Acta Scientiarum
http://periodicos.uem.br/ojs
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v46i1.63835

Effect of cutting time and storage time on the nutritional value of stargrass hay

Matheus Gonçalves Ribeiro[1*], Tamara Tais Tres[2], Antonio Vinícius Iank Bueno[1], João Luiz Pratti Daniel[1] and Clóves Cabreira Jobim[1]

[1]Departamento de Zootecnia, Universidade Estadual de Maringá, Avenida Colombo, 5790, 87020-900, Maringá, Paraná, Brazil. [2]Escola Agrícola de Jundiaí, Universidade Federal do Rio Grande do Norte, Natal, Rio Grande do Norte, Brazil. *Author for correspondence: E-mail: ribeiro.matheus@gmail.com

ABSTRACT. The objective of this study was to assess the effect of cutting time on the nutritional composition and dehydration rate of stargrass, as well as the nutritional value of the hay as a function of storage time. Two plant cutting times were analyzed: at 13:00 (H13) and 17:00 (H17). After cutting, the dehydration rate of both the plant and its fractions until baling was monitored. The bales were checked for nutritional composition and digestibility after 30, 60, 90 and 120 days. At the time of cutting, a difference was observed for the concentrations of ethanol-soluble carbohydrates, which were higher for H17 (90.3 g kg^{-1}) compared to H13 (52.9 g kg^{-1}). Leaf dehydration rates were higher in the H17 treatment. Cutting time had no influence on the nutritional value of the hay. With storage time, there was an increase in the levels of neutral detergent fiber and acid detergent fiber, and a reduction in the content of ethanol-soluble carbohydrates. It was concluded that cutting at 17:00 allows for a greater accumulation of soluble carbohydrates in the plant. Cutting time does not change the time required for dehydration and the nutritional value of the hay. Storage time reduces soluble components and increases fibrous constituents.

Keywords: soluble carbohydrates; dehydration; storage; haymaking; forage quality.

Received on June 2 2022.
Accepted on February 28 2023.

Introduction

Throughout the day, sunlight acts directly on the photosynthetic capacity of plants, boosting carbon dioxide (CO2) fixation and converting the greenhouse gas into carbohydrates. The first molecules produced by plants, through photosynthesis, are simple carbohydrates, such as glucose and fructose, which will later be complexed in the form of sucrose, starch and fructans (Taiz, Zeiger, Møller, & Murphy, 2015).

Postponing the cutting of forage plants to the end of the afternoon is a way to increase the concentrations of highly digestible carbohydrates (e.g., non-fiber carbohydrates – NFCs) (National Research Council [NRC], 2016). In this context, for instance, forage cutting/harvest management at different times of the day has been presented as a tool to improve the energy value of forage.

The effect of harvesting forage in the late afternoon was evaluated in animals by Vasta et al. (2012), who concluded that lambs grazing on ryegrass in the afternoon had a fatty acid (FA) profile rich in conjugated linoleic acid in their meat, which is desirable for good human health. Evaluating dairy cows at the end of lactation, Vibart et al. (2017) observed a small difference in production and concentrations of milk fat and protein when the animals grazed on ryegrass in the afternoon.

Applying this strategy to the production of preserved forages, cutting in the afternoon can be a way to reduce fibrous components and increase forage digestion, in addition to contributing to greater nutrient preservation. This strategy was studied by Yari et al. (2012), with alfalfa hay; they reported that plants harvested in the late afternoon showed higher concentrations of photoassimilates. In a study by Dong, Wang, Dong, and Shao (2022) with sorghum harvested at 7:00, 13:00 and 17:00, there was an increase in soluble carbohydrate contents as the hours of the day passed.

Thus, harvesting forage in the afternoon could suggest a higher fraction of readily soluble nutrients, but with a shorter dehydration time during the first day of haymaking. There is a lack of studies of this nature with tropical forages in the literature, especially in Brazilian conditions.

Another factor that directly influences hay quality is storage period, since the action of microorganisms and oxidative reactions can occur, mainly depreciating soluble compounds (Coblentz, Coffey, Young, &

Bertram, 2013; Abot, et al., 2015; Sunahara et al., 2017). According to Collins (1995), the greatest changes in nutritional composition and nutrient losses are related to hay with high moisture content (250 g kg^{-1}) during storage, with moisture being considered adequate to prevent mold growth after baling of 200 g kg^{-1}.

Based on these assumptions, the objective of this research was to assess the effect of cutting time on the nutritional value and dehydration rate of stargrass, as well as the nutritional value of the hay as a function of storage time.

Material and methods

Field management

The experimental area used was located on the Iguatemi Experimental Farm, belonging to the State University of Maringá. An area of 0.55 ha^{-1} with stargrass (*Cynodon* spp) already working as a haymaking field for five years was used. This area received maintenance fertilization with 60 kg ha^{-1} of K_2O and 45 kg ha^{-1} of N.

A standardization cut was made, and the forage was harvested after 60 days of regrowth. Seeking better homogeneity in data collection, the hay field was divided into five experimental blocks.

