) of the silage fermentation temperature was observed in the time measured in hours (Table 4).

Table 4 - Regression equations adjusted for the silage fermentation temperature with and without additives

Silages	Regression equations[1]	R^2
Pejibaye	$\hat{Y} = -1.369X^2 + 12.655X + 22.107$	0.88
Pejibaye + banana	$\hat{Y} = -0.8095X^2 + 5.9524X + 40.286$	0.89
Pejibaye + rice	$\hat{Y} = -1.2024X^2 + 11.179X + 26.643$	0.87
Pejibaye + citrus pulp	$\hat{Y} = -1.2500X^2 + 11.917X + 23.536$	0.84

[1] Significant by "t" test (P<0.05). [2]R^2 = Coefficient of determination

The greatest effluent production (P<0.05; Table 5) were observed to pejibaye residue silage plus banana. The lowest gas losses occurred at pejibaye plus rice silage. Total losses occurred more intensity at silages pejibaye without additives and added of banana.

Table 5 - Fermentative losses of pejibaye silages (*Bactris* gasipaes) without and with additives

Characteristics	Treataments[1]				SMD[2]	CV (%)
	P	P+B	P+R	P+CP		
Effluent (kg)	2.90 b	3.48 a	1.65 c	1.40 c	0.42	8.51
Gases (g/100 g)	8.34 a	7.52 a	4.01 c	5.17 b	0.99	7.50
Total loss (% DM)	13.45a	13.92 a	7.40 b	7.63 b	1.42	6.44

Average followed by same letters in the rows do not differ from each other by Tukey's test (P <0.05).
[1]P = pejibaye silage without additives; P+B = pejibaye silage with banana; P+R = pejibaye rice silage; P+CP = Citrus pulp pejibaye silage.
[2]Significant minimum difference

The chemical composition differed (P<0.05) among the silages produced (Table 6) for all the variables studied. The DM contents showed significant differences (P<0.05) among the silages, with the highest contents in the silage plus citrus pulp, followed by silage plus rice. The inclusion of these additives enabled an increase in DM to approximately 92.2 g/kg and 84.5 g/kg, respectively. However, there was a reduction of 2.3 g/kg in the DM content in the silage plus banana when compared to the pejibaye residue silage without additives. The CP content differed significantly (P<0.05) among silages, with the highest value found when rice was included and the lowest value found in pejibaye silage without additive (40.8 g/kg CP).

Table 6 – Chemical composition and *in vitro* dry matter digestibility (IVD) of silages made with pejibaye residue (*Bactris gasipaes*) without and with additives

Variable	Treatments[1]				SMD[3]	CV (%)
	P	P+B	P+R	P+CP		
Dry Matter[2]	200.3 c	198.0 c	284.8 b	292.5 a	0.37	0.73
Crude Protein[2]	40.8 d	53.1 c	76.0 a	56.3 b	0.18	1.56
Crude Fiber[2]	332.5 b	238.6 c	200.5 d	461.2 a	0.80	1.56
Neutral Detegent Fiber (NDF)[2]	627.4 a	526.2 b	461.2 c	472.1 c	1.66	1.54
Acid Dertergent Fiber (ADF)[2]	450.4 a	374.1 b	326.5 d	344.1 c	0.68	0.87
Lignin[2]	66.4 b	75.5 a	45.3 c	45.5 c	0.44	3.73
Cellulose[2]	377.6 a	316.1 b	275.9 d	293.8 c	0.88	1.33
Hemicellulose[2]	177.0 a	152.1 b	134.7 c	128.0 d	0.34	1.09
Ether Extract[2]	9.2 c	9.2 c	15.5 b	21.4 a	0.06	2.27
Nitrogen Non-Extract[2]	578.3 d	649.9 c	673.5 a	669.4 b	0.46	0.35
Ash[2]	39.2 b	49.3 a	34.6 c	39.2 b	0.10	1.28
Non-fibrous carbohydrates (NFC)[2]	283.4 c	362.2 b	412.7 a	411.0 a	0.19	2.44
NDF/NFC	22.1 a	14.5 b	11.2 c	11.5 c	0.27	2.69
in vitro dry matter digestibility (%)	62.0 c	66.6 b	69.3a	69.3a	0.52	0.36

