Animal Science/ Original Article

Qualitative parameters and nutritional potential of arboreal cotton silage

Abstract – The objective of this work was to evaluate the qualitative parameters and nutritional potential of silage of arboreal cotton (*Gossypium hirsutum*) shoots. The experiment was carried out in a 4×2 factorial arrangement, for two silage forms (in natura or pre-dried), with four treatments, as follows: without additives (WA); with inoculant (WI); with 2% ground corn (GC); and with 2% ground corn with inoculant (GC+I). The fermentative quality and nutritional parameters of the silages were evaluated. Fermentative quality was better in the WI and GC+I silages. The dry matter content was higher in the pre-dried silage, while the crude protein contents of in natura silage were higher in the WA and WI treatments. The lowest values of neutral detergent fiber and acid-digested lignin were observed in the WI treatment, for pre-dried silage. Total digestible nutrients and total volume of gas were higher in the pre-dried silage, in the WI and GC treatments, respectively. In vitro dry matter digestibility was lower in WA silage, in both forms. Silage of arboreal cotton associated with inoculant or with inoculant with ground corn shows a better fermentation profile and improves the energy and nutritional values, both in natura and pre-dried forms; however, in natura silage is less laborious for rural producers.

Index terms: *Gossypium hirsutum*, *Lactobacillus plantarum*, digestible nutrients, domestic ruminant, semiarid.

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Parâmetros qualitativos e potencial nutricional da silagem de algodão arbóreo

Resumo – O objetivo deste trabalho foi avaliar os parâmetros qualitativos e o potencial nutricional da silagem da parte aérea do algodão (*Gossypium hirsutum*) arbóreo. O experimento foi realizado em arranjo fatorial 4×2, para duas formas de silagem (in natura ou pré-seca), com quatro tratamentos, conforme a seguir: sem aditivos (SA); com inoculante (CI); com 2% de milho moído (MM); e com 2% de milho moído e inoculante (MM+I). Foram avaliados a qualidade fermentativa e os parâmetros nutricionais das silagens. A qualidade fermentativa foi melhor nas silagens CI e MM+I. Os teores de matéria seca foram maiores na silagem pré-seca, enquanto a proteína bruta na silagem in natura foi maior nos tratamentos SA e CI. Os menores valores de fibra em detergente neutro e lignina digerida em ácido foram observados no tratamento CI, para a silagem pré-seca. Os nutrientes digestíveis totais e o volume total de gás foram maiores na silagem pré-seca, nos tratamentos CI e MM, respectivamente. A digestibilidade in vitro da matéria seca foi menor na silagem SA, nas duas formas. A silagem de algodão arbóreo associada ao inoculante ou ao inoculante com milho moído apresenta o melhor perfil fermentativo e melhora o valor energético e nutricional, tanto na forma in natura como na pré-seca; porém, a silagem in natura é menos trabalhosa para os produtores rurais.

Termos para indexação: *Gossypium hirsutum*, *Lactobacillus plantarum*, nutrientes digestíveis, ruminantes domésticos, semiárido.

Introduction

The ruminant production in the Northeastern Brazil is an important income-generating activity for the local population, that contributes to the economic and social development of the region. The livestock activity present in this region faces some obstacles because the availability and quality of forage resources are affected by rainfall scarcity and irregularities of rainfall, high annual evaporation, and shallow soils with low moisture retention capacity (Silva et al., 2014). In this scenario, research should be directed to alternative foods that are adapted to its environmental conditions. In the Semiarid region there is no perfect forage alternative, therefore, outputs to alleviate the situation of farmers in the dry season are sought, such as the production and conservation of native or adapted forage species, in order to increase the productive efficiency (Campos et al., 2017).

Among the forage alternatives for nutrient supply to meet the nutritional requirements of ruminant animals raised in this region, the use of several species of plants that have forage potential are outstanding, but their nutritional characteristics are generally not known, as is the case for arboreal cotton [*Gossypium hirsutum* var. *marie-galante* (G.Watt) J.B.Hutch.]. This plant has a high level of genetic diversity in this region (Menezes et al., 2017). In years of intense droughts, after the harvesting of feathers, the use of plant leaves in the diets contributes to the nutritional supplementation to feed cattle (Menezes et al., 2015, 2017).