The treatments consisted of a cut made at 13:00 (H13) or 17:00 (H17), which resulted in approximately six and ten hours of exposure to light, respectively, on the first day.

Forage mass availability was estimated by means of destructive sampling, just before cutting. Samples were collected close to the ground, at ten different points (two per block), using a metal square (0.25 m^2).

To better characterize the available forage, the morphological components (leaf, stem+sheath, and senescent+dead material) were separated from a composite sample of approximately 500 g. After separation, the contents of the samples, subjected to morphological separation or not, were placed in a forced ventilation oven at 55°C until constant weight, for drying.

The estimated forage mass was 6.6-ton ha^{-1} DM at the time of cutting, with 402.2 g kg^{-1} DM of leaves, 533.0 g kg^{-1} DM of stem+leaf sheath, and 64.8 g kg^{-1} DM of senescent+dead material.

For haymaking, the forage was mowed approximately 5 cm above the soil surface with the aid of a disc mower without conditioning system (AT 9165, Agritech, Indaiatuba, Brazil).

At 13:00 on the day after mowing, the forage was turned over using a rake set to spread. Due to the predominant good meteorological conditions and evaluations during the dehydration period, it was considered that only one forage turning operation was sufficient.

On the fourth day after cutting, with the aid of a moisture meter (F-2000, Delmhorts Instruments Co., Towaco, USA), it was observed around 13:00 that the forage had moisture around 180 g kg^{-1} DM; during the dehydration process, moisture was monitored 4 times a day until the moment of baling was established.

Upon reaching the desired moisture for baling, the forage was wound up and packed in prismatic bales (approximately 12 kg; AP 41N baler, Nogueira, Itapira, Brazil), which were identified by treatment (H13 or H17).

Dehydration behavior

To show the real behavior throughout the dehydration period, a dehydration curve of the forage mass in the field was built. Five samples per treatment (one per block) were collected for evaluation of moisture content and building of the dehydration curve, as shown in the itinerary described in the paragraph below.

First day of dehydration (D1): moment of cutting; two and six hours after cutting (the latter only for H13). Following days (D2 and D3): the forages were sampled at 08:00, 11:00, 14:00 and 17:00. Last day (D4): samples were collected similarly to the previous day until 14:00, the time at which baling started.

To observe the representativeness of the morphological components of the forage, as well as the losses resulting from haymaking, a subsample per block was fragmented into these fractions. Immediately after collection and separation, the samples were dried in an oven at 55°C for DM determination.

Because of their different cutting times, the best way to compare the dehydration curves was by determining the fractional dehydration rate (k), given in percentage per hour (% h^{-1}). In order for k to be obtained, the moisture values (in g kg^{-1} DM) for whole plant, leaf and stem+sheath samples at four different times were used: at the time of cutting; at 17:00 on D2 and D3, and at the time of baling, at 14:00 on D4. Moisture values were transformed into natural logarithm (ln), per block, linear equations were determined, and fractional dehydration rates (k) were estimated by the angular coefficient of the curve.

Storage

At the time of baling, three forage samples were randomly collected from the windrow and sent to the greenhouse for DM determination. The samples collected at the time of baling were considered as storage time zero. Twelve bales from each treatment were randomly selected and stored in a shed for 30, 60, 90 and 120 days.

The shed where the bales were stored had a concrete floor, a ceiling height of 4 m with a tiled roof, and completely open sides. The piles of bales were placed at the center of the shed in order to avoid exposure to rain. The bales were placed on pallets to avoid direct contact with the floor, with one pile of bale per treatment.

Meteorological data for the experimental period are shown in Figure 1.

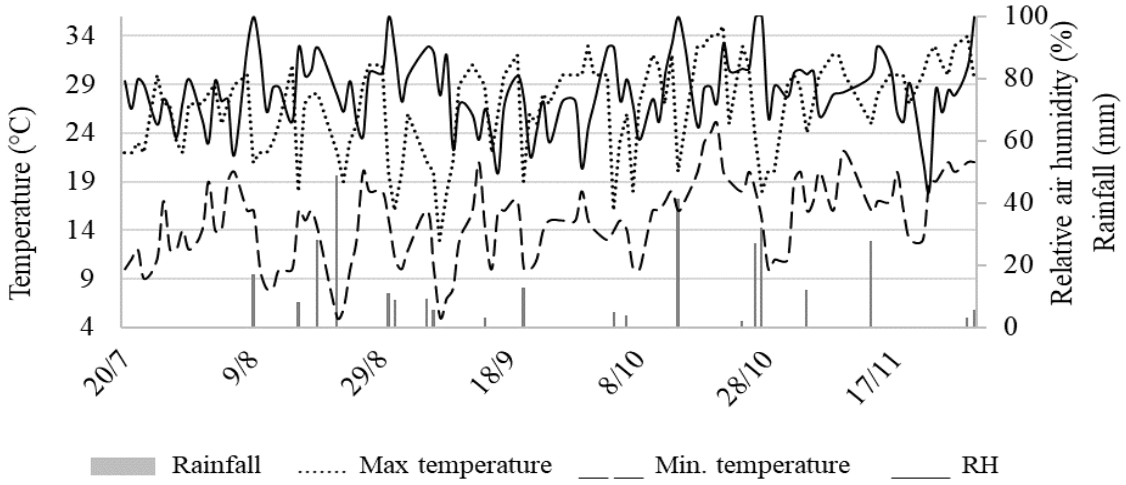

Figure 1. Meteorological data for the experimental period. Rainfall (mm), Maximum and minimum temperatures (°C), and Relative air humidity (%).
Source: Iguatemi experimental farm's meteorological station.

