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ANIMAL PRODUCTION

Silage of the agro-industrial co-product of babassu palm heart processing in sheep feed

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ABSTRACT: *The inner bark or less tender sheath generated from industrial manufacture of canned babassu palm (Attalea speciosa) heart is inadequate for human consumption, often being discarded inappropriately and giving rise to environmental pollution. Accordingly, the aim of this study was to assess the intake and digestibility in sheep fed on silage of the agro-industrial co-product of babassu palm (ICBP)enriched with different additives, or on sugarcane silage. Fifteen Santa Inês sheep were distributed in a completely randomized design, consisting of five treatments and three replicates. The treatments comprised babassu palm silage enriched with broken maize (BM), broken rice (BR), cassava scrapings (CS), coffee husk combined with maize kernel (CC), and sugarcane silage (SC), all supplemented with concentrate, at a voluminous:concentrate ratio of 65:35. Silages based on ICBP and SC had similar intake of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), and non-fibrous carbohydrate (NFC). Increasing the additive fraction in ICBP silages favored the digestibility of DM, OM, CP, NFC, neutral detergent fiber (NDF), and total digestible nutrients (TDN). Our results indicated that silage based on additive-enriched ICBP can be used in the diet of ruminants, especially those based on broken maize and cassava scrapings that provide superior nutritional quality compared to the other silages assessed.*
Key words: *Attalea speciosa, animal nutrition, alternative feed, inner bark, roughage.*

Silagem de coproduto da industrialização do palmito de babaçu na alimentação de ovinos

RESUMO: *No processo industrial de fabricação de palmito babaçu (Attalea speciosa) em conserva, a entrecasca ou bainha menos tenra, apresenta características impróprias à alimentação humana, sendo muitas vezes descartada de forma inadequada, oferecendo riscos de poluição ambiental. De tal forma, objetivou-se avaliar o consumo e a digestibilidade em ovinos recebendo silagens de coproduto da industrialização de palmito babaçu (CIPB) com diferentes aditivos ou silagem de cana-de-açúcar. Utilizou-se 15 ovelhas da raça Santa Inês, distribuídas em delineamento inteiramente casualizado, constituindo de cinco tratamentos e três repetições. Os tratamentos compreendiam dietas de silagem de babaçu enriquecidas com quirera de milho (QM), quirera de arroz (QA), raspa de mandioca (RM), casca de café combinada com quirera de milho (CC), e silagem de cana-de-açúcar (CA), todos complementadas com concentrado, na relação volumoso:concentrado, 65:35. Silagens a base de CIPB e CA tiveram consumos de matéria seca (MS), matéria orgânica (MO), proteína bruta (PB), extrato etéreo (EE) e carboidrato não-fibroso (CNF) semelhantes. O incremento de aditivos às silagens de CIPB favoreceram a digestibilidade da MS, MO, PB, CNF, fibra em detergente neutro (FDN) e de nutrientes digestíveis totais (NDT). Silagem a base de CIPB pode ser utilizada na dieta de ruminantes com a inclusão de aditivos, especialmente quirera de milho e raspa de mandioca, que conferem qualidade nutricional superior às demais silagens avaliadas.*
Palavras-chave: *Attalea speciosa, alimentação animal, alimento alternativo, entrecasca, volumoso.*

INTRODUCTION

Ruminants are herbivorous animals belonging to the suborder Ruminantia, specialists in forage plant grazing (grasses and legumes) and extracting nutritional components through symbiotic relationships with microorganisms, including bacteria and protozoa, present in their digestive apparatus. The main benefit of these microorganisms is their ability to convert different vegetable materials rich in fiber, and with no use in human food, into products of high biological value such as milk and meat (LEEUW et al., 1999; LANA, 2005).

Consequently, the co-products generated by the palm-canning industry, especially the inner bark, can be used in ruminant feed due to the presence of dietary fiber and other nutrients (RODRIGUES NETO et al., 2001; OLIVEIRA et al., 2010; SCHMIDT et al., 2010). Residues of in natura palm have a high moisture content, meaning that the provision for animal feed is immediate (MORAES et al., 2011). Ensilage is the technique recommended for storing and preserving this type of food, because it

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provides greater durability (RODRIGUES NETO et al., 2001).