Average followed by same letters in the rows do not differ from each other by the Tukey test (P <0.05)
[1]P = pejibaye silage without additives; P+B = pejibaye silage with banana; P+R = pejibaye rice silage; S+CP = Citrus pulp pejibaye silage
[2]Expressed as g/kg of dry matter.
[3]Significant minimum difference

The contents of NDF and ADF decreased significantly (P<0.05) when the additives were included in the pejibaye silage, the lowest NDF values being found in the pejibaye residue silages with the inclusion of rice and citrus pulp. For ADF, the lowest value was obtained in the pejibaye residue silage with rice inclusion, followed by the treatment with citrus pulp inclusion.

The inclusion of banana in the pejibaye residue silage increased the lignin concentration (P<0.05), followed by the pejibaye residue silage without additive. There were no significant differences (P<0.05) among the silages with added rice and citrus pulp.

The contents of cellulose and hemicellulose showed significant differences (P<0.05) among the silages, with the highest value observed in the pejibaye residues silage without additives.

There was a significant effect (P<0.05) of the treatments on EE contents in the different silages, with better values in the silage with the inclusion of citrus pulp, followed by the pejibaye residue silage with the inclusion of rice. The pejibaye silage without an additive or with banana inclusion showed worst results and did not differ from each other (P>0.05).

There were significant differences among the treatments (P<0.05) for the content of nitrogen non-extract, with the best values observed in pejibaye silage plus rice, followed by silage plus citrus pulp, banana and pejibaye silage without additives.

There was significant differences (P<0.05) among silages ashes, with the greatest content found in the silage added of banana. The pejibaye silages without additive and with the addition of citrus pulp presented the same values (P>0.05). On the other hand, the silage added of rice presented the least values of ashes.

The addition of rice and citrus pulp to the silages increased the contents of NFC (P<0.05) and the NDF/NFC ratio decreased in this treatments (P<0.05). Improved results of *in vitro* digestibility (*in* vitro DIG) were found in the pejibaye residue silage added of citrus pulp and rice, followed by the silage with banana (P<0.05).

The results of initial, final weight, daily weight gain of sheep consuming silages with pejibaye residue without and with feed additives are shown in Table 7. No significant differences were observed (P>0.05) for any of these variables.

Table 7 - Initial, final and daily weight gain of sheep consuming silages with pejibaye residue without and with additives

Performance (kg)	Treatments[1]				Average	CV (%)
	P	P+B	P+R	P+CP		
Initial weight	38.40	39.10	38.66	38.50	38.67	11.30
Final weight	37.60	37.20	40.50	37.75	38.26	9.30
Daily weight gain	-1.96	-5.18	4.64	-1.52	-1.00	10.40

[1] P = pejibaye silage without additives; P+B = pejibaye silage with banana; P+R = pejibaye silage with rice; P+CP = pejibaye silage with citrus pulp.

Intake silages made with pejibaye residues (*Bactris gasipaes*) ensiled without and with additives are shown in Table 8. There were significant differences (P<0.05) in DM intake, with the highest values found in animals fed pejibaye residue silage added of rice. Significant differences (P<0.05) were observed in consumption as a percentage of LW (live weight) among the silages, with the highest values obtained with the pejibaye residue silage with rice and citrus pulp. The worst consumption was found in the silage without additives. The highest consumption in g/kgLW^{0,75} was observed (P<0.05) in the silages with inclusion of rice and citrus pulp.