At each sampling time, three bales were drawn randomly and fully ground (Hammer Grinder 30 hp, Pereira Máquinas Agrícolas, Londrina, Brazil), passing through a screen with a 5 mm sieve. After grinding, the whole material was homogenized, and a representative sample was collected and sent to the laboratory for DM evaluation.

Laboratory analysis

To evaluate the impact of cutting time on forage quality and the changes during storage, samples collected at cutting time, baling time and after different storage periods were analyzed.

Following dehydration in a forced ventilation oven, all samples were milled in a knife mill to 1 mm and stored in jars with lids. Analyses were performed in accordance with Association of Official Analytical Chemists (AOAC, 1990) for crude protein (CP; procedure No. 984.13), ether extract (EE; 920.39), ash (942.05), and total DM (procedure 930.15). For neutral detergent fiber (NDF) determination, sulphite and thermostable amylase were not added; acid detergent fiber (ADF) was analyzed sequentially to NDF, both in accordance with the methodology proposed by Goering and Van Soest (1979).

Ethanol-soluble carbohydrates (ESCs) were obtained by extraction in ethanol solution, 800 mL L^{-1}, following Hall, Hoover, Jennings, and Webster (1999). In vitro DM digestibility was determined using a methodology proposed by Tilley and Terry (1963), adapted for artificial rumen (Holden, 1999).

Organic matter (OM) values were calculated using ash values, with 1000 – ash (g kg^{-1} DM) being equal to OM. Hemicellulose (Hem) was obtained by the NDF – ADF difference. Neutral detergent-soluble compounds (NDSCs) were obtained through the calculation proposed by Van Soest (1994). To calculate non-fiber carbohydrates (g kg^{-1} DM), the equation proposed by the NRC (2016) was used, with NFC = 1000 – (NDF + EE + CP + ash).

Statistical analyses

The impact of cutting time on forage quality at the time of cutting and k values (whole plant, leaf, and stem+sheath) was analyzed by means of a completely randomized block design using mixed models (PROC MIXED, SAS Institute Inc., Cary, NC, USA), considering treatment effects as fixed effect, and block effect as random. Means were considered statistically different when presenting a p value < 0.05.

To compare the effect of cutting time and storage period, a completely randomized experimental design was used in a factorial scheme with repeated measures over time (PROC MIXED, SAS Institute Inc., Cary, NC, USA). For the cutting time effect (C), means were compared by F test at 5% significance, considering response trend ($0.05 > p < 0.10$).

For storage period effect (S) or interaction effect (C x S), data were compared by orthogonal contrasts (linear and quadratic). When a contrast effect was observed, PROG REG (SAS Institute Inc., Cary, NC, USA) was used to estimate the regression equations, considering the highest regression coefficient (r^2) and lowest mean squared error (RMSE).

Results and discussion

Evaluating the nutritional composition of stargrass (*Cynodon* spp) at the time of cutting for haymaking (Table 1), only ESC levels showed a difference, with higher values in the forages harvested at 17:00, which had an average concentration 71% higher (90.3 *vs.* 52.9 g kg^{-1} for H17 and H13, respectively) in relation to the 13:00 cut.

The higher concentration of ESCs for forage cut at 17:00 in relation to forage cut at 13:00 was a response attributed to the cutting time, due to the greater fixation of atmospheric CO_2 by the plant as a result of photosynthesis; in C4 plants, this accumulation derives from a fixation and assimilation that is greater than what the plant requires (Taiz et al., 2015; Silva, Brito, Lafrenière, & Berthiaume, 2020). A study conducted with different cutting times for the sorghum-sudangrass hybrid also identified a higher content of soluble carbohydrates for cutting in the late afternoon (Dong et al., 2022).

Table 1. Forage nutritional value at cutting time (n, 10).

Items‡	H13† Mean	H17† Mean	SE	*P value*
DM	310.2	306.3	8.0	0.825
OM	935.2	929.5	2.0	0.111
CP	94.2	95.8	4.3	0.838
EE	17.5	17.6	0.6	0.937
NDF	722.1	705.4	5.7	0.190
ADF	340.5	333.6	3.7	0.173
Hem	381.5	371.8	3.3	0.274
NDSCs	213.1	224.1	4.7	0.385
NFCs	98.5	112.0	5.8	0.414
ESCs	52.9b	90.3a	8.9	0.039

† Cutting made at 13:00 (H13) and 17:00 (H17); ‡data presented in g kg^{-1} of dry matter (DM). OM: organic matter. CP: crude protein. EE: ether extract. NDF: neutral detergent fiber. ADF: acid detergent fiber. Hem: Hemicellulose. NDSCs: neutral detergent-soluble compounds; NFCs: non-fiber carbohydrates; ESCs: ethanol-soluble carbohydrates; SE: standard error.