Silage from materials with low levels of dry matter favor the growth of bacteria of the genus *Clostridium*, resulting in a loss of nutritional value and food palatability (SAMPAIO et al., 2000). Thus, including a solid ingredient to increase the dry matter content and favor the fermentation process during the ensilage of palm co-products is indispensable. Additives used must have a satisfactory dry matter and nutritional content, preferably obtained with the minimum financial investment (COUTO FILHO et al., 2007). Some solid ingredients such as cassava scrapings, coffee husk, broken maize, and rice can be incorporated into silage to fulfil some of the requirements listed above (PIRES et al., 2009; OLIVEIRA et al., 2010; CABRAL et al., 2015).

Given current environmental concerns, reutilizing waste with forage potential is a sustainable alternative for use in animal feed since it can lead to reduced accumulation of potential pollutants, as well as being an alternative to the use of cereal grains (ÍTAVO et al., 2000; PEREIRA et al., 2013). In economic terms, extensive animal production systems require external sources of nutrients to guarantee animal performance throughout the year (HOFFMANN et al., 2014), especially in dry season when forage is limited.

However, information on silage of the babassu palm (*Attalea speciosa*) co-product in ruminant feed is still scarce (CABRAL et al., 2015). Accordingly, this study aimed to evaluate silages of babassu palm inner bark combined with different solid ingredients, as well as sugar cane silage, in the feeding of sheep.

MATERIALS AND METHODS

The experiment was carried out at the Federal Institute of Education, Science, and Technology of Rondônia, IFRO, Campus Ariquemes, in the Municipality of Ariquemes, RO. The local coordinates are 9° 56’ 56” S and 62° 57’ 42” W, at an altitude of 140 meters. The animal experiments were performed from February to April 2016, with 10 days for adaptation of the animals to the facilities and handling in confinement. The following 63 days were used for collection of daily intake data, as well as feces and urine samples.

Fifteen female Santa Inês sheep, with an initial average weight of 34.3±4.6 kg and a mean age of 10.0±3.0 months, were weighed on arrival and subjected to sanitary measures against endo and ectoparasites, and vaccination against clostridiosis. They were later housed individually in a brick shed, in 1.20 m × 0.80 m (0.96 m^2) stalls with a slatted and suspended wooden floor, and equipped with individual feeders and drinkers, as well as a feces-separating device and a urine collector suitable for digestibility tests.

The experiment was randomized, consisting of five treatments, with three animals per treatment, totaling 15 experimental units. Treatments were organized into five diets, consisting of agro-industrial by-product of the babassu palm (*A. speciosa*) (ICBP) combined with ingredients based on natural matter (NM), in the following proportions: BM = ICBP+ 25% broken maize; BR = ICBP+ 25% broken rice; CS = ICBP+ 25% cassava scrapings; CC = ICBP + 10% coffee husk + 15% broken maize; and SC = sugarcane silage. In addition, the silage was inoculated with *Lactobacillus plantarum* (Silobac® 5), with a minimum guarantee of 1×10^{-11}CFU.g^{-1}, following the manufacturer’s recommendations: 1g of inoculant for 1 t of silage, at a concentration of 2 L of solution. t^{-1} silage. For silage production, a dry matter content above 35% was adopted (Table 1). Total ration (roughage and concentrate) supplied to animals was formulated to be isoproteic (15% GW).

To compose the ICBP silages, the inner bark was processed immediately after agro-processing of the ICBP in a tractor-type silage harvester, with cut-size set to 1 cm, and homogenized with different solid ingredients (broken maize and rice, cassava scrapings, and coffee husk) and commercial inoculant. Raw material for the manufacture of sugarcane silages, variety SP701011, was obtained from a two-year-old grassland, processed in a tractor-type silage harvester (cut size also 1 cm), and homogenized with the commercial inoculant. A mean compaction density of 550 kg.m^{-3} for the ICBP and sugarcane silages, and a fermentation period equivalent to 65 days, were adopted for the study.

Animals were fed with diets based on dry matter (DM) containing 65% roughage (ICBP silage + additives or sugarcane silage) and 35% concentrate, with the same formulation being used for all treatments (Table 1). Feed was provided twice a day, once at 8 a.m. when the leftovers were recorded and the previous intake calculated to determine the *ad libitum* provision, estimated from 10% of the leftovers; and again at 4 p.m. to obtain the second half of the value calculated for the morning. The feed provided was sampled and homogenized, with a composite sample for each animal. Likewise, refused

Table 1 – Percentage composition of ingredients and chemical bromatological composition of the sugarcane silage and the babassu palm agro-industrial by-product (ICBP) silage enriched with different nutritional additives.