The silage of the aerial part of arboreal cotton may have good potential to be used, mainly associated with spineless cactus in the diets for ruminant animals, to correct the deficiency of neutral detergent fiber, dry matter, and crude protein of this cactus (Silva et al., 2017; Moraes et al., 2019). At first, it is necessary to know the nutritional characteristics of arboreal cotton, as this silage can be used as roughage supplementation, or associated with concentrated foods. There are few studies in the literature on the quality of arboreal cotton silage, so it is necessary to know its nutritional quality for the correct use in the diets for ruminant animals.

The objective of this work was to evaluate the qualitative parameters and nutritional potential of silage of the aerial part of arboreal cotton.

Materials and Methods

Samples for the ensiling process were collected from a cultivated area of arboreal cotton, situated at the experimental farm of the Universidade Federal Rural de Pernambuco (UFRPE), in the municipality of Garanhuns, in the state of Pernambuco, Brazil (08°58'43"S, 36°27'15"W, at 822.76 m altitude). The region's climate is classified as a tropical type Aw, according to the Köppen-Geiger's classification, with 21.2°C mean annual temperature, and from 75 to 83% relative air humidity. The soil of the experimental area is characterized as "franco-argilo-arenoso" (Santos et al., 2018), which corresponds to a sandy loam soil.

The point for the collection of plants was chosen 120 days after the cutting, at approximately 50 cm height, corresponding to 1,260.5 m^2 area, with a total of 1,296 plants. To the ensiling process of arboreal cotton, the aerial part of the plants (leaves and branches) was collected, and the material was chopped in a stationary machine MC1n 2.0e (Laboremus, Campina Grande, PE, Brazil) into 1 cm particles. Part of the material was exposed to the sun for 4 hours (pre-dried), then ensiled, and the other part was ensiled soon after the material was chopped. The forage mass was homogenized with additives of the respective treatments, then it was immediately compacted, using a wood compactor, and stored in experimental polyvinyl chloride (PVC) tube silos, containing a Bunsen type valve at the top, and sand at the bottom; tube measures were 53 cm long by 10 cm diameter. The density used was 650 to 700 kg m^{-3} of fresh matter. The silos were maintained in an environment at 20.4°C and 70% humidity.

Two forms of silage (in natura and pre-dried) were performed, with five replicates (tube silos), and four treatments were used for each form of silage, as follows: WA, without additives; WI, with bacterial inoculant; GC, with 2% ground corn; and (GC+I), 2% ground corn + bacterial inoculant. The bacterial inoculant was composed of strains of *Lactobacillus plantarum* and *Pediococcus pentosaceus*, and the amount used was 1 g inoculant per ton of forage mass. Before the ensiling process for in natura and pre-dried forms, arboreal cotton had respectively: 222.2 and 357.8 g kg^{-1} dry matter (DM), expressed as grams per kilogram of fresh matter; 95.6 and 94.9 g kg^{-1} DM of ash; 244.8 and 239.8 g kg^{-1} DM of crude protein (CP); 15.7 and 19.8 g kg^{-1} DM of ether extract (EE); 510.3 and 495.3 g kg^{-1} DM of neutral detergent fiber (NDF);

and 269.8 and 239.3 g kg^{-1} DM of acid detergent fiber (ADF).

The weighing was done before and after fermentation to quantify gas losses, and sand was also weighed to quantify effluent losses. The silos were opened 30 days after the ensiling process. After opening, the silage was pressed, using a manual press to extract the liquid, which whose pH was measured by using a digital pH meter (PHS3BW, Bel Engineering, Monza, Italy). Ammoniacal nitrogen (NH$_3$-N) was quantified by the calorimetric method with indophenol formation (Chaney & Marbach, 1962).

Silage was homogenized and sampled, and 10 cm of it was discarded from the bottom and top of the silo. Subsequently, the samples were pre-dried in a forced-air ventilation oven Te-394/2 (Tecnal, Piracicaba, SP, Brazil), at 55ºC for 72 hours, and ground in MA 580 Wiley knife mill (Marconi, Piracicaba, SP, Brazil), with 1 mm and 2 mm sieves. The analyses concerning the chemical composition of dry matter (DM), organic matter (OM), ash, crude protein (CP), and ether extract (EE) were performed according to AOAC (Helrich, 1990). The NDF, ADF, and acid-digested lignin (ADL) were determined according to Van Soest et al. (1991). Corrections of NDF for ash and protein to obtain NDFap were performed according to Mertens (2002) and Licitra et al. (1996), respectively. The hemicellulose (HEM) and cellulose (CEL) fractions were estimated by the equations HEM = NDF - ADF, and CEL = ADF - ADL, respectively.