Table 8 – Dry matter intake of the silages made with pejibaye residues (*Bactris gasipaes*) without and with additives

Intake	Treatments[1]				CV (%)	SMD[2]
	P	P+B	P+R	P+CP		
kg DM/day	0.62 b	0.74 b	1.08 a	0.89 b	17.7	0.16
g/kg LW (%LW)	1.91 c	2.40 b	3.10 a	2.70 a	18.9	0.46
g/kg LW$^{0.75}$	51.3 b	56.4 b	85.4 a	81.9 a	17.9	4.12

Average followed by same letters in the rows do not differ from each other by the Tukey test (P <0.05).
[1]P = pejibaye silage without additives; P+B = pejibaye silage with banana; P+R = pejibaye silage with rice; P+CP = pejibaye silage with citrus pulp.
[2]Significant minimum difference

The results of nutrients apparent digestibility coefficients of the silages made with pejibaye residues (*Bactris gasipaes*) without and with additives are shown in Table 9. Significant differences (P<0.05) were observed in all the variables evaluated. The best coefficients of DM digestibility and CP apparent digestibility were obtained with silages added of rice and citrus pulp. The highest EE digestibility value was obtained with the silage added of rice (P>0.05), followed by the silage with the addition of citrus pulp and the addition of banana.

Table 9 - Apparent digestibility coefficients of the nutrients of silages made with pejibaye residues (*Bactris gasipaes*) without and with additives

Digestibility	Treatments[1]				CV (%)	SMD[2]
	P	P+B	P+R	P+CP		
Dry Matter	0.536 b	0.549 b	0.639 a	0.642 a	3.10	3.33
Crude Protein	0.587 b	0.563 c	0.614 a	0.621 a	2.96	1.93
Ether Extract	0.557 d	0.611 c	0.743 a	0.712 b	2.39	2.72
Neutral Detergent Fiber (NDF)	0.493 a	0.462 b	0.493 a	0.519 a	8.61	2.86
Hemicellulose	0.469 a	0.429 b	0.426 b	0.408 c	5.42	1.42
Acid Detergent Fiber (ADF)	0.449 b	0.437 b	0.471 b	0.546 a	7.36	4.18
Total Carbohydrate	0.559 b	0.538 b	0.669 a	0.642 a	4.92	3.67
Non-Fibrous Carbohydrate (NFC)	0.557 b	0.529 b	0.645 a	0.614 a	6.15	3.88
Total Digestible Nutrient (TDN)	0.620 c	0.666 b	0.693 a	0.693 a	3.41	1.54

Average followed by different letters in the rows differ from each other by the Tukey test (P<0.05)
[1]P = pejibaye silage without additives; P+B = pejibaye silage with banana; P+R = pejibaye silage with rice; P+CP = pejibaye silage with citrus pulp.
[2]Significant minimum difference

Significant differences (P<0.05) in digestibility regarding the constituents of the cell wall were observed among the different silages. The worse results of NDF were observed in the silage with banana inclusion. The treatment with pejibaye residue without additives showed the greatest hemicellulose digestibility (P<0.05), followed by the inclusion of banana and rice. For the ADF levels, only the silage with the inclusion of citrus pulp differed from the others (P<0.05), showing an improvement in digestibility. The treatments with the addition of rice and banana were similar to the pejibaye residue without additives for this variable.

The digestibility of total carbohydrates was high (P<0.05) in the silages with addition of rice and citrus pulp and lower in silages with pejibaye residue without additives and with the addition of banana. The digestibility of NFC was significant (P<0.05) among the silages with the addition of rice and citrus pulp, which were superior to the other treatments.

The inclusions of rice and citrus pulp in the pejibaye residue silage increased (P<0.05) the TDN levels of the silages with the inclusion of rice and citrus pulp.