Item	ICBP silage[1] enriched with different nutritional additives				Sugarcane silage
	BM[2]	BR[3]	CS[4]	CC[5]	
Ingredient	Proportion of the ingredients in the diets (% DM)				
----Roughage----					
ICBP	48.75	48.75	48.75	48.75	-
Sugar cane	-	-	-	-	65.00
Broken maize	16.25	-	-	9.75	-
Broken rice	-	16.25	-	-	-
Cassava Scrapings	-	-	16.25	-	-
Coffee husk	-	-	-	6.50	-
----Concentrate----					
Ground Maize	15.75	15.75	15.75	15.75	15.75
Soy Bran	17.50	17.50	17.50	17.50	17.50
Mineral supplement for sheep [6]	1.75	1.75	1.75	1.75	1.75
----Nutrient----					
Dry matter	53.40	46.48	56.51	56.51	54.12
Organic matter [7]	94.66	95.55	93.68	93.68	94.00
Crude protein [7]	15.96	14.60	15.88	15.88	16.48
Ether extract [7]	2.11	2.33	2.10	2.10	2.33
Neutral detergent fiber [7]	46.42	46.82	44.50	44.50	51.51
Non-fibrous carbohydrate [7]	31.86	32.90	32.90	25.21	33.57
Total carbohydrates [7]	76.58	75.10	75.70	75.19	78.62
Acid detergent fiber [7]	29.66	24.90	28.92	28.92	34.72
Hemicellulose [7]	16.16	21.19	14.89	14.89	16.16
Lignin [7]	3.14	2.60	3.18	3.18	4.03
Ash [7]	3.87	2.68	4.62	4.62	4.47

[1] ICBP: Agro-industrial co-product of babassu palm; [2] BM: ICBP silage + 25% broken maize, based on natural matter content; [3] BR: ICBP silage + 25% broken rice, based on natural matter content; [4] CS: ICBP silage + 25% cassava scrapings, based on natural matter content; [5] CC: ICBP silage + 10% coffee husk + 15% broken maize; [6] Guarantee levels per kg of product: Calcium (min-max), 200–250 g; copper (min.), 1 mg; phosphorus (min.), 70 g; fluorine (max.), 700 mg; cobalt (min.), 175 mg; magnesium (min.), 6000 mg; iodine (min.), 175 mg; manganese (min.), 1500 mg; sulfur (min.), 12 g; selenium (min.), 27 mg; sodium (min.), 80 g; zinc (min.), 6000 mg; [7] % of dry matter.

feed (leftovers) was weighed, sampled (10% of the total), and stored in a freezer at −10 ºC for subsequent analysis. Feces and urine samples were collected in the afternoon from day 38 to day 42 of the experimental period, with a sampling of 10% of the total produced per animal being used for laboratory analysis, according to VALADARES et al. (1997).

Samples obtained were subjected to laboratory analysis according to the methodology described by DETMANN et al. (2012), and the following were determined: DM, methodology INCT-SC G-003/1; ash (ASH), methodology INCT-SC M-001/1; crude protein (CP), methodology INCT-SC N-001/1; ether extract (EE), methodology

Table 2 – Intake and digestibility of nutrients in silages of the agro-industrial co-product of babassu palm (ICBP) enriched with different nutritional additives or of sugarcane silage.