Figure 2 shows the actual dehydration curve, obtained with whole-plant samples (Figure 2A) and leaf and stem+sheath fractions (Figures 2B and 2C, respectively) throughout the dehydration period. It is observed that there is a fluctuation in moisture content for the plant and its respective fractions during the days of dehydration. When the relative humidity of the ambient air is very high, as is often the case at night, the vapor pressure gradient can invert, drawing moisture back into the plant (Rotz, 1995). A similar result was found in the study by Pasqualotto et al. (2015), in which the plants showed rehydration in the morning because of dew, although their DM levels increased throughout the day.

Among the morphological components of the plant, at the end of the dehydration period, the stem+sheath fraction in the H17 treatment showed higher moisture (358.8 g kg^{-1} DM) compared to the H13 treatment (267.3 g kg^{-1} DM), consequence of a lower dehydration rate (k), as observed in Figures 2C and 3C.

The treatment harvested at 17:00 stayed less time exposed to solar radiation for initial water loss. However, the shorter dehydration time did not affect the DM content of the whole plant for baling, which was 807 g kg^{-1} for the H13 treatment and 801 g kg^{-1} for the H17 treatment (Table 2), a determining factor for the storage quality of this food (Collins, 1995).

The fractional dehydration rate (k) (Figure 3) of the whole plant was 1.68% h^{-1} for the H13 treatment and 1.71% h^{-1} for the H17 treatment, with no difference between treatments. The fractional dehydration rate of the stem fraction also showed no difference, with values of 1.33 and 1.07% h^{-1} for H13 and H17, respectively. For the leaf fraction, H17 had a higher k compared to H13 (2.60 *vs.* 2.36% h^{-1}, respectively, $p < 0.05$).

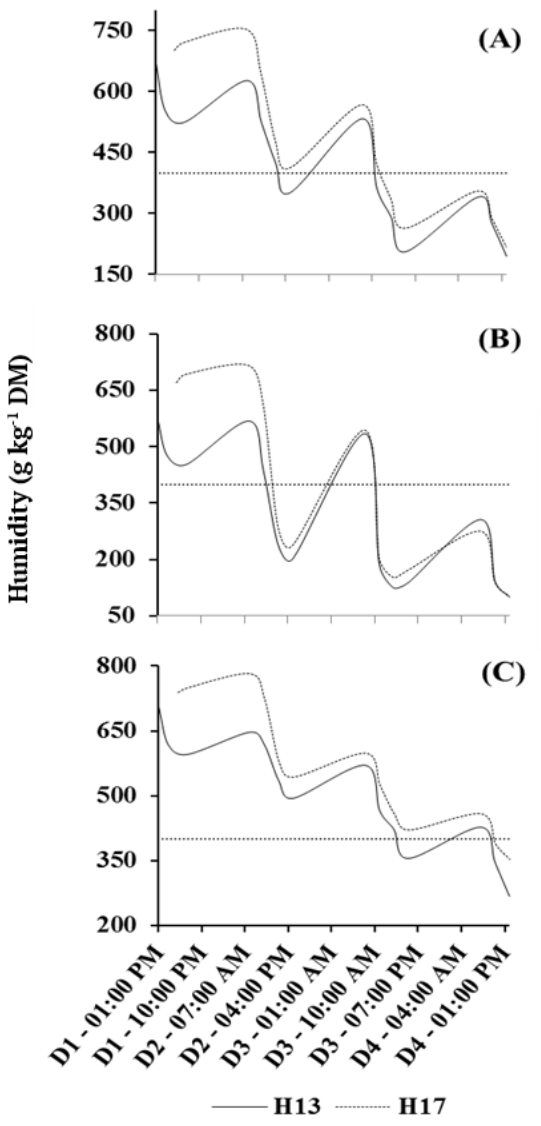

Figure 2. Actual dehydration behavior curve for African stargrass plants (A), as well as leaf (B) and stem+sheath (C) fractions, mowed at 13:00 (H13) or 17:00 pm (H17). Dotted line demarcating the "death" point of the plant (400 g kg^{-1} DM).

Table 2. Nutritional composition (g kg^{-1} DM) of African stargrass hays mowed at 13:00 and 17:00 throughout the storage period (n, 30).