DISCUSSION

The pejibaye silage without additive or added of banana presented lesser values of specific mass than the other treatments (Table 2). However, it is considered that the silages which present specific mass values between 600 and 800 kg NM/m^3 are regarded as adequate, as the residual oxygen levels are not sufficient to impair the fermentation process (TOMICH et al., 2003). During the silos opening process, it was observed that the pejibaye residue silages without additives and with the inclusion of the by-products presented a good preservation aspect. The best pH reduction obtained with silage without additives differs from those obtained by Oliveira et al. (2010) who evaluated the chemical composition pejibaye by-products silages and reported a pH variation from 3.78 to 3.93, values similar to those observed in this experiment with the inclusion of additives. Possibly, due to the high moisture content of the pejibaye used in the present study, there may have been a reduction by dilution of the acidification power of the organic acids produced in the process. The values obtained are within the safety margin for consumption, which, according to Tomich et al. (2003) is equal to or lesser than 4.0 for an adequate fermentation of silages with DM content lesser than 20g/100 g. The particle size can change according to the characteristics of the ingredient and processing, and is directly linked to the final quality of the ensiling process. Based on corn silage, a silage to have good quality must have particle sizes between 1.0 and 2.0 cm and specific gravity around 600 kg (NM)/m^3 (SCHMIDT et al., 2010). However, it should be noted that to ensure ruminal motility, the particle size must be at least 3.0 cm (McDONALD et al., 1991). Losses during the fermentation process in the silo may be associated with the presence of oxygen, caused by the penetration of air during storage or the feed-out phase. The presence of oxygen in the silo is dependent on the specific mass of the silage, and this, in turn, is influenced by the particle size of the forages (RÊGO et al., 2016). In this experiment, all treatments presented particle size around 2 cm^2, with no significant difference between them, allowing good silage fermentation.

The fermentative behavior of the silages was already expected, since every fermentation process generates caloric increase in the first days of its making. However, the measured temperatures were higher in all treatments when compared to the fermentation temperatures of corn silages, with no significant differences between them. (McDONALD et al., 1991). Two factors contribute to the acceleration in the heating process generated by the microorganism's multiplication during fermentation, which are the amount of available nutrients (high levels of soluble carbohydrates, mainly starch) and the moisture content of the material (McDONALD et al., 1991; MACHADO et al. 2012). According to Mertens (1989) good quality silages generally show progressive heating, with a peak temperature between the first and second days, which was observed in the results obtained in the present experiment for all the silages that reached peak temperatures of fermentation between 24 and 48 hours after preparation. For ensiled materials with a high moisture content, such as the pejibaye residue (close to 80g/100g), heating is immediate as long as there are nutrients, mainly available soluble carbohydrates.

The equations adjusted to temperature along the fermentation days of the silage (Table 4) behaved differently between the treatments used, since they presented progressive growth from the 1st day of fermentation temperature, with emphasis on the silage with inclusion of bananas, with peak temperature in shorter time (24h), when compared to other treatments that occurred between 36 and 48h.

The greatest gas losses registered in the silages with pejibaye residue differ from Schmidt et al. (2010) who evaluated the urea inclusion effect (1.0 g/100g of NM) and quicklime (1.0 g/100g of NM) compared to the control treatment (without additives) in the residues ensilage (sheath) from the production of heart-of-palm (*Bactris gasipaes* Kunth). These authors observed that the losses by effluents and gases increased with the application of quicklime and the DM total losses were 15.1; 14.4 and 26.6 g/100g for control, urea and quicklime silages, respectively, and concluded that the additives applied in the silage were not effective in reducing fermentative losses in the conservation process.

The different silages chemical compositions observed in Table 6, are related to the residue composition used, which directly influence the final product quality. The higher dry matter (DM) content of the silage plus citrus pulp (P<0.05) was due to this ingredient, containing higher amounts of pectin in its composition than rice and bananas (LANA, 2000). The water retention capacity of a wet forage may be related to the pectin content of this food, as reported in a study on forage palm (SILVA MACÊDO et al., 2017), which could explain the DM values obtained in the present study. However, this variable was not evaluated in this experiment. Rice has a large amount of starch and low humidity, increasing the energy value as well as absorbing excess moisture and, consequently, increasing the DM levels in silage (MONTEIRO et al., 2011). According to Senger et al. (2005) silages with higher levels of DM, when well compacted preserve a greater amount of sugars that can be used as an energy source by ruminal microorganisms. Losses of protein, carbohydrates and minerals can occur through the effluent of ensiled materials with a high moisture content, and the volume is influenced mainly by the DM content and the degree of compaction (LAMMERS et al., 1996). The crude protein of the silage produced only with the pejibaye residue was below the values observed by Rodrigues Neto et al. (2001) and OLIVEIRA et al. (2010) 8.5 and 9.6 g/100g, respectively, which indicates variability in the composition of different residues from the heart-of-palm production