Variables	Experimental diet[1]					P value	SEM[2], %
	BM	BR	CS	CC	SC		
Dry Matter							
Intake, kg.day^{-1}	0.875	0.742	0.877	0.99	0.693	0.114	15.77
Digestibility, %	83.00a[3]	78.47ab	83.43a	73.11ab	65.59b	0.005	5.89
Organic Matter							
Intake, kg.day^{-1}	0.767	0.640	0.745	0.868	0.663	0.177	15.06
Digestibility, %	84.10a	79.47ab	84.10a	74.27ab	67.34b	0.005	5.55
Crude protein							
Intake, kg.day^{-1}	0.134	0.110	0.131	0.159	0.103	0.058	16.05
Digestibility, %	70.06ab	63.57ab	80.72a	58.98b	68.25ab	0.031	9.93
Ether extract							
Intake, kg.day^{-1}	0.018	0.015	0.017	0.023	0.016	0.060	15.63
Digestibility, %	85.25	80.08	88.20	84.06	73.89	0.069	6.46
Neutral detergent fiber							
Intake, kg.day^{-1}	0.364ab	0.294b	0.337ab	0.467a	0.317ab	0.027	15.32
Digestibility, %	79.72a	72.80a	73.26a	69.22a	47.96b	0.002	9.39
Non-fibrous carbohydrates							
Intake, kg.day^{-1}	0.252	0.220	0.260	0.220	0.226	0.543	14.73
Digestibility, %	66.74a	58.71a	70.30a	20.35b	18.34b	0.000	22.65
Total digestible nutrients							
Intake, kg.day^{-1}	0.617a	0.474ab	0.603a	0.503ab	0.293b	0.010	17.45
Digestibility, %	72.37a	64.60a	71.52a	54.60ab	42.12b	0.003	11.51

[1] Roughage of diets: BM = ICBP silage + 25% broken maize; BR = ICBP silage + 25% broken rice; CS = ICBP silage + 25% cassava scrapings; CC = ICBP silage + 10% coffee husk + 15% broken maize; SC = sugarcane silage. [2] SEM: standard error of the mean. [3] Means followed by different letters in the same row differ according to Tukey's test $P<0.05$).

INCT-SC G-004/1; neutral detergent fiber (NDF), methodology INCT-SC F-001/1; acid detergent fiber (ADF), methodology INCT-SC F-003/1; and lignin (LIG), methodology INCT-SC F-006/1. The procedure to determine the pH of the silages followed the recommendation of CHERNEY &CHERNEY (2003). Non-fibrous carbohydrate (NFC) and total digestible nutrients (TDN) were determined according to SNIFFEN et al. (1992).

The determination of apparent digestibility of DM, organic matter (OM), CP, EE, NDF, NFC, and TDN of the experimental diets were obtained according to the equation described by SCHNEIDER and FLATT (1975). The intake of DM, OM, CP, EE, NDF, NFC, and TDN were assessed. The data obtained for intake and digestibility were submitted to analysis of variance (ANOVA) and the means were compared by Tukey's test with 5% significance, using the statistical analyses program SISVAR (FERREIRA, 2014).

RESULTS AND DISCUSSION

Diets composed of ICBP silages displayed nutritive values similar to the SC diet (Table 1). Additives qualitatively influenced the levels of NDF, ADF, and LIG in the ICBP silages. RODRIGUES NETO et al. (2001), evaluating the chemical composition of silages of peji baye palm stem, leaf, and sheath by-products enriched with ground maize (10% NM), obtained NDF, ADF, and LIG values of 56.1, 36.2, and 11.5% DM, respectively. According to the authors, the additive caused a dilution of cell wall constituents, possibly because the content of structural components was reduced compared to the co-product.

Inclusion of cassava scrapings, broken rice, broken maize, and coffee husk additives (Table 1) increased the DM content of the ICBP-based silages, exceeding the minimum limit of 30% (REZENDE et al., 2011). Diets of ICBP and SC silages had similar intakes of DM, OM, CP, EE, and NFC (Table 2). RABELO et al. (2013) recorded 0.387 kg.day^{-1} DM intake for sheep fed exclusively on a diet of SC silage. The higher intake of SC silage obtained in this experiment (Table 2) was due to the provision of concentrate to the diet.

The CS and BM diets presented greater DM and OM digestibility due to the higher degradability of the starch fraction present in these silages, differing significantly from the SC diet. According to SIMAS et al. (2008), the ruminal digestibility of cassava starch is greater than maize, with 91 and 65%, respectively. CABRAL et al. (2015) recorded lower DM and OM digestibility for Santa Inês sheep, with 81.9 and 82.6%, respectively, when evaluating silage of the industrial co-product of peji baye palm (ICPP) enriched with 15% maize, with a voluminous :concentrate ratio of 40:60.