Total carbohydrate (TC) fractions were estimated by TC = 100 - (CP + EE + ash), according to Sniffen et al. (1992). Nonfibrous carbohydrate (NFC), corresponding to the fractions A+B1, was measured by the equation NFC = 100×(CP + NDFap + EE + MM). The B2 fraction, which corresponds to the available fraction of fiber, was estimated by the difference between NDFap and the fraction C. The fraction C, corresponding to indigestible NDFap was determined according to the equation: C = (100 × NDFap (% DM) × 0.01 × lignin (% NDFap) × 2.4) / TC (% DM).

The levels of nonprotein nitrogen (NPN), neutral detergent insoluble protein (NDIP), and acid detergent insoluble protein (ADIP) were determined according to Licitra et al. (1996). Fraction A was obtained by the difference between total N and insoluble N (residual) in trichloroacetic acid (10%). The fraction B1 + B2 was calculated from the equation: B1 + B2 = 100 - (A + B3 + C). Fraction B3 was obtained by the difference between NDIP and ADIP, and fraction C was considered as ADIP.

Total digestible nutrient values (TDN) were estimated according to the National Research Council (NRC, 2001). In vitro dry matter digestibility (IVDMD) was obtained according to the two-stage methodology described by Tilley & Terry (1963) with changes proposed by Holden (1999). To measure the gas production kinetics, the in vitro technique was applied, using a pressure transducer according to Theodorou et al. (1994), in which 1 g of an air-dried sample (milled at 2 mm) was incubated in flasks (160 mL) together with 90 mL of nutrient medium, and CO$_2$ was then injected with 10 mL of ruminal fluid from two rumen-fistulated 6-year-old female cattle Girolando (5/8 Holstein x Gyr). Then the flasks were sealed with rubber stoppers and aluminum seals.

Subsequently, the flasks were incubated in a greenhouse that simulated a constant temperature rumen of 39°C. Cumulative gas production was estimated by measuring the pressure of the gases produced during the fermentative process, using a pressure transducer Logger AG100 (Agricer, São Paulo, SP, Brazil), in times 0, 2, 4, 6, 8, 10, 12, 15, 18, 21, 24, 30, 36, 42, and 48 hours after incubation.

The pressure per inch (PSI) was transformed into milliliters (mL) through the equation: Gas production (mL) = 5.1612×PSI - 0.3017, r² = 0.9873, generated in the Production Laboratory (LPG) of the Universidade Federal do Agreste de Pernambuco (Ufape) based on 937 observations, and adjusted for white and incubated dry matter. The cumulative gas production data were adjusted by the bicompartmental logistic model (Schofield et al., 1994) using the procedure NLMIXED of SAS.

$$V_t = \frac{V_{f1}}{1+e^{[2-4 \times kd1 \times (T-L)]}} + \frac{V_{f2}}{1+e^{[2-4 \times kd2 \times (T-L)]}} + \varepsilon,$$

in which: V_t is the accumulated volume over time t; V_{f1} is the maximum volume of gas for the fast digestion fraction (NFC); Kd_1 (h^{-1}) is the degradation rate of the rapid digestion fraction; L is latency in hours; T is time (h); V_{f2} is the maximum volume of gas for the slow digestion fraction (FC); kd_2 (h^{-1}), the specific rate of gas production by fraction degradation (FC).

Data were subjected to the analysis of variance, and the means were compared by the Tukey's test, at 5%

probability, through the statistical program SAS (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

The pH values in natura and pre-dried silage were smaller in the WI and GC+I treatments (Table 1). However, the pH values in all treatments described here were higher than the ideal range from 3.8 to 4.2 for a good fermentation proposed by McDonald et al. (1991). Treatments with the bacterial inoculant had the lowest pH values. This result suggests that in these treatments there was a larger population of lactic acid-producing bacteria, which favored a greater reduction of pH. Higher lactic acid content in the treatments without bacterial inoculation can be attributed to the greater acidification power of acetic and butyric acids. High pH values indicate a possible higher production of acetic and butyric acid, which are typical acids of undesirable fermentations (Pinho et al., 2013; Bezerra et al., 2019).