The reduction of the NDF and ADF concentrations was already expected with the inclusion of additives (P<0.05) due to the NDF losses that occur during ensiling, which can be relatively high, and correspond mainly to the solubilization of the hemicellulose fraction (McDONALD et al., 1991). In addition to the fact that the residues included, have low levels of NDF and ADF. The results presented in this study were worse to those reported by Rodrigues Neto et al. (2001) who observed 75.2 and 61.0 g/100g of DM for the NDF and ADF fractions, respectively, of the pejibaye residue silage. However, they partially agree with Schmidt et al. (2010) who evaluated the effect of the inclusion of urea (1g/100g of FM) and quicklime (1/100g of FM) compared to the control treatment (without additives) in the ensilage of residues (sheath) from pejibaye heart-of-palm production *(Bactris gasipaes, Kunth*) and found that there was a NDF reduction content and an ADF fraction increase in all the silages, indicating hemicellulose fraction disappearance. The authors concluded that the pejibaye heart-of-palm residue can be classified as a medium quality feed with a high moisture content.

Rodrigues Neto et al. (2001) also observed that there was a NDF and ADF reduction in pejibaye by-products silage (stem, leaves and sheaths) added with ground corn.

The banana used in this experiment had contents of 6.45 g/100g of lignin, impacting the silage production with a higher concentration of this plant cell wall component ($P<0.05$). The high lignin concentration in silages can be considered a negative factor from a nutritional point of view (OLIVEIRA et al., 2010).

Starch is classified according to its physicochemical structure and its susceptibility to enzymatic hydrolysis, which may affect digestibility in a feed. In general, the main factors that can interfere with the use of this polysaccharide include its botanical origin, amylose/amylopectin ratio, degree of crystallinity, physical form and type of starch processing, as well as interactions between this substance and other constituents of the feed (RAMOS et al. 2011). The concept of starches that are totally hydrolysable by amylases has been modified for resisting enzymatic digestion, it is the fraction called resistant starch. The green banana is rich in resistant starch, with high resistance to pancreatic α-amylase, and the action of amylases on starch from different sources remains a matter of investigation (RAMOS et al. 2011).

According to Oliveira et al. (2010) unlike cassava bran and cornmeal, palm kernel cake favored the increase in lignin concentration, probably due to the high content of this component in this additive (13.97 g/100g in DM) compared to the pejibaye by-product (6.83 g/100g in the DM).

The cellulose concentrations in silage pejibaye, without additives, observed in the present study were higher than those obtained by Rodrigues Neto et al. (2001) which can be considered as average levels. The inclusion of banana, rice and citrus pulp in the pejibaye residue silage promoted a decrease in cellulose levels, a similar fact was found in relation to hemicellulose, where the inclusion of additives reduced its concentration. During the fermentation process, hemicellulose breakdown occurs, which provides additional sugars for lactic fermentation. After the utilization of the soluble carbohydrates from the original material, hemicellulose may undergo acid hydrolysis and release soluble components for fermentation (ÁVILA et al., 2003). Thus, obtaining significantly different hemicellulose contents among the silages evaluated can be explained by the hemicellulose hydrolysis difference between evaluated additives, which is influenced by several factors, such as hemicellulose enzymatic activity present in the forage and produced by bacteria and acidic hydrolysis realized by organic acids produced presence during the fermentation process (McDONALD et al., 1991).

Van Soest (1994) found increased concentration of hemicellulose in corn silage. This result was due to the higher concentration of lignin in this treatment, which leads to the hypothesis of protection of hemicellulose by lignin, making difficult the acting of specific enzymes in their degradation during the silage fermentation. However, in the present study, lignin higher concentration was observed in the pejibaye residue silage added of banana.

The EE content is related to the silage organic acids production and its higher production promote higher silages EE content (SILVA MACÊDO et al., 2017). According to Gonçalves et al. (2011) higher ether extract contents are observed in grain silages, due to the fact that they are plants that store their energy in the grain like oil.