	Cutting time										SE	*P value*‡		
	13:00 (H13)					17:00 (H17)								
	Storage (Days)											C	S§	C*S
Items†	0	30	60	90	120	0	30	60	90	120				
DM	807	881	907	902	912	801	880	904	905	916	5.6	0.96	<0.01L,Q	0.89
OM	935	934	939	932	931	937	929	924	925	928	4.0	0.09	0.46	0.33
CP	87.1	92.6	80.5	88.3	94.3	84.3	103	115	114	80.8	9.8	0.15	0.43	0.13
EE	14.0	14.8	13.7	12.7	15.1	14.3	12.1	13.2	13.5	15.5	1.0	0.61	0.26	0.48
NDF	727	737	767	754	755	716	749	751	755	754	10.3	0.65	0.01L,Q	0.70
ADF	339	354	380	373	376	337	367	364	372	370	9.2	0.69	<0.01L,Q	0.63
Hem	387	382	387	381	379	378	382	387	383	383	7.7	0.89	0.95	0.93
NDSCs	208	197	172	178	176	221	180	173	170	174	11.1	0.73	<0.01L,Q	0.73
NFCs	107	89.5	78.0	77.0	66.5	123	64.9	44.7	42.5	77.7	15.2	0.25	0.01L,Q	0.31
ESCs	46.1	47.8	42.4	37.6	33.6	53.2	34.7	18.7	18.5	28.4	6.6	0.06	0.02L	0.20
IVDMD	600	582	550	566	549	617	599	597	577	577	23.4	0.18	0.35	0.94

†Data presented in g kg-1 of dry matter (DM). OM: organic matter. CP: crude protein. EE: ether extract. NDF: neutral detergent fiber. ADF: acid detergent fiber. Hem: Hemicellulose. NDSCs: neutral detergent-soluble compounds; NFCs: non-fiber carbohydrates; ESCs: ethanol-soluble carbohydrates; IVDMD: in vitro DM digestibility; SE: standard error of the interaction; ‡ Cutting time effect (C), storage time (S), and interaction between factors (C*S); § Orthogonal contrasts: Linear (L), Quadratic (Q).

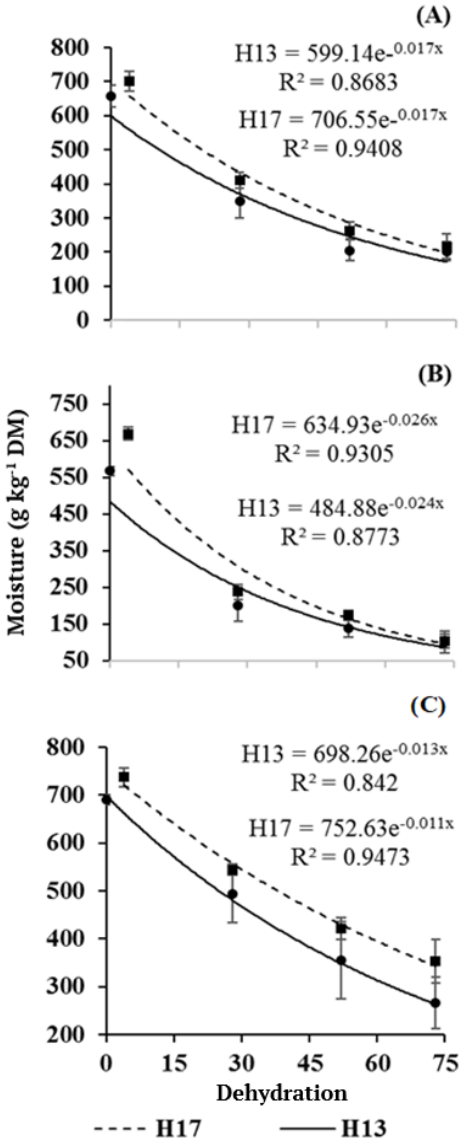

Figure 3. Dehydration rate used to determine fractional dehydration rate (k) values for: A, whole plant (n, 40); B, leaf (n, 40) and; C, stem+sheath (n, 40).

The leaves cut at H17 eliminated a greater amount of water per hour; even with a shorter period of exposure to the sun for dehydration, they reached the end of the dehydration period with a moisture content similar to that of the treatment mowed at 13:00 (100.3 *vs.*102.7 g kg^{-1}, respectively; $p > 0.10$). The water loss rate of the stem+sheath fraction is lower compared to that of the leaf, due to the morphological differences of the tissues (Machado, Neres, Castagnara, Nath, & Diaz, 2019).

Figures 2B and 3B illustrate this balance between cutting times. The leaves have a metabolically more active tissue than the stem does, and a lower proportion of fiber and lignin, which acts as a barrier in dehydration; water evaporates quickly from the leaf blade, dragging part of the stem water with it (Moser, 1995).

Table 2 presents the nutritional composition of the hays during the storage period. Cutting time had no effect ($p > 0.05$) on the evaluated hay variables (DM, OM, CP, EE, NDF, ADF, Hem, NDSCs, NFCs and ESCs, IVDMD).

For DM concentrations, the mean values observed during storage stood at 881.4 *vs.* 881.2 g kg^{-1}, respectively, for H13 and H17. The mean NDF and ADF concentrations for H13 were 747.20 and 364.6 g kg^{-1} DM, and 744.7 and 362.1 g kg^{-1} DM for H17.

The neutral detergent-soluble compounds (NDSCs) showed mean levels of 186.2 g kg^{-1} DM in the H13 treatment, and 183.7 g kg^{-1} DM in the H17 treatment. Cutting time also did not influence the mean NFC concentrations, the values of which stood at 83.6 g kg^{-1} DM for H13 *vs.* 70.5 g kg^{-1} DM in H17.