Although the pH values were above the ideal range, this result did not compromise the quality of silage. Therefore, the gas losses of in natura silage did not differ among treatments, but those of pre-dried silage showed the highest values in the WA and GC treatments. Between the two forms of silage, the gas losses in the pre-dried silage was higher than that of in natura silage in all treatments (Table 1). The lower production of gases of in natura silage may have occurred because of the lower presence of *Clostridium* bacteria during fermentation, as they produce butyric acid and CO_2, and their presence in the fermentation process is not desired. The values resulting of the two silages with their respective treatments are considered low, which is an indication of silage quality.

The effluent losses were higher in the treatments WI, WA, and GC+I of in natura silage. These results can be attributed to the higher moisture content present in these treatments (Table 1). The lowest value of effluent losses occurred in the GC treatment, as a result of the use of ground corn as moisture absorbing additive, which favored the reduction of the losses of the ensiled material. The use of absorbent additives is one of the main techniques used to soften the effluent production in the ensiled material, reducing secondary fermentation, as they favor the increases of both dry matter content and nutritional quality (Andrade et al., 2012; Bezerra et al., 2019). Consequently, regarding the DM content, in natura and pre-dried silage, GC+I showed higher values than the other treatments (Table 2).

The lower values for effluent losses in pre-dried silage may be related to the shrinkage that was performed before silage. The pre-dried is an important technique that aims to prevent nutrient losses through percolation in the ensiled material. Besides that, the wilting is a practice that helps increase the DM content and reduces the effluent production (Corrêa et al., 2016). Therefore, the DM of pre-dried silage was higher than that of in natura silage (Table 2).

Ammonia nitrogen (NH_3-N), expressed as a percentage of total nitrogen (% total N) showed differences between treatments in the in natura silage, in which the treatment with ground corn (GC) was higher than the other treatments (Table 1). In the form of pre-dried silage, the treatments without additive (WA) and ground corn (GC) had higher values of ammonia nitrogen than the other treatments, therefore, showing good preservation of proteins and nitrogen compounds in the two analyzed materials. McDonald et al. (1991) reported that concentrations below 10% in this ratio indicates silage of excellent quality.

The CP contents of in natura silage were higher in the treatments WA, GC, and WI, and the lowest CP values were found in the GC+I treatment (Table 2). The treatments in which corn was added as an additive, the protein content was lower, as the low content of CP

Table 1. Fermentative characteristics of the different treatments applied to arboreal cotton silage [*Gossypium hirsutum* var. *marie-galante* (G.Watt) J.B.Hutch.][1].

Trait	Silage	Treatment[2]			
		WI	GC	GC+I	WA
pH	In natura	4.69Ca	5.16Ba	4.46Da	5.25Aa
	Pre-dried	4.51Db	4.90Bb	4.63Ca	5.20Aa
Gas losses[3]	In natura	1.06Ab	1.26Ab	1.05Ab	1.28Ab
	Pre-dried	2.16Ba	2.59ABa	2.11Ba	3.04Aa
Effluent losses[4]	In natura	2.46ABa	2.31Ba	2.59ABa	3.08Aa
	Pre-dried	2.20Aa	2.18Aa	2.17Aa	2.35Ab
NH_3-N	In natura	0.61Ba	1.02Aa	0.63Bb	0.75ABb
	Pre-dried	0.79Ba	1.20Aa	0.86Ba	1.24Aa

[1] Means followed by equal letters, uppercases in the rows and lowercases in the columns, do not differ by Tukey's test, at 5% probability. [2]WI, with bacterial inoculant; GC, 2% ground corn; GC+I, 2% ground corn + bacterial inoculant; WA, without additives. [3]Percentage of dry matter (% DM). [4]Ensiled fresh matter (kg Mg^{-1} FM). NH_3-N, ammonia nitrogen (% of Total N).

in corn led to a dilution effect of this nutrient in the silage. In comparison between silages, the treatments WA and WI of in natura silage were superior to those of pre-dried silage (Table 2). The present study corroborates the findings of Bergamaschine et al. (2006) on 'Marandu' *Brachiaria brizantha*. The authors observed a 20.1% reduction in the CP content of the material subjected to pre-drying under the sun for 4 hours, which was attributed to soluble protein losses due to the extravasation of cellular content. The CP concentrations were higher than the values described

by Silva et al. (2015) and Coutinho et al. (2015), who evaluated silage of arboreal species and herbaceous legumes present in the Brazilian Semiarid region.