Citrus pulp is an ingredient rich in pectin which is its main source of NFC (SENGER et al., 2005) that explains its higher concentration in silage ($P<0.05$). DM and NFC values (Table 6) obtained in the present study, were higher than those observed by Senger et al. (2005) who analyzed the chemical composition of corn silages harvested with DM three levels (20, 26 and 28 g/100g) and found NFC values of 22.8; 30.8 and 32.6 g/100g, respectively. NDF and NFC concept aims to separate carbohydrates fractions with predictable digestibility and metabolizations. Diets with high NDF/NFC ratio mostly present low digestibility. It was observed that this relationship was approximately twice as great as in the treatment with pejibaye residue silage without additives when compared to pejibaye residue silages with rice and citrus pulp, which did not differ significantly between them. High NDF/NFC ratios characterize the predominance of carbohydrates that require enzymatic systems of slow digestion, causing a greater ruminal filling effect (MACHADO et al., 2012). Therefore, silages with higher DM content have lower NDF/NFC ratio and are more digestible. The data from the present study confirm these facts, since the *in vitro* digestibility of the different silages followed the NDF / NFC ratio.

Fritz et al. (2018) evaluating the effect of rice residues and banana stem as additives on the nutritional value of pejibaye residue silage, observed a higher dry matter content when the pejibaye residue was ensiled together with the rice residue, as in the present experiment. However, these authors found no significant differences in silages produced only with pejibaye or with the addition of additives for crude protein, NDF, ADF, EE, NNE and NFC.

The absence of significant results among sheep for initial, final and daily weight gain (P>0.05), observed in Table 7, can be explained due to the short period in which this assay was carried out. This fact usually occurs in digestibility assays, as the data collection period is relatively short (21 days) and the animals are in maintenance (SILVA and LEÃO, 1979). Apparent digestibility serves as a scientific tool to evaluate the nutrients of a given experimental diet and not directly animal performance.

Consumption in relation to live weight, regardless of the silages provided, obtained in the present study, can be considered satisfactory, because according to the NRC (1985), under tropical conditions, sheep and goats for flesh consume between 1.5 to 3.0 g/kg of LW.

Wilkins et al. (1971) stated that the DM content can account for only 15.8 g/100g in the variations in intake between silages. Therefore, it can be that other factors contributed to the differences observed in the intake of dry matter. Working with oats, Lopez and Muhlbach (1994) did not obtain improvement in DM digestibility by adding 10 g/100g of ground corn to the pejibaye residue silage, however the CF digestibility decreased by 0.122. The increase in the DM content of tropical grass silages due to the addition of agro-industrial by-products has already been observed by several authors (MONTEIRO et al., 2011; FRITZ et al., 2018). These results allow the calculation by the metabolic live weight ($LW^{0.75}$) of diets for different categories and animal species. Lopez and Muhlbach (1994) obtained a consumption of 56.4 g / kg of $LW^{0,75}$ for sheep using oat silage made from 10 g/100g of ground corn. Compared to the results of the present study, it was observed that the silage with ground corn additive showed consumption similar to the silages without additive or with banana, but presented lesser results than the silages with rice and citrus pulp. Rodrigues Neto et al. (2001) evaluated the consumption of cattle fed silages of pejibaye by-products without additives and added with sugar, citrus pulp and cornmeal and obtained a consumption of 44.5; 44.9; 87.0 and 84.1g/kg of $LW^{0,75}$ for the respective treatments, noting that there were no significant differences in silages with the inclusion of citrus pulp and ground corn, but that both were significantly better than silages without additives and with added sugar.

Consumption involves signals such as hunger and satiety that operate through hormonal and neural mechanisms to control voluntary intake. When high quality diets are given to animals, they feed to meet their energy demand, and their intake is limited by their genetic potential to use the absorbed energy. However, when poor quality diets are fed, the animal consumes the feed at the level that corresponds to the capacity of the gastrointestinal tract. The dominant role of physiological regulation and physical limitation in intake is modified by stimuli related to palatability and dietary management (MERTENS, 1989).

Dry matter intake in the different forms, in which it was expressed, probably increased in the pejibaye residue silage with the addition of rice, because of the increasing effect on DM digestibility. This is an important characteristic of rice, unlike other silages, as it has high levels of total CHO, CP and NNE. The increase in DM intake can also be attributed to palatability, which is associated with the high level of soluble carbohydrates present in these ingredients.