The H13 treatment tended to have a higher OM concentration (P=0.09) compared to the H17 treatment, with mean values during the storage period being 934.1 *vs.* 928.4 g kg^{-1} DM, respectively. The same behavior

was observed for the mean ESC values (P=0.06), with H13 presenting a concentration of 41.5 g kg^{-1} DM, which is higher than H17 (30.7 g kg^{-1} DM).

Pasqualotto et al. (2015) observed a reduction in stomatal conductance in Tifton 85 leaves one hour after cutting, which caused a drop in net photosynthesis and triggered a negative net photosynthesis due to respiration after the plant was sectioned. This is what has the most influence on the reduced ESC concentration of the plant after cutting (Moser, 1995).

Once the cut is made and the dehydration phase begins, the plant continues breathing, and its enzymes remain active for some time after the cut. In addition to these events, microorganisms that are naturally present in forages continue their activity as long as there is sufficient moisture; these processes reduce the content of soluble carbohydrates, and the longer the dehydration, the greater the effect on this component (Collins, 1995).

This may explain why the H13 treatment presented 52.9 g kg^{-1} DM of ESCs at the time of cutting (Table 1) and reached 46.1 g kg^{-1} DM of ESCs at baling (Table 2), while the H17 treatment accumulated a higher content of soluble carbohydrates at cutting (90.3 g kg^{-1}), with a reduction in these contents at the time of baling (53.2 g kg^{-1} DM of ESCs). That is, there were greater ESC losses during the dehydration process for the H17 treatment compared to H13 (losses of 37.1 g kg^{-1} *vs.* 6.8 g kg^{-1}). It is noteworthy that, in addition to plant respiration, ESC depletion may also occur due to the action of microorganisms (Machado et al., 2019; Taffarel et al., 2013), which was not assessed in this study.

According to Moser (1995), plant respiration ceases as soon as it reaches 40% moisture, which is considered the moment until which the harvested material remains alive; in the H13 treatment, the plants breathed for approximately 28 hours (17:00 D2 – Figure 2A), when their moisture level reached 350.8 g kg^{-1} DM. In the H17 treatment, the plants breathed for approximately 45 hours (14:00 D3, moisture of 335.8g kg^{-1} DM); this is also due to the climatic conditions, since, on the first day of dehydration, the plants in the H17 treatment remained exposed for a shorter time to sunlight, because of the time at which they were cut.

Baling was done with both materials (H13 and H17) presenting DM contents above 800 g kg^{-1}, as recommended by the literature (Kumar, Brar, Verma, Kumar, & Singh, 2019), even with higher moisture in the stem fraction, which represented 533.0 g kg^{-1} DM.

Assessing the effects of storage periods (S – given in days) on hay nutritional composition, a significant effect was observed for DM, NDF, ADF, NDSC, NFC and ESC levels.

through orthogonal contrasts, it was possible to find that the dm concentration had a linear ($p < 0.001$) and quadratic ($p < 0.001$) behavior, and the equation that presented the highest R^2 and lowest RMSE to describe the effect of storage on DM was: DM (g kg^{-1}) = 809.80190 + 2.3296 * S – 0.01264 * S^2, which resulted in $R^2 = 0.91$ with RMSE = 13.25.

As the storage days passed, there was an increase in the DM content of the hays harvested at both cutting times. Considering this change in the hay during the storage period, it was found that the material tends to lose water, reaching a point of balance with the relative humidity of the air (Figure 1).

The storage period imposed a linear ($p < 0.01$) and quadratic ($p < 0.05$) effect on NDF values. The best fitting equation was: NDF (g kg^{-1} DM) = 721.48190 + 0.87598 * S – 0.00513 * S^2 (RMSE=16.50; R^2=0.43).

The same behavior was observed in the result for acid detergent-insoluble fiber (ADF), showing $p < 0.01$ and $p < 0.05$ in comparisons by orthogonal contrast (linear and quadratic, respectively) in the storage phase, with lower RMSE (14 .68) and higher R^2 (0.47) for the ADF equation (g kg^{-1} DM) = 339.34 + 0.78894 * S – 0.00432 * S^2.

Another factor observed during the evaluation period was that, even with stable forage moisture in bales, NFCs and ESCs (both included in the NDSC values) were depleted throughout the storage period. This reduction can be explained by a possible microbiological development and likely oxidation of these components. Machado et al. (2019) also identified a loss of soluble carbohydrates with storage.

In a study assessing the effect of cutting height and storage on the quality of *Cynodon* spp. hay, Sunahara et al. (2017) observed a behavior similar to that seen in this research; the authors attributed the higher concentrations of fibrous compounds, throughout the storage period, to the consumption of soluble carbohydrates, resulting in the concentration effect of these components, which, in this study, showed a consequent reduction of in vitro DM digestibility.

Unlike the DM, NDF and ADF contents, which showed an increase, neutral detergent-soluble components, NFCs and ESCs reduced during storage. The reduction of the NDSCs can be expressed by this equation: NDSCs (g kg^{-1} DM) = 213.9 – 0.99537 * S + 0.0057 * S^2 (RMSE = 17.56 and $R^2 = 0.47$). Comparisons of means by orthogonal contrasts showed a linear ($p < 0.01$) and quadratic ($p < 0.05$) effect.