There was no difference for neutral detergent fiber (NDF) between treatments of in natura silage. However, in pre-dried silage, the WA, GC, and GC+I showed higher NDF values than the other treatments, and the WI showed the lowest NDF content (Table 2). In the two forms of silage, the average NDF values of treatments were lower concerning *Clitoria ternatea*, *Leucaena leucocephala*, *Bauhinia cheilantha*, and

Table 2. Chemical composition and total digestible nutrients of different treatments applied to silage of arboreal cotton [*Gossypium hirsutum* var. *marie-galante* (G.Watt) J.B.Hutch.][1].

Trait[2]	Silage	Treatment[3]			
		WI	GC	GC+I	WA
Dry matter (DM, g kg⁻¹ of fresh matter)	In natura	232.9Bb	228.4BCb	248.7Ab	217.7Cb
	Pre-dried	355.8Aa	355.2Aa	352.8Aa	344.4Aa
Organic mater (OM, g kg⁻¹ of DM)	In natura	905.6Ba	908.7Aa	904.6Bb	903.5Ba
	Pre-dried	905.5ABa	907.5Aa	907.3Aa	905.0Ba
Crude protein (CP, g kg⁻¹ of DM)	In natura	243.2Aa	236.7ABa	227.7Ba	245.1Aa
	Pre-dried	232.7Ab	233.1Aa	235.6Aa	231.8Ab
Ether extract (EE, g kg⁻¹ of DM)	In natura	20.7Aa	22.2Aa	22.3Aa	16.2Aa
	Pre-dried	20.6Aa	19.7Aa	15.3Ab	19.8Aa
NDF[2]	In natura	540.4Aa	558.8Aa	529.1Aa	565.1Aa
	Pre-dried	523.6Ba	528.1ABa	557.3ABa	569.1Aa
NDFap[2]	In natura	392.8Aa	393.9Aa	379.7Aa	396.9Aa
	Pre-dried	371.1Aa	383.1Aa	388.7Aa	406.9Aa
ADF[2]	In natura	314.9Ba	351.2Aa	332.3ABa	344.9Aa
	Pre-dried	294.5Ba	313.8Bb	297.5Bb	346.0Aa
Cellulose[2]	In natura	187.4Aa	189.7Aa	185.5Aa	198.1Aa
	Pre-dried	186.9Aa	196.9Aa	180.2Aa	198.0Aa
Hemicellulose[2]	In natura	225.4Aa	207.6Aa	196.8Ab	220.2Aa
	Pre-dried	229.1Aa	214.2Aa	259.8Aa	223.1Aa
ADL[2]	In natura	127.5Ba	161.4Aa	146.8ABa	146.8ABa
	Pre-dried	107.6Bb	116.9Bb	117.3Bb	147.9Aa
NDIP[2]	In natura	125.5Ba	133.6ABa	123.5Bb	140.2Aa
	Pre-dried	126.1Aa	126.1Aa	137.2Aa	134.4Aa
ADIP[2]	In natura	43.6Ca	55.8ABa	48.0BCa	56.8Aa
	Pre-dried	40.7Ba	41.2Bb	40.3Bb	52.0Aa
Nonfibrous carbohydrate (NFC)[2]	In natura	248.8Ab	255.8Aa	275.0Aa	245.3Aa
	Pre-dried	281.1Aa	271.6Aa	267.6Aa	246.5Aa
Fibrous carbohydrate (FC)[2]	In natura	392.8Aa	393.9Aa	379.7Aa	396.9Aa
	Pre-dried	371.1Aa	383.1Aa	388.8Aa	406.9Aa
TDN[2]	In natura	499.0Ab	458.7Cb	484.6Bb	456.5Cb
	Pre-dried	524.7Aa	516.3Ba	503.9Ca	464.9Da

[1]Means followed by the equal letter, uppercases in the rows and lowercases in the columns, do not differ by Tukey's test, at 5% probability. [2]NDF, neutral detergent fiber; NDFap, neutral detergent fiber corrected for ash and protein; ADF, acid detergent fiber; ADL, acid digested lignin; NDIP, neutral detergent insoluble protein; ADIP, acid detergent insoluble protein; TDN, total digestible nutrients. [3]WI, with bacterial inoculant; GC, ground corn; GC+I, ground corn + bacterial inoculant; WA, without additives. [2] (g kg⁻¹) of DM.

Mimosa caesalpiniifolia, which are part of the diet of ruminants in the Semiarid region (Santos et al., 2017). The NDF is an indicator of food quality, and high levels of NDF in the diet reduce the voluntary intake in ruminants by the filling effect (Pinho et al., 2018). However, according to Alves et al. (2016), the unavailability of fiber in both quantity and quality causes disturbances in the animal energy metabolism and can compromise the animal performance, interfering with the characteristics of end products.

The highest concentrations of acid detergent fiber (ADF) and acid digested lignin (ADL) were found in the GC, GC+I, and WA treatments of in natura silage (Table 2). In pre-dried silage, the highest content of these compounds was obtained in the WA treatment. When the two forms of silage were compared, in nature silage was superior to pre-dried silage for: ADF, when subjected to the GC and GC+I treatments; and ADL, when subjected to WI, GC, and GC+I (Table 2). ADF, the most indigestible fraction of food, and lignin presented low or no digestibility, which influences the digestibility of plant cell wall components (Wanderley et al., 2012).

Neutral detergent insoluble protein (NDIP) and acid detergent insoluble protein (ADIP) content were higher in the treatments GC and WA in natura silage (Table 2). There was no difference for NDIP in the form of pre-dried silage. The treatment GC+I had higher NDIP contents in pre-dried silage than that of in natura silage. Comparing the two forms of silage, there was a difference in the treatments GC and GC+I, in which ADIP concentrations were higher in natura silage than in pre-dried silage (Table 2). Attention should be paid to the levels of NDIP and ADIP because, if a considerable part of the crude protein of the feed is linked to the fibrous fraction, lignin becomes resistant to microorganism enzymes, that is, it is unavailable for microorganisms, which decreases digestibility of forage in the animals, affecting the efficiency of rumen microbial synthesis and the animal performance (Licitra et al., 1996; Nunes et al., 2016; Oliveira et al., 2020).

The total carbohydrate (TC) concentration in the in natura silage was higher in the GC+I treatment, and the lowest TC content occurred in the WI treatment (Table 3). The treatments applied to the pre-dried silage form showed no differences in TC contents. When comparing both forms of silage, pre-dried silage subjected to the WI and WA treatments was

superior to in natura silage. Moreover, fractions A + B1 (soluble fraction) and B2 (potentially degradable fiber) did not differ between treatments, nor silage forms (Table 3). The proportion of fraction B2 was higher than fractions A + B1 and C, which can be attributed to higher cellulose contents concerning the nonfibrous carbohydrates found in the evaluated silages, and, because of this, they may present a slow rate of ruminal degradation.

The content of fraction C (the most unavailable carbohydrate fraction) was the highest in the GC, GC+I, and WA treatments, and the lowest, in the WI treatment, both for in natura and pre-dried silages. When comparing the forms of silage, fraction C differed in the WI and GC treatments, being superior

Table 3. Carbohydrates and nitrogen compounds fractionation of the different treatments applied to silage of arboreal cotton [*Gossypium hirsutum* var. *marie-galante* (G.Watt) J.B.Hutch.][1].

Trait[2]	Silage	Treatment[3]			
		WI	GC	GC+I	WA
		Carbohydrate			
TC[4]	In natura	641.6Bb	649.7ABa	654.7Aa	642.2ABb
	Pre-dried	653.1Aa	654.7Aa	654.4Aa	652.4Aa
A + B1[5]	In natura	387.7Aa	393.6Aa	420.6Aa	381.8Aa
	Pre-dried	430.9Aa	414.8Aa	407.8Aa	377.2Aa
B2[5]	In natura	485.3Aa	441.0Aa	433.4Aa	475.8Aa
	Pre-dried	460.1Aa	459.0Aa	464.2Aa	476.3Aa
C[5]	In natura	127.0Ba	165.3Aa	146.0ABa	142.3ABa
	Pre-dried	108.0Bb	126.1ABb	130.0ABa	146.4Aa
		Nitrogen compounds			
CP[4]	In natura	243.2Aa	236.7ABa	227.7Ba	245.1Aa
	Pre-dried	232.7Ab	233.1Aa	235.6Aa	231.8Ab
A[5]	In natura	162.8ABa	174.6Aa	125.9Ba	140.6ABa
	Pre-dried	118.9Ab	143.6Aa	126.7Aa	130.7Aa
B1 + B2[5]	In natura	321.4ABa	265.6Bb	330.2Aa	287.4ABa
	Pre-dried	338.8Aa	315.1Aa	290.7Aa	289.0Aa
B3[5]	In natura	336.4Aa	328.9Aa	332.8Ab	340.4Aa
	Pre-dried	367.3Aa	364.0Aa	411.5Aa	355.8Aa
C[5]	In natura	179.4Ba	230.9Aa	211.2ABa	231.6Aa
	Pre-dried	175.0Ba	177.3Bb	171.1Bb	224.4Aa

[1]Means followed by the equal letter, uppercases in the rows and lowercases in the columns, do not differ by Tukey's test, at 5% probability. [2]Trait: TC, total carbohydrate; A+B1, soluble fraction; B2, potentially degradable fiber; C, indigestible fiber; CP, crude protein; A, nonprotein nitrogen; B1+B2, high and medium nitrogen fraction ruminal degradation; B3, slow degrading nitrogen fraction; C, unavailable nitrogen fraction. [3]WI, with bacterial inoculant; GC, ground corn; GC+I, ground corn + bacterial inoculant; WA, without additives. [4](g kg⁻¹) of DM. [5](g kg⁻¹) of TC.

in in natura silage (Table 3). Lower values for this fraction are more desirable because fraction C is linked to carbohydrates unavailable for digestion. Forages with high levels of fraction C interfere with the ruminal repletion, due to the indigestible characteristic of this fraction, consequently affecting the animal feed intake (Mendoza et al., 2014).

Nitrogen fractionation of in natura silage showed higher concentration in fraction A in the GC treatment (Table 3). When forage has a high protein content and most of this protein is in fast degradation fractions (nonprotein nitrogenous compounds), it is necessary to supply a carbohydrate source with a high ruminal degradation rate to allow the microbial synthesis in the rumen to be efficient (Oliveira et al., 2020).

The fraction B1 + B2 in natura silage showed the highest value in the GC+I treatment. In pre-dried silage, this fraction did not differ between treatments (Table 3). Among the evaluated treatments, the WI ,in the pre-dried silage, and the GC+I, in the in natura silage, showed the highest contents for the fraction B1 + B2, thus having greater potential as a source of

rumen digestible protein than the other treatments. The concentrations of fraction B3 did not differ for both in natura and pre-dried silages. In the comparison between the two silages, the GC+I treatment in the pre-dried silage was higher than that of in natura silage (Table 3). The higher content of fraction B3 obtained in the GC+I treatment of pre-dried silage may interfere with a lower ruminal degradation, but the protein that escapes ruminal degradation may have high intestinal digestibility (rumen undegraded protein).

In fraction C (nitrogenous compounds), the highest levels in natura silage were observed in the treatments WA and GC. This result can be attributed to the N of this fraction that is most unavailable, as it is made up of proteins and N compounds linked to lignin, compounds of plant metabolism (tannins), and products derived from the chemical reaction of Maillard, which are resistant to microbial digestion and degradation (Sniffen et al., 1992). Thus, the higher concentrations of fraction C in N compounds, as well as the fraction C of the carbohydrates obtained in the treatment WA negatively influenced the in vitro dry matter

Table 4. In vitro gas production parameters and dry matter digestibility (IVDMD) of different treatments applied to silage of arboreal cotton [*Gossypium hirsutum* var. *marie-galante* (G.Watt) J.B.Hutch.][1].

Trait[2]	Silage	Treatment[3]			
		WI	GC	GC+I	WA
Vt₁	In natura	114.2Cb	130.2ABa	135.9Aa	121.1BCa
	Pre-dried	125.3ABa	137.2Aa	126.1ABa	116.8Ba
Vt₂	In natura	121.1Cb	141.7ABa	143.3Aa	129.0BCa
	Pre-dried	133.4ABa	145.5Aa	134.4ABa	126.4Ba
Vf1	In natura	17.97Ba	20.50ABb	26.66Aa	22.8ABa
	Pre-dried	18.72Ba	28.86Aa	21.38Ba	18.70Ba
kd1	In natura	0.177Aa	0.118Aa	0.120Aa	0.117Aa
	Pre-dried	0.145Aa	0.114Aa	0.135Aa	0.142Aa
Vf2	In natura	103.2Cb	121.2Aa	116.6ABa	106.2BCa
	Pre-dried	114.6Aa	116.7Aa	113.0Aa	107.6Aa
kd2	In natura	0.032Aa	0.029Bb	0.031Aa	0.030ABa
	Pre-dried	0.031Aa	0.030Aa	0.030Aa	0.030Aa
Lag time	In natura	13.21Aa	12.63Aa	12.29Aa	12.30Aa
	Pre-dried	12.92Aa	12.58Aa	12.64Aa	10.75Aa
IVDMD (g kg⁻¹ of DM)	In natura	443.3Aa	444.7Aa	458.3Aa	427.9Ba
	Pre-dried	446.3Aa	446.1Aa	454.2Aa	427.5Ba