The silage without an additive showed the least digestibility coefficients (0.620). Oliveira et al. (2010) analyzing heart-of-palm sheath, observed *in vitro* DM DIG values of 0.742, characterizing this residue as a good quality roughage.

It was observed in the present study that the additives allowed improvements in pejibaye residue silage *in vitro* DIG, and the treatments with the addition of citrus pulp and rice produced good quality roughages similarly to those found by Codognoto et al. (2019) who studying the digestibility of silage of babassu heart-of-palm industrialization by-product, receiving as an additive cracked corn, broken rice, cassava root scrapings or coffee husks combined with cracked corn, showed superior DM, CP, NDF and TDN digestibility in sheep compared to sugarcane silage.

The inclusion of banana in the pejibaye residue silage allowed improvements in the material *in vitro* digestibility, but it was not capable of increasing DM levels, besides presenting higher levels of lignin and greater fermentation intensity, increasing effluents loss, and mainly gas losses.

On the other hand, the inclusion of rice allowed improvements in the material digestibility, minimized problems of excess moisture, presented lesser lignin levels, when compared to the other treatments, but the fermentation in this treatment was also very intense, increasing losses.

The inclusion of citrus pulp improved digestibility, minimized the problems of excess moisture in the material, presented better lignin levels and less intense fermentation, minimizing total fermentative material losses. The ensiling of the by-products of the extraction of the pejibaye heart-of-palm with the addition of rice and citrus pulp provided silages of good quality. Rodrigues Neto et al. (2001) observed that the addition of 10 g/100g of citrus pulp or ground corn provided medium quality silages and nutritional value similar to most of the conventional forage silages.

The apparent digestibility coefficients of protein in the present study (Table 9) were worse to those observed by Rodrigues Neto et al. (2001) for pejibaye residue silages without an additive and with the addition of citrus pulp, but were superior to those observed by Machado et al. (2011) for sorghum silages, ranging from 0.486 to 0.567. According to Rodrigues Neto et al. (2001) heating reduces proteins solubility and, consequently, also reduces ruminal degradability. The greater EE digestibility in silages with additives may be a consequence of the higher EE levels and lesser structural CHO levels in these silages (MORENO et al., 2010).

The additives inclusion worsened hemicellulose digestibility and banana residue inclusion worsened NDF digestibility, on the other side, citrus pulp inclusion improved ADF digestibility. Assessing elephant grass silages with 12 g/100g of by-products of the dehydrated cashew pseudo-fruit, with two levels of concentrate (1,5 and 2,5 g/100g of LW), Rego et al. (2009) obtained DM intake lesser than those recorded in silages with 10,5 g/100g of the cashew by-product, probably due to the higher NDF content (73,0 g/100g) observed in these silages.

In the present study, the contents obtained for TCHOs were significantly ($P<0.05$) lower, when compared to the results of Rodrigues Neto et al. (2001). The combination of banana and pejibaye residue negatively altered the NFC content of this treatment.

The results obtained on the TDN digestibility coefficient were higher than those of Rodrigues Neto et al. (2001) in pejibaye residue silages without an additive (0,520) and in the treatments with sugar, citrus pulp and ground corn inclusion (53,8; 64,4 and 66,4 g of TDN /100g DM, respectively). Monteiro et al. (2011) found that the grass silage with rice bran showed the lowest levels of NDF and ADF in relation to pure elephant grass. These decreases can be explained by the lower NDF content of the additives, such as rice bran, in relation to that of pure elephant grass, and by the lower production of effluent, observed visually, in the added silages. In the present study, the highest TDN concentration when including rice residues and citrus pulp was due to the silage produced from them presenting a higher concentration of total NFC and CHO.

CONCLUSIONS

Heart-of-palm pejibaye residue silage showed average particle size, pH and density values within the range appropriate for their manufacture.

Among the additives used in this study, silage with 15 g/100g of rice provided the best nutritional value of the silage.

The silage with the inclusion of rice residue and citrus pulp showed the best *in vitro* digestibility coefficient, and better apparent digestibility for most of the analyzed nutrients.

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