The effect of storage time on concentrations of non-fiber carbohydrates showed a linear and quadratic effect ($p < 0.05$) by the respective contrasts. The equation to demonstrate the decline in NFC contents that best fitted presented RMSE = 26.45 and an $R^2 = 0.39$: NFCs (g kg^{-1} DM) = 113.97 – 1.43221 * S + 0 .00908 * S^2.

In the present study, NFC and ESC losses stood respectively at 37.22 and 37.60% in relation to the initial values. Considering that the NDSCs constitute the fully digestible material, these losses accounted for 3.97% of digestible DM. For hay stored with adequate moisture, DM losses are around 5% (Kumar et al., 2019; Neres, Nath, & Hoppen, 2021). Storage time, in addition to causing changes in the fibrous composition, can favor fungal growth (Neres et al., 2014).

Unlike the other response variables, ESC content showed, in comparisons by orthogonal contrasts, a linear effect and a quadratic trend. However, the quadratic equation showed the lowest RMSE (12.85) and the highest R^2 (0.30) for ESC reduction during storage: ESC (g kg^{-1} DM) = 50.65095 – 0.46295 * S + 0.00245 * S^2.

Cutting times and storage times did not cause a significant difference for the CP, EE, hemicellulose and IVDMD variables, with mean DM values of 94.0, 13.9, 383.0 and 581.3 g kg^{-1}, respectively. There was no interaction effect between the two factors for any of the parameters analyzed in the present study.

Despite showing no difference ($p > 0.10$), IVDMD values reduced by 4.52% DM until the end of the evaluation period, which may be a reflection of NDSC degradation over the storage period, signaling the need to evaluate the quality of hay stored for longer periods.

Considering the results of the present study, advancing the cutting time during the day resulted in higher concentrations of ethanol-soluble carbohydrates at cutting time; however, this difference did not affect hay quality, as it was reversed during the dehydration process. Therefore, the cutting time for stargrass hay can be defined considering the work logistics on the farm, without changing the nutritional composition of this food. The reduction of readily digestible compounds during storage raised the concentrations of fibrous components at the end of the storage period, which shows that storage is a critical period for maintaining the quality of this food.

Conclusion

Cutting time at 17:00 allows for greater accumulation of soluble carbohydrates in the plant. However, cutting time does not affect the time required for dehydration and the nutritional value of stargrass hay.

Prolonged storage time influences the nutritional value of the hay, reducing soluble components and increasing fibrous constituents.

References

Abot, A. R., Farias, E. B., Oliveira, M. V. M., Torres, F. E., Oliveira, D. P., Teodoro, P. E., & Ribeiro, L. P. (2015). Chemical-Bromatological composition of leucaena hay as function of drying and storage times. *Bioscience Journal*, *31*(5), 1450-1457.

Association of Official Analytical Chemists [AOAC]. (1990). O*fficial methods of analysis*. *Arlington*. Virgin Islands, USA: AOAC.

Coblentz, W. K., Coffey, K. P., Young, A. N., & Bertram, M. G. (2013). Storage characteristics, nutritive value, energy content, and in vivo digestibility of moist, large rectangular bales of alfalfa-orchardgrass hay treated with a propionic acid-based preservative. *Journal of dairy science*, *96*(4), 2521-2535. DOI: https://doi.org/10.3168/jds.2012-6145

Collins, M. (1995). Hay Preservation effects on yield and quality. In K. J., Moore, & M. A., Peterson (ed.), *Post-harvest physiology and preservation of forages* (p. 67-90). Madison: WI: CSSA Special Publications. DOI: https://doi.org/10.2135/cssaspecpub22

Dong, Z., Li, J., Wang, S., Dong, D., & Shao, T. (2022). Time of day for harvest affects the fermentation parameters, bacterial community, and metabolic caracteristics of sorghum-sudangrass hybrid silage. *American society for microbiology*, *7*(4). DOI: https://doi.org/10.1128/msphere.00168-22

Goering, H. K., & Van Soest, P. J. (1979). *Forage fiber analyses (apparatus, reagents, procedures, and some applications)*. Washington, D.C.: Agricultural Research Service, USDA.

Hall, M. B., Hoover, W. H., Jennings, J. P., & Webster, T. K. M. (1999). A method for partitioning neutral detergent-soluble carbohydrates. *Journal of the Science of Food and Agriculture*, *79*(15), 2079-2086. DOI: https://doi.org/10.1002/(SICI)1097-0010(199912)79:15<2079::AID-JSFA502>3.0.CO;2-Z

Holden, L. A. (1999). Comparison of methods of in vitro dry matter digestibility for ten feeds. *Journal of dairy science*, *82*(8), 1791-1794. DOI: https://doi.org/10.3168/jds.S0022-0302(99)75409-3

Kumar, B., Brar, N. S., Verma, H. K, Kumar, A., & Singh, R. (2019). Nutritious feed for farm animals during lean period: silage and hay review. *Forage Research*, *45*, 10-22.