[1]Means followed by the equal letter, uppercases in the rows and lowercases in the columns, do not differ by Tukey's test, at 5% probability. [2]Vt₁, total observed volume (mL g⁻¹ DM); Vt₂, total volume (mL g⁻¹ DM) found from model; Vf1, volume (mL) from gases produced by the degradation of the fraction A+B1 of Cornell Sistem (NFC) fast fermentation; kdl (% h⁻¹), degradation rate of fast digestion fraction (NFC); Vf2, volume of gases produced by the degradation of fraction B2 of Cornell Sistem (FC), slow degradation; kd2 (% h⁻¹), specific rate of gas production by degradation of fraction B2 (FC); IVDMD, in vitro dry matter digestibility. [3]WI, with bacterial inoculant; GC, ground corn; GC+I, ground corn + bacterial inoculant; WA, without additives.

digestibility (IVDMD), in the two silage forms that did not receive additive (Table 4). However, the total digestible nutrient (TDN) value of the WI treatment was higher than those in the other treatments in both silage forms (Table 2). This result can be attributed to the lower levels of ADL, fraction C of the carbohydrate, and nitrogenous compounds.

The total volume of gas observed for the variables Vt1, Vt2, Vf1, and Vf2 in natura and pre-dried silages for GC+I and GC treatments were higher than those of the other treatments (Figure 1 and Table 4). These results are attributed to the higher total carbohydrate (TC) for Vt1 and Vt2. The gas volume of the variable Vt1 showed values close to that of Vt2, confirming the fit of the applied model (Table 4). For Vf1 and

Vf2 the largest volumes of gases produced can be attributed to A + B1 and B2 carbohydrate fractions, respectively. Thus, the carbohydrates in the fraction B2 of these treatments showed a higher degradation potential. The highest final volume of gas had a greater availability of nutrients for rumen microorganisms (Oliveira et al., 2020).

The highest degradation rate in the variable kd2 was observed in the WI, GC+I, and WA treatments of in nature silage (Table 4). The highest value can be attributed to the lower levels of ADL and fraction C of carbohydrates. Between the two forms of silage, kd2 was superior in pre-dried silage subjected to the GC treatment. The degradation rate kd1 did not differ between the two forms of silage.
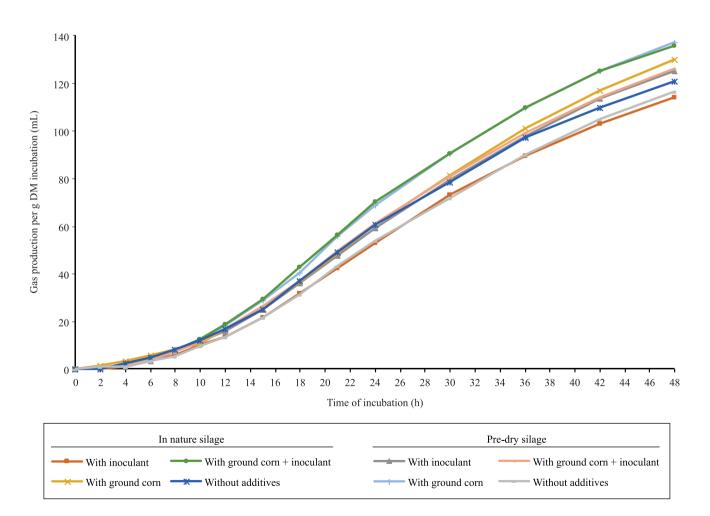

Figure 1. Total volume of gases produced during in vitro incubation in the different treatments applied to silage of arboreal cotton [*Gossypium hirsutum* var. *marie-galante* (G.Watt) J.B.Hutch.].

Conclusions

1. Arboreal cotton (*Gossypium hirsutum* var. *marie-galante*) silage associated with the bacterial inoculant or inoculant with 2% ground corn, has a better fermentation profile, besides improving the energy and nutritional value, both in nature and pre-dried forms of silage.

2. In natura silage shows a greater advantage to the rural producer than the pre-dried silage because it is less laborious and does not depend on climatic conditions for pre-drying.

Acknowledgments

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