The CP digestibility of the CC diet was affected by the silage additive, differing significantly from the CS diet (Table 2). The coffee husk component of the diet has a nitrogen-cell-wall fraction (ADIN and NDIN) that decreases the nitrogen availability for ruminal microorganisms (ROCHA et al., 2006; BERNARDINO et al., 2009; VIANA et al., 2012). BERNARDINO et al. (2009) evaluated sheep fed diets of elephant grass silage containing0, 10, 20, and 30% coffee husk additive, and observed a maximum CP digestibility of 69.9% with inclusion of 10% coffee husk to the silage. Furthermore, the observed behavior followed a negative linear model with increasing levels of inclusion of coffee husk to the silage. CABRAL et al. (2015) evaluated ICPP + maize (15%) silages and obtained a CP coefficient proportional to 78.2%, while for RODRIGUES NETO et al. (2001) it was equivalent to 71% for a ICPP + maize (10%) diet, higher than recorded in this experiment. The significant digestibility of CP in the CS diet is due to the additive, which is rich in non-structural total carbohydrates, having a protective effect on the protein since starch prevents degradation of proteins before they are used by ruminal microorganisms (CABRAL et al., 2015).

The diets evaluated showed no difference in intake or digestibility of EE (Table 2). The concentrations of this ingredient are higher than those reported by CABRAL et al. (2015), who reported an average intake and digestibility of 0.068 kg.day^{-1} and 74.4% of EE, respectively, for ICPP silages.

There was a significant difference in NDF intake between diets (Table 2). The CC diet displayed a higher NDF intake, equivalent to 58% of the BR diet (Table 2); this was in accordance with the recommendation of LEITÃO et al. (2005), in which coffee husk, together with other feed with higher nutritional value, especially higher energy content, ensures a higher intake of DM. However, the level of inclusion of the broken maize additive (9.75% DM) in the CC diet was insufficient to match the NFC content recorded for the other diets (Table 1).

The ICBP silage diets, with additives rich in NFC and high ruminal degradability, presented greater NDF digestibility (Table 2) than the SC diet. Thus, as observed by SIMAS et al. (2008), neither the source of the starch, nor the starch content (broken maize and rice and cassava scrapings), influenced NDF digestibility among the ICBP diets (Table 2). For the SC diet, LIG is the cell wall component that most affects the availability of non-starch polysaccharides, reducing availability of food energy (VAN SOEST, 1994). Nevertheless, the NDF intake in SC silages was higher than recorded by RABELO et al. (2013), at 0.226 kg.day^{-1}. Thus, ICBP silages enriched with energy additives enhanced the fermentation process and reduce undesirable fermentation (CABRAL et al., 2015), resulting in improved digestibility of the BM, BR, CS, and CC diets.

Except for coffee husk, the low fiber content of the additives tested reduced components of the cell wall in ICBP silages, leading to significant NFC digestibility for BM, BR, and CS diets. However, CABRAL et al. (2015) recorded greater NFC digestibility for ICPP silage and ICPP silage + maize (15%; voluminous :concentrate ratio of 40:60) of 76.3 and 87.9%, respectively. For the SC diet, the NDF and LIG content (Table 1) negatively affected digestibility, because fiber is the most limiting factor for animal performance (CARVALHO et al., 2010). Moreover, high levels of NDF hindered DM ingestion, and consequently its digestibility, impacting on energy intake by animals. Soluble sugars from sugarcane, readily digestible and of variable quality, also did not affect NFC and TDN digestibility in the SC diet (Table 2).

The BM and CS diets displayed significantly higher intake of TDN compared to the SC diet. When assessing ICPP and ICPP silage in sheep diets, CABRAL et al. (2015) recorded an average TDN intake of 0.602 kg.day^{-1}, similar to this study, especially for the BM and CS diets (Table 2). Diets based on ICBP presented similar TDN digestibility. RODRIGUES NETO et al. (2001), in a trial conducted with cattle to determine the intake and digestibility of silages of peji baye palm by-products, obtained TDN digestibility of 66.4% with a silage + maize (10%) treatment, lower than for the BM and CS diets (Table 2).

CONCLUSION

Silages of the industrial co-product of babassu palm enriched with solid additives presented similar or higher intake and digestibility of nutritional ingredients than sugarcane silage.

ICBP silage enriched with broken maize and cassava scraping additives confers nutritional quality to the feed, enabling its use in sheep diet.

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DECLARATION OF CONFLICTING INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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