Machado, I. W. J., Neres, M. A., Castagnara, D. D., Nath, C. D., & Diaz, T. C. (2019). Dehydration curve, gas exchange, and nutritional value of Bermudagrass hay under diferrent condiutions of storage. Semina: *Ciências Agrárias*, *40*(5), 1965-1978. DOI: https://doi.org/10.5433/1679-0359.2019v40n5p1965

Moser, L. E. (1995). Post harvest physiological changes in forage plants. In: K. J., Moore, & M. A., Peterson (Ed.), *Post-harvest physiology and preservation of forages* (p. 1-20). Madison, WI: CSSA Special Publications. DOI: https://doi.org/10.2135/cssaspecpub22.c1

National Research Council [NRC]. (2016). *Nutrient requirements of beef cattle*. Washington, DC: National Academies Press.

Neres, M. A., Castagnara, D. D., Mufatto, L. M., Fernandes, T., Hunoff, C. A., Wobeto, J. R., & Nath, C. D. (2014). Changes in Tifton 85 bermudagrass hay storage in the field or under shed. *Archivos de Zootecnia*, *63*(243), 555-558. DOI: https://doi.org/10.4321/S0004-05922014000300017

Neres, M. A., Nath, C. D., & Hoppen, S. M. (2021). Expansion of hay production and marketing in Brazil. *Heliyon*, *7*(4), 1-8. DOI: https://doi.org/10.1016/j.heliyon.2021.e06787

Pasqualotto, M., Neres, M. A., Guimarães, V. F., Klein, J., Inagaki, A. M., & Ducati, C. (2015). Gas exchanges and dehydratation in different intensities of conditioning in tifton 85 bermudagrass: Nutritional Value during hay storage. *Asian-Australasian Journal of Animal Aciences*, *28*(6), 807-815. DOI: https://doi.org/10.5713/ajas.14.0826

Rotz, C. A. (1995). Field curing of forages In K. J., Moore, & M. A., Peterson (Ed), *Post-harvest physiology and preservation of forages* (p. 39-66). Madison, WI: CSSA Special Publications

Silva, L. H. Brito, A. F., Lafrenière, C., & Berthiaume, R. (2020). Effects of cutting time and maceration on preference and nitrogen balance in beef steers fed mixed birdsfood trefoil-timothy grass hay cut at sunrise or sundown. *Translate basic science to industry innovation*, *4*(3), 1-13. DOI: https://doi.org/10.1093/tas/txaa168

Sunahara, S. M. M., Neres, M. A., Sarto, J. R. W., Nath, C. D., Scheidt, K. C., & Kuhn, O. J. (2017). Nutritional value of tifton 85 bermudagrass at two cutting heights and different times of storage. Semina: *Ciências Agrárias*, *38*(4). DOI: https://doi.org/10.5433/1679-0359.2017v38n4p2129

Taffarel., L. E., Mesquita, E. E., Castagnara, D. D., Costa, P. B., Neres, M. A., Horn, M. B., ... Meinerz, C. C. (2013). Dehydration curve, fungi and mycotoxins in Tifton 85 hay dehydrated in the field in shed. *Revista Brasileira de Zootecnia*, *42*(6), 395-403. DOI: https://doi.org/10.1590/S1516-35982013000600003

Taiz, L., Zeiger, E., Møller, I., & Murphy, A. (2015). *Plant physiology and development*. Sunderland, MA: Sinauer Associates, Inc.

Tilley, J. M. A., & Terry, R. A. (1963). A two-stage technique for the in vitro digestion of forage crops. *Grass and Forage Science*, *18*(2), 104-111. DOI: https://doi.org/10.1111/j.1365-2494.1963.tb00335.x

Van Soest, P. J. (1994). *Nutritional ecology of the ruminant*. Ithaca, NY: Cornell University Press.

Vasta, V., Pagano, R. I., Luciano, G., Scerra, M., Caparra, P., Foti, F., ... Avondo, M. (2012). Effect of morning *vs.* Afternoon grazing on intramuscular fatty acid composition in lamb. *Meat Science*, *90*, 93-98. DOI: https://doi.org/10.1016/j.meatsci.2011.06.009

Vibart, R. E., Tavendale, M., Otter, D., Schwendel, B. H., Lowe, K., Gregorini, P., & Pacheco, D. (2017). Milk production and composition, nitrogen utilization, and grazing behavior of late-lactation dairy cows as affected by time of allocation of a fresh strip of pasture. *Journal of dairy science*, *100*(7), 5305-5318. DOI: https://doi.org/10.3168/jds.2016-12413

Yari, M., Valizadeh, R., Naserian, A. A., Ghorbani, G. R., Rezvani Moghaddam, P., Jonker, A., & Yu, P. (2012). Botanical traits, protein and carbohydrate fractions, ruminal degradability and energy contents of alfafa hay harvested at three stages of maturity and in the afternoon and morning. *Animal Feed Science and Technology*, *172*(3-4) 162-170. DOI: https://doi.org/10.1016/j.anifeedsci.2012.